University of Alberta

Income Diversification, Water Access and Household Welfare in Rural Zimbabwe

By

©

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A thesis submitted to the faculty of graduate studies and research in partial fulfillment of the requirements for the degree of *Doctor of Philosophy*

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Edmonton, Alberta

Fall 2006

Your file Votre référence
ISBN: 978-0-494-23087-9
Our file Notre référence
ISBN: 978-0-494-23087-9

ABSTRACT

Income diversification and access to domestic water resources are analyzed for households in semi-arid regions of rural Zimbabwe to highlight potential variables for welfare improvement for similar households. Agricultural and natural resource activities account for 75 percent of total gross income for all sampled households. Income from natural resource woodlands is important for the poorest households, contributing 28 percent of their total gross income. This is not the case for wealthier households for whom livestock contributes up to 21 percent of total income for the relatively wealthiest quartile. Nonfarm income shares are similar across wealth quartiles. However, remittances from skilled off-farm labor predominate for the wealthier, and unskilled rural wage labor income predominate for the poorest. Overall, there is relative specialization in dryland agriculture and livestock income by wealthier households, in contrast to diversified incomes with larger shares from woodlands, rural wages and home industry for poorer households.

Detailed analysis is made of water site choices and frequency of trips for domestic water provision with a focus on access to common pool water resources by households in two different land tenure systems. Property rights attributes of water sources indicating lower relative exclusivity and higher use restrictions are found to be significant in deterring water site choice. Restrictions on volumes of water are not important to site choices for households in areas with private ownership of land, in contrast to areas where land is communally owned. There is a consistent preference for domestic water sourced from relatively exclusive wells close to homesteads, rather than collection from

community boreholes despite their better water quality and more reliable supply. Trip frequency to all water sites is reduced by higher travel costs (valued by labor time), but increases during dry-season months. In areas with private land ownership, on average, wealthier households demand larger water volumes per capita. From imputations of effective demand, households are prepared to pay 12 to 29 hours of labor time per cubic metre of domestic water. This is highest for households with most constrained access to water resources (double that of other households on average).

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PART I: Introduction and Background

Chapter 1: Introduction

This thesis analyzes income diversification and water use by rural households in different land tenure systems in Zimbabwe. The research problem of this thesis is to analyze household behavior responses to economic, social, institutional and environmental influences. An underlying assumption is the need to advance understanding of rural household livelihoods in order to inform policy promoting natural resource management and household-level welfare.

1.1 Background to the Problem

Most rural households in Sub-Saharan Africa are engaged in agriculture, with farming systems dominated by crop production and with almost complete reliance on household resources, such as intensive use of household labor. The farming systems emphasize a high degree of household self-sufficiency, integrating multiple production and consumption activities in household livelihood activities. This situation results in diversification of assets, activities and income sources through the allocation of production resources of traditional agricultural households (Ellis, 2000). These rural households, characterized by limited access to other types of assets, have been shown to derive a wide range of natural products from the environment (Dasgupta, 1993). Access to natural resources, as an important means for providing subsistence and income, is therefore a key factor affecting household livelihoods. In this regard, this thesis analyzes the economic behavior of rural households as impacted by access to natural resources.

The main premises of the analysis are as follows. Rural household livelihoods are dependent on natural resources such as agricultural land, water, woodlands and grazing areas. These natural resources have common pool resource (CPR) characteristics, defined as arrangements where access is shared and where limiting the number of users or level of appropriation by each user impacts the resources (Ostrom, 1990). Access rights to these natural resources are mediated through various institutional arrangements, both formal and informal, so that individuals in an exclusive group have access to the benefits from the resource. The exclusive groups and rules of natural resource use may not necessarily be well defined (Ostrom, 1990). In practice, even if these are well defined for an exclusive group of resource users, it may be difficult to exclude other potential users from natural resources in common areas.

Institutional arrangements for access to natural resources have been widely discussed in the property rights literature. These discussions have ranged in focus from traditional property rights scholars' belief in the efficiency of individualized or private property (e.g. Demsetz, 1967; Field, 1985). Other authors in the literature, such as Baland and Platteau (1996) and Ostrom (1990, 1994) have focused on the success of common property institutions for natural resource management. New institutional economics has viewed institutions as imposing constraints on human economic behavior (North, 1990; Ostrom, 1994). However, the view of institutions that can support and enforce claims to benefits from natural resources has evolved over time to consider institutions as endowing resource users with greater agency and as inseparable from users' knowledge and beliefs (Mehta *et al.,* 2000). As a result, with regard to natural resource access, the importance of social norms, routines, conventions, kinship ties, lineage, reciprocity and beliefs is recognized in influencing outcomes (Mehta *et al.,* 2000).

Ribot (1998) defines access to natural resources as the freedom and social ability to obtain or make use of natural resources. Whilst access to natural resources is mediated through institutions as noted above, the patterns of use also relate to the resource user's capacity and constraints. The individual-specific capacity of resource users reflects differential endowments of complementary assets. These complementary assets may include information, skills, implements, labor, markets, and social capital (instrumental in conferring and securing entitlements to resources) and may aid or limit natural resource access. Consequently, exclusive rights of use to certain natural resources do not automatically create conditions for enhancing natural resource-related production, management and sustainability (Nemarundwe *et al*, 2005). Given varied structural conditions, differentiated livelihoods outcomes may have a direct bearing on the relative poverty of rural households. It is therefore not surprising that household decisions allocating limited labor, land, cash and capital inputs to production and consumption activities are impacted by relative access to natural resources and other assets.

Given the preceding background, this thesis analyzes rural household income diversification in livelihoods strategies and then proceeds to a more detailed analysis of water use decisions. The study focuses on the decisions of selected rural households in three distinct land tenure systems with varying property rights to the common pool natural resources (CPR) of land, woodlands and grazing, with a focus on water. The specific topics and questions addressed are discussed further in the next section.

1.2 Thesis Topics and Structure

In analyzing rural household behavior, we interpret descriptive statistics and results of econometric models. The analyses apply data from field observation, Participatory Rural Appraisal (PRA) meetings, key informant interviews and formal quantitative surveys of households in selected sites in rural Zimbabwe. This thesis is organized in four parts with four topics focusing on natural resource access and use in household livelihoods decisions. These topics are briefly summarized below and addressed more specifically in each of Parts I, II, III and IV of the thesis respectively.

The first topic, addressed in Part I, is to provide background information on the selected study sites and the study sample household socio-economic characteristics. We also describe the institutional context of common pool natural resource (CPR) access and use that affects these households. The descriptive information of Part I is provided for sample households in each of the three land tenure systems as the backdrop to the econometric models postulated and developed in Parts II and III of the thesis. Part I of the thesis is divided into three chapters with Chapter 1 introducing the research topics. Chapter two presents a conceptual model, based on household production theory, for rural household livelihood optimization, which underlies the analytical models of Parts II and III. Chapter 3 provides background information and descriptions of the study site, household characteristics, institutional characteristics and the policy landscape influencing access to natural resources for the sample households.

The second topic, addressed in Part II of the thesis, is the analysis of the distribution of income, from six aggregate income-generating activities, in total gross income of households in the selected communal areas. The six income-generating activity categories are dry-land agriculture, wetland agriculture (gardens), livestock, woodlands, home industry and remittances. Measures of income diversification are computed for each household based on the distribution of income among these six activities. Econometric analysis is applied to investigate determinants of income diversification and the proportion of total income from each activity. The purpose of this component of the study is to investigate inter-household differentiation in dependence on different income activities, as explained by such variables as wealth, household composition and measures of efficiency and income levels. In particular, the role of income from woodlands as a natural resource is explored. There are two chapters in Part II, Chapters 4 and 5 of the thesis. In Chapter 4 the specific empirical questions are outlined and the empirical literature on income diversification and rural household livelihoods is reviewed. Chapter 5 presents econometric analyses of income diversification and income shares from each income activity based on data for selected households. These results are discussed in the context of the existing empirical literature, highlighting the largely neglected role of income from natural resources as a distinct activity in communal area household livelihood strategies.

The third research topic, addressed in Part III of the thesis, is the analysis of sampled household's choices of water collection sites to collect water for domestic uses and the frequency of these trips. The analysis is conducted on data from households located in selected resettlement areas and small scale commercial farming areas. This focus of the thesis is based on the belief that access to water resources is a key factor, since the study sites are located in a semi-arid region of the country. Consequently it is expected that the allocation of time and other household resources in order to secure adequate water for domestic uses will be vital to household wellbeing. Relative to this topic of the thesis, we analyze patterns of water resource use by estimating econometric models for water collection site choices and trip counts, based on household data on water collection and trip logs. The analysis incorporates measures of seasonal, environmental, social and economic variables that may impact water collection decisions. This topic is discussed in Chapters 6, 7 and 8. Chapter 6 presents the research questions and a background literature review. In Chapter 7 empirical models of water collection site choices are applied, the results of these are discussed and relative measures of household welfare are presented. In Chapter 8 results are reported for models of water collection trip counts, imputed point demand for water, demand elasticity estimates and effective demand imputations.

The thesis concludes in Part IV with the final topic addressed in Chapter 9. This chapter highlights the common threads found in the analysis undertaken in the thesis. The main findings of the thesis are synthesized into a discussion of potential implications at the local level for policy relating to management of natural resources. Contributions to the literature are noted, as are limitations of the study and suggestions for further work.

Chapter 2: Modeling Household Livelihood Optimization

A conceptual model of the rural household as a micro-economic decision-making unit is postulated. This model characterizes production and consumption activities in household livelihood strategies as the basis of analytical models assessed in Parts II and III of this thesis. The conceptual household model is based on household production theory as advanced by Michael and Becker (1973) and extended by Singh *et al* (1986) to agricultural households. In the sections that follow we discuss household behavior, the conceptual optimization model and the empirical application.

2.1 The Livelihoods Framework and Household Behavior

Chambers and Conway (1992) define a livelihood as comprising the capabilities, assets and activities required for a means of living. A livelihood is said to be sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets while conserving the natural resource base. Sustainable livelihoods have been a constant theme in the debate on poverty alleviation strategies in the context of poverty-environment linkages and debates on access to resources, entitlements and capabilities (Sen, 1981; Blaikie, 1989; Bryant 1992; Leach *et al.*1998).

The livelihoods framework distinguishes five types of assets. These are described as: natural (such as land and water); financial; physical (houses, equipment, vehicles, livestock); human assets (quantity and capacity or skill); and social capital, referring to the networks of trust, exchange and mutual support which individuals and households maintain (IFAD, 2004[1]). The livelihoods framework recognizes that few poor rural households depend on a single income source, with diversification of

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[1] The Sustainable Livelihoods Framework http://www.ifad.org/sla/background/english/256.1

activities being regarded as a key component of secure and sustainable livelihoods (Carney, 1998). In this regard, inadequacy of the household's asset portfolio, vulnerability to stresses and shocks combined with a lack of local institutional and policy support, are seen to lead households to fall into poverty (IFAD, 2004). Ellis (2000) discusses dimensions of household income diversification as a deliberate strategy, a response to crisis and risk, a safety net for the poor and a means of wealth accumulation for the rich. For example, scholars have observed that a successful sustainable rural livelihood strategy combines subsistence production and control over rural land with skills to enter higher paid labor markets in urban areas (Ellis 2000; Swift 1998). It is therefore of potential interest to development policy to understand the complex patterns of asset trade-offs in rural households in pursuit of livelihoods outcomes, relative to given constraints and opportunities.

Although the livelihoods framework has contributed to rural development by emphasizing the concept of diversification, a key limitation is that livelihoods do not have a common metric such as money. This means that livelihoods can not be easily compared across households, and one can not measure the impact of changes in key policy or market variables. According to Barrett and Reardon (2000) this limitation creates a fundamental rift between economic analyses and livelihoods discussions in debates on poverty alleviation. In reviewing conceptual issues in the empirical literature on income diversification, Barrett and Reardon (2000) recommend that production function theory guide analysis of the components of diversification behavior. The link between livelihoods and production theory is that: (1) assets are the factors of production, representing the capacity of the household to diversify; (2) activities are the *ex ante* production flows of asset services; and (3) incomes are the *ex post* flows or outcomes from combining assets and activities (Barrett and Reardon, 2000).

Information on prices and wages used to value inputs and outputs generates estimates of incomes from household livelihood optimization, creating a link to the aggregate functioning of the economy and markets and policy (Barrett and Reardon, 2000). In practice however, market prices are not always defined for goods and services produced in rural areas of developing countries. Ellis (2002) links household capabilities, assets and activities and production and consumption functions with inputs and outputs and wages and prices, and assumes that income in a given time period is the most direct and measurable outcome of the livelihood process. A similar approach is followed in our specification of the conceptual model of rural household livelihood optimization that underlies the empirical analysis undertaken in this thesis.

2.2 An Empirical Model of Household Livelihood Optimization

The household production theory framework (Michael and Becker, 1973) provides a useful approach to identifying trade-offs in household asset allocations to various activities. Household production theory conceptualizes the household as both producer and consumer with constraints on labor time, income and other assets in optimizing welfare. This has been adapted as a relevant behavioral model underlying empirical studies of agricultural households in developing countries by many scholars (Barnum and Squire, 1979; Low, 1986; Singh *et al*, 1986; de Janvry *et al*, 1991, Amacher *et al.*, 1992; Cavendish, 1997; Hatton-Mcdonald, 1998; Dosman, 2000; Zindi, 2006). The rural household is widely studied by extending the agricultural household production model to specific empirical applications, as in this thesis.

The household is hypothesized to be partially commercialized, producing output for sale and for own consumption. Inputs for production are purchased, provided from own assets or collected from the natural resource environment. The assets that the household has at its disposal for allocation include labor, land, cash, natural and physical assets (such as draft power, implements) as inputs to production. Production may be defined as the transformation of physical product to be used for direct consumption, exchange or sale. Household production can include non-agricultural income generation and domestic activities.

Following Singh *et al* (1986), the proposed empirical model hypothesizes a single household utility function. Full income pooling and a single household budget constraint are also assumed, in line with utility and income pooling of traditional models of household resource allocation. The patterns of time and income allocation within the household are assumed to be founded in social norms about the roles of each household member (Thomas, 1990). Household members are hypothesized to negotiate the activities and expenditures which underlie household optimization decisions. This negotiation is also hypothesized to be relevant for the provision in a joint household utility function of such household goods and activities as food crop production, child rearing and meal preparation (Katz, 1992).

Rural households are assumed to be constrained by market failures that apply for labor, land, and capital inputs and for outputs from production (e.g. crops, wild foods, water). The term market failure is used here as defined by De Janvry, Fafchamps and Sadoulet (1991) as a situation where the cost of a transaction through market exchange creates disutility, with the result that the market is not used for the transaction. This definition of market failure is household-specific, with selective market failures resulting in relatively self-sufficient households. Household-specific marginal productivities and shadow prices for outputs and inputs are not equated to market prices (Barrett, Reardon and Webb, 2001). The assumption of household-specific shadow prices for inputs and outputs results in an underlying optimization model in which production and consumption decisions are non-separable. Non-separable production and consumption decisions are linked by endogenous prices and determined simultaneously rather than recursively (Heltberg *et al,* 2000).

Following Singh *et al* (1986) the household utility function has multiple activities and the objective of optimizing production-consumption decisions related to household welfare (livelihood). This may be specified as follows for a representative household:

$$U = U\left[\sum Q_i(.) + T_l \middle| Z\right] \qquad (2.1)$$

where $Q_i(.)$ represents the production function for each production activity i (i = domestic[2] production, dryland agriculture, irrigated agriculture, livestock, woodland products, wage labor and home industry--such as craftwork, beer brewing, gold panning, pottery making); T_l represents the balance of total household labor time, sometimes referred to as leisure[3], remaining after labor has been allocated to all other labor-using production activities (i); and Z represents a vector of household socio-demographic and other characteristics such as wealth, household composition, education and skills. Household characteristics are postulated as indicators of household preferences and tastes by Lancaster (1966).

In optimizing the utility function specified in Equation (2.1) each household faces a production function constraint, a household labor time constraint and a budget constraint (combining income and expenditure).

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[2] Domestic production includes the rearing of children, care of the infirm, maintenance of social relationships and the daily recurrent tasks of securing the day to day material survival of the household such as cooking, collecting water and fuelwood for energy and cleaning (Smith, 1994).

[3] In a survey of the literature on agricultural household models, Zindi (2006) finds two major approaches to modeling leisure in the utility function of households. One school of thought suggests that leisure should not be incorporated into the utility function of peasant households. Lobdell and Rempel (1995) argue that leisure can be excluded in the objectives of peasant households for two reasons. First, it is argued that in peasant households the typical trade-off is between types of work, or between more or less work efforts, rather than between work and leisure per se. The other reason is that in a society where significant amounts of time and effort are invested in the maintenance of social relationships, the distinction between work and leisure becomes problematic (Lobdell and Rempel, 1995). Assuming leisure can be excluded from the utility function, the amount of family labor devoted to farm and off-farm work can be taken as a proxy of the total stock of time available to the household. In cases where a leisure component is excluded, domestic activities can be counted as work. A similar approach is to model leisure as being weakly separable from the other arguments of the utility function (Renkow 1990). A second set of studies on agricultural household models explicitly model leisure in the utility function. Such studies include Strauss (1982, 1984), Lau et al (1978), Coyle (1994) and Young and Hamdok (1994). One justification for including leisure as an argument in utility is that in communities where significant off-farm income earning opportunities exist, the opportunity cost of leisure is significant. This scenario holds in communities where, during the dry season, household members with off-farm income earning opportunities seek seasonal employment off-farm. Leisure can be derived as a residual, that is, the difference between total time available and number of working hours/day in paid or on-farm employment (Young and Hamdok 1994).

An aggregate production function may be specified for each production activity (i) as follows:

$$Q_i \left[T_i, W_i, V_i \,|Z, K, S_{NR}\right] \qquad (2.2)$$

where: T_i represents labor time in hours allocated to the activity; W_i represents water input or consumption; V_i represents a vector of purchased inputs; K represents production technology embodied in fixed household capital assets such as land, animal draft power and production implements; and S_{NR} represents a vector of characteristics[4] for the fixed natural resource stocks of land, water, woodlands and grazing. Water as a natural resource stock is singled out as an input in production and consumption functions because of the focus on water access in Part III.

The household collects and uses water for production activities by applying labor (T_w) and capital implements embodied in (K). A production function for water collected $W_i(.)$ as an input to $Q_i(.)$ may be represented as:

$$W_i\left[T_w|Z, K, S_{NR}\right] \qquad (2.3)$$

A number of empirical applications in the literature on household models in developing country situations emphasize differences in labor allocation decisions by gender (e.g. Ahmed, 1992; Amacher, 1992; Tinker, 1994; Tisch and Paris, 1994). Assuming that there is significant division of labor in the household according to gender so that labor resources of male m and female f household members are not homogenous, a household labor time constraint may be summarized as follows:

[4] Characteristics of natural resources such as property rights and other access conditions for water, woodland and grazing resources may include population density, site location and distance from homesteads, quality and abundance of natural resource products given seasonal factors, access restrictions, information and number of users. These will vary according to location or site and over time. Sites may also differ in terms of differ in terms of amenities and joint production opportunities and benefits, such as scenery, meeting with friends along the way and others as discussed by Hegan *et al* (2002).

$$\overline{T} = T_i + T_w + T_l \qquad (2.4)$$

where: $\overline{T}$ represents total labor available in the household.

The household budget constraint combines total income (*M*) and total expenditure constraints (*E*) as follows:

$$M = p_i Q_i + p_T T_l + R \geq E = p_v V_i + p_T T_i + p_w W_i(.) + p_T T_w \qquad (2.5)$$

where: p_i represents prices for output from each production activity; p_V represents prices of purchased goods and inputs; p_w represents implicit price of water collected by households; and p_T represents price of household labor time. Total income is the sum of income from all production activities plus any exogenous income. For the budget constraint to hold, income should be greater than or equal to expenditures on all purchased goods and inputs. From a production function perspective, remittance income *R* from family members employed off-farm is an exogenous transfer in the total income constraint.

An implicit production function for all production activity in the household may be specified to account for intermediate outputs and inputs of household production. Examples of intermediate production include use of the output from crop production to produce domestic goods or to produce livestock products. The implicit production function is assumed to be quasi-concave, increasing in all outputs and decreasing in all inputs or factors of production and may be summarized as follows:

$$G\left[Q_i , W_i, V_i, T_i , T_w \middle| Z, K, S_{NR}\right] = 0 \qquad (2.6)$$

The resultant constrained household optimization problem from Equations (2.1) to (2.6) is as follows:

Maximize:

$$\begin{aligned}\Psi &= U[Q_i() + T_l] \\ &- \lambda\begin{Bmatrix} Q_i(T_i, W_i, V_i | Z, K, S_{NR}) + W_i(T_w | Z, K, S_{NR}) \\ + p_i Q_i + p_T T_l + R - p_v V_i - p_T T_i - p_w W_i(.) - p_T T_w \end{Bmatrix} \\ &- \mu G(Q_i, W_i, V_i, T_i, T_w | Z, K, S_{NR})\end{aligned} \qquad (2.7)$$

The first order conditions at the optimum solution for Equation (2.7) are as follows:

$$\frac{\delta\Psi}{\delta Q_i} = U_{Q_i} - \lambda(1 + p_i) = 0 \qquad \Rightarrow U_{Q_i} = \lambda(1 + p_i) \qquad (2.8)$$

$$\frac{\delta\Psi}{\delta T_l} = U_{T_l} - \lambda p_T = 0 \qquad \Rightarrow U_{T_l} = \lambda p_T \qquad (2.9)$$

$$\begin{aligned}\frac{\delta\Psi}{\delta\lambda} &= p_v V_i - R - (1 + p_i) Q_i(T_i, W_i, V_i | Z, K, S_{NR}) \\ &- (1 - p_w) W_i(T_w | Z, K, S_{NR}) - p_T(T_l - T_i - T_w) = 0\end{aligned} \qquad (2.10)$$

$$\frac{\delta\Psi}{\delta\mu} = G[Q_i, W_i, V_i, T_i, T_w | Z, K, S_{NR}] = 0 \qquad (2.11)$$

$$\frac{\delta\Psi}{\delta T_i} = U_{Q_i} * Q_{T_i} - \lambda(Q_{T_i} - p_T) - \mu G_{T_i} = 0 \qquad (2.12)$$

$$\frac{\delta\Psi}{\delta W_i} = U_{Q_i} * Q_{W_i} - \lambda(Q_{W_i} - p_W) - \mu G_{W_i} = 0 \qquad (2.13)$$

$$\frac{\delta\Psi}{\delta V_i} = U_{Q_i} * Q_{V_i} - \lambda(Q_{V_i} - p_v) - \mu G_{V_i} = 0 \qquad (2.14)$$

$$\frac{\delta\Psi}{\delta T_{T_w}} = -\lambda(W_{T_i} - p_T) - \mu G_{T_w} = 0 \qquad (2.15)$$

At an optimum solution for an optimization problem we assume: that the ratio of marginal utilities for each pair of consumption goods are equated to the ratio of prices of the goods; the optimal combination of goods is produced; and all factors of production are allocated efficiently amongst potential uses (Binger and Hoffman, 1998).

Solving equations (2.8) to (2.15) gives conditions for optimal allocations or conditional input demands of household labor time, purchased inputs and water to each production activity $Q_i(.)$. Combining Equations (2.8) and (2.12) to (2.15) gives expressions for $\frac{\mu}{\lambda}$; setting these equal to each other gives:

$$\frac{p_i Q_{T_i} - p_T}{G_{T_i}} = \frac{p_i Q_{W_i} - p_w}{G_{W_i}} = \frac{p_i Q_{v_i} - p_v}{G_{V_i}} = \frac{W_{T_i} - p_T}{G_{T_w}} \qquad (2.16)$$

The expression $\frac{\mu}{\lambda}$ is interpreted as the shadow price or the endogenous value of household inputs of labor time, purchased inputs and water used in production. In Equation (2.16) we see that the shadow prices of these inputs are equated to expressions of the value of the marginal product of the inputs in the production processes represented by $Q_i(.)$, $W_i(.)$ and $G(.)$. Thus, households equate the marginal utility of producing each output to its shadow price. The first-order conditions for household labor time allocation obtained from solving the optimization problem illustrates how households allocate resources across different activities. For example if the value of the marginal product of allocating labor to food crop production were greater than the value of the marginal product derived from other activities outside food crop production, the household would tend to specialize in food-crop production, relative to other activities such as cash crops, livestock or wage labor. This mechanism for resource allocation reflects household-specific opportunity costs of fixed assets and variable inputs and natural resources.

From Equations (2.10) and (2.16) the conditional input demand functions for household labor time, purchased inputs and water are seen to depend on own price, price of other goods, price of purchased inputs, price of output and all exogenous variables. Generalized reduced form conditional input demand functions for household labor time, purchased inputs and water at an optimal solution may be represented as follows:

$$T_i * [p_T, p_i, p_V, p_w, R|Z, K, S_{NR}] \qquad (2.17)$$

$$T_w * [p_T, p_i, p_V, p_w, R|Z, K, S_{NR}] \qquad (2.18)$$

$$V_i * [p_T, p_i, p_V, p_w, R|Z, K, S_{NR}] \qquad (2.19)$$

$$W_i * [p_T, p_i, p_V, p_w, R|Z, K, S_{NR}] \qquad (2.20)$$

Similarly, the optimal output level (Q_i^*) for each production process may be represented as follows:

$$Q_i * \left[T_i^*, W_i^*, V_i^* | Z, K, S_{NR}\right] \qquad (2.21)$$

The generalized reduced form demand functions for household labor time, purchased inputs and water and optimal output level outlined in Equations (2.17) to (2.21) form the basis of econometric analysis as discussed in sections that follow.

2.3 Situating the Study Contribution to the Literature

The general theoretical framework outlined in Section 2.2 showing households as producers and consumers underlies the applied empirical models postulated in Part II and III of the thesis. In Part II, household resource allocations to one or more income-generating activities are considered as part of livelihood strategies. In Part III household water collection site choices and water collection trip counts for domestic uses are studied as part of household decisions. The reduced form Equations (2.17) to (2.21) from the household optimization problem are applied as the structural equations underlying econometric models postulated and estimated to generate results in Parts II and III. The basis of these econometric models are the equations for the optimal output levels (Q_i^*) and allocations of inputs or conditional input demands of household labor time (T_i^*, T_w^*), purchased inputs (V_i^*) and water (W_i^*) for each production activity. The analysis does not apply mathematical programming techniques to optimize the objective function specified in Equation (2.7).

A contribution to the literature by this study of household behavior is that we account for the natural resources of water, woodlands and grazing in household income-generating strategies. Numerous studies of rural household income diversification have been conducted, as reviewed by Barrett Reardon and Webb (2001) and as discussed in Part II, Chapter 4 of this thesis. Few of the studies focusing on rural household income diversification account for income from natural resources. Cavendish (1997) is a pioneer in econometric analysis of rural household demand for natural resource products in Zimbabwe. However, Cavendish (1997) does not conduct an in-depth analysis of natural resource demands related to the extent of rural household income diversification and its varied components. Another pioneering study is that by Campbell *et al* (2002) who analyze rural household income sources and relative poverty by employing descriptive and inferential statistical analysis. Adhikari (2005) adds to this literature by explicitly analyzing forest resource demands by households and comparing descriptive statistics for forest incomes with other household income sources in Nepal. In Part II of the thesis, this study extends the work of these authors by applying econometric analysis to measures of income diversification and income shares from various production activities accounting for the contribution of natural resource incomes for selected rural households in developing countries.

Much debate on access to and utilization of natural resources by rural households has focused on existing resources, property rights, institutions, governance systems and power relations (for example Nemarundwe, 2003; Mehta, 2000; Ostrum, 1990; Ostrum *et al*, 1994). The study of interactions between actual household-level micro-economic decisions and natural resource access and use is complex and difficult. This study provides some contributions to understanding the field of natural resource management by analyzing the outcomes of household-level micro-economic decisions. For example, in Part III of the thesis, in analyzing water resource access and use decisions by households, we define property rights variables related to water resources for rural households and apply these in empirical models of behavior. As a result, we identify statistically significant relationships between theoretical measures of property rights characteristics of water resources and the economic behavior of households.

In the specific context of Zimbabwe, a contribution of this study is in analyzing rural household behavior in three distinct land tenure systems. These are the land tenure systems that apply in resettlement areas (RA), small scale commercial farm areas (SSCF) and communal areas (CA), each with different property rights regimes for natural resources. An underlying assumption is that there may be significant differences in social institutions such as norms of behavior conditioning access to and use of natural resources in the different tenure systems, and that these may have potential impacts on economic behavior of households. To date, much of the literature on rural household resource allocation in Zimbabwe has focused on the CA land tenure system. In Part II of the thesis we analyze CA household income diversification behavior and in Part III of the thesis we analyze water resource use patterns of RA and SSCF households.

The analysis of household behavior and natural resource access undertaken in this thesis applies two rich data sets, each collected for a cross-section of households over regular survey intervals spanning approximately fifteen months. The resultant data sets allow us to investigate the effect of seasonal factors in household decisions, providing for a broader understanding of household decision making than would be given by focusing on a single survey. In addition, the richness of the data set allows us to employ relatively sophisticated statistical modeling techniques including seemingly unrelated regressions (SUR) for systems of equations (in Part II), as well as conditional logit (CL) and random parameters logit (RPL) specifications of discrete choice models and Poisson count data models (in Part III) for the analysis. From the nature of the data, results from econometric model estimation are amenable to generating interpretations with potentially significant local-level policy application.

Chapter 3: Study Area, Sample Data & Natural Resource Access

This chapter addresses the first topic of the thesis which is to provide background information on the selected study sites and sample households in Zimbabwe. We begin by briefly describing the policy and legal landscape of natural resource access in Zimbabwe. This is followed by descriptions of the specific study sites, data collection methods and sample household characteristics. We then proceed to discuss the outcomes of the institutional context of common pool natural resource (CPR) access and use observed at community and household levels at the study sites. This background information provides context to the analytical results presented in Parts II and III of the thesis.

3.1 The Policy and Legal Landscape for Natural Resource Access

In this section we describe the purpose of the macro-level policy and legal institutions for natural resource access and use in Zimbabwe as these may potentially affect incentives for household behavior. In addition, existing policy informs the process of generating recommendations for more effective management of natural resources at local levels. It is important to note, however, that there may be considerable divergence between the purpose or objective of the prescribed macro-level policy and legal institutions, and the observed outcomes of household-level behavior regarding natural resource access and use. Thus, the summary of prescribed policy and legislation informs us of the policy intent, although practice may appear somewhat at odds to this intent.

3.1.1 Historical background of legislation for natural resource access

This section draws on the work of Nemarundwe *et al* (2005). The legal framework for access to natural resources in Zimbabwe lies within the context of colonial rule introduced by the British in 1890 and administered by the British South Africa Company (Murombedzi 1994, Mandondo 2000). Access to land and natural resources in rural Zimbabwe was determined by the Land Apportionment Act (1930) which divided the country into African and European areas according to race, with land of high agricultural potential, having better access to water resources for production allocated to Europeans and with marginal lands allocated to Africans. Land was classified into use-areas, including areas specified for large scale commercial farms (LSCF), small scale commercial farms (SSCF - formerly Purchase Areas) and communal areas (formerly termed Tribal Trust Lands (TTL)). Congestion and environmental degradation in tribal trust lands led to the enactment of the Native Land Husbandry Act, 1951 (NHLA). This legislation attempted to address environmental degradation by demarcating communal land into arable, settlement and grazing areas and enforcing cattle de-stocking. The NLHA met resistance from African nationalist movements and led to the enactment of the Land Tenure Act in 1969; this was intended to promote conservative land management practices.

With the attainment of independence from colonial rule in 1980, the new Zimbabwean Government embarked on a land redistribution policy. Resettlement areas (RA) were created with the objective of redressing colonial imbalances in access to land and water resources and to relieve pressure on overpopulated communal areas (CA). The process has continued over the years, culminating in the Fast Track Land Reform (FTLR) exercise that began in 2000. That resettlement process was initially facilitated by the enactment of the Land Acquisition Act (1992) and has since been accompanied by the enactment of various laws and regulations governing access, use and benefit sharing arrangements over natural resources in both communal and resettlement areas. Through the FTLR which began in 2000, about 200 000 previous residents of communal and urban areas and their families became new resettlement area residents. The FTLR program resettled people according to two schemes, A1 and A2. The A1 scheme was directed to decongest the CA and to settle the poor and landless. The A2 scheme was meant for those with means to carry out commercial farming on small and medium scale farm sizes ranging from 50 to 200 hectares (Sukume, Moyo, Matondi, 2003).

With regard to rural administration, in 1971 the colonial government created Rural Councils (RC) for local administration in African areas and conservation areas in the LSCF areas. More recently, these were re-enacted as Rural District Councils (RDC) which are tasked with overseeing day-to-day local government administration of rural districts. In addition, a directive by the Prime Minister in 1982 introduced elected leadership through village development committees (VIDCOs) and ward development committees (WADCOs) initiating a bottom-up approach. However, these new institutions were observed to down-play the role of traditional leaders and to result in some confusion over management and allocation of communal resources (Nemarundwe *et al*, 2005). The government of Zimbabwe subsequently enacted the Traditional Leaders Act (TLA) of 1998 in order to address conflicting roles of the newly created institutions and traditional leaders. Traditional leaders now have the authority to allocate land to individuals and to resolve conflicts over natural resources and social matters. The elected village and ward leaders now play a role in facilitating development plans through the relevant Rural District Councils (RDC).

3.1.2 Current land and resource tenure systems in rural Zimbabwe

The history outlined above has left rural Zimbabwe with four distinct land tenure systems: for CA, RA, SSCF and LSCF areas. CA land tenure, where *usufruct* rights to the land and its natural resources apply based on local residence, is the predominant means by which land is held in Zimbabwe. As of 2000, over 65% of the Zimbabwe population resided in the CA in rural areas (Sukume, Moyo and Matondi, 2003). The RA land tenure applies communal tenure of natural resources in common areas. In addition, individual households are given ninety-nine year leases to individual land for crop fields and homesteads (Rukuni, 1992).

In the SSCF and LSCF areas, there is individual title to land through either leasehold or freehold arrangements. Although land is held privately in LSCF and SSCF areas, key natural resources such as rivers that cross farm boundaries are held in common (Campbell *et al*, 2000). Although LSCF are located in rural Zimbabwe, these households are not considered in this study of small-scale rural farmers. The farmers in the CA and RA localities are referred to as smallholder farmers. Together with the households in the SSCF areas, these are also referred to as small-scale farmers in Zimbabwe (Rukuni, 1992). In addition, although the FTLR program has resettled former residents of communal and urban areas in RA since 2000, the specific communities studied in this thesis are all in selected CA, RA and SSCF areas where resettlement was conducted prior to 2000.

3.1.3 Legislation for specific natural resources

The natural resources of importance to rural household livelihoods in Zimbabwe are woodlands, grazing and water. All woodlands in Zimbabwe are legally managed under the Forest Act of 1948. The Forest Act has been largely viewed as focused on promotion of forest industrial development for commercial purposes on private lands, without really addressing forestry issues and needs in the communal areas (Nemarundwe *et al*, 2005). In response to this criticism, the government enacted the Communal Lands Forest Produce Act (1987), to regulate harvesting of woodland products by CA households. However, recent opinions (Mandondo 2000; Matondi 2001) note that both acts are restrictive in precluding commercialization of natural resources by only allowing subsistence use by inhabitants of designated communal areas. On the other hand, the Rural District Council (RDC) has authority to permit utilization of natural resources for commercial purposes. Thus, local resource users are potentially disenfranchised in local management of natural resources because of the RDC power hierarchy.

Water rights allocated under the Water Act of 1976 attached water rights to land and led to inequitable allocation and access to water favoring previously European-settled areas. In response to this anomaly, the Zimbabwe Government enacted the new Water Act of 1998. This act detaches rights to water from ownership of land and now requires that all water beyond primary uses be allocated through permits. The Act led to the creation of Catchment and Sub-catchment Councils to decentralize water management through administering water rights and disputes locally. The catchment areas are based on watersheds and take no cognizance of administrative boundaries. The Water Act sets limits for water uses defined as primary. Primary use refers to water use for domestic and human needs, support of animal life (other than fish farms and animals in feedlots), for dip tanks and for making bricks for private use of the owner/lessee or occupier of the land concerned. The upper capacity limit of private storage facilities for water is specified as 5,000 cubic meters per household, above which a permit is required from the Catchment Council. The Catchment Councils have been provided with authority to set practical limits on water use *"in order to safeguard public interests where deemed necessary"*. The intent is to protect the rights of communal area residents to water resources for livelihoods.

Small-scale mining, particularly alluvial gold panning in water courses, was previously not recognized as a legitimate or legal activity. The Government of Zimbabwe enacted the Mining, Alluvial Gold, Public Streams Regulations (1991) in response to increased small scale mining activities and the need to implement some controls. The regulations give local authorities the power to issue mining licenses, collect revenue from these licenses, and enforce provisions such as the requirement to provide proof of residence as a condition for being issued a license (Shoko 2002). The overall enforcement of the mining regulations is the responsibility of the RDC in conjunction with local traditional leaders, village and ward institutions (Nemarundwe *et al*, 2005).

More recently, following consultations with stakeholders, the Zimbabwe Government enacted the Environment Management Act (EMA) (2002) as an overarching law to promote integrated environmental management. Stated objectives of the act include: (i) preparation of national and local level environmental plans; (ii) dividing government functions from those of numerous stakeholders for more effective coordination; (iii) establishing an environmental fund (iv) promoting incentives to benefit sharing arrangements for natural resource management and (v) assessing the environmental, economic, social and equity impacts of development over time. The EMA agency is proposed to be decentralized to local levels, with representatives at the national, provincial, district, ward and traditional leadership levels (Nemarundwe *et al*, 2005). Traditional leaders are to participate as the recognized custodians of the land (natural resources) on behalf of communities. However, this participation in key decision-making may be uncertain given the history of environmental management by technical sub-committees.

3.2 Background to the Selected Study Sites

The specific study sites identified for the study are the Mutangi CA, Romwe CA and the Nyahombe RA in Chivi District, and the Mushawasha West SSCF area in the adjacent Masvingo District, all within Masvingo Province in South East Zimbabwe. Campbell *et al* (2002) have studied the roles of different sources of smallholder livelihoods in the Mutangi and Romwe communal areas in this region of Zimbabwe. In light of information from that previous work, which incorporates primary data already collected as part of that previous livelihood survey, Mutangi and Romwe CA households are included in this study. The selected Nyahombe RA and Mushawasha West SSCF study sites were the closest areas in proximity to Mutangi and Romwe CA. This selection was for logistical reasons and also because these RA and SSCF sites, although in different land tenure systems, have similar climate and natural resources to the selected Mutangi and Romwe CA sites.

Most of the land in Masvingo province in South Eastern Zimbabwe is semi-arid and falls into agro-ecological[5] regions IV and V. The selected study sites fall within the Runde River Catchment Area. Mean annual rainfall is between 450 and 500 mm and falls mostly during the wet season summer months between November and March. Average monthly temperatures in the region range between a maximum of 30^{0}C and minimum of 5^{0}C. The region is characterized by the uncertainty of recurrent droughts and risk of frequent crop failures that cause farmers to adopt risk-coping strategies that include heavy dependence on natural resources (Campbell *et al*, 2002; Frost and Mandondo, 1999). Dry-land rain-fed agriculture and range grazing of livestock are typical household activities in the region. In addition, households may have small garden plots close to homesteads fed by wells or located near water sources. Many households also engage in home industries such as craftwork, beer brewing, brick making and alluvial gold panning.

The closest large centre to the study sites is Masvingo City, the provincial capital, with a total population of 55,000 persons (CSO, 1992). The Mushawasha West SSCF site is in Masvingo District, about 20km south of the city along the Beitbridge road to South Africa. The Mutangi and Romwe CA and Nyahombe RA sites are in the adjacent Chivi District. Chivi District covers a radius of 3534km^2 and has a population density of 44.5 people per square km (CSO, 1992). The Nyahombe RA site is at Ngundu Halt, which is about 100 km south of Masvingo city on Beitbridge road and a popular market point on the road to South Africa. The Nyahombe RA site is located about 20 km east of Ngundu Halt along the tarred road to Chiredzi that leads further east in south eastern Zimbabwe. Romwe is located 4 Km from Ngundu Halt along the Beitbridge road. Mutangi is located 80km south west of Masvingo City and 19km from Chivi Business Centre.

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[5] Zimbabwe is divided into five Agro-ecological Regions (or Natural Regions) based on a description of land quality in terms of topography, soil, precipitation, vegetation and suitability for crop or livestock production. Agricultural production potential decreases from region I to IV as rainfall become lower and more erratic. Production activities recommended for regions IV and V are extensive livestock farming and drought resistant crops (Chasi and Shamudzarira, 1992). Rukuni (1992) estimates that over 75% of the CA land in Zimbabwe is located in natural regions IV and V.

3.3 Data Collection

The data for the CA households analyzed in this thesis were collected from the Mutangi and Romwe CA sites in surveys conducted between 1998 and 2000 as described by Campbell *et al* (2002). Further field research for this study was conducted between June 2002 and November 2003, with the purpose of collecting survey data on selected RA and SSCF households. The focus in data collection from these RA and SSCF households was on households' water resource access and use. The data for the CA households focuses on income sources including woodlands products.

3.3.1 Data collection from CA households

The study of households in the Mutangi and Romwe CA sites employs a dataset collected from quarterly survey visits to households during the course of a livelihood analysis by Campbell *et al* (2002). Initial informal surveys involving Participatory Rural Appraisal (PRA) meetings and key informant interviews were followed by design of formal quantitative survey questionnaires to collect data on household activities. The questionnaires were designed and administered to households in Mutangi and Romwe CA on six rounds of survey visits in each of five quarterly periods covering the 15 months period between December 1998 and February 2000. These surveys included questions on household income, expenditure and use of purchased inputs and labor from the perspective of an adult male, adult female and a child in each household. These data were collected quarterly in order to capture seasonal variation and several rounds of visits were conducted within each quarter to gather data on activities that were unlikely to be recalled after three months. The survey in the first round of the first quarter collected background information on relatively constant household characteristics such as household physical assets (land size, housing) and demographic features.

The other survey rounds administered to the CA households in the four quarters between March 1999 and February 2000, applied questions on large expenditures items based on three month recall. These also included questions on income sources, dryland crop production, major inputs, livestock situation and woodland use patterns. Twenty rounds of weekly recall data were collected during the year from questions on woodland harvesting; water use, input purchases and income sources. Daily recall data were collected on labor use (i.e. what was done in the last 24 hours) from an adult male, adult female and a child in the household. In addition, the fifth quarter questionnaire asked for more background information on village names, organizations involved in collective gardens and access to these. The complete data set for the Mutangi CA sample covers 125 households in 18 villages, out of the total of 453 households inhabiting the area. Data were also gathered on 125 households from the total of 417 households inhabiting the 10 villages in the Romwe CA site. The sampled 250 CA households were selected from complete village lists using a stratified random sampling method, with households selected from each village in proportion to the total number of households in the village. The final data applied in the analysis included 1999 households after 51 households were eliminated from the sample because of data collection problems of enumerators.

3.3.2 Informal surveys for data collection from RA and SSCF households

Qualitative research methods including key informant interviews and Participatory Rural Appraisal (PRA) meetings were conducted in the initial stage of field research. The qualitative research stage was valuable in introducing the researcher to the target community and in facilitating survey logistics such as sample frame development, sample selection, enumerator recruitment and pre-testing the formal questionnaires. The qualitative research process began in June 2002 with introduction to the political and administrative leaders (Ward Councilors) in three study sites, one in Mushawasha West SSCF (Ward 21) and two in Nyahombe RA (Ward 27 and 29). The next stage was to host introductory meetings for community members. During participatory meetings held with community members, leaders and key informants, community resource mapping exercises were conducted, as were discussions on natural resource access and rules. Participatory meetings held with community members were also an opportunity to advertise for enumerator assistance and to conduct interviews for recruitment. As a direct outcome from the meetings, sample frame definition, discussed further in the next section, was possible.

3.3.3 Sample selection of the RA and SSCF households

One household from each of the 101 farms found in the Mushawasha West SSCF site was included in the formal survey sample. A household is defined in this study as a group of nuclear family members that eat from the same kitchen. On the small scale commercial farms we typically observed more than one nuclear household due to multiple wives and adult children establishing their households at the family farm. The average number of households found on each SSCF farm in the SSCF area was 3.0, compared to 1.2 for the RA households. The household included in the survey sample was that of the most senior household head on each farm. The average farm size of SSCF farms was 64.4 hectares and farms ranged in size from approximately 50 to 156 hectares. The response rate at the time of initial survey of SSCF households was 97 percent, with 3 farm households declining to participate in the survey.

The Nyahombe RA site had approximately 500 households in total living in 14 villages. The first criterion in sample household selection in Nyahombe was to include all contiguous households in a given village since these would share water sources. Based on the outcome of PRA meetings and resource mapping exercises in this site, it was decided to include all households from six villages (Village Numbers 3, 5, 6, 8, 12 and 13) in the survey sample. These villages were spatially located to represent the different regions in the RA site and included households with access to the range of water source types found amongst households in that site. In a seventh village (Village Number 14), 27 of the total of 48 households were included in the survey sample. These households were selected because they were directly contiguous to Village 13 and shared community pools in the Runde River. Complete household lists were compiled for these selected villages and the total sample selected from them included 249 households. A response rate of 100 percent was achieved. Table 3.1 lists the numbers of sampled households for each village in the Nyahombe RA site.

Table 3.1: Number of Households Sampled in Each Village in Nyahombe RA

Village Name	Number of Households
Village 3	99
Village 5	30
Village 6	30
Village 8	22
Village 12	29
Village 13	12
Village 14	27
Total	249

3.3.4 Formal survey administration for the RA and SSCF households

A series of 13 monthly survey questionnaires was administered over the 15 month period between August 2002 and October 2003. This survey period allowed us to follow household water use patterns use over a year in response to seasonal environmental variables and seasonal production opportunities and constraints. Survey enumerators were recruited from amongst the local residents. Each enumerator was designated to conduct monthly surveys for the same sample of some 31 households. The design of questions was driven by the need to elicit responses that could be accurately recalled within the survey interval period of one month. Therefore, information on household income and expenditure was elicited for the period covering the month since the last survey visit, because recall of these seemed likely to be accurate for this time period. However, the sampled information on household labor time allocation and domestic water collection trip logs were elicited for the three days immediately prior to the day of the survey visit. Questions on water collection trips for large-scale water uses such as brick molding and watering gardens were asked for the period covering the month since the previous survey visit. This recall period was chosen because of the relatively low frequency of large scale water uses compared to domestic water use.

The first questionnaire administered in the first month of survey (Round 1) collected background information on the sample households. The information sought was on household size and composition by age, gender, education, occupation and location; asset ownership; and income sources. Information on water sources in household choice sets was also sought as were travel distances and the time taken to reach water points. In the first survey interview, each household was asked to select three household members, an adult male, an adult female and a child (between 10 and 16 years of age) to participate in the monthly surveys. In addition, spatial reference coordinates for each household were collected using a global positioning system (GPS) device to geo-reference the sampled households' homesteads, agricultural fields, gardens and the distinct locations of water sources. The coordinate data enabled identification of the distinct geographically located water sources in household choice sets.

The second to twelfth round (Round 2 to 12) of survey questionnaires, administered each month between October 2002 and September 2003, were identical. Questions elicited information on household income sources and expenditures during the month prior to the survey visit. The adult male, adult female and child, identified in Round 1, were asked about time-use activities during the three days previous to the survey visit. A water collection trip log was compiled with information on whether rain water had been collected and the water collection trips made to water sources visited by the household in the three days prior to the monthly survey visit. The water collection trip log included details for each trip on the site visited, the family member performing the task, time spent on the trip, volume of water collected, the mode of water transportation, the primary purpose of the trip or intended use of water collected and joint production activities conducted during the trip. In addition to all the questions in the Round 2 to 12 questionnaires, the Round 13 questionnaire also included questions on harvests of field crops for the year and sale of livestock. Copies of all survey questionnaires are provided in Appendix I-9 to III-9.

3.4 Sample Household Characteristics

3.4.1 Settlement history

Most communal area (CA) settlements in Chivi district were established following mass forced relocation of Zimbabwe's African population in the 1950s. At this time, inhabitants of the land were forced to leave their homes to make way for settlement of European land grantees who had served in WWII (Campbell *et al, 2002).* Some of the households in the survey sample, for example the adult children of original settlers, established their households after this major relocation exercise to the CA site. However, individual household-specific data on the year in which each household established residence at the study site was only collected for the RA and SSCF households. These data were not available for the sampled CA households.

The main resettlement exercise in which households were allocated land in the Nyahombe Resettlement Area was conducted in 1982. Almost half of the sampled households established settlement in 1982. Many of the occupants of households that were established in Nyahombe between 1990 and 2002 are referred to as "squatters" by local residents since their homes were not established as part of the initial land allocation exercise in 1982. In the RA site, 20% of sampled households were established between 1990 and 2000 and 18% between 2000 and 2002. There were notable increases in the numbers of new households established in the two years between 2000 and 2002 in the Nyahombe RA site. Many of these new households occupied areas in communal grazing lands and in previously un-cleared land on river bank areas across the Runde River. These settlement patterns reflected the increasing demand for land by the adult children of the originally resettled farmers.

In the Mushawasha SSCF site, the majority of farm households were established before 1960. Over 72% of the sampled SSCF households were established before 1980, 25% were established between 1980 and 2000, and less than 3% were established between 2000 and 2002.

3.4.2 Household demographic composition

The composition of the household labor pool for the sampled households is described in Table 3.2. These data show that the CA, RA and SSCF households have a similar mean household size, around 6.5 members each. On average the CA and RA households have a larger proportion of children than the SSCF households. Data on education levels show that SSCF households had on average more members educated above the primary school level, compared to the CA and RA households. This follows from the age composition of the CA and RA households where many members are children and minors compared to more adult members in the SSCF households. Moreover, as will be shown below, SSCF households tend to be wealthier than CA and RA households, a characteristic frequently associated with higher levels of education. Thus, we find that SSCF households have a larger pool of relatively educated adult members.

Table 3.2: Mean Number of Household Members by Demographic Group

Demographic Group	Mean CA Household members	Mean RA Household members	Mean SSCF Household members
Adult Males	1.42	1.39	1.85
Adult Females	1.85	1.45	1.71
Children (10-16 years)	1.84	1.85	1.26
Minors (0-9 years)	1.40	1.62	1.24
Seniors (66+ years)	a	0.35	0.40
Total No. HH Members	**6.51**	**6.66**	**6.46**
Sample Size (N)	199	248	101

Note: a=data not collected for CA households

3.4.3 Asset ownership

Table 3.3 presents statistics on household ownership of major assets in the sampled CA, RA and SSCF areas. Land holdings, livestock numbers, types of housing, productive equipment and household luxury goods/equipment ownership have been cited by Campbell *et al* (2002) as major household assets that indicate differentiation in wealth status.

Table 3.3: Physical Assets Ownership for CA, RA and SSCF Households

	CA Households N=250		RA Households N=247		SSCF Households N=101	
Physical/Natural Asset	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Land						
Dryland (hectares)	4.21	2.10	5.42	7.60	13.01	15.10
Irrigated/Garden (m^2)	0.22	0.24	1240	2003	2381	2546
Livestock						
Cattle other	3.94	4.59	3.26	5.382	6.79	6.877
Draft cattle	a	a	2.62	2.894	3.76	2.574
Milk Cows	a	a	1.52	2.21	3.04	2.453
Goats	4.12	5.42	2.28	3.938	4.30	5.981
Productive Equipment						
Scotch carts	0.43	0.50	0.48	0.61	0.98	0.748
Plough	0.83	0.38	1.04	0.769	1.57	0.864
Wheelbarrow	0.57	0.50	0.58	0.6	1.08	0.620
Cultivator	c	c	0.32	0.636	0.76	0.723
Luxury Goods/Equipment						
Radio	0.45	0.50	0.62	0.65	0.83	0.634
Television	0.10	0.30	0.14	0.351	0.39	0.49
Bicycle	c	C	0.41	0.717	0.47	0.677
Kerosene Stove/Oven Stove[b]	0.02	0.15	0.13	0.408	0.33	0.670
Solar Panels	0.10	0.30	0.13	0.353	0.28	0.512
Type of Housing	N	%	N	%	N	%
Pole/Mud/Thatch/ Tin	3	1.2	41	16.5	2	2
Brick/Thatch	135	54.0	129	52.0	25	24.8
Brick/Asbestos/Tin	111	44.4	74	29.8	73	72.3

Note: a - The figure shown for number of cattle for CA is the total of all cattle in all categories
b - This variable measures 'oven stoves' for the CA and kerosene stoves for RA and SSCF
c - Data not available/not calculated for CA households

Highlights of the statistics in Table 3.3 are that in addition to having larger tracts of land, SSCF households have at their disposal more productive implements and inputs for crop production, including scotch carts and wheelbarrows for transportation, animals for draft power and luxury goods. These numbers indicate a tendency for relatively higher wealth levels among the SSCF households compared to the CA and RA households. The CA households, in turn, have lower levels of almost all assets, with the exception of goats, and different types of housing. Fewer RA households (31.5%) have the type of housing that requires higher investment, such as brick walls and a tin or asbestos roof, compared to 44% of CA households. The wealth levels in the RA and CA households are similar overall, whilst for SSCF households, average wealth levels are higher.

Based on the descriptive statistics we conclude that the prevalence of multiple households on SSCF farms may be related to the larger average farm sizes of 64.4 hectares that apply for this group, compared to the average 6.1 hectares for RA farms. These figures suggest that the average SSCF land holding could accommodate up to 10 different nuclear households before each household reaches the average land holding size of RA households.

3.5 Conditions of Access to Common Pool Natural Resources

This section describes access to the common pool resources (CPR) of water, woodlands and grazing in the selected study site communities with a focus on social institutions. We provide a brief summary of issues in woodlands and grazing resource access for the CA household sample. This is followed by a more detailed description of water resource access and use in the RA and SSCF areas where detailed primary data on water resource access was collected. The discussion of CPR access and use in the CA sites is brief because we did not collect primary data there. We therefore draw on the work of Mandondo *et al* (2004) and Nemarundwe (2003) who have collected primary data at these sites.

3.5.1 Access to woodlands and grazing in Mutangi and Romwe CA

Both formal and informal institutional arrangements have been shown to govern access to common pool resources in rural areas of Zimbabwe. These institutional arrangements may be defined as rules and regulations governing resource use (Ostrom, 1990). The rules and regulations in a community determine who has access to the CPR, what resource use units are authorized, the timing of resource use and mechanisms for monitoring and enforcing rules. The underlying assumption is that identifiable groups of inter-dependent CPR users have a stake in and desire to manage the CPR collectively (McCay and Acheson, 1987; Ostrom, 1990). Thus, as suggested by Dasgupta (1999), whilst economic incentives and self-interest may drive behavior in CPR management this is also facilitated by social capital which tends towards collective outcomes. In practice, social networks have been shown to uphold informal agreements in natural resource access and use so that these agreements are kept. Quoting Nemarundwe (2003) *"access to resources is complex, embedded in social and power relations and also highly dynamic due to the constant interplay between agency and structure"*. In addition, complex natural resource access rights are found to ensure survival and basic food security for individuals within rural communities. This phenomenon may have implications for households' incentives relative to long term investments in natural resources for production and accumulation.

In their study of village level CPR management institutions in the Mutangi and Romwe CA sites, Madondo *et al* (2004) apply the analytical framework proposed by Haley and Luckert (1990). In this framework[6], property right conditions including exclusiveness, use designation, fees, operational control, and allotment type and size, are hypothesized to have systematic effects on economic behavior and hence natural resource management. The framework is applied by Kundhlande and Luckert (1998) in characterizing natural resource tenure in rural Zimbabwe. Madondo *et al* (2004

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[6] The property rights literature has focused on typologies categorizing CPR management regimes under four broad groups namely state, private property, common property and open access. However, as Murphree (1992) suggests, open access denotes lack of a management regime rather than constituting a management regime. It is now more common to conceptualize property rights as a bundle of rights not over a single resource, but over benefit streams from single resources.

find significant but minor differences in the characteristics of property rights among land classes and by type of products. For example, property rights characteristics are found to vary between household plots, community woodlands, riverine areas and sacred areas as distinct land classes. In addition resource access characteristics vary by types of products such as exotic fruit species compared to indigenous fruit species, animals and water. The concept of distinct resource areas with multiple uses and multiple levels of access is therefore concluded to be central to CPR access and use in these CA locations.

Nemarundwe (2003) and Hegan *et al* (2003) find that exclusivity of resource use is highest for households with homesteads in closest proximity to the resource. In addition, it is found that the closer the natural resource area is to homesteads, the greater the need for others to seek permission for use. In less exclusive resource areas such as mountains, grazing and riverine areas, permission often has to be sought from traditional leaders for specific harvesting rights. These rights may come with specified allotment types and sizes for wild foods and materials such as honey, fruit, fish, firewood, timber and certain tree species. Some mountain areas that are considered sacred are inherently respected in the norms of locals and thus are not exploited for their natural resources. Nemarundwe (2003) also cites evidence of variations in resource property rights characteristics according to seasonal time periods in the Mutangi and Romwe CA sites. For example, crop fields which are freely crossed during the dry season are not permitted to be trespassed on during the cropping season by either people or livestock, as a means of keeping crops secure. Nemarundwe (2003) attributes differences in perceptions by men and women of CPR products to individual values attached to resources as these are used in activities traditionally conducted by males or females and specific households.

Researchers familiar with the Mutangi and Romwe sites note evidence of challenges to sustainable woodland and riverine areas largely due to increased population pressures in the area. These challenges include man-made bushfires, stream bank cultivation, encroaching settlements and reduction of indigenous tree availability.

More detailed discussion and examples of specific CPR access issues in the Mutangi and Romwe CA regions are pursued in Madondo *et al* (2004) and Nemarundwe (2003).

3.5.2 Access to water in the CA, RA and SSCF sites

Under the new Water Act (1998) all water is vested in the authority of the President. Household water use, beyond volumes required for basic consumptive or primary uses, is now subject to water permit application and is controlled by the Zimbabwe Water Authority (ZINWA) through Catchment Councils (CCs) and Sub-catchment Councils (SCCs). In reality, the concept of entitlement or right of access to a water source in the study areas is somewhat distinct from the concept of water as vested in the President's authority. Property rights to community or shared water resources in the CA, RA and SSCF areas are not formally or documented. Communal systems of water allocation are guided by tradition with institutionalized norms that are self-monitoring and self-enforcing (Mtisi & Nicol, 2003).

In this study, water resources found in the selected CA, RA and SSCF communities include rain water, natural and human-made surface and ground water sources and riverbed resources. Nemarundwe and Kozanayi (2001) find that the main sources of water in Romwe and Mutangi CA regions are dams, boreholes, rivers, streams and wells. The dams and boreholes are communally owned, wells are mostly privately owned, whilst water from the river is treated as an open access resource. There are elected committees for the management of dams and boreholes and these are responsible for collecting annual user fees from households for maintenance. Households that are not members of the local community or villages in the Romwe and Mutangi CA sites are required to seek prior consent before collecting water from community dams and boreholes. However, access to water is never denied and is granted without a fee. The informal rules in existence for use and management of the CPR are flexible, showing an ability to adapt to the changing needs of communities with seasonal changes (Nemarundwe and Kozanayi, 2001).

Households sink private wells to reduce the time spent in fetching water and maintaining irrigated garden plots. Sinking a well in a field is also used as a form of securing rights to the land. A survey conducted by Campbell *et al* (2002) finds that 42.8% of Mutangi and Romwe CA households have a shallow well. For privately-owned water sources, such as shallow wells, management is the responsibility of the owner. Social networks are found to be crucial in facilitating access to and management of water resources. When considering a well from which to seek permission to collect water, households usually take into account familiarity with the well owner and whether they assisted in digging the well. Benefits such as reciprocal sharing of labor, draft power and land accrue to private well owners in exchange for allowing other households to collect water from them (Nemarundwe and Kozanayi, 2001).

Nine general types of water sources, with varying physical and property rights characteristics, were identified within the RA and SSCF sample in this study. Table 3.4 lists and describes the nine general types of water source identified in the RA and SSCF study areas. The description of access conditions by type of water source applies the following property rights characteristics proposed by Haley and Luckert (1990): exclusivity; use designation; use restrictions and fees. These characteristics are found relevant for describing water resource access for the sample households as listed for each water source type in Table 3.4.

Table 3.4: Description and property rights variables of general types of water sources found in the RA and SSCF sample

Water Source Description and Property Rights Variables				
Type of Water Source	**Descriptive Features**	**Use Designation -** Denotes most usual uses. May vary for individual and group exclusive water sources	**Use Restriction -** Volume capacity of containers or unit effort and denotes most usual use restrictions, these may vary by owner and location of water source	**Fees -** Costs associated with use of the water source
1.Shallow well	Ground Water Human-made Low Investment Point source Depth: 1-12m Quality: Poor Seasonal Open Wells	Household specific designated uses dependent on location of well Cooking and drinking for shared wells	Up to 60 liter capacity container may be used to collect water Water amount extracted limited in some shared wells in RA No use of scotch carts permitted to collect water No metal pots used for cooking permitted Laundry/bathing nearby not permitted Area around well should be constructed in brick/concrete	none
2. Deep Well/Borehole	Ground Water Human-made High Investment Mechanical Pump Point source Depth: >12m Quality: High Seasonal/All Year Closed Wells	Cooking and drinking	Up to 60 liter capacity containers may be used to collect water Water amount extracted is limited Livestock watering not permitted Brick molding not permitted Garden irrigation not permitted Water rationing is imposed when rainfall is low Water collection not permitted after dark Users must sweep area clean	Group fees to repair broken equipment/ hand pumps
3. Stream	Surface Water Natural Flowing Quality: Good Seasonal	Cooking, drinking Laundry, bathing Garden, livestock	Large capacity containers such as 200 liter Drums may be used to extract water Cultivation and gardens close to stream is not permitted Fish rearing is not permitted	none
4. Spring/Sponge	Ground/Surface Natural Flowing Quality: Good Seasonal/All Year	Cooking and drinking	Up to 60 liter capacity containers may be used to collect water Use of metal pots used for cooking is not permitted	none

Water Resource Description and Property Rights Variables				
Type of Water Source	**Descriptive Features**	**Use Designation -** Denotes most usual uses. May vary for individual and group exclusive water sources	**Use Restriction -** Volume capacity of containers or unit effort and denotes most usual use restrictions, these may vary by owner and location of water source	**Fees -** Costs associated with use of the water source
5. River	Surface Natural Flowing Quality: Variable Seasonal/All Year	Laundry and bathing Watering livestock Irrigated gardens Alluvial gold panning	Large capacity containers such as 200 liter Drums may be used to extract water No chemicals permitted (chemicals are mostly used for alluvial gold panning)	none
6. Riverbed Pool	Ground/surface Manmade/dug Shallow Point source Quality: good/poor Seasonal	Cooking and drinking	Up to 60 liter capacity containers may be used to collect water Livestock use is not permitted Bathing is not permitted Well should be covered after use	none
7. Dam	Surface Man-made Point source Quality: Variable Seasonal/All Year	Irrigated gardens Livestock Filling dip tank Brick molding	Large capacity containers such as 200 liter Drums may be used to extract water Bathing and laundry is not permitted Fish rearing and fishing is not permitted	Irrigated garden community fees State dam use fees Catchment authority fees
8. Waterway Pool /Stagnant Pool	Surface Natural Flows/Stagnant Seasonal/All Year Quality: Good/Poor	Laundry and bathing Watering gardens	Up to 60 liter capacity buckets may be used to extract water Alluvial gold panning is not permitted because it clogs pool	none
9. Tap/Canal	Piped/pumped Manmade Quality: high Year round High investment	Cooking, drinking, Bathing and laundry Watering garden		Monthly use fees for piped water by volume used Fee to repair broken tap equipment

The descriptions of the general types of water sources in Table 3.4 show a range from naturally occurring water sources such as rivers and streams to dams, boreholes and taps which require relatively high capital investment for construction and involve costs for subsequent maintenance.

Although most water sources are managed as common property resources, elements of open access to water resources are quite strong where users of a given resource are not clearly defined or known to the group. Use restrictions for water sources are defined and more numerous for discrete water sources like boreholes, as compared to water sources that transcend community boundaries, such as rivers. An example is in the prevalence of alluvial gold panning as a major income-seeking activity in the riverbeds of the major Runde and Tokwe rivers. Alluvial gold panning is potentially damaging to riverbed resources because of the use of chemical agents and the clogging of waterways during the lifting and sifting of sand involved in the gold extraction process. Rules restricting gold panning activity in waterway pools (water source number 8 in Table 3.4) are known and generally observed. It appears that the social norms, courtesies and informal rules seem to work at the community level as operational controls on the use of relatively bounded community water resources but are not as effective in the case of the major river. In practice, current Government legislation requires individuals to seek permits in order to engage in gold panning but this law was generally not upheld at individual or community level, nor was it enforced by rural district council authorities.

Formal exclusion of other households from using water sources is rare. Households will often share their 'private' water sources making these exclusive to the use by a group of neighboring households because of social networks. In addition, as observed by Bolding (1997) in the Nyanyadzi River catchment area, further entitlements to water are ascribed based on individual household's perceptions of boundaries for water users, given the location of the specific water sources and water uses. For example, a household might restrict access to a shallow well that is located in gardens and used for irrigating crops.

Not all of the nine identified water source types are found in each community studied. The different types of water sources found in specific communities influence the types of income generating activities that household members pursue. For example alluvial gold panning activity is more prevalent for households with access to the Runde and Tokwe rivers (that is, Villages 12, 13 and 14). Another example is irrigated gardens as a source of income and a means of increasing food security. As Sen (1999) notes, the success of vegetable production in semi-arid regions depends on access to a reliable water source. The survey results show that about 30% of the RA sample and about 60% of CA sample have garden plots irrigated by dams, collector wells or waterway pools.

The preceding discussion in Part I of this thesis highlights variables for analytical models in Parts II and III. These models apply the data described in Chapter 3.

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PART II: Income Diversification in Mutangi and Romwe CA

Part II of this thesis addresses the second topic which is the analysis of income diversification by households in communal areas of Zimbabwe. Six income generation activities[7] were identified amongst the sample households for the study. These are: three agricultural income classes of irrigated agriculture, dryland agriculture and livestock; and three non-agricultural income classes of woodlands, home industry and wages, and remittances from relatives in employment at a location away from the rural home. In Chapter 4 empirical questions for the study are outlined and findings from the empirical literature on rural household income diversification are reviewed. In Chapter 5 econometric analysis is applied to constructed measures of income diversification and income shares from each activity to investigate determinants of these. Implications of model estimation results are then discussed in the context of existing empirical literature, highlighting the role of income from woodlands as a distinct activity in CA household livelihood strategies.

Chapter 4: Research Questions, Literature Review & Measurement

4.1 Introduction and Research Questions

The historic picture of rural Africans as farmers relying on land for agriculture is no longer supported by empirical evidence. Barrett, Reardon and Webb (2001) show that diversification of incomes, assets and activities in rural areas worldwide has become

[7] Following the example of Barrett, Reardon and Webb (2001), income sectors are defined according to the nature of the product and types of factors used in the production process. Income sources within these sectors are further defined according to functional and locational activity classes. The income sectors are primary (including the functional classes: agriculture, mining and other extractive industries); secondary (with manufacturing as a functional class); and tertiary (functional classes: services and wage employment). The functional classification defines non-farm income sources to include all activities outside the agriculture and extractive (from natural resources) sector regardless of location (i.e. on-farm or off-farm). In terms of location, on-farm income activities are those conducted on one's own property regardless of sectoral or functional classification.

the norm. Authors report evidence of non-farm income sources accounting for as much as forty-five percent of average household incomes (Bryceson and Jamal 1997; Reardon, 1997; Little *at al.*, 20001). Comparative empirical evidence suggests diversification of household income sources is greatest in rural Africa (Reardon et al. 1998) and nearly as high in Latin America (Reardon and Berdegue, 1999). In a study of the shift from agrarian economies and rural employment in six African countries, Bryceson (2002) found non-agricultural activities contributing to sixty to eighty percent of rural household income.

The review by Barrett *et al* (2001) shows that typically participation in non-farm income activities in rural Africa is positively correlated with income and wealth (in the form of land and livestock). This suggests that the poor face entry barriers and unaffordable investment costs for participation in non-cropping activities. Further, it is expected that income diversification in rural Africa will accelerate as a result of reduced government presence in rural areas in the context of World Bank and IMF led Structural Adjustment Programs (SAP) and widespread natural and humanitarian disasters (Bryceson and Jamal, 1997; Little *et al.* 1999). These two factors in particular have brought about the need for creative household-level coping strategies including diversified livelihood activities. Nonetheless, some authors claim that this type of accelerated diversification is transitory as it is associated with stress (Saith, 1992). However, a recent review by Rigg (2005) challenges the focus on the distribution and availability of land and other rural resources to address rural poverty as it overlooks observed patterns of diversification out of agriculture.

The definition of farm income sources adopted by most scholars (e.g. Barrett *et al.*, 2001) includes income extracted from natural resources (such as gathering woodlands products, hunting and fishing). However, few studies of rural household income diversification to date actually enumerate income from these natural resource-based activities when calculating total household income from farm sources. An exception is the study of non-agricultural earnings by Lanjouw *et al.* (2001) that accounts income from hunting and gathering or fishing but excludes other natural resource products such as from woodlands. The result is that income reported in most studies is in actual fact income from agriculture (crops and livestock) and under-estimates total household income of farming households by omitting income from natural resource products. This omission is problematic given that numerous authors have since shown a significant contribution by natural resource incomes to households, as high as twenty to thirty percent of total household incomes (for example, Amacher, Hyde and Kanel, 1996; Cavendish, 2000; Adhikari, 2002; Campbell *et al.*, 2002; Veveld *et al.*, 2004; Adhikari, 2005). These authors show that both the relatively poor and wealthy households rely on natural resource incomes although the level of reliance is highest for the poor. Thus, the true magnitude of interventions that are needed to lift households out of poverty by reducing entry barriers to non-farm income opportunities is underestimated to the extent that natural resource-based incomes are underestimated. A further challenge concerns incentives for sustainable management of natural resources where all households participate in natural resource income activities regardless of relative wealth or poverty.

There are rich and mixed empirical findings from the literature on the components and determinants of diversified household livelihoods strategies. Our analysis aims to contribute to the empirical literature by examining the income diversification strategies including income from natural resource uses, for selected households in rural Zimbabwe. Understanding income diversification behavior may have development policy implications for directing transfers to the poor and redressing market constraints for labor, land and capital. These constraints condition allocation of limited household assets and directly impact the poverty and environmental effects of diversification to non-farm income sources.

The specific empirical questions to be addressed by this analysis are as follows:

1. *What is the observed pattern of income diversification?* A number of measures of income diversification are constructed and analyzed based on the relative shares of total gross household income from each income generating activity.

2. *What are the significant determinants of diversification?* Is diversification related to wealth, initial household resource endowments, economies of scope or scale, total household income, income from each activity and/or region of household location?

3. *What are the determinants of the income shares from each activity?* Using the share of income from each income activity, what factors affect income portfolio composition and how? Are these related to, for example: relative poverty which may pre-dispose households to higher reliance on natural resource incomes; wealth and high total income as investment barriers to non-farm income activities; and/or household socio-economic and demographic variables?

To set the stage to explore the empirical questions outlined, the rest of Chapter 4 reviews empirical findings from the literature on income diversification behavior. We discuss measures of income diversification and present an applied conceptual model for analyzing income diversification and its components.

4.2 Relevant Themes in the Literature on Income Diversification

4.2.1 Empirical findings and explanations for income diversification

Income diversification may be observed at various levels such as the national, regional, community, household or individual levels, each with different reasons for diversification. Motivations for diversification have been categorized as either due to *push* factors or *pull* factors by Barrett *at al.* (2001). Push factors are those that encourage decision-makers to leave a particular condition while pull factors draw them to a particular condition. At the level of individuals or households, push factors for diversification have been shown to include management of risk, diminishing returns to assets, response to crisis and high market transactions costs that induce self-provision of commodities. Pull factors at household and individual level arise due to exploitation of complementary production activities and specialization because of comparative advantage in skills and assets. The broad pattern of continued diversification is seen as consistent with increasing specialization according to comparative advantage (Haggblade et al., 1989; von Braun and Pandya-Lorch, 1991; Bernstein et al., 1992; Saith, 1992; Reardon, 1997; Ellis, 1998; Reardon et al., 1998; Reardon et al., 2000).

The aggregate levels of communities, regions and nations are assumed to combine the behavior of individuals and households. Barrett *at al.* (2001) show motivation for diversification at these aggregate levels to result from push factors such as limited risk bearing capacity of weak financial institutions, constraints in labor and land markets and climatic uncertainty. Aggregate level pull factors include local engines of growth due to commercialization, proximity to urban areas with market opportunities and exogenous policy changes. An example is that rural development may expand market access, inducing a shift from the production of primary goods in order to satisfy local rural demand toward production of secondary goods for urban and foreign markets, thereby stimulating diversification of the rural economy away from farming (Hymer and Resnick, 1969; Stewart and Ranis, 1993). Thus, long-term trends in infrastructure improvement, urban growth, and increasing population density may lead to development of the rural non-farm sector (Anderson and Leiserson, 1980).

This study considers the specific case of household-level diversification for rural households in Sub-Saharan Africa. Several researchers expect that non-farm income and asset diversification will continue to be important to households in rural Africa. Rigg (2005) identifies propelling forces for rural transformation which include: i) erosion of profitability of small-holder agricultural production; ii) emergence of new local and non-local non-farm opportunities; iii) increasing land shortage and environmental degradation; and iv) cultural and social change. These forces for transformation have historically manifested themselves in rural-urban migration which has led to farm labor shortages whilst increasing remittance income flows to rural areas (Rigg, 2005). Rigg (2005) also cites evidence in rural South East Asia of generational effects, with older households exhibiting predominantly agricultural income whilst off-spring households showed far greater reliance on non-farm activities. Given that income, activity and asset diversification is widespread and expected to continue, the causes of observed diversification patterns and their effects on household welfare are of interest. The significance of risk aversion and other factors in motivating diversification behavior is further discussed below.

Risk reduction, in the face of climatic variability, market constraints and resource constraints, is thought to be a key reason for rural income and asset diversification in rural Africa (Barrett and Reardon, 2000). Empirical studies have shown that for poor households, highly diversified portfolios typically exhibit low marginal returns, or desperation-led diversification (Barrett, 1997; Reardon *at al*, 2000; Little *at al.*, 2001). In this context income diversification in the presence of risk aversion implies willingness to accept lower income for limited risk exposure and greater security (Barrett *at al*, 2001; Ellis, 2000). Risk management is therefore motivated by the desire to smooth income flows and consumption in the face of limited access to insurance markets (Barrett and Reardon, 2000). For example, there is limited access to crop failure insurance, and an absence of social safety nets such as unemployment benefits or social insurance. Diversification then becomes a form of self-insurance with the pursuit of production activities that are weakly or negatively covariate (by sector and location) to reduce income variability. Examples of empirical studies addressing the motivation to smooth income and consumption through diversification include Murdoch (1990), Alderman and Paxson (1992), Reardon *et al.* (1992), Fafchamps (1992), Udry (1995), Carter (1997), and Bardhan and Udry (1999).

Economic theory considers risk aversion to be decreasing in income and wealth (Binger and Hoffman, 1998). Therefore we expect that poor rural households in Africa are likely to be risk averse and diversified. However, numerous studies in Africa have shown that diversification rises with wealth or income in absolute and relative terms (Barrett *et al*, 1998; Reardon *et al*, 1998). Thus, these scholars conclude that risk reduction does not satisfactorily explain observed patterns of non-farm diversification activity in rural Africa. Related to this conclusion, household capacity to cope with shocks such as drought has been found to be associated with the extent of non-farm diversification in Burkina Faso (Reardon *et al,*, 1992). Although wealthier households were found to diversify as an *ex ante* self-insurance strategy, poor households were also found to be more likely to diversify (to hunting, weaving, beer brewing) as an *ex post* response to shocks such as crop failure or livestock death. Thus, *ex-post* diversification in this case is induced after the outcome of a risky scenario is realized.

Missing or incomplete markets for credit, labor, land and insurance result in high transaction costs that preclude leasing of agricultural land, hiring labor and market access for products. Missing markets for farm inputs such as credit also create entry barriers to income activities such as livestock production that require capital. Omamo (1998) finds that the motivation for diversification in the face of such market constraints is to achieve self-sufficiency in consumption due to costly physical access to markets for goods. Related to the concept of market access is the observation that rural households in peri-urban areas are stimulated to produce more non-farm goods and services for the urban markets in Uganda and Tanzania (Lanjouw *et al.*, 2001; Smith *et al.*, 2001). Physical market access is found to be a key determinant of non-farm earnings (Block and Webb, 2001; Canagarajah *et al.*, 2001).

Diversification may also be induced by diminishing and time varying returns to productive assets. For example, with undeveloped asset markets for land rental, a household may be unable to exchange land for cash to achieve the optimal mix of assets (Barrettt *et al.*, 2000). Similarly, seasonal labor markets during crop production periods may result in limited wage employment opportunities during other times of the year leading to diversification. Economies of scope, which may exist when an input bundle generates higher per-unit profits when employed in multiple outputs than when specialized in one output, are proposed as significant in influencing income diversification of households in Africa by Barret *et al.* (2001). Economies of scope differ from economies of scale which favor specialization because of increased unit profits with increased amounts of all inputs in production. However, empirical tests of the role of economics of scope in rural household diversification have yet to be performed and validated.

Barret *et al.* (2001) highlight some generalizations in the empirical literature on the causes and impacts of household-level income diversification. As a cause for diversification, wealthy households are found to diversify more because they have the capacity to overcome substantial barriers to diversifying into other income activities relative to poor households. A generalization on the impact of diversification is that it is results in a positive relationship between increased non-farm income and household welfare indicators such as wealth, total income, nutrition status and consumption. However, the direction of causality between income diversification and welfare indicators (such as wealth, total incomes, non-farm income) may be difficult to ascertain.

Entry or mobility into high-return income niches is found to be limited to a subpopulation of relatively wealthy households within communities (Dercon and Krishnan, 1996; Carter and May, 1999). Abdulai and Crole-Rees (2001) study the determinants of income diversification amongst rural households in Southern Mali and find that a lack of capital, long distance to markets and a low level of education were significant entry-constraints that prevented non-farm income diversification. A pattern of wealth-differentiated barriers of entry to the non-agricultural sector has also been found by empirical studies in Burkina Faso, Cote d'Ivoire, Ethiopia, Kenya, Rwanda, South Africa and Tanzania, by scholars including Francis and Hoddinott (1993), Dercon and Krishnan (1996), Andre and Platteau (1998) and Carter and May (1999). Further, Reardon *et al.* (2000) suggest that this pattern is more common in Africa relative to other low- and middle-income regions in the world.

The observed positive relationship between non-farm income and household welfare indicators in Africa, suggests that diversification is a potentially valuable area of inquiry for understanding the unequal distribution of non-farm earnings and total income across households (Reardon *et al.*, 2000). For example, Canagarajah *et al.* (2001) find that income inequality in Uganda is increased by non-farm earnings, and that women, the poor, uneducated, recent immigrants, and those with limited social ties in communities have less access to remunerative opportunities. Although a positive relationship tends to be observed between non-farm income diversification and total household income, this is not always the case. For example, there is also evidence from panel data across Africa to suggest that greater non-farm income diversification causes more rapid growth in earnings and consumption across households regardless of relative wealth (Block and Webb, 2001; Canagarajah *et al.*, 2001). Moreover, Hazell and Haggblade (1993) found that both the poorest and wealthiest households had the highest shares of non-farm income in developing country contexts. This phenomenon is clarified by Barret *et al.* (2001), who note that the wealthy continue to farm, but have greater freedom to move between income sectors. On the other hand, the composition of non-farm income for the poor does not represent free mobility. Instead, diversification for the poor may involve off-farm, unskilled labor, which may not reduce the risk of income variability nor increase incomes (Barret *et al.*, 2001). Further, Barrett and Reardon (2000) point out that in Rural Africa, it is important to distinguish between wealth, or accumulated surplus over time, and annual income, which is more transitory[8] in rural Africa.

Based on the general trends in the empirical literature, Barret *et al.* (2001) highlight the need to address challenges of access to non-farm income opportunities for the poor such as: lack of clear institutional ownership of the non-farm income diversification agenda by governments; investment in rural financial institutions and market infrastructure; and increased efforts in health and education to stem the threats of HIV/AIDS and violence in rural areas.

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[8] For example in the context of this study, wealth and income are not found to be highly correlated as incomes are reported in a year with above average rainfall which translates to higher annual incomes economy wide.

4.2.2 Natural resource income and diversification

Taking a broad look at the observed patterns of diversification amongst rural households, literature suggests that poor households are likely to diversify to natural resource incomes such as hunting, weaving and beer brewing (Reardon *et al*, 1992). This pattern may be attributed to thin rural labor markets which make wages largely unavailable as an income earning activity, thereby pushing livelihoods towards natural resources use. Moreover, such households have limited assets to explore other non-farm income opportunities (Barrett et al, 2001). Further, it is believed that poverty increases the marginal individual rate of time preference, resulting in shorter time horizons in consumption of common pool natural resource products (Adhikari, 2005).

A number of other authors have shown a significant contribution of natural resource and environmental incomes to households (Dasgupta, 1993; Amacher, Hyde and Kanel, 1996; Cavendish, 2000; Adhikari, 2002; Campbell *et al.*, 2002; Veveld *et al.*, 2004; Adhikari, 2005). In a meta-analysis of 54 studies of forest resource incomes for the rural poor, Veveld *et al.* (2004) find that environmental income plays an important role in increasing total incomes for all households, not just the poorest. Forest income was found to be a major factor in providing a safety-net to smooth income variability from other sources and in equalizing local income distribution. Vedeld *et al* (2004) also showed that high total household income was associated with relative specialization in high-return activities. In addition, they find an average contribution of 22 percent of household income from forest resources for the sampled populations, although agricultural and non-farm income contributed higher shares of total household income.

A study by Cavendish (1997), on environmental resource use by communal area households in Zimbabwe found that these households derive over thirty percent of their income from various environmental products and services. The level of dependence on natural resources as a percentage of household income was shown to be greatest among the poorer households. Poor households were found to rely heavily on communally-held natural resources such that maintenance of the commons would be critical to their welfare. Nemarundwe (2001) also notes that natural resource users have benefited differentially from institutional conditions on utilization of deteriorating natural resources with the poor households and women benefiting less due to weaker entitlements to resources.

However, similar to Dasgupta (1993), Cavendish (2000) also find that whilst the poor depend more on common pool natural resources in relative terms, in absolute terms their dependency is lower than wealthier households. Motivations for natural resource use for the poor are shown as related to minimizing risk of variable consumption. On the other hand, motivations for the relatively wealthy may be to enhance their incomes by selling natural resources where market opportunities exist (Dasgupta, 1993). This parallels results from Hazell and Haggblade (1993) discussed earlier, of high shares from non-farm income for both the poorest and wealthiest households in developing countries. Cavendish (2000) also concludes that the use and value of environmental resources is likely to vary substantially from year to year in response to both climatic and economic variables.

Lanjouw *et al.* (2001) study non-agricultural earnings in peri-urban areas of Tanzania. These authors find that an average of eight percent of household income was derived from natural resources through hunting and gathering (fishing). They also found that for the wealthiest quintile of households this share was as high as 16% and as low as 1% for the poorest. In Nepal, a study of community forest incomes by Adhikari (2005) shows that the wealthiest households have the largest incomes from community forest products in both relative and absolute terms. The high natural resource income share is attributed to greater use of community forest graze and browse products by the wealthy who owned more livestock than the poor.

In sum, the empirical literature on rural income diversification recognizes the importance of natural resource income for households of varying income and wealth levels. Although natural resource income shares are significant and high in some cases, agricultural income and non-farm income sources are generally found to contribute higher shares to total household incomes. The mixed findings observed regarding the relationship between the share of natural resource income for the poor versus the relatively wealthy may be attributed to accounting methods used. For example, a conceptual question regarding how community graze and browse products (which are intermediate inputs in livestock production) are incorporated in household income accounts is highlighted by the findings of Cavendish (1997; 2000), Campbell *et al.* (2002), Veveld *et al* (2004) and Adhikari (2005). The results from Adhikari (2005), showing higher income shares from community forest products for the wealthy than the poor, are in contrast to those of Cavendish (1997; 2000) and Campbell *et al.* (2002). This discrepancy may be due to how livestock grazing and browse income are accounted for in Adhikari (2005) who explicitly account for natural resource grazing and browse inputs in livestock income, while the latter studies do not.

In general, the studies of household income diversification reviewed in this, and the preceding, section have not paid detailed attention to accounting for natural resource based incomes sources. An important implication from the literature is the need to account for the full range of natural resource incomes in poverty assessments. Without this, rural incomes and the capacity to inform policy for sustainable natural resource use will continue to be underestimated. Thus, the policy challenge of expanding the potential of non-farm income sources to the majority of poor rural Africans is exacerbated given the sketchy information on the magnitude of natural resource income demands of both poor and relatively wealthy rural households.

The review of the empirical literature on the causes and impacts of rural household income diversification behavior highlights the importance of variables such as wealth, total income in a given period, the shares of farm income, non-farm income and natural resource income. However, a lot of questions are still outstanding regarding the direction of causality between income diversification and these variables. As noted by Ellis (1999), the complexity of diversification and its interrelation to poverty, income distribution, farm productivity, environmental conservation and gender relations is not clear and has been shown to be counter-intuitive or contradictory between case studies at times. This thesis study attempts analyze the empirical relationships between these variables for our specific study sample in Chapter 5.

4.2.3 Measuring income diversification

There are three general approaches found in the literature for summarizing observed income diversification patterns. One is reporting the levels of income and income shares from the different income sectors and functional classes, as reviewed by Reardon *et al.* (1998, 2000). A second way is to report the stock of wealth in different forms of assets or the amount of each productive asset (e.g. labor) allocated to a given activity. These two methods are computationally simple for relatively aggregate levels of income activity analysis. The third approach, applied to disaggregate analyses of a vector of income levels or income shares, is the construction of scalar measures or indices of diversification. This third approach is followed in this study.

The scalar measures or indices of diversification are essentially measures of dispersion of the income variable. There are three commonly used measures of dispersion as follows. The Gini coefficient is widely used in the economic geography literature (e.g. Kugman, 1991) and the economic development literature (e.g. Meier & Rauch, 2000). The Herfindahl index is widely used in the industrial organization economics literature (e.g. del-Monte, 1992). The coefficient of variation (CV) is a common measure of dispersion in statistics.

The Gini coefficient is derived from the Lorenz curve (Gini, 1955). The Lorenz curve is constructed by ranking all income observations from lowest to highest and plotting the cumulative proportion of the population on the X-axis and the income variable on the Y-axis. A 45 degree diagonal line represents perfect equality and the Gini coefficient compares the deviation of the cumulative frequency and size curve to the equality distribution. The greater the deviation of the Lorenz curve, from the diagonal line the greater the inequality. The Gini coefficient is an integral calculated as double the area between the equality diagonal and the Lorenz curve. The range of the Gini coefficient is between zero (for perfect equality of income from all activities) and one (for specialization in one income activity).

If we denote the Lorenz curve as $L(u)$, this leads to a formula for the Gini coefficient G as follows:

$$G = 1 - 2\int_0^1 L(u)du \tag{4.1}$$

Dorfman (1978) proposes a proof for a formula for the Gini coefficient which applies to both discrete and continuous distributions of the income variable. The coefficient is defined and valid even with an infinite upper limit to the income of an entity, provided the mean of the distribution is finite. This formula is as follows:

$$G = 1 - \frac{1}{\mu}\int_0^{y^*}[1 - F(y)]^2 dy \tag{4.2}$$

Where:

$F(y)$ is the cumulative probability distribution of income

μ is its mean, assumed finite, and

y^* is the upper limit, which may be infinite

A simple discrete geometric approximation for Equation (4.2) is obtained as the mean difference between every possible pair of individual income levels or shares [denoted by s_i ($i=1,\ldots,n$ with $i \neq j$)] divided by the mean income level share (μ) as follows:

$$G = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}|s_i - s_j|}{2n^2\mu} \tag{4.3}$$

The Herfindahl index, like the Gini uses every data point (making it a full information measure) and falls between zero and one, with one reflecting complete specialization and zero reflecting complete diversification. The Herfindahl index is calculated simply as the sum of squared income shares (s_i=1,.....,n) for all income activities as follows (del-Monte, 1992):

$$HI = s_1^2 + s_2^2 + ... + s_n^2 \tag{4.4}$$

A disadvantage of the Gini coefficient as compared to the Herfindahl index as a measure of diversification is that the Gini coefficient is invariant regarding the addition or subtraction of the number of income activity shares available to the individual decision-maker. Therefore, the Gini coefficient only changes in response to relative shares and not to absolute shares, unlike the Herfindahl index which responds to increases in numbers of activities. The Herfindahl index is therefore a preferred measure of diversification for highly disaggregated data with many activity shares (delMonte, 1992).

The coefficient of variation (CV) is simply the standard deviation (σ) of a variable y divided by its mean (μ), for a population N where σ represents CV as follows:

$$CV = \sigma = \sqrt{\frac{\sum (y - \mu)^2}{N}} \tag{4.5}$$

The more dispersed the data, the higher the coefficient of variation (Greene, 2000). A high CV implies a more equal distribution of income activity levels or shares and a more diversified household. This measure is simple to compute and is not easily skewed by outliers or by inflation. A disadvantage is that the CV can take any value between zero and infinity with no intuitive standard for an acceptable level of variation (or diversification in this study) unlike the Gini coefficient and Herfindahl index.

These three measures for summarizing income diversification have different implicit weighting schemes. For example, the Gini coefficient is sensitive to changes in inequality around the median. While the coefficient of variation is responsive to changes in the upper end and the Herfindahl index is responsive to the number of observations/entities used in its calculation. As such these measures may not rank income diversifications in the same way (Karoly, 1992).

The analysis of diversification among selected rural households in Mutangi and Romwe applies constructed measures of the Gini coefficient, Herfindahl index and coefficient of variation based on observed income data as outlined in Chapter 5. The three indices of diversification are compared by correlation analysis to determine whether they result in similar rankings of income diversification. If it is found that the ranking is similar, it is only necessary to discuss results based on a single index.

4.3 An Applied Conceptual Framework for Analyzing Income Diversification

This study considers the value in monetary terms of production activities in household livelihoods portfolios in an attempt to understand observed income diversification behavior. We employ disaggregated household-level data on household production activities that include the use of woodland resources valued at local market prices at the study sites in South Eastern Zimbabwe. In this section we outline postulated conceptual and statistical models for econometric analysis of the determinants of observed income diversification and relative income shares from various household production activities.

4.3.1 Conceptual model of household income diversification

The general conceptual framework outlined in Chapter 2 (in Part I) showed rural households as producers and consumers optimizing livelihoods objectives with production function, labor and income constraints. The livelihood objective function assumes multiple production activities and variable inputs as decision variables as specified by Equation (2.7) in Chapter 2. This household livelihood optimization model underlies the empirical models outlined below to analyze the observed income shares from each production activity and the observed level of income diversification.

As a starting point, we consider the reduced form equation for the optimal level of aggregate output (Q_i^*) from each production activity defined in Equation (2.21) as follows:

$$Q_i * \left[T_i^*, W_i^*, V_i^* | Z, S_{NR}\right] \qquad (4.6)$$

where: $T_i * [p_T, p_i, p_V, p_w, R|Z, S_{NR}]$, $W_i * [p_T, p_i, p_V, p_w, R|Z, S_{NR}]$ and $V_i * [p_T, p_i, p_V, p_w, R|Z, S_{NR}]$ represent optimal allocations or conditional input demands of household labor time, water and purchased inputs for each production activity *i* respectively; p_i is price of output from each production activity; p_V is price of purchased inputs; p_w is an implicit price of water collected by households; p_T is price of household labor time; Z represents household socio-economic and demographic characteristics such as wealth, capital assets, household composition, education and skills; S_{NR} represents characteristics of the natural resource stocks of woodlands, water and grazing; and *(i =1,......,I)* represents the production activities of dryland agriculture, irrigated agriculture, livestock, woodlands, home industry and wage labor. Remittance income *R* is viewed to be strictly exogenous and linked to household optimization through the budget constraint.

The optimal level of aggregate output (Q_i^*) from each production activity is translated into gross income from each activity by valuing production output at prevailing market prices (p_i). Total household gross income is the summation of the gross income from each production activity plus remittance income. Income shares from each production activity are derived as a proportion of total gross income as follows:

Gross Income from production activity *i*: $p_i Q_i^*$ *(4.7)*

Total gross income from all production activities and remittances:

$$\sum_i p_i Q_i^* + R = M \tag{4.8}$$

Share of gross income from production activity *i*:

$$\frac{p_i Q_i^*}{\sum_i p_i Q_i^* + R} \tag{4.9}$$

Indices of household income diversification (Gini Coefficient, Herfindahl Index and Coefficient of Variation) are constructed based on the computed share of gross income from each production activity as specified in Equation (4.9). A selected index of income diversification is then applied in econometric analysis with per capita total household gross income as an explanatory variable. This relationship to per capita income when applied to income inequality measures (rather than measures of income diversification), is formalized in what is widely referred to as the Kuznets-type inverted-U hypothesis. The Kuznets (1955)[9] hypothesis postulates that income inequality first rises and then falls with a country's development (typically measured by income per capita).

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[9] Kanbur (2000) presents a recent survey of literature in application of the Kuznets hypothesis. The recent empirical literature applies what is termed a weak version of the original unconditional (strong) version by Kuznets (1955) by recognizing and finding that other variables may be involved and these can augment or offset the basic demand forces at play significantly (Higgins and Williamson, 1999; Deininger and Squire, 1996 and 1998).

The specification of econometric models to analyze determinants of income diversification and gross income shares from each production activity builds on the empirical literature, reviewed in Section 4.2, by incorporating postulated explanatory variables representing influences on decisions to diversify income sources. These explanatory variables are the arguments of the reduced form Equation (4.6) defined by the vectors of variables ($T_i^*, V_i^*, W_i^*, p_i, p_w, p_V, p_T, Z, S_{NR}, R$). These variables encompass household wealth, assets, demographic composition, labor, water, purchased inputs, prices and characteristics of natural resources of water, woodlands and grazing. For econometric estimation, the prices of outputs and inputs (p_i, p_w, p_V and p_T) are included implicitly in the value of output (income), the value of purchased inputs and the value of labor allocated to each production activity. Households are assumed to be price takers and the prices observed are assumed not to vary across households for this cross-sectional study sample.

Although the motivation of risk management in diversification has been found to be important this is not assessed in the current study because we have no data on household specific risk preferences. Arguably, the observed household specific diversification strategy as measured by the indices and income activity shares is in fact itself an *ex post* outcome of implementing relative risk preferences.

4.3.2 Statistical models to analyze income diversification and activity shares

Three sets of econometric models are postulated for the analysis. The first model investigates factors influencing calculated diversification measures by ordinary least squares (OLS) regression. The predicted levels of diversification from model estimation inform us about the relative position of households with regard to diversification of income sources and about what variables influence this position in general. However, this does not give any insight into the composition of diversified income strategies in terms of specific activities for heterogeneous households.

The second set of econometric models is therefore postulated to un-package the components of observed household income diversification. This is achieved by Probit regression analysis to investigate the probability of a household participating in each of six distinct income generation activities. The results of Probit analysis inform us about which income activities households are most likely to participate in for income generation. However, this model does not inform us about the relative proportion or level of household income that is generated by each activity and how these may be related to heterogeneity in wealth, income and other variables.

Outstanding questions regarding the causality and effects of observed levels of diversification, wealth, total household income and income from specific types of high-return (such as cash crops, livestock) or low-return (such as wage labor) activities permeates the literature. Thus, the third set of econometric models explores the empirical relationship between these variables in order to make inferences about some of these causal relationships. Of interest is the interaction between diversification, wealth, total household income, farm and non-farm composition of income sources and the contribution of natural resource income in this milieu. Income share equations for each of six income generating activities are employed as dependent variables and analyzed as a seemingly unrelated regression (SUR) system to account for contemporaneous correlation across equations. The share equations specified include predicted measures of diversification from estimating the first set of econometric models. The predicted diversification indices are an instrumental variable representing a households' endogenous diversification level in explaining income shares by activity. The SUR for income activity shares also includes the inverse Mills ratio (IMR) generated by Probit analysis to account for the impact of sample selection in household participation in each income activity on the magnitude of income shares. The three sets of econometric models estimated are further described below.

The first econometric model is postulated to assess the determinants of relative income diversification across the sample of households. The constructed relative indices of diversification for household h, the Gini coefficient ($Gini^h$), the Herfindahl index (HI^h) and the coefficient of variation (CV^h) are dependent variables. The OLS estimation equation for the measures of diversification is as follows:

$$Gini^h \,/\, HI^h \,/\, CV^h = f(m^h, s_i^h, Z^h, S_{NR}, \varepsilon^h) \qquad \forall i = 1,\ldots.., I \tag{4.10}$$

where: m^h *(M/household size)* represents household per capita total gross income; s_i^h is a vector of income shares from each activity i; Z^h is a vector of household socio-demographic, assets, wealth and other characteristics; S_{NR} represents characteristics of natural resource stocks for water, woodlands and grazing; and ε^h is an error term. We specify a corresponding vector of estimated parameters β for statistical estimation.

The second set of econometric models is specified to analyze the probability of household participation in each income activity. Although six aggregate income generating activities were identified amongst the sample households, not all income activities appear in the diversification strategy of each household. It is possible to observe zero values for income activity shares ($s_i^h = 0$) which are not due to a random occurrence but are a consequence of a household's decision or capability to participate in a given income activity for its livelihood. Thus, a participation equation for each income activity is postulated in order to account for possible sample selection bias due to sample attrition because of zero income shares. For regression of discrete dependent variable models, the practice is to construct a probability model that links the decision to the explanatory variables (Greene, 2000).

The postulated binary participation decision in this application may be represented as:

$$\Pr ob(C_i^h = 1) = f\{ v_i^h > -Z^h\gamma \} \qquad \forall i = 1,....., I$$

(4.11)

where: $C_i^h = 0,1$ is the binary indicator variable assuming a value of 1 for participation by household *h* income activity *i*; participation is determined by Z^h, a vector of household socio-demographic, asset and other characteristics with a corresponding vector of estimated parameters γ and error term v_i^h. A continuous probability distribution for v_i^h is used to specify the regression model. The Probit model assumes a normal probability distribution for v_i^h where the function $\Phi(.)$[10] represents the univariate standard normal cumulative distribution function (cdf), as follows (Greene, 2000):

$$\Pr ob(C_i = 1) = \Phi(Z\gamma) \qquad \forall i = 1,....., I \qquad (4.12)$$

Estimation of the discrete choice model is based on the method of maximum likelihood. The Inverse Mills Ratio (*IMR*) is estimated by the probit regression to represent the hazard rate, indicating the likelihood of leaving the state corresponding to 1, in the binary participation decision. The IMR is computed as a ratio of the standard normal density function and the standard normal cumulative distribution function for $C_i^h = 1$, as discussed in Heckman (1979), as follows:

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[10] The univariate standard normal distribution function is $\phi(\cdot) = \dfrac{\exp[-1/2(Z)^2]}{\sqrt{2\pi}}$

$$IMR_i^h = \frac{\phi\left(Z^h \hat{\gamma}\right)}{\Phi\left(Z^h \hat{\gamma}\right)} \qquad \forall i = 1, \ldots, I \tag{4.13}$$

The IMR is then included as an explanatory variable in the regression of income activity shares, as a hazard rate correction for sample selection bias for households that do not participate in a given income activity.

The third econometric model postulated is for joint estimation of household income activity shares is a SUR system. This model explores significant determinants of the magnitude of each of the income activity shares in a diversified household income portfolio. Multivariate estimation techniques allow model specification as a system of simultaneous equations with jointly determined dependent variables while accounting for contemporaneous correlation in the residuals across equations. A widely applied model for estimating regression coefficients for the systems of equations is the seemingly unrelated regression (SUR) using the Zellner (1962) estimation technique. The seemingly unrelated regression model may be specified as follows:

$$Y_i = X_i \beta_i + \mu_i \qquad \forall i = 1, \ldots, I \tag{4.14}$$

where: Y_i is a vector of n observations on a dependent variable (income shares in this study); X_i is a full-column rank $n \times k_i$ matrix of explanatory variables (defined by the variable vectors $(m^h, s_i^h, Z^h, S_{NR}, \varepsilon^h)$ as described in previous sections); β_i a vector of k_i unknown coefficients; and $\mu = (\mu_{i1} + \mu_{i2}, \ldots\ldots, \mu_{in})'$ a $n \times 1$ vector of random errors. The notation in compact form is:

$$Y = X\beta + \mu$$

(4.15)

Where $Y = \begin{pmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_I \end{pmatrix}$ $X = \begin{pmatrix} X_1.0 \ldots\ldots 0 \\ 0 \cdots X_2 \ldots 0 \\ 0 \ldots\ldots \ddots \\ 0 \ldots 0 \ldots X_I \end{pmatrix}$ $\beta = \begin{pmatrix} \beta_1 \\ \beta_2 \\ \vdots \\ \beta_I \end{pmatrix}$ $\varepsilon = \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_I \end{pmatrix}$

$E[\varepsilon] = 0$ and $E[\varepsilon\varepsilon'] = \Sigma \otimes I_N$

(4.16)

The income shares for the six identified income activities (*i=dryland agriculture, irrigated agriculture, livestock, woodlands, home industry and wages, remittances*) are described in the next chapter (Table 5.3). Since the income activity shares sum to one, one of the share equations is eliminated during econometric estimation to avoid over-determination and singularity. For the econometric models estimated and presented in Chapter 5, the income activity share for remittances is omitted.

All postulated econometric models are estimated using the SHAZAM econometrics computer program (White, 2000). The data employed and estimation results for these models are discussed in Chapter 5.

Chapter 5: Modeling Income Diversification of Households

This chapter reports estimation results for the three empirical models, described in Section 4.3, which are postulated to analyze income diversification and income shares from different livelihood activities. We outline the empirical model specification and *a priori* expected effects of explanatory variables. This is followed by descriptions of the data and variables applied in the econometric analysis and a discussion of model estimation results. The chapter conclusion summarizes findings and interprets their implications.

5.1 *Specification of Applied Empirical Models and a priori Expectations*

Three empirical models are specified to analyze: a) determinants of income diversification indices across households; b) household participation in each of six income generating activities; and c) determinants of the magnitude of income shares from each income generating activity. Dependent variables for models a) to c) are: a) an index measures of income diversification (three measures, the Gini coefficient, Herfindahl index and Coefficient of Variation are considered); b) a binary variable for each income activity which assumes a value of one if a household received income from that activity and is zero otherwise; and c) the share of income from each activity.

Explanatory variables in all models are defined by the vectors of variables $(m^h, s_i^h, Z^h, S_{NR}, \varepsilon^h)$ arising from optimization of the household livelihood objective and based on the empirical literature (as discussed in Sections 4.2 and 4.3). These variables include household per capita total gross income, an index of household wealth, a measure of average return to purchased inputs and labor, household demographic composition and resource characteristics. The discussion of *a priori* expected effects of explanatory variables is informed by empirical findings in the literature on income diversification as summarized in Section 4.2.

5.1.1 Empirical model for determinants of income diversification

An ordinary least squares (OLS) estimation equation for the determinants of relative income diversification in the sample of households is specified. The constructed relative measures of diversification, the Gini coefficient, the Herfindahl index and the coefficient of variation are postulated alternative dependent variables. The empirical equation is specified as follows:

$$\begin{aligned} Gini_h \,/\, HI_h \,/\, CV_h &= \alpha_0 + \beta_1 pcyincome_h + \beta_2 pcyincome_h^{\,2} + \beta_3 IEM_h \\ &+ \beta_4 IEM_h^{\,2} + \beta_5 drylandsh_h + \beta_6 wetlandsh_h + \beta_7 livestocksh_h \\ &+ \beta_8 woodlandsh_h + \beta_9 hhwagesh_h + \beta_{10} remitsh_h + \beta_{11} wealth_h \\ &+ \beta_{12} labor_h + \beta_{13} irrigation_h + \beta_{14} site_h + \beta_{15} gender_h \\ &+ \beta_{16} education_h + \beta_{17} age_h + \varepsilon_h \end{aligned} \qquad (5.1)$$

where the explanatory variables for each household (*h*) are defined in Table 5.1.

Lower values of the dependent variables imply greater income diversification whilst higher values imply increased income specialization. Thus, a positive coefficient sign implies an explanatory variable effect that tends to increase income specialization whilst a negative sign favors diversification. Table 5.1 summarizes the expected directions (+/-) of the effect of the various explanatory variables on the diversification measures.

We expect the following relationships among variables and income specialization/diversification. Higher per capita total gross income (*pcyincome*) is expected to increase the capacity of the household to invest in inputs that increase output from specialization in income activities such as dryland agriculture. The marginal effect of per capita total gross income is expected to be decreasing, implying a negative effect for its squared term. The income efficiency measure (IEM) is constructed to measure the return on every dollar invested in labor and purchased inputs for all income activities. We expect a higher IEM to be positively correlated with increased diversification. We hypothesize that this relationship results from a potential for economies of scope when a household's input bundle generates higher per-unit profits from being employed in multiple outputs rather than being specialized in producing a single output. Thus we expect that a higher IEM may be related to increased diversification although at a decreasing rate, implying a negative effect for its squared term.

Table 5.1: Definitions of Explanatory Variables and Expected Effects on Income Diversification

Explanatory Variables	**Expected Effect on Diversification Measures Gini (*gini*)/ Herfindahl (*HI*)/ Coefficient of Variation (*CV*)**
Per Capita Total Gross Income Received from all Income Sectors combined (*pcyincome*)	+
Per Capita Total Gross Income Squared (*pcyincome*^{2})	-
Income Efficiency Measure (IEM) of average return to purchased inputs and labor	+
Income Efficiency Measure Squared (IEM^2)	-
Share of Gross Income Received from Irrigated Gardens (*wetlandsh*)	_
Share of Gross Income Received from Dry Land Agriculture (*drylandsh*)	+
Share of Gross Income Received from Livestock (*livestocksh*)	+/_
Share of Gross Income Received from Woodlands (*woodlandsh*)	_
Share of Gross Income Received from Wages/Home Industry (*hhwagesh*)	_
Share of Gross Income Received from Remittances (*remitsh*)[b]	--------
Wealth Factor Score from Principal Components Analysis (*wealth*)	+/-
Total household labor pool in adult male equivalents (*labor*)	+/-
Study site where household is located (Romwe=1; Mutangi=2) (*site*)	+/-
Access to good source of irrigation for garden (*irrigation*)	+/-
Age of household head (*age*)	+/-
Gender of household head Male=1; Female=2 (*gender*)	+/-
Education of household head (*education*)	+/-
Number of children in household (*children*)	+/-
Number of adult females in household (*adultfemales*)	+/-

Note: Variable names are in parentheses; (+) implies increased specialization; (-) implies increased diversification; b = there is no expected sign on *remitsh* because it is the base case, omitted from the regression. The other share signs are interpreted relative to this base case

Higher shares of income from irrigated gardens (*wetlandsh*), woodlands (*woodlandsh*) and home industry and wages (*hhwagesh*) are each expected to lead to increased diversification. Higher incomes in each of these three activities are expected to reflect a diversified strategy because of limited opportunities for households to expand and specialize in each activity. For example, irrigated gardens face the constraint of limited access to accessible sources of water, whilst wage labor activities face the constraint of thin rural labor markets. Woodlands activities are regulated by communal access to woodlands and the attendant social norms that tend to limit the ability of households to specialize in this activity as an income source. For the income activities where there is potential to specialize, such as dryland agriculture and remittance income the expected sign is positive. For livestock income although the potential to specialize exists, severe barriers in the form of capital constraints to purchase livestock may result in a negative sign implying increased diversification.

The direction of the effect of the rest of the variables postulated to explain relative income diversification is unclear, remaining as empirical questions to be tested. It is unclear what effect greater wealth (*wealth*) may have on relative specialization or diversification. Mixed findings are reported in the empirical literature, which suggest on one hand that higher initial wealth is expected to provide the capacity to overcome entry barriers into some income activities and hence favor diversification, whilst on the other hand this could potentially allow investments in income specialization that could exploit benefits from economies of scale. Similarly, for the relatively poor households, diversification is seen as a survival strategy to try to reduce total income variance. Further, although it has been found that wealth and income are generally positively correlated, leading us to expect similar signs of effect on diversification, this may not always be the case. This is because transitory income at a given point in time in rural Africa is variable particularly between years with above or below average rainfall in the study areas.

5.1.2 Empirical model for participation in income activities

The applied empirical specification for Probit estimation of equation (4.11) for participation in each income activity is:

$$\Pr ob(C_i = 1) = \alpha_0 + \gamma_1 wealth_h + \gamma_2 labor_h + \gamma_3 irrigation_h + \gamma_4 site_h + \gamma_5 gender_h + \gamma_6 education_h + \gamma_7 age_h + \gamma_8 children + \gamma_9 adultfemales + \varepsilon_i^h \quad (5.2)$$

The IMR is the estimated Inverse Mills Ratio as defined by Equation (4.13) while all other variables are as defined in Table 5.1. Table 5.2 summarizes the expected directions (+/-) of the effect of the various explanatory variables on participation in each income activity.

Table 5.2: Expected effects of Explanatory Variables for Participation in Income Activities

EXPLANATORY VARIABLES	*Wetlandsh.*	*Drylandsh*	*libestocksh*	*woodlandsh*	*hhwagesh*	*remitsha*
Wealth Factor Score from Principal Components Analysis (*wealth*)	+/-	+/-	+	-	-	+/-
Total household labor pool in adult male equivalents (*labor*)	+/-	+/-	+/-	+/-	+/-	+/-
Access to good source of irrigation for garden (*irrigation*)	+	-------	-------	-------	-------	-------
Study site where household is located (Romwe=1; Mutangi=2) (*site*)	+/-	+/-	+/-	+/-	+/-	+/-
Gender of household head Male=1; Female=2 (*gender*)	+/-	+/-	+/-	+/-	+/-	+/-
	+/-	+/+	+/-	+/-	+/-	+/-
Education of household head (*education*)	+/-	+/-	+/-	+/-	+/-	+/-
Age of household head (*age*)	+/-	+/+	+/-	+/-	+/-	+/-
Number of children in household (*children*)	+/-	+/-	+/-	+/-	+/-	+/-
Number of adult females in household (*adultfemales*)	+/-	+/+	+/-	+/-	+/-	+/-

Note: Variable names are in parentheses

We hypothesize that household characteristics such as wealth (*wealth*), labor pool (*labor*), access to water for irrigated gardens (*irrigation*), village (*site*) of household location, household composition (*children* and *adultfemales*), and household head age (*age*), education (*education*) and gender (*gender*) explain participation in an income activity. We expect that wealth (*wealth*) will increase the probability of participating in livestock income activity because of relatively the high investment cost of livestock purchase. In contrast, we expect wealth to have a negative impact on the probability of deriving income from woodlands and wage labor and home industry, which are relatively low-return activities. Households with access to accessible sources of water are expected to have a higher probability of participating in irrigated gardens. For the remaining variables postulated to determine participation in income activities, it is unclear what the sign of effect will be and this will be assessed by econometric analysis.

5.1.3 Empirical SUR model of income activity shares

The applied empirical SUR estimation equation for income activity shares ($Share_i$) is specified as follows:

$$\begin{aligned} Share_i &= \alpha_0 + \beta_1 pcyincome_h + \beta_2 pcyincome_h^2 + \beta_3 IEM_h \\ &+ \beta_4 IEM_h^2 + \beta_5 wealth_h + \beta_6 labor_h + \beta_7 irrigation_h + \beta_8 site_h \\ &+ \beta_9 \hat{gini}_h + \beta_{10} IMR_{ih} + \mu_h \end{aligned} \quad (5.3)$$

where: $Share_i$ is income share for activity i=dryland agriculture, irrigated gardens, livestock, woodlands, home industry and wages, remittances; $\hat{gini}_h$ is the predicted measure of diversification from the model of diversification indices against explanatory variables specified in equation (5.1); and IMR_h is a random variable generated by the Probit model as specified in equation (5.2) which is included as an explanatory variable to correct for sample selection bias. In the estimated SUR model, the income activity share for remittance (*remitsh*) income is omitted to avoid singularity, since otherwise the income activity shares sum to one.

Table 5.3 summarizes the expected direction of effects (+/-) of explanatory variables on the dependent variables of income activity shares. For most of the explanatory variables there are no *a priori* expectations for the sign.

The predicted measures or indices of diversification are postulated as endogenous[11] explanatory variables in determining the share of income from each activity as

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[11] An endogenous variable is defined as one that is caused by one or more variables contained within the model being evaluated.

postulated in equation (5.3). Higher values of the predicted level of income diversification (*gini, HI, CV*) indicating relative specialization are expected to be associated with increased income shares from dryland agriculture because of a potential for relatively higher returns from specialization in this activity. It is unclear whether to expect income shares for the other activities to increase or decrease with relative specialization.

Table 5.3: Definition of Explanatory Variables and Expected Effects on the Magnitude of Income Shares from Each Income Activity

EXPLANATORY VARIABLES	*Wetlandsh.*	*Drylandsh.*	*livestocksh*	*woodlandsh*	*hhwagesh*	*remitsha*
Per Capita Total Gross Income Received from all Income Sectors combined (*pcyincome*)	+	+	+	+	+	+
Per Capita Total Gross Income Squared (*pcyincome*²)	-	-	-	-	-	-
Predicted Gini (*gini*)/ Herfindahl Index (*HI*) / Coefficient of Variation (*CV*)	+/-	+	+/-	+/-	+/-	+/-
Inverse Mills Ratio (*IMR*)	+	-	-	-	-	+
Income Efficiency Measure (*IEM*) of average return to purchased inputs and labor	+/-	+/-	+/-	+/-	+/-	+/-
Income Efficiency Measure Squared (*IEM*²)	+/-	+/+	+/-	+/-	+/-	+/-
Wealth Factor Score from Principal Components Analysis (*wealth*)	+/-	+/-	+	-	-	+/-
Total household labor pool in adult male equivalents (*labor*)	+/-	+/-	+-	+/-	+/-	-
Study site where household is located (Romwe=1; Mutangi=2) (*site*)	-	+	+	+/-	+/-	+/-
Access to good source of irrigation for garden (*irrigation*)	+	------	-------	-------	------	------ -

Note: Variable names are in parentheses

The income activities with highest probabilities for participation by all households are expected to have an insignificant effect on the coefficient for the sample selection hazard rate (*IMR*). These activities are dryland agriculture, because all households rely on dryland crops for food production, and woodlands income, because woodlands are communal resources that may be used by all households. The income activities with entry barriers, such as livestock and remittances, are expected to have a positive and significant IMR coefficient, indicating sample selection.

Wealth is expected to be associated with a capacity for higher initial investment in livestock, resulting in higher income shares in this sector. The shares of the woodlands and home industry and wages activities are expected to be negatively related to wealth and income levels, as these are postulated to be diversification strategies that have minimal entry barriers and are largely pursued by the poor. A smaller labor pool could be associated with a larger income share from remittances because none of the on-farm household labor is employed by this activity. The regional location of a household as measured by the variable (*site*) may impact the size of income shares from the different activities because of inherent regional differences in opportunities and constraints. For example, households in Romwe are expected to have larger income shares from irrigated gardens because they are located in a relatively wet region compared to Mutangi households. Similarly, income shares from livestock activities may be higher in Mutangi because of the drier agro-climate favoring livestock production compared to crops. The income share from irrigated gardens is expected to be negatively related to the variable indicating poor access to a source of irrigation water (*irrigation*). The irrigation access variable is expected to be insignificant in influencing income shares from all other sectors.

5.2 Data Descriptions

The data and the data collection process were described in detail in Chapter 3 in Part II of the thesis. Following are details on how the collected data was use to calculate values of variables.

5.2.1 Income activities and income shares

Income from each income activity in this study is calculated for the whole year and refers to the period from January to December 1999 inclusive. The year 1999 was a relatively good year in terms of average rainfall. This was also a year of relative economic stability in Zimbabwe. Since the year 2000 to date, Zimbabwe has experienced persistent drought and a spiraling rate of inflation.

Household total gross income for the year, in Zimbabwe dollars (Z$)[12], is the unit of measure for this analysis. Total gross income combines cash income and imputed non-cash income, such as production for own consumption, without subtraction of expenses, imputed at prevailing prices during the survey year. Campbell et al (2002) identified seven classes of activities of sample households in Mutangi and Romwe communal areas (Table 5.4). Six of these activities, excluding domestic activities, are subsequently referred to as income generating activities, and are included in this analysis.

Table 5.4: Income Generating Activities in Analysis of Household Livelihood Strategies

Income Activities	Example Activities and/or Products
Dryland Crops	Maize, sorghum, millet, ground nuts etc. (rainfed)
Gardening (Irrigated/wetland agriculture)	Tomatoes, green beans, okra, etc. (irrigated)
Livestock production	Cattle, donkeys, goats, pigs, poultry and products such as milk, manure, hide consumed and sold etc.
Woodland use	Wood and non-wood products including construction wood, fuelwood, thatch, small animals, fruits, mushrooms etc.
Wage labor and home industry	Wages from local employment (e.g. domestic and agricultural work) and cash-generating home industries such as carving, brick molding, fixing bicycles/implements, making household utensils from scrap metal, etc.
Remittances and gifts	Cash sent by family members not living with the household, and gifts
Domestic	Maintenance of basic household health and nutrition including: preparing and eating meals, housekeeping and construction, attending gatherings, traveling, leisure and sleeping and education

Source: Campbell *et al* (2002)

Table 5.5 summarizes descriptive statistics for household total gross income and income shares from each activity defined in Table 5.4. The share of income from each income activity is calculated as a proportion after aggregating income from all six activities. Thus the income shares are discrete variables of non-negative proportions that sum to one across all income activities for each household.

[12] The reported income values are in Zimbabwe dollars (Z$), for which the exchange rate conversion was Z$38-40 to US$1 during the time of survey (i.e. between mid-January 1999 and mid-January 2000).

Table 5.5: Descriptive Statistics for Gross Income and Income Share by Activity for the Year (1999) In Z$

Income Source	Mean N=181		Std. Dev.		Minimum		Maximum	
	Gross	Share	Gross	Share	Gross	Share	Gross	Share
Dryland Agriculture	10,963	0.346	10,937	0.164	668	0.036	77,081	0.766
Irrigated Gardens	2,320	0.078	3,586	0.107	0	0	19,580	0.585
Livestock	5,730	0.158	8,052	0.170	0	0	59,289	0.837
Woodlands	3,930	0.182	2,476	0.149	561	0.013	13,215	0.619
Home Industry & Wages	3,004	0.095	7,563	0.122	0	0	78,910	0.796
Remittances	5,157	0.141	8,553	0.151	0	0	77,381	0.760
Total Gross Income	31,103	1.00	22,678		5,694		144,20	

Notes: Std. Dev. = standard deviation; The means for income shares do not add up to the exact shares as depicted by the gross income means because gross income means are derived for all household even those with zero income for a particular activity. Mean shares are derived relative to each household's total gross income and then averaged across households. This is the reason that the mean woodlands income share is larger than the income share for livestock, even though the mean absolute income for livestock is higher than that of woodlands.

From Tables 5.5 we see that all sample households received income from dryland agriculture and woodland activities. Dryland agriculture on average contributes the largest absolute amount and share of household income, and is the main source of household food provision. The second and third largest absolute income values are from livestock activities for those households who participate in this, followed by remittances. From the income shares we see that woodlands activity, which is a primary source of household energy inputs, generates the second largest income share after dryland agriculture. However, the mean of the absolute gross income value for woodlands is the fourth largest. The large woodlands income share shows that for certain households, the share of woodlands income relative to other income sources is quite high. Table 5.5 suggests that livestock and remittance income activities, for which mean absolute gross income values are larger than for woodlands, are not large components of income shares for the majority of households. Irrigated gardens contribute the smallest mean value of absolute gross income and the smallest income share of all activities. This reflects constraints to many households of access to a source of irrigation water for gardens.

5.2.2 Constructed measures of income diversification

Three scalar measures of income diversification across income activities (the Gini Coefficient (Gini), the Herfindahl Index (HI) and the Coefficient of Variation (CV)) are constructed using SPSS (SPSS Inc., 2004) by applying mathematical formulae as outlined in Section 4.2.2. Table 5.6 summarizes descriptive statistics for these measures of diversification.

Table 5.6: Descriptive Statistics for Income Diversification Indices Across Income Activities

Diversification Measure	**Mean** N=181	**Standard Deviation**	**Minimum**	**Maximum**
Gini Coefficient	0.393	0.092	0.17	0.63
Herfindahl Index	0.339	0.089	0.19	0.71
Coefficient of Variation	0.165	0.041	0.06	0.30

Table 5.7 outlines a correlation matrix for the diversification measures and indicates level of significance of correlations showing that all three measures of diversification are highly and significantly positively correlated. In particular we find that the Herfindahl index and the coefficient of variation are almost exactly correlated. Thus, econometric analysis of measures of income diversification will only be conducted with the calculated Gini coefficient and Herfindahl index.

Table 5.7: Correlation Matrix for Calculated Measures of Income Diversification

Diversification Measure	Gini Coefficient	Herfindahl Index	Coefficient of Variation
Gini Coefficient	1.000		
Herfindahl Index	0.754	1.000	
Coefficient of Variation	0.786	0.988	1.00

Notes: Pearson Correlation results reported; All Pearson (parametric) and Spearman's Rho (non-parametric) correlations are significant at the 0.01 level (2-tailed)

5.2.3 Relative index of household wealth

Relative wealth was identified as an important factor in describing household livelihoods in Mutangi and Romwe CAs by Campbell *et al* (2002). In addition studies reviewed in the preceding sections on household income diversification in rural Africa indicate wealth or initial asset endowments as an important factor explaining income diversification. The Mutangi and Romwe CA households were grouped according to asset status based on analysis of quantitative data collected by Campbell *et al* (2002). A relative wealth index was created based on indicators of wealth status using Principal Components Analysis by Campbell *et al,* (2002). This combined variables that included area of dryland fields, area of irrigated land, type of housing, remittances during the survey period, numbers of cattle, goats, donkeys, numbers of various types of productive equipment (e.g. plough, scotchcart, wheelbarrow, machete etc.) and numbers of specified types of household equipment (e.g. mortar and pestle, sewing machine, television etc.). Through an iterative process eliminating series of variables, the analyses generated a continuous variable index of relative wealth ranking for each household. This index was used to rank households to generate quartiles of households in Mutangi and Romwe for the study by Campbell *et al*, (2002). Means of Gini coefficient for income diversification, gross incomes and income shares by activity for the four wealth groups are presented in Table 5.8.

Table 5.8: Means of Gini Coefficient, Gross Income and Income Share Measures by Activity for Four Wealth Groups

Wealth Group	Gini Coeff.	Total Gross Income	Irrigated Agric.	Dryland Agric.	livestock	woodlands	Wages/ home industry	remittances
I Poor (N=49)	0.412	17,800	0.088	0.325	0.066	0.276	0.135	0.111
II Medium Poor (N=50)	0.400	23,505	0.071	0.356	0.137	0.212	0.101	0.123
III Medium Wealthy (N=50)	0.368	30,032	0.077	0.344	0.212	0.157	0.097	0.113
IV Wealthy (N=50)	0.393	52,809	0.077	0.358	0.215	0.085	0.046	0.218
Whole Sample (N=50)	0.393	31,103	0.078	0.346	0.158	0.182	0.095	0.141

Table 5.8 shows that as a relative index of income diversification the Gini coefficient (used for illustration), decreases consistently from the lowest wealth group to the highest. Based on our interpretation of the Gini coefficient, with smaller values indicating greater diversification in income-generating activities, the means in Table 5.7 suggest that wealthier households are relatively more diversified. Mean total gross household income increases from poorer to wealthier households. Mean income shares from dryland agriculture and irrigated agriculture are similar across relative wealth groupings. The woodlands income shares have the widest range across wealth groups combining an average of 8.5% for the poorest households and an average of 27.6% for the wealthiest in terms of contribution to total income for these quartiles. This is followed by the livestock income shares which range from a mean share of 6.6% for the poorest households to 21.5% for the wealthiest

households. The overall pattern of mean income shares in Table 5.7 suggests that the wealthier households have the largest mean income shares from livestock and remittances, and smallest mean income shares from woodlands and from wages and home industry activities.

5.2.4 Relative measure of income efficiency

The income efficiency measure (IEM) applied here is calculated as a simple ratio of total gross income from production activities to the value of purchased inputs and labor inputs to all production activities. The IEM is a relative number with no units and therefore can be compared across households in differing circumstances at different scales of production activity. This measure reflects the return on every dollar invested in labor and purchased inputs.

In calculating labor cost to households, the total amount of labor time in hours applied to each income activity, as recorded from surveys, is valued at a specified wage rate. Time in hours spent on each income sector by each type of household member over the entire survey period is multiplied by an hourly[13] wage rate multiplied by the labor equivalent unit for each type of household member and multiplied by the household composition for each household. We apply the conversion scale for labor equivalent units proposed by Johnson (1990) for agricultural households in the tropics. This scale assigns each adult male a weight of 1.0, each adult female a weight of 0.8 and each child a weight of 0.5. We assume that there are 252 working days in the year with an average of 21 working days per month for the calculation. The hourly wage rate of Z$2 is used for the labor cost calculation, as described in footnote 12. The descriptive statistics for the household labor

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[13] In the study of Mutangi and Romwe CA household resource allocation Campbell *et al* (2004) propose hourly wage rate of Z$9 based on rates of Z$72/day and an 8 hour working day for the sample households. However, Zindi (2006) finds that a wage rate of Z$2 is more appropriate for use in estimation given the high level of unemployment in the study area and inability of the formal labor market to clear at the higher wage rate. An hourly wage rate of Z$2 is used in this analysis.

equivalent units and IEM calculated for the sample are presented in Table 5.9 and discussed below.

5.2.5 Descriptive statistics for explanatory variables

Descriptive statistics for all other explanatory variables are presented in Table 5.9.

Table 5.9: Descriptive Statistics for Explanatory Variables (N=199)

EXPLANATORY VARIABLES	Type of Variable	Mean	Standard Deviation	Minimum	Maximum
Per Capita Total Gross Income Received from all Income Sectors combined *pcyincome*)	Continuous	9085	6552	1868	45034
Per Capita Total Gross Income Squared (*pcyincome²*)	Continuous	1.3E+08	2.3E+08	3.5E+6	2.0E+09
Income Efficiency Measure (IEM) of average return to purchased inputs and labor	Continuous	2.68	1.44	0.94	12.97
Income Efficiency Measure Squared (IEM²)	Continuous	9.27	15.15	0.89	168.13
Wealth Factor Score from Principal Components Analysis (*wealth*)	Continuous	0.00	1.00	-1.60	2.74
Total household labor pool in adult male equivalents (*labor*)	Continuous	4.52	1.44	1.80	9.40
Gender of household head Male=1; Female=2 (*gender*)	Binary	1.34	0.47	1	2
Number of adult females in household (*adultfemales*)	Continuous	1.85	1.06	0	6
Age of household head (*age*)	Continuous	52.28	15.23	20	94
Education of household head (*education*) (None=1; Primary =2; Secondary=3; College =4)	Categorical	1.94	0.62	1	4
Study site where household is located (Romwe=1; Mutangi=2) (*site*)	Binary	1.38	0.48	1.00	2.00
Access to good source of irrigation for garden (Yes=1; No=2) (*irrigation*)	Binary	1.32	0.47	1	2

Note: Variable names are in parentheses

Table 5.9 shows that the average household generates Z$2.68 for every Z$1 invested in purchased inputs and labor based on the calculated IEM. Sample households have a labor pool of on average 4.5 adult male equivalents with a range of 8 adult male equivalents. The average age of household head is quite high at 52 years with most households heads educated below the primary school level.

5.3 *Model Estimation Results*

The final models estimated exclude some of the variables initially postulated as explanators [defined by Equations (5.1), (5.2) and (5.3)]. Preliminary analysis disclosed a number of insignificant variables whose exclusion resulted in better overall goodness of fit for estimated models. Goodness of fit measures were based on model diagnostic statistics such as the Mean Square Error (MSE), variance of error terms, log likelihood function and model R^2. Insignificant variables were also excluded from the final analyses where there was evidence of significant correlation with other significant variables in models estimated. Appendix I-5 presents a matrix of bivariate correlations for all variables postulated for the analysis of the three sets of empirical models.

In the sections that follow we report and discuss results of econometric estimation for three sets of models. The first results reported are for a model investigating factors influencing the values of calculated measures of relative income diversification across households. The second set of results discussed inform us about the probability for each household of participating in each of the six identified income activities to gain further insight into the general composition of diversified income strategies by households. The third results section reports on the relative proportion of total gross household income that is generated by each activity, in order to further analyze composition of diversified household incomes in quantitative terms.

5.3.1 Income diversification

Three indices of income diversification were defined in Section 5.2.2. The coefficient of variation is not analyzed further as a measure of income diversification because of its almost exact correlation with the Herfindahl index, as shown in Section 5.2.2. In selecting which of these two measures to analyze we considered the fact that the Herfindahl index has an intuitive interpretation since the range of values assumed fall between zero (for complete diversification) and one (for complete specialization), similar to the Gini coefficient. In contrast, the coefficient of variation may assume any value between zero and infinity.

Although the dependent variables (Gini coefficient and the Herfindahl index) are continuous, the range of values they assume is not the entire real number line. The range of values for the dependent variables is truncated below at zero and above at one. This suggests that linear regression by OLS may be inappropriate because of correlation of the error terms and the dependent variable resulting in inconsistent parameter estimates. Thus, we also estimated a truncated regression[14] applying maximum likelihood techniques with Gini coefficient and the Herfindahl index as dependent variables. However, the estimation results from truncated and OLS regression with the Gini coefficient and the Herfindahl index as dependent variables are found to be very similar. Thus, the ordinary least squares (OLS) estimation results for these diversification measures are reported (in Table 5.10) and discussed in sections that follow. Wealth was not included in the final regression model because of its insignificant effects on all measures of diversification. This appears to result from significant negative correlation with woodlands income share and positive correlations with the IEM, per capita total gross income, livestock income share and remittance income share (see Appendix I-5).

The OLS estimation results in Table 5.10 show that the explanatory variables have a similar effect on both measures of diversification with the same variables exhibiting the same sign and significance. Thus we select only one set of predicted values for one of the measures of diversification to carry forward as an instrumental variable in the analysis of income activity shares with results reported in section 5.3.3. We select

[14] The estimation results of truncated regression of measures of income diversification measures will be made available on request.

the predicted Gini coefficient because this model has better overall goodness of fit. The Gini coefficient is also favored because of its wide use in the literature on development economics.

Table 5.10: OLS Estimation Results for Income Diversification Measures

Variable/ Diagnostic Statistic	**GINI Coefficient**		**Herfindahl Index**	
	Coefficient	*St. Error*	*Coefficient*	*St. Error*
CONSTANT	0.340***	0.046	0.203***	0.049
pcyincome	0.376E-05***	0.103E-05	0.408E-05***	0.110E-05
IEM	-0.034***	0.011	-0.029***	0.012
IEM²	0.004***	0.001	0.004***	0.001
drylandsh	0.186***	0.043	0.204***	0.046
wetlandsh	-0.242***	0.061	-0.073	0.109
livestocksh	-0.156***	0.049	0.123***	0.053
wodlandsh	0.126**	0.055	0.176***	0.058
hhwagesh	-0.166	0.055	-0.123**	0.058
remitsh	----------	--------	------	------
irrigation	0.035***	0.012	0.032**	0.013
Log Likelihood Function	233.41		221.05	
Mean Y	0.391		0.337	
Variance (sigma sq)	0.0046		0.0052	
Sum Squared Errors (SSE)	0.772		0.887	
R^2	0.481		0.387	
R^2 adjusted	0.454		0.354	
N	179		179	

Notes: *** = significant at 1%; **= significant at 5%; *= significant at 10%; the income share for remittances is omitted to avoid over-identification since the income activity shares sum to one.

The positive coefficient for the variable *pcyincome* shows that at higher levels of per capita income, households are more specialized. In general, we see that the measures of diversification have a quadratic relationship with the income efficiency measure (*IEM*). From the negative sign of the coefficient for IEM we conclude that higher income efficiency over all income activities favors diversification, in line with our expectation of the role of economies of scope. However, from the positive coefficient on the quadratic term we find that at higher levels of the IEM, specialization is favored. This result suggests the presence of economies of scale (as opposed to scope) as income increases to higher levels.

With regards to the effect of the shares of income from each activity, we omit the remittance income share and evaluate the effect of the other income shares relative to this omitted variable. The remittance income share is chosen as the base case because this is an exogenous income transfer and does not use on-farm household labor or purchased inputs. We find that relative to the share of income from remittances, higher dryland income and woodland income shares lead to greater specialization among sample households. On the other hand, higher income shares from livestock, irrigated gardens and from home industry and wages activities have a negative and significant effect on specialization, implying more diversified strategies. Thus, as expected, households with higher dryland incomes may choose to be more specialized, because of potentially high income returns from investing inputs in this activity. In contrast, despite barriers to scale (expansion) of woodlands activity, the results suggest that households with higher woodland incomes could also be relatively specialized. This may be attributed to limited options to diversify to other activities that may need investments or resources such as purchased inputs, irrigation inputs and livestock. The significant positive sign for *irrigation* suggests that households with no access to a good source of water are less diversified since their capacity to participate in irrigated agriculture as an income activity is limited.

In the light of the results on significant factors associated with the relative levels of income diversification or specialization, a pertinent question concerns the components of diversified or specialized income strategies of households. This question is explored next in the estimation results of Probit participation models for each income generating activity.

5.3.2 Household participation in income activities

The probability of each household participating in each of the six identified income activities is estimated using a Probit model. The data shows that all sample households received income from dryland agriculture and woodlands activities. Dryland agriculture is practiced by all households as this is the main source of subsistence food production. Woodland products are sought by all households because they are located in common areas for use by all households and because they provide key household inputs such as fuelwood, the primary energy source for cooking. We therefore estimate participation equations for the four income activities in which some households did not participate.

Table 5.11 presents Probit estimation results for the selection equation estimating participation in each income activity for livestock, irrigated gardens, remittances and home industry and wages. The predicted participation rate (*IMR*) in each income activity is subsequently included as an explanatory variable in the third model to analyze the size of income share for each activity. This procedure corrects for attrition in the income shares in those subsequent models due to possible sample selection bias.

Few of the postulated variables are significant in determining the inclusion of each income generating activity in household's livelihood portfolio. About 77% (sample N 153/199 in Table 5.11) of sample households participate in irrigated/wetland gardens. The positive significant signs on coefficients for the household labor pool and gender of household head indicate that households with more labor and with female heads are more likely to be engaged in irrigated gardens as an income activity. Female-headed households are expected to be more likely to engage in irrigated gardens since garden production is usually the domain of women.

The negative significant sign for households with higher numbers of adult female members is puzzling as it suggests that these households are less likely to engage in irrigated gardens. The variable indicating households that do not have access to a good source of water for irrigation has a significant negative sign. This result is expected since it implies that limited access to this resource is an entry barrier manifested as a smaller likelihood of participating in irrigated gardens.

Table 5.11: Probit Estimation Results for Participation in Each Income Activity

Variable/ Diagnostic Statistic	Irrigated/Wetland Agriculture		Livestock		Home Industry & Wages		Remittances	
	Coefficient	*S Error*	*Coefficient*	*S Error*	*Coefficient*	*S Error*	*Coefficient*	*S Error*
CONSTANT	1.661*	0.892	0.732	0.722	2.168***	0.508	-0.862	0.717
labor	0.497***	0.173	0.178**	0.101	------	------	------	------
wealth	------	------	1.293***	0.245	-0.155	0.103	0.528**	0.216
site	-0.305	0.262	0.480*	0.259	-0.363	0.215	0.913**	0.376
age	-0.014	0.008	------	------	-0.013*	0.007	------	------
gender	0.555**	0.302	------	------	------	------	1.034*	0.468
No irrigation	-0.725**	0.281	------	------	------	------	------	------
adultfemales	-0.478**	0.204	------	------	------	------	------	------
education	------	------	-0.349	0.212	------	------	------	------
Correct Predictions %	86.03		83.92		81.91		90.95	
Log-Likelihood F(0)	-74.175		-105.130		-94.080		-60.413	
Log-Likelihood F(B)	-60.741		-69.903		-89.472		-48.398	
McFadden R2	0.181		0.335		0.049		0.199	
Likelihood-Ratio Test(chi-2)	26.867***		70.459***		9.216**		24.029***	
Sum Squared Residuals	24.169		22.291		28.347		14.450	
Weighted SSR	175.60		169.99		194.21		142.37	
Scale Factor	0.177		0.158		0.251		0.081	
Observed Y=1	153		155		163		181	
Sample N	179		199		199		199	

Notes: *** = significant at 1%; **= significant at 5%; *= significant at 10%

Livestock was reported as an income source by almost 78% of the sample of households (sample N 155/199 in Table 5.11), the lowest participation level for all income activities. We find that the probability of participating in livestock activity increases significantly with increases in the household labor pool and wealth level and for households located in Mutangi communal area relative to Romwe. Wealth is the most important factor in participation in livestock activity, significant at the 1%

level and with a coefficient greater than one. This is consistent with expectations given that livestock are an accumulated asset contributing to wealth. Wealthy households are expected to have greater access to livestock reflecting an entry barrier to this activity due to the capital cost of acquiring a livestock herd. That households in Mutangi are more likely to engage in the livestock income activity is also as expected, given that Mutangi is located in a relatively drier region where livestock income may be one of the few viable income options.

About 82% (sample N 163/199 in Table 5.11) of households participate in home industry and wage employment as an income generating activity. However, only the variable measuring age of household head is significant in explaining participation in this activity. Households with younger heads are less likely to participate in home industry and wage employment. Although we would expect that younger household members would participate in wage labor, some home industry activities (such as wood carving, pottery making, basketry, metal working and other crafts) require specialized skills acquired over time that may be skills of older household members.

Remittances from family members in wage employment at a location away from the home are a source of income for almost 91% (sample N 181/199 in Table 5.11) of households. We find that wealthier households are more likely to receive remittance income. This is potentially because of the investment in education of household members who are then able to obtain skilled employment in towns and cities. However, this association may also raise questions of causality since purchases of many of the households assets used in generating the wealth index may be linked directly to remittance incomes. Households in Mutangi are also more likely to participate in remittance income activity as compared to households in Romwe, suggesting that this may be one of few viable income sources in the drier semi-arid region. As expected, households with a female head have a higher probability of receiving remittance income because the male heads of those households are usually employed off farm and remit income back to communal area households.

Having gained some insight into the components of diversified household income strategies, another question of interest concerns the relative magnitude of income shares from each activity and the issue of causality amongst factors. In the next section we explore this question through joint estimation of income share equations for each activity in order to isolate and identify relationships.

5.3.3 Magnitude of income shares by activity

Table 5.12 presents results of joint estimation of share equations for each income activity using seemingly unrelated regression (SUR) multivariate estimates. These estimates account for contemporaneous correlation in the residuals across equations. Explanatory variables include predicted IMR for each equation from Probit participation models to account for sample selection and the predicted Gini coefficient to account for endogenous income diversification levels influencing income shares. The share equation for remittance income is omitted from the system to avoid over-determination since otherwise these shares sum to one. Thus, the effects of explanatory variables on income shares are interpreted relative to the omitted remittance income share.

The system model diagnostic statistics in Table 5.12 indicate a high level of significance, with a system R^2 of 99.8% and model chi-square statistic significant at the 1%level of significance. In addition, the null hypothesis of a diagonal covariance matrix is rejected at the 1% significance level by both the Breusch-Pagan Lagrange Multiplier test and the Likelihood Ratio test. This result shows the presence of contemporaneous correlation of error terms across the share equations for the income activities, thus justifying joint estimation as a system.

Table 5.12: SUR Estimation Results for System of Income Activity Share Equations (Remittance Income Share Omitted)

Variable/ Diagnostic Statistic	Dry Land Agriculture		Livestock		Woodlands		Wetland Agriculture		Home Industry & Wages	
	Coefficient	St. Error	Coefficient	St. Error	Coefficient	St. Error	Coefficient	St. Error	Coefficient	St. Error
CONSTANT	-0.528***	0.072	0.764***	0.066	0.008	0.074	0.366***	0.041	0.229***	0.052
gini	1.851***	0.143	-1.236***	0.14	0.783***	0.145	-1.140***	0.098	-0.323***	0.117
wealth	0.017	0.011	0.043***	0.010	-0.037***	0.011	-0.002	0.006	-0.048***	0.008
pcyincome	-0.144E-05	0.190E-05	0.815E-05***	0.183E-05	-0.846E-05***	0.194E-05	0.113E-05	0.113E-05	0.449E-05***	0.141E-05
IEM	0.084***	0.016	-0.114***	0.015	-0.028*	0.016	0.005	0.010	-0.033***	0.013
IEM²	-0.010***	0.001	0.007***	0.001	0.002	0.0015	0.0002	0.001	0.006***	0.001
site	-0.026*	0.016	-------	-------	0.032*	0.017	-------	-------	-0.011	0.012
labor	0.018***	0.007	0.013**	0.010	-0.009	0.007	-------	-------	-------	-------
irrigation	-------	-------	-------	-------	-------	-------	0.100***	0.009	-------	-------
IMR	-------	-------	0.013	0.010	-------	-------	0.011*	0.006	0.028***	0.008
Mean of Y	0.343		0.159		0.183		0.071		0.094	
R2	0.544		0.576		0.461		0.307		0.406	
Sum of Squared Errors (SSE)	2.113		2.166		2.186		1.108		1.532	
Variance (Sigma2)	0.0124		0.0127		0.0128		0.006		0.0090	
N	179		179		179		179		179	
System Diagnostic Statistics										
Log of Likelihood Function			1150.67		991.855					
System R2			0.998							
Overall System Significance (Chi-2)			1107.5***							
Breusch-Pagan LM Test for Diagonal Covariance Matrix (chi-2)			209.66***							
Likelihood Ratio Test for Diagonal Covariance Matrix			665.51***							

Notes: *** = significant at1%; **= significant at 5%; *= significant at10%; the remittance income activity share equation is omitted to avoid over determination since the income shares sum to one.

The results in Table 5.12 indicate that the predicted Gini coefficient is a significant explanatory variable for the size of all income activity shares at the 1% level of significance. The predicted Gini coefficient is positively related to the size of dryland agriculture and woodland income shares, suggesting that households with higher income shares from these activities are relatively more specialized. This result is consistent with the results from models of income diversification and probabilities of participation by activity in Tables 5.10 and 5.11. All households are shown to participate in dryland agriculture and woodlands income activity. Further, evidence of relative specialization for households with higher woodlands income shares suggests that these households have few income activities in their livelihood portfolios beyond woodlands and dryland agriculture.

Table 5.12 also shows that the predicted Gini coefficient is negatively associated with the size of income activity shares for livestock, irrigated cultivation and home industry and wages. This result indicates that these activities are components of more diversified household livelihoods strategies.

Wealth is a significant determinant of the size of income share from livestock, woodlands and home industry and wages (coefficients are significant at the 1% level of significance). The livestock income share is higher at higher wealth levels. In contrast, woodlands, home industry and wages income shares are higher for households that have lower wealth levels, suggesting that these activities are components of livelihoods strategies for poorer households.

From Table 5.12 it is seen that the income shares from livestock and home industry and wages activities are significantly higher in households with higher total per capita income for the year. The woodlands income share is significantly lower at higher levels of per capita household income. Thus, we find that woodlands income is generally related to lower levels of total household income per capita. Although higher incomes from home industry and wages would have been expected at lower levels of total household income per capita, the opposite result is observed likely because we apply measures of gross income from each activity without accounting for income input costs which tend to be in the home industry and wage sector.

In Table 5.12, the dryland agriculture income activity share is increased by a higher level of total income efficiency as measured by the variable IEM. Livestock, home industry and wages and woodlands income shares are lower at higher levels of the income efficiency measure IEM. Thus, we see that dryland agricultural production is consistent with producing the highest level of income for the sample households' total expenditures on cash and labor inputs. This finding for the dryland activity suggests some scale economies that result in higher income from employing cash and labor inputs in this sector relative to the other income activities that show insignificant or negative and significant coefficients for IEM The quadratic term for IEM is negative and significant for dryland agriculture, suggesting a decreasing effect on the size of income share as IEM increases. Livestock and home industry and wages income shares have a positive and significant quadratic coefficient for IEM, indicating these income activity shares may increase at much higher levels of IEM.

A positive and significant coefficient on the study site for the woodlands income share shows that households in Mutangi have larger income shares from woodlands. The negative and significant coefficient on dryland agriculture activity shows that households in Mutangi have lower income shares from this activity. This is consistent with the feature that Mutangi households, located in a drier region relative to Romwe households have lower dryland crop outputs and hence lower dryland crop incomes.

The size of the household labor pool is significant in increasing the income shares for dryland agriculture and livestock activities compared to labor-constrained households. The positive and significant coefficient for *irrigation* indicates that households claiming that they do not have access to a good source of water actually do have higher incomes from irrigated gardens.

The IMR hazard rate accounting for sample selection in the participation in each income activity is significant for irrigated gardens and the home industry and wages activity shares. Thus, we conclude that sample selection is significant in determining income levels from irrigated gardens as these are related to access to a good source of irrigation water. Sample selection is also found to be significant in limiting income shares from home industry and wages. This may reflect a prerequisite of acquired trade skills (such as in wood carving, pottery making, basketry, metal working) that may constrain income earnings from home industries. In addition, thin rural markets for wage labor limit earnings from this activity.

We now turn to discussion of conclusions from the results of all the estimated models in the context of the empirical questions posed in Section 4.1, relating these to the empirical literature on rural household income diversification that was reviewed in Section 4.2.

5.4 Chapter conclusions

The previous empirical literature highlights the importance of non-farm income diversification in household livelihoods across most of rural Africa. However, substantial entry barriers to non-farm income activities have been shown to limit some of these opportunities to the relatively wealthy households (Rosenzweig and Binswanger 1993; Dercon and Krishnan, 1996; Barrett 1997; Dercon 1998; Carter and May, 1999; Reardon *et al.* 2000). Empirical evidence also points to the poorest households being more likely to diversify to natural resource-based income-generating strategies (Reardon *et al*, 1992; Cavendish, 1997; Cavendish, 2000; Lanjouw *et al.*, 2001; Campbell *et al.*, 2002; Veveld *et al*, 2004; Adhikari, 2005). Conversely, studies of rural household income diversification have tended to include incomplete assessment of natural resource incomes, undermining the capacity to inform policy for poverty alleviation and sustainable natural resource management.

This study contributes to the discourse on rural household income diversification by including incomes derived from woodlands resources as a distinct income-generating activity. We apply income data collected for selected households in a semi-arid area of rural Zimbabwe to explore observed patterns of income diversification and significant factors. The data were collected for the year 1999 which was an above average year in terms of rainfall, incomes and hence overall economic output for the country. We add to the empirical literature by constructing scalar indices of diversification to disaggregated data on income shares for each income-generating activity and applying these in econometric analysis. Many previous studies simply compare income levels, income shares or asset allocations to different types of income-generating activities as measures of diversification in econometric analysis (Reardon *et al.*, 1998, 2000; Block and Webb, 2001). We also explore causality between income diversification patterns, household wealth, total income, non-farm income and natural resource income through joint system estimation of income shares from different livelihood activities with predicted diversification indices as an endogenous variable.

The descriptive statistics presented in Table 5.5 show income diversification patterns dominated by agriculture and natural resource-based income sources which account for around 75% of total gross income over all households. Households in the poorest and wealthiest quartiles have similar shares from dryland agriculture and irrigated gardens. However, the composition of these income sources differs significantly across relative wealth groupings, with agriculture (combining livestock and crops) contributing 47.9% of total income for the poorest quartile and 65% of total income for the wealthiest quartile. The difference in agricultural income for the relatively wealthy households is contributed by livestock income. For the poorer households, the combined agriculture and natural resource-based income share is augmented by income from woodlands which contribute an average income share of 27.6% to total income. Thus, when we account for natural resource incomes from woodlands, we conclude that both wealthy and poor households have similar agriculture and natural resource-based income shares. These statistics results support findings of entry barriers to livestock income opportunities and heavier reliance on natural resources for the relatively poor households. On average, about one quarter of total gross income is from all non-farm sources for the combined sample and for both the poorer and relatively wealthier household quartiles. This contrasts to findings in previous literature which suggest that relatively wealthier households have higher non-farm income shares. However, the composition of non-farm income sources differs. For the wealthiest quartile less than one fifth of non-farm income is from wages and home industry with the rest from remittances. For the poorest quartile we find almost equal shares of income from remittances and wages and home industry. Thus, our findings support previous literature on the composition of non-farm incomes, showing greater reliance on remittances from skilled labor in off-farm employment for the relatively wealthiest, in contrast to income from unskilled rural wage labor and home industry activities for the relatively poorest.

Regarding the relationships between income diversification patterns, household wealth, total income, non-farm income and natural resource income key conclusions about the relationships found in this study are as follows. In Table 5.5 we show that households in the wealthiest quartiles are less diversified than households in the poorest quartile. Our interpretation, using the constructed Gini coefficient as the measure of income diversification, suggests that poorer households have similar income shares across activities whereas the wealthier have a more uneven distribution of income shares across activities. Relative specialization among wealthier households is due to small shares of woodlands and wages and home industry, with greater reliance on dryland agriculture and livestock income. Total income for relatively poorer households is increased by woodlands incomes while total income for the relatively wealthier is increased by livestock incomes. This supports our hypothesis of woodlands as a more important income source for the poorest and those with lowest total income levels.

The analysis of income shares for each activity shows that returns to cash and labor inputs as captured by our calculated income efficiency measure, are highest for households with higher income shares from dryland and wetland agriculture. The lowest returns to cash and labor inputs are found with higher livestock, woodlands and wages and home industry shares (see Table 5.12). We also found that livestock, wages and home industry are components of diversified income strategies. We therefore conclude that although income efficiency generally increases with diversification, there are economies of scale from relative specialization in dryland agriculture. Thus, with higher dryland agriculture income shares economies of scale may be more significant than economies of scope.

We show that woodlands incomes are significant components of diversified livelihoods strategies for the poorest households as found in much of previous literature. However, comparison of results across studies and sites is made difficult by incomplete accounting for the different components of income within natural resource activity. Comparability of our results to other studies is also complicated by the question of how prices for non-marketed woodlands products are derived. In particular, the question of how livestock grazing and browse in livestock production, is explicitly valued and accounted for is unanswered given that livestock incomes are highest for the relatively wealthy. This highlights the potential to underestimate the true extent of natural resource income dependence amongst both the relatively wealthiest and relatively poorest rural households in income and poverty assessments.

Results from Table 5.11 for participation in the different income activities, indicate that female headed households are more likely to participate in wetlands agriculture and to receive remittance income from family members employed away from the rural home. However, the sustainability of the remittance income source is questionable given the prevalence of HIV/AIDS and its impact on the workforce as the source of remittance income in Zimbabwe. Therefore, challenges to provision and sustenance of rural non-farm income opportunities including wage labor opportunities are even more urgent. This analysis was however, limited to a cross-section of household-level data, for the year 1999, for selected households in a semi-arid region of Zimbabwe. Thus, a limitation of this study is the inability to analyze issues relating to income diversification over a time series that might capture dynamic effects on the components of income strategies over time.

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Appendix I-5 Correlation Matrix for Variables in Income Diversification

Variable	Gini/CV Herfindahl	Per Capita Total Income	Wealth Factor Score	Incom Efficiency (IEM)	Dryland Ag. Share	Wetland Ag. Share	Livestock Share	Wood Lands Share	Hind. & Wages Share	Remit. Share	Labor	Site	Age	Gender	Educ. ation	Irrig. ation	Adult Female
Gini/ Herfindahl/ CV	1.00																
Per Capita Total Income	-----	1.00															
Wealth Factor Score			1.00														
Income Efficiency (IEM)	-----	0.50	-0.19	1.00													
Dryland Ag. Share	0.37	------	------	0.22	1.00												
Wetland Ag. Share	-0.37	------	------	------	-----	1.00											
Livestock Share	-0.44	0.23	0.49	-0.26	-0.16	------	1.00										
Woodlands Share	-----	-0.60	-0.56	-0.27	-----	-0.15	-0.49	1.00									
H. Ind. & Wages Share	-0.16	------	-0.29	------	-0.19	------	-0.37	0.25	1.00								
Remittance Share	-----	0.24	0.25	0.31	-----	-0.24	-----	-0.23	-0.28	1.00							
Labor	-----	-0.21	0.24	-----	-----	------	0.26	------	------	------	1.00						
Site	-----	------	-----	-----	-----	-0.15	------	------	------	0.22	-----	1.00					
Age	-----	-0.22	0.18	-----	0.22	-0.15	0.17	------	-0.25	------	0.22	-----	1.00				
Gender	-----	0.18	0.18	-----	-0.16	------	------	------	------	0.28	-0.16	-----	-0.22	1.00			
Education	-----	0.20	-----	0.15	-----	------	------	------	------	------	-----	-----	-0.50	------	1.00		
Irrigation	-----	------	-----	------	-----	-0.14	------	------	0.16	------	-----	-----	-----	------	------	1.00	
Adult Females	-----	-----	0.33	------	-----	------	0.27	-0.18	-0.22	------	0.60	-----	0.38	------	------	-----	1.00

Notes: Spearman's Rho non-parametric correlation test results reported for variables with correlations significant at the 0.01 and 0.05 level (2-tailed) only.

PART III: Domestic Water Access in Nyahombe RA & Mushawasha SSCF

Part III of this thesis addresses the third topic outlined in Part I, Section 1.2. The main objective is to analyze household domestic water collection site choices and trips relative to the demand for water as a component of livelihoods strategies. This is achieved by analyzing household water collection trip log data for thirteen months in 2002/2003 for selected rural households in Zimbabwe. The selected households are located in a semi-arid region where access to water resources is critical to livelihoods. Thus, decisions about allocation of household labor time and other assets relative to securing water for domestic, production and income generating uses are expected to be crucial.

There are three chapters in Part III. Chapter 6 provides an introduction to the research problem and outlines the specific research questions that are addressed. This is followed by a review of relevant theoretical and empirical literature and a conceptual model for analyzing rural household water demand. Chapter 7 presents estimation results for econometric models of domestic water collection site choices. Chapter 8 extends the analysis to modeling water collection trip counts for domestic uses and applies the results in making inferences about household water demand elasticities.

Chapter 6: Research Questions and Literature Review

6.1 Introduction and Research Questions

The objective of the analysis presented in the sections that follow is to explore the welfare effects of differential access to water resources to meet demands for water by selected rural households. Most water resources in rural areas are common pool resources. As such, access is shared and the level of appropriation impacts the resource (Ostrom, 1990). Access to these water resources is mediated by various formal and informal institutional arrangements so that exclusive groups of individuals have access to their benefits. Rural household water demands may be influenced by the composition of water resources that the household has access to, given household heterogeneity in socio-demographic and asset characteristics. Of interest are attributes of water resources related to institutions governing property rights[15] to resources, water resource quality, supply quantity and other physical attributes.

For the rural households that are the focus of this analysis, water is not traded in formal markets. Water collection trips are made to various water sources as part of day to day household efforts to secure water for domestic use and production. Water resources are critical for domestic water uses such as drinking, cooking, laundry and bathing. In addition water has many income-generating uses, including watering of crops, livestock and for home-based micro-industries such as brick molding, beer brewing, pottery and gold panning. The analysis postulates that in a given period, a household decides on the number of distinct water collection trips to make to satisfy its water demands. On each decision occasion, these trips are allocated to a number of water sources and water collection sites that may be exclusive for use by an individual household or group.

[15] Institutions and property rights are defined and discussed in Section 6.2.1.

The specific empirical questions to be addressed are as follows:

1. *What are the relative costs*[16] *of differential access to water sources and collection sites* for domestic uses by the sampled households, as influenced by household characteristics and the composition and variable attributes of water resources such as supply quality and volume, physical characteristics and property rights characteristics?

2. *What is the average number of distinct water collection trips* that a household must make in order to satisfy daily domestic water requirements? The number of water collection trips is postulated to be affected by the relative cost of variable access to water sources or water collection sites, as estimated in question 1), and by household preferences for water collection trip attributes and household tastes;

3. *What is the estimated volumetric (quantitative) demand for water* for domestic uses by households based on results from addressing questions 1) and 2) and observed water volumes collected on trips?

4. *What can be inferred from a policy perspective* about the potential benefits of improved access to water resources and water pricing based on the results from addressing questions 1), 2) and 3)?

The analyses conducted in the rest of Part III of the thesis may be important as a basis on which to draw inferences on the potential benefits of improved access to water resources, with implications for household-level welfare. Further, there is potential to inform policy for generating water pricing systems, potentially relevant in relation to implementing water use legislation such as the Water Act (1998) of Zimbabwe.

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[16] This cost or price is measured by the expected value of maximum utility for each water collection trip for all sites in the household's choice set. This relative utility index is computed from the results of estimating discrete choice models of site choice valued in terms of 'travel time', our value metric in this study.

The rest of Chapter 6 reviews theoretical and empirical literature on common pool resource access and management and household behavior. This is followed by a summary of literature on findings from behavioral studies on rural household domestic water demand. We then outline a conceptual framework that is relevant to analyzing rural household water demand and that is applied in Chapters 7 and 8.

6.2 Common Pool Resource Access and Management

For analyzing welfare impacts of differential access to water resources, it is important to understand the institutional context (both theoretical and empirical) within which these resources are used. This is the purpose of this section.

Arrangements for access to common pool natural resources have been studied widely in both the theoretical and empirical literature in attempts to understand their impact on individual behavior in contributing to collective outcomes for resource management. The common pool natural resource use arrangements that have been shown to affect individual and group behavior are described in Section 6.2.1. Section 6.2.2 discusses the patterns and extent of common pool natural resource use by communities and individual households observed in the literature.

6.2.1 Definition of institutions and property rights and their application

Institutions are loosely thought of as organizations or mechanisms of social structure governing the behavior of two or more individuals. Institutions are identified with a social purpose and permanence, transcending individual intentions, with the purpose of making and enforcing rules governing cooperative human behavior (Wikipedia, 2005). In economics, institutions have been seen as the means to rectify inefficient market outcomes due to transactions costs (Coase, 1937; Williamson, 1979). Transactions costs refer to costs of making exchanges where there are two or more agents in a market, and are sometimes referred to as "institutional costs" (Cheung, 1992). The issue of determining the types of institutions that would minimize transactions costs of markets has been the focus of the new institutional school of economics associated with authors such as Coase (1937, 1960), Williamson (1979), North (1990) and Richter (1997). New institutional economics applies neoclassical economic views in studying institutions, in contrast to the traditional institutional economics school (associated with Commons, 1930; Samuels; Bromley; Hodgson, 1998; and Mayhew) (North, 1990).

North (1990) describes institutions as human-devised constraints with the objective of reducing uncertainty by specifying a stable incentive structure. In this regard, North highlights the importance of separating institutions from "organizations" where institutions are said to refer to the rules of the game and organizations to the players. Constraints are said to exist on many levels with both formal rules and informal constraints (such as conventions and norms of behavior). These formal and informal rules are seen as creating sufficient conditions for credible commitments in transactions, thereby enforcement costs (North, 1990). Similarly, organizations, as an aspect of institutions, are also found on many levels, with differing authority systems such as governments, cooperatives, traditional leaders and even groups of households (Bromley, 1989; Lewis, 1986).

Ciriacy-Wantrup and Bishop (1975) define a property right as the ability to call upon the authority of an institution to support and enforce a claim to a defined benefit stream. An implication is that economic outcomes may be difficult to explain without accounting for the informal constraints of conventions and norms of behavior which are essential for upholding property rights (North, 1990). North (1990) also points out that it takes much longer to evolve norms of behavior than to create formal rules.

Institutional arrangements for access to natural resources have been widely discussed in the property rights literature which includes the work of Ciriacy-Wantrup (1963), Ciriacy-Wantrup and Bishop (1975), Bromley (1989), Ostrom (1990, 1994), and Baland

and Platteau (1996). Many of these authors have focused on the successes or failures of common property institutions for management of natural resources found in the commons. Ciriacy-Wantrup and Bishop (1975) clearly define common property as a social institution in which property rights to a resource are distributed among a number of defined users with equal rights to the resource. This definition is expanded by the National Academy of Sciences (1986), McKay and Acheson (1987) and Bromley (1989; 1991).

The concept of exclusivity is central to traditional categorizations of property rights placing private property (assuming individual exclusive rights) at one end of the spectrum. Other property regimes are common property (assuming a defined group of exclusive users), public (state) property and open access (Ostrom, 1990). Hobley and Shah (1996) argue that the traditional dichotomy between public and private property in resource management is crude and that these may be more realistically categorized as a continuum of institutional and property right relationships according to the nature of the particular resources to be managed. In an attempt to un-package these, Haley and Luckert (1990) summarize sets of rules that can underlie a property right in terms of a number of characteristics. These property rights characteristics are expected to affect benefit streams from natural resources by restricting or controlling use and hence to have systematic effects on economic behavior. Some of these characteristics of property rights include comprehensiveness, exclusivity, use designation, duration, fees, transferability, operational requirements and control, allotment type and allotment size.

According to the property rights school of thought, when a resource is scarce and the relative returns to the costs of excluding users exceeds the returns to internal governance, the result is a shift towards individual exclusivity to foster efficiency (Field, 1986). However, in developing countries it has been shown that there may be prohibitive transactions costs in enforcing exclusivity (Baland and Platteua, 1998) as well as significant opportunity costs and distributional outcomes that undermine the potential to move to efficiency. For example, individualizing resource rights in the context of poverty and natural resource dependence may result in uncertain income flows and income inequity for the disenfranchised (Dasgupta, *et al.*, 1979; Runge, 1992). In addition, Baland and Platteau (1998) point out that the role of social and political institutions in the evolution of rights may not always lead to efficiency. Thus, optimality may in fact exist at varying levels of common property and/or exclusivity.

Social norms have been instrumental in ensuring that the rights to natural resource users in Zimbabwe (Mtisi and Nicol, 2000, and Nemarundwe, 2003). However, there is scepticism regarding the capacity of local traditional institutions to manage local resources as common property in the face of pressures such as population growth, migration and government interventions, as shown for woodland resources by Campbell *et al.* (2000). Much of the debate on access to natural resources and utilization by rural households has focused on the resources themselves, property rights regimes, the community and local institutions, the legal framework, governance systems and power relations (for example Nemarundwe, 2003; Mehta, 2000; Ostrum, 1990; Ostrum *et al*, 1994). Therefore, we focus on the interaction between rural household micro-economic decisions and the nature of property rights to common pool resources with water as our case study.

This study seeks to analyze the relative welfare impacts of differentiated access to common pool water resources by sampled households, as measured from observed water use behavior patterns. In Chapter 7 we define property rights variables describing exclusivity, use designation, allotment size (volume) and operational controls (restrictions) of water resources and apply these in empirical models of behavior. As a result, we isolate and validate statistically significant relationships that are consistent with expectations based on economic theory, between theoretical measures of property rights characteristics of water resources and the economic behavior of rural households.

Its is also expected that positive economic rents may accrue to common pool resource users reflecting heterogeneity (in location, assets, gender, preferences and tastes) amongst users as discussed by Hegan (2000) and Hegan *et al.* (2003). As Hegan (2000) points out, while heterogeneity can be independent of institutions that create property rights characteristics such as exclusivity, these may also be co-determined. Thus, we analyze the effect of both heterogeneity of resource users and property rights characteristics of water resources but note, however, that it may be impossible to completely disentangle and completely isolate their independent effects.

6.2.2 Community based natural resources management outcomes

The community-based natural resources management (CBNRM) paradigm appeared in mainstream rural development approaches in the 1980s. The paradigm was based on observations such as by Dasgupta (1999), that whilst economic incentives and self-interest may drive individual behavior, sustainable natural resource management is facilitated by social capital which may tend towards collective outcomes. Thus, effective community-based natural resources management is seen to be facilitated by local and traditional practices in partnership with other institutions (Tsing *et al*, 1999; Barrow and Murphree, 2001). There has therefore been much interest in developing theory and policy on community level institutions for the management of natural resources as common property resources (McCay and Acheson, 1987; Ostrom, 1990, 1994; Cleaver, 2000).

The common property resource literature has focused on the role of group heterogeneity in the success or failure of collective action in common pool resource (CPR) management (Baland and Plateu, 1996; McKean, 1992; Veveld, 2000; Dayton-Johnson, 2000; Varughese and Ostrom, 2001). However, a criticism of the common property resource literature is that it has focused disproportionately on emphasizing theoretical outcomes rather than the empirical complexities on the ground (Campbell *et al.*, 2000). A negative spin-off from this focus is that, for example in the case of woodlands resources in Zimbabwe, unfounded optimism based on the CPR literature has led to little or no emphasis on developing institutions for sustainable woodlands management.

More recently it has become clear that to be successful, community-based natural resources management should be linked to issues of equity in access to natural resources, the promotion of sustainable livelihoods and poverty alleviation (DFID, 1997; Carney, 1998). The distribution of benefits that arise from common property resource management has tended to reflect inequalities (heterogeneity) in private wealth so that despite potential efficiency of common property management, household-level distributional outcomes are of concern (Roe, 1991; McKean, 1992; Leach *et al.*, 1998; Adger and Luttrell, 2000; Adhikari, 2005). Recent results from empirical studies confirm that there may be distributional problems related to structured attempts to manage CPR with limited evidence of positive impacts on the livelihood of the very poor and marginalized sections of communities (Campbell *et al*, 2001; Beck and Nesmith, 2001; Kumar, 2002; Adhikari, 2005).

Forms of heterogeneity (inequality) amongst resource users are exhibited as differential distributions of wealth and power, preferences, opportunity costs, claims to natural resources, ethnicity and other economic variables (Adhikari, 2005). In the specific context of rural Zimbabwe, Nemarundwe *et al.* (2005) find that patterns of resource use relate to heterogeneity in the resource user's capacity and constraints. Relatively exclusive use rights for some natural resources may not automatically enhance production, management and sustainability. Fortman and Nabane (1992) also show that the natural resources, woodlands, water and grazing, are gendered resources with many of the products from woodlands and water being collected by women and children. In addition, it has been shown that the management of livestock and the collection of timber and poles that have higher income returns are largely the domain of men (Rocheleau, 1992; Cleaver and Elson, 1995; Joshi, 2002). Further, other authors show that a range of interests related to politics of local elites, ethnicity, kinship, power, status, affection and social networks influence natural resource access and use (Crehan, 1992; Makamuri, 1995; Frost and Mandondo, 1999;

Nemarundwe, 2001; Nemarundwe, 2003). Thus the varied outcomes of natural resource access and use may have a direct bearing on the relative economic position and poverty of rural households.

A recent publication by FAO (2002) points out that there has been relatively little research on sustainable livelihoods in the various natural resource sectors such as forests, water and pastures (grazing) despite the important role they still play in rural livelihood strategies. A study by Cavendish (1997; 2000) is an example of economic analysis of household decisions regarding environmental resources. Cavendish (1997; 2000) shows the importance of heterogeneity among households to differential appropriation costs. For example, access to technology such as ownership of a scotch cart dramatically decreases the unit labor costs of collecting natural resources such as firewood and construction wood. Cavendish also highlights the importance of substitutes (i.e. "backstops") as a determinant of environmental resource utilization. The range of backstop technologies was shown to include different species, different collection sites, increased efficiency in resource use and purchased or other exclusive substitutes for common pool resources (Cavendish, 1997; 2000).

Amongst the common pool natural resources of forests/woodlands, water and grazing, which are important to rural household livelihoods, water has been the least studied to date. However, there has been increasing interest in water resource management issues because of growing demand with population growth and concerns about a potentially finite global water supply (Green and Baden, 1994). The World Bank (1993) recommended water resources management model is: *the treatment of water as an economic good, combined with decentralized management and delivery structures, greater reliance on pricing, and fuller participation by stakeholders.* For water resources, the range of possible backstops or substitutes may include the range of water source types, technology, site locations and water distribution systems to which a household may have access.

In the specific context of this study, we focus on household access to and utilization of water resources. Thus, we attempt to contribute to the literature through the economic analysis of household water use patterns, given the range of accessible substitutes, as those options affect relative welfare based on water demand. Our study focuses on the empirical reality of common pool water use outcomes for selected rural households. The study has potential relevance for policy and practice for common pool water resources management.

6.3 Summary of Results from Behavioral Studies of Domestic Water Demand in Developing Countries

This analysis employs micro-economic data on observed behavior in common pool water resource access and use to analyze tradeoffs that are affected by heterogeneity of resource users and property rights characteristics of water resources. The following summary of previous behavioral studies of domestic water demand in developing countries informs our choice of methods and interpretation of results.

6.3.1 Supply-led versus demand-led approaches

Focus on behavioral studies of household water demand has been fuelled by the failed outcomes of numerous publicly funded water and sanitation programs in low income countries over the past forty years (McRae and Whittington, 1988). These public water and sanitation programs had been largely based on engineering specifications and supply-led projections of household water demands. Water provision charges (tariffs) were based on an institutionally accepted figure of 3-5% of total household income as the maximum that households should pay for domestic water and wastewater services, with no attention paid to cost recovery or household capacity to pay (e.g. World Bank, 1975; van Damme and White, 1984).

Some household responses to particular public water supply initiatives appear to be perverse, with many households observed to prefer using their traditional water resources instead of the modern public water outlets (Merrett, 2002). For example, Zimconsult (1998) shows that the hand-pump fitted borehole, as the principal technology for improved rural water supply by the government of Zimbabwe, is not used on a regular basis. Households find it easier to obtain water from traditional sources, such as rivers or unprotected wells while regarding boreholes as back-ups during periods of drought. Water pricing is conceived in public water supply projects as a tool for increasing economic efficiency and for promoting environmental conservation. However, problems of non-payment by households for water services have occurred, with sanctions such as disconnection from the system seldom being implemented (Altaf, Whittington, Jamal and Smith, 1993). Thus, as Whittington *et al.* (1991; 1993) conclude, traditional approaches to water service provision are often out of touch with demographic and financial realities and made with little understanding of household water demand behavior.

Behavioral studies of household water demand arose out of the realization that embodying the revealed preferences of individual households was critical to successful design of water provision projects given the complex water markets in existence at local levels (Whittington, 1991). There have since been numerous demand-focused studies of domestic or residential water use in developing countries (Altaf *et al.*, 1989; Singh *et al.*, 1993; Briscoe and Whittington, 1991; Altaf and Hughes, 1994; Whittington, 1991). The studies in developing countries have focused on estimating household water demand in response to various pricing and water source options to assess the potential willingness to pay for existing services and for water service delivery improvements. Contingent valuation methods have been widely applied in these assessments. Other studies have focused on household choices amongst different types of water sources by applying discrete choice modeling approaches. Most studies have analyzed residential water demand in urban areas with metered water delivery systems. Many other studies have been conducted in rural, peri-urban and urban areas where households have access to purchased water options at some defined market prices, as well as to traditional water sources. Some of the important conclusions from these behavioral studies are summarized below; this is followed by discussion of this study's contribution.

6.3.2 Complex networks for water access and distribution

The market networks for water access and distribution have been shown to be socially complex (Whittington *et al.*, 1989; Merrett, 1997; 2002). There is evidence of multiple sourcing of domestic water where high-priced and high-quality water may be reserved for drinking and cooking (Merrett, 1997; 2002). A number of studies have shown combinations of water sources including collection from communal and private sources, purchase from vendors and piped public supplies (Mu *et. al.*, 1990; Whittington *et al.*, 1989, 1990, 1991; Merrett, 1997, 2002; Acharya & Barbier, 2002; Gulyani, Talukdar and Kariuki, 2005). For example, Whittington, Lauria and Mu (1991) find six means of water access for urban households as listed in Table 6.1.

Table 6.1: Types of Water Access for Urban Households in Onitsha, Nigeria - 1987 Dry Season

Access branch	Volume (million gallons[a]/day)	Unit Price (naira[b]/gallon)	Unit Price (US$/litre)
Household collection form private boreholes	0.30	0.027	0.028
Truck sales to households	1.00	0.020	0.021
Shop sales to households	1.55	0.050	0.053
Doorstep vendor sales to households	0.11	0.127	0.134
Shallow well collection by households	0.30	0.000	0.000
Public piped supply to households	1.50	0.003	0.003
Total or weighted average	4.76	0.026	0.027

Source: Adapted from Whittington *et al.* (1991) Fig. 1.
Notes: * One imperial gallon = 4.5461 litres; In 1987 the exchange rate of the US$ to the naira was 1:4.3; all prices for water are observed in markets are not based on behavioral models

An interesting feature permeating the literature on developing country household water supply and demand is that researchers find a marked divergence in the range of prices that households are willing to pay for a litre of water depending on the source (Mu *et. al.*, 1991; Whittington *et al.*, 1989, 1990, 1991; Merrett, 1997, 2002; Acharya & Barbier, 2002; Gulyani, Talukdar and Kariuki, 2005). Table 6.1 highlights this feature for the study by Whittington *et al.* (1991). Interestingly, Table 6.1 shows that water collection by households from shallow wells is assumed to incur no monetary cost, although the collection time (time spent queuing, drawing water and the journey to and from the well) can be lengthy and exhausting, as pointed out by Merrett (2002). Equally intriguing is the feature that the lowest unit water charges found are for public sector water supply while the highest per unit water charges are those by private vendors that literally distribute water to the doorstep of each household.

6.3.3 Water demand elasticities and expenditures

Green and Baden (1994) point out that the growing literature on the willingness to pay for water indicates that income elasticities of demand for improved water supply are relatively low, and that price elasticities of demand for improved water sources are relatively high. Thus, they conclude that income has a small effect on the level of demand for improved water supplies, but that the level of costs will significantly affect take up and usage. This conclusion is supported in a recent study of household water demand in 17 cities in Central America and Venezuela by Strand and Walker (2005) and an earlier study in Nigeria by Mu *et al.*, 1990. The majority of households had access to tap water with some households having non-tap or *coping* water sources according to the authors. Income elasticities of water demand are found to be small for all households, well below 0.1, the observed developed country standard value (Nieswiadomy, 199; Nieswiadomy and Cobb, 1993; Nauges and Thomas, 2000; Renwick and Green, 2000). Strand and Walker (2005) find price elasticities of water demand in Central American cities to be about -0.3 for tap water and -0.1 for non-tap coping water sources. The price elasticity estimate for households with non-tap water sources is shown to be much lower on average, and to increase with increases in water hauling costs. These results (Strand and Walker, 2005) can be compared to estimates of short-run price elasticities for residential water demand in both developed and developing countries. These have been found to range between -0.52 and -0.15 in urban areas of California (Berk *et al.*, 1980; Nieswiadomy, 1992; Renwick, 1996) and estimated around -0.17 in a study of residential water demand employing contingent valuation methods in South Africa (Veck and Bill, 1998).

A prominent feature of observed household behavior is that water demand is found to be more responsive to average price than to marginal price, with elasticity estimates based on average price being higher and more significant. This result is found from studies on Latin American data (such as Gomez, 1987; Bachrach and Vaughan, 1994; Strand and Walker, 2005) and has been shown by several other studies in developed countries (Nieswiadomy, 1992; Nieswiadomy and Cobb, 1993; Renwick and Archibald, 1998; Nauges and Thomas, 2000; Renwick and Green, 2000). We are not aware of documented evidence on this issue in Africa.

With respect to income actually spent on water acquisition, some studies have estimated that approximately 9% of household income is spent in Kenya, and 8% for households in Nigeria (Mu *et al.*, 1990; Whittington *et al.*, 1991). In addition, scholars find that households allocate a much higher percentage of total income to domestic water purchases in the dry season as compared to the wet season. The relative proportion was shown to be up to 2.5 times higher in the dry season for the poorest households than in the wet season in Onitsha, Nigeria (Mu *et al.*, 1990). Similar results were found in Ethiopia, Haiti and Sudan (Merrett, 2002). These studies strongly refute the widely touted figure of 3-5% of total income as the maximum that developing country households would pay for domestic water and wastewater services (e.g. World Bank, 1975; van Damme and White, 1984).

Water demand has been shown to be influenced by household heterogeneity in tastes, habits, composition, incomes, assets and access to credit (Merrett 1997; 2002). Results by Strand and Walker (2005) concur showing that non-tap or coping source households in Central America are much poorer and use up to twenty percent less water than metered tap users. Further, these non-tap households faced much higher water prices in addition to substantial costs of up to 11 hours per month in hauling water to homes.

6.3.4 Valuing time spent in water collection: the role of women

A number of studies have attempted to value time spent collecting water. These studies assume that improved water delivery systems would benefit women who are viewed as having the primary responsibility for the task. The benefits would be through time saved which could then be allocated to other productive uses (Churhill *et al.*, 1987; Cairncross and Cliff, 1987). The discrete choice modeling approach is applied by Mu *et al.* (1990) to model household choice of water sources in Kenya with the objective of valuing household time. Mu *et al.* (1990) model household choice amongst different types of water sources such as open wells, kiosks and vendors and find a value for time spent collecting water of US$0.31 per hour (approximately equivalent to the wage rate for unskilled labor). Thus, these authors conclude that the choice of water delivery technology by a community may be influenced by the value attached to time savings in this task. A criticism of the discrete choice modeling approach in water demand analysis is its failure to address the measurement of volumetric water demands of households and associated demand elasticities (Merrett, 2002). This approach does not account for the fact that any tariff for water should be volumetric, regardless of whether the cost in evaluated in monetary terms or by collection time (Merrett, 2002).

Although household water provision is still a female responsibility in most of rural Africa, some authors claim that there is a misplaced tendency for donors and governments to assume that women's strategic interest in water is primarily to have access to convenient, reliable, and safe water for the maintenance of family health (Kaminga, 1991; Green and Baden, 1994; Rathgeber, 1996; Zimconsult, 1998; Merrett, 2002). It is suggested that these assumptions fail to capture women's equally pressing needs for water to enable them to engage in economic production activities in agriculture, in micro-enterprise, or in other areas (Rathgeber, 1996; Zimconsult, 1998).

Kamminga (1991) notes that the benefits to women of improved water supplies may be overestimated and costs underestimated. For example, women's time spent in collecting water may simply be replaced by time spent collecting fees or attending meetings, thus not freeing up women's time for other activities (Kamminga, 1991). Further, unless the new water supply is considerably closer than the old one, the time saved may not be sufficient to be put to productive use (Zimconsult, 1998). It has also been found that whereas women might respond positively to willingness to pay questions for improved water access, they may be unable to commit resources to such investments because of patriarchal decision-making structures in intra-household resource allocation processes (Merrett, 2002). Given these varied issues concerning the role of women in water resources development and management, Green and Baden (1994) conclude that more rigor is required to assess costs and benefits and quantify the economic value and opportunity costs of women's time spent in water collection and management.

The preceding summary of empirical findings from behavioral studies of household domestic water demand in developing countries, taken in conjunction with the earlier discussion on common pool resource access and management, sets the stage for our analysis of rural household demand for water for domestic uses. In the next section we elaborate our approach to empirical analysis and outline the conceptual model applied.

6.4 Study Approach and Conceptual Model for Analyzing Domestic Water Demand

In the specific context of this study, the sampled households in rural Zimbabwe do not have access to water that is traded in markets with monetary prices. Thus we use household labor time allocations to water acquisition to value water resources. We therefore add to the literature, which analyzes residential water demand where households have access to purchased water options at some defined market price, by conducting similar analysis for rural households with no purchased options for water.

For the specific rural households studied, water is obtained from water collection sites that are accessible by groups of households. The attempt to satisfy a household's demand for water may be viewed as comprising three decision making dimensions. Specifically: the number of separate trips taken to water collection sites; the allocation of these trips across a set of spatially located and mutually exclusive water collection sites, based on time and effort for water collection trips; and the volume of water collected per trip. Household decisions regarding the number of water collection trips to make, and allocation of these trips to specific types of water sources and sites are viewed in the context of an underlying household production framework, as outlined in Chapter 2. Applied econometric models for analysis of water demand assume the outcomes of household input allocations from the household welfare optimization problem, specified by Equation (2.7), are used to generate an optimal solution reflecting household-specific opportunity costs of these inputs.

The basis of the econometric models in Chapter 7 and 8 is the reduced form equations for the optimal input allocation or conditional input demand for labor time $T_w * [p_T, p_i, p_V, p_w, R|Z, S_{NR}]$ and for water $W_i * [p_T, p_i, p_V, p_w, R|Z, S_{NR}]$ by each household across its production activities i as specified in Section 2.2 by Equations (2.18) and (2.20) where: p_i is price of output from each production activity; p_V is price of purchased inputs; p_w is an implicit price of water collected by households; p_T is price of household labor time; Z represents household socio-economic and demographic characteristics such as wealth, production technology embodied in capital assets, household composition, education and skills; S_{NR} represents characteristics of the natural resource stocks of water and R represents exogenous remittance income.

The reduced form equations may be disaggregated to the level of time allocation and water demand for each water collection trip, conditional on the number of separate water collection trips the household decides to make, and also conditional on the choice of discrete water collection site k to visit on each trip. The relationship between the time allocated to specific water collection sites and water demand stems from the fact that the optimal time allocation to a given water collection site is a conditional input demand for labor to acquire the desired volume of water demanded by the household for various activities. The optimal time allocation, conditional on water demand, depends on the water collection site choice. Households are assumed to form and adjust expectations about costs and benefits associated with different water collection sites, and hence to make decisions to switch between water sources and sites on different choice occasions in order to optimize returns to variable inputs. Thus, we learn about the relationship between water collection site choices, time allocations to this task and volumes of water demanded by specifying and estimating econometric models for water collection site choices, as well as for demand for water collection trips (trip counts), conditional on the site choices made by households.

The data employed in this analysis relate to observed behavior of households directed toward consuming given levels of a non-market good, water in this case. Thus, a revealed preference approach such as the travel cost method is a relevant demand estimation method for this application. Travel cost methods rely on observations of people's behavior, shown particularly in expenditure for transportation and other trip-related expenses incurred when traveling to and from the site of interest. Moreover, travel cost methods can be used to estimate the benefits derived from a specific site, such that this information can be used to find optimal levels of service provision (Bishop and Heberlein 1990). Travel cost modeling as originally proposed by Hotelling (1948) has been widely used to estimate the benefits or costs of environmental quality changes through analyzing the choices of recreational site users in the developed world. Few travel cost studies have been conducted applying data from Sub-Saharan Africa (exceptions are Hatton-McDonald, 1998; Hegan *et al*, 2003 who model fuelwood collection). Travel cost theory is applied to model water collection site choice with the various attributes of the sites as well as a measure of travel cost (i.e. the opportunity cost of time to get to each site) as important factors in choice. The opportunity cost of time spent on the trip is often computed on the basis of a minimum wage or an hourly wage estimated from family income. However, the opportunity cost of time is not well defined in terms of wage rates in our study sites because of thin rural labor markets observed at the study sites. Thus, as an alternative measure, we use time expenditure incurred in traveling to the given water sources as a means of expressing the relative welfare (economic surplus) of households.

The analysis assumes a two-stage budgeting process in modeling rural household water demand. In the first stage the household decides how many separate water collection trips to make, constituting a trip count model. In the second stage the household decides how to allocate the chosen number of trips to a number of the water collection sites in its opportunity set. The underlying theory is the two-stage budget approach proposed by Gorman (1971) and is utility-consistent. Hausman (1981) and Small and Rosen (1981) have shown that the utility-consistent approach allows for exact welfare measurement, important for measuring deadweight loss[17].

The link between the trip counts and site choices is through a price index for trips made to the composite of water collection sites in the household's water resource opportunity or choice set. This price index is derived from the site choice model estimation as a per trip expected value of maximum utility derived in relation to labor time. This price index is then applied in the first stage model as one of the determinants of numbers of trips made, and hence water demand. A similar modeling approach was employed by Hausman, Leonard and McFadden (1995) in a study to assess losses in economic surplus due to reduced trip frequency to recreational sites that had experienced environmental damage.

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[17] Deadweight loss is a measure of allocative inefficiency representing the net loss in economic welfare due to a distortion. This measure thus shows the reduction in consumer and producer surplus resulting from restricting output to below its efficient level (Binger and Hoffman, 1998).

Based on the findings from theoretical and empirical research, as discussed in the preceding sections, explanatory variables for econometric models of water collection site choice and trip demand include: characteristics of the types of water sources and collection sites in the household's opportunity set embodied in a vector S_{NR} representing physical characteristics and property rights conditions for water resources[18]; attributes of water collection trips such as technology employed and joint production opportunities exploited; and a vector Z^h of household socio-demographic and asset characteristics as an indicator of household preferences and tastes (Lancaster, 1966). For the purpose of econometric estimation we define a vector of estimated parameter coefficients β for the explanatory variables and an error term ε_{kt}^{h} to reflect uncertainty as to the possible outcomes of optimal household strategies.

Our analysis addresses some criticisms of previous behavioral studies (discussed by Merrett, 2002). Data analyzed in this study was elicited from adult female respondents in household surveys. Adult female members of households are assumed to have the best information on the complex choices made about water supply because they not only fetch, but also use, most domestic water (Merrett, 2002). We also analyze household water collection choices amongst a number of sites with different types of water sources for each trip made. The choices are evaluated on numerous survey occasions in different months during a 15 month survey period that covered both dry season and wet seasons. In considering substitutes in household water resource choice sets, we account for use of different types of water sources by households.

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[18] Property rights and access conditions for common pool water resources may include exclusivity, restrictions, operational controls, quality and supply of water, information and numbers of other users. These conditions vary according to location, type of site and season. Common pool resource sites may also differ in terms of joint production opportunities (such as gardening and fuelwood collection) and amenities (such as scenery and friends along the way) as discussed by Hegan *et al* (2003).

We also account for the spatial (geographic) feature of water collection sites. In addition, different conditions of water access and distribution are accounted for by including variables measuring property rights characteristics (e.g. exclusivity, restrictions and operational controls) of water sources and mode of transport (i.e. technology differences like draft power). These nuances in modes of water access and distribution may be important to designs of water supply because they may result in differential costs and welfare implications across households. Further, the concept of affordability (assumed to capture the concept of effective demand i.e. ability and willingness to pay) of water from various sources is captured in using the household's feasible choice set as actually specified by households. Affordability is also directly expressed in the choices households make as revealed in preferences for sites visited.

Our application of discrete choice methods does not compromise analysis of volumetric water demands by households. Thus, we add to the richness of analysis by looking at discrete choices amongst water collection sites and then extending this analysis to frequency of visits to sites and to volumetric water demand and elasticity estimates. This approach accounts for different sources of water, with different implicit prices, as these affect household domestic water collection and demand patterns. Conventional volumetric water demand analysis would either assume one price for water from all types of sources, or analyze separate demand functions for water from different sources. The latter approach is adopted by Acharya & Barbier (2002) in analysis of domestic water demand in rural Nigeria where separate demand functions are estimated for water from that is purchased and for water that is collected from communal sources by households. However, in this study, we estimate site choice models for the different types of water sources and apply results accounting for different water sources accessed by households to extrapolate water demand. As a result, we are able to obtain relative measures of expected economic surplus valued in terms of household labor time for unit water volumes as well as for each water collection trip.

The rest of the Chapters in Part III present statistical models and estimation results for: 1) water collection site choices made by households and 2) expected value of maximum utility from water collection sites in a household's choice set (in Chapter 7); 3) the separate water collection trips made to meet water demands through trip count models and 4) inferences on household point water demand, elasticity estimates and effective demand for water (in Chapter 8). Analytical models are applied to data for sampled households in RA and SSCF areas in rural Zimbabwe.

Chapter 7: Modeling Domestic Water Collection Site Choice

In this chapter we report models of water collection site choices for basic domestic water uses. The discussion that follows outlines the statistical models used to analyze household water collection site choices and welfare measures for water demand.

7.1 Statistical Models of Site Choice

A household's choice of a water site can be represented by a non-negative discrete random variable that can be analyzed by specifying a discrete dependent variable statistical model. We assume that there is some uncertainty as to the possible outcomes of choice so that econometric models to generate probabilities of choice amongst discreet alternatives are derived by specifying a density distribution for unobserved random error terms.

Discrete choice from a set of competing alternatives falls in the category of dominance measures. Dominance measures are a form of numerical assignment allowing the analyst to investigate which one or more objects are more or less preferred to one another (Louviere *et al*, 2000). In this study context, choice of water collection sites relative to other sites and the probability of observing this choice indicates preferences for sites by the household. These choice and preference measures are dominance measures that are consistent with random utility theory (Luce and Suppes, 1965). Random utility theory provides an underlying theory of consumer behavior to validate the measurement of preference or choice. Random utility theory allows us to combine sources of preference and choice data in order to make inferences about behavior.

The following discussion of the discrete choice model draws on the work of Louviere *et al* (2000). The elements of choice are: 1) the objects of choice and sets of alternatives available to the decision makers, known as choice set generation; 2) the observed attributes of decision makers and a rule for combining them; 3) a model of individual choice and behavior, and the distribution of behavior patterns in the population. Let G represent the universal or global set of alternatives in a choice set, and S the set of vectors of measured attributes of the decision makers such that a given individual in the population will have an attribute vector $s \in S$ and face the subset of alternatives $C \subseteq G$. The actual choice of alternative k (where the alternative is described in terms of a vector x of attributes) for an individual can be defined as a draw from a multinomial distribution with selection probabilities:

$$P(x|s, C) \forall x \in C \tag{7.1}$$

To relate the selection probabilities of alternatives to the economic rationality assumption of utility maximization, we assume that each individual defines utility in terms of attributes. The utility function may be partitioned into a deterministic and a random component. The random component accounts for unobserved factors in choice and errors in measurement which can be characterized by a stochastic distribution in the sampled population. We define the utility of water collection site k to household h as U_k^h with V_k^h representing the deterministic or systematic utility component and ε_k^h representing the random component as follows:

$$U_k^h = V_k^h + \varepsilon_k^h \qquad \text{where} \qquad V_k^h = \sum \beta_k \, s_k^h \tag{7.2}$$

The β_k are utility parameters that may be constant or vary across individuals. The assumption is that alternative q will be chosen if and only if $U_q^h > U_k^h$ for all $k \neq q$. Given that we do not observe ε_q^h and ε_k^h, we can only make inferences about choice outcomes through a probability of occurrence. Thus from equations (7.1) and (7.2) we relate the probability of the outcome to the utility associated with the alternative in what is known as a random utility model as follows:

$$P\left(x_q^h \middle| s_q, C\right) = P_q^h = P\left[\{\varepsilon(s, x_k) - \varepsilon(s, x_q)\}\langle\{V(s, x_k) - V(s, x_q)\}\right]..\forall k \neq q \tag{7.3}$$

To relate the random utility model represented by equation (7.3) to a statistical specification for empirical application we make an assumption about the distribution of the elements of utility across the population. Simple specifications such as the multinomial logit and conditional logit models impose the assumption of independent and identically distributed error terms (IID) imposing non-independence between alternatives (i.e. cross-substitutions between pairs of alternatives are equal and unaffected by the presence or absence of other alternatives). With this distributional assumption, the probability that site q is chosen on a given occasion is:

$$P\left(x_q^h \middle| s_q, C\right) = \frac{\exp(X_q\beta)}{\sum_{k=1}^{M}\exp(X_k\beta)} ...\forall k \neq q \tag{7.4}$$

More complex specifications that allow for more behavioral realism by permitting non-independence between alternatives include the multinomial probit and the mixed logit or random parameters logit models (Louviere *et al.*, 2000). The multinomial probit specification assumes that the Q-dimensional disturbance vector, $\varepsilon_{qt} = (\varepsilon_{1t}, \ldots\ldots, \varepsilon_{qt})$, is normally distributed, that is, $\varepsilon_{qt} \sim NID(0,\Sigma)$, where Σ is the covariance matrix. This specification relaxes the IID condition and allows correlation between the sites, avoiding the restrictive assumption of independence of irrelevant alternatives (IIA) of the conditional logit model. The mixed logit or random parameters logit model specification is equivalent in form to the multinomial probit model although the mixed logit or random parameters logit assumes that the variances of the random component of the utility function are distributed as extreme value type 1 (EV1) compared to the normal distribution for the multinomial probit (Louviere *et al*, 2000). Although independent and identically distributed error terms (IID) exist in the random parameters logit specification, independence of irrelevant alternatives (IIA) is not induced, allowing cross-correlations among the alternatives.

The statistical models for analysis of water collection sites choice applied in this study are the mixed logit or random parameters logit and conditional logit specifications. The random parameter logit model specifically measures preference and taste heterogeneity by assuming that individual choices are conditional on a specified distribution of random coefficients according to a set of parameters. If we represent the distribution parameters of random coefficient β in the sample by ψ, the probability of household h choosing site q will be:

$$\overline{P}_q^h = \int P\left(x_q^h \middle| s_q, C\right) f\left(\beta \middle| \psi\right) d\beta \tag{7.5}$$

where $P\left(x_q^h \middle| s_q, C\right)$ is as defined in Equation (7.4) and $f\left(\beta \middle| \psi\right)$ is the probability density function for random coefficient β with parameters ψ. The random parameters logit model specification is estimated based on simulated maximum likelihood procedures because the integral expressions as defined in Equation (7.5) do not have a closed form.

Measures of economic surplus (CS^h) for the aggregate of all sites in the choice set can be calculated from the site choice model defined by Equation (7.4) for each trip. Economic surplus may be defined as a person's utility, in monetary terms, received in the choice situation (Train, 2002). Small and Rosen (1981) show that for the extreme value distribution of error terms and where utility is linear in income, the expected per trip surplus for the conditional logit specification is equivalent to the log-sum term. This is the log of the denominator in the choice probability and this result derives simply from the mathematical form of the extreme value distribution (McFadden, 1981; Train, 2002). Expected per trip surplus is evaluated in terms of the marginal utility of income by dividing the log-sum term by the absolute value of the coefficient on the income term. In this study case we apply the travel time variable (*Time*) as our metric in lieu of income and define per trip surplus from water collection site choices as follows:

$$CS^h = \frac{1}{-\beta_{Time}} \ln\left(\sum_{k=1}^{M} \exp(\beta X_k) \right) \tag{7.6}$$

The per trip economic surplus for the random parameters logit model specification may also be defined as:

$$CS^h = \frac{1}{-\beta_{Time}} \ln\left(\sum_{k=1}^{M} \exp\left[(\beta^{\psi}_{random}, \beta_{fixed}) X_k \right] \right) \tag{7.7}$$

Where β_{Time} is the coefficient on the variable representing the implicit water collection cost (in terms of travel time) and β^{ψ}_{random} and β_{fixed} represent the random and fixed coefficients in the model respectively. A measure of total expected surplus from all water collection trips can be calculated by multiplying per trip surplus by the predicted trip frequency (count) for the household.

7.2 Applied Empirical Models and A Priori Expectations

Many authors report that measures of benefits and costs derived from discrete choice models applying random utility theory are highly sensitive to the determinants of demand that are included (e.g. Kling & Thompson, 1996). Thus the choice of relevant variables in analysis is critical. These variables are discussed below.

7.2.1 Determinants of site choice

A number of explanatory variables in water collection site choice are postulated based on *a priori* knowledge. This knowledge is guided by economic theory, results of empirical studies in the literature, and factors identified from preliminary informal participatory surveys conducted at the study sites between June and August 2002. Previous case studies conducted in Zimbabwe indicate that critical determinants of household environmental resource utilizations are income, wealth, household preferences, household composition, gender, age, collection costs, species substitutes, site substitutes, access to backstops, season and spatial proximity (Dewees, 1989; Campbell et al, 1991; McGregor, 1995; Fortmann and Nabane, 1992; Campbell and Mangono, 1994; Cavendish, 1997; Hatton-McDonald, 1998; Frost and Mandondo, 1999).

Other studies conducted by Kundhlande and Luckert (1998) and Hegan *et al* (2003) have highlighted the importance of resource tenure and property right characteristics of natural resources in household natural resource use decisions. Moreover, with regard to rural water demand in Zimbabwe, Van der Zaag (2003) postulates population, household size, level of service of water supply for each household, water quality, tariff levels, willingness and ability to pay, local knowledge and indigenous practice and climate as important determinants.

Table 7.1 lists responses given by household members in the selected study sites to survey questions on factors considered when choosing a water collection site. It is instructive to contrast these responses with the *a priori* variables that were postulated to influence household decisions (see Table 7.1). We find that the variables expected to be important *a priori* were not different from those cited by the study area households.

Table 7.1: Factors Cited by RA and SSCF Households in Choice of Water Collection Sites (N = Total Number of Households and N Trips = Total Number of Water Collection Trips)

Factor Cited by Households *ex post*	RA households % N = 200 NTrips= 9129	SSCF households % N = 77 NTrips = 3813	Equivalent *A priori* Variable
Within walking distance/Near	28.8	16.0	Time/Distance from homestead
Abundant supply	21.5	46.1	Availability
Potable/clean source of water	20.6	24.5	Quality
Joint activities/Field/Garden/Gold	7.8	3.7	Joint Production Opportunities
Weather conditions/Only Source	1.6	6.8	Weather
Habit	2.8	1.3	Habit
Use of water/Use Designation	16.7	1.4	Intended Use
Quality/distance/availability/use	0.2	0.2	Combination of above
	100	100	

Notes: The list in Table 6.1 is aggregated for all water colelction sites and trips and the percentages represent the proportion of all recorded water collection trips for which the specific factor was cited in site choice.

7.2.2 Applied empirical models and *a priori* expectations

Summarizing the preceding discussion of postulated determinants of water collection site choice, we identify five inferred groups of variables as potentially important in household water collection site choice decisions. Table 7.2 lists the five identified groups of explanatory variables with examples.

Table 7.2: Inferred Groups of Variables in Water Collection Site Choice with Examples

Variable Group	Examples
1. Household Characteristics	Wealth, Size, Composition, Location
2. Water Source Characteristics	Quality, Volume, Walking Distance/Time
3. Water Source Types[a]	Borehole, Deep Well, Shallow Well, River, Dam, Tap, Stagnant Pools, Riverbed Pool, Stream
4. Water Source Property Right Characteristics	Exclusivity, Use Restrictions, Operational Control, Allotment Size
5. Trip Attributes	Technology Used During Trip, Season of Trip, Gender of Trip Participant, Joint Production Activities of a Trip

[a] Water source types and their general characteristics were described in Table 3.5 in Section 3.4 in Part I of the thesis.

In order to include property rights attributes in regressions (i.e. variable group 4), it was necessary to quantify these attributes. Table 7.3 shows numerical assignments of each water source type to indices defining three property rights attributes for econometric analysis. Three property right attributes are defined to measure relative exclusivity, allotment size and restrictions. The numerical assignment of relative indices for the property right attributes is based on the water source types and captures characteristics of institutions, physical attributes, water supply, quality, reliability, use restrictions, and number of users derived from informal survey findings as described in Table 3.5 in Section 3.4 in Part I of the thesis.

The attribute of relative exclusivity indicates the degree to which a water source type may be restricted to use exclusively by smaller rather than a larger group of households. Three dummy variable categories[19] are defined for this attribute with *Exclusivity1* representing the relatively most exclusive water sources and *Exclusivity2* representing the relatively least exclusive water sources. Each of the eight distinct types of water sources were grouped into an exclusivity category based on judgments of the researcher and corroboration with key informants during field observations made over the course of a year spent at the study sites.

Table 7.3: Numerical/Category of Property Right Attributes for Each Type of Water Source

Property Right Attributes	**Shallow Well**	**Deep Well/ Borehole**	**Stream**	**River**	**River bed Pool**	**Dam**	**Stagnant Pool**	**Tap**
Exclusivity (relative index)	1	3	3	3	2	3	2	1
Allotment Size (defined as volume constraint) Up to 60litres = 1; Above 60litres = 2	1	1	2	2	1	2	1	1
Restrictions (use designations & operational controls)	*Number of Restrictions*							
1. No animal watering 2. No fish rearing 3. No alluvial gold panning 4. No laundry 5. No brick molding 6. Metal pots not permitted 7. Required to keep area clean 8.Stream bank cultivation not permitted 9. Use of chemicals not permitted	6	7	5	1	6	3	5	7

Notes: The numerical assignment of relative indices for property right attributes is based on the water source types and captures characteristics of institutions, physical attributes, water supply, quality, reliability, use restrictions, number of users etc. derived from informal survey findings as described in Table 3.5 in Section 3.4 in Part I.

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[19] A more statistically consistent approach to employing an exclusivity index for each water source type would be to treat each level of the exclusivity index as a separate dummy variable as done for analysis of categorical variables. This is not done in the site choice models estimated and reported in this thesis because of two issues: a) the problem of reducing degrees of freedom due to adding seven dummy variables to the independent variables in site choice b) the limited ability for identification of the specific effect of exclusivity characteristics of water source types where the exclusivity index is coded according to water source types. This would result in confounded effects of water source type and exclusivity. Thus, an alternative approach to incorporating a measure of relative exclusivity of water source type used in this analysis is to recode the index to group water source types with similar levels of exclusivity in three categories.

The attribute allotment size refers to permitted water collection volumes at the different types of water source. This attribute assumes two values, one indicating water source types with an upper limit on water volume collected of 60 litres and the other indicating upper limits for water volumes above 60 litres. The third property right attribute indicates relative restrictions on water sources types related to use designations and operational controls. This attribute has a numeric assignment that shows the total number of restrictions, from the list in Table 7.3, that are generally observed for each water source type. The maximum possible number of such restrictions, as listed in Table 7.3, is nine. The number of restrictions found in practice range from 1 to 7.

Table 7.3 Indicates that water use types includes aspects of property rights. That is, these two groups are highly correlated because water source types are largely distinguished by their property rights. Thus, property right and water use type variable groups cannot be included in the same econometric models. That is, based on the groupings of variables in Table 7.2, two separate empirical models are postulated to explain water collection site choices. One of the two models includes group 3 (water source type) explanatory variables, while the other considers group 4 (water source property rights characteristics) as explanatory variables.

The applied empirical specification for the indirect utility U_k^h to household h from choosing water collection site k in Equation (7.2) is defined as follows:

Model with Group 3 Variables: Water Source Types

$$\begin{aligned} U_{kh} =\ & \beta_1 Time_k + \beta_2 Quality_k + \beta_3 Borehole_k + \beta_4 Stream_k + \beta_5 River_k \\ & + \beta_6 RiverbedPool_k + \beta_7 Dam_k + \beta_8 StagnantPool_k + \beta_9 Tap_k + \beta_{10} Children * Q_k \\ & + \beta_{11} HouseholdSize * T_k + \beta_{12} InlandVillage * T_k + \beta_{13} SothCart * T_k \\ & + \beta_{14} DraftPower * T_k + \beta_{15} JWildFood * Q_k + \beta_{16} JProduction * Q_k + \beta_{17} JBathe * Q_k \\ & + \beta_{18} Gender * Q_k + \beta_{19} WetSeason * Q_k + \beta_{20} EarlyDrySeason * Q_k + \varepsilon_k \end{aligned} \quad (7.8)$$

Model with Group 4 Variables: Water Source Property Right Attributes

$$\begin{aligned} U_{kh} &= \beta_1 Time_k + \beta_2 Quality_k + \beta_3 Exclusivity_k + \beta_4 AllotmentSize_k + \beta_5 Restrictions_k \\ &+ \beta_6 Children * Q_k + \beta_7 HouseholdSize * T_k + \beta_8 InlandVillage * T_k + \beta_9 SotchCart * T_k \\ &+ \beta_{10} DraftPower * T_k + \beta_{11} JWildFood * Q_k + \beta_{12} JProduction * Q_k + \beta_{13} JBathe * Q_k \\ &+ \beta_{14} Gender * Q_k + \beta_{15} QWetSeason * Q_k + \beta_{17} EarlyDrySeason * Q_k + \varepsilon_k \end{aligned} \tag{7.9}$$

In Equations (7.8) and (7.9), β represents a vector of estimated parameters for the explanatory variables and ε_k an error term for site *k*. In order for discrete choice model estimation to identify parameters for the explanatory variables in site choice, these variables must vary across alternative sites. In the discrete choice model specification, one set of parameter estimates is generated for all alternative specific variables. Therefore, since household demographic variables do not vary across alternative water collection sites, these variables are interacted with the alternative specific variables *Time* and *Quality* for inclusion in econometric estimation. The final choice of interaction terms included in estimation is based on best model fit. Explanatory variables and *a priori* expected effects are described in Table 7.4.

We expect that a longer travel *Time* to water collection sites, as a measure of cost or effort, will result in reduced likelihood of site choice. *Quality* of water at the site is expected to increase the probability of site choice for domestic water use.

Three property right attributes are hypothesized to influence water site choice. A higher level of *Exclusivity* for a water collection site is expected to favor choice of a particular site by a given household. Intuition leads us to expect that fewer households would visit more exclusive sites, implying a negative sign of effect on site choice for exclusivity.

Table 7.4: Description and *A Priori* Expected Sign of Variables in the Analysis of Site Choice

Variable	Description	Expected Sign
Time	Time (in minutes) it takes to walk to each water site from the homestead	-
Quality	Dummy variable for perception of water quality at each water site 1=potable/good and 0=contaminated/poor	+
	Property Right Attributes	
Exclusivity1	Set of 3 dummy variable categories for relative exclusiveness to a	+
Exclusivity2[a]	group of households of each water source type (defined in Table 7.3).	+/-
Exclusivity3	Category 1 for highest level of exclusivity and category 3 for lowest.	-
Allotment Size	Relative index of volume limits for each water source type (defined in Table 7.3)	+/-
Restrictions	Relative index of the number of restrictions for each water source type (defined in Table 7.3)	-
	Water Source Types - Set of Dummy Variables	
Shallow Well[a]	Omitted	
Borehole	Dummy variable for deep well and borehole = 1; 0 otherwise	+
Dam	Dummy variable for dam = 1; 0 otherwise	-
River	Dummy variable for river = 1; 0 otherwise	-
Riverbed Pool	Dummy variable for riverbed pool = 1; 0 otherwise	+
Stream	Dummy variable for stream = 1; 0 otherwise	+/-
Stagnant Pool	Dummy variable for stagnant pool = 1; 0 otherwise	+/-
Tap	Dummy variable for tap and collector well = 1; 0 otherwise	+
	Household variables interacted with alternative specific variables	
Children Q*	Household composition ratio of children to adults * *Quality*	+/-
*Household Size*T*	Number of members in the household * *Time*	+/-
*Inland Village*T*	Dummy variable for village location (*Inland*= 1 or *Riparian* = 0) * *Time*	+/-
*Scotch cart*T*	Number of scotch carts owned * *Time*	+/-
	Trip attributes interacted with alternative specific variables	
Draft Power*T	Dummy variable for transport mode (*Draft Power*=1; *Manual*=0) * *Time*	+/-
*J-Wild Food*Q* *J-Production*Q* *J-Bathe*Q* *J-None*Q*[a]	Set of 4 dummy variables for joint activity on trip (*J-Wild Food*=1; 0 otherwise; *J-Production*=1; 0 otherwise, *J-Bathe*=1; 0 otherwise and *J-None* = 1; 0 otherwise) * *Quality*	+/-
*Gende-Femaler*Q* *Gende-Maler*Q*	Dummy variable for gender of person on trip cited (*Female*=1; 0 not cited; *Male*=1; 0 not cited) * *Quality*	+/-
*Wet Season*Q* *Early Dry Season*Q* *Late Dry Season*[a]**Q*[a]	Set of 3 dummy variables for season (*Wet Season*=1; 0 otherwise *Late Dry Season*=1; 0 otherwise, and Early Dry Season=1; 0 otherwise) * *Quality*	+/-

Notes: a= omitted dummy variables to avoid singularity during estimation.

However, the variable *exclusivity* as defined indicates relative exclusivity of water collection sites within a given household's choice set. Therefore, we expect a positive sign of effect on site choice for sites that are relatively more exclusive amongst those a particular household has access to. Thus, the exclusivity constraint defined does not apply to the household whose choice behavior is observed but to other households (i.e. who are excluded from access to specific sites). It is unclear what the effect of *Allotment Size* restrictions on water collected at a site will be on site choice for domestic water uses. One would expect constraints on water volume collected at specific site to discourage choice of those sites all things being equal. However, the water collection sites with volume capacity restrictions tend to have better quality potable water for domestic uses. Thus it is unclear which effect between the volume constraint and quality considerations would outweigh the other in determining the coefficient sign for the effect of variable *Allotment Size* on site choice. A greater number of *Restrictions* at sites is expected to decrease the likelihood of site choice.

The impact of water source type on site choice is estimated and interpreted relative to the omitted water source type dummy variable, *Shallow Well*. We expect a positive sign for choice of *Borehole, Tap* and *Riverbed Pool* for domestic water uses. These sites tend to be more reliable in terms of supply over the year. The water source types *River* and *Dam*, are expected to be less likely to be chosen for domestic uses because they are usually shared for large scale water uses such as livestock and garden watering, brick molding and gold panning. It is not clear whether the *Stream* and *Stagnant Pool* would be preferred water source types for domestic use.

The expected effects of household demographic variables and trip attributes that are interacted with alternative specific variables in water collection site choice are unknown and remain to be tested in the empirical models.

7.3 Data and Variables Used in the Analysis

The data employed in this analysis show household preferences for water collection sites. For the RA and SSCF households, water collection and use trips were made as part of day to day efforts by households to secure water for domestic and production needs. Domestic water uses observed included drinking, cooking, laundry and bathing. Water uses for production and income-generation activities included watering of crop and vegetable gardens, watering livestock, brick molding, beer brewing, making pottery and gold panning. This thesis analyses water collection trips for domestic water uses only.

The data set was collected during formal quantitative surveys of households in two study sites, Nyahombe RA and Mushawasha West SSCF. The surveys were conducted in a series of monthly rounds of questionnaires administered over the 15 month period between August 2002 and October 2003. This survey period allowed us to follow household water collection and use over a year, spanning both the wet and dry climatic seasons. It was expected that there would be significant differences in the pattern of water use over the year, in response to seasonal production opportunities and constraints. The data collection process, the sample households and the data were described in more detail in Chapter 3.

7.3.1 Descriptive statistics for variables

Table 7.5 presents descriptive statistics for the variables described in Table 7.4 for RA and SSCF households.[20] In comparing RA and SSCF household statistics, we find that for domestic water collection, RA households tend to walk for longer periods to reach water collection sites. Property right characteristics appear similar among the two sets of households. However, the distribution of types of water sources shows that almost 12% of SSCF households have access to dams, compared to less than 5% of RA households. Dugout riverbed pools are more prevalent in the RA area, with 16% of households using these compared to 4% of SSCF households. We see that the percentage of households with access to taps and collector wells, boreholes and deep wells and shallow wells are similar.

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[20] Table 7.4 also contains results for Village 3a. The relevance for including these results is explained in the next section.

The interaction term *Children*Q* has largest value for the combined RA households sample because the RA households tend to have more children. The interaction term *Scotch cart*T* has by far the largest value for SSCF households because they own greater numbers of scotchcarts, although they have lowest average time taken to walk to water collection sites.

Table 7.5: Summary Statistics for Variables Used in the Analysis of Site Choices

Variable	**RA Households** N=203 Households N Trips = 7674				**SSCF Households** N=84 Households N Trips = 3452				**Village 3[a] Households** N=67 Households N Trips = 2641			
	Mean	**S.D.**	**Min**	**Max**	**Mean**	**S.D.**	**Min**	**Max**	**Mean**	**S.D.**	**Min**	**Max**
Time	13.769	20.367	1	180	11.338	15.577	1	120	19.963	32.203	1	180
Quality	0.337	0.473	0	1	0.308	0.462	0	1	0.315	0.464	0	1
Exclusivity1	0.280	0.449	0	1	0.293	0.455	0	1	—	—	—	—
Exclusivity2	0.248	0.432	0	1	0.148	0.355	0	1	—	—	—	—
Exclusivity3	0.472	0.499	0	1	0.559	0.496	0	1				
Allotment Size	1.345	0.475	1	2	1.450	0.497	1	2	1.283	0.450	1	2
Restrictions	4.930	1.990	1	7	4.839	1.825	1	7	5.310	1.754	1	7
Shallow Well	0.259	0.438	0	1	0.271	0.445	0	1	0.406	0.491	0	1
Borehole	0.126	0.332	0	1	0.112	0.315	0	1	0.163	0.369	0	1
Dam	0.048	0.214	0	1	0.119	0.323	0	1	0	0	0	0
River	0.172	0.378	0	1	0.127	0.333	0	1	0.127	0.333	0	1
Riverbed Pool	0.163	0.369	0	1	0.040	0.196	0	1	0.085	0.278	0	1
Stream	0.125	0.330	0	1	0.205	0.403	0	1	0.156	0.363	0	1
Stagnant Pool	0.0854	0.279	0	1	0.103	0.303	0	1	0.063	0.243	0	1
Tap	0.021	0.144	0	1	0.024	0.154	0	1	0	0	0	0
*Children *Q*	0.4379	0.956	0	7.33	0.182	0.482	0	4	0.338	0.787	0	4
*Household Size*T*	85.513	152.38	0	1560	65.655	130.22	0	1440	124.43	231.47	0	1560
*Inland Village*T*	10.269	20.839	0	180	—	—	—	—	1	0	1	1
*Scotch cart*T*	14.596	33.152	0	480	24.151	46.185	0	480	18.436	51.119	0	480
*Draft Power*T*	3.364	12.852	0	180	5.676	12.189	0	120	5.696	20.976	0	180
*JWild Food*Q*	0.018	0.133	0	1	0.005	0.071	0	1	0.075	0.263	0	1
*JProduction*Q*	0.018	0.134	0	1	0.012	0.108	0	1	0.053	0.224	0	1
*Joint Bathe*Q*	0.010	0.101	0	1	0.001	0.027	0	1	0.058	0.233	0	1
*JNone*Q*	0.290	0.290	0	1	0.291	0.454	0	1	0.814	0.389	0	1
*Gender*Q*	0.281	0.449	0	1	0.223	0.416	0	1	0.265	0.441	0	1
*Wet Season*Q*	0.144	0.351	0	1	0.162	0.368	0	1	0.120	0.325	0	1
*Late Dry Season*Q*	0.088	0.283	0	1	0.069	0.254	0	1	0.094	0.293	0	1
*Early Dry Season*Q*	0.130	0.337	0	1	0.103	0.304	0	1	0.123	0.328	0	1

Notes: a Descriptive statistics are included for Village 3 households, which is a sub-sample of the RA households. The reason for analysis of data for the Village 3 sub-sample households is discussed next in Section 7.3.2.

Means for the variable *Draft Power*T* show that SSCF households use draft power on many more water collection trips than do households in the whole RA sample. This may be explained by the observation that SSCF households own more draft power implements such as scotch carts.

7.3.2 Defining universal and household specific choice sets for water sites

The assumptions of the discrete choice framework require that the set of alternatives, known as "the choice set" exhibit the following three properties. The alternatives must be *mutually exclusive*, the choice set must be *exhaustive* and the alternatives must be *finite* (Train, 2002). Making inferences about the true choice sets of decision makers is considered one of the biggest challenges in discrete choice modeling (Louviere *et al*, 2000). Misspecification of choice sets results in biased inferences about preferences and parameters (Swait and Ben-Akiva, 1985).

The main challenge in defining choice sets in this case study is in that the total number of geographically located alternatives across all households is very large. The analytical approach when stated preference (SP) data is applied is usually to assume a *universal* choice set of alternatives as determined by the researcher (Louviere *et al*, 2000). However, this approach does not account for individual-level choice sets where a decision maker may only consider a sub-set of the universal alternatives. Knowledge of the choice set is assumed to be unavailable in revealed preference (RP) data applications. One approach in practice is to assume that all alternatives are available to all decision makers. However, a shortcoming of this approach is that inclusion of irrelevant alternatives can lead one to underestimate the effects of attribute changes. Another approach is to eliminate choice alternatives from the universal choice set to generate a sub-set for individual decision makers by applying some deterministic criteria (Louviere *et al*, 2000).

LIMDEP (Greene, 2002) was the econometric software used for the discrete choice model estimation in this study. Using this software one can specify discrete choice model data in two ways. The first is to define a *universal* choice set from which individuals make their choices whilst not all alternatives are available to all individuals. This is the case when individuals are observed in many different locations where one or more alternatives may not be available to them. Second, individuals may choose amongst a set of household-specific alternatives with no universal choice set defined. An example where a universal choice set is not applied is the case of choosing a shopping center to visit when individuals are in many different geographic locations such as cities so that many different choice sets are observed, but there is no well defined *universal* choice set (Greene, 2002). For the first case, where a universal choice set is specified, LIMDEP has an internal limit of 100 alternatives that can be specified for estimation, while still specifying alternative specific constants. It is also possible to allow up to 200 alternatives in estimation, with the shortcoming that alternative specific constants cannot be specified unless one includes actual dummy variable constants for the 200 alternatives in estimation. For the second case, where a universal choice set is not specified, LIMDEP internally counts rows of data for each observation based on a specified variable indicating individual choice set size. Because a universal choice set is not defined, LIMDEP simply uses the largest number of choices for any individual to determine the maximum number of alternatives. Thus, alternative specific constants and probabilities will not be meaningful.

In this study, a household specific choice set for water collection sites was defined by using survey questions to elicit an inventory of all the different geographic water collection sites that a household might visit throughout the year (see questionnaires in Appendix 9-I to 9-III at the end of Part IV). The identified water collection sites were distinguished geographically and numbered based on spatial reference coordinates collected using a global positioning system (GPS) device. The result was that the *universal* choice set of water sites identified for all sample households combined included 296 and 312 distinct geographic water collection sites for RA and SSCF households respectively. The household level choice set incorporating relevant alternatives included an average of 5.02 geographic sites with a minimum of 1 and a maximum of 8 sites for RA households and a mean of 5.56 and a minimum of 1 and maximum of 9 sites for SSCF households.

Given the large number of geographic alternative sites in our study, we begin by estimating a discrete choice model from part of the study site specifying a universal choice set that can be accommodated by the econometric software. That is, we use a sub-sample of 33% of the RA households from Village 3 who have a water collection site choice set of 82 geographically distinct water collection sites to estimate this model. Next, we use data for the whole RA and SSCF household samples without specifying a universal choice set (i.e. with generic choice sets) to estimate similar site choice models. The Village 3 RA sub-sample models are estimated to test for significant differences in coefficient estimates and welfare measures between model specifications with universal choice sets defined for water sites in comparison to generic choice sets for water sites. In models where the universal choice set is not specified, water collection sites that were not visited at least once by at least one household in the sample are included in household choice sets as long as they were identified by the household as an alternative during the data collection surveys. In models where the universal choice set is specified, site choice models exclude sites that were never visited over the survey period.

The Village 3 households are located inland rather than being adjacent to the major rivers Runde and Tokwe in Nyahombe RA. From Table 7.5 we see that average time taken to walk the distance to water collection sites is up to 50% longer for Village 3 households than is the case for the whole RA sample and the SSCF sample household means. Village 3 households can be considered to be more representative of rural villages in Zimbabwe with fewer water collection options.

7.4 Site Choice Estimation Results

The presentation and discussion of results of site choice model estimation are arranged as follows. Separate models are estimated for all RA households (203 households with 7674 trips), all SSCF households (84 households with 3452 trips) and for Village 3 RA households (67 households with 2641 trips). Two sets of models ere estimated for the Village 3 RA households, one with universal choice sets [i) in Table 7.6] for water collection sites and another with generic choice sets [ii) in Table 7.6].

Table 7.6: Summary of Site Choice Models Estimated

RA Village 3 Sub-Sample[a]
i) Universal Choice Set Specified
a) Water source types - Equation (7.8)
Model 1: Conditional Logit
Model 2: Random Parameters Logit
b) Property rights characteristics of water source types - Equation (7.9)
Model 3: Conditional Logit
Model 4: Random Parameters Logit
RA Village 3 Sub-Sample[a]
ii) Generic Choice Set Specified - Universal Choice Set Not Specified
a) Water source types - Equation (7.8)
Model 5: Conditional Logit
Model 6: Random Parameters Logit
b) Property rights characteristics of water source types - Equation (7.9)
Model 7: Conditional Logit
Model 8: Random Parameters Logit
RA Households
iii) Generic Specific Choice Set Specified - Universal Choice Set Not Specified
a) Water source types - Equation (7.8)
Model 9: Conditional Logit
Model 10: Random Parameters Logit
b) Property rights characteristics of water source types - Equation (7.9)
Model 11: Conditional Logit
Model 12: Random Parameters Logit
SSCF Households
iv) Generic Choice Set Specified - Universal Choice Set Not Specified
a) Water source types - Equation (7.8)
Model 13: Conditional Logit
Model 14: Random Parameters Logit
b) Property rights characteristics of water source types - Equation (7.9)
Model 15: Conditional Logit
Model 16: Random Parameters Logit

Notes: a= Model estimation results for all Village 3 RA models are not presented in the main body of the text. They are presented in Appendix 7-I. We discuss these results briefly in Section 7.4.1 in order to conduct a comparison of universal choice set and generic choice set specifications to justify the generic choice set specification for analysis of the complete data set.

The two sets of models for Village 3 Ra households are estimated to test for potential misspecification of the site choice model due to failure to specify universal choice sets by comparing models derived from generic choice set and universal sets. In Models 1 to 4 (estimation results are in Appendix 7-I), a discrete choice model specifying a universal choice set of water collection sites, for the sub-sample of RA households in Village 3, is estimated. Estimation generates alternative specific descriptive statistics and probabilities of choice for the 82 geographically distinct water collection sites.

Estimation results for Models 5 to 8 apply discrete choice models for Village 3 RA households where a generic choice set is specified (presented in Appendix 7-I).

All models for the combined RA household sample [iii) in Table 7.6] and the SSCF (D in Table 7.6) household sample are estimated with generic choice sets. The models C and D for the combined RA household and SSCF household samples are estimated to include all observations in the complete sample in site choice models. Within these sub-samples for Village 3, all RA and all SSCF households, separate models are also estimated for water collection trips with variables for water source types, as defined in Equation (7.8) and water source property right attributes, as defined in Equation (7.9).

7.4.1 Results of testing universal versus generic choice set specifications

A challenge in this study of water collection site choices is in that the universal choice set of geographic sites across all households is very large and cannot be accommodated by Limdep in econometric estimation. Consequently, there is a potential to mis-specify choice sets, potentially resulting in biased inferences about preferences and parameters. We therefore test potential errors that might arise from this possibility by analyzing trip log data for a sub-sample, consisting of the RA households from Village 3. This enables comparison of the results of alternative models based on the universal choice sets relative to the models tested on generic choice sets.

Comparison of model estimation results for Models 1 to 4 (i.e. universal choice set) with models 5-8 (i.e. universal choice set not specified) show virtually no difference in coefficient estimates and goodness of model fit based on diagnostic statistics such as the log likelihood function value and the chi-square. The calculated means for the expected value of maximum utility (economic surplus/welfare measures) for the two alternative model specifications are also similar.

Further, estimation results of Models 1 to 8 are similar to those for the whole RA sample reported in Models 9 to 12 (in Tables 7.7 and 7.8) in terms of significant coefficients. The main differences in sign and significance of variables may be attributed to the idiosyncrasies of the Village 3 sub-sample. This peculiarity of Village 3 site choice estimates is highlighted in discussion of welfare measures for water site choice models in Section 7.4.3. All random parameter logit (RPL) models for the Village 3 households, in Appendix 7-I, are significant and show a modest improvement in log likelihood function value over the conditional logit (CL) models, and a significant standard deviation for the coefficient on the *Time* variable.

Based on the similarity of results of site choice model estimation for the Village 3 RA households where universal choice sets and generic choice sets are specified, we conclude that little, if any, information is lost by failing to specify universal choice sets for all households and by including irrelevant alternatives based on household-reported choice sets. Thus, we proceed to estimate site choice models with generic choice sets for all RA households (Models 9 to 12 in Tables 7.7 and 7.8) and for all SSCF households (Models 13 to 16 in Tables 7.9 and 7.10). We now turn to discussion of these estimation results.

7.4.2 Results of site choice models with generic choice sets

Estimation results for site choice models for domestic water use by RA and SSCF households are presented in Tables 7.7 to 7.10. The majority of explanatory variables are highly significant at the 1% level and carry the expected signs. For example, the alternative specific variables *Time* and *Quality* have the expected negative and positive signs respectively. The negative coefficient for travel cost measured by *Time* implies a reduced likelihood of site choice with increased travel cost. The positive coefficient on *Quality* suggests that households are more likely to collect water from sites that are perceived to carry water that is relatively clean or potable. The coefficient for the *Quality* variable has by far the largest marginal rate of substitution (MRS) in absolute terms with respect to the coefficient of the *Time* variable (calculated as the quotient of coefficient of *Quality* and *Time*) compared to all other coefficients. Thus quality of water source appears to be the most important single determinant of site choice for domestic water use.

Based on likelihood functions values between -1612 and -6118, the overall performance of all models is good. Model pseudo R^2 are modest, as expected for discrete dependent variable models, averaging about 0.61 for RA models and about 0.79 for SSCF models. The Log Likelihood values show that the RPL models provide a slight improvement in fit over all the CL Models. These results are reflected in Models 10 and 12 (in Table 7.7. and 7.9) for RA households and Models 14 and 16 (in Tables 7.8 and 7.10) for SSCF households. All model results indicate that *Time* is a significant normally distributed random parameter with significant standard deviation at the 1% level of significance. The interpretation of this result is that there is significant heterogeneity across the sample of households in the effect of the given variable on utility of water collection site choice. A non-random coefficient would imply that all sampled households value the particular variable in the same way whether positive or negative, or place no value on the variable if it is insignificant.

Table 7.7: RA Tenure - Site Choice Estimation Results A) Water Source Type Variables

Model 9: Conditional Logit			Model 10: Random Parameters Logit		
Variable	**Coefficient**	**Std. Error**	**Variable**	**Coefficient**	**Std. Error**
			Random parameters in utility function		
Time	-0.070***	0.006		-0.088***	0.008
			Non-random parameters in utility function		
Quality	3.100***	0.191		3.204***	0.201
Borehole	-0.092*	0.053		-0.113**	0.056
River	-0.577***	0.073		-0.426***	0.076
Stream	-1.012***	0.073		-0.958***	0.075
Riverbed Pool	0.253***	0.047		0.330***	0.049
Dam	-0.424***	0.117		-0.624***	0.140
Stagnant Pool	0.166**	0.074		0.252***	0.008
Tap	1.620***	0.128		1.662***	0.135
*Draft Power*T*	0.012***	0.003		0.021***	0.004
*Wet Season*Q*	0.103	0.111		0.177	0.122
*Early Dry Season*Q*	0.275**	0.109		0.348***	0.119
*JWild Food*Q*	-0.742***	0.160		-0.922***	0.169
*JProduction*Q*	-0.122	0.228		-0.235	0.241
*JBathe*Q*	-0.810***	0.195		-1.008***	0.201
*Gender-Female*Q*	0.355**	0.179		0.426**	0.188
*Gender-Male*Q*	-0.107	0.225		-0.058	0.238
*Scotch cart*T*	-0.003***	0.001		-0.005***	0.001
*Household Size*T*	0.003***	0.0003		0.003***	0.0004
*Children*Q*	-0.163***	0.384		-0.169***	0.041
*Inland Village*T*	0.0354***	0.006		0.045***	0.007
			Standard deviation of random parameters		
			Sd- *Time*	0.039***	0.003
Number of observations	7674		Number of observations	7674	
Log-Likelihood	-6023.807		Log-Likelihood	-5972.285	
Pseudo R^2	0.622		Pseudo R^2	0.625	

Notes: *,**,*** indicates significance at the 10%, 5% and 1% significance level respectively

Table 7.8: SSCF Tenure - Site Choice Estimation Results A) Water Source Type Variables

Model 13: Conditional Logit			**Model 14: Random Parameters Logit**		
Variable	**Coefficient**	**Std. Error**	**Variable**	**Coefficient**	**Std. Error**
			Random parameters in utility function		
Time	-0.073***	0.011		-0.084***	0.012
			Non-random parameters in utility function		
Quality	4.446***	0.463		4.634***	0.498
Borehole	0.051	0.081		0.085	0.084
River	-0.391***	0.126		-0.345***	0.131
Stream	-1.385***	0.109		-1.395***	0.112
Riverbed Pool	-1.569***	0.156		-1.564***	0.159
Dam	-1.427***	0.198		-1.418***	0.203
Stagnant Pool	-2.884***	0.209		-3.047***	0.221
Tap	0.194	0.173		0.284	0.181
*Draft Power*T*	0.003	0.007		0.005	0.008
*Wet Season*Q*	0.911	0.265		0.909***	0.274
*Early Dry Season*Q*	-0.395*	0.220		-0.377*	0.228
*JWild Food*Q*	-0.792	0.485		-0.768	0.509
*JProduction*Q*	-0.859**	0.413		-0.931**	0.419
*Gender-Female*Q*	-0.586	0.455		-0.637	0.486
*Gender-Male*Q*	-1.253***	0.479		-1.355***	0.511
*Scotch cart*T*	0.011***	0.003		0.009***	0.003
*Household Size*T*	0.0001	0.001		-0.0003	0.001
*Children*Q*	0.487***	0.185		0.511***	0.194
			Standard deviation of random parameters		
			Sd- *Time*	0.045***	0.008
Number of observations	3452		Number of observations	3452	
Log-Likelihood	-1590.666		Log-Likelihood	-1584.127	
Pseudo R^2	0.790		Pseudo R^2	0.791	

Notes: *,**,*** indicates significance at the 10%, 5% and 1% significance level respectively

Table 7.9: RA Tenure - Site Choice Estimation Results B) Water Source Type Property Rights

Model 11: Conditional Logit			Model 12: Random Parameters Logit		
Variable	**Coefficient**	**Std. Error**	**Variable**	**Coefficient**	**Std. Error**
			Random parameters in utility function		
Time	-0.107***	0.006		-0.127***	0.007
			Non-random parameters in utility function		
Quality	3.106***	0.190		3.212***	0.201
Allotment Size	-0.813***	0.104		-0.825***	0.108
Restrictions	-0.045**	0.021		-0.071***	0.022
Exclusivity1	-0.099**	0.044		-0.182***	0.047
Exclusivity3	-0.287***	0.058		-0.361***	0.061
*Draft Power*T*	0.011***	0.003		0.020***	0.004
*Wet Season*Q*	0.052	0.111		0.113	0.122
*Early Dry Season*Q*	0.203*	0.108		0.268**	0.118
*JWild Food*Q*	-0.657***	0.158		-0.839***	0.167
*JProduction*Q*	0.037	0.227		-0.104	0.239
*JBathe*Q*	-0.724***	0.194		-0.920***	0.201
*Gender-Female*Q*	0.358**	0.178		0.450**	0.187
*Gender-Male*Q*	-0.168	0.225		-0.106	0.239
*Scotch cart*T*	-0.003**	0.001		-0.006***	0.002
*Household Size*T*	0.003***	0.0004		0.003***	0.0004
*Children*Q*	-0.169***	0.038		-0.170***	0.041
*Inland Village*T*	0.076***	0.006		0.087***	0.007
			Standard deviation of random parameters		
			Sd- *Time*	0.041***	0.004
Number of observations	7674		Number of observations	7674	
Log-Likelihood	-6118.39		Log-Likelihood	-6061.364	
Pseudo R^2	0.617		Pseudo R^2	0.620	

Notes: *,**,*** indicates significance at the 10%, 5% and 1% significance level respectively

Table 7.10: SSCF Tenure - Site Choice Estimation Results B) Water Source Type Property Rights

Model 15: Conditional Logit			Model 16: Random Parameters Logit		
Variable	Coefficient	Std. Error	Variable	Coefficient	Std. Error
			Random parameters in utility function		
Time	-0.066****	0.010		-0.070***	0.011
			Non-random parameters in utility function		
Quality	4.432****	0.453		4.561***	0.473
Allotment Size	-1.704***	0.172		-1.716	0.174
Restrictions	-0.158***	0.037		-0.157***	0.038
Exclusivity1	2.268***	0.127		2.318***	0.131
Exclusivity3	2.456***	0.153		2.523***	0.159
*Draft Power*T*	0.003	0.007		0.005	0.008
*Wet Season*Q*	0.957***	0.264		0.969***	0.270
*Early Dry Season*Q*	-0.333	0.218		-0.307	0.224
*JWild Food*Q*	-0.782	0.480		-0.771	0.493
*JProduction*Q*	-0.911**	0.411		-0.966**	0.415
*Gender-Female*Q*	-0.608	0.445		-0.660	0.461
*Gender-Male*Q*	-1.253**	0.470		-1.335***	0.488
*Scotch cart*T*	0.011***	0.003		0.008**	0.003
*Household Size*T*	0.001*	0.001		0.0005	0.001
*Children*Q*	0.482	0.182		0.490***	0.187
			Standard deviation of random parameters		
			Sd- *Time*	0.034***	0.009
Number of observations	3452		Number of observations	3452	
Log-Likelihood	-1615.331		Log-Likelihood	-1791.687	
Pseudo R^2	0.7760		Pseudo R^2	0.7874	

Notes: *,**,*** indicates significance at the 10%, 5% and 1% significance level respectively

For a normally distributed random variable we can calculate the proportion of sample households that value the variable positively or negatively as a determinant of water collection site choice based on the standard normal cumulative distribution function. We find that the standard deviation for the coefficient on the *Time* variable for the SSCF households (Sd-*Time* = 0.045 in Model 14) is approximately the same as that for the RA households (Sd-*Time* =0.039 in Model 10) when water source type variables are included in the regression. In contrast, we find that standard deviation for the *Time* coefficient for the SSCF households (Sd-*Time* =0.034 in Model 16) is slightly smaller than that for the RA households (Sd-*Time* = 0.041 in Model 12) when water source property rights variables are included in the regression. This shows a wider variation in individual household disutility due to the time taken to walk to water sources in the RA when the property rights characteristics of water source types are considered. Thus, it appears that time taken to walk to water sources is a more significant factor in deterring site choice when property rights characteristics of water collection sites are considered by RA households when compared to SSCF households. This finding may be a reflection of the observation that more distant water sources such as community boreholes and rivers tend to be less exclusive. In addition, for boreholes use restrictions and volume capacity limits are common.

The other notable differences between determinants of domestic water site choice for the RA and SSCF tenure households is in the significance and sign of the other groups of variables postulated. These groups of variables are: water source type variables; the property rights variables for each type of water source; trip attributes; and household demographic variables interacted with alternative specific variables. The impact of each of these groups of variables is examined further below. Further, we find that most of the fixed (non-random) variable coefficients have a similar effect on utility in terms of sign and significance for all the CL and RPL models for RA and SSCF households. Where significant differences appear between the effect of explanatory variables in the CL and RPL model, these are highlighted in the discussion that follows.

7.4.2.1 Water source type variables

Models 9 and 10 for RA households in Table 7.7 and Models 13 and 14 in Table 7.8 for SSCF households include descriptors of water source type as explanatory variables. There are eight dummy variables, defined to describe water source types (as explained in Table 7.4). The dummy variable for *Shallow Well* is omitted in all models estimated to avoid singularity. Therefore, interpretation of all water source type coefficients is relative to this omitted type of water source.

In Models 9 and 10 we see that RA households are more likely to visit water sources that are *Riverbed Pool, Stagnant Pool* and the *Tap* than *Shallow Wells* for domestic water use (Table 7.7). The SSCF households are not more likely to visit any other water source relative to a *Shallow Well* (Table 7.8). This result is consistent with the finding in the descriptive statistics in Table 7.5 that the SSCF households have access to a larger number of shallow wells than RA households. Shallow wells are typically constructed by the household and used by small groups of people with social ties. This finding also suggests that shallow wells in the SSCF area may have more reliable water supplies as compared to RA shallow wells. For the SSCF household models, the *Borehole* and *Tap* coefficients are both positive but insignificant Thus, we find that RA households are more likely to choose the hand dug riverbed pools and naturally occurring stagnant pools that require little investment in construction for domestic water use. These water sources also tend to be communally shared by larger groups. Further, we find that SSCF households rely on household owned wells. These findings confirm the expectation that RA households may be poorer and have less access to exclusive water resources and hence depend more on communal resources than is the case for SSCF households. The negative coefficients on utility from choice of the other types of water sources, i.e. *Stream, River* and *Dam* show that these water source types are less likely to be chosen relative to the *Shallow Well* for domestic water use. This is not surprising given the relatively poor water quality of these types of water sources due to their potential contamination because of numerous uses, including animal watering, which is permitted for these water sources.

7.4.2.2 Water source property rights variables

Models 11 and 12 for RA households in Table 7.9 and Models 15 and 16 in Table 7.10 for SSCF households include indices for the property rights characteristics *Allotment Size, Restrictions, Exclusivity1* and *Exclusivity2,* defined in Table 7.4, as explanatory variables in site choice for domestic water use. The property rights variables perform well as explanators in all models. All models have negative signs on the coefficient for *Allotment Size*. The negative and significant sign on *Allotment Size* (volume capacity) limits for water collected by RA households shows that water sources with capacity limits are more likely to be chosen for domestic water collection (where the variable assume a higher value for greater volumes permitted). Water sources that permit larger volume water uses typically permit large scale water uses, such as livestock watering and brick molding, which contaminate water, making it less suitable for domestic consumption. Thus, the effect of water quality considerations appears to outweigh the effect of volume constraints in determining the likelihood of domestic water site choice. The RPL model for SSCF households, Model 16 (in Table 7.10) has an insignificant coefficient on *Allotment Size* coefficient, suggesting that permitted water volume capacity limits are not an important factor in site choice for this group of households The negative sign for *Restrictions* indicates that sites with more use restrictions and operational controls are less likely to be visited by all households as expected.

The exclusivity dummy variables exhibit divergent effects site choice for RA versus SSCF households. For RA households we find that relative to the omitted category *Exclusivity2*, water sources in categories *Exclusivity1* and *Exclusivity3* are least likely to be chosen. This implies that both the most exclusive and the least exclusive water sources are least likely to be visited as compared to those with medium exclusivity. This result is likely a reflection of the limited access to highly exclusive water sources such as taps and personal shallow wells in category *Exclusivity1* for RA households. Whilst there is still evidence of households not preferring the least excusive water sources in category *Exclusivity3* in general. For SSCF households we find that the omitted category *Exclusivity2* water source types are less likely to be chosen relative to both most exclusive category *Exclusivity1* and least exclusive category *Exclusivity3* water sources. Although this result shows a clear preference for the more exclusive water sources, it again reflects relatively limited access to the types of water sources such as waterway pools and riverbed pools in category *Exclusivity2* and greater access to water sources in category *Exclusivity3* water sources such as rivers, dams and streams by SCF households.

7.4.2.3 Trip attributes: season, technology, gender & joint production activities

Observed trip attributes on each site choice occasion are interacted with *Quality* and *Time* alternative specific variables for inclusion in the discrete choice models. The interaction terms are described in Table 7.4.

The variable *Draft Power*T* interacts time to walk to a water source with a dummy variable indicating whether water collection was conducted using draft power on each trip occasion. The omitted dummy variable indicates that water collection was conducted manually on that trip. For RA households, this variable has a positive and significant effect on site choice in all models (Models 9 to 12 in Table 7.7 and 7.9). This indicates that sites that have longer travel times are more likely to be chosen on trip occasions where draft power is used to collect water, relative to trips where water is carried manually. The coefficient estimate for *Draft Power*T* is insignificant in all SSCF models (Models 13 to 16 in Table 7.8 and 7.10).

*Wet Season*Q* and *Early Dry Season*Q* interact perceived water quality at water collection sites with dummy variables indicating whether the trip occasion fell in the wet season (defined as the months between January and April) or early dry season (defined as the months between May and August). The dummy variable for the late dry season (the months between September and December) is omitted. For RA households (Models 9 to 12 in Tables 7.7 and 7.9), the coefficient for *Early Dry Season*Q* is positive and significant in all models. The implication is that water sources with higher quality are more likely to be chosen on trip occasions that fall in the early dry season relative to the late dry season. The marginal rate of substitution (MRS) of the coefficient on the early dry season variable with respect to the coefficient of the *Time* variable is higher in absolute terms in models with water source type variables and all wet season coefficients are insignificant. For SSCF households (Models 13 to 16 in Tables 7.8 and 7.10), the coefficients for both *Wet Season*Q* and *Early Dry Season*Q* are significant in all models. The wet season coefficient is positive whilst the early dry season coefficient is negative. This implies that water sources with higher quality are more likely to be chosen on trip occasions that fall in the wet season and less likely to be chosen on trip occasions falling in the early dry season relative to the late dry season. This finding suggests that the late dry season for households located in the SSCF area may not be characterized by as much water stress as that for the households located in the RA. In addition, we see that the magnitude of the coefficient on the wet season variable is very large, again showing that water source quality is a very important factor in site choice and even more so in the wet season.

The variables *JWild Food*Q*, *JProduction*Q* and *JBathe*Q* refer to interactions of perceived water quality at water collection sites with dummy variables indicating whether a joint production activity was conducted on the trip occasion. The omitted variable indicates that no joint production activity was conducted on the trip occasion. In all models for RA and SSCF households, the coefficients on the joint production activity variables are negative. For the RA households, coefficients for collecting wild foods and for bathing (including, laundry, swimming and playing) are significant. For SSCF households only the coefficient for production (including garden, livestock, field, gold panning activities etc.) is significant. In the models for SSCF households, the variable for bathing (including, laundry, swimming and playing) as a joint activity is omitted because the mean of this variable is so small that model estimation produced a fixed parameter estimate when it was included. Therefore, the results indicate that all households are more likely to choose poor quality water collection sites when a joint production activity is conducted simultaneously on the water collection trip for domestic use relative to trips where there is no joint activity. This follows from the observation that water related to joint production activities such as fishing, laundry, watering gardens, gold panning, swimming are more likely to be permitted in the relatively poor quality water sources (see Tables 3.5 and 7.3). We also find that RA households are more likely to conduct joint activities (such as bathing, swimming, collecting fuelwood) on domestic water collection trips as compared to SSCF households.

The variable *Gender-Female*Q* and *Gender-Male*Q* interact perceived water quality at water collection sites with dummy variables indicating whether a female or male household member conducted the water collection task on the given trip occasion. The results in Models 9 to 12 (in Table 7.7 and 7.9) for RA households show a positive and significant coefficient on *Gender-Female*Q* indicating that on water collection trips conducted by female household members, sites of higher quality were more likely to be chosen, relative to water collection trips where the gender of the person conducting the trip is not specified. The coefficient for the variable indicating trips conducted by males is negative and insignificant for the RA households. In contrast for the SSCF households in Models 13 to 14 (in Table 7.8 and 7.10) the coefficients for trips conducted by male household members are negative and significant in all models, whilst the coefficient for females is negative and insignificant. This result suggests that good quality water collection sites are less likely to be chosen when male household members conduct water collection trips in the SSCF relative to relative to water collection trips where the gender of the person conducting the trip is not specified. The RA and SSCF results combined highlight an interesting gender dimension in domestic water collection site choice decisions. Female household members are found to seek higher quality water sources when compared to their male counterparts on water collection trips relative to trips where the gender of the person conducting the trip is not specified.

7.4.2.4 Household demographics: scotchcarts owned, household size, composition & location

Some household demographic variables are interacted with *Quality* and *Time* alternative specific variables for inclusion in the discrete choice models as factors influencing choice. These variables are described in Table 7.4.

The variables *Household Size*T* and *Children*Q* try to capture the effect of household size and demographic composition on water collection site choices for domestic use. Household size and the ratio of children to adults in the household are interacted with the time to walk to site and perceived water quality at the site, respectively. The positive and significant coefficient on *Household Size*T* for RA households indicates that households with more members are more likely to choose water collection sites that take longer to reach. Although, we see that the effect of travel *Time* on site choice is negative, the effect of larger household size is to increase the probability of choosing sites with a greater travel time. This may arise because larger families require larger volumes of water and may travel longer distances in search of water because of volume constraints at local water sources. Household size is an insignificant factor in choice of sites with higher travel costs as reflected in three out of four models for SSCF households. The exception is a coefficient significant the 10% level of significance in the CL Model 15 which does not account for heterogeneity in the variable *Time* as does the RPL Model 16 (Table 7.10).

Estimation results for Models 9 to 12 in Tables 7.7 and 7.9 for RA households show that households with a higher ratio of children to adults are less likely to choose good quality water collection sites for domestic water use as reflected in the negative and significant coefficient for *Children*Q*. This may reflect possible time constraints in the household and the feature that there may be fewer adult household members to collect water such that children may be responsible for the task and may pay less attention to water quality. The variable *Children*Q* is positive and significant in the SSCF household Models 13 and 14 (in Table 7.8) with water source type variables as explanatory variables. This suggests that SSCF households with higher ratio of children to adults are more likely to choose good quality sites, with the opposite found among RA households for unknown reasons.

The travel *Time* to water collection sites is interacted with the number of scotch carts owned by a household to generate the variable *Scotch Cart*T*. The number of scotch carts owned by the household is used as a proxy for relative wealth or asset ownership. For SSCF households, all models in Tables 7.8 and 7.10 show a positive and significant coefficient for *Scotch Cart*T*. This indicates that wealthier households who own more scotch carts are more likely to choose sites with higher travel times.

However, ownership of scotchcarts may also be interpreted as an indicator of potential to use this technology as draft power on water collection trip. We have also included *Draft Power*T* as a variable indicating whether water collection was conducted using draft power on each trip occasion in model estimation. The insignificant coefficient estimate for *Draft Power*T* in all SSCF models (Models 13 to 16 in Table 7.8 and 7.10) suggests that there may be some confounding of effects on site choice between these two variables. In all RA household models in Tables 7.7 and 7.9, the opposite effect is found. A negative and significant coefficient for *Scotch Cart*T* shows that the wealthier households owning more scotch carts are more likely to choose water collection sites with lower travel times.
However, a positive and significant effect on site choice for *Draft Power*T* in all RA household models (Models 9 to 12 in Table 7.7 and 7.9) suggests that sites that have longer travel times are more likely to be chosen on trip occasions where draft power is used. These results for RA households overall suggest that the relatively wealthy households in the RA have access water sources that have shorter travel times than is the case for the poorer households and where travel times to water sources are longer, draft power is generally used.

A dummy variable is used to indicate whether the village is located inland relative to the two major rivers, Tokwe and Runde, in the study area. The dummy variable *Inland Village*T* is interacted with travel *Time* to water collection sites. SSCF household cannot be classified in this way because households are not organized by villages in this land tenure system. The RA model estimation results in Tables 7.7 and 7.8 indicate a positive and significant coefficient for the *Inland Village*T* interaction term in all models. We find that RA households located inland are more likely to choose water collection sites with a higher travel time. This reflects a feature expected that households located in riparian areas for major water sources are more likely to have closer access to more water sources because of the associated river catchment ecosystem.

The next section discusses relative welfare implications of the differences in determinants and significance of household water collection site choices as derived from site choice models estimated.

7.4.3 Expected value of maximum utility from site choices per trip

An important application of discrete choice models is in calculating the benefits derived from sites with potential to inform policy for welfare improvement and water access. The basis of benefit estimation is economic surplus derived from the demand for the good. An individual's surplus is defined as the utility, in monetary terms that the person receives in the choice situation (Train, 2002). For this study we use the variable *Time* as our valuation metric in lieu of the marginal utility of income, and define the per trip economic surplus in terms of labor time [as in Equations (7.6) and (7.7)]. Because we do not observe utility directly, we derive expected economic surplus by specifying a distribution for the random error terms, in specifying discrete choice models, as discussed in Section 7.1.

Measures of benefits and costs derived from discrete choice models applying random utility theory have been shown to be sensitive to the explanatory variables included and the ability to accurately specify the choice sets of decision makers (Kling & Thompson, 1996; Louviere *et al*, 2000). As such, calculated means for expected values of maximum utility (log-sum) and estimates of per trip economic surplus for all models applied for RA and SSCF households are presented in Table 7.11.

The expected per trip economic surplus measures in Table 7.11 are higher for the SSCF households than for the whole RA household sample. However, the estimates also show substantially higher expected value of maximum utility (surplus measures) from water collection sites for the Village 3 RA sample (Models 5 to 8) compared to all RA households and SSCF sample (Models 9 to 16). Thus, we find that RA households in Village 3 are willing to pay much more to acquire water for essential domestic needs relative to the whole RA sample and SSCF households.

Table 7.11: Comparison of Expected Value of Maximum Utility (log-sum term), Coefficient on Time Variable and Mean Economic Surplus from Site Choice Models 5 to 8 (In Appendix 7-I) and Models 9 To 16 (In Tables 7.7 To 7.10)

MODEL	Log-Sum	β_{Time}	(in minutes) Economic surplus
Model 5 - Village 3 Water Source Types CL	2.432	-0.029	82.877
Model 6 - Village 3 Water Source Types RPL	1.779	-0.039	45.615
Model 7 - Village 3 Property Rights CL	5.324	-0.029	185.268
Model 8 - Village 3 Property Rights RPL	3.804	-0.043	88.478
Model 9 - RA Water Source Types CL	3.268	-0.070	46.396
Model 10 - RA Water Source Types RPL	3.299	-0.088	37.485
Model 11 - RA Property Rights CL	1.818	-0.107	16.936
Model 12 - RA Property Rights RPL	1.427	-0.127	12.441
Model 13 - SSCF Water Source Types CL	4.119	-0.073	56.425
Model 14 - SSCF Water Source Types RPL	4.129	-0.084	49.155
Model 15 - SSCF Property Rights CL	3.777	-0.066	56.972
Model 16 - SSCF Property Rights RPL	4.922	-0.070	48.635

The expected surplus measures also show a higher expected value of maximum utility from water collection sites when alternative sites are valued in terms of the influence of water source types as compared to the value in terms of water source property rights variables for the RA sample (Models 9 to 12). The opposite result is found (i.e. higher surpluses for property right models) for Village 3 RA households (Models 5 to 8) and for SSCF households (Models 13 to 16). This suggests that the willingness to pay for the exclusivity, allotment size and restriction attributes of water collection sites is relatively high for SSCF and much higher for Village 3 RA households compared to other RA households. This suggests that a premium is placed on the relatively exclusive and less restricted access to water sources and water collection volumes enjoyed in the SSCF area where land and many water resources within farms are owned by households in nuclear and extended families. The surplus measures accounting for property rights variables for Village 3 households are again a reflection of relatively poor access to mostly communally owned water sources for Village 3 RA households.

The results in Table 7.11 for RA household Models 9 to 12 show that including the variable *Inland Village*T* (in site choice Models 9 to 12 in Tables 7.7 and 7.9) results in much lower per trip economic surplus measures compared to Models 5 to 8 for Village 3 RA households estimated without this interaction term. The variable *Inland Village*T* measures heterogeneity amongst all RA households as far as location relative to major rivers. The effect of heterogeneity in household location for Village 3 RA households in particular is to increase per trip economic surplus for inland villages and reduce it for villages that are riparian to major rivers. Thus, the high surplus measures observed for Village 3 RA households may be attributed to the relatively poorer access to alternative water sources observed compared to SSCF households and the other RA households particularly those located riparian to major rivers.

In general we see that per trip economic surplus estimates from all CL model specifications are higher than those from RPL model specifications (where the economic surplus is calculated at mean values of random parameters for RPL models). This is as expected because CL models tend to generate over inflated coefficients hence inflated welfare measures because of not accounting for heterogeneity in random parameters. The negative of the economic surplus calculated by applying Equations (7.6) and (7.7), presented in Table 7.11 may be interpreted as a price index or cost for the composite of sites in a household's choice set for each water collection trip. These trip price indices represent a relative measure of household willingness to pay for the water collection sites in their choice set. We apply the price index in estimation of count models for water collection trip frequencies as outlined in Chapter 8.

7.5 Chapter Conclusion

This chapter has applied travel cost methods to data on site choices for domestic water collection in rural Zimbabwe. A challenge addressed in this study of water collection site choices is that the universal choice set of geographically located alternatives across all households is very large and cannot be accommodated by the econometric estimation software employed. Thus, in specifying discrete choice models, we test for potential errors due to specifying a generic choice set based on types of water sources instead of a universal choice set of geographically differentiated water sites. These errors may arise from misspecification of the choice sets of individual decision makers and from the inclusion of irrelevant choice alternatives. The test is conducted by comparing alternative site choice model estimation results, using a sub-sample of our trip log data to make the number of sites computationally manageable. In the alternative models, a universal choice set of geographic water sites is specified for all households in one version and in another version generic water choice sets based on general water source types, are specified for each household. The model estimation results show that the significance of explanatory variables and calculated means for the expected value of maximum utility (log-sum) for the two alternative model specifications are almost identical. We conclude that little or no information is lost in the estimated site choice models for the expanded data set by failing to specify universal choice sets accurately and by including irrelevant alternatives based on household reported choice sets.

In practice, for similar empirical studies, most researchers do not rely on individual or household specified choice sets (Louviere *et al*, 2000). Researchers usually assume that either all universal alternatives are available to all individuals in the sample or else they rely on their own subjective definition of individual choice sets. Therefore, we provide empirical results showing that households are able to accurately define the alternatives in their own water site choice sets

We find that the composition of water source types and their travel times in household choice sets is an important factor in site choices. We find that Village 3 RA households, located inland, are more likely to visit water collection sites with a higher travel times compared to households riparian to major rivers. As a result, RA households in riparian areas rely more on naturally occurring water sources such as stagnant pools and hand dug riverbed pools compared to boreholes and shallow wells for inland villages.

We analyze relationships between household choices and measures of water source property right attributes measuring relative exclusivity, allotment size (volume capacity limit) and restrictions. These relationships are found to be significant and consistent with expectations based on economic theory, thus contributing to the empirical literature in this area of research. The impact of property right constraints on the SSCF households and Village 3 RA households, relative to the combined RA sample, is to increase the maximum value of expected utility from all water sites, equivalent to increasing the willingness to pay for all sites in the choice set. In contrast, the impact of property right constraints on the combined RA sample site choices is to reduce the willingness to pay for all sites in the choice set. This result is attributed to a premium placed on the relatively exclusive and less restricted access to water sources enjoyed in the SSCF area. In the Village 3 RA, compared to the combined RA sample, the property right variables increase surplus measures as a reflection of relatively poor access to mostly communally owned water sources such as boreholes and shallow wells with a range of exclusivity or restriction characteristics. This is particularly the case for households in Village 3 RA households located inland and far away from major rivers.

In models estimated with water source types as opposed to property rights, households in all sub-samples are more likely to visit shallow wells than community boreholes for domestic water collection. This is similar to results from studies in Zimbabwe which show that state or donor funded community boreholes are not frequented by households who prefer traditional water sources such as family shallow wells (Zimconsult, 1998). Further, there was evidence of limited community involvement in maintaining boreholes so that many of these ended up non-functional (Zimconsult, 1998). This finding is attributed to the greater travel distances to community boreholes than to household owned wells and household preference for relatively exclusive water sources with the result that community boreholes are used as a back-up water source in the dry season or when there is low rainfall and drought. Our findings show that relatively exclusive water sources such as household owned shallow wells are preferred, particularly in the SSCF area. Where there are limited alternative water sources as in Village 3 RA, community boreholes are used more frequently. Thus, a glaring feature of the results is the apparent preference for relatively exclusive water sources such as the shallow well for domestic water uses by households in all sub-samples. These factors need to be considered seriously before one-size-fits-all implementation of community water supply projects if these are hoped to have a significant impact and to succeed in recovering costs.

An important implication of the significance of the differential composition of water source types and their property rights variables in household-specific choice sets and household demographic and trip attribute variables is that there is a great deal of heterogeneity in the water access and supply means across households. This suggests that some households would potentially be willing to pay much more for water supply improvements while others may not. For example, we conclude that the Village 3 RA households located inland are willing to pay the most to acquire water for essential domestic needs, relative to the riparian RA households and the SSCF area households, reflecting relative differences in access to domestic water resources.

As discussed earlier, the impact of household demographic and property rights variables on household behavior cannot be disentangled entirely. This is because household demographic variables are interacted with alternative specific variables and property rights variables are derived from characteristics of water source types. Although this situation poses challenges for analysis, we are still able to show modest differences in patterns of effects due to these sets of variables in household water collection site choices. For example, from the calculated expected economic surplus measures we see that the effect of explicitly accounting for property right attributes in explanatory variables on household choices is to result in consistently higher values for willingness to pay.

The household demographic and asset ownership variable coefficients also highlight interesting results. For example, there appears to be a gender dimension in domestic water collection site choices where good quality water sites are less likely to be chosen when male household members conduct water collection trips as compared to female household members. Further, technology applying draft power for water collection is found to be important in expanding potential site choices for all households to distant sites. Wealthier RA households as measured by numbers of scotchcarts owned are seen to choose sites with lower travel times reflecting relatively better access to closer water sources than the relatively poor.

With regards to welfare measures, the expected per trip economic surplus estimates are higher in model specifications (i.e. conditional logit models) that do not account for unobserved household heterogeneity (as done by the random parameters logit models). Thus, we validate the finding that failure to account for unobserved heterogeneity in site choice models over-inflates welfare estimates for our particular study site. A contribution of this study is in extending the result that failure to account for parameter heterogeneity inflates welfare measures to the limited literature on site choice models applied to the context of developing country households and natural resources.

At the local policy level, our results highlight important considerations for rural household water provision for similar types of households. One of these is the need to quantify differences across communities in level of access to a variety of water sources and sites. Another is that quality of water at water collection sites is an important factor in domestic water collection site choices. However, despite consistent concerns with water quality in site choice decisions, households are shown to be less likely to choose boreholes with good quality water because of the opportunity cost of travel time and a preference for relatively exclusive water sources such as family shallow wells. Further, the need to quantify the potential effects of household heterogeneity in wealth, technology, gender and household composition on water demand behavior is shown.

Chapter 8: Modeling Domestic Water Collection Trip Counts

This chapter extends the analysis of household domestic water collection site choices to model water collection trip counts for domestic uses. Models are estimated from the data on rural household water collection for the RA and SSCF sample households (described in Chapter 3 in Part I and in Chapter 7, Section 7.3). We outline the econometric models postulated for predicting domestic water collection trip counts. This is followed by descriptions of data and variables and presentation and discussion of estimation results of the models.

The postulated trip count models extend the estimation of expected economic surpluses per trip that were discussed in Section 7.4.3. The negative of calculated expected economic surplus (means presented in Table 7.11) are interpreted as a price index or cost for the composite of sites in a household's choice set for each water collection trip. These trip price indices represent a relative measure of household willingness to pay for the water collection sites in their choice set. We apply the price index in estimation of count models for water collection trip frequencies. A similar modeling approach was employed by Hausman, Leonard and McFadden (1995) in a study to assess losses in economic surplus due to reduced trip frequency to recreational sites that had experienced environmental damage.

Count models are postulated to predict the numbers of water collection trips in order to derive total expected economic surplus from all water collection trips made by a given household. This provides another dimension to the comparison of the relative welfare of households regarding the frequency of water collection trips, given household water resource choice sets for domestic water provision.

8.1 Econometric Model for Water Collection Trip Counts

The number of separate trips made to water collection sites by a household within a given time period is a non-negative integer random variable whose behavior can be analyzed by specifying a statistical model for count data. The count of trips as a dependent variable is truncated and censored. Econometric models defined in attempts to address these econometric issues in the empirical literature have included double-hurdle models. Double-hurdle models combine models that have discrete dependent variables, used to predict the probability of participation, with continuous dependent variable models which are applied to estimate quantity demanded of the good, conditional on participation (e.g. Heckman 1979; and Bockstael et al, 1990). Count data models were subsequently developed and applied specifically for non-negative integer valued dependent variables (Hellerstein and Mendelsohn, 1993). A number of researchers have applied popular count data models such as the Poisson model and the Negative Binomial (NegBin) to recreational demand in developed countries (e.g. Creel and Loomis, 1990; Yen and Adamowicz, 1994; Hausman, Leonard and McFadden, 1995; Englin and Shonkwiler, 1995).

8.1.1 Poisson and negative binomial model specification

The underlying distribution of the Poisson model generates equivalent mean and variance parameters, thus violating the important assumption of homoscedasticity in econometric modeling. One result, sometimes observed in the application of count data models, is inadequate treatment of over-dispersion, with typical estimation results over-predicting the true frequency of small values and under-predicting the true frequency of large counts (Habb and McConnell, 1996; Creel and Loomis, 1992; and Hausman et al., 1995). Where there is over-dispersion, the observed variance assumes values larger than the mean. A variance that is larger than the mean implies unobserved heterogeneity in the population parameters. A major cause of over-dispersion is the fast decay process of the dependent variable (Hausman *et al*, 1984). For example, recreation trip makers are observed to make one or two trips, with few of them making more than two trips, resulting in a long tail for trip count. The NegBin model was developed as an alternative to the Poisson model by Hausman *et al* (1984) to accommodate this shortcoming. Another shortcoming of count models includes the problem of under-predicting the frequency of zeros when data has many zero responses. This has been accommodated by a variation of the Poisson model known as the Zero Inflated Poisson (ZIP) model (Hausman *et al,* 1984).

The water collection trip count variable employed in this analysis does not have any zero observations. Thus, the Poisson and NegBin models are considered appropriate statistical models and are both employed in the analysis of predicted trip frequencies.

Following Cameron and Trivedi (1998), the econometric model assumes that Y_i the count of separate water collection trips made by the ith household, follows a Poisson distribution given by:

$$P(Y_i = k) = \frac{e^{-\lambda}\lambda^k}{k!}$$

$$\lambda_i = \exp(\beta X_i) \qquad (8.1)$$

where λ is the Poisson parameter to be estimated, representing mean and variance of the count, and $k = 0,1,2,........n$. In specifying the regression model to be tested, the parameter λ is allowed to vary according to a defined function of a matrix of explanatory variables X_i and β, a vector of parameters to be estimated. The Poisson regression allows inferences to be made on the probability of trip occurrence.

The NegBin model allows the mean and variance of the count variable to be distinct. It is an alternative to the biased and inconsistent estimates produced by the Poisson model when data exhibits over-dispersion due to unobserved measurement errors and/or omissions that generate unobserved heterogeneity (Grogger and Carson, 1991). The NegBin model assumes that the dependent variable has a multiplicative error term that is uncorrelated with the explanatory variables and follows a Gamma distribution Γ as follows:

$$P(Y_i = k|\theta_i) = \frac{\Gamma(k+\lambda_i)}{\Gamma(\lambda_i)\Gamma(k+1)}\left(\frac{\theta_i}{1+\theta_i}\right)^k\left(\frac{1}{1+\theta_i}\right)^{\lambda_i} \quad (8.2)$$

where λ_i is a log-liner function of covariates as follows: $\ln\lambda_i = \exp(\beta X_i)$. From Equation (8.2) the mean and variance of Y_i are given by:

$$E(Y_i) = \theta_i\lambda_i$$

$$Var(Y_i) = (1+\theta_i)\theta_i\lambda_i \quad (8.3)$$

As $\lambda \to \infty$ Equation (8.2) becomes the Poisson distribution function. The term $(1+\theta_i)\theta_i$ may be interpreted as the dispersion parameter which scales the variance. Test of over-dispersion or under-dispersion test the null hypothesis that the dispersion parameter is equal to one and if this hypothesis is not rejected, the null model with equal mean and variance for Y_i prevails.

8.1.2 Overall model goodness of fit

Measures of goodness of fit proposed for Poisson and NegBin models include the deviance value and the log-likelihood ratio (Agresti, 1990). The deviance value, defined as $2[LL(\beta)-LL(0)]$, follows a chi-square distribution, where $LL(0)$ represents the log likelihood function generated by count model estimation with a constant term alone and $LL(\beta)$ represents the log likelihood function of estimation with explanatory variables and the vector of parameters β. The chi-square test of the deviance value tests the null hypothesis that the estimated model has equivalent explanatory power to the model with the constant term alone (Agresti, 1990). The likelihood ratio is analogous to the R-square test in linear regression models and indicates the proportion of explanatory power of explanatory variables over the constant term in predicting the count. The likelihood ratio is defined as

$\rho^2 = \left[1 - {LL(\beta)}/{LL(0)}\right]$ and assumes a value between zero and one with higher values indicating higher explanatory power (Agresti, 1990).

8.1.3 Relative significance of explanatory variables on predicted trip count

The partial derivative of the predicted count with respect to explanatory variables indicates the changes in variables that may potentially affect observed counts. From Equation (8.1) the partial derivative from a Poisson count model is defined as:

$$\frac{\delta\lambda}{\delta x} = \frac{\delta \exp(x\beta)\delta x\beta}{\delta\beta\delta x} = \exp(x\beta)\beta = \lambda\beta \tag{8.4}$$

where λ is the predicted trip count and x is a vector of explanatory variables. However, for NegBin and random effects count models, the value of the marginal effect is nonlinear and depends on both the coefficient of x and the expected value $E(y)$ (Shankar *et al*, 1995). Thus, to measure the true relative effect of explanatory variables on counts, elasticity parameters are proposed by Shankar *et al* (1995) as follows:

$$E(y) = \frac{\delta\lambda}{\delta x} * \frac{x}{\lambda} \tag{8.5}$$

The econometric models applied in this analysis are those specified by Equations (8.1) and (8.3). The applied empirical model specifications and the variables employed in the analysis are described in more detail in the next sections.

8.2 Variables, A Priori Expectations and an Empirical Model

This section discusses variables postulated to influence water collection trip counts for domestic uses, *a priori* expectations of the effect of explanatory variables on trip counts and applied empirical models.

In Poisson and NegBin count models, the mean count is typically parameterized as a semi-log function of socioeconomic and other variables. The dependent variable in this study is the number of separate water collection trips made by the household in the three days prior to the survey visit in each month. The variables in this analysis are from the dataset described in Chapter 3 and in Section 7.3. The postulated explanatory variables are described in Table 8.1.

We assume that a household attempts to meet its volumetric demand for water by making a number of trips to water collection sites and collecting a specified volume of water on each trip. As our first explanatory variable in Table 8.1, *TripPrice* is based on per trip expected economic surplus for the composite of water sites in a household's choice set, calculated from travel cost models of water collection site choice (described in Table 7.11). We expect an inverse relationship between the negative of the expected economic surplus, specified as *TripPrice* and trip count. We also expect that demand for water for basic domestic needs may be price inelastic at lower quantities, whilst demand for water for less essential needs may be more price elastic.

We expect that if the *VolumePC* of water collected per household member per trip is high, then fewer water collection trips will be taken. Per trip water volumes may also be influenced by capacity limits imposed by site-specific rules and technical limits due to the mode of transport. Related to this, the traditional mode of transporting water for domestic use is to walk and carry water containers manually.

Table 8.1: Description and *A Priori* Expected Effect of Variables in Trip Count Models

Variable Label	Description	Expected Sign
	Trip attributes	
TripPrice [a]	*TripPrice* is the negative of the value of the calculated per trip expected economic surplus, in terms of labor time, from site choice models in Chapter 7. Means are presented in Table 7.11.	+
VolumePC [a]	Mean volume per capita of water collected per trip in liters (per household member).	-
DraftPowerProp [a]	The proportion of the total number of trips that used *DraftPower*.	-
GendeProp [a]	The proportion of the total number of trips conducted by a female household member.	+/-
JointProductionProp [a]	The proportion of the total number of trips made with joint production activities such as gathering fuelwood or wild foods, work in gardens, field crops, livestock, bricks, or bathing.	+/-
	Season Dummy Variables	
Oct-DecProp [a] *Jan-MaPropr* [a] *Apr-JunProp* [a]	Variables indicating the proportion of the total number of trips conducted in quarterly seasons in the year, with 4 as follows: for the months October to December 2002, *Oct-Dec*, January to March 2003, *Jan-Mar*, April to June 2003, *Apr-Jun*. July to September ,2003 is omitted to avoid singularity in estimation.	+ +/- +/-
	Household demographic variables	
Riparian Village	Dummy variable = 1 if the RA household is located adjacent to major rivers (riparian); = 0 otherwise.	-
HouseholdSize	Number of household members	+/-
Children	Ratio of children to adults in the household	+/-
ScotchCarts	Number of scotch carts and wheelbarrows owned by the household	-
ThatchedRoof	Dummy variable = 1 if the buildings at homestead are made with thatched roof; = 0 otherwise.	+

Notes: [a] =Denotes time varying variables that change in value for each survey observation (monthly).

Where a greater proportion of trips are conducted using *DraftPoweProp*, larger volumes may be collected per trip and thus fewer trips would need to be made. This implies a negative expected coefficient for the variable *DraftPowerProp*. We expect that female household members bear the bulk of responsibility for water collection for domestic uses. However, it is unclear whether more domestic water collection trips would be conducted in total if a greater proportion of trips on average were conducted by women. Therefore, there is no *a priori* expectation for the variable indicating the proportion of trips conducted by female household members.

Households may pursue *JointProductioProp* activities such as collecting wild foods and products, bathing, laundry, gardening on domestic water collection trips. Participation in joint production activities for a large proportion of trips may affect the number of trips that households make for domestic water collection, but the direction of this influence is unclear. However, it could be observed that more trips may be needed to collect adequate water to meet household needs if a greater proportion of trips are conducted with a joint production activity as this may reduce the volume capacity of water collection per trip.

Seasonal weather patterns are expected to be a potentially important influence on the number of trips made to collect water for domestic uses. Collecting rainfall for use in a given month is expected to reduce the number of trips a household needs to make to collect water. Thus, we expect more water collection trips to be conducted in the dry late season months *Oct-DecProp* implying a positive coefficient for the variables compared to the omitted variable for early dry season months *Jul-SeptProp*. The coefficients for the other season variables *Jan-Mar* and *Apr-Jun* may be positive or negative relative to *Jul-SeptProp*.

Location of households near the major rivers may reduce the number of water collection trips a household needs to make. This arises because volumes of water that can be collected may be higher where shorter distances to walk to water sources lowers the burden for each task. In addition major rivers are water sources without restrictions on water quantity collected. Thus, we expect the variable *RiparianVillage*, indicating household location adjacent to the major near rivers to have a negative effect on water collection trip count.

Households with more members are expected to make more water collection trips, implying a positive coefficient for *HouseholdSize*. Even so, per capita water use may be lower in large households because of economies of use in cooking and for other domestic water uses. Thus the coefficient for *HouseholdSize* may either have a positive or negative effect on trip counts. Household composition variable *Children* reflecting the ratio of children to adults in any household may also affect trip count. With proportionately more children than adults in a household, we expect fewer trips to be made to water collection sites for two reasons. First, basic water needs are lower for children relative to adults (Strand & Walker, 2005). Second, time allocations may differ in such households because of child rearing demands such that the net effect of ratio of children in the household on trip count may be either positive or negative.

Proxies for wealth characteristics of households include *ScotchCarts* for ownership of scotch carts and wheelbarrows and *ThatchedRoof* for type of roofing material on houses. We would expect that relatively poor households, those with thatched roofs and fewer scotch carts and wheelbarrows, may tend to make more water collection trips. Wealthier households could make fewer trips because of higher volumes collected per trip if these were conducted using scotchcarts as the primary means of transporting water when draft power is used. In addition, corrugated metal roofing material as a technology for rainwater collection is also limited to wealthier households thus potentially reducing the number of water collection trips they may need to make. Therefore we expect a negative sign on the coefficient for variable *ScotchCarts* and a positive sign on the coefficient for variable *ThatchedRoof.*

Two trip count models are estimated; one for all RA household data and another for all SSCF household data. The only difference in the empirical specification for the two models is that the variable *RiparianVillage* is not included in the model for SSCF households. This is because there are no villages in the SSCF area. The empirical model specification for βX_i in Equation (8.1) is as follows:

$$
\begin{aligned}
\beta X_{it} = {} & \beta_1 Trip\Pr ice_t + \beta_2 VolumePC_i + \beta_3 ThatchedRoof_i \\
& + \beta_4 S\cot chCarts_i + \beta_5 HouseholdSize_i + \beta_6 Children_i + \beta_7 Gender\Pr op_i \\
& + \beta_8 DraftPower\Pr op_i + \beta_9 Jo\operatorname{int}\Pr oduction\Pr op_i + \beta_{10} RiparianVilage \\
& + \beta_{11} Oct - Dec\Pr op_i + \beta_{12} Jan - Mar\Pr op_i + \beta_{13} Apr - Jun\Pr op_i + \varepsilon_i
\end{aligned}
\qquad (8.6)
$$

Descriptive statistics for the postulated explanatory variables are presented in Table 8.2.

Table 8.2: Summary Statistics for Variables in Trip Count Models

Variable	RA Households N=1972 Trip Counts				SSCF Households N=685 Trip Counts			
	Mean	S.D.	Min	Max	Mean	S.D.	Min	Max
Trip Count[a]	3.67	1.782	1	16	4.704	1.875	1	12
TripPrice[c]	37.59	14.16	-18.09[21]	70.47	48.510	13.938	0	81.83
VolumePC	7.613	7.484	0	70	9.907	16.619	0	250
DraftPowePropr	0.266	0.388	0	1	0.554	0.442	0	1
GendePropr	0.895	0.237	0	1	0.853	0.242	0.10	1
JointProductionProp	0.210	0.300	0	1	0.065	0.211	0	1
Oct-DecProp	0.255	0.436	0	1	0.258	0.438	0	1
Jan-MarProp	0.241	0.428	0	1	0.227	0.419	0	1
Apr-JuPropn	0.254	0.436	0	1	0.270	0.444	0	1
Riparian Village	0.281	0.449	0	1	——	——	——	——
HouseholdSize	6.346	3.998	1	25	5.049	4.060	1	18
Children	1.416	1.186	0	7.333	0.570	0.797	0	4
ScotchCarts	1.083	1.016	0	5	2.012	1.194	0	5
ThatchedRoof	0.524	0.499	0	1	0.274	0.446	0	1

Notes: [a] Trip Count is the dependent variable in count models
[b] Trip Price estimates are based on expected economic surplus measures presented in Table 7.11

Table 8.2 shows that SSCF households on average have a higher *TripPrice*, conduct more water collection trips, collect larger volumes of water per household member and use draft power to transport water more frequently. There are more household

[21] Intuitively, we would expect all economic surplus measures (from which the variable *TripPrice* is derived) with means presented in Table 7.11 to be strictly positive. This is because the economic surplus measures as defined represent the positive value to a household of having its choice set of water collection sites. Negative values of economic surplus would imply that a household is better off not having water sources in its choice set. However, the descriptive statistics for variable *TripPrice* show a range, with some negative values of expected economic surplus. This result is shown to be technically possible based on the mathematical computation of the economic surplus measures. In the data, the negative surplus measures occur for a few RA households in village 3. These households are found to make fewer and longer water collection trips, taking between 79 and 120 minutes on average compared to the whole RA sample average of about 14 minutes. The village 3 RA households also have fewer water sources in their choice set and are located furthest from major rivers. These results suggest that the water collection site choices of Village 3 RA households might be analyzed separately from the whole RA sample in case their utility function may have different parameters, another area for future work.

members and greater proportions of children in RA households. Wealth levels, shown by more *ScotchCarts* owned and fewer *ThatchedRoofs*, are higher for SSCF households.

8.3 Trip Count Model Estimation Results

Econometric models are estimated using LIMDEP 8.0 (Greene, 2002). A trip count model is estimated for all RA households (model A) and all SSCF households (model B). The estimated count models assume a left truncated dependent variable at a value of 'one' since this was the observed minimum number of water collection trips conducted per household. Poisson models and Negative binomial (NegBin) models were estimated to test for dispersion in trip count data. In all models, the null hypothesis of Poisson count is not rejected, therefore Poisson model results are reported.

Model estimation results are presented in Table 8.3 and discussed in the sections that follow. Based on deviance value and log-likelihood ratio as goodness of fit measures, all models have good overall fit. Chi-square tests for all models reject the null hypothesis that the estimated models have explanatory power equivalent to the model with a constant term. The explanatory power of variables in the estimated models is moderate, as shown by the values of log-likelihood ratios, 0.05 for SSCF households and 0.13 for RA households. The specific effect of explanatory variables is discussed further in the next sections.

The significant positive sign for the coefficient on *TripPrice* for RA households indicates that where per trip expected economic surplus valued in terms of household time is higher, more water collection trips are made. As a corollary, the negative of the trip economic price may be considered as the relative cost per trip of water collection, implying that with a higher per trip cost, fewer water collection trips would be made by the household.

Table 8.3: Poisson Trip Count Model Estimation Results for RA and SSCF Households

Explanatory Variable	Model A RA Households		Model B SSCF Households	
	Coefficient	Std. Error	Coefficient	Std. Error
Constant	1.060***	0.084	1.920***	0.132
TripPrice[c]	1.561***	0.133	-0.108	0.191
VolumePC	-0.263***	0.032	-0.042**	0.019
DraftPowePropr	-0.421***	0.051	-0.158***	0.047
GenderProp	-0.344***	0.059	-0.001	0.062
JointProductionProp	-0.108*	0.056	-0.019	0.098
Oct-DecProp	0.240***	0.042	-0.318***	0.061
Jan-MarProp	0.180***	0.043	-0.376***	0.069
Apr-JunProp	0.021	0.043	-0.237***	0.053
RiparianVillage	-0.135***	0.034	--------	--------
HouseholdSize	0.009**	0.004	0.008	0.005
Children	-0.015	0.016	0.012	0.029
ScotchCarts	0.032**	0.014	-0.022	0.018
ThatchedRoof	-0.024	0.030	-0.024	0.048
Log Likelihood *(B)*	-29998.548		-1233.646	
Log Likelihood *(0)*	-3464.938		-1298.259	
Deviance Value - Chi-Square	932.779		129.225	
Log-Likelihood Ratio	0.135		0.050	
N-Trip Counts	1972		685	
N-Households	195		65	
Predicted trip count λ	3.309		4.603	

Notes: *,**,* indicates significance at the 1%, 5% and 10% significance level respectively**

The coefficient for *TripPrice* in the SSCF household model is insignificant, suggesting that per trip costs, valued in terms of household time, are not an important consideration in SSCF household decisions concerning the numbers of domestic water collection trips. This may be because the trip price index is derived from site choice models estimated in Chapter 7 whose results suggested that SSCF households have relatively better and more homogenous access to water sources. This was in contrast to RA households who were observed to have much more heterogeneity in access to water resources. As expected, a higher *VolumePC* of water collected on each trip reduces the number of water collection trips a household needs to make to meet its water requirements for domestic uses for both RA and SSCF households.

The significant negative coefficient for the variable *DraftPowerProp* shows that where a higher proportion of trips use mechanical power to transport water, either by RA and SSCF households, fewer trips are made because larger volumes of water can be collected. For RA households, significant coefficients for water collection trip variables showing the proportion of trips conducted by a female household member (*GenderProp*) and trips with joint production activities (*JointProductionProp*) show negative relationships with trip counts. Thus, although we had no *a priori* expectation, we find that in households where female members make most water collection trips, fewer trips are made in total. This may reflect relative efficiency at performing the water collection task by women who are responsible the bulk of domestic water collection and use in households. We also find fewer trips are likely to be made when a higher proportion of trips include joint production activities. This result may reflect the feature that the bulk (79%) of domestic water collection trips tend to be conducted for the sole purpose of acquiring water for domestic uses without joint production activities.

The seasonal effects of quarterly survey periods on predicted trip count is that relative to the period *July-SeptProp* (the omitted variable category for late dry season months). Relative to this period, more water collection trips were likely to be made in *Jan-MarProp* and *Apr-JunProp* for RA households. For the RA households, the quarter between October and December was probably the driest over the survey period. Thus, we would expect more domestic water collection trips to be made during this time. Relative to the quarter *July-SeptProp,* fewer water collection trips were made on average in all other quarters. The finding of increased number of domestic water collection trips between July and September for SSCF households may arise from the dry season beginning earlier at this site (being located about 100km away from RA sites) where it was also observed that the wet season began months earlier.

For the RA households, *RiparianVillage* has a negative and significant coefficient on trip count, as expected. Thus, households located adjacent to major rivers make on average fewer domestic water collection trips as expected. The demographic variable *HouseholdSize* and the wealth variable *ScotchCarts* have a positive and significant effect on trip count for RA households. This shows greater water demands in larger households as expected. Furthermore, wealthy households in RA areas are found to have larger water demands as they are shown to make more trips. The variables *Children* and *ThatchedRoof* were insignificant in all RA and SSCF models potentially due to insufficient variation. A notable difference in the coefficients on explanatory variables for domestic water trip counts by SSCF households compared to RA households is that all household wealth and demographic composition variables are insignificant for the SSCF. Thus it appears that wealth and demographic heterogeneity variables are relatively less important in influencing domestic water collection trips for the SSCF households. This may be related to the relative homogeneity in wealth and water resource access observed amongst the SSCF households.

8.4 Trip Count Elasticities, Point & Effective Demand for Water

We now turn to extrapolation of predicted trip counts from the models reported in Table 8.3 to an investigation of the relative impact on the predicted water collection trip count from changes in explanatory variables through estimates of marginal effects and elasticities. We also extrapolate trip counts and expected economic surplus from water collection site choices (with means in Table 7.11) point demand and effective demand for domestic water by to rural households.

8.4.1 Water collection trip count elasticities

It is instructive to compare predicted water collection trip counts between RA and SSCF households and to analyze the impact of explanatory variables. Exploration of these features of household water collection trips allows inferences to be made about the elasticity of water demand. As reviewed from the literature in Section 6.3.3, water for basic domestic uses is considered to be a necessity in economic terms. This implies an economic relationship between volume demand and price that is inelastic (i.e. having an absolute value of less than one). The elasticity of water collection trip count and water demand with respect to explanatory variables other than price is an empirical question largely because the author was unaware of any similar studies analyzing domestic water collection trip counts and their elasticities with respect to various explanatory variables.

In Table 8.4 we present the statistically significant marginal effects and elasticity estimates of explanatory variables for RA and SSCF household trip count models.

Table 8.4: Significant Marginal Effects and Elasticity Estimates at Means of Explanatory Variables in Trip Count Models for RA (Model A) and SSCF (Model B) Households

	RA - Model A		**SSCF - Model B**	
VARIABLE	Marginal Effect	Elasticity	Marginal Effect	Elasticity
TripPrice	3.962	0.450	-------	-------
VolumePC	-0.667	-0.153	-0.169	-0.036
DraftPowerProp	-1.067	-0.086	-0.626	-0.075
GendePropr	-0.872	-0.236	------	------
JointProductionProp	-0.273	-0.017	-------	-------
Oct-DecProp	0.608	0.047	-1.264	-0.071
Jan-MarProp	0.457	0.033	-1.495	-0.074
Apr-JunProp	-------	-------	-0.943	-0.055
RiparianVillage[a]	-0.034	------	------	-------
HouseholdSize	0.023	0.044	------	-------
ScotchCarts	0.080	0.026	------	-------

Notes: [a] For the dummy variable *Riparian Village* the marginal effect only is reported. The elasticity of the dummy variable as defined by Equation (8.5) collapses to its coefficient for all households for whom the variable assumes a value of one. The elasticity is zero for households for whom the dummy variable assumes a value of zero.

From Table 8.4 we see that all trip count elasticity estimates for explanatory variables with significant marginal effects have values well below one (in terms of absolute value), implying that trip counts are inelastic with respect to all variables. This feature, which is likely due to domestic water being a necessity, makes it challenging to get meaningful economic results from domestic water demand estimation, for example in terms of responsiveness of demand to prices.

The range of (absolute value) elasticity estimates for predicted trip counts is very small, from 0.036 to 0.075 for SSCF households. The equivalent range of absolute elasticity estimates is from 0.003 to 0.45 for RA households, reflecting greater relative elasticity of domestic water collection trip counts for RA households overall. This finding is likely due to the better overall access and greater homogeneity in level of access to water resources amongst SSCF households as compared to RA households for whom we observed greater heterogeneity of water access.

From Table 8.4 we find that only two variables, *DraftPowerProp* and *VolumePC*, have significant elasticity estimates for SSCF household trip counts apart from the season dummy variables. This may be a direct reflection of insignificant household wealth and demographic variables in the trip count analysis as shown in Table 8.3 due to relative homogeneity and the fact that domestic water is a necessity. The variable *TripPrice* has by far the largest effect, in elasticity terms, on trip counts for RA households. Trip counts are increased by a factor of 0.45 per unit of increase in the variable *TripPrice* (implying a decrease in per trip cost). Thus, RA households proportionately increase the number of domestic water collection trips made when there is a unit reduction in per trip cost valued in terms of labor time. The *Trip Price* variable is insignificant in its effect on the SSCF household water collection trip counts and hence has no elasticity effect for SSCF household.

The elasticity estimate for the variable *VolumePC* (measuring volume per capita) for RA households is more than four times that for SSCF households. This suggests relatively fewer institutional and physical restrictions on water collection amongst the sampled SSCF households compared to the RA households. That is, SSCF households may generally collect as much water as they want on each trip whereas, for RA households when presented the opportunity (i.e. constraints reduced) to collect more water on a given trip, they respond by collecting significantly more water and reducing trip frequency. The slightly smaller elasticity estimate for *DraftPowerProp* on trip counts for SSCF households implies a smaller percentage decrease in trip counts with a unit increase in the percentage use of draft power. This again suggests that SSCF households generally use draft power to a relatively homogenous extent over water collection trips and across households and supports the observation that they collect larger volumes of water per trip average compared to RA households (see Tables 8.2 and 8.5).

The variable *GenderProp* has the second largest elasticity effect (0.236) on domestic water collection trip counts for RA households. Thus, a unit increase in the proportion of domestic water collection trips conducted by a female household member results in an increase in trip counts by a factor of 0.236. A unit change in the proportion of trips with participation in joint production activities (measured by *JointProductionProp*) reduces trip counts by a factor of 0.017 for RA households. For the SSCF households, unit changes in season variables have larger elasticity effects (between 0.055 and 0.074) in reducing trip counts in the early dry and wet season months of the year. This compares to elasticity estimates between 0.033 and 0.047 showing proportionate change in trip counts for RA households for a unit change in the proportion of trips conducted in the driest and wettest months of the year. In general for both RA and SSCF households, trip counts are significantly positively elastic in both the driest and the wettest months of the year. Proportionate increases in trip counts of 0.044 and 0.026 are observed per unit increase in the variables *HouseholdSize* and *Scotchcarts* respectively. This result is much smaller than results for elasticity to household size found for domestic water demand in Central American cities by Strand and Walker (2005) who show an additional family member increasing water demand by a factor of 5% to 10% across households of different sizes.

8.4.2 Calculated point demand for domestic water

We extend the estimated predicted water collection trip counts and observed volumes of water collected per trip by households to assess household point demand for water. We assume that a household attempts to meet its volumetric demand for water by making a number of trips to water collection sites and collecting a specified volume of water on each trip. The total volume of water demanded (in litres) in a year may therefore calculated as the product of the number of water collection trips and the mean volume of water collected on each trip.

Table 8.5 presents calculated means of yearly household and per capita point water demand based on means of variables and predicted trip counts for RA and SSCF sample households. The mean household point water demand volumes in Table 8.5 show that SSCF household members consume almost double the volume of water per capita per day (*VolumePC/day*) on average compared to RA households (row D. in Table 8.5). This result is consistent with findings that the sampled SSCF households tend to have greater access to water resources than do the RA households, and is also consistent with the feature that SSCF households are located in a relatively wetter region of the semi-arid study sites. The water demand for domestic uses ranging between 8.4 and 15.2 litres per capita per day are well below the WHO (2002) recommended levels of 50 litres of water use per capita per day.

Table 8.5: Calculated Mean Household Point Demand for Domestic Water

Variable	RA Model A	SSCF Model B
A. *HouseholdSize* (means from Table 8.2)	7.051	5.049
B. Trips per day: Predicted Mean Trip Count λ (from Table 8.3) divided by 3 days [a]	1.103	1.534
C. *VolumePC* per trip (from Table 8.2) - in litres	7.613	9.907
D. *VolumePC*/day (C. multiplied by B.) - in litres	8.397	15.197
E. *VolumePC*/Year (D. multiplied by 365 days in a year) - in litres	3,065	5,547
F. Daily Volume/Household (D. multiplied by A.) - in litres	59.207	76.730
G. Annual Volume/Household (E. multiplied A.) - in litres	21,610	28,006

Notes: a= The trip count variable records all water collection trips over three days. We therefore divide the predicted trip count by 3 days to get the number of trips made per day.

It has however, been observed that rural households in Africa tend, on average, to use much lower volumes of water for essential needs (van Der Zaag, 1993; Zimconsult, 1998; Acharya & Barbier, 2002). For example, in an assessment of the water resources needs for households in communal areas in rural Zimbabwe it is shown that the amount of water collected from community boreholes is 8 to 10 litres per capita per day (Zimconsult, 1998). This figure is similar to the range of water volumes used by the sampled RA households but much lower than that for SSCF households, as shown in Table 8.5. It is also worth noting that Zimconsult (1998) points out that the design criteria for borehole construction in these communities projects planned water consumption figures of 30 litres per capita per day, amounts that would seem to lead to more capacity than needed. In another study in a wetland area of Nigeria, Acharya & Barbier (2002) find that average domestic water demands for households are 24 litres per capita per day. These figures are higher than those found in our study although they are still lower than the WHO recommendation of 50litres/capita per day for water consumption.

8.4.3 Imputed effective demand for domestic water

We impute effective demand for water access improvements based on household revealed preferences in water collection site choices behavior as modeled in Chapter 7. We assume effective demand to refer to the willingness, as well as the ability, to purchase or obtain a product or good through some means of exchange such as money or labor. As discussed in Section 7.4.3, the expected per trip economic surplus from water collection site choices represents a relative measure of household willingness to pay for the water sites in their choice set. This is essentially the willingness to pay or a welfare measure for the level of water access that households currently have. The effective water demand is valued in terms of household labor time allocated to domestic water collection. This calculation is based on expected economic surplus measures form site choice models in Chapter 7 and predicted trip counts from models in Chapter 8.

Table 8.6 shows imputed values for effective water demand in terms of household labor time in hours per volumetric unit of water collected for domestic uses by RA and SSCF households. The mean value of imputed effective demand for water for the combined SSCF household model (Model 12) is higher than for the RA household sample (Model 9). This arises from the combination of higher expected economic surplus for water collection site choices, higher trip counts and higher water volumes collected per trip for SSCF households. We also impute effective water demand measures for sub-samples of RA households located in villages that are riparian to major rivers (Riparian RA Villages in Table 8.6) and for households located inland from major rivers (Inland RA Villages in Table 8.6).

Table 8.6: Imputed Effective Demand in Terms of Expected Economic Surplus Valued in Terms of Labor Time Allocated to Domestic Water Collection Per Unit Volume of Water

Variable	RA Model 9 In Table 7.11	SSCF Model 12 In Table 7.11	Riparian RA Villages	Inland RA Villages
H. Expected per trip economic surplus[a]	46.396	56.525	38.381	92.292
I. Expected Economic Surplus/Day (H. multiplied by B. in Table 8.5)	51.175	86.709	42.334	101.798
J. Expected Economic Surplus/litre (I. divided by F. in Table 8.5)	0.864	1.130	0.715	1.719
K. Effective Demand -Hours/m^3 (J. divided by 60 minutes/hour and multiplied by 1000 litres/m^3)	14.4hrs/m^3	18.8hrs/m^3	11.9hrs/m^3	28.6hrs/m^3

Notes: The expected per trip economic surplus is based on water collection site choice models estimated in Chapter 7. Means are reported in Table 7.11. The site choice model means reported in Table 8.6 are for models with water source type variables only for illustration. An equivalent range of values for effective demand can be imputed for site choice models with water source property right variables.

These two sub-samples of RA households are observed to have significant differences in level of access to reliable water resources with RA households located inland, spatially further from major rivers having the poorest level of access to water resources. Table 8.6 shows that RA households in inland villages have much higher values of effective demand for water for domestic uses (almost 2.5 times greater than that of RA households in riparian villages).

The results in table 8.6 provide insights into the ability for households to invest in improved water supply. That is, these households could be willing and able to invest between approximately 12 and 29 hours to secure one cubic metre of water. However, many investments in water resources require upfront costs with benefits accruing over time. A critical determinant of willingness to commit to the investment is the household-specific rate of time preference in consumption of household produced and purchased commodities. The household rate of time preference shows how future benefits and costs based on comparing utility at different points in time are discounted (Binger and Hoffman, 1998). It is generally believed that poverty increases the marginal individual rate of time preference, resulting in shorter time horizons in consumption (Adhikari, 2005). Empirically, households in Zimbabwe have been shown to exhibit high rates of time preference, preferring current consumption over future consumption (Kundhlande 2002). Therefore, in practice, a household may not want to invest 300 hours (hypothetically - of labor time taken away from generating other consumption goods) today in construction of improved water supply infrastructure in order to save one hour every day in collecting 50 litres of water over the next ten years (time that would have been spent collecting domestic water without improved water supply).

Robinson (2003) advocates a change in the water supply paradigm for poverty reduction in Zimbabwe, away from government water programs based on community boreholes or deep wells (for domestic water uses) and from building capital intensive formal irrigation schemes (for productive water uses in commercialized small-scale agriculture). The alternative proposed is to provide household water for both domestic use and garden production through low-cost family-owned upgraded family wells[22]. Robinson (2003) estimates the capital cost of an upgraded family well with a washer pump and rope and capacity to provide all domestic water needs, as well as to water a 0.03 hectare garden, would be around US$100 per family. These costs for a well include labor for digging and lining, payment of an artisan builder, provision of sand and bricks and the external inputs of 3 bags of cement, a windlass and a tin lid (Robinson, 2003).

Information on the total labor requirements (in hours) for constructing an upgraded family well would enable us to evaluate relative costs and benefits and whether this would be a viable water supply alternative for the sampled households. This would be achieved by comparing the total labor requirements (costs) for well construction to

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[22] It is unclear what the hydrological impact of implementing upgraded family wells for numerous rural area households would be particularly in micro-catchment areas and in areas with a high/low water table. It is also unclear to what extent the wells would be able to meet /basic domestic water needs throughout the year during both dry and wet seasons for households located in semi-arid or arid regions.

effective demand (benefit) in hours of labor per cubic metre of water supplied (calculated in Table 8.6) in cost benefit analysis with an appropriate wage rate and discount rate to reflect rates of time preference. Determining an appropriate opportunity cost of labor for domestic water collection may be difficult because of the informal and generally thin rural labor markets. However, some hypothetical wage rates that can approximate rural household labor markets, for example the government stipulated minimum wage[23] for farm workers in Zimbabwe, may be applied to get some indication of monetary values. Otherwise, local values for wage rates may be elicited from survey respondents. This issue and the question of how subsidies for construction of family wells would be provided are beyond the scope of this thesis.

8.5 Chapter Conclusion

This chapter extended the analysis of household site choices for domestic water collection to evaluating the frequency of these trips to water collection sites in order to meet daily water demands. Predicted water collection trip counts are applied to calculate household point water demands and trip demand elasticities and to impute effective demand for domestic water, highlighting the relative welfare of households with differential access to domestic water resources.

We find that water collection trip frequency is decreased by higher trip costs in terms of labor time, higher water volumes collected per trip and use of draft power as a mode of transporting water per trip. For the relatively wealthier SSCF households, per trip labor time cost of water collection has no effect on trip frequency. These results confirm similar findings by Strand and Walker (2005) which show very small estimates of price elasticity of water demand for poorer households in Central

[23] The government stipulated minimum wage for farm workers was estimated to be about US$5.60 per month after adjustment for the current rate of inflation (ZWNEWS - December 11, 2005). The calculated hourly wage rate based on 22 working days per month and an 8 hour work day is US$0.03/hour.

American cities. (These authors also show that the price elasticity increases with increase in water transport costs). Season is a significant influence for all households with highest trip frequency recorded during the driest months of the year. As expected, increase in household size increases household water demand for RA households whilst household demographic variables have no impact on SSCF household water collection trip counts. We find that in addition to being wealthier and having better and relatively homogeneous access to water resources than RA households, the sampled SSCF households are located in a wetter region, make more frequent water collection trips and collect larger volumes of water on average.

Estimated water collection trip count elasticities for explanatory variables with significant marginal effects indicate that trip counts are inelastic with respect to all variables. This feature, which is likely due domestic water being a necessity makes it challenging to get meaningful economic results from domestic water demand estimation, for example in terms of responsiveness of demand to prices. However, we find that water collection trip counts for RA households reflect greater relative elasticity as compared to SSCF households again due to the relatively poorer overall access and greater heterogeneity of water access for RA households. This observation is particularly evident for the response of trip count to per trip labor costs in hours, the largest proportionate effect observed on trip count of 0.45 per unit change in per trip labor costs for RA households. This is followed by the next highest response of trip counts to volume of water collected per capita by a factor of 0.15 per unit change in volume for RA households relative a factor of 0.036 for SSCF households. Further, per trip costs and household demographic variables are found to be insignificant in influencing water collection trip count elasticity for SSCF households in contrast to RA households.

Based on imputed point demand for domestic water, all sampled households consume between 15% and 30% of per capita water volumes considered essential to ensure adequate nutrition and sanitation (WHO, 2002). This indicates that the rural households studied are conservative in their water use volumes and may be in a condition of relative water stress. The observed water use volumes are relatively low even in comparison to households in rural Nigeria that are shown to consume almost 50% of the WHO recommended water volumes per capita (Acharya & Barbier, 2002). It should also be noted that Zimbabwe government policy for designing water supply projects for rural communities projects per capita water consumption at 60% of WHO volumes (Government of Zimbabwe, 1995).

Projections of imputed effective demand for domestic water are conducted based on expected economic surplus from water collection site choices, predicted trip frequencies and average volumes collected per trip. These values for imputed effective demand for water are based on revealed preferences and are not hypothetical, as are those based on contingent valuation. Our calculations show that households are currently prepared to expend between 12hrs/m^3 and 29hrs/m^3 of labor time for domestic water provision. This labor time, valued at an appropriate wage, gives an indication of the volumetric water charges that these households might be prepared to pay for domestic water, in monetary terms. Assuming a wage rate of US$0.03/hour[24] the imputed effective demand for water for domestic uses may be between US$0.36/m^3 and US$0.87/m^3. The highest value for effective demand for domestic water uses is found for the sub-sample of households observed to have the poorest level of access to water resources. Thus, we find that rural households are heterogeneous in their current level of water access and their water demand patterns. Consequently, water supply interventions for different groups of households need to target the particular situation and needs of these groups in order to succeed.

At the local level, although the rural households studied do not currently pay for water, water use legislation [Water Act (1998)] includes provision for payment for water use permits and volumetric water charges for water uses beyond primary needs. Within this framework, the delineation of primary water uses is somewhat

[24] This wage rate is taken from the government stipulated hourly wage rate for agricultural workers in Zimbabwe in real terms in December, 2005.

obscure. For example, whether household income generation may be considered to be primary uses, or deemed to be commercial is unclear. Further, currently regulated upper limits for private water storage facilities for primary water use of water of 5 000 cubic meters per household in the Water Act (1998) are not a binding constraint. The current water use volumes for both domestic and productive water uses, including livestock, for the households studied in both resettlement and small scale commercial farm land tenure systems, are well below this upper limit. However, the extent to which these households may have to pay for water for all the mentioned uses in future is unclear at this point given the constantly changing macro-economic policy environment and its micro-economic impact on household behavior.

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Appendix I - 7 Models 1-8 Village 3 RA Site Choice Estimation Results

Site Choice Estimation Results with Universal Choice Set Specified

RA Village 3 Site Choice Estimation Results with Universal Choice Set Specified A) Water Source Type Variables

Model 1: Conditional Logit			Model 2: Random Parameters Logit		
Variable	Coefficient	Std. Error	Variable	Coefficient	Std. Error
			Random parameters in utility function		
Time	-0.029***	0.006	Time	-0.035	0.005***
			Non-random parameters in utility function		
Quality	3.618***	0.345	Quality	3.631***	0.355
Borehole	-0.031	0.083	Borehole	0.013	0.088
Stream	-0.286***	0.094	Stream	-0.254***	0.096
River	-1.571***	0.127	River	-1.524***	0.133
Riverbed Pool	-0.904***	0.112	Riverbed Pool	-0.844***	0.120
Stagnant Pool	-1.037***	0.146	Stagnant Pool	-1.025***	0.147
Household Size*T	0.004***	0.000	Household Size*T	0.005***	0.001
Draft Power*T	0.006**	0.003	Draft Power*T	0.008**	0.004
Scotch cart*T	-0.007***	0.001	Scotch cart*T	-0.009***	0.002
Wet Season*Q	-0.364**	0.174	Wet Season*Q	-0.395**	0.183
Early Dry Season*Q	0.643***	0.207	Early Dry Season*Q	0.609***	0.219
Children*Q	-0.499***	0.083	Children*Q	-0.480***	0.083
JWild Food*Q	-0.490**	0.250	JWild Food*Q	-0.592**	0.260
JProduction*Q	0.981**	0.409	JProduction*Q	1.046**	0.439
JBathe*Q	0.913**	0.355	JBathe*Q	0.824**	0.363
Gender-Female*Q	-0.412	0.303	Gender-Female*Q	-0.334	0.313
Gender-Male*Q	-1.069***	0.375	Gender-Male*Q	-1.054***	0.385
			Standard deviation of random parameters		
			Sd- Time	0.017***	0.005
Number of observations	2630		Number of observations	2630	
Log-Likelihood	-2376.703		Log-Likelihood	-2373.403	
Pseudo R^2	0.7949		Pseudo R^2	0.7947	

Notes: *,**,*** indicates significance at the 10%, 5% and 1% significance level respectively

RA Village 3 Site Choice Estimation Results with Universal Choice Set Specified B) Water Source Type Property Rights

Model 3: Conditional Logit			Model 4: Random Parameters Logit		
Variable	**Coefficient**	**Std. Error**	**Variable**	**Coefficient**	**Std. Error**
			Random parameters in utility function		
Time	-0.028***	0.003	Time	-0.042***	0.006
			Non-random parameters in utility function		
Quality	3.467***	0.347	Quality	3.508***	0.364
Volume	0.498***	0.122	Volume	0.516***	0.123
Restrictions	0.230***	0.032	Restrictions	0.240***	0.034
Exclusivity	0.136***	0.347	Exclusivity	0.122***	0.028
Household Size*T	0.003***	0.001	Household Size*T	0.005***	0.001
Draft Power*T	0.007**	0.003	Draft Power*T	0.011**	0.005
Scotch cart*T	-0.007***	0.001	Scotch cart*T	-0.116***	0.002
Wet Season*Q	-0.363**	0.173	Wet Season*Q	-0.421**	0.187
Early Dry Season*Q	0.636***	0.208	Early Dry Season*Q	0.579**	0.227
Children*Q	-0.477***	0.080	Children*Q	-0.448***	0.085
JWild Food*Q	-0.639**	0.251	JWild Food*Q	-0.780***	0.261
JProduction*Q	0.841**	0.400	JProduction*Q	0.939**	0.450
JBathe*Q	0.656*	0.354	JBathe*Q	0.512	0.364
Gender-Female*Q	-0.322	0.303	Gender-Female*Q	-0.202	0.318
Gender-Male*Q	-0.944**	0.373	Gender-Male*Q	-0.928**	0.389
			Standard deviation of random parameters		
			Sd- Time	0.027***	0.005
Number of observations	2630		Number of observations	2630	
Log-Likelihood	-2410.073		Log-Likelihood	-2399.483	
Pseudo R^2	0.7920		Pseudo R^2	0.7925	

Notes: *,**,*** indicates significance at the 10%, 5% and 1% significance level respectively

Site Choice Estimation Results with Household Generic Choice Set Specified

Model 5 (conditional Logit) - Water Source Type Variables

```
+------------------------------------------+
| Discrete choice (multinomial logit) model |
| Maximum Likelihood Estimates              |
| Model estimated: Oct 12, 2005 at 07:04:53PM. |
| Dependent variable          Choice    |
| Weighting variable          None      |
| Number of observations      2641      |
| Iterations completed        7         |
| Log likelihood function     -2521.011 |
| Log-L for Choice  model = -2521.01093 |
| R2=1-LogL/LogL* Log-L fncn R-sqrd RsqAdj |
| Constants only. Must be computed directly. |
|          Use NLOGIT ;...; RHS=ONE $ |
| Response data are given as ind. choice. |
| Number of obs.= 2641, skipped  0 bad obs. |
+------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]
WSTIMED	-.2935122285E-01	.35398448E-02	-8.292	.0000
BHCON	-.3072495661E-01	.78565751E-01	-.391	.6957
RIVER	-1.446870769	.12401289	-11.667	.0000
STREAM	-.2018005023	.94197626E-01	-2.142	.0322
MUFCON	-.6752018103	.10495694	-6.433	.0000
WWPCON	-.9918603788	.14643707	-6.773	.0000
QUALITY	3.609273559	.37000449	9.755	.0000
TIMEHHS	.3708756100E-02	.55372690E-03	6.698	.0000
TIMEMECH	.6178699718E-02	.30339157E-02	2.037	.0417
QUALWET	-.6342441215	.16190805	-3.917	.0001
QUALED	-.1300155665	.16522846	-.787	.4314
TIMESCO	-.7284019948E-02	.13159859E-02	-5.535	.0000
QUALKID	-.4618638456	.79888134E-01	-5.781	.0000
QUALJW	-.4972747558	.24724554	-2.011	.0443
QUALJPR	1.047232126	.40909520	2.560	.0105
QUALJBT	.7828031762	.35023039	2.235	.0254
QUALTFEM	-.1356560929	.30551662	-.444	.6570
QUALTMAL	-.7498518541	.37398290	-2.005	.0450

(Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

Model 6 (Random Parameters Logit) - Water Source Type Variables

```
+------------------------------------------+
| Random Parameters Logit Model            |
| Maximum Likelihood Estimates             |
| Model estimated: Oct 12, 2005 at 07:18:00PM. |
| Dependent variable          WSCHOICE     |
| Weighting variable             None      |
| Number of observations        11024      |
| Iterations completed             25      |
| Log likelihood function    -2515.000     |
| Restricted log likelihood  -5139.149     |
| Chi squared                5248.298      |
| Degrees of freedom               19      |
| Prob[ChiSqd > value] =      .0000000     |
| R2=1-LogL/LogL* Log-L fncn R-sqrd RsqAdj |
| No coefficients -5139.1487 .51062 .50951 |
| Constants only.  Must be computed directly. |
|           Use NLOGIT ;...; RHS=ONE $     |
| At start values -2521.0109 .00238 .00012 |
| Response data are given as ind. choice.  |
+------------------------------------------+
+------------------------------------------+
| Random Parameters Logit Model            |
| Replications for simulated probs. = 500  |
| Halton sequences used for simulations    |
| Number of obs.= 2641, skipped  0 bad obs. |
+------------------------------------------++--------------------+---------------+--------+---------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] |
+---------+--------------+----------------+--------+---------+
              Random parameters in utility functions
WSTIMED -.3895436395E-01 .55254572E-02 -7.050 .0000
     Nonrandom parameters in utility functions
BHCON    .1954127094E-01 .82559319E-01   .237  .8129
RIVER    -1.371885346    .13078684  -10.489  .0000
STREAM   -.1572759171    .96239169E-01 -1.634 .1022
MUFCON   -.5693202923    .11453541   -4.971  .0000
WWPCON   -.9754311019    .14805388   -6.588  .0000
QUALITY  3.557883692     .38445316    9.254  .0000
TIMEHHS  .5092784882E-02 .85031095E-03 5.989  .0000
TIMEMECH .8755625119E-02 .41990912E-02 2.085 .0371
QUALWET  -.6335202460    .17172553   -3.689  .0002
QUALED   -.5598887767E-01 .17775794   -.315  .7528
TIMESCO  -.1079016942E-01 .20454351E-02 -5.275 .0000
QUALKID  -.4378055208    .83741511E-01 -5.228 .0000
QUALJW   -.6436356613    .25887972   -2.486  .0129
QUALJPR  1.121182087     .44896697    2.497  .0125
QUALJBT  .6375871322     .36095537    1.766  .0773
QUALTFEM -.1578801749E-01 .31889793   -.050  .9605
QUALTMAL -.7117064201    .38835452   -1.833  .0669
     Derived standard deviations of parameter distributions
NsWSTIME .2204845818E-01 .49664731E-02 4.439 .0000
(Note: E+nn or E-nn means multiply by 10 to + or -nn power.)
```

Model 7 (conditional Logit) - Water Source property Rights Variables

```
+-------------------------------------------+
| Discrete choice (multinomial logit) model  |
| Maximum Likelihood Estimates               |
| Model estimated: Oct 12, 2005 at 07:07:24PM. |
| Dependent variable          Choice    |
| Weighting variable           None    |
| Number of observations        2641    |
| Iterations completed             7    |
| Log likelihood function    -2539.674    |
| Log-L for Choice  model = -2539.67385    |
| R2=1-LogL/LogL* Log-L fncn R-sqrd RsqAdj |
| Constants only.  Must be computed directly. |
|             Use NLOGIT ;...; RHS=ONE $ |
| Response data are given as ind. choice.    |
| Number of obs.= 2641, skipped  0 bad obs. |
+-------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]
WSTIMED	-.2873731607E-01	.34158888E-02	-8.413	.0000
USEVOL	.5503053353	.12212638	4.506	.0000
RESTRICT	.2212089130	.31280830E-01	7.072	.0000
EXCLUSIV	.1395082520	.25807058E-01	5.406	.0000
QUALITY	3.581828096	.36900730	9.707	.0000
TIMEHHS	.3425360156E-02	.54474815E-03	6.288	.0000
TIMEMECH	.7289908081E-02	.30470011E-02	2.392	.0167
QUALWET	-.6433895517	.16125969	-3.990	.0001
QUALED	-.1259998770	.16469666	-.765	.4442
TIMESCO	-.7281168883E-02	.13190813E-02	-5.520	.0000
QUALKID	-.4631637301	.79747979E-01	-5.808	.0000
QUALJW	-.6080915255	.24851718	-2.447	.0144
QUALJPR	.9292440829	.40261571	2.308	.0210
QUALJBT	.6124922095	.35051432	1.747	.0806
QUALTFEM	-.1080574110	.30431778	-.355	.7225
QUALTMAL	-.7076938966	.37187271	-1.903	.0570

(Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

Model 8 (Random Parameters Logit) - Water Source Property Rights Variables

```
+-------------------------------------------+
| Random Parameters Logit Model             |
| Maximum Likelihood Estimates              |
| Model estimated: Oct 12, 2005 at 07:12:02PM. |
| Dependent variable         WSCHOICE       |
| Weighting variable            None        |
| Number of observations       11024        |
| Iterations completed            23        |
| Log likelihood function     -2526.863     |
| Restricted log likelihood   -5139.149     |
| Chi squared                  5224.570     |
| Degrees of freedom               17       |
| Prob[ChiSqd > value] =       .0000000     |
| R2=1-LogL/LogL*  Log-L fncn  R-sqrd  RsqAdj |
| No coefficients  -5139.1487  .50831  .50731 |
| Constants only.  Must be computed directly. |
|            Use NLOGIT ;...; RHS=ONE $     |
| At start values  -2539.6738  .00504  .00302 |
| Response data are given as ind. choice.   |
+-------------------------------------------+

+-------------------------------------------+
| Random Parameters Logit Model             |
| Replications for simulated probs. = 500   |
| Halton sequences used for simulations     |
| Number of obs.= 2641, skipped  0 bad obs. |
+-------------------------------------------+
+---------+--------------+----------------+--------+---------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] |
+---------+--------------+----------------+--------+---------+
                         Random parameters in utility functions
WSTIMED   -.4327417217E-01  .58421338E-02  -7.407  .0000

          Nonrandom parameters in utility functions
USEVOL     .5710671205      .12418846      4.598  .0000
RESTRICT   .2290418324      .33033307E-01  6.934  .0000
EXCLUSIV   .1266761082      .26736313E-01  4.738  .0000
QUALITY    3.537777872      .38707266      9.140  .0000
TIMEHHS    .5547576934E-02  .91903492E-03  6.036  .0000
TIMEMECH   .1088850291E-01  .47150652E-02  2.309  .0209
QUALWET   -.6479242957      .17413035     -3.721  .0002
QUALED    -.3354608161E-01  .18035259     -.186   .8524
TIMESCO   -.1231469918E-01  .21959817E-02 -5.608  .0000
QUALKID   -.4320092246      .84731647E-01 -5.099  .0000
QUALJW    -.7695531517      .25959912     -2.964  .0030
QUALJPR    1.036046263      .45554562      2.274  .0229
QUALJBT    .4464052144      .36058248      1.238  .2157
QUALTFEM   .3807295452E-01  .32009013      .119   .9053
QUALTMAL  -.6708984681      .39005884     -1.720  .0854
          Derived standard deviations of parameter distributions
NsWSTIME   .2905046807E-01  .48864966E-02  5.945  .0000
(Note: E+nn or E-nn means multiply by 10 to + or -nn power.)
```

Appendix I-8 Correlation Matrix for Variables in Water Collection Trip Counts

RA HOUSEHOLDS

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1 Trip Price - RA	1.00															
2 Trip Count - RA	0.20	1.00														
3 Volume/Trip/Capita	0.06	-0.25	1.00													
4 No Rain Water Collected	-0.94	—	-0.07	1.00												
5 Thatched Roof	-0.55	-0.48	—	0.10	1.00											
6 Scotch carts & Wheelbarrows	0.13	—	0.12	-0.11	-0.14	1.00										
7 Household Size	0.07	—	0.13	-0.07	-0.07	0.11	1.00									
8 Children	-0.09	-0.06	0.19	—	—	-0.09	0.67	1.00								
9 Female Collected Trips Ratio	020	-0.12	0.21	0.10	—	—	—	-0.05	1.00							
10 Draft Power Trips - Ratio	-0.21	-0.20	0.40	-0.05	-0.05	0.20	-0.24	0.14	-0.08	1.00						
11 Joint Production Trips Ratio	-0.27	—	0.06	—	-0.09	—	0.05	0.05	-0.06	—	1.00					
12 Riparian Village	0.25	—	-0.07	-0.14	—	0.05	0.06	0.04	—	-0.09	-0.11	1.00				
13 Oct-Dec 2002 Trips Ratio	-0.132	—	—	0.11	—	—	—	—	—	0.05	0.12	—	1.00			
14 Jan-Mar 2003 Trips Ratio	—	0.06	—	-0.15	—	—	—	—	-0.07	—	—	—	-0.33	1.00		
15 Apr-Jun 2003 Trips Ratio	0.086	—	—	—	—	—	—	—	—	—	-0.09	—	-0.34	-0.33	1.00	
16 Jul-Sept 2003 Trips Ratio	—	0.05	—	0.06	—	—	—	—	-0.05	—	—	—	-0.34	-0.33	-0.33	1.00

Notes: Spearman's Rho non-parametric correlation test results reported for variables with correlations significant at the 0.01 and 0.05 level (2-tailed) only.

SSCF HOUSEHOLDS

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 Trip Price - SSCF	1.00														
2 Trip Count - SSCF	0.13	1.00													
3 Volume/Trip/Capita	0.20	-0.13	1.00												
4 No Rain Water Collected	0.12	-0.07	—	1.00											
5 Thatched Roof	-0.12	—	—	0.09	1.00										
6 Scotc- carts & Wheelbarrows	0.08	—	0.13	—	-0.31	1.00									
7 Household Size	0.14	—	0.42	—	—	0.20	1.00								
8 Children	0.25	—	0.38	—	-0.11	—	0.65	1.00							
9 Female Collected Trips Ratio	—	0.12	-0.24	-0.12	—	—	—	—	1.00						
10 Draft Power Trips - Ratio	—	-0.20	0.23	—	—	0.08	—	—	-0.27	1.00					
11 Joint Product Trips Ratio	-0.22	0.07	—	—	0.09	—	—	—	—	-0.08	1.00				
12 Oct-Dec 2002 Trips Ratio	-0.23	-0.16	—	0.26	—	—	—	—	-0.08	—	0.08	1.00			
13 Jan-Mar 2003 Trips Ratio	-0.32	-0.15	—	-0.36	—	—	—	—	0.08	-0.12	—	-0.31	1.00		
14 Apr-Jun 2003 Trips Ratio	0.14	—	—	—	—	—	—	—	—	—	—	-0.36	-0.33	1.00	
15 Jul-Sept 2003 Trips Ratio	0.40	0.30	0.07	0.10	—	—	—	—	—	0.11	—	-0.34	-0.31	-0.35	1.00

Notes: Spearman's Rho non-parametric correlation test results reported for variables with correlations

PART IV: Chapter 9 - Conclusions and Policy Implications

This thesis analyzed income diversification and access to domestic water resources for selected rural households in rural Zimbabwe in three distinct land tenure systems with varying property right institutions for natural resources. The first focus of the thesis was on income diversification, where this work contributes to the discourse by incorporating income from woodlands for communal area households. The second focus of the study was on access to common pool water resources for domestic water provision for households in semi-arid regions. Data were collected in quantitative surveys of households conducted between January 1999 and October 2003 in two communal areas (CA), one resettlement area (RA) and one small scale commercial farming area (SSCF) in Masvingo province, in south eastern Zimbabwe.

In Part II of the thesis we examined the income portfolios and diversification strategies of selected rural households. The analysis was limited to a cross-section of household-level data thus limiting application of our study findings due to the inability to analyze income diversification patterns over time in response to dynamic factors. As a background to our study, the empirical literature highlights the importance of non-farm income diversification in rural Africa and shows substantial entry barriers to non-farm income opportunities. This literature also shows significant relationships between diversification to non-farm income and such household welfare indicators as wealth, although the direction of causality may be difficult to ascertain. Further, the literature points to the significance of natural-resource based incomes for the poor although studies of rural income diversification have tended to exclude natural resource incomes. Even so, studies of rural household income diversification have tended to include incomplete assessment of natural resource income. Thus, the study contributes to the discourse on rural household income diversification by including woodlands resources as a distinct income-generating activity.

We explore observed patterns of income diversification as shown by the relative share of total gross household income from each of several income-generating activities, the values of constructed measures diversification and causality between income diversification patterns, household wealth, total income in a given period, non-farm income and natural resource income. Our results show income diversification patterns dominated by agricultural and natural resource income sources. This result contrasts to findings in the literature by showing that both relatively wealthy and poor households have similar agricultural and natural resource income shares when we account for natural resource incomes from woodlands. We find evidence of entry barriers to livestock income opportunities for the poor and barriers to increased scale in irrigated agriculture to be experienced by both poorer and wealthier households alike.

Non-farm sources account for around one quarter of total gross income for all households in contrast to previous findings in the literature suggesting that wealthier households have higher non-farm income shares. However, the composition of non-farm income sources shows greater reliance on remittances from skilled labor in off-farm employment for the wealthier, in contrast to unskilled rural wage labor and home industry activities for the poorest households. That female-headed households tended to be more likely to receive income from remittances raises challenges to sustenance of these non-farm income opportunities, particularly in the face of the current scourge on the workforce by HIV/AIDS. A related challenge is to create wage labor opportunities to increase incomes in rural wage labor for the rural poor.

Analysis of causality between diversification, wealth and income shows that the wealthiest are slightly less diversified than the poorest and that total income is augmented by woodlands income for the poorest and by livestock income for the wealthier. We also find that although income efficiency generally increases with diversification, there are economies of scale from relative specialization in dryland agriculture with of economies of scale surpassing economies of scope in this case. We show that woodlands incomes are significant components of diversified livelihoods strategies for the poorest households as found in much of previous literature. In addition, the negative relationships between higher woodlands income shares and both relative wealth and total gross income per capita suggest that they are an inferior activity in economic terms.

As a caveat, it should be noted that income data analyzed in Part II of this thesis were collected for the year 1999 which was an above average year in terms of rainfall, incomes and hence overall economic performance for the country. Thus these results have the limitation of not being representative of a normal year or a relatively bad year in order to enrich the analysis. Further, comparison of results across studies and sites is made difficult by incomplete accounting for the different components of income within natural resource activity. Comparability of our results to other studies is also complicated by the question of how prices for non-marketed woodlands products are derived. This highlights the potential to underestimate the true extent of natural resource income dependence amongst both the relatively wealthiest and relatively poorest rural households in income and poverty assessments.

In Part III of the thesis we investigated household choices of water collection sites for domestic water supply and the frequency of such trips for domestic water provision. A challenge addressed in the analysis of water collection site choices is that the universal choice set of geographically located alternative water collection sites across all households is very large and could not be accommodated easily by econometric estimation. Thus, in specifying discrete choice models for water sites we test potential errors in welfare measures that may arise from assuming generic choice sets based on general types of water sources. From estimation results we find that bias does not seem to be associated with not specifying a universal choice set of geographic water sites and provide empirical evidence that households are able to accurately define their own household-specific choice sets. In the context of this study we find that failure to specify a universal choice set does not significantly change coefficients and welfare measures in our site choice models, although all geographic site alternative-specific constants and information become meaningless where generic choice sets are specified.

We contribute to the empirical literature by linking household-level micro-economic decisions to property right attributes, showing a significant influence of these attributes on household behavior. Property right attributes of water sources indicating lower relative exclusivity and higher use restrictions are found to be significant in deterring water site choice. Restrictions on allotment size of water are not important to site choice for households in areas with private ownership of land in SSCF areas, in contrast to RA areas where land is communally owned. However, for households with the most constrained level of access to domestic water resources, water sites with less exclusivity and greater restrictions on uses and water volumes are chosen, reflecting limited alternatives for water provision. An implication of the significant differential composition of water resources that were found in household-specific choice sets and the impact of property right attributes is that there is significant heterogeneity in the type of water access and means of water supply across households. This suggests that some households would potentially be willing to pay much more for water supply improvements while others may not.

We also show that all households are more likely to visit household owned shallow wells for domestic water provision than community boreholes, despite the greater water quality and reliability of water supply from boreholes. This is consistent with previous empirical findings that state- or donor-funded community boreholes are not frequented by households who prefer traditional and relatively exclusive water sources such as family wells. This is attributed to the greater travel distances to community boreholes and household preference for relatively exclusive water sources except in times of rainfall drought. Further, households with most constrained access to water resources, in terms of property right attributes, travel cost, quality and water source types, are shown to be willing to pay the most to acquire water for essential domestic needs. In addition, access to technology through applying draft power for transporting water is important in expanding potential site choices to more distant sites for the relatively wealthy.

In order to report accurate welfare measures for water demand based on water collection site choices, per trip welfare measures are translated into the frequency of trips for domestic water provision. We find that trip frequency to water sites is reduced by higher travel costs valued in terms of labor time, increased by volume capacity for water collected on each trip and increased in the drier months of the year. Domestic water provision trips increase in frequency during dry-season months. Relatively wealthy households, in areas with private land ownership generally demand larger water volumes per capita on average and the water volumes are insensitive to trip costs valued in terms of labor time. Further, demographic variables are generally insignificant in effecting SSCF household trip behavior, apparently because of relative homogeneity in asset ownership and access to water resources that is observed for these households. RA households exhibit greater heterogeneity in water access and demographics. We also find that the rural households studied are conservative in their water use volumes and may be in a condition of relative water stress. The observed water use volumes are relatively low, between 15% and 30% of per capita water volumes considered essential to ensure adequate nutrition and sanitation by the WHO. The observed water demands are also low in comparison to Zimbabwe government design policy for water provision which projects per capita water consumption at 60% of WHO recommended volumes.

Own-elasticity estimates for water collection trip counts are found to be relatively inelastic since water for domestic use is a necessity. Thus there are challenges to arriving at meaningful economic results from domestic water demand estimation in terms of responsiveness of demand to prices. However water collection trip counts are found to exhibit greater relative responsiveness to per trip costs in the case of RA households, as compared to SSCF households, apparently due to more variable levels of water access that apply for the former group.

Analysis of actual household behavior in water collection site choices and trip frequencies for water provision allows us to impute effective demand for domestic water in volumetric terms. Our calculations show that the households studied are currently paying between 12 and 29 hours of labor time per cubic metre of water acquired for domestic use. The effective demand valued at a hypothetical wage rate of US$0.03/hour is estimated between US$0.36/$m^3$ and US$0.87/$m^3$. These values give an indication of the volumetric water charges that rural households are currently incurring and might be prepared to pay to acquire water for domestic uses, in monetary terms. The highest effective demand, more than double that of other households on average, is observed for households with the most constrained access to domestic water resources. Thus it is concluded that water supply interventions need to recognize the heterogeneity of household groups if they are to have the intended impacts.

The quantitative estimates outlined in the study provide insights relevant to policy for rural domestic water supply and demand management and for potential water pricing mechanisms that could apply to households in similar circumstances. However, we conclude that even in this condition of relatively limited resources and water stress reflected in the feature that households maintain their water consumption levels well below WHO recommendations, these households have some substitution possibilities for domestic water provision that are separate from public water projects. Thus, policies that target water projects will be dependent on the role that each water source holds in complex household decisions. In turn these decisions are determined by subjective values placed on attributes such as water quality, travel cost and property rights, and are conditional on household heterogeneity in wealth and other characteristics. All these types of factors provide numerous areas for policy influence and must therefore be considered, before any "one-size-fits-all" water provision initiatives are implemented, if objectives of achieving significant welfare impact and cost recovery are to be met.

In the context of current water use legislation in Zimbabwe, stated objectives are to foster efficient use of water resources through water pricing. Although the rural households studied do not currently pay for water, water use legislation [Water Act (1998)] includes provision for payment for water use permits and volumetric water charges for water use levels beyond primary needs. Within that framework, there is no delineation of whether household income-generating water uses may be considered to be primary uses, or deemed to be for commercial benefit. In addition, we find that the currently regulated upper limits for private water storage facilities for primary water use of water of 5 000 cubic meters per household in the Water Act (1998) is not in fact a binding constraint. The current water use volumes for both domestic and productive water uses, including watering livestock herds, for the households studied in both resettlement area and small scale commercial farm area land tenure systems, are well below this upper limit. In this context, the extent to which these households may have to pay for water in future is currently unclear. However, it is apparent that macro-level policy is in a constant state of flux with variable micro-level impacts on household behavior.

The findings of this thesis on income diversification patterns and access to water resources may have direct implications for future policy targeted at improving livelihoods and natural resource management for similar types of households. The actual data that are derived and applied in this study are from a sample of 473 households in selected CA, RA and SSCF prior to the fast track land resettlement program of 2000 in Zimbabwe. However, the analytical framework and general results may be more widely applicable to the emerging class of post-2000 fast track land resettlement program RA and SSCF farmers in semi-arid regions of rural Zimbabwe.

References

Government of Zimbabwe. (1998). Water Act No.31 [Chapter 20:24] Harare: Government Publications

Appendix I - 9 RA & SSCF: Round 1 Questionnaire

IES/UZ/UA Community Land Management Questionnaire

Introduction:

Greetings. Your household is being visited today as part of a survey for a study to learn about the different ways in which you use the common resource water throughout the year. Village leaders have been informed about this study and have given permission for this study to be carried out. Participation in this survey by your household is voluntary. If you participate in this survey you will be assisting a student, who is studying at the University of Alberta in Canada, and the Institute of Environmental Studies at the University of Zimbabwe. The information to be collected from this study will help us to understand how water is used and how this is important to your livelihoods. Your participation in this study will be of no personal benefit to you. However, it is hoped that your answers may inform decision makers who are in a position to assist you indirectly. I am requesting about an hour of your time once a month for a year. I would like to speak to three members of your family, an adult male, an adult female and a child. I will ask some questions about your household composition, assets, production, and about where you collect water and how it is used. I will record your responses to these questions. During the interview you can choose not to answer any question and you are free to withdraw from the interview at any time. Please feel free to ask for clarification on anything in the interview that is not clear. Your responses will be treated with strict confidentiality. No reference to your name shall be made and your responses shall be numbered to maintain your anonymity.

Would you be willing to participate in this survey? Yes----1 No-----0

Date -- Ward No./SSCF No. ----------------------------------

Village-- Family Name---

Number of respondents------------------------------- Enumerator's name --------------------------------

Start Time of interview-------------------------------- End Time of interview-------------------------------

Round 1 - 1st Visit

A Household Characteristics

We would like to find out some background information about your household, its members, assets, income sources and inputs.

A.1 Respondent characteristics and household composition

1.) *(Interviewer should record the sex of the respondent)* Male........1 Female......0

2.) *What is your relationship to the head of this homestead (musha)?* ______________

3.) *What ethnic (rudzi) group is the head of this homestead?* ____________________

4.) *When (in what year) did the family (mhuri) settle at this location?* ___________

5.) *Where did the family (mhuri) move from to come to this location?* ___________

6.) *How many kitchens (households) are there at this homestead?* ______________

7.) *Whose kitchen are you (the respondent) a member of? (Indicate relationship to the head of the homestead)* ____________________

(Enumerator should identify the head of the homestead's [baba] kitchen [household] or the oldest son/most senior person's household for the survey. The following questions apply to the household identified.)

8.) *How many people eat from your kitchen (members of your household that live here)?* ________________

9.) *What is the household head's age? (please make sure that this is the head [saimba] of the respondent's kitchen/household)* ___________________________

10.) *What is the household head's level of education?(circle appropriate)*
None ....0 Primary school....1 Secondary school.......2 High School.......3
College/University......4 Adult Literacy.......5

11.) *Does the household head have a Master Farmer certificate (saimba vane chitupa cheurimi)? (circle appropriate response).* No....0 Yes...1

12.) *What is the household head's occupation? (Indicate details of occupation and location of job or residence if not on-farm labor).*
On-farm labor -----0
Off-farm employ (specify) ______________________________
Home industry (specify) ________________________________
Other (specify) _______________________________________

13.) *What is the marital status of the household head?*
Single -----0 Married------1 Divorced ------ 2 Widowed -------3
Other (specify e.g. if more than one wife indicate number of wives) ______________

(If there is more than one wife please ask the following information from the first wife's kitchen [vahosi])

14.) *(For each of the people mentioned in Q8, ask the questions in the table below)*

	Name	Sex	Age	Relation to head Of kitchen/HH	Education	Occupation & location
1.	------------	-----	-----------	-----------------	--------------	--------------
2.	------------	-----	-----------	-----------------	--------------	--------------
3.	------------	-----	-----------	-------------------	--------------	--------------

4. ------------	-----	-----------	-------------------	--------------	-------------
5. ------------	-----	-----------	-------------------	--------------	-------------
6. ------------	-----	-----------	-------------------	--------------	-------------
7. ------------	-----	-----------	-------------------	--------------	-------------
8. ------------	-----	-----------	-------------------	--------------	-------------
9. ------------	-----	-----------	-------------------	--------------	-------------
10. -----------	-----	-----------	-------------------	--------------	-------------
11. -----------	------	------------	-------------------	--------------	-------------
12. ------------	------	-----------	-------------------	--------------	-------------
13. -----------	-----	-----------	-------------------	--------------	-------------
14. -----------	------	------------	-------------------	--------------	-------------
15. -----------	------	------------	-------------------	--------------	-------------

We would like to choose three of these household members to talk to a number of times over the next year about household activities: one male adult (over 16), one female adult (over 16) and one child (10-16). Are there three members who know about household activities that will generally be around over the upcoming year? (Circle the selected names in the list above and then interview each of the three household members separately for Section B of the questionnaire).

A.2 Wealth and asset characteristics

15.) *(Interviewer should observe the type of main house and circle the appropriate number)*
Pole and Dagga and thatch ...0 Brick and thatch ...1
Pole and Dagga plus tin ...2 Brick and asbestos ...3
Brick and tin ...4

16.) *How much personal [yenyu imi] ___________ land does your household have (in acres, hectares, number of trees or garden beds)? (Ask for each land use type listed below and indicate the type of units used)*

Total (*yose*) -----------------------
Dry land ------------------------------
Irrigated land-----------------------
Wetland (*dambo/doro*) --------------
Orchard-----------------------------
Woodlot --------------------------------
Paddocks ---------------------------
Grazing Area -------------------------

17.) *Do you own -------------- (ask for each item in list and indicate number of units)?*

Item	Units
Scotch cart	0 1 2 ....
Plough	0 1 2 ....
Cultivator	0 1 2 ....
Axe	0 1 2 ....
Wheelbarrow	0 1 2 ....
Hoe	0 1 2 ....
Manual saw (*saha*)	0 1 2 ....
Radio	0 1 2 ....
TV	0 1 2 ....
Bicycle	0 1 2 ....
Kerosene stove	0 1 2 ....
Kerosene lamp	0 1 2 ....
Solar Panels	0 1 2 ....

18.) *Do you own_____________ (ask for each livestock type in list and indicate number)?*

Animal	Number
Draft Cattle	....
Milk Cows	....
Other Cattle	....
Donkeys	....
Goats	....
Chickens	....
Turkeys	....
Ducks	....
Doves (*kirimba*)	....
Other (specify)	....

19.) *Does your household have a personal ____________? (Ask for each type of water source listed below and indicate the number of units where applicable).*

Water Source			Number
Shallow well (*tsime*)	Yes 1	No 0	----------------
Deep well (*mugodhi*)	Yes 1	No 0	----------------
Borehole	Yes 1	No 0	----------------
Spring (*chitubu*)	Yes 1	No 0	----------------
Sponge (*dekete*)	Yes 1	No 0	----------------
Stream (ru*kova*)	Yes 1	No 0	----------------
River (*rwizi*)	Yes 1	No 0	----------------
Riverbank pool (*mufuku*)	Yes 1	No 0	----------------
Dam	Yes 1	No 0	----------------
Natural Pool (*dziva*)	Yes 1	No 0	----------------
Stagnant Pool (*Guvi*)	Yes 1	No 0	----------------
Tap	Yes 1	No 0	----------------

Other water source (specify) ______________________________________

(If yes to any item in Q19 identify the location of the water source relative to the location of the homestead kitchen for mapping using the form on page 23)

A.3 Income sources

20.) *In the last month did you receive income in* ***cash*** *or in* ***kind*** *from _________*
21.) *In the last month how much* ***cash*** *income did you receive from __________*
22.) *In the last month how much* ***in kind*** *income did you receive from ________*
(Ask all three questions for each listed income source and ask about any other income sources. Details should include any relevant extra information given)

Income Source	Yes/No	Amount Cash	Quantity Kind	Rank Cash	Rank Kind	Details.
1. Dryland crops	------------	----------	----------------	--------	----------	--------------
Maize	------------	----------	----------------	--------	----------	--------------
Cotton	------------	----------	----------------	--------	----------	--------------
Groundnuts	------------	----------	----------------	--------	----------	--------------
Wheat	------------	----------	----------------	--------	----------	--------------
Sunflower	------------	----------	----------------	--------	----------	--------------

Other ------------ ---------- ---------------- -------- ---------- --------------
2. Garden crops ------------ ---------- ---------------- -------- ---------- --------------
Tomatoes ------------ ---------- ---------------- -------- ---------- --------------
Onions ------------ ---------- ---------------- -------- ---------- -------------
Cabbage ------------ ---------- ---------------- -------- ---------- --------------
Leaf (*muriwo*) ------------ ---------- ---------------- -------- ---------- --------------
Other ------------ ---------- ---------------- -------- ---------- --------------
3. Cattle ------------ ---------- ---------------- -------- ---------- --------------
Beef ------------ ---------- ---------------- -------- ---------- --------------
Milk ------------ ---------- ---------------- -------- ---------- --------------
4. Small Livestock ------------ ---------- ---------------- -------- ---------- --------------
Goats ------------ ---------- ---------------- -------- ---------- --------------
Sheep ------------ ---------- ---------------- -------- ---------- --------------
Other ------------ ---------- ---------------- -------- ---------- --------------
5. Poultry/Fowl ------------ ---------- ---------------- -------- ---------- -------------
Chickens ------------ ---------- ---------------- -------- ---------- --------------
Turkeys ------------ ---------- ---------------- -------- ---------- --------------
Ducks ------------ ---------- ---------------- -------- ---------- --------------
Other ------------ ---------- ---------------- -------- ---------- --------------
6. Woodlands ------------ ---------- ---------------- -------- ---------- --------------
Firewood ------------ ---------- ---------------- -------- ---------- --------------
Fruit ------------ ---------- ---------------- -------- ---------- --------------
Timber ------------ ---------- ---------------- -------- ---------- --------------
Carvings ------------ ---------- ---------------- -------- ---------- --------------
Other ------------ ---------- ---------------- -------- ---------- --------------
7. Home Industry ------------ ---------- ---------------- -------- ---------- --------------
Brick Making ------------ ---------- ---------------- -------- ---------- --------------
Beer Brewing ------------ ---------- ---------------- -------- ---------- --------------
Pottery ------------ ---------- ---------------- -------- ---------- --------------
Other ------------ ---------- ---------------- -------- ---------- --------------
8. Hired labor (*maricho*)------------ ---------- ---------------- -------- ---------- --------------
9. Remittances ------------ ---------- ---------------- -------- ---------- --------------
10. Credit (informal,formal)--------- ---------- --------------- ---------- ---------- -------------
11. Gold Pan (*zungura*) ------------ ---------- ---------------- ----------- -------- ------ --------
12. Pension ------------ ---------- ---------------- -------- ---------- ------------- --------
13. Food for Work----------- ---------- ------------- ---------- ---------- ------------ --------
14. Food Aid (*Care*)------------ ---------- ------------- ----------- ---------- ------------ --------
13. Other ------------ ---------- ---------------- -------- ---------- ------------ --------
14. Other ------------ ---------- ---------------- -------- ---------- ------------ --------

23.) *Would you please rank your income sources in the last three months from first to last according to importance as a source of* ***cash*** *income.*

24.) *Would you please rank your income sources in the last three months from first to last according to importance as a source of* ***in kind*** *income.*

A.4 Input and resource stocks

25.) *Do you have any* _______________*?*

26.) *How much/how many of ____________ do you have in quantity or dollar amount? (Ask both questions for each listed item and ask about any others. Details may include the item's intended use and when it will be used).*

Item	Yes/No	Amount/Quantity (specify units)	Details
1. Maize grain	------------	------------------------------	--------------------------
2. Cash savings	------------	------------------------------	--------------------------
4. Firewood	------------	------------------------------	--------------------------
5. Fodder/Hay/residues	-----------	------------------------------	--------------------------
6. Full time workers	--------------	------------------------------	--------------------------
7. Inputs (fertilizer, seed)	--------------	------------------------------	--------------------------
8. Other	--------------	------------------------------	--------------------------
9. Other	--------------	------------------------------	--------------------------

B Intra-household decision making

(Ask to interview the three household members identified in section A i.e. one male adult (over 16), one female adult (over 16) and one child (10-16) for the following sections. Ask the following questions separately for each adult male, adult female and child identified in section A.)

We would like to ask you about the various family and personal activities that you participate in and about your participation in making decisions about how time, income and other resources are used in your household.

B.1 Separate and joint production activities

ADULT MALE/ ADULT FEMALE/ CHILD (10-16)

1. *Do you have any production activities (e.g. gardens, crafts, sewing, etc.) that you conduct personally and receive income in* ***cash*** *or in* ***kind*** *from?*
   Yes....1 *No......0* *(If 'No' to Q1 go to Q7.)*

2. *If yes to Q1, can you name each of these activities? (list the activities mentioned and make sure they are not family/joint activities)*
   Activity 1 --
   Activity 2 --
   Activity 3 --

3. *Does any other member of the household participate in or help you with __________ activity? (ask for each activity mentioned in question 2 above, details should include which family members help and any other information given)*

	Yes/No	Details
Activity 1	------------	--
Activity 2	------------	--
Activity 3	------------	--

4. *Do you receive any money from the personal activity ____________? (Ask for each activity mentioned in question 2. If 'No' to Q4 go to Q7.)*

5. *If yes to Q4, in the last month how much cash income did you receive from personal activity ________? (Ask for each activity mentioned in question 2)*

	Amount	Details
Activity 1	-----------	---
Activity 2	-----------	---
Activity 3	-----------	---

6. *What did you do with the money you earned from activity ___________? (Ask for each activity mentioned in question 2 and you can indicate more than one response from below)*

		Details
Activity 1	-----------	---
Activity 2	-----------	---
Activity 3	-----------	---

Save it ---- 0 Share it --------1 Give to HH Head ------2 HH Groceries---3 Personal purchases------4 Education------5 Other(specify)_____________

7. *Do you as an individual (imi pachenyu) receive any share of the money from family/joint production activities?*

Yes.....1 *No.......0* *(If 'No' to Q7 go to Q11)*

8. *If Yes to Q7, can you name each of the family activities from which you received cash income in the last month. (List the activities mentioned)*
9. *How much cash income did you receive from __________ in the last month. (Ask for each activity mentioned in Q8.)*

	Name/List	Amount and Details
Activity 1	---------------	---
Activity 2	---------------	---
Activity 3	---------------	---

10. *What did you do with the money you received from ____________ (ask for each activity mentioned in Q8)? (You can indicate more than one response item from below and summarize any details given)*

		Details
Activity 1	-----------	---
Activity 2	-----------	---
Activity 3	-----------	---

Save it ---- 0 Share it --------1 Give to HH Head ------2 HH Groceries----3 Personal purchases------4 Education------5 Other (specify) _____________

B.2 Participation in decision making

ADULT MALE/ ADULT FEMALE/CHILD (10-16)

11. *Do you participate in the decision on ____________________? (munotorawo nzvimbo pakuronga kwe __________ kungave kuti ________?)*
12. *How much input do you make in the decision on ___________? (kubtsira kanakuti kutoranzvimbo mune kuronga nezve __________ kwamunoita kunonga kwakadii,*

kwakarerukira kuti padoko, pakuru, zvakafanana nevamwe kana kuti zvichinyanya kurerukira kwamuri imi?)

13. *Who else in the household participates in the decision on ___________? (ndiani umwe mumba ano batsira pakuronga nezve _________?)*
(ask for each decision item in the table citing the examples given and tick the relevant boxes)

Who participates in decision *Decision Item*	Yes/No	None	Little	Same	Most	All	Father	Mother	Child 10-16 years	Other
1. Field crops - which to grow, when to plant, when to prepare land, area, when to harvest, time in fields										
2. Garden crops - which to grow, when to prepare land, area, when to harvest, time in fields										
3. Livestock - where to take them for grazing, who herds them, purchases and sales										
4. Firewood - when, by who, how much, where its collected, draft power use										
5. Water - when, by who, where and how much is collected, draft power use										
6. Money Joint and personal - who receives, distributes, controls, how much is shared, what its used for										
7. Big Purchases - big items such as TV, radio, scotch cart, bicycle										
8. Grocery Purchases - cooking oil, salt, sugar, soap										
9. Off-farm work/job - whether and when you can go and find a job, who should go to work e.g. maricho										

C Water sources and sites - 'choice set'

(Ask to interview the adult female for the following section.)

We would like to ask you about the types and sources of water you use.

(Tirikuda kukubvunzayi nezve mhandu ne nzvimbo dzamunowana mvura yamunoshandisa imimi nepamusha penyu.)

1. *Name or describe all the* ***different*** *types of water source and the sites/location from which your household might collect or use water at any time during the year? (doma mhando ne nzvimbo dzakasiyanasiyana dzese dzamuno teka kana kuchera kana kushandisa mvura, imi panguva dzakasiyanasiyana dzegore)*

(Circle in the table below each water source the respondent indicates and if applicable write down the names of any other sources. Please provide details of the specific name and location of each water source given to distinguish them. Together the different sources identified are the respondent's 'choice set'. You should also identify the location of each water source relative to the location of the homestead kitchen for mapping using the form on page 23.)

2. *Who owns (muridzi we____) __________ (insert water source and site from table below)? (For example it could belong to a specific household even though others may use it, the community, a neighbor, a school, a clinic etc.)*

(Ask this question for each water source and site/location in the choice set and fill in the table below specifying the name of the owner where applicable.)

3. *What are the* ***uses*** *(e.g. coking and drinking, bathing and laundry, watering gardens, watering livestock, brick making etc.) of the water collected at ______________ (insert water source and site from table below)? (basa ramunonyanya kushandisa mvura yamuno teka ku ________ panguva zhinji nderechii?*

(Ask this question for each water source and site/location in the choice set and fill in the table below.)

4. *When you select _____________ (insert water source and site from choice set in table below) to collect water instead of any other, what is the main reason (factor/characteristic) that you consider? Kana muchisarudza kunono chera mvura ku _________ (taura mhando ne nzvimbo ye mvura) muchisiya dzimwe mhando kana nzvimbo munokoshesa chii?*

(Ask this question for each water source in the choice set and refer to the list of characteristics below to help you fill in the response or give examples to the respondent and then summarize any details given in the table below. Bvunza mubvunzo uyu uchizo nyora mhinduro wa tarisa pane chimwe chezvinhu zvakanyorwa pasi apa uyezve unyore zvimwe zvinenge zvatsananguruwa)

Examples of Factors/Characteristics

Distance	(from homestead, from garden etc.)
Quantity of water	(availability)
Quality of water	(potable, contaminated etc. - *kuchengeteka*)
Use of water	(zvaino shandiswa)
Weather conditions	*(mamirire ekunze nekushandura kwawo mawanikwe emvura)*
Rules and restrictions	(on quantity, timing of water collection)
Joint activities	(collect firewood, water garden, - kubataidza mamwe mabasa pakunochera mvura)
Site access rules	(kubvumidwa kupasvika)
Accessibility/difficulty	(of terrain and water extraction - kugona kusvika, kufambika nevanhu ne ngoro, kukwanisa kusunda bhara, kugozha kwe kuchera mvura)

Technology (buckets, gourds, draft power needs, etc. - kuno da zvisengesi, zvekutakurisa zvino diwa kushandiswa kuenda ipapo)

Number of other users (Congestion at site, previous visit experience)
Habit (kujairira nzvimbo)

Q1. Type of Water Source	Q1. Site Name /Location	Q2. Who owns the water source?	Q3. Uses of Water from that source	Q4. Factors/ Characters in selecting source
1. Shallow well (*tsime*)				
2. Deep well (*mugodhi*)				
3. Borehole				
4. Spring (*chitubu*)				
5. Sponge				
6. Stream (*svikova*)				
7. River (*rukova*)				
8. Riverbank pool (*Mufuku*)				
9. Dam				
10. Pool in waterway (*dziva*)				
11. Stagnant Pool (*Guvi*)				
12. Tap				
13. Collector well				
14. Other (specify				

~~~~~~~~~ THANK YOU FOR PARTICIPATING IN THIS SURVEY ~~~~~~~~~
~~~~~~~~~

RESOURCE MAPPING FORM

Date --
Ward No./SSCF No. -----------------------------------
Village---
Family Name---
Enumerator's name ------------------------------------
Start Time of Mapping-------------------------------
End Time of Mapping---------------------------------

LANDMARKS	Site Name	Location	Coordinates (GPS)	Distance (from kitchen)	Time (from kitchen)
1.Homestead Kitchen					
2. Gardens					
3. Crop fields					
4. Woodlot					
5.Grazing area					
6. Paddocks					
7.Wetlands (*doro*)					
8. Road					
9. School					
10. Clinic					
11. Hill (*gomo*) {specify name}					
12. Woodland					
13. Market Place					
14.Business Center/ Town ship					
15.Other					
16.Other					

WATER SOURCE	Site Name	Location	Coordinates (GPS)	Distance (from kitchen)	Time (from kitchen)
1.Shallow well (*tsime*) **Depth**					
2.Deep well (*mugodhi*) **Depth**					
3.Borehole (*chibhorani)* **Depth**					
4.Spring (*chitubu*)					
5. Sponge					
6.Stream (*svikova*)					
7. River (*rukova*)					
8.Riverbank pool *(Mufuku)*					
9. Dam					
10.Pool in waterway (*dziva*)					
11.Stagnant Pool (*Guvi*)					
12. Tap					
13.Collector well **Depth**					
14.Other (specify)					
15.Other (specify)					

NOTES:

1. For distances and times taken from the kitchen to the resource site, use the path that is used by the members of the household when visiting the site/place to determine how much time it actually takes them to get there in hours and minutes
2. For dams and pools, if possible measure or else estimate the length and width of dam wall and estimate length, depth and width of water so we can determine capacity and/or volume of water
3. For shallow wells, deep wells and boreholes, ask for information on depth
4. Include coordinates and other mapping information for any other significant landmarks near the homestead and any other water sources not listed in the tables above.

Appendix II - 9 RA & SSCF: Round 2 to 12 Questionnaire

IES/UZ-University of Alberta Community Land Management Questionnaire

Round 2-12 Questionnaire

Date -- Ward No./SSCF No. --------------------------------------
-
Village--- Family Name---
-
Number of respondents---------------------------- Enumerator's name ----------------------------------
--
Start Time of interview----------------------------- End Time of interview--------------------------------
-

A Income and Expenditure

(Ask to interview either the adult male or adult female identified in section A of the first round questionnaire for this section.)

We would like to find out about your household's income sources and purchases and expenditures over the last month.

A.1 Income sources

27.) *In the last month did you receive income in **cash** or in **kind** from* ________
28.) *In the last month how much **cash** income did you receive from* __________
29.) *In the last month how much **in kind** income did you receive from* ________
(Ask all three questions for each listed income source and ask about any other income sources. Details should include any relevant extra information given)

Income Source	Yes/No	Cash	Kind	Amount Cash	Quantity Kind	Rank Details.	Rank
1. Dryland crops	----------	---------	----------------	--------	----------	-------------	
Maize	----------	---------	----------------	--------	----------	-------------	
Cotton	----------	---------	----------------	--------	----------	-------------	
Groundnuts	----------	---------	----------------	--------	----------	-------------	
Wheat	----------	---------	----------------	--------	----------	-------------	
Sunflower	----------	---------	----------------	--------	----------	-------------	
Other	----------	---------	----------------	--------	----------	-------------	
2. Garden crops	----------	---------	----------------	--------	----------	-------------	
Tomatoes	----------	---------	----------------	--------	----------	-------------	
Onions	----------	---------	----------------	--------	----------	-------------	
Cabbage	----------	---------	----------------	--------	----------	-------------	
Leaf (*muriwo*)	----------	---------	----------------	--------	----------	-------------	
Other	----------	---------	----------------	--------	----------	-------------	

3. Cattle ------------ ---------- ---------------- -------- ---------- --------------
Beef ------------ ---------- ---------------- -------- ---------- --------------
Milk ------------ ---------- ---------------- -------- ---------- --------------
4. Small Livestock ------------ ----------- ---------------- -------- ---------- --------------
Goats ----------- ---------- ---------------- -------- ---------- --------------
Sheep ----------- ---------- ---------------- -------- ---------- --------------
Other ----------- ---------- ---------------- -------- ---------- --------------
5. Poultry/Fowl ----------- ----------- ---------------- -------- ---------- --------------
Chickens ----------- ---------- ---------------- -------- ---------- --------------
Turkeys ---------- ---------- ---------------- -------- ---------- --------------
Ducks ----------- ---------- ---------------- -------- ---------- --------------
Other ----------- ---------- ---------------- -------- ---------- --------------
6. Woodlands ------------ ---------- ---------------- -------- ---------- --------------
Firewood ----------- ---------- ---------------- -------- ---------- ---------
Fruit ------------ ---------- ---------------- -------- ---------- --------------
Timber ----------- ---------- ---------------- -------- ---------- --------------
Carvings ------------ ---------- ---------------- -------- ---------- ----------
Other ----------- ---------- ---------------- -------- ---------- --------------
7. Home Industry ----------- ---------- ---------------- -------- ---------- --------------
Brick Making ------------ ---------- ---------------- -------- ---------- --------------
Beer Brewing ----------- ---------- ---------------- -------- ----------- -----------
Pottery ----------- ---------- ---------------- -------- - ----------- -----------
Other ------------ ---------- ---------------- -------- ---------- --------------
8. Hired labor (*maricho*) --------- ---------- ---------------- ------- ---------- ------------
9. Remittances ----------- ---------- ---------------- -------- ---------- --------------
10. Credit (informal,formal) ------- ---------- ------------- ---------- ---------- ------------
11. Gold Pan (*zungura*) ------------ ---------- ----------- ----------- -------- ------ ---------
12. Pension ------------ ---------- ------------ -------- ---------- ------------- ------------
13. Food for Work----------- ---------- ------------- ---------- ---------- --------- --------
14. Food Aid (*Care*) ---------- ---------- ------------- ----------- ---------- ---------- --------

30.) *Would you please rank your income sources in the last month from first to last according to importance as a source of* ***cash*** *income. (Use the cards with symbols representing each category of income source to remind the respondent of the income sources they are ranking.)*

31.) *Would you please rank your income sources in the last months from first to last according to importance as a source of* ***in kind*** *income. (Use the cards with symbols representing each category of income source to remind the respondent of the income sources they are ranking.)*

A.2 Purchases and expenditures

32.) *Would you please list all the purchases and expenditures that you made over the last month and the amount used?*

Item	Amount Z$
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--	-------------------------------

A.3 Individual share of income

ADULT MALE TIME USE/ ADULT FEMALE TIME USE/ CHILD TIME USE

ACTIVITY DESCRIPTION	*Time Begun*	*Time End*	*Total Time*	*Who sent you*
DAY 1:				
DAY 2:				
DAY 3:				
Total Time				

C Log of water collection trips and site attributes

C.1 Log of water collection trips in the last three days

(For the following section, ask to interview the same adult female interviewed in Round one for section C)

We would like to ask you about the trips you made to collect water in the last week.

1. How many separate trips to collect or use water, used by **your** household, collected in any way, did your household members make during the last three days? *Record the number of trips.* ______________

Ask the following questions (2 to 15) while filling in the relevant boxes in the 'trip log' sheet on page 12.

2. On which days of the week did these trips occur? *Record this information on the 'trip log' sheet attached. Only record all the trips in the last three days starting with the most recent*

3. Who (which family member) went to collect/use water **on this trip only**? *Ask for each trip.*

4. Where (site/place and water source) did this person go to collect/use water **on this trip only**? *Ask for each trip.*

5. On this particular trip **who sent the person in Q3 and who decided which site/place** they should go to collect/use water from? *EG. Husband, wife, mother, father etc. Ask for each trip.*

6. On this particular trip **why did the person in Q5 decide** that water be collected/used at **this site**/place? *EG. Abundant water, near to homestead etc. Ask for each trip.*

7. On this particular trip who **accompanied** them to collect/use water? *EG. Husband, wife, mother, father, brother, sister, friend etc. Ask for each trip.*

8. On this particular trip, how long were they away from home during water collection/use? *Fill in the amount of **time** in minutes. Ask for each trip.*

9. a) On this particular trip, how much/what **quantity** of water did they collect. *EG. In buckets, drums, chikanga, mugomo, chigubhu etc? Ask for each trip and specify the units or type of container used and its capacity.*

   b) On this particular trip, how much/what **quantity** of water did you **want** to collect. *I.E. did you manage to get as much water you wanted to collect? In buckets, drums, chikanga, mugomo, chigubhu etc Ask for each trip and specify the units or type of container used and its capacity.*

10. On this particular trip, **how** did they carry the water? *EG. Manually or used animal draft, wheel barrow, scotch cart (owned by the household or borrowed or hired). Ask for each trip.*

11. What was (or will be) the **use** (e.g. drinking, washing, bathing, gardens, beer brewing, livestock, other) of water collected on this trip? *Ask for each trip and list the different uses if more than one.*

12. How would you rate the **availability** (abundance or quantity of water) relative to the other places you might have collected water from, for **the same use** on this particular trip? *High, Medium or Low? (Rating: 1-High, 2-Medium, 3-Low, 9-Don't Know). Ask this question separately for each trip.*

13. How would you rate the **quality** (e.g. is it contaminated, salty, oily, rusty, silted, potable, clear, or other measure of water quality mentioned) of water collected for **this use** on this particular trip relative to the other places you might have collected water for the same use? *Ask this question separately for each trip.*
14. On this particular trip, were there any other pleasant or useful things that you did such as collecting some fruit, small animals, insects or fuelwood, or you might have stopped at your garden or visited a friend. *List the **joint activities** indicated for each trip separately.*

15. On this particular trip at the site/place you visited to collect/use water, were there any **rules/restrictions regulating** any aspect of by whom, how, and when water collection is

done. For example, use of drums, scotch carts, livestock use, other villagers, time of use or quantity collected.

16. In the last month did you collect/use water for production e.g for:
Brick molding Yes....1 No....0
Beer brewing Yes....1 No....0
Cotton Spraying Yes....1 No....0
Watering gardens Yes ....1No....0
Other (specify) ________________________________
(If yes to any of these activities, ask questions 1 to 16 for each of the activities filling in the information in the trip log sheet on page 13. For watering gardens, only record information for trips made in the last week if there were no trips recorded for the last three days, and not the whole month)

17. In the last month, did you have access to as much water for **productive**/commercial uses (watering gardens and livestock, brick molding, beer brewing) as you had needed?
No....0 Yes....1 Don't know......2
Why/Why not________________________________

C.2 Attributes of alternative water sites not visited in the last week

*(Ask the following questions for each of the **different** points, sites, areas, places and type of water source that the household might collect water from during the year (listed in section C of the round 1 questionnaire. Ask questions 18 to 24 while filling in the relevant boxes in the table on page 15.*

18. How much (**quantity**) of water do you think you would have collected if you had gone to ________________ *(insert site name/place)* in the last three days? *Ask for each site in the choice set listed in section C of the first round questionnaire not visited in the last week and write down the quantity indicating units and type of container and means of carrying it (e.g. manual, scotch cart) that would have been used*

19. How long (**time**) do you think you would have been away from home, to collect the water, if you had collected water from ________________ *(insert site name)* instead in the last three days? *Ask for each site in the choice set listed in section C of the first round questionnaire not visited in the last week and write down the amount of time in hours and minutes for each place in their choice set.*

20. How would you rate the **availability** (abundance or quantity of water) relative to the other places you might collect water from, in the last three days? *High, Medium or Low? (Rating: 1-High, 2-Medium, 3-Low, 9-Don't Know). Ask this question separately for each place in their choice set.*

21. How would you rate the **quality** (e.g. is it contaminated, salty, oily, potable, rusty, clear, or other perceived measure of water quality mentioned) of water relative to the other places you might collect water from, in the last three days? *Ask this question separately for each place in their choice set.*

22. At ____________ (*water source/site*) that your household could have visited to collect water in the last three days are/were there any **rules/restrictions regulating** any aspect of

by whom, how, and when water collection is done. For example, use of drums, scotch carts, livestock use, other villagers, time of use or quantity collected.

23. At ____________ (*water source/site*) or along the way there, or on the way back home, are there any pleasant or useful things that you could have done had you visited this place to collect water in the last three days? For example there maybe some fruit, small animals or insects that you collect. Or you might be able to stop at your garden or visit a friend. *List the **joint activities** indicated, or write down any other activity that is mentioned to occur when away from home collecting water for each place in their choice set not visited in the last week.*

24. What was the main **reason** for your not visiting ______________ *(place)* to collect water in the last three days? *Ask for each water collection site in the choice not visited in the last week.*

Trip log for water collection visits

Trip#	2 Day	3 Who went	4 Source/ site/place	5 Who sent and who chose site	6 Why chose site	7 Accompanied	8 Time length of trip	9 a)Qty b)Qty wanted	10 How Head, Cart	11 Use of water	12 Availability	13 Quality	14Joint activit	15 Rules
1														
2														
3														
4														
5														
6														
7														

Site Attributes for Sites Not Visited

Q1. Water Source	Q18. Quantity	Q19. Time	Q20. Availability	Q21. Quality	Q22. Rules	Q23. Joint Activity	Q24. Reason
1. Shallow well (*tsime*)							
2.Deep well (*mugodhi*)							
3. Borehole							
4.Spring (*chitubu*)							
5.Sponge							
6.Stream (*svikova*)							
7.River (*rukova*)							
8.Riverbed pool *Mufuku*							
9. Dam							
10. Pool in waterway (*dziva*)							
11.Stagnant Pool (*Guvi*)							
12. Tap							
14. Other (specify)							

~~~~~~~~~~ THANK YOU FOR PARTICIPATING IN THIS SURVEY ~~~~~~~~~~
~~~~~~~~~~

Round 13 Questionnaire

Date -- Ward No./SSCF No. -----------------------------------
--
Village--- Family Name--
--
Number of respondents---------------------------- Enumerator's name ---------------------------------
--
Start Time of interview------------------------------ End Time of interview------------------------------
-

Household Characteristics

(Ask to interview either the adult male or adult female identified in section A of the first round questionnaire for this section.)

A.1 Homestead demographic composition

1.) *How many kitchens (households) are there at this homestead?* _______________

2.) *How many people eat from each kitchen at this homestead (members of each household/kitchen that live here) (ask for each of the kitchens mentioned in Q2.)?*
Kitchen 1 _________________ Kitchen 2 _________________
Kitchen 3 _________________ Kitchen 4 _________________

3.) *How many people eat from your kitchen (members of your kitchen that live here)?* ____________

4.) *How many wives does the household head of your kitchen have? (please make sure that this is the head [saimba] of the respondent's kitchen)* ________________

A.2 Wealth and asset characteristics

5.) *How much personal [yenyu imi]* __________ *land does your household have (in acres, hectares, number of trees or garden beds)? (Ask for each land use type listed below and indicate the type of units used)*
Total (*yose*)__________________ Dry land _________________
Irrigated land_________________ Wetland (*dambo/doro*)_____________
Paddocks _________________ Grazing Area _________________

6.) *Does your household own* __________ *(ask for each item, animal or personal water source in the list and indicate number of units owned)?*

Item	Yes/ NO Number	Animal	Yes/ NO Number	Water Source	Yes/ NO Number
Scotch cart		Cattle/Cows (all)		Shallow well (*tsime*)	
Plough		Draft Cattle		Deep well (*mugodhi*)	
Cultivator		Milk Cows		Borehole	

Wheelbarrow		Donkeys		Spring (*chitubu*)	
Manual saw		Goats		Sponge (*dekete*)	
Radio		Sheep		Stream (ru*kova*)	
TV		Chickens		River (*rwizi*)	
Bicycle		Ducks/Turkeys		Riverbankpool (*mufuku)*	
Kerosene stove		Other		Dam	
Kerosene lamp		Other		Natural Pool (*dziva*)	
Solar Panel				StagnantPool (*Guvi*)	
Other				Tap	

7.) **TAP expenditure** - *How much did you pay per month for your tap in $ (water charges - ask those who have a tap) Aug 2002 ________ Sept 2002________ Oct 2002 _______Nov 2002_______ Dec 2002_______Jan 2003_______ Feb 2003_______ Mar 2003_______ Apr 2003________*
May 2003_______ Jun 2003________ Jul 2003_______ Aug 2003______Sept 2003________

A.4 Input and resource stocks

8.) *Do you have any ________________?*
9.) *How much/how many of ____________ do you have in quantity or dollar amount? (Ask both Qs for each listed item and any others. Detail item's intended use and when it will be used).*

Item	Yes/ NO	Qty/Amount (specify units)	Price/ Value $	Intended Use of stock
Maize Grain				
Mealie Meal				
Cash Savings				
Firewood				
Fodder/Hay/ Crop Residue				
Fulltime worker				
Fertilizer				
Seed - Maize				
Seed - Cotton				
Other				

A.5 Harvest Yields

10.) *Did you harvest any ________________ this year?*
11.) *How much of ____________ did you harvest in quantity or dollar value?*
12.) *Did you sell any ____________ this year?*
13.) *What quantity of ___________ did you sell?*
14.) *At what price or how much did you sell______________?*
15.) *What will you do with the rest of __________ which you are keeping?*
(Ask all questions for each listed item and ask about any others. Details may include the item's intended use and when it will be used).

Item	Yes/ NO	Qty/Amount harvested	Sold Yes/No	Qty/Amount sold	Price/ Amount sold $	Use of stock
Maize						
Cotton						
Sunflower						
Wheat						
Groundnuts						
Round nuts						
Tomatoes						
Cabbage, Veges						
Onions						

Beef/Cows						
Goats, Sheep						
Chickens, turkey						
Firewood						
Fruit						
Other						

NB: The Remaining Sections of the Round 13 Questionnaire are Identical to the Round 2-12 Questionnaire in Appendix 9-II