University of Alberta

An Economic Analysis of Afforestation in Rural Zimbabwe

by

Pamela Anne Jagger ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Science

in

Forest Economics

Department of Rural Economy

Edmonton, Alberta

Spring 1999

0-612-40062-X

University of Alberta

Library Release Form

Name of Author: Pamela Anne Jagger

Title of Thesis: *An Economic Analysis of Afforestation in Rural Zimbabwe*

Degree: Master of Science

Year This Degree Granted: 1999

Pamela A Jagger

36 Sierra Morena Way S.W.,
Calgary, Alberta T3H 3C3

31 January, 1999

Trees are useful to man in two distinct ways: as producers of a wide variety of goods, commonly called "forest produce", and as custodians of favorable environmental conditions. It would not make sense to try to quantify one of these functions as being more important than the other. Both are indisputably essential to the well being, and indeed the survival, of man.

Gunnar Poulsen

University of Alberta

Faculty of Graduate Studies and Research

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled *An Economic Analysis of Afforestation in Rural Zimbabwe,* submitted by Pamela Anne Jagger in partial fulfillment of the requirements for the degree of Master of Science in Forest Economics.

Dr. Martin K. Luckert

Dr. Vic Adamowicz

Dr. Jim Beck

Date approved by thesis committee Feb 2/99

This thesis and the many hours of work that have gone into it are dedicated to my parents, Bob and Marion Jagger who have given me two of the greatest gifts: strength of character and love.

Abstract

In Zimbabwe rural afforestation efforts by government and non-government organizations have focused on the formation of cooperative tree growing groups to undertake agroforestry or small-scale afforestation projects involving the propagation of the exotic species *E. camaldulensis*. However, since the inception of several afforestation projects in the mid-1980's the majority of woodlots that have been established are located on individual smallholdings; cooperative tree-growing groups are not frequently observed in Zimbabwe's Mutoko District. Economic return estimates suggest that woodlots planted as individual smallholdings and cooperative tree growing ventures are both economically profitable, but that subsidies play a significant role in motivating cooperative groups to grow trees. Socioeconomic and biophysical analysis indicates that there are characteristics that may be attributed to each tenure type and that the biophysical rate of tree growth may influence economic returns on investment. The policy implication is that if the adoption of cooperative woodlots to remain a major focus of extension efforts, than the provision of subsidies and extension support to cooperatives to plant trees should be intensified, and issues of institutions and governance with respect to cooperative groups more closely examined.

Acknowledgements

Fist and foremost I would like to acknowledge the International Development Research Council of Canada (IDRC), and more indirectly the Canadian people for their financial support through the Value of Trees Project. It is my sincere hope that Canadians are not only aware, but also proud of the impact that the financial and technical assistance they contribute to countries in need has on the daily lives of rural people in Africa.

I thank the people of Mutoko District, Mashonaland East Province, Zimbabwe, who were kind enough to invite me into their lives for a brief time to let me learn about how the majority of people in the world live and conduct their daily business. I owe particular acknowledgment to the people of Nyahunure Ward for their kindness, hospitality, honesty and joy. Thanks to Councilor Odios Nyakudanga for making every effort to support my project and going out of his way to make me feel at home in Mushimbo. I am grateful to my Research Assistants: Passmore Kagoro, Wensolos Musekiwa and Peter Tsiga for their amazing hard work and long days spent in the field, and also for their collective sense of humor, which got us through many windy days of tree measuring. Thank you also to the Mushimbo Clinic for welcoming me each time I returned to your village and providing me with a tree to set my tent under.

I have two institutions to acknowledge. First the Institute of Environmental Studies at the University of Zimbabwe. Thanks to Dr. Bruce Campbell, and his support staff: Felicity, Grace, Annie, Sherman, and Chipo. Many thanks to Solomon Mafuta for his exceptional Technical Assistance while in the field, sense of humor and stories of how Zimbabwe has changed over the years. I learned a great deal from you. I would like to thank Witness Kozanayi for doing a wonderful job of training Passmore, Wensolos, Peter and myself on the art of surveying in rural Zimbabwe. Thanks also to Allison Goebel, Isla Grundy, Billy Makamuri and Alois Mandondo who answered my questions, edited the earlier drafts of my survey and provided a collegial environment within which to work.

From the Department of Rural Economy at the University of Alberta I wish to acknowledge first and foremost my advisor Marty Luckert who provided me with an exceptional and challenging Graduate school experience and introduced me to Africa. Thanks also to the following members of the academic staff who I feel have significantly contributed to my experience and shaped my views as a Forest Economist: Vic Adamowicz, Michele Veeman, Terry Veeman, and Jim Unterschulz. Thanks to Steve Titus; Department of Renewable Resources for comments regarding my tree measurement data, and Jim Beck, Chair, Department of Renewable Resources who sat on my thesis committee. In addition I would like to acknowledge the hard work and contribution of the support staff in the Department of Rural Economy, in particular, Dawn in the library, Wendy, Liz and Judy in the front office, and Jim and Chris in the computer lab. Finally from the Department of Rural Economy I have many contemporaries, colleagues and friends to thank for their ongoing support and for providing a challenging and productive environment within which to work. Thanks to Glen Armstrong, Donna Dosman, Michel Haener, Renée Kim, Godfrey Kundhlande, Yasmin Rahemtulla, Miriam Renner, Fiona Salkie and many others.

From the Canadian Forest Service, where I worked periodically during the time I was doing my degree, I would like to acknowledge Janaki Alavalapati, Peter Boxall, Dianne Korber, Bonnie McFarlane and Bill White for providing an enjoyable and productive working environment both before my time in Africa and after. I would also like to acknowledge Ken Chomitz from the World Bank, and Roger Sedjo of Resource for the Future. I have benefited greatly from being able to discuss my thesis work and developing country forestry problems in general with both of you.

Possibly my greatest support over the past three years has come from a remarkable group of friends, some whom I've known for a very long time, and others whom I've had the good fortune to come to know while doing my studies. From my time spent in Zimbabwe, Oliver Baethge, Erica Bornstein, Ben Deaville, Dorthe Stecher, Jo Terry, Claire Trumper and many others. Most of these people I came across at Jill and Bill McCracken's house, the folks who provided me with a safe and comfortable place to stay while in Harare. Finally, I would like to thank friends in both Canada and the United States who have offered me not only friendship, but who have continually expressed genuine interest in both my studies and thesis project, Troy Bauman, Kelly Blackett, Krista Boyd, Maryetta and Gus Buysen, Heather De Santis, Dianne Gereluk, Shauna Kelly, Dan O'Brien, Tanya Padberg, Doug Pratt, May Tweedle, Anu Varma, Susan Westenberger, Scott Williams and Heather Yewchuk. It many ways I feel as though I have been able to share a small bit of my experience with each of you, and that has given me great joy.

PJ

Table of Contents

List of Tables

List of Figures

List of Plates

List of Abbreviations

ADA – Agricultural Development Assistance, a European Union funded NGO
AGRITEX – Agricultural Extension Service
BA – Basal area
BCR – Benefit-cost ratio
COOPIBO – A Belgian NGO, well established in the Mutoko region
DBH – Diameter at breast height
EIRR – Economic internal rate of return
FEO – Forestry Extension Officer
GO – Government Organization
IRR – Internal rate of return
LEV – Land expectation value
LMH – Lorey's mean height
MAI – Mean annual increment
NGO – Non-government organization
NPV – Net present value
RAP – Rural Afforestation Project
TNG – Tree Nursery Group
TTL – Tribal Trust Lands
VIDCO – Village Development Committee

Chapter 1 - Introduction

This Chapter presents a brief overview of the background to the research problem, the objectives of the study and a general overview of the thesis structure.

1.1 Woodland resource pressures and afforestation policy in Zimbabwe

The rural population of Zimbabwe is largely dependent upon woodland resources for the provision of timber for use as building poles, fuelwood, and a variety of non-timber uses such as the supply of fruit, honey and insects for household consumption (Clarke, 1994). Scholars hypothesize that historical over-exploitation of woodland resources, increasing populations relegated to marginal lands (communal areas), and land tenure policies which fail to create effective incentives to manage resources sustainably have left rural smallholders with a seriously degraded land base (Makamuri, 1995; Moyo *et al.*, 1991; Scoones *et al.*, 1993). In several of Zimbabwe's communal areas demand for woodland resources by rural populations is too great, causing shortages of woodland produce and the subsequent depletion of the existing resource base.[1] This situation has encouraged rural farmers to consider the propagation of fast growing exotic tree species to meet current demands for wood and non-wood produce.

Awareness of woodland resource pressure in Zimbabwe has evolved over the past 75 years. Excessive deforestation on communal lands was observed by the Southern Rhodesian Land Commission as early as 1925 (Makamuri, 1995). The cause of deforestation was acknowledged to be overcrowding of tribal groups on marginal agricultural land, combined with illegal timber harvest by mining companies. In 1928 the *Communal Areas Forest Produce Act* attempted to address issues of illegal harvesting of timber from reserve areas by mining companies, but failed to address overcrowding and resource scarcity on the tribal lands. State initiated afforestation efforts commenced in 1948 with the introduction of *The Forest Act* (Scoones and Matose, 1993). This legislation involved the evolution of the Forestry Commission whose primary mandate would become the promotion of exotic tree species. By the late 1940's the first forestry employees were trained specifically for the purpose of conducting forestry extension work on the Tribal Trust Lands (TTL). Extension workers were responsible for both the establishment of tree seedling nurseries and introducing tree planting initiatives (Banks, 1981).[2]

---

[1] In 1982, 77% of the total demand for indigenous timber was for fuel and 19% for poles (for use as construction material). In Zimbabwe more that 4 million tones of wood are consumed annually, the equivalent of clearfelling 100 000 ha, or the sustainable yield from 2 million ha of reasonable quality wood, or more than 10 million ha of sparse cover on rough grazing land. Acute shortages are currently observed in regions where the average population density exceeds 20 persons per square kilometre. This is the case in four Zimbabwean provinces: Manicaland, Mashonaland East, Masvingo and Midlands (Moyo *et al.*, 1991).

[2] Present day Communal Areas were formally known as Tribal Trust Lands. Under the colonial administration tribal populations were confined to these lands.

Early attempts at afforestation were only marginally successful as the logistics of carrying out forestry projects in remote areas proved too much for the colonial government. The "Colonial Forestry Package" as Makamuri (1995) refers to it, did not see the first successful wide scale promotion of *Eucalyptus* species until the early 1970's. Eucalypt seedlings were distributed first to schools with tree-growing projects yielding very low seedling survival rates. State intervention persisted throughout the 1970's and by the end of the decade eucalypts had gained favour with schools as well as the local elite in many of the communal areas.[3]

Throughout the past thirty years, the colonial administration and the post-independence government as well as several local non-government organizations (NGOs) have introduced numerous rural afforestation schemes.[4] Several of these initiatives have promoted the planting of the exotic species, *Eucalyptus camaldulensis*, selected for its rapid growth rates and genetic plasticity. Arguably the most intensive post independence afforestation project is the Rural Afforestation Program (RAP) which commenced in 1981.[5] This program was a World Bank initiative that offered financial and technical support to the Forestry Commission, as well as local NGOs. The focus of the Program was to establish eucalypt nurseries and block plantations primarily for the provision of fuelwood. The propagation of *E. camaldulensis* for use as building poles and the other market and nonmarket benefits it provides were auxiliary motivations of the project (Makamuri, 1995).

One of the main objectives of the Rural Afforestation Program was to promote the establishment of cooperative woodlots. This goal was and still is shared by both government extension agencies and local non-government organizations; substantial subsidies in the form of extension support and inputs to production are provided to tree growing groups (COOPIBO, 1992). A major unanticipated outcome of the RAP is a high frequency of woodlots owned by individual smallholders rather than cooperative tree growing groups (Mandondo, 1993). If this trend is indicative of smallholder preferences, Mandondo (1993) suggests that future tree planting initiatives should be directed toward individual household plantings. This thesis will provide a comparative economic analysis of the incentive structures motivating individual smallholders and cooperative tree growing groups to establish eucalypt woodlots in the Mutoko communal area.

---

[3] Makamuri (1995) suggests that the adoption of exotic tree species by local elite may be attributed to the perception of tall trees as a symbol of status and wealth.

[4] Among the NGOs involved are: COOPIBO a Belgian NGO, and Agricultural Development Assistance (ADA) funded by the European Union.

[5] The Rural Afforestation Study was published by the Whitsun Foundation in 1981. This report outlined a five-year forestry development strategy with the primary goal of slowing deforestation on the Tribal Trust Lands by providing fuelwood. Acknowledgment of other market and nonmarket uses associated with *Eucalyptus* were not discussed or quantified in any of the pre-project literature (Makamuri, 1995).

1.2 Objectives

It is hypothesized that the outcome of afforestation projects such as the Rural Afforestation Program may be affected by economic incentives that will motivate individual smallholders and/or cooperatives to plant trees. The central objective of this thesis is to address the following questions:

- What are the economic returns to smallholders and cooperative tree growing groups from planting *E. camaldulensis*?
- What factors influence the economic returns on investment in tree growing projects?
- Are there characteristics associated with individual smallholders and/or cooperative tree growing groups that provide insight into why so many individual woodlots were undertaken?

By understanding more about the economic incentives facing woodlot owners, it is hoped that forestry related aid projects may be better informed.

1.3 Thesis structure

Chapter 2 includes a brief historical overview of the evolution of the present communal area land tenure system in Zimbabwe, as well as a review of the theory pertaining to the economic incentives associated with individual smallholder and cooperative efforts to plant trees. A brief literature review of studies that assess the economic valuation of exotic tree species in small-scale afforestation and agroforestry in a smallholder and/or cooperative context is also presented. In addition, a review of the ecological debate surrounding *Eucalyptus* species and their use in small-scale afforestation and agroforestry systems is provided. Chapter 3 includes the methods used to estimate economic returns, an overview of the study area and questionnaire, and a discussion of the general characteristics of woodlots in the Mutoko communal area. In Chapter 4 the basis for sensitivity analysis with particular reference to the opportunity cost of land, wage rates, output prices and average rates of harvest are presented. Chapter 4 also includes the economic return estimates. Chapter 5 illustrates the methods used to estimate two econometric models. Explanatory variables to be used in the models and their expected signs are discussed; the models are formally expressed and estimation results presented. Chapter 6 summarizes the results, and provides concluding remarks. In addition policy recommendations for future afforestation projects, limitations of the study and some suggestions for future research are discussed.

Chapter 2 - Literature Review

Chapter 2 provides an overview of the literature pertaining to the factors that are thought to influence the key explanators in each of the three research questions presented in Chapter 1. The central discussion is focussed around the issues of economic returns on investment and land tenure, and is prefaced by a brief overview of the history of land tenure in Zimbabwe. To provide a frame of reference for the analysis presented in Chapter 4, a brief overview of the literature pertaining to economic valuation of exotic tree species in small-scale afforestation and agroforestry is presented. Finally, as a component of the debate surrounding the use of *Eucalyptus* species in small-scale afforestation projects and agroforestry systems, the ecological impacts of *Eucalyptus* are discussed.

2.1 Historical overview of land tenure in Zimbabwe

In the majority of the sub-Saharan African nations, rights associated with using and holding land have changed a great deal over the past two centuries. In many cases historical context has played a significant role in motivating the current state of land ownership. The following is a brief overview of the historical events that have influenced the existing land tenure system on Zimbabwe's communal lands.

Prior to colonization, land tenure in Southern Africa could be defined as "customary or tribal" (Gluckman, 1945). The central premise of this type of tenure is the right of every tribe member to a certain minimum use of the tribe's territory. This pattern of use differs from the legal constructs we acknowledge today such as usufruct rights, ownership and possession of land. Tribal land tenure was closely linked to the social and political organization of the tribe. Land was held and worked primarily to fulfill the subsistence needs of indigenous society (Gluckman, 1945).

The tribal land tenure system was significantly altered under the colonial administration established in 1923.[6] A primary outcome of the introduction of western land holding systems was the evolution of land into a negotiable asset. The commercialization of land served the needs of the colonial administration as higher production levels of export earning cash crops could be expected from lands commanding a higher market value. A land market replaced interpersonal allocation of land, and the need to have holdings formally demarcated and documented introduced rigidity into the system. These events lead to the designation of tribal peoples to Tribal Trust Lands, which are known to be marginally productive. Indigenous peoples were allowed to maintain "customary land tenure" while on the Tribal Trust Lands, however villages were expected to remain stabilized (Yudelman, 1964).

[6] The British established the area of land currently known as Zimbabwe as a self-governing colony, Southern Rhodesia, in 1923.

By the time of independence in 1980, Zimbabwe had three main distinct classes of land tenure, state land, communal areas and commercial land (Bruce *et al.*, 1993). Western land tenure institutions were well established on the communal lands. Changes in Zimbabwean land legislation after independence were minor and included the evolution of new property rights arrangements, namely Resettlement Areas, and the abolition of laws imposing racial restrictions on land ownership. Because much of the country's foreign export earnings were, and remain, reliant upon commercial land for the production of cash crops such as tobacco, coffee and tea, there was little incentive for the new government to entirely restructure the land holding system. The outcome of this is the maintenance of the status quo on the communal lands, with population pressure continuing to infiltrate an over-utilized land base.

The current system of land tenure in the communal areas is characterized as land title based on the right of avail. *The Communal Lands Act* of 1982 repealed the *Tribal Trust Lands Act* of 1979 (Moyo *et al.*, 1991). This resulted in the power to use and occupy the communal lands resting with District Councils. Land allocation is based on decisions made by the traditional chief or District Council who acts upon the advice of a Village Development Committee (VIDCO). Whether the seat of power actually resides with the traditional or political hierarchy is variable among the communal areas, and is based largely on historical context. The rights conferred upon the land holder include the rights to cultivate the land, graze livestock, take timber for building and for fuelwood, use water and occupy a site on which to build a house (Moyo *et al.*, 1991). Land may be acquired through marriage, a convention of the tenure construct that precludes unmarried women from holding land; however, widows may inherit rights to land. An interesting feature of the communal land tenure system is that rights of avail are not part of Zimbabwe's written laws, and are thus enforceable through consensus only (Moyo *et al.*, 1991).

2.2 Impact of land tenure on decision making and economic incentive structures

As our knowledge of small-scale afforestation, agroforestry techniques and rural development expands, the importance of considering the entire range of social and institutional incentives, in addition to traditional financial incentives becomes increasingly evident. The following section provides an overview of the literature pertaining to the various factors that drive decisions influencing economic returns and the choice of land tenure system under which to plant trees.

Sub-section 2.2.1 provides a brief review of the literature that focuses on the role that market and nonmarket benefits play in influencing tenure type.[7] That discussion will be followed by two sub-sections that present literature regarding incentives to plant trees individually and cooperatively.

The remaining three sub-sections briefly touch upon the topics of tenure security and its' role in incentives to tree plant, socioeconomic factors that influence tree planting decisions, and finally a brief overview of the importance of the biophysical performance of the resource.

2.2.1 The role of market and nonmarket values and costs in creating incentives to plant trees

Both market and nonmarket benefits and costs play a role in defining the overall incentive structure motivating tree planting. Although benefit-cost analysis of social forestry projects has extended well beyond consideration of the singular relationship between market benefits and costs as financial incentives, in many cases the full range of nonmarket benefits and costs are overlooked.[8] Identifying the complete portfolio of benefits and costs is necessary if the holistic nature of the relationship between trees, quality of the environment and human values is to be fully understood.

Market benefits or costs are those outputs and inputs that can be easily quantified in monetary terms. Inputs or costs of forestry projects are usually captured in the following categories labour, land, equipment, raw materials, and structures and civil works required (FAO, 1992). Outputs are understood to be all outputs produced by the project and its' ancillary activities, which would not have been produced in the absence of the project (Dasgupta *et al.*, 1972). Nonmarket benefits are more complex to identify and quantify. Some positive nonmarket values of forestry projects include watershed management, natural forest conservation and skilled labour which is the result of training undergone through the project (FAO, 1992). Nonmarket values are externalities that arise when the existence or operation of a project results in a net gain or loss to society; this gain or loss is not reflected in the willingness to pay for the output of the project (Dasgupta *et al.* 1972).

The smallholder or cooperative's incentive to invest in tree growing projects or other land uses is largely dependent upon the economic returns that the particular land use is projected to have. Return on investment is comprised of the summation of market and nonmarket values and costs. The household or cooperative group will guide their investment decisions according to the solution that optimizes utility or profit. There are costs that might discourage the smallholder or cooperative from incorporating trees into her portfolio, and returns and other benefits that will prompt the smallholder or cooperative to incorporate them (Arnold, 1984). It may be the case that either market or nonmarket benefits associated with tree crops are more effectively realized under certain institutional arrangements. For example, when trees are located in a cooperative woodlot,

---

[7] In this analysis market benefits are poles and fuelwood. Nonmarket benefits or values are benefits such as windbreaks or other benefits that did not a directly motivate the smallholder or cooperative to plant trees, but result in some net benefit to the tree owner.

[8] Financial analysis can be defined as, "the information on actual amounts and timing of inflows and outflows of funds" (Laarman *et al.* 1991).

the nonmarket values of the tree crop that are linked to the physical location of the trees (for example, windbreak values) are difficult for all group members to benefit from equally.

It is important to note that stakeholders may have different value estimates associated with their willingness to invest resources in afforestation projects. For example, it may be the case that the smallholder, forest service and society will have different factors contributing to their individual benefit-cost relationships (Arnold, 1984). The smallholder may be motivated by improving household food and income situations, the forest service motivated by the desire to establish low cost plantations, and society motivated by a desire to increase carbon stores or improve biodiversity. Taking into account all of the factors discussed in this section, the complex nature of identifying the full range of benefits and costs for each of the stakeholders involved in tree growing projects becomes evident. As the range of socioeconomic tools is expanded and refined, we will be better able to model these complex systems.

2.2.2 Incentives to tree plant on individual smallholdings

Literature on the subject of rural economic incentives implies that under certain circumstances different institutional constructs may yield more efficient economic and social outcomes (Barrows and Roth, 1989; Bruce and Fortmann, 1989; Cernea, 1988; Cernea, 1981; Filius, 1982; Francis, 1987; Gregersen *et al.*, 1989). Proponents of rural afforestation programs may target individual smallholders to employ land in tree production. Gregersen *et al.* (1989) cite: perceived net benefits, relative security or risk involved in the project and the opportunity cost of undertaking tree planting within the context of the total farming system as factors which will influence the smallholder's incentive to grow trees.

Perceived net benefits may be approached from a different sociological perspective by individual smallholders than for other units of social organization involved in tree growing. Smallholders may see a direct correlation between inputs such as labour and materials, and outputs. This provides the decision maker with a direct, easily understood, proportionate and less uncertain correlation between investment and returns (Gregersen *et al.* 1989). Further, distribution of benefits is largely simplified under individual ownership and management authority resides with the primary household decision maker rather than an amorphous entity which may be comprised of a group of individuals with competing priorities.

Relative security or risk may be a major factor influencing smallholder decisions. Whether or not to plant trees on a plot of land may be influenced by insurance against risk and investment for economic return (Livingstone, 1986). Earning income for the household unit is a major incentive in eliciting widespread participation at the household level in tree growing activities (Gregersen *et* *al.* 1989). Investment in tree growing at the smallholder level is often motivated by a desire to diversify cropping systems which spreads risk over land uses, often reducing the impact of ecological disturbances or market failures.

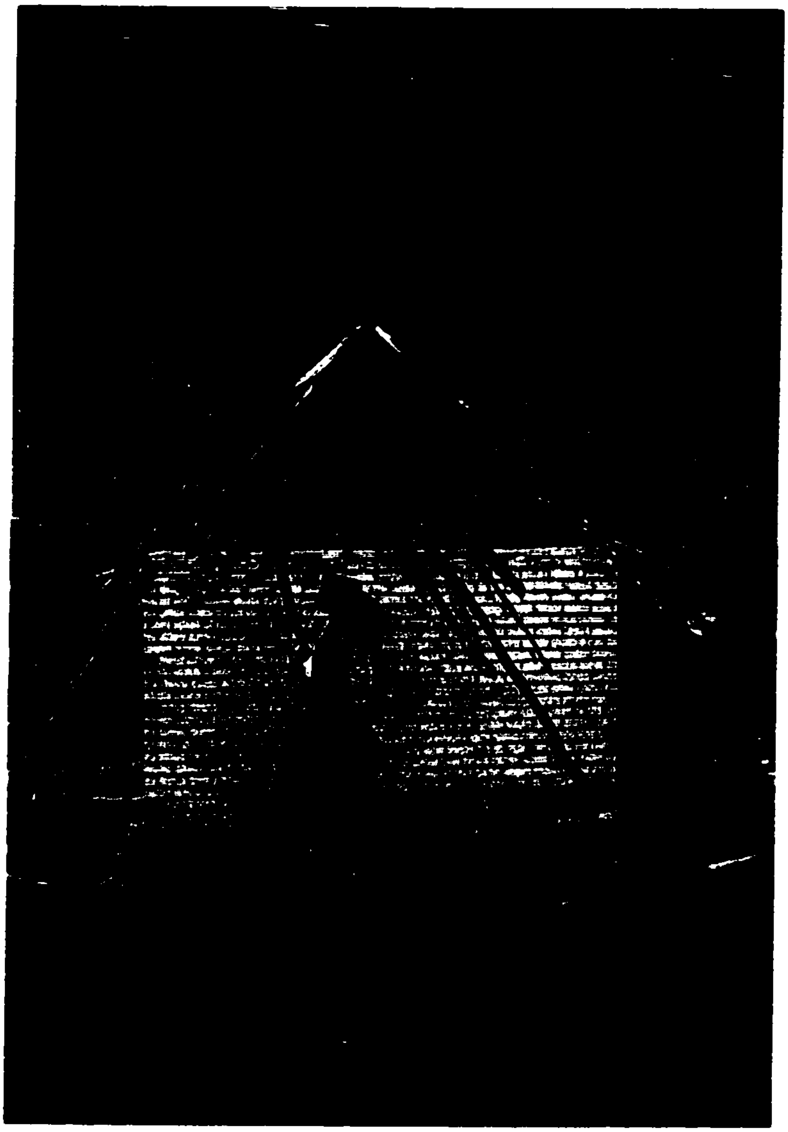

Plate 2.1: Individual smallholders roofing hut with *Eucalyptus* poles

Smallholders are faced with defined budget constraints and may seek to choose the resource allocation solution that will yield the greatest returns. Opportunity cost of land may be a major factor in this decision making process. Bruce and Fortmann (1989) suggest that because trees are slow-maturing, that they will be assessed by smallholders differently than low risk annual crops which offer almost immediate returns on investment and little chance of significant losses. It is argued that initial investment costs of tree planting are substantially higher than for other frequently observed land uses, and that there are considerably higher opportunity costs associated with propagating tree crops as the benefits can only be recouped in the long run. A positive aspect of small-scale tree planting at the individual smallholder level is the ability to increase the productive capacity of land. For example, smallholders are not forced to displace existing land uses when they plant trees on farm boundaries, internal field borders and watercourses (Gregersen *et al.* 1989).

Osemoebo (1990) conducted a study of an afforestation project in Nigeria which focused on why smallholders were unwilling to engage in tree growing at the individual household level. Factors influencing lack of success of this afforestation program included inadequate information about the farmer's social and economic behavior (for example, discount rates), as well as lack of information regarding the farming system and silviculture of trees. In addition, unattractive short-term income incentives compared with food crops, and poor working relations between farmers and foresters contributed to the lack of success for this particular afforestation program. Conversely, in the Mbeere region of Kenya, there is a high correlation between economic advance (for example, high cash crop income, fair communications, good soil) and desire for individual woodlot ownership (Brokensha and Glazier, 1973). Tree planting activities promising high returns are easily adopted by smallholders in rural areas. These factors highlight the importance of providing appropriate incentives when promoting tree planting in rural communities, and speak to the necessity of incorporating a wide range of socioeconomic information into the policy making process.

2.2.3 Incentives to tree plant on cooperative plots

Rural afforestation projects often target cooperative groups. It is implicitly assumed that through cooperative ventures the flow of benefits from trees can be conserved and equally distributed among smallholders who represent the majority in rural communities (Arnold, 1984; Cernea, 1981; Runge, 1992). This hypothesis supports collective resource management at the village level. It is theorized that the free rider problem associated with public goods may be overcome through the joint use of resources. Public choice theory asserts that rational individuals will free ride under circumstances where the group is large or there is the potential for the individual to be excluded from the group (Wade, 1992). People will seek to act in a cooperative manner only when the free-rider problem is overcome. This will occur when individuals join together to plant trees under circumstances where there is a set of institutional arrangements that will negate the free rider problem.

The development community acknowledges that the majority of cooperative afforestation ventures are unsuccessful. Arnold (1984) suggests that the success of cooperative tree planting projects is predicated upon groups with shared economic objectives and situation, and socio-cultural homogeneity. The property rights literature is replete with references to the set of conditions that are required for the cooperative institution to motivate the equal distribution of benefits and the improvement of community welfare. A brief overview of the literature dealing with this topic is presented below.

Hyami *et al.*, (1985), Ostrom (1995), Runge (1992), Shepard (1992) and Wade (1992) present a portfolio of requirements for effective collective action. This portfolio includes:

- clearly defined boundaries (i.e. who is authorized to use the resource),
- rules which address how much of the resource may be appropriated by each individual,
- when and where resources may be appropriated and the technology that may be used ,
- the ability of group members to collectively modify operational rules,
- a well established monitoring system which allows for auditing of resource conditions and appropriation behavior,
- a staggered penalty system which links the severity of the misuse with the penalty,
- effective conflict resolution mechanisms,
- minimal rights of recognition to organize,
- rights need to be well defined, in some cased written down, agreed upon by all local people and defined such that they preclude outsiders from accessing the resource
- benefits of institutional change must exceed the costs in order for the change to occur.

If this long list of requirements is in fact what is required to establish successful cooperative ventures, it becomes evident why the accomplishments of cooperatives may be limited in situations such as those which exist on Zimbabwe's communal lands.

Runge (1992) proposes that in many cases joint use rights are the only alternative for groups where poverty is a factor and resources are scarce. High levels of uncertainty with respect to future income streams result from poverty, dependence on low value added outputs and a reliance on natural resources such as soil and water which are often characterized by random disturbances over time. It is known that the rural poor typically have less land and rely significantly more on common property resources to provide household subsistence needs (Jodha, 1986).[9] Highly risk averse individuals will act collectively to pool their risk, reducing the impacts of potentially negative project outcomes. The range of factors influencing the success or failure of cooperatives is linked to many factors well beyond the scope of economic and institutional incentives. For example, Livingstone (1986) notes that in many African cases, the likelihood of cooperative

[9] Jodha (1986) classifies the rural poor as landless labourers or those with small farm plots (<2 ha of dryland equivalent).

resolution of the common property problem has decreased where different ethnic groups have been brought into one common area

As a possible solution to the problems plaguing the success of cooperative action, Cernea (1981) proposes *ex ante* assessment of factors such as land tenure, community power structure and current patterns of usufruct rights to forest produce. This may facilitate the identification of the requirements for the cooperative venture to be successful. Cernea (1981) bases his assertion on an *ex post* sociological analysis of the World Bank sponsored *Hill Farming Project* in Azad Kashmir, Pakistan.[10] He notes that the actual flow of benefits was directed towards various social groups that were directly related to community power structure rather than to the total community. Land that was initially identified as being community land was often operated and used as private land by members of the community that had the power to exert their influence accordingly. Finally, the project relied on the support of individual farmers to act as relevant decision makers and as an executive decision making body regarding the distribution of benefits in cooperative ventures. Because the community administration was not directly involved in these decision-making processes, benefits tended to accrue to individuals rather than to the community on the whole.[11]

2.2.4 Tenure security

Afforestation and agroforestry are thought to be more capital or input intensive than traditional agriculture. Thus in the rural economy context, substantial investment in afforestation is required (Adeyojo, 1984). Security of tenure encourages the smallholder or cooperative to make the necessary investments, which may lead to significant economic gain. Place *et al.*, (1994) suggest that land tenure security exists when, "an individual perceives that he or she has the rights to a piece of land on a continuous basis, free from imposition or interference from outside sources, as well as ability to reap the benefits of labour and capital invested in that land, either in use or upon transfer to another holder". This definition has three main components: breadth, duration and assurance, with legal and economic dimensions.

Breadth or robustness of rights focuses on the bundle of rights associated with the land holding. The greater the number of rights associated with the parcel of land, the higher the economic value of the holding. This applies to incentives as the ability to transfer rights for example, either temporarily through rent or permanently through sale, is crucial to the recovery of returns from land improvement upon transfer or alienation of land (Migot-Adholla *et al.* 1994). Duration is

---

[10] This project commenced in the late 1970's and spanned a similar period of time as the Rural Afforestation Program in Zimbabwe.

related to the fact that time horizons must be sufficiently long enough to enable the smallholder or cooperative to recoup the full income stream generated by the investment (Place *et al.*, 1994). Trees are known to have a benefit stream that often extends far into the future. It is interesting to note that project planners have traditionally promoted fast growing exotic tree species perhaps with the intention of circumventing issues associated with the much longer time horizons required to grow indigenous tree species. Assurance relates to the ability of the smallholder or group to hold rights and duration of tenure with certainty (Place *et al.*, 1994). The concept of assurance is often complex as tenures, particularly those in developing nations, are known to be dynamic systems that change due to weak legal enforcement and limited resources.

Haley and Luckert (1990) cite tenure security as one of the key characteristics of forest tenures.[12] Tenure security is a function of the property right holders' perceptions, where, trust in the political system, past experience and the probability of social and political change are the factors defining security. Security will depend on the likelihood of renewal or replacement when the ownership agreement expires, whether or not there is a probability of use rights being negatively modified prior to the end of the agreement and the possibility of rights being expropriated without proper compensation.

The combination of these characteristics of tenure security form the basis for the traditional argument that ownership security affects investment incentives and the availability of resources to finance investment (Besley, 1995; Feder *et al.*, 1987; Gavin *et al.*, 1996; Haley and Luckert, 1990; Hayes *et al.*, 1997 and Roth *et al.*, 1994). Tenure insecurity may lead to reduced benefits over time; tenure security may lead to changes which will be minor, beneficial or non-existent (Haley and Luckert, 1990). These concepts are relevant to the question of what characteristics tenure types have, and provide the basis for why non-government organizations and government organizations (GOs) that are promoting cooperative tree planting offer extensive subsidies and/or rural credit to tree growing groups. The importance of tenure security is an integral component of the willingness of smallholders or groups to undertake afforestation projects.[13]

2.2.5 Impact of socioeconomic variables on incentives to tree plant

Socioeconomic characteristics of households or groups are known to have some influence on the factors motivating incentives to tree plant. Although there are numerous socioeconomic variables

---

[11] For further discussion of the factors influencing the success of cooperative tree growing projects in developing economies see: Bradley *et al.*, (1993); Fortmann *et al.*, (1992); Jodha, (1986); Murombedzi, (1990a) and Murombedzi, (1990b).

[12] Other characteristics of property rights include: comprehensiveness, duration, transferability, and right of tenure holder to economic benefits and exclusiveness. These characteristics are adapted from Scott and Johnson (1983).

[13] For further discussion of tenure security and its' relevance to rural afforestation projects see: Bruce *et al.* (1994); Fortmann *et al.* (1992); and Jackson (1984).

that may potentially be discussed, this presentation will focus on gender, level of education and indicators of household wealth.

2.2.5.1 Gender

Issues associated with the role that women have on influencing tree-planting decisions are relevant to afforestation problems in rural Zimbabwe. If policy is designed assuming the male household head acts as an autonomous decision maker in the household unit, traditional female motives for growing trees such as the provision of fuel for cooking and beer making, and other woodland produce needs associated with traditional female roles may be overlooked. On a daily basis women rely on forest produce for the provision of fuelwood, medicines and fruits for household consumption. This experience provides them with a very well developed knowledge of whether or not the timber and non-timber requirements of households can be met and sustained over time (Fortmann *et al.*, 1993). In recent years women have been forced to seek woodland resource sources situated further away from their homesites. Thus, it may be in the female's interest to establish sources of woodland produce either closer to home or on household plots.

In the case of individual family smallholdings, the incentive to plant trees becomes implicit in the female's ability to excerpt pressure on the household head to devote land to the propagation of tree crops. Relative to men, women in developing economies have fewer resources available to them, including land, labour, internal capital and external finance (Place, 1995). Fortmann and Rocheleau (1985) propose that the tree component of agroforestry systems are often planted in the places where women have usufrucuary rights, (i.e. croplands and fallows as well as the spaces in between the rows of men's crops and the spaces along hedgerows, roads etc.). In cases such as this, men's commercial needs are displaced by women's commercial needs, and distribution of household income may be significantly altered (Fortmann and Bruce, 1991).

An interesting component of the gender discussion that has particular reference to the problems examined in this thesis is the role that women have in cooperative tree growing groups. As was noted in the above section dealing with incentives to tree plant in cooperative groups, there is evidence to suggest that cooperative projects disproportionately benefit the wealthier and more powerful members of the social hierarchy. By directing cooperative tree growing efforts towards women and the poor, the shift of benefits away from women and the poor towards the better off can be circumvented (Cernea, 1981). This phenomenon is considered by NGOs and other organizations that promote tree planting, and often results in women's groups being the social segment that is targeted and endowed with the resources to plant trees.[14]

---

[14] For further discussion of the gender issues as they relate to rural afforestation see: Fortmann, (1985); Fortmann and Bruce, (1993); Fortmann and Rocheleau, (1985); Goebel, (1997); Hoskins, (1980) and Watson *et al.*, (1996).

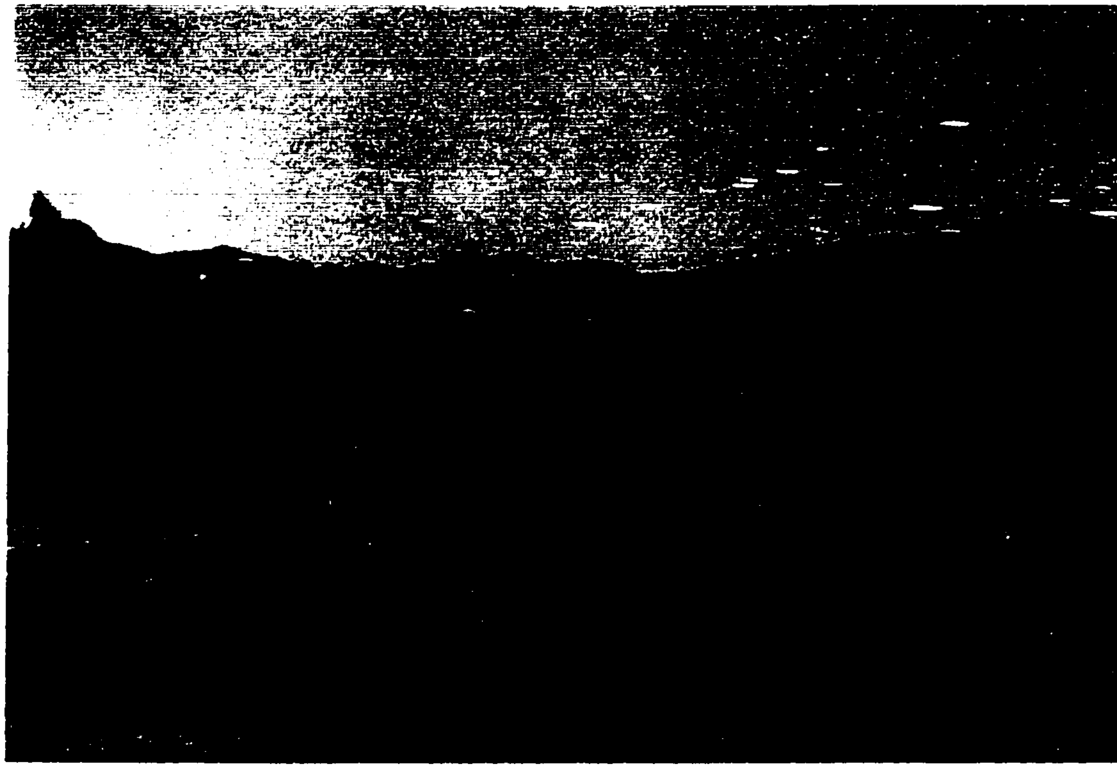

Plate 2.2: Young woodlot, women's cooperative tree growing group

*2.2.5.2 **Education and income level***

Level of education and household income are known to be positively correlated (Phillips, 1994).[15] Hyami and Ruttan (1985) view education as a component of institutional innovation that will generate new income streams. Often those members of society who are most highly educated take on positions that offer cash income such as teacher, extension worker, or a position within the local political hierarchy. Along with these positions comes increased social status and power to exert influence within the local community. This characteristic of the "income level-status" relationship is closely linked to the discussion presented in the above section dealing with incentives to tree plant in cooperative groups, and the phenomenon of individuals with community status gaining a disproportionate quantity of the benefits stream.

In the context of the afforestation problem, household wealth is assumed to have a significant impact on investment decisions regarding whether or not to tree plant in a cooperative group or individually.[16] Wealthy households will be more willing to diversify their cropping systems which implies a willingness to participate in tree growing projects (Gregersen *et al.*, 1989). Wealthy

[15]For a meta-analysis of the link between education and farm level efficiency/productivity see Phillips (1994).
[16]Household wealth in this context is considered to be a function of such component variables as: annual agricultural yield, number of cattle and number of household implements such as scotchcarts, ploughs etc., and type of dwelling, rather than an annual cash income.

Plate 2.3: Typical village scene, smallholder hut and compound

households more easily achieve diversification of household activities. Cash income allows for the purchase of resources such as seedlings and chemical pesticides, motivating positive economic returns facilitated by investment risk that is lower than it would be for households with fewer resources (Barrows *et al.*, 1989; Hayes *et al.*, 1997 and Raintree, 1991).

Tree crops are often considered sound, long term investments for individual households as they will provide cash income during drought years when cash crop outputs are low and/or livestock mortality high (Livingstone, 1986). In addition, wealthy households may desire to display their wealth to the community by planting tall trees in their household compounds, known in many African communities to be symbols of status and power (Makamuri, 1995). The question to the smallholder is whether or not he/she is willing to invest scarce capital and labour inputs to tree growing. This may be highly dependent on the current relative wealth of the smallholder.

2.2.6 Expected biophysical performance of the resource

Attention devoted to selecting appropriate species for afforestation and agroforestry projects has recently increased. It is becoming increasingly evident that choice of tree species and its associated benefits will have a significant impact on the individual smallholder or cooperative's willingness to participate in tree growing projects. Peters (1996) suggests that the final selection criteria of the chosen species will likely be based largely on economic criteria.[17] However, it is important to note that the biophysical performance of the tree species in question is not solely judged by fiber production as may be the case in many developed economy forestry models. Non-timber values and ecological system interactions are recognized and factored into decision making processes.[18] Raintree (1991) suggests that tree species must be selected based on the diagnosed needs and opportunities of specific social/geographic groups. It may be the case that individual smallholders of certain income levels will prefer to plant a particular tree species that poorer cooperative groups may not be interested in.

2.3 Economic valuation studies of exotic species used in afforestation and agroforestry projects

Economic valuation studies of exotic species used for afforestation and agroforestry projects are diverse and becoming increasingly abundant as the role of economics and sociology in shaping both small-scale afforestation and agroforestry policy becomes evident. The majority of economic valuation studies have been conducted during the past 20 years in conjunction with the emergence of agroforestry as an academic area of interest. Valuation studies generally fall in one of two categories, straightforward financial benefit-cost analyses of the primary inputs and outputs of production, or in depth socioeconomic analyses which incorporate shadow priced values and secondary benefits or costs associated with tree crops. The following discussion of the economic valuation literature pertaining to agroforestry species in the developing economy context is by no means exhaustive. It is intended to provide an overview and some brief examples of the tools commonly used by economists in estimating the value of trees in rural economies.

Basic benefit-cost analysis generally takes into account the financial costs (in the form of cash inputs and labour requirements), and financial benefits (stumpage for timber or market values for forest produce such as fuelwood). Internal rates of return, net present values, benefit-cost ratios and less frequently land expectation values and land opportunity costs, suitably discounted are the five benefit-cost criteria which are generally estimated. Benefit-cost analysis includes sensitivity analysis with varying wage rates, prices and discount rates. Some examples of financial benefit-cost analyses for various *Eucalyptus* species include: Ara *et al.*, (1990); Babu *et al.*, (1986); Osemeobo (1989), and Pohjonen *et al.*, (1988).

Babu *et al.* (1986), provides a representative example of financial benefit-cost analysis. Their study provides an analysis of afforestation for two *Eucalyptus* spp. grown on the denuded lands of the Doon Valley in India. *E. camaldulensis* and *E. grandis* were established in a small-scale

---

[17] Peters (1996) acknowledges that in addition to economic values social, cultural and ecological factors should also be considered.

[18] See the following section regarding economic valuation of exotic small-scale afforestation and agroforestry species for a discussion of the incorporation of non-timber and other values into benefit-cost analysis.

plantation format with the intention of providing fuelwood to rural populations. Costs included initial expenditures for establishment of the plantation, fencing, soil conservation methods and blanking (i.e. replacement of dead seedlings). The majority of costs were accrued in the first three years after planting with the only costs thereafter being those associated with annual maintenance, management of coppiced crops and an annual per hectare opportunity cost of land. Benefits were estimated solely on the value of fuel from the plantation. Other "intangible" benefits such as watershed management and the accumulation of leaf litter were not quantified and therefore were omitted from the final analysis. Financial economic return estimates based on a discount rate of 10% yield a benefit cost ratio of 1.28 for the main crop, and 1.68 for the sum of the main and first coppice crop. Based on these results it was concluded that *Eucalyptus* plantations raise the profitability of denuded lands in the Doon Valley.

Benefit-cost analyses that incorporate adequately shadow priced factors of production and outputs, as well as quantify secondary benefits and costs associated with exotic agroforestry species are becoming increasingly more common. Anderson (1987) suggests that, "complete benefit-cost analysis is difficult as quantification of the benefits and costs are uncertain, however, some economic quantification is necessary to direct public policy towards afforestation". As the dearth of knowledge and importance regarding the impact of tree-crop interactions grows, economic analysis takes on a more holistic perspective. With reference to *Eucalyptus* spp., the most common studies of this nature take into account the impact, positive, negative or neutral that trees have on the cropping systems that they typically border, however, other biophysical variables are increasingly being considered by researchers. These impacts are directly incorporated into benefit-cost analysis through the estimation of either market or nonmarket values. Examples of such studies include: Ahmed (1989); Anderson (1987); Kihiyo (1996); Malik *et al.*, (1990); Mathur *et al.*, (1984); Saxena, (1991) and Stone *et al.*, (1993).

Stone *et al.* (1993) simulate an economic analysis of the exotic species *Leucaena leucocephala* Lam. de Wit in Kenya by applying an adaptation of the Faustmann principle to incorporate economic and biological data to estimate the net present value of future rotations. Volumetric growth functions are estimated for leucaena at various planting densities and an optimal rotation for harvesting is estimated using a dynamic optimization technique in discrete time. The bio-economic model is extended to incorporate secondary benefits associated with soil improvement through nitrogen and organic matter accumulation. Based on existing price data employing a discount rate of 10%, Stone *et al.*, (1993) were able to estimate NPVs of $2 244.00 USD/ha for a planting density of 5 000/ha and $2 591 USD/ha for a planting density of 20 000/ha. The incorporation of secondary benefits did not alter the optimal rotation length results, but provided an enriched model that could by used to assess complicated agroforestry systems. With this data, simulations over different ecological zones provide insight into the benefits and costs of exotic tree species on whole agroforestry systems, rather than simply as compartmentalized segments of a greater system.

2.4 Ecological impacts of __Eucalyptus spp.__

Over the past 30 years a debate surrounding the use of *Eucalyptus* as an appropriate species for both afforestation and agroforestry projects in developing countries has arisen in the ecology literature. There is considerable evidence both for and against the promotion of *Eucalyptus*.[19] In the study area, *E. camaldulensis* was the species selected for woodlot production under the World Bank's Rural Afforestation Project.[20] *E. camaldulensis* was chosen for its rapid growth rates and ability to adapt to a wide variety of environmental conditions. Indigenous species were overlooked because of their perceived lack of genetic plasticity and slow growth rates (Mandondo, 1995).

The link between the ecology and economics of *Eucalyptus* species is highlighted by the following example. Investment in tree production to supplement existing crops is frequently observed in India. The National Social Forestry Project was started in India in the late 1970's with the intent that farmers would plant trees to meet subsistence needs (Blair, 1986). Saxena (1992) reports that farmers who chose to plant *Eucalyptus* on farm bunds anticipated good supplemental income after a few years with no loss in agricultural production. They did however suffer losses of up to 49% in agricultural output in the ninth and tenth years of tree production. Examples such as this one provide the impetus for attempting to reconcile the debate surrounding *Eucalyptus*. Currently *Eucalyptus* species have many strong advocates, development agencies and industrial interests in the developed nations being among them.[21] The following two sections provide an overview of the ecological debate surrounding this tree species, and allude to the many aspects of smallholder welfare that may be impacted.

2.4.1. Positive aspects of employing __Eucalyptus spp.__ in afforestation and agroforestry projects

Eucalyptus is well known for its' rapid growth rates and genetic plasticity. It is reported that in semi-tropical climates such as those of southern Africa, eucalypts are grown to merchantable size in 12-15 years (FAO, 1979). In other parts of the developing world eucalypts achieve merchantable size at approximately 7-10 years (Jayawickrama *et al.*, 1993). Growth rates such as

[19] For an extensive list of reference pertaining to *Eucalyptus* species see "Environmental, social and economic impacts of eucalypts - an annotated bibliography", on the FAO Forestry Web page; [http://www.fao.org/waicent/forestry/htm/].
[20] For the purposes of this study, the definition of a woodlot is extended beyond that of a parcel of land specifically demarcated for tree production. See Chapter 3 for the complete definition of a woodlot as defined for this analysis.
[21] For example, in People's Republic of Congo, wide scale planting of *Eucalyptus* has been promoted to the extent that the government encourages the clearing of indigenous forest for conversion to *Eucalyptus* plantations. Timber processed from these exotic species woodlots is purchased by the Norwegian forestry companies and processed in Norway (Kaiser, 1988).

these are substantially faster than indigenous species found in similar regions. Where fuelwood is scarce and the demand for forest produce high, there is significant benefit associated with the planting fast growing species. In addition, in many cases the propagation of eucalypts will slow or stop the harvesting of wood and non-wood forest produce from indigenous woodland. This has significant benefits in terms of maintaining current levels of biodiversity. Further, eucalypts in some regions are reported to exhibit immunity when faced with destructive pathogens (FAO, 1979). For smallholder farmers who must consider the risk of employing scarce resources in tree growing, choosing a species that has significant genetic plasticity and will resist pathogens is an important factor in their decision making process.

Eucalypts are reported to have substantial benefits with regard to the control of salinity in soils. This benefit is of particular significance to agroforestry systems.[22] *Eucalyptus tereticornis* in India was observed to lower top soil pH from 10.5 to 9.5 over a five year period (Young, 1990). However, it should be noted that a component of the soil improvement may be attributed to drainage enhancement by ditches, which were dug during tree planting. This is hypothesized to lead to better leaching of soils, and in turn, contribute to decreased salinity.

Species in the *Eucalyptus* family are known to be both flood and drought resistant providing them with a far higher probability of surviving ecological disturbances than other tree species (Rocheleau *et al.*, 1988). Flooding has positive impacts on mean leaf area. Bacon *et al.*,(1993) note that short term flooding temporarily improves tree moisture status and increases the overall growth rate of the trees. In agroforestry systems this characteristic is also beneficial as the use of eucalypts in floodplain management has significant potential for crop salvage after water logging has occurred. In addition to their flood resistant characteristics, eucalypts are known to survive drought due to their ability to rapidly develop an extensive root system.[23] This capability allows the trees access to water either stored in the ground or at the water table level, giving eucalypts a competitive advantage over other plants. Although intuitively this characteristic does not seem to suit agroforestry systems, in cases of extreme drought, survival of trees may allow for the provision of income when cash crops are destroyed.

---

[22] Saline soils create water stress in trees and other plants. Eucalypts are known to have a very high tolerance for saline soils. Mensforth *et al.* (1994), suggest that *Eucalyptus camaldulensis* planted on highly saline soils situated beside streams will continue to rely on saline ground water during moderate to high rain fall periods. The implications for soil improvement are that even in areas where fresh water sources are available, evidence suggests that eucalypts will continue to rely on saline ground water therefore facilitating a decrease in salinity through transpiration. Agricultural crops will perform better in soils with decreased salinity.

[23] The roots of eucalypts are known to extend as far as 10 to 25 m below ground surface (Bacon *et al.*, 1993).

Plate 2.4: Example of the extreme conditions under which *E. camaldulensis* can grow

Finally, Hill *et al.*, (1995) suggest that eucalypts, provide sustenance for bees. The flowers are particularly well suited for bee fodder while the tree physically provides shelter for a swarm or beehive. The practice of apiculture in conjunction with tree growing in agroforestry systems may have far reaching economic benefits.

2.4.2. Criticisms associated with employing Eucalyptus spp. in afforestation and agroforestry systems

The premise of incorporating trees and agriculture into one coexisting system is motivated by the fact that trees and shrubs are known to use their extensive root systems to absorb substantial quantities of nutrients from lower soil horizons and enrich the topsoil through leaf litter (Verinumbe, 1987). This process is further enhanced by the presence of a tree canopy that promotes organic matter accumulation, microbial activity and mineralization. Thus, if effectively managed, forested land can be simultaneously cropped to produce high yields of both agricultural output, timber and non-timber forest produce. However, several of the inhibitory characteristics of eucalypts may impact the symbiotic relationship that has the potential to exist between agricultural crops and trees.

In ecosystems where water is often in short supply eucalypts can be problematic as they are thought to deplete water supplies (Poore and Fries, 1985). Calder *et al.*, (1993) conducted a study

of the hydrological impacts of *Eucalyptus* plantings in India. Results indicate that in some regions euclaypts exhibited greater water use than recorded rainfall for that season. A possible hypothesis for this is a phenomenon known as "soil water mining".[24] If this is occurring there is the potential for eucalypts to be out competing other intercropped species for scarce water.
A second major ecological concern associated with eucalypts is the evidence that they use excessive amounts of soil nutrients. This may be partially attributed to the fact that eucalypts are non-leguminous and therefore do not function in a nitrogen fixing capacity (Gregersen *et al.*, 1989). In the case of *Eucalyptus* evidence suggests that poor crop performance is often the outcome of intercropping on apparently rich soils (Saxena, 1992; Sanginga *et al.*, 1992).[25]

Perhaps the greatest criticisms associated with *Eucalyptus* species are a slow rate of leaf decomposition coupled with the allelopathic effects that leaf litter has on adjacent crops. It is recognized that slow leaf litter breakdown in itself does not result in reduced nutrient return. However, the adverse effects of inter-planted crops due to shading or toxins may impact the rate of leaf litter breakdown. For example, agricultural crops grown in mulched eucalypt soils exhibited only limited benefit from nutrients released from decomposing leaf material (Young, 1990). Data provided by Lisanework *et al.* (1993) suggests that leaf extracts from *E. camaldulensis*, *E. globulus*, and *E. salinga* have the potential to inhibit germination, radicle elongation and growth of chickpea, maize, pea and teff. The decrease in productivity may be attributed to the presence of chemical substances in the extracts of leaves, which would suggest allelopathic potential.

To compound the issue of the impact that allelochemicals have on crops, the effects are intensified in areas of low rainfall, where there is strong competition with crops for water (Malik *et al.*, 1990). Lisanework *et al.*, (1993), found that seed germination and radicle growth are reduced to a greater extent when the concentration of leaf extracts is increased. Thus where rainfall is low or erratic there is insufficient quantities of water to dilute phytotoxic substances with run off or leaching from top soil.

2.4.3. Reconciling the debate?

The evidence provided in Section 2.4 of this Chapter provides no clear solution as to whether or not *Eucalyptus* is an appropriate species for use in agroforestry systems, however, several points

---

[24] Soil water mining is the process of the roots of the tree penetrating successively deep layers in the soil each year at a rate of approximately 1 m per year. It is assumed that over time the roots can penetrate deep enough to reach the water table (in the Indian study, the water table is assumed to be at approximately 30 m below ground level), which implies unsustainable growth between trees and agricultural crops.

[25] Sanginga *et al.*,(1992) provide empirical evidence for the hypothesis that euclaypts deplete soil nutrients. Experiments conducted in the lab, greenhouse and in the field suggest that soil currently or previously occupied by euclaypts may be suitable for cultivation of maize, but may require nutrient supplementation especially with K and Mg. Eucalypt woodlots were observed to be high in NH_4-N, P and Ca contents, however, relative to indigenous woodlands they were noted to be low in pH, NO_3-N, Mg and K. It is also noteworthy that in field trials increased soil depth was associated with decreasing amounts of K.

may move us towards reconciliation of the debate. First it is important to note that eucalypts may not be unique in reference to the impact of trees on agroforestry systems. Poor and Fries (1985) suggest that the negative ecological impacts associated with eucalypts are common to all non-indigenous tree species, thus singling out the eucalypt may be inappropriate. Second, more research is required regarding the ecological impact of trees on agricultural crops. Agroforestry is a relatively young science and there is currently insufficient empirical data across regions and species to draw generalized conclusions. Finally, and with particular reference to this project, it is essential that both the ecological and economic tradeoffs associated with the planting of these trees be quantified and evaluated. It may be the case that the total gain to the farmer from both woodlot and agricultural output is greater than that which was previously observed under a different land use scenario.

Chapter 3 – Methods, Study Area Background and Data Collection

Section 3.1 presents the methods used to address the central research question of this thesis, "What are the economic returns to smallholders and cooperative tree growing groups from planting *E.camaldulensis* woodlots?", methods used to estimate economic returns to woodlots are discussed. Section 3.2 provides details regarding the study area, information on geographic location and environmental conditions. An overview of the questionnaire is provided and the structure of the study sample is discussed in Section 3.3. Following the discussion of the study sample, the types of woodlots found in the study area and their general relationship to households, cropping systems and gardens is presented. In Section 3.5, the different types of woodlots found in the study area and the defining criteria for woodlots that qualified for the study are presented. Finally, Section 3.6 provides a summary of the general characteristics of individual and cooperative woodlots in the study area.

3.1 Structure of the benefit-cost analysis

Estimates of economic returns to smallholders and cooperative tree growing groups that plant woodlots are achieved through the calculation of three benefit-cost criteria: internal rates of return (IRR), net present values (NPV) and benefit-cost ratios (BCR).[26] IRR is commonly utilized in benefit-cost analysis. It represents the breakeven discount rate, the rate at which the present value of benefits equals the present value of costs. The internal rate of return concept is illustrative of what society can expect to receive in consumption benefits for a given investment of its scarce resources (FAO, 1992). Calculation of an IRR circumvents the *ad hoc* choice of an appropriate discount rate (Price, 1989).[27] IRR is formally expressed as:

$$\sum_{t=0}^{T} \frac{Rt}{(1+r)^{t}} = \sum_{t=0}^{T} \frac{Ct}{(1+r)^{t}}; \qquad (1)$$

where R_t, C_t, are revenue and cost at time t, and T is the time horizon of the investment.

It should be noted that IRR is not suitable for all project analyses. IRR is an appropriate tool for analysis when a project involves initial investment and later returns. In cases where investments

---

[26] Land expectation value (LEV) is another common measure used for evaluating forestry projects. LEV is defined as the present value of a perpetual stream of net benefits and is evaluated at the bare land stage at the beginning of the rotation (Pearse, 1990). Without the ability to project perpetual harvest streams in the study area, we instead concentrate on 15 year time horizons. Note that given the discount rates employed in this analysis, values beyond 15 years would not have large influences on estimates beyond the chosen time horizon.

[27] Dixon *et al.*, (1994) note that IRR is the value of *r* that meets the set condition of a zero net present value. The calculated IRR must be compared to some other financial interest rate or discount rate to determine whether the project is financially or economically attractive. In the case of many development bank forestry projects i.e. the Asian Development Bank and the World Bank, it is standard to use an EIRR (economic internal rate of return) with a cut-off rate of 10 to 12 % to determine the economic attractiveness of the project.

occur after returns have begun to be realized, multiple solutions may result. This is a consideration for this particular study, as investment and benefit streams are not temporally segregated in all of the woodlots in the study sample. However, IRRs obtained for the subset of the sample that does not yield multiple solutions will be employed to choose discount rates for sensitivity analysis. The second benefit-cost criteria, NPV is defined as; "the sum of all revenues, suitably discounted, minus the sum of all costs, suitably discounted" (Price, 1989). NPV is formally expressed as:

$$NPVi = \sum_{t=0}^{T} \frac{Rt}{(1+r)^t} - \sum_{t=0}^{T} \frac{C_t}{(1+r)^t}. \qquad (2)$$

Although IRR and NPV rely primarily on the same information, NPV requires that an appropriate discount rate be chosen. Appropriate discount rates for estimating NPVs are derived from IRR estimates. For the purpose of conducting sensitivity analysis a variety of discount rates will be used. [28]

Benefit-cost ratios are the final benefit-cost criteria estimated. BCR is the present value of revenues or benefits, divided by the present value of the costs. Investments are deemed acceptable if the benefit-cost ratio is greater than 1 (Price, 1989).[29] BCR is formally expressed as:

$$BCRi = \frac{\sum_{t=0}^{T} \frac{Rt}{(1+r)^t}}{\sum_{t=0}^{T} \frac{C_t}{(1+r)^t}}. \qquad (3)$$

An advantageous feature of the BCR specific to this study is that it is unit independent (i.e. values do not need to be presented on a per hectare basis).[30] BCR allows for a straightforward comparative analysis of woodlots of different sizes.

[28] Sensitivity analysis deals with the introduction of separate and independent changes in values used for estimates of IRRs NPVs and BCRs. Because all data are subject to error, and changes in values will occur over extended periods of time, sensitivity analysis is useful to assess past events (Sedjo, 1983).
[29] If the BCR is exactly equal to 1, the project will produce zero net benefits over its lifetime. The discounted benefits will be equal to the discounted costs. A BCR of less than 1 implies that the project generates losses from an economic perspective (Dixon *et al.*, 1994).
[30] The BCR focuses on the generation of benefits per unit of costs, not on the absolute magnitude of net benefits generated which is what NPV provides (Dixon *et al.*, 1994).

For each of the benefit-cost criteria presented above, both private and social values will be estimated. Private values reflect only those costs and benefits which are attributable directly to the smallholder or cooperative. Private costs include the costs of land, labour and capital that are borne directly by the smallholder or tree-growing group. Private benefits associated with the tree crop (i.e. those which may be directly captured by the smallholder or cooperative), include poles and headloads of fuelwood. Estimates of private values for woodlots are important as they provide insight into the household or cooperative's economic decision making process. By choosing to employ factors of production in tree growing, factors are taken out of their next best alternative use. Household or cooperative investment decisions will be reflective of expected return on investment.

Social values include private values plus values attributable to society in general. The primary difference between private and social return on investment estimates in this analysis will be subsidies that are offered to smallholders or cooperative groups by GOs and NGOs. As was discussed in Chapter 2, the provision of subsidies is thought to be an important factor influencing the formation of cooperative tree growing groups (Cernea, 1981). When land and other inputs are provided as subsidies to cooperatives, the opportunity cost associated with the decision to plant trees may be much lower for a cooperative than for a smallholder who plants a similar sized woodlot.

Table III.1 presents a summary of the values incorporated into the private and social benefit cost estimates. It should be noted that Table III.1 includes the range of costs and benefits that could

Table III.1: Summary of costs and benefits used in economic return estimates

Private Costs	Social Costs	Benefits (Private and Social)
Opportunity cost of land	Social opportunity cost of land	Value of poles harvested
Financial cost of seedlings	Cost of seedlings for initial planting	Value of fuelwood harvested
Labour cost of receiving extension advice	Cost of providing extension advice	
Labour cost of land clearing		
Labour cost of ploughing/digging		
Labour cost of gathering and applying organic matter		
Labour Cost of weeding		
Labour cost of gathering and applying water		
Financial cost of seedlings for blanking[a]	Cost of seedlings for blanking	
Labour cost of blanking		
Labour cost of digging fire breaks		
Financial cost of chemical pesticides		
Labour cost of applying chemical pesticides		
Labour cost of preparing and applying organic pesticides		
Labour cost of gathering material and building individual fences		
Labour cost for harvest		

a. Blanking is additional planting done to fill in blanks due to scattered failure of a tree crop (Price, 1989).

be most easily quantified given the constraints of the study environment, research budget etc. However, there are numerous other benefits and costs, both private and social, which are beyond the scope of this particular study. Table III.2 provides a brief overview of some of the possible costs and benefits that would be incorporated into a more exhaustive analysis.

Table III.2: Summary of select costs and benefits omitted from economic return estimates

Private Costs	Social Costs	Benefits (Private and Social)
	Cost of organic matter gathered from indigenous woodlands	Watershed management
	Cost of water	Erosion control
	Cost of materials gathered from indigenous woodland to build individual fences	Windbreak values
Financial cost of woodlot fencing material[a]	Cost of materials harvested from indigenous woodland for fencing material	Fodder values
Labour cost associated with building fences around woodlots	Value of subsidized woodlot fencing material	Value of preserving grain through use of leaves to repel weevils
Labour cost of repairing woodlot fences	Cost of materials harvested from indigenous woodland for fencing repair	Medicinal values
	Timber and non-timber losses associated with clearing of indigenous woodland for cooperatives	Value of honey produced in association with woodlots
		Value as live fencing
		Value of tethering livestock
		Shade values
		Carbon sequestration values

a. Although data was gathered regarding the type of external woodlot fencing, price of materials and labour costs for building and repair, the information is not incorporated into the benefit-cost analysis for two reasons. First, in the majority of cases the fence did not serve the unilateral function of protecting the woodlot. Rather, fences generally expanded well beyond the area of the woodlot to service cropping areas, gardens etc. To identify the exact portion of the fence that could be attributed to protecting the woodlot would require detailed data collection and estimation of what portion of the total fencing cost should be attributed to the woodlot. Secondly, fences were seldom erected in the same year that the woodlot was established. This is especially true in the case of the cooperative woodlots that often received fencing material from the Forestry Commission years after the woodlot had been well established. Thus, the value of the fence regarding the protection of the tree crop, particularly in the early stages of the woodlot is questionable.

A broader benefit-cost analysis would incorporate many of the values cited in the above table. It should be noted however that the quantification of a number of these values is particularly challenging as a number of the costs and benefits are nonmarket values.

3.2 Overview of the study area

The Mutoko communal area is located in Mashonaland East Province in northeastern Zimbabwe (See Figure III.1). The study area falls within Natural Region IV, an area characterized as the semi-extensive farming region.[31] Rainfall is relatively low (450-650 mm), the region is subject to periodic droughts and has occasional dry spells during the rainy season. The area is best suited to drought resistant, low risk crops. Individual smallholdings in the Mutoko communal area are typically comprised of one or two cropping fields that are generally cultivated in the rainy season; maize and pearl millet are the most frequently planted crops (Govaerts, 1989).[32] In addition to cropping fields, smallholders also establish garden plots which are utilized primarily for household

[31] Zimbabwe is divided into five distinct natural regions. The characteristics of soil type, rainfall and other climatic factors comprise the main criteria for differentiation

[32] Zimbabwe's rainy season is somewhat variable, generally commencing in October but possibly as late as January, and ending in March or April (Moyo *et al.* 1993). Most small holder farmers will wait for the first rains to come before planting cropping fields.

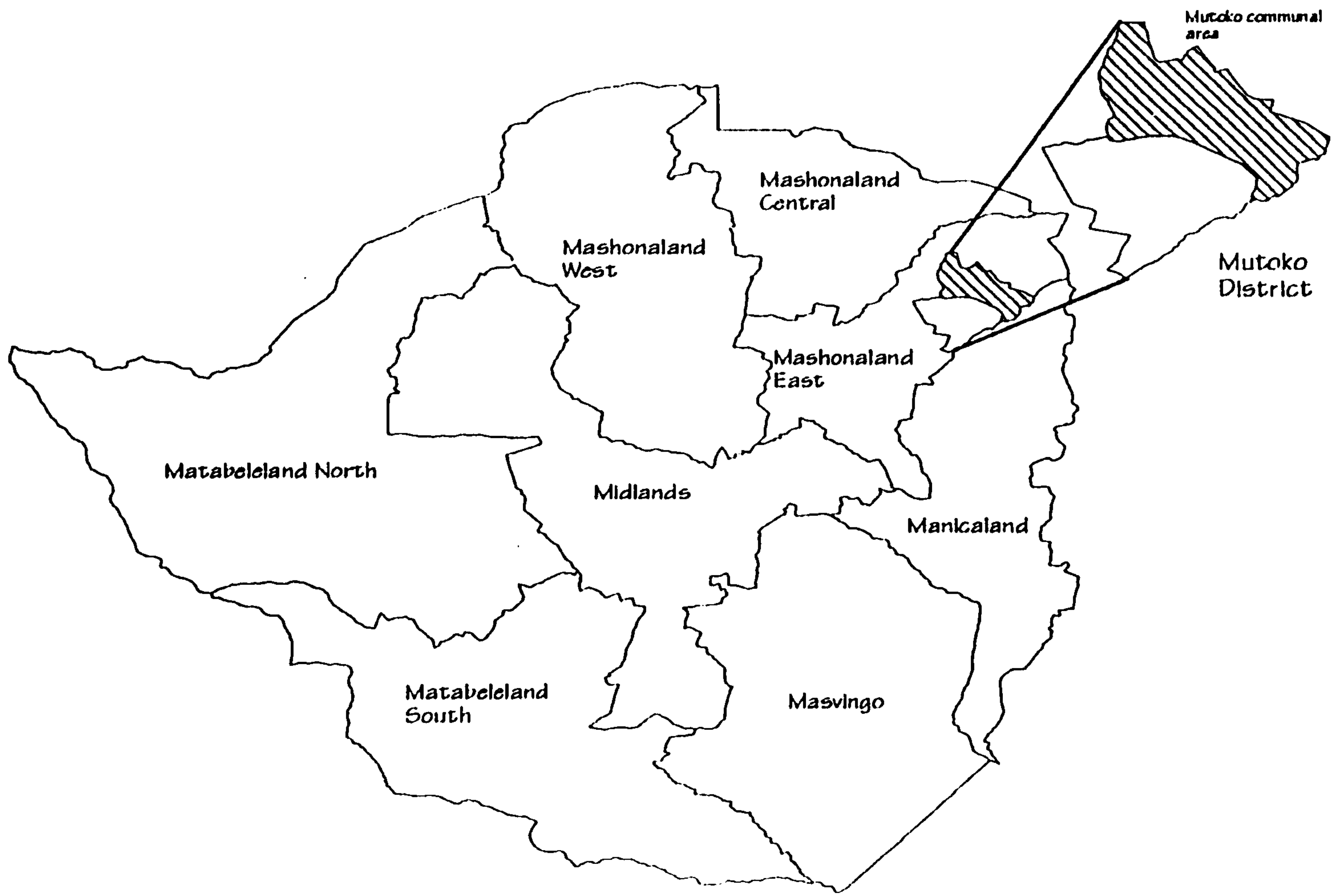

Figure III.1: Map of Mutoko District, Mashonaland East Province, Zimbabwe consumption. Farming systems are generally suitable only for small-scale livestock production as drought conditions often have adverse effects on cattle and goats.

Mashonaland East is one of four provinces in Zimbabwe that currently faces a fuelwood deficit (Moyo *et al.*, 1993).[33] Harvest of indigenous timber by local people is generally for building poles, and woodlands are thinned for fuelwood (Moyo *et al.*, 1991). Indigenous woodland in the Mutoko communal area is comprised of: *Baikiaea plurijuga*, *Guibourtia coleosperma* and *Pterocarpus anoglensis* (COOPIBO, 1992). Although utilization of indigenous woodland seldom results in complete deforestation, the quality and density of woodlands has been reduced over time. In response to this, a number of smallholder farmers and cooperative groups have employed a portion of their scarce land in the production of fast growing exotic tree crops for the purpose of supplying timber for building, fuelwood and fruit for household consumption. There is a high frequency of *E. camaldulensis* woodlots in this area.

Plate 3.1: Coppice shoots and multiple harvests, *E. camaldulensis*

The Mutoko communal area is comprised of 20 administrative Wards including Mutoko Centre, the growth point for the surrounding populations. This study encompasses the six wards shaded in Figure III.2, all of which were located east of Mutoko Centre. The total area of the Mutoko communal land is 4 291 km^2, with only 36% of this land area classified as arable. Census data from 1992 indicate an average household size of 4.9 people and a population density of 32.1 persons per km^2 (CSO, 1992). As was discussed in Chapter 2, land distribution in Zimbabwe's communal areas was formerly done by traditional leaders, and has more recently fallen under the jurisdiction of District Councils. Within the Wards that comprise the study area, land allocation is currently left largely to the discretion of traditional leaders with the political hierarchy intervening only when land disputes occur.

The government agency AGRITEX employs one Agricultural Extension Officer for each Ward. The primary goal of AGRITEX is to provide technical, advisory, and extension services that focus on soil conservation and land use planning at the smallholder level. Forestry extension support to the Mutoko communal area is offered at the district level from the government parastatal Forestry Commission. A Forestry Extension Officer (FEO) resides in Mutoko Centre and provides extension support from this point to the 19 Wards in the district. The primary focus of the FEO is to promote the economic benefits of forestry to the smallholder farmer. In the past, forestry extension support in Mutoko has focused on the planting of exotic species for timber, fuelwood and fruit production. However, support recently has moved towards the incorporation of indigenous woodland species in tree planting schemes at the household level (Zimbabwe Forestry Commission, 1996).[14] Owing to limited manpower and distribution of materials required for tree planting (for example, seeds, polythene tubes and seedlings), supplied by the Forestry Commission in Mutoko, forestry extension support is often incorporated into the role of the ward level AGRITEX extension officer.

Selection of the study area was influenced by research mileage budget constraints, a desire to choose a study area that was not too frequently surveyed, and the need to locate a site with a high frequency of individual and cooperative woodlots. The Mutoko communal area is approximately 200 km's northeast of Harare where the administrative support base for the research project, The Institute of Environmental Studies is located.

---

[13] In 1993 it was estimated that Zimbabwe's forest cover was being reduced at a rate of 1.5 % per year. Data available for the communal areas suggests that wood stocks were halved between 1963 and 1973 and have probably been halved again since the late 1970's (Moyo *et al.*, 1993).

[14] In the 1995-1996 fiscal year total tree seedling production by the Zimbabwe Forestry Commission was 6 306 180. Sixty percent were plantation species mainly *eucalyptus*, 20% were exotic fruit trees such as various species of mango, peach, guava, avocado and citrus and 20% were indigenous agroforestry and fodder species (Zimbabwe Forestry Commission, 1996).

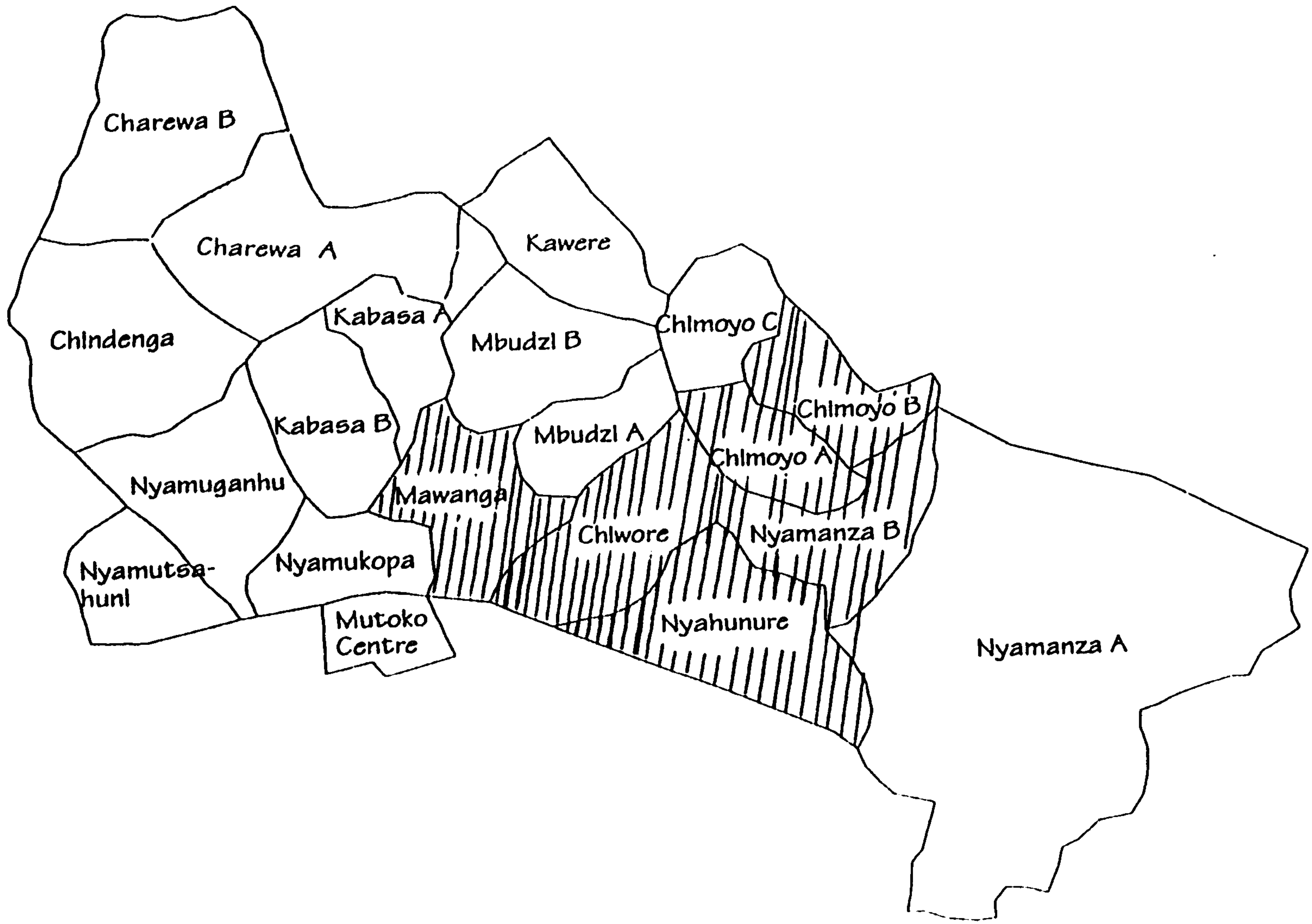

Figure III.2: Map of study are administrative wards in Mutoko District, Zimbabwe

As nearness to Harare makes the Mutoko District a popular location for survey work, a study site furthest away from Harare, east of Mutoko Centre was chosen. Discussions with key informants confirmed the hypothesis that little survey work had recently been completed in this area, thus, smallholders and cooperatives were more likely to participate in the woodlot study.[35] The final consideration was to find an area with a high frequency of cooperative and individual woodlots. Interviews with a number of key informants assisted in determining a central point for the study area. Mushimbo Village in Nyahunure Ward, which is located approximately twenty-five km's southeast of the Mutoko Centre on a sand track road was selected. Nyahunure Ward is known to have a very high frequency of cooperative woodlots relative to other wards.

3.3 Overview of the questionnaire

The questionnaire encompassed three main categories that fulfilled the majority of the quantitative data requirements for this analysis (See *Appendix A*). Section I provides a profile of the inputs and outputs of the production process. The goal of this Section was to acquire data that would be appropriate for estimating economic returns to planting *E. camaldulensis* woodlots in the Mutoko communal area. Costs include physical inputs such as seedlings and pesticides, as well as detailed information on the labour requirements for various woodlot management activities. Benefits are primary woodlot outputs, and include harvestable poles and headloads of fuelwood. In addition, frequency data for the following secondary benefits were gathered: shelterbelts/windbreaks, livestock fodder and leaves used to line grain bins to protect agricultural surplus from being destroyed by weevils. For farmers and cooperatives that had planted multiple stands of *E. camaldulensis*, it was specified that data on the costs and benefits for each woodlot be estimated based on results from the first stand planted. In cases where respondents were uncertain regarding the details of the cost and benefits for the first stand, data were gathered on the second stand planted and values estimated accordingly.[36]

Section II of the questionnaire focused on wages paid to hire labour, socioeconomic indicators and perceptions of tenure security. In addition to gathering detailed information on variables such as age, gender and education level of the respondent, data regarding wealth indicators for each household and the Chairperson of each cooperative were obtained. Tenure security was assessed through questions related to whether or not the tenurial institution had remained static over time, if the individual or group residing on the land felt that they would be removed from their land any

---

[35] Personal communication, Charles, COOPIBO Project Director, Mutoko Centre, June 23, 1997. Personal communication, Odious Nyakudanga, Nyahunure Ward Councilor, June 24.1997. Personal communication, Cheneso Gunda, Mutoko Forestry Extension Officer, Mutoko Centre, June 26, 1997.

[36] For Section I of the questionnaire, data for the second planting was gathered for 9% of the total woodlots sampled. Of the 9% all were individually owned woodlots. This generally occurred when the individual who planted the trees was no longer living or had moved to the city. The majority of these cases were female headed households where women were either widowed or left to manage the farm while husbands moved to urban areas to secure cash income for the family.

time in the future and the number of years the household or cooperative had been established on the current plot of land.

The third section of the questionnaire provides data for estimating tree and stand volume, mean annual increment and planting density. These data are used to estimate the biophysical growth rate of the trees over time. Data for ten trees from the centre of each planting line or woodlot were gathered with the assumption that these 10 trees would provide sufficient information to estimate average tree volumes. Number of times harvested or coppiced, diameter at breast height (dbh), height and average spacing were assessed. Finally, additional data that included qualitative observations and anecdotal comments from respondents were noted.

Three locally recruited Research Assistants, Passmore Kagoro, Peter Tsiga and Wensolos Musekiwa, who were recruited by the principal researcher, Pam Jagger, conducted surveys. The surveys were administered during the winter months of July, August and September of 1997, a favorable time for interviewing as cropping fields are fallow during this period allowing for easier access to woodlots. Respondents were generally available for interviewing while working in their garden plots. Research Assistants administered the questionnaire to survey respondents in Shona,

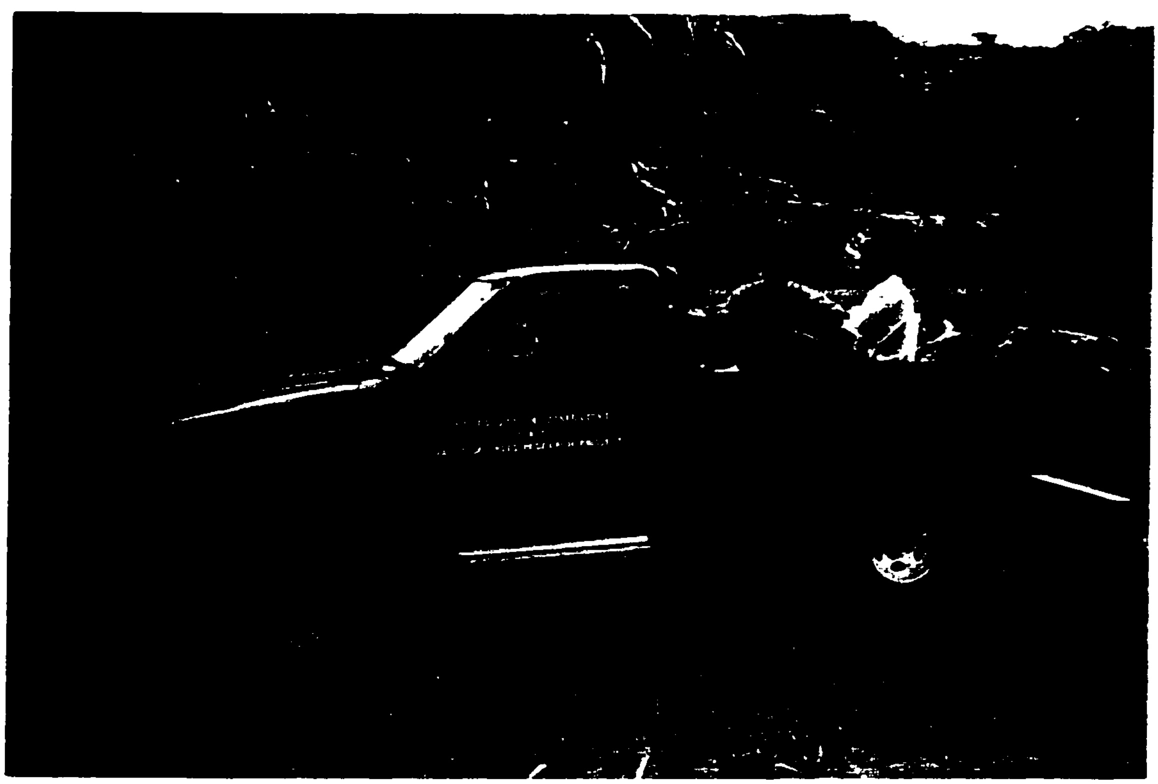

Plate 3.2: The survey team

the predominant local language in northeastern Zimbabwe. As a token of appreciation for participating in the woodlot study, respondents were given a package of vegetable seeds in exchange for the time they devoted to responding to the questionnaire.[37] Overall interest in the survey and the response rate were exceptional. Only one smallholder refused to participate in the study out of 102 households or cooperative groups contacted.

3.4 Structure of the sample

As comparative analysis of individual and cooperative woodlots is one of the major objectives of this analysis, it was necessary to survey significant numbers of each category of the total population of woodlots. Individual woodlots are plentiful in the study area, with approximately 63% of the total number of woodlots under individual ownership.[38] In the defined study area 20 cooperative woodlots were known to be in existence. The questionnaire was administered in a non-random manner to the total population (i.e. 100% of the total number of cooperative woodlots in the study area) of cooperative woodlots during surveying in order to obtain a statistically acceptable sample size. Individual woodlots were randomly selected for the survey based on a geographic distribution within each Ward.[39] Every third household with an individual woodlot was surveyed (see study definition of a woodlot as described in the following section). To maintain a balanced ratio of individual to cooperative woodlots in each Ward, a ratio of five individual woodlots surveyed for every one cooperative woodlot was the basis for the study sample. This generalized rule was observed whenever possible, however, circumstances during surveying such as the availability of woodlot owners for interviewing, frequently occurring funerals, and the incidence of a higher proportion of cooperatives in some Wards made adhering to a stringent decision rule difficult. The structure of the sample by Administrative Ward is presented in Table III.3. Of 101 woodlots surveyed, 80% were owned by individual smallholders and 20% were run by cooperative groups. It is noteworthy that in addition to individual and cooperatively owned woodlots, there is a relatively high frequency of school owned woodlots in

---

[37] The average time required for respondents to answer all of the questions in the survey was 27 minutes. Tree measurements were taken after the survey was completed. This allowed the respondent the option of returning to work in the garden or home site, or observing the woodlot measurements. It is noteworthy that a great number of respondents were very interested in the woodlot measurement process and were curious to know how the height of their trees in particular related to the height of neighbor's trees.

[38] Mandondo (1993) employed a pure random sampling technique in his analysis of *E. camaldulensis* woodlots in the Murewa and Mutoko districts of northeastern Zimbabwe. His results indicated for a sample size of 120 woodlots: 63% individually owned, 30% school owned and 7% cooperatively owned.

[39] Although statistical analysis that relies on an aggregate sample of non-random and randomly selected respondents may be questionable for some uses, gathering a total population sample for individual woodlots was not possible due to the high number and wide geographic distribution of individual woodlots. The implication of this is that cooperative woodlots could be over-represented in cases where cooperative and individual woodlots are combined. Accordingly, in cases where

Table III.3: Number of woodlots surveyed by Ward and tenure

Name of Ward	Individual Woodlots (n=81)	Cooperative Woodlots (n=20)
Mawanga	6	2
Chiwore	16	2
Nyahunure	46	12
Chimoyo A	6	3
Chimoyo B	0	1
Nyamhanza B	7	0

the Mutoko communal area. As the economic incentive structure which motivates schools to plant trees is somewhat different than that of the two other tenure types, it was determined that school owned woodlots would be omitted from this analysis.[40]

3.5 Study definition of a woodlot

Households in the communal area demand building poles and fuelwood. Because commercial markets for these products are thin or non-existent, it is common for most households to grow some *Eucalyptus* trees for the provision of poles and fuelwood to satisfy internal household demand. Based on the high frequency of households that grew some *E. camaldulensis*, it was necessary to clearly define what number and configuration of individual trees would be classified as a woodlot eligible for surveying.

In Mutoko three general tree-planting configurations are common for *E. camaldulensis*. First, trees may be planted as internal borders to gardens or cropping fields (Figure III.3a). The second

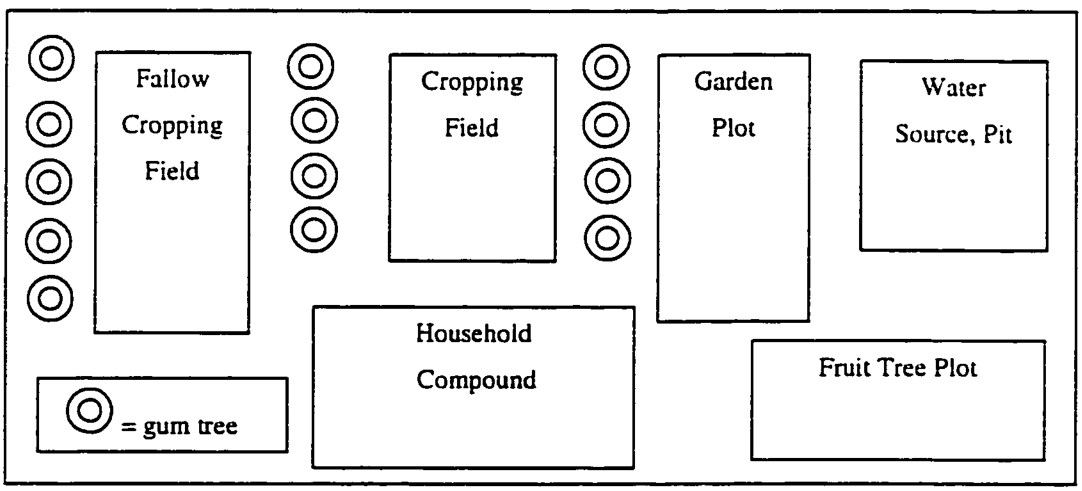

Figure III.3a: Planting of trees as internal borders to gardens or cropping fields

---

both types of woodlots are combined, the cooperative woodlot component will be weighted so that it represents its true proportion of the total woodlot sample.

[40] School children are a homogeneous group, concentrated around the primary activity of attending school. Schools traditionally have a built in leadership system which makes the assignment of relatively short term technical tasks such as tree planting a viable project (Gregersen *et al.*, 1989).

common planting configuration is planting trees as living boundary fences, for the demarcation of a cropping field, garden or homestead boundary, or to provide a means by which livestock may be corralled (Figure III.3b). Neither of these methods of tree planting requires the smallholder to take

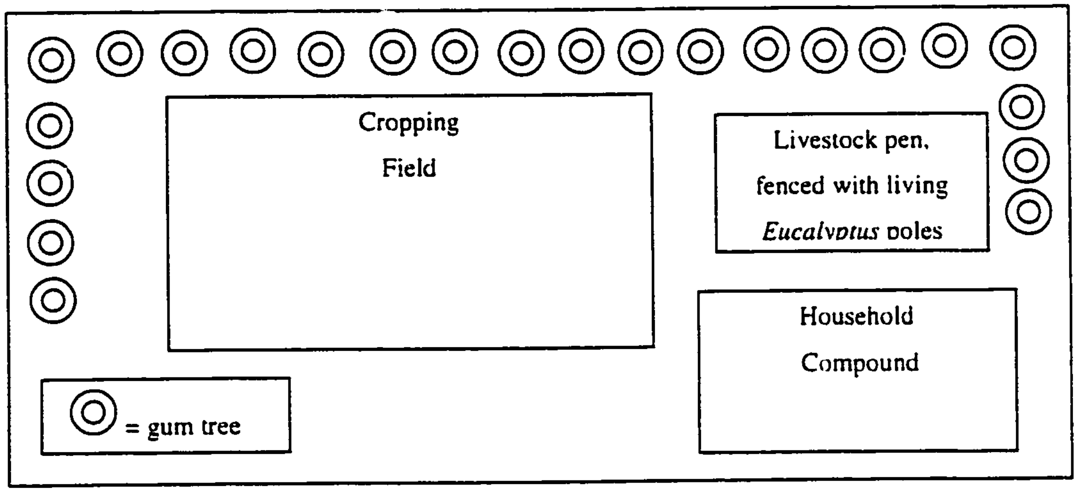

Figure III.3b: Planting of trees to demarcate boundaries, as living fences or livestock fencing

significant parcels of land out of its current production schedule.[41] The third common tree planting configuration is the "true" woodlot. A woodlot is defined as a restricted area of woodland or cropping area usually maintained as a source of fuel, poles or other timber or non-timber outputs. In cases where "true" woodlots are observed it is assumed that the farmer has taken land out of its' former production schedule either diversifying or substituting away from crops, vegetable growing or livestock grazing to plant trees (Figure III.3c).[42]

---

[41] Population growth in the communal areas has reduced the average communal land holding to less than 3 ha, indicating that determining the land uses which will yield the highest returns while minimizing the land input required is crucial to smallholders (Moyo *et al.*, 1991).

[42] Of the total sample, 23% of land utilized for tree production was previously utilized for livestock grazing, 10% for garden plots, and 59% as cropping fields. The remainder were erosion gullies, boundaries, fallow crop land, planted with sisal (a fibrous shrub used to slow soil erosion) or riverine area.

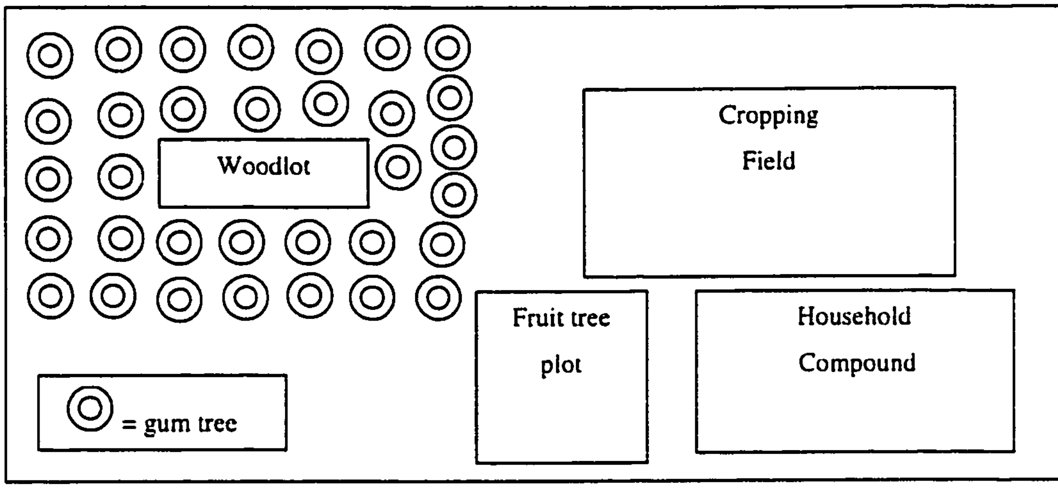

Figure III.3c: Planting of trees as "true" woodlots

Households or cooperatives were eligible to be surveyed if their woodlot could be categorized as one of the three woodlot types discussed above, and was comprised of 10 or more living trees which fell within a 20 x 20 m plot. It was determined during pre-testing that following stringent decision rules regarding the acceptability of woodlots for the study given the above criteria would be difficult in some cases. In a few cases woodlots were erratically spaced or exhibited outlier trees that fell outside the 20 x 20 m woodlot boundary. Thus, allowances were made for woodlots which took the form of long planting lines, and also for oddly spaced woodlots that might exhibit two or fewer outlier trees.

3.6 General characteristics of woodlots

Individual and cooperative woodlot owners are known to plant several different stands of *E. camaldulensis* over time. Table III.4 provides a summary of the average age for each of the first

Table III.4: Mean age of first, second and third stands, years[a]

	Individual woodlots (n=81)	Cooperative woodlots (n=20)
First stand	8.1	4.4
	(6.1)	(3.8)
	n=79[b]	n=20
Second stand	4.9	2.6
	(3.7)	(1.5)
	n=35	n=8
Third stand	2.1	2.0
	(1.7)	
	n=13	n=1

a. Values in parenthesis represent standard deviations.

b. Two respondents failed to recall the precise age of their youngest woodlot. For the following economic return estimates data for second planting was used for these two observations.

three stands planted for individual and cooperative woodlots. The table indicates that individual woodlots are generally older than cooperative's. This result is somewhat unexpected as one of the key mandates of the Forestry Commission and the majority of NGOs that have promoted tree growing in the area since the mid 1980s has been the establishment of cooperative tree growing groups (see discussion in Chapter 1). Data in Table III.4 also indicate that multiple stands are more common in individual woodlots. Although approximately 43% of individual woodlots and 40% of cooperative woodlots planted two stands of trees, 16% of individual woodlots planted a third stand, as compared with only 5% of cooperative woodlots.

Table III.5 indicates that cooperative woodlots generally plant a far greater number of seedlings than individual woodlots. That cooperative woodlots are generally much larger than individual

Table III.5: Mean number of seedlings planted in the first, second and third stands[a]

	Individual Woodlots (n=81)	Cooperative Woodlots (n=20)
First stand	320 (1418) n=81	1604 (1652) n=20
Second stand	127 (349) n=35	1792 (2279) n=8
Third stand	518 (1649) n=13	200 n=1

a. Values in parenthesis represent standard deviation.

woodlots may be related to the fact that cooperative's have a much larger labour pool to draw from, indicating the ability to take on much larger tasks. In addition, the provision of subsidized resources, that individual woodlot owners may not have access to, might influence the comparative size of woodlots under the two tenure types.

A final woodlot characteristic, survival rates, was estimated for each woodlot by assessing what percentage of seedlings had survived out of the total number planted. Survey respondents were asked to recall the number of seedlings they originally planted and the number of live seedlings or trees that had lived beyond three years of age in their woodlots. In cases where respondents failed to recall numbers of seedlings planted and the number that had survived, the total number of live trees and harvested stumps were physically counted during surveying. Based on assumptions regarding average spacing between seedlings, estimates of seedling or tree mortality were possible. Survival rates for the first, second and third even aged stands for both tenure types are summarized in Table III.6. Survival rates are hypothesized to be dictated by factors such as soil quality, access to water, whether or not the woodlot was fenced at the time of planting and the incidence of drought in the first three years after the tree crop was planted. Generally survival

Table III.6: Survival rates first, second and third stands, percent

	Individual Woodlots (n=81)	Cooperative Woodlots (n=20)
First stand	74%	76%
Second stand	85%	78%
Third stand	88%	100%

rates appear to be comparable for both tenure types, with a possible trend in survival rates improving over time. It should be noted that it is very likely that survival rates are higher for third stands in cooperative woodlots due to the fact that many of the cooperatives are less than three years old. In addition, improved management techniques over time, or other environmental factors outside the scope of woodlot management may be influencing woodlot survival rates.

Chapter 4 – Estimating Economic Returns: Benefit and Cost Data and Results

Chapter 4 focuses on the estimation of values used to calculate economic returns and the economic return estimation results. Section 4.1 discusses the data employed in estimating the costs of production and the value of benefits. Section 4.2 presents and discusses estimates of economic returns.

4.1 Estimating the costs of production and the values of benefits

The following section presents data used for estimating the value of factors of production: land, labour and capital. In addition, the specific assumptions employed in estimating the flow of primary benefits over time are presented.

4.1.1 Opportunity cost of land

Opportunity cost of land is one of the main costs associated with woodlot establishment in the Mutoko communal area. To estimate the private and social value of the opportunity cost of land, per hectare values derived from secondary data sources and key informant interviews were incorporated into the analysis.[43] Opportunity cost of land is dependent upon its next best alternative use. Although secondary data specific to the study area are limited, values hypothesized to be indicative of the opportunity cost of land under various land uses are summarized in Table IV.1. Land values for grazing are the lowest, with land utilized for

Table IV.1: Opportunity cost of land under various land uses, 1997 $ ZWD/ha

Secondary data source	Land use	Opportunity cost of land, 1997 $ZWD/ha
Gwaai Working Group (1997)	Grazing livestock	69
Campbell, B.[a]	Garden	450
Gwaai Working Group (1997)	Cropping field	400

a. Personal communication, Dr. Bruce Campbell, Director, Institute for Environmental Studies, University of Zimbabwe, 25 May, 1998, Harare, Zimbabwe.

agriculture being significantly higher and garden plots most highly valued.

For private economic return estimates, opportunity cost of land is incorporated into calculations only for individual woodlots that originally planted greater than 50 seedlings. It is assumed that woodlots with 50 or less trees planted them as row or boundary crops, thus requiring no land to be taken out of its current productive use. Of the total number of individual woodlots surveyed, 40% planted greater than 50 seedlings. In the majority of cases land designated for cooperative woodlots was previously utilized as a communal resource, thus, there is assumed to be little or no

[43]The total area occupied by each woodlot was estimated using data regarding the total number of trees planted and average spacing of trees.

private opportunity cost associated with taking this land out of its' previous production schedule.[44] However, for the social benefit-cost estimates, opportunity cost of land is estimated for all woodlots that planted greater than 50 seedlings, including 100% of the cooperative woodlots in the sample.

Table IV.2 summarizes the previous uses of land that individual and cooperative woodlots are

Table IV.2: Previous land use, greater than 50 seedlings planted

Previous land use	% of Individual woodlots >50 seedlings planted (n=32)	% of Cooperative woodlots > 50 seedlings planted (n=20)
Grazing livestock	15.5	55
Garden	15.5	40
Cropping field	69	5

currently established on. The majority of land taken out of production by individual smallholders for woodlot production was agricultural cropland. Of the communal lands designated for cooperative woodlots, the majority of lands were previously utilized for grazing or cooperative gardening.

4.1.2 Labour cost (wage rates)

Labour is generally considered the primary input in the production process in many subsistence economies (Anderson, 1987). In rural economies, markets for labour often yield lower prices than would be experienced in urban or commercial markets; thus it is essential to identify an appropriate range of site specific values for this input. Wage rate data were gathered for hired labour in Section II of the questionnaire, as well as through interviews with key informants. In identifying an appropriate range of wage rates, gender was considered wherever relevant. It was initially hypothesized that average daily wage rates for male and female labour would be significantly different in the context of the rural economy.

Results of the wage rate survey and interviews with key informants are presented in Table IV.3.

[44]The private opportunity cost of land for cooperatives was not estimated, as it was not known which people that had previously used the communal land for grazing or gardening were the participants in the new woodlot project. Therefore

Table IV.3: Daily wage rates for men, women and children, 1997 $ZWD[a,b]

Data Source	Wage rate male	Wage rate female	Wage rate child[c]
Average for hired labour in Mutoko District Section II Questionnaire	$38 (30.36) n=14	$10 n=1	$4 n=1
AGRITEX wage paid for casual labour	$22	$22[d]	N/A
Research Assistant wage rate	$32.50	$32.50	N/A
Minimum wage as legislated by the Zimbabwean government	$18	$18	N/A
Cotton Company, Mutoko District	$6[e]	$8	$4

a. All wage rates are given in Zimbabwe dollars. From July 1997-September 1997 the exchange rate to the USD ranged from 10.0 to 14.0.

b. Value in parenthesis represents the standard deviation.

c. For the purpose of this study, any individual 15 years or less in age was considered a child.

d. It is likely that this is the wage rate that women in Mutoko would be paid as casual labour, however, to date no women have been hired by the Agricultural Extension Service (AGRITEX) in Mutoko (Makonyere, 1997)[45].

e. Wage rates paid by the Cotton Company are based on the number of kgs of cotton picked per day. Wage paid per kg is 40 cents. Women on average pick 20 kgs per day, men pick 15 kgs and children pick 10 kgs.

The wage rates presented in the above table for hired labour, and Research Assistant wages are thought to be generally higher than the average wages rate that would be observed within the rural market for labour. There are two possible reasons for this. First, employment opportunities such as those offered with research projects occur infrequently and are open only to a select segment of the rural population, typically those who are more highly educated. Second, the types of jobs that labour would typically be hired for are physically intensive (for example, fencing or digging firebreaks), implying a higher wage rate. In addition, as with Research Assistant jobs, opportunities to work as hired labour do not occur frequently.

The initial hypothesis of a wage differential between male and female workers is not clearly supported by the above data. It is however evident that the wage rate for children is lower than for adults. A literature search for secondary data sources that might shed some light on the rural market for labour failed to indicate that a wage differential between male and female adult workers exists in rural Zimbabwe (Adams, 1991; Gwaai Working Group, 1997; Mehretu and Mutambirwa, 1992). Based on the assumption that the wage rates cited in the first four rows of Table IV.3 are slightly higher than the typical rural market for labour, and assuming no wage differential between men and women, the following schedule of wage rates were selected for economic return estimates. A range of values is provided for the purpose of conducting sensitivity analysis. Schedule A is thought to represent the lower bound on the rural labour market in Mutoko communal area, and is likely most indicative of the lowest rural wage rates paid for every day

opportunity cost of land for cooperatives was estimated only at the social level.

[45]Personal communication, Mr. Lawrence Makonyere, District Extension Officer, AGRITEX, 10 September, 1997, Mutoko, Zimbabwe.

Table IV.4: Schedule of wage rates to be used in sensitivity analysis, 1997 $ZWD

	Wage rate adult	Wage rate child
Schedule A	15	5
Schedule B	22.5	7.5
Schedule C	30	10

tasks. Wage rate Schedule C indicates the upper bound on average daily wage rates paid in the study area, and is only slightly lower than typical wages paid for infrequently occurring, high skill or labour intensive jobs. Schedule B represents a mid-range set of wage rates, that are likely indicative of the average wage paid for the completion of daily tasks in the rural market.

It was anticipated that the amount of labour devoted to various tree-growing activities would vary according to gender, the size of the woodlot in question, and the management activity being undertaken. Table IV.5 presents data illustrating the average labour input for men, women and children respectively, for individual and cooperative woodlots differentiated by woodlot size category. Woodlots where smallholders had originally planted 50 or less seedlings are considered small. Woodlots where smallholders had planted 51 to 100 seedlings are medium sized, and woodlots with greater than 100 seedlings are large. Overall results indicate that women receive

Table IV.5: Average labour inputs by number of trees planted (hours per year)[a]

Management Activity	Individual woodlots, ≤50 seedlings planted, N=49			Individual woodlots, ≥51 and ≤100 seedlings planted, n=16			Individual woodlots, ≥101 seedlings planted, n=16			Cooperative woodlots, ≥101 seedlings planted, n=20		
	Male	Female	Child	Male	Female	Child	Male	Female	Child	Male	Female	Child
Receiving extension advice	5.06 (7.08) n=13	2.81 (2.17) n=8	N/A[b]	2.83 (3.62) n=3	6.20 (7.85) n=5	N/A	2.67 (0.58) n=3	35.33 (56.04) n=3	N/A	6.5 (10.53) n=8	62.4 (87.07) n-10	N/A
Clearing land for planting	7.83 (4.58) n=6	6.00 (5.29) n=3	3.00 (1.41) n=2	N/A	N/A	N/A	67.00 (57.11) n=3	126.00 n=1	N/A	54.00 (32.90) n=4	64.40 (107.35) n=5	28.00 n=1
Plough/dig holes	7.21 (10.15) n=44	7.69 (7.55) n=13	5.22 (2.95) n=9	10.00 (11.69) n=14	6.57 (3.21) n=7	13.6 (13.45) n=5	15.19 (21.35) n=16	5.50 (6.19) n=6	18.00 (19.80) n=2	41.35 (61.53) n=17	57.88 (95.22) n=16	88.00 n=1
Digging firebreaks	3.33 (2.56) n=9	2.00 (0.00) n=2	N/A	12.00 (10.58) n=3	N/A	N/A	2.75 (1.77) n=2	N/A	N/A	49.86 (78.49) n=7	48.86 (40.43) n=7	N/A
Individual seedling fences*	17.67 (15.33) n=15	18.00 (13.08) n=3	31.33 (23.86) n=3	20.33 (8.02) n=3	N/A	21.00 n=1	57.33 (49.37) n=3	16.00 n=1	24.00 n=1	14.00 n=1	128.00 (155.56) n=2	N/A
Apply organic matter*	8.26 (7.42) n=23	5.43 (3.21) n=7	8.00 (5.51) n=6	20.65 (42.85) n=8	5.50 (1.19) n=4	7.20 (3.63) n=5	20.14 (16.33) n=7	27.00 (21.21) n=2	60.00 (33.94) n=2	15.50 (18.93) n=5	36.63 (24.90) n=4	N/A
Weeding*	5.45 (6.16) n=29	4.88 (4.16) n=8	11.00 (6.45) n=11	5.13 (4.97) n=8	2.50 (2.12) n=2	9.00 (4.24) n=2	10.25 (13.38) n=12	7.08 (8.46) n=6	4.17 (3.40) n=3	13.70 (15.14) n=10	54.91 (38.58) n=11	N/A
Watering*	2.89 (3.79) n=16	2.39 (1.45) n=9	5.88 (8.71) n=8	2.41 (1.37) n=9	3.25 (1.89) n=4	4.00 (2.00) n=3	4.83 (1.17) n=6	3.50 (1.29) n=4	9.00 (0.00) n=2	12.20 (11.80) n=5	16.60 (13.39) n=5	N/A
Blanking*	2.83 (1.44) n=6	N/A	3.5 (0.71) n=2	3.00 (1.00) n=3	1.83 (0.76) n=3	4.75 (3.89) n=2	4.07 (2.78) n=7	2.00 n=1	8.5 (0.71) n=2	2.75 (1.50) n=4	16.17 (9.11) n=6	N/A
Apply chemical pesticide	2.05 (2.22) n=5	0.75 n=1	4.00 n=1	6.54 (11.64) n=4	N/A	N/A	5.00 (3.61) n=3	N/A	N/A	7.75 (1.26) n=4	3.00 n=1	N/A
Apply organic pesticide	9.25 (9.98) n=4	24.00 n=1	N/A	5.00 (1.41) n=2	4.00 n=1	N/A	2.00 n=1	2.00 n=1	N/A	10.00 (2.83) n=2	8.00 (0.00) n=2	N/A
Total hours year one[c]	72	74	72	88	30	60	191	224	124	228	497	116
Total hours years two, three[cd]	19	13	29	31	13	25	39	40	82	44	124	N/A

a. Values in parenthesis represent standard deviations.
b. Where N/A appears it indicates that no labour for that the corresponding gender/age category and woodlot type was observed in the data set.
c. Average annual values are rounded to the nearest whole hour.
d. Annual management activities generally occur in either year two or three or both, there were only a few respondents that cited weeding and watering in year four. Beyond year four, it is assumed that trees are established to the degree that they would no longer benefit from additional weeding etc.
*Management activity may occur in multiple years, all other labour inputs are assumed to occur only in Year 1.

more extension advice than men, with the exception of small individual woodlots where men are observed receiving the majority of extension advice. The trend towards women receiving extension advice for medium to large woodlots may be tied to the desire for the Forestry Commission and NGOs to target women and women's groups in forestry extension initiatives.

For individually owned woodlots, labour intensive activities such as land clearing, ploughing and digging holes, applying organic matter and digging firebreaks are generally undertaken by men. In cooperative woodlots, the division of labour for these intensive tasks was more equitably divided between men and women. In many cases, children were minimally involved in labour intense activities with the exception of ploughing and digging holes. For small woodlots, gathering materials and building fences around each seedling planted is a task that may significantly decrease seedling mortality rates. As with the other labour intensive management tasks, men are generally involved in building these fences. Very few medium and large sized woodlot holders built fences around individual seedlings.

Tasks such as weeding, watering and blanking that occur in multiple years are generally equally distributed between men, women and children, with children contributing significantly in small and medium woodlots. In cooperative woodlots women generally complete these tasks. The application of pesticides (both chemical and organic) is traditionally undertaken by men, and is observed as such, even in cooperative woodlots with a high proportion of female members.

The average number of hours dedicated to woodlot labour in year one for men, women and children was tabulated for each woodlot size and tenure type. Year one of production is the most labour intensive. The division of total hours of labour for small individual woodlots was almost equal among men, women and children with 218 being the sum of the average total number of hours. Medium sized individual woodlots demonstrate significant labour differentiation in the first year's efforts, with men contributing almost three times the amount of labour that women do, and one third more than children. The total average number of hours of labour for medium sized individual woodlots is 177. This is an unintuitive result; one would anticipate that larger woodlots would require higher labour inputs. Small individual woodlot owners may be investing an inefficient amount of labour in tree production.[46] Alternatively, the establishment of small individual woodlots on field boundaries or in long planting lines may require more effort to maintain than woodlots established in traditional woodlot formations such as those that fall in the mid-size woodlot category. Women are the primary labour source for large individual and cooperative woodlots. This result is expected for cooperative woodlots, as the majority of woodlot members are women.

The average total number of hours invested in woodlot management in year one for large individual woodlots is 541 hours, a significant increase from the small and medium sized woodlots. The average total number of hours dedicated to woodlot management tasks for cooperative woodlots in year one is 840 hours.[47]

In years two and three labour inputs decrease significantly. Interestingly, women's role in woodlot management decreases considerably for small and large woodlots in years two and three (13% and 17% decreases for small and large individual woodlots respectively). Labour contributions for men women and children remain proportionately equal for medium sized individual woodlots, and the role of labour participation by women in cooperative woodlots increases by 15% in years two and three.

For this analysis, the single social labour cost (i.e. a cost expended but not incurred by the woodlot owner or group) is time dedicated to providing extension advice. To estimate the social value of this cost, the number of hours of advice provided to each woodlot (see above Table IV.5 for summary statistics on average time spent receiving extension advice) is multiplied by the standard hourly wage rate for an extension officer, $21.[48] Of the total sample, 43% of individual woodlots and 90% of cooperative woodlots received extension advice. Sources of extension advice are presented below in Table IV.6. The majority of individual woodlot owners received extension

Table IV.6: Source of extension advice, percent

Source of advice	Individual woodlots (n=35)[a]	Cooperative woodlots (n=18)
Forestry Commission	11	11
AGRITEX	46	33.5
Local NGO	6	33.5
School	23	0
Other Farmer	3	0
Combination of AGRITEX and Forestry Commission	6	22
Other	6	0

a. May not equal 100% due to rounding.

advice from the AGRITEX extension worker, with very few benefiting from extension advice offered by NGOs. Schools are another common source of advice regarding tree growing; an expected result as tree growing and woodlot management are integral components of the Agriculture Program in Zimbabwean rural schools. The majority of cooperative woodlots received extension advice from either AGRITEX extension officers or local NGOs. It is also very

[46] Economic return estimates presented later in this chapter will shed light on this possibility.
[47] Note the variation in number of hours dedicated to woodlot management tasks is largely related to the size of the woodlot in question. Further, cooperatives are on average occupy much greater area than large individual woodlots given that high numbers of seedlings are planted in cooperative woodlots.
[48] This value is based on a monthly wage rate of $3300 ZWD (1997), and assumes 20 working days a month at 8 hours per day. Value is rounded to the nearest dollar. Personal Communication, Mr. Chasauka Sumburero, Chiwore Ward AGRITEX Officer, Mutoko District Zimbabwe, 15 August, 1997.

common for cooperatives to receive extension advice from a combination of Forestry Commission and AGRITEX extension officers. This is not surprising given the Forestry Commission's interest in cooperative tree growing groups, combined with their inability to reach the remote villages that AGRITEX extension officers may have better access to.

4.1.3 Material costs

Material costs can be divided into two categories, private costs which include cash paid for inputs by smallholders or cooperatives, and social costs for capital inputs which take the form of subsidies provided to the smallholder or tree growing group. Material inputs include seedlings for planting, seedlings for blanking and chemical pesticides.

Prices estimated from survey data for each woodlot in the sample were used to calculate private and social values for woodlot materials. Smallholders and cooperatives rely on several sources to supply them with the seedlings required for woodlot establishment, for blanking which generally takes place during the first three years after planting, and chemical pesticides. Table IV.7 provides prices and sources of acquisition for these inputs. Sources of material inputs provided free of charge are also presented. Prices paid by individual woodlot owners for seedlings vary greatly,

Plate 4.1: Cooperative woodlot, Mutoko Communal Area

Table IV.7: Price and source of material inputs to production, 1997 $ZWD[a,b,c]

	Forestry Commission	Purchased from a local TNG[d]	From a TNG that they are involved in	AGRITEX	NGO	Local school	Other Farmer	Purchased from store	Other
Seedlings for initial planting									
Seedling price	$0.45 (0.59) n=27	$5.44 (6.64) n=2	$0.29 n=1	$0.48 n=1	$0.51 n=1	$0.65 (0.32) n=5	$1.57 (1.45) n=2	$3.89 (4.98) n=2	N/A
Seedling source, purchased (Individual woodlots n=41)	66%	5%	2.5%	2.5%	2.5%	12%	5%	5%	0%
Seedling source, subsidy (no cost) (Individual woodlots n=40)	10%	5%	60%	3%	0%	5%	0%	0%	17%[e]
Cooperative woodlots (n=20)	10%	20%	65%	0%	5%	0%	0%	0%	0%
Seedlings for blanking									
Seedling price	$0.39 (0.48) n=4	N/A	N/A	N/A	$0.62 n=1	$0.37 n=1	N/A	N/A	$3.87 n=1
Seedling source, purchased (Individual woodlots n=7)	57%	0%	0%	0%	14.3%	14.3%	0%	0%	14.3%[e]
Seedling source, subsidy (no cost) (Individual woodlots n=14)	7%	7%	50%	0%	0%	0%	0%	0%	36%[e]
Cooperative woodlots (n=6)	0%	0%	100%	0%	0%	0%	0%	0%	0%
Chemical Pesticides[f]									
Chemical pesticide price	$98.77 n=1	N/A	N/A	N/A	N/A	N/A	N/A	$58.52 (58.76) n=8	$3.75 n=1[h]
Chemical pesticide source, purchased (Individual woodlots n=7)	10%	0%	0%	0%	0%	0%	0%	80%	10%[i]
Cooperative woodlots (n=3)	0%	0%	0%	0%	0%	0%	0%	100%	0%
Chemical pesticide source, subsidy (no cost) (Individual woodlots, n=6)	33%	0%	0%	0%	0%	0%	0%	0%	67%[i]
Cooperative woodlots (n=1)	0%	0%	0%	0%	0%	0%	0%	0%	100%

a. May not sum to 100% due to rounding.
b. Values in parenthesis represent standard deviations.
c. All values are in presented in real dollars (1997 Zimbabwe dollars). Prices are adjusted for inflation at a rate of 14% per annum.
d. TNG is a tree nursery group.
e. Other includes, given by a friend, grown in independent nursery or could not recall the source of the seedlings.
f. Prices paid for chemical pesticides purchased at a store are for 5 individual woodlots and 3 cooperative woodlots.
g. Chemical pesticide prices were cited by respondents on a per application basis. Generally smallholders and cooperatives were able to apply pesticide to their entire woodlot with one purchased package of pesticide.
h. Other represents disused oil that was purchased from a local grinding mill.
i. Indicates pesticides given by friends.

which may suggest that organizations such as the Forestry Commission and other quasigovernment or non-government groups are selling seedlings at partially subsidized prices.[49] For social benefit-cost estimates, because a partial subsidy is assumed for many of the seedling prices provided in the above table, a value of $3 per seedling, which is closer to the upper bound on observed seedlings prices is employed in analysis.

The Forestry Commission is the major source of seedlings purchased by smallholders. Schools also appear to be a common source of purchased seedlings for either initial planting or blanking. Cooperatives were not observed paying cash for seedlings for either initial planting or blanking. This finding is indicative of the degree that subsidized inputs are offered to cooperative tree growing groups. The primary source of fully subsidized seedlings for both individual and cooperative woodlots was tree nursery groups, of which the individual smallholder or tree-growing groups were members. The proportion of subsidized seedlings obtained from the Forestry Commission and NGOs, such as COOPIBO, that operate in the Mutoko communal area was surprisingly low. However, the Forestry Commission and COOPIBO are the main suppliers of polythene tubes and seeds, and encourage the development of cooperative tree seedling nurseries as an incentive to motivate smallholders and groups to plant trees.

Prices paid for chemical pesticides are very high, which may explain why few woodlot owners and tree growing groups use chemical pesticides in their woodlots. The average prices paid for chemical pesticide for one woodlot treatment were $105.28 and $54.66 for individual and cooperative woodlots respectively. That cooperative woodlots pay lower prices is a surprising result given that they are generally much larger than individual woodlots and should therefore require greater quantities of pesticides. In the social benefit-cost analysis the price of chemical pesticides for one application was assumed to be $100, indicating a non-subsidized value for this material input. The majority of chemical pesticides were purchased from local shops. Of the four cooperatives that utilized chemical pesticides, three purchased pesticides at a shop in the town of Mutoko and one from the Forestry Commission.

[49] Although seedlings prices were not observed to vary greatly between those purchased for initial planting and those purchased for blanking, the analysis treated them separately. Seedlings for initial planting are a crucial input to the production process. The woodlot owner has no choice but to obtain some number of seedlings so that she/he may undertake the production process. Blanking however is a management technique that may enhance woodlot production over time, but is not a necessity. The infrequency of blanking as observed in the total sample is indicative of the fact that few farmers choose to replace dead seedlings. Because the decision-making process regarding the acquisition of seedlings for initial planting and blanking are thought to be quite different, the results are divided in the above table.

4.1.4 *Estimating the flow of benefits for woodlots*

The following subsection presents the methods used to derive the flow of benefits over time for the total sample of woodlots. In addition, price data for the two primary woodlot outputs, poles and fuelwood are presented and discussed.

At the time the survey was conducted, 56% of individual woodlots and 10% of cooperative woodlots had harvested poles or fuelwood from their woodlots. This was a somewhat unexpected finding given that a number of woodlots had been established for some time. A study of harvesting patterns revealed three notable findings. First, the commercial market for poles or fuelwood is thin or non-existent in the study area. Second, woodlot owners in the Mutoko communal area were harvesting poles according to their own internal household demand for poles, or the household demand of neighbours and relatives, and this demand was what in fact was motivating harvesting decisions. Third, it was discovered that fuelwood was generally not independently harvested from woodlots, but rather taken off of poles when they were cut for building or construction purposes. This final finding is in contrast to expectations given the emphasis on the use of *Eucalyptus* as an alternative fuelwood source as promoted through the Rural Afforestation Program.[50]

The sample of cooperative woodlots that had harvested poles was thought too small to be representative of cooperative harvesting patterns. Given this assumption, harvesting data for the two tenure types were aggregated. The goal of this aggregation was to formulate an average harvest decision rule for individual smallholders and cooperatives in the region to value the flow of primary benefits over time.[51] A set of "average harvesting decisions" allows for the projection of the future benefits stream to individual smallholders and cooperatives for each woodlot.

Four factors were used to project the benefits stream for each woodlot, the average age of the first, second, third and fourth harvests of the oldest single stand; the hypothesized coppicing ability of each stem of the species *E. camaldulensis* after each consecutive harvest; the average percentage of the total stand harvested for each consecutive harvest; and the estimated relationship between poles harvested and fuelwood yield. Given these relationships it was possible to extrapolate from existing harvest data a proposed stream of benefits for each woodlot. This stream of benefits is hypothesized to represent demand for poles and fuelwood for only the local market. As was noted

---

[50] *E. camaldulensis* was a poor choice of species for an afforestation program with the goal of reducing fuelwood pressure on indigenous woodland. It is well known that this species does not burn long or hot enough to satisfy the cooking and heating demands of rural Zimbabweans (Mandondo, 1993).

[51] Because cooperative harvest decisions are based largely on patterns exhibited by individual woodlots over that planted over 100 seedlings, economic return estimation results cooperatives should be interpreted very broadly. As has already been noted, cooperatives are on average much bigger than even the large individual woodlots in the study area.

above, at the time of surveying there was virtually no access to commercial or regional markets for poles or fuelwood.

Following the conventions of the woodlot size categories noted earlier in this Chapter, data were grouped for small woodlots (≤50 seedlings planted), medium woodlots (≥51 and ≤100) and large woodlots (≥101). Due to the small sample of cooperative woodlots that had harvested poles (10%), data for the total sample was aggregated. Table IV.8 provides data on the average age of harvest for the first four consecutive cuts of the oldest stand (first group of contiguous trees planted).[52] Data in Table IV.8 indicate several harvest trends. Small woodlots owners generally

Table IV.8: Average age of harvest, years[a,b]

Stand size (# of trees)	Average age of stock harvested first cut	Average age of stock harvested second cut	Average age of stock harvested third cut	Average age of stock harvested fourth cut
Less or equal to 50 seedlings planted	6.88[c] (4.32) n=30	8.59 (3.84) n=8	9.13 (2.75) n=8	12.5 (3.73) n=2
Greater than or equal to 51 and less than or equal to 100 seedlings planted	4.71 (4.64) n=7	8.20 (6.3) n=5	9.33 (6.30) n=3	N/A
Greater than or equal to 101 seedlings planted	5.18 (2.75) n=11	7.33 (3.33) n=6	10.00 (4.24) n=2	12.33 (11.15) n=2

a. One woodlot was omitted from the data set for these estimates as it was identified as an outlier, so n=100. For the omitted woodlot the third and final cut occurred when the stand of trees was 32 years old.

b. Values in parenthesis represent standard deviations.

c. For estimation of woodlot benefits values were rounded to the nearest year, for example for large woodlots harvests were assumed to occur in years 5,7,10 and 12.

conduct their first harvest when the trees are older, whereas medium and large woodlot owners harvest trees at a younger age. There are several possible reasons for this. If trees are planted as lines or intercropped with other species, competition for nutrients and water may cause the trees to grow slower than they would if planted in a monoculture configuration.[53] Second, trees planted in lines or other area minimizing configurations may have been planted for windbreak or other non-timber values. If this is the case, smallholders may reluctantly harvest and sell poles even in times of severe economic stress (i.e. in drought years). Medium and large woodlots on the other hand, with greater total stock and higher opportunity costs of land may be more willing to harvest and use or sell their stock.

[52] For the total sample, the average year of the first planting was 1990. Average year for individual and cooperative plantings were 1989 and 1993 respectively.

[53] A monoculture configuration assumes that there trees are evenly spaced both length and widthwise across a given area.

Second cuts occur generally 2 to 3 years after the first harvest. This may be attributed to two factors. First, the harvested trees will have had time to coppice and secondly, smallholders or cooperatives may have simply been waiting for larger poles to utilize for a particular construction purpose. The final harvest for each size of woodlot generally occurs when the trees are around 12 or 13 years. This is likely a result of poles becoming too large for harvest and/or utilization for any practical purpose after this age, (i.e. harvest equipment costs and transport costs are too high, or poles are too large for roofing or fencing). Also, the fact that by a certain age the trees have significant secondary benefits associated with them may influence the decision of whether or not to harvest. Values such as sheltering crops and erosion control may encourage smallholders to leave the trees standing rather than harvest them.

The second factor required for estimating the benefit stream of woodlots in the Mutoko communal area is the hypothesized coppicing ability of each tree after it has been cut. The following characterization was employed to represent the coppicing ability of *E. camaldulensis*. Seedlings grow into single stem trees. After the first harvest, those trees that were cut coppice into two stems. The total stems available for the second cut in each woodlot is represented by the number of unharvested trees that survived plus two times the number of poles harvested in the first harvest. After the second cut, harvested trees are assumed to coppice into four shoots. Thus the total number of available stems for the third harvest is the number available prior to the second harvest plus two times the number of stems harvested. Individual trees are assumed to coppice a maximum of 4 times.[54] Further coppicing results in stems that are too small for utilization as building poles, and therefore will not be harvested.

Given the proposed coppicing ability of each individual tree, the percentage of the total available stock cut may be determined for each successive harvest. Survey data revealed that individual smallholders and cooperatives seldom harvested their total tree crop. This is likely due to the fact that different household building tasks require a variety of different pole sizes. As with data on average harvest age, data on percent of total stock harvested are based upon aggregated data and are presented according to the size of the woodlot. Assumptions regarding the coppicing ability of the trees presented above are built into the estimates of the percentage of the total stand harvested. Results are presented below in Table IV.9. Data presented in the above table support the general

[54] It should be noted that assumptions regarding the coppicing ability of *E. camaldulensis* are assumed to be indicative of the average tree. Some trees will produce more than four shoots after being harvested twice and others less.

Table IV.9: Percent of even aged stock harvested for poles, by size of stand[a,b]

Stand size (# of trees)	Percent of stock harvested first cut	Percent of stock harvested second cut	Percent of stock harvested third cut	Percent of stock harvested fourth cut
Less than 51 seedlings planted	42.64 (44.10) n=30	29.99 (28.54) n=17	20.70 (22.48) n=8	10.77 (6.14) n=2
Greater than 50 and less than 101 seedlings planted	32.35 (39.58) n=7	17.30 (21.51) n=5	24.38 (14.77) n=3	N/A
Greater than 100 seedlings planted	21.06 (33.84) n=11	6.21 (14.51) n=6	11.80 (11.47) n=3	3.44 n=2

a. For one of the individual woodlots surveyed 7 consecutive harvests of one even aged stand were recorded. Four was the maximum number of harvests observed for all of the other woodlots in the sample.

b. Values in parenthesis represent standard deviations.

assumption that household demand is motivating harvest decision rules. Smaller woodlots harvest a greater proportion of their total woodlot stock to satisfy household demand. It follows that larger woodlots will have to harvest a smaller proportion of their total stock to satisfy similar household demands. In general, any cuts occurring after the first cut are a smaller proportion of the total stock.

The final requirement for estimating the benefits stream for the primary woodlot outputs is estimating the empirical relationship between poles harvested and the amount of fuelwood that the harvested poles yield. It is assumed that the amount of fuelwood produced is related to the consumption of building poles. In the case study area fuelwood is only obtained from *E. camaldulensis* when poles are harvested for some construction purpose.[55] Estimates for projected benefits are based on a ratio of 7 poles harvested to 4 headloads of fuelwood harvested, which is derived from survey data.

It was noted above that harvesting appears to be motivated by household demand. There is currently no access to commercial markets for poles in the Mutoko communal area. Nonetheless, it is of interest to consider the impact that entry into such a market would have on economic returns. It should be noted that this is only a hypothetical scenario, although relevant as the Rural Afforestation Program presupposed some access to commercial markets in the estimation of project rates of return. The commercial market scenario assumes that individual smallholders and cooperatives will harvest trees according to household demand until the trees reach age 15. To this point the flow of benefits will be equivalent to the status quo harvest. The commercial market scenario assumes that at year 15, any of the original seedlings planted that had not already been harvested at some point (i.e. no coppiced shoots), will be harvested for sale in a commercial market. Large trees harvested for sale will also have some fuelwood stock associated with them. For ease of analysis the above noted ratio of 4 headloads of fuelwood for every 7 poles harvested will be observed. It is assumed that fuelwood derived from these large poles will be utilized only in the rural market.

To clarify the information and data presented in this subsection an example is provided below of the estimation of the primary benefits stream for a large woodlot (i.e. more than 100 seedlings planted). Consider an individual woodlot that takes the form of a traditional woodlot. Of the 200 seedlings initially planted 150 trees have survived. The information used to calculate the number of poles and the number of headloads harvested over the first 15 years of the rotation is presented below in Table IV.10 for both the status quo and the case where the woodlot owner has access to the commercial market for gum poles.[56] Under the current woodlot management paradigm in the Mutoko communal land, which assumes harvest decision are driven only by household demand,

Table IV.10: Summary example, primary benefits stream for large woodlot

	Age of harvest (years)[a]	# Poles available for status quo harvest	Percent of total stand harvested[b]	Number of poles harvested	Number of fuelwood headloads harvested
First cut	5	150	21	(150 x 0.21)=32	32 x 0.57 = 18
Second cut	7	(150 - 32)+(32 x 2)=182	6	(182 x 0.06)=11	11 x 0.57 = 6
Third cut	10	(182-11)+(11 x 2)=193	13	(193 x 0.13)=25	25 x 0.57 = 15
Fourth cut	12	193-6=187	3	(193 x 0.03)=6	6 x 0.57 = 3
Final cut (Commercial market only)	15	150 - (32+11+25+6)=76	100	(76 x 1.00)=76	76 x 0.57 = 43
Total poles and fuelwood harvested				Status quo scenario = 74 Commercial scenario=150	Status quo scenario = 42 Commercial scenario = 85

a. Data taken from Table IV.8.
b. Data taken from Table IV.9.

the number of poles and headloads of fuelwood harvested form this particular small individual woodlot are 74 and 42 respectively. If access to a commercial market is assumed, in year fifteen the total number of original stems remaining are harvested. In the above example in year fifteen 76 poles are harvested and 43 headloads of fuelwood. We assume the remaining coppiced shoots are left standing for non-timber benefits beyond year 15.

[55] Generally when an *E. camaldulensis* tree is harvested the primary stem will be utilized as a building pole. Extraneous branches gathered from the main stem comprise what is termed fuelwood.
[56] Gum pole is the colloquial term for a pole from a *Eucalyptus* spp. tree. The use of the term gum rather than *Eucalyptus* is common throughout Zimbabwe.

4.1.4.1 *Prices for poles and fuelwood*

To estimate the value of benefits over time, the quantity of outputs projected in the previous section are multiplied by prices that reflect rural market values for poles and fuelwood, and in the access to commercial markets example, market prices for poles. Primary price data for poles were collected during surveying from woodlots that had sold harvested poles. Consideration of this primary data, combined with information gathered from key informants and gum pole processing facilities in Zimbabwe provided the range of prices presented in Table IV.11. In addition to actual prices, estimated harvest costs and stumpage values are presented in Table IV.11.

Table IV.11: Gum pole prices, 1997 $ZWD

Market price and data source	Price per harvested pole	Estimated transport cost	Stumpage value
Rural market Price[a]			
Mutoko communal land (Average price as estimated from survey data)[b]	$44 (34.23)[c] n=40	$0.64[f]	$43.34
Resettlement Area, north of Bindura[d]	$10	$0.64	$9.36
Commercial market price			
Zimbabwe Forestry Commission (Prices at Mtao Commercial Gum tree lot located south of Harare)	$450[e]	$143.64	$306.36
Harare Commercial Timber Lot (Price at lot in Harare)	$400[e]	$143.64[g]	$256.36

a. All prices are in 1997 Zimbabwean dollars, inflated at a rate of 14% per annum.
b. Because only 2 cooperative woodlots had sold poles at the time of surveying, price data were aggregated for individual and cooperative woodlots.
c. Value in parenthesis represents standard deviation.
d. Personal communication. Mr. Musavaya Chikore, Forestry Extension Officer, Bindura Headquarters, 7 September, 1997, Bindura, Zimbabwe. Mr. Chikore was the Forestry Extension Officer in Mutoko District from 1998-1996. In addition to providing pole price data in the Bindura area, Mr. Chikore was able to provide considerable insight into the evolution of woodlot establishment in the Mutoko communal area.
e. Pole price is for a 9 metre pole with a weight of approximately 110 kgs. All poles sold at Mtao are treated with creosote to prevent termite attack.
f. For example, assuming the median adult wage rate of $22.50 per day, working a 10 hour day and harvesting 3.5 poles per hour yields a harvest cost of $0.64 per pole. In the rural areas there is assumed to be little or no cost associated with the transportation of poles.
g. From data provided by the Zimbabwe Forestry Commission the transportation costs of delivering poles was estimated. The cost of transporting a large gum pole is approximately 0.62 cents per km. The study area lies approximately 230 kms from the nearest major commercial market (Harare), thus the total cost of transportation per large pole is estimated to be $143 Zimbabwe dollars.

Pole price data presented in Table IV.11 reflect the commonly observed differential between rural market prices and commercial prices in markets for forest products in developing countries. Prices indicated in the first two rows are rural prices, the first for the study area and the second from Model B Resettlement farms north of Harare. The later two prices are reflective of the commercial or industrial market for gum poles. The commercial gum poles prices cited are for very large poles (for example, the size that one would anticipate a fifteen-year-old gum tree might grow to).

Stumpage values in Table IV.11 are derived from the price of the pole minus the cost of harvesting and transport. For poles sold in the rural market, harvest costs are based on data from woodlots that had already harvested poles. Data indicated that harvesting of poles and fuelwood would occur at a rate of 3.5 poles per hour, and this relationship was assumed to hold for both small and large poles. All harvest costs assume that adult males do the harvesting, and that pole and fuelwood harvesting occurs concurrently. For poles sold in commercial markets both harvest and transportation costs are considered. The average commercial gum pole price is $425, thus the stumpage value of the pole to the smallholder is estimated to be approximately $280.[57]

There is no cash driven market for fuelwood in the study area. Generally fuelwood harvested by individuals and cooperatives is utilized for household consumption only. Although there is seldom any trade or sale of fuelwood gathered from *E. camaldulensis* between smallholders, data from elsewhere on the Mutoko communal land and other regions in Zimbabwe, and secondary data provide an acceptable range of prices. Price data in Table IV.12 indicate that there is little

Table IV.12: Prices per headload of fuelwood, 1997 $ZWD[a]

Data Source	Price per headload
Mutoko communal land [b]	$5
Resettlement area, north of Bindura [c]	$3
Hotsprings Working Group – Jinga[d]	$2.96
Hotsprings Working Group – Matendueze[d]	$5.19

a. Prices have been inflated at a rate of 14% per annum to reflect prices in 1997 Zimbabwe dollars.

b. Personal communication. Miss. Cheneso Gunda, Forestry Extension Officer, Mutoko, 26 June, 1997, Mutoko, Zimbabwe.

c. Personal communication. Mr. Musavaya Chikore, Forestry Extension Officer, Bindura Headquarters, 7 September, 1997, Bindura, Zimbabwe.

d. Source, Campbell *et al.* 1994.

variation in the value of fuelwood in the rural market. As with poles, Mutoko communal area woodlot owners currently have no access to commercial markets for fuelwood. Further, it is assumed that even if poles are sold in commercial markets, fuelwood will still be utilized exclusively in the rural market.

[57] This estimate makes the simplifying assumption that beyond labour and material inputs, transportation costs are the only costs associated with commercial gum pole production. For example, although the majority of poles sold in commercial markets are soaked in creosote, costs such as this, which are not borne by the smallholder or cooperative are not included in this analysis.

Table IV.13 summarizes the prices that will be used to conduct sensitivity analysis in the economic return estimations. Schedules A and B represent prices employed to evaluate economic returns to woodlots based on access to only the rural market, this is the current situation

Table IV.13: Schedule of pole and fuelwood prices used in sensitivity analysis, 1997 $ZWD[a]

	Poles	Fuelwood
Schedule A (No access to commercial markets)	$15	$3
Schedule B (No access to commercial markets)	$40	$5
Schedule C (Access to commercial markets, at year 15)	$280	$5

a. All prices are given in 1997 Zimbabwe dollars.

in the Mutoko communal area. Based on the distribution of pole prices observed in the Mutoko communal area, $15 per pole is representative of the lower range of prices as well as prices for poles in other rural areas of Zimbabwe. Price Schedule B provides prices that approximate average prices for poles observed in the immediate study area, and the higher price observed for fuelwood. Schedule C is presented as an alternative hypothetical scenario to assess the impact that entrance into commercial timber markets might have on economic returns to woodlots.

4.2 Economic return estimates

Private and social internal rate of return estimates are presented in Table IV.14 for the existing woodlot output market in the Mutoko communal area, assuming that smallholders and cooperatives have no access to commercial gum pole or fuelwood markets. An alternative scenario, where smallholders and cooperatives do have access to commercial markets is also presented. The World Bank criteria of 10 to 12 % as the benchmark economic internal rate of

Table IV.14: Internal rate of return estimates, percent[a]

	IRR – Private (n=81)		IRR – Social (n=20)	
Wage rates, Adult=$15/day, Child=$5/day	Individual Woodlots	Cooperative woodlots	Individual Woodlots	Cooperative woodlots
Pole=$15/pole Fuelwood=$3/headload	28% (33) n=75[b]	59% (41) n=20	8% (21) n=69	-15% (33) n=14
Pole=$40/pole Fuelwood=$5/headload	48% (43) n=79	99% (54) n=20	22% (27) n=77	12% (30) n=18
Access to Commercial Markets Pole=$280/pole Fuelwood=$5/headload	58% (35) n=81	101% (53) n=20	30% (15) n=81	35% (6) n=20
Wage rates, Adult=$22.5/day, Child=$7.5/day	Individual Woodlots	Cooperative woodlots	Individual Woodlots	Cooperative woodlots
Pole=$15/pole Fuelwood=$3/headload	22% (32) n=73	46% (36) n=20	6% (21) n=69	-17% (32) n=14
Pole=$40/pole Fuelwood=$5/headload	42% (40) n=77	81% (48) n=20	20% (27) n=77	9% (30) n=18
Access to Commercial Markets Pole=$280/pole Fuelwood=$5/headload	50% (233) n=81	84% (46) n=20	27% (16) n=81	34% (6) n=20
Wage rates, Adult=$30/day, Child=$10/day	Individual Woodlots	Cooperative woodlots	Individual Woodlots	Cooperative woodlots
Pole=$15/pole Fuelwood=$3/headload	14% (29) n=71	29% (29) n=20	2% (21) n=69	-20% (31) n=13
Pole=$40/pole Fuelwood=$5/headload	31% (37) n=77	58% (40) n=20	16% (27) n=77	7% (29) n=17
Access to Commercial Markets Pole=$280/pole Fuelwood=$5/headload	40% (31) n=81	64% (37) n=20	24% (17) n=81	31% (6) n=20

a. Values in parenthesis represent standard deviations.
b. In some cases multiples solutions resulted for IRR estimates. Therefore in a few cases, the total number of IRR estimates is lower that the number of observations for the corresponding category.

return (EIRR) that yields an acceptable rate of return for a project will be employed. Based on this criterion, in all cases, private IRR estimates indicate that individual and cooperative woodlots exhibit acceptable rates of return. Cooperative woodlots are estimated to be considerably more profitable than individual woodlots, due in large part to the size of the woodlot, relative to the inputs required to grow trees. However, this finding, and all others pertaining to cooperatives, should be very broadly interpreted given the uncertainty surrounding actual harvest patterns for cooperatives. Social internal rate of return estimates indicate that individual and cooperative woodlots are economically profitable when prices of $40 for poles and $5 for headloads of fuelwood are employed in the analysis. Cooperative woodlots are marginally economically profitable when low wage rates and low output prices are used to estimate EIRRs. When social internal rates of return are estimated assuming status quo household consumption over the first 14 years, followed by harvest of the remaining original stems in year 15 for commercial markets, woodlots are in all cases economically profitable.

The EIRR estimate that is hypothesized to best represent the average set of wage rate and price criteria in the study area is the case where daily wage rates are $22.5 and $7.5 for adults and children respectively, and output prices are $40 for poles and $5 for headloads of fuelwood. Estimates of private economic returns for individual and cooperative woodlots are 42% and 20 % respectively, and social economic returns 20% for individual woodlots and 9% for cooperative woodlots. To illustrate the influence that woodlot size has on economic returns, data are presented in Table IV.15 for the average case described above. Economic returns for individual

Table IV.15: IRR estimates by size of woodlot, percent

	Private IRR Estimates	Social IRR Estimates
Individual woodlots		
Less than 51 trees originally planted (n=49)	41%	23%
	(27)	(14)
Greater than 51 and less than 101 trees planted (n=15)	71%	32%
	(48)	(35)
Greater than 100 trees planted (n=13)	12%	-9%
	(53)	(36)
Cooperative woodlots		
Greater than 100 trees planted	81%	9%
	(55)	(33)
	n=20	n=18

a. Values in parenthesis represent standard deviations.

woodlots are highest for medium sized woodlots at both the private and social levels. Although large individual woodlots yield acceptable rates of return, it is interesting to note that they are not the highest. At the private level cooperative woodlots exhibit the highest economic returns, however, when social costs are taken into account, both small and medium sized individual woodlots have higher economic returns. These findings are illustrative of the impact that subsidized inputs have on the economic returns observed for very large woodlots. Private IRR estimate results indicate that in the absence of subsidized inputs such as land, and other key material inputs to production, woodlots would be less profitable. This finding suggests that smallholders, and certainly cooperatives may not have undertaken tree growing initiatives to the degree that they have in this region during the past 20 years.

One of the primary goals of estimating internal rates of return in this analysis was to determine a range of discount rates suitable for estimating net present values and benefit-cost ratios. As was discussed in Chapter 3, choice of an appropriate discount rate is important for two reasons. First, discount rates represent the opportunity cost of inputs to production over time. Higher discount rates put more emphasis on present values than future values, indicating a higher opportunity cost of capital and other inputs to production. Second, the discount rate is indicative of the rate of time preference of the household or the group. How much the economic unit values having something today versus having it a year from now is embodied in the discount rate. Higher discount rates indicate a desire to have returns now rather than at some time in the future.

Private IRR estimates for the average case discussed above are 42% and 81% for individual and cooperative woodlots respectively; social estimates are 20% and 9% for individual and cooperative woodlots respectively. Because 10% is the lower bound of the EIRR estimate that is considered an acceptable project return, and because it is close to the low end IRR estimate cited above (9%), it will be used in the sensitivity analysis. A mid-range discount rate of 35% was chosen as it is close to the average of the aggregated estimation results for individual and cooperative woodlots at the private and social level. The highest discount rate used in the sensitivity analysis is 50%. At the private level, for individual woodlots, 50% is approximately the highest discount rate observed under the status quo scenario. This upper bound is thought to be indicative of the personal rate of time preference observed in rural Zimbabwean households.[58]

Private and social net present value estimates at the three above noted discount rates are presented in Table IV.16 for both individual and cooperative woodlots. It should be noted that NPV and BCR estimates were possible for the total sample of woodlots, whereas IRR estimates in some cases resulted in multiple solutions. In addition, economic return estimates for the scenario that assumes access to a commercial market for gum poles are not provided in the tables below. IRR estimates presented above provide sufficient insight as to the impact that access to commercial markets will have on woodlot investment returns.

[58] Personal communication, Mr. Godfrey Kundlhande, PhD. Candidate, University of Alberta, Department of Rural Economy, 27 January, 1998, Edmonton, Alberta, Canada.

Table IV.16: Net present value estimates, 1997 $ZWD [a]

	NPV Private		NPV Social	
10% Discount Rate	Individual woodlots (n=81)	Cooperative woodlots (n=20)	Individual woodlots (n=81)	Cooperative woodlots (n=20)
Wage rates, Adult=$15/day, Child=$5/day				
Pole=$15/pole	$507	$4932	-$444	-$2856
Fuelwood=$3/headload	(4293)	(6561)	(1545)	(5256)
Pole=$40/pole	$2559	$14348	$1601	$6560
Fuelwood=$5/headload	(13708)	(17349)	(9667)	(12246)
Wage rates, Adult=$22.5/day, Child=$7.5/day				
Pole=$15/pole	$365	$4391	-$587	-$3397
Fuelwood=$3/headload	(4279)	(6367)	(1736)	(5371)
Pole=$40/pole	$2417	$13807	$1464	$6061
Fuelwood=$5/headload	(13643)	(17337)	(9613)	(12028)
Wage rates, Adult=$30/day, Child=$10/day				
Pole=$15/pole	$222	$2850	-$730	-$3938
Fuelwood=$3/headload	(4289)	(6230)	(1962)	(5602)
Pole=$40/pole	$2274	$13266	$1321	$5478
Fuelwood=$5/headload	(13585)	(17266)	(9570)	(11870)
35% Discount Rate	Individual woodlots (n=81)	Cooperative woodlots (n=20)	Individual woodlots (n=81)	Cooperative woodlots (n=20)
Wage rates, Adult=$15/day, Child=$5/day				
Pole=$15/pole	-$94	$1030	-$1044	-$5345
Fuelwood=$3/headload	(1339)	(2148)	(3237)	(4847)
Pole=$40/pole	$554	$4145	-$396	-$2231
Fuelwood=$5/headload	(4292)	(5633)	(1050)	(2822)
Wage rates, Adult=$22.5/day, Child=$7.5/day				
Pole=$15/pole	-$219	$552	-$1169	-$5823
Fuelwood=$3/headload	(1495)	(2287)	(3353)	(5220)
Pole=$40/pole	$428	$3667	-$523	-$2708
Fuelwood=$5/headload	(4317)	(5523)	(1282)	(3143)
Wage rates, Adult=$30/day, Child=$10/day				
Pole=$15/pole	-$345	$75	-$1295	-$6301
Fuelwood=$3/headload	(1693)	(2562)	(3493)	(5632)
Pole=$40/pole	$303	$3189	-$647	-$3186
Fuelwood=$5/headload	(4364)	(5476)	(1540)	(3557)
50% Discount rate	Individual woodlots (n=81)	Cooperative woodlots (n=20)	Individual woodlots (n=81)	Cooperative woodlots (n=20)
Wage rates, Adult=$15/day, Child=$5/day				
Pole=$15/pole	-$208	$267	-$1157	-$5848
Fuelwood=$3/headload	(880)	(1442)	(3805)	(5320)
Pole=$40/pole	$173	$2140	-$776	-$3975
Fuelwood=$5/headload	(2454)	(3337)	(2018)	(3500)
Wage rates, Adult=$22.5/day, Child=$7.5/day				
Pole=$15/pole	-$329	-$196	-$1278	-$6311
Fuelwood=$3/headload	(1120)	(1781)	(3898)	(5686)
Pole=$40/pole	$52	$1677	-$897	-$4438
Fuelwood=$5/headload	(2530)	(3344)	(2167)	(3903)
Wage rates, Adult=$30/day, Child=$10/day				
Pole=$15/pole	-$450	-$658	-$1399	-$6773
Fuelwood=$3/headload	(1385)	(2230)	(4013)	(6088)
Pole=$40/pole	-$69	$1215	-$1018	-$4900
Fuelwood=$5/headload	(2640)	(3454)	(2346)	(4349)

a. Value in parenthesis represent standard deviations.

At the 10% discount rate private NPVs are positive for all wage rates and prices. As would be expected, the highest NPVs are observed where very low wage rates and high prices are employed in the sensitivity analysis. At the social level NPVs estimated at the 10% discount rate are positive only where high prices of $40 dollars per pole, and $5 per headload of fuelwood are used in the analysis. Again, the highest economic returns are observed where low wage rates are combined with high prices. At the 35% discount rate, private NPVs are positive for individual woodlots only when the higher price schedule is used. In all cases cooperative woodlots yield positive private NPVs. At the social level all NPVs are negative, indicating that the higher rate of time preference has a significant impact on whether or not positive returns are observed. At the 50% discount rate positive private returns are observed for individual woodlots with high output prices and low to medium wage rates. Cooperative woodlots yield positive private returns for the following two cases: low wages and high prices, and high prices with medium or high wage rates. At the social level woodlots do not show positive economic returns.

Because IRRs and NPVs do not adequately capture profitability relative to the scale or size of woodlots, benefit-cost ratios were estimated. Estimation results are presented in Table IV.17.

Table IV.17: Benefit-cost ratio estimates[a]

	BCR Private		BCR Social	
10% Discount Rate	Individual woodlots (n=81)	Cooperative woodlots (n=20)	Individual woodlots (n=81)	Cooperative woodlots (n=20)
Wage rates, Adult=$15/day, Child=$5/day				
Pole=$15/pole	3.67	6.00	1.03	0.70
Fuelwood=$3/headload	(4.22)	(3.50)	(0.67)	(0.29)
Pole=$40/pole	9.41	15.40	2.65	1.78
Fuelwood=$5/headload	(10.82)	(14.10)	(1.72)	(0.75)
Wage rates, Adult=$22.5/day, Child=$7.5/day				
Pole=$15/pole	2.64	4.01	0.91	0.64
Fuelwood=$3/headload	(2.86)	(3.66)	(0.61)	(0.28)
Pole=$40/pole	6.76	10.28	2.34	1.64
Fuelwood=$5/headload	(7.35)	(9.39)	(1.56)	(0.28)
Wage rates, Adult=$30/day, Child=$10/day				
Pole=$15/pole	2.08	3.01	0.82	0.60
Fuelwood=$3/headload	(2.18)	(2.75)	(0.56)	(0.27)
Pole=$40/pole	5.34	7.71	2.11	1.53
Fuelwood=$5/headload	(5.60)	(7.04)	(1.44)	(0.68)
35% Discount Rate	Individual woodlots (n=81)	Cooperative woodlots (n=20)	Individual woodlots (n=81)	Cooperative woodlots (n=20)
Wage rates, Adult=$15/day, Child=$5/day				
Pole=$15/pole	1.26	2.63	0.28	0.25
Fuelwood=$3/headload	(1.50)	(3.40)	(0.16)	(0.09)
Pole=$40/pole	3.24	6.74	0.72	0.65
Fuelwood=$5/headload	(3.85)	(8.72)	(0.42)	(0.23)
Wage rates, Adult=$22.5/day, Child=$7.5/day				
Pole=$15/pole	1.93	1.75	0.25	0.24
Fuelwood=$3/headload	(1.05)	(2.27)	(0.15)	(0.09)
Pole=$40/pole	2.37	4.50	0.65	0.60
Fuelwood=$5/headload	(2.69)	(5.81)	(0.39)	(0.22)
Wage rates, Adult=$30/day, Child=$10/day				
Pole=$15/pole	0.74	1.32	0.23	0.22
Fuelwood=$3/headload	(0.82)	(1.70)	(0.15)	(0.08)
Pole=$40/pole	1.90	3.37	0.59	0.56
Fuelwood=$5/headload	(2.11)	(4.36)	(0.38)	(0.22)
50% Discount rate	Individual woodlots (n=81)	Cooperative woodlots (n=20)	Individual woodlots (n=81)	Cooperative woodlots (n=20)
Wage rates, Adult=$15/day, Child=$5/day				
Pole=$15/pole	0.71	1.74	0.15	0.16
Fuelwood=$3/headload	(0.82)	(2.50)	(0.09)	(0.05)
Pole=$40/pole	1.82	4.46	0.38	0.40
Fuelwood=$5/headload	(2.11)	(6.42)	(0.22)	0.13)
Wage rates, Adult=$22.5/day, Child=$7.5/day				
Pole=$15/pole	0.52	1.16	0.13	0.14
Fuelwood=$3/headload	(0.59)	(1.67)	(0.08)	(0.05)
Pole=$40/pole	1.34	2.97	0.34	0.37
Fuelwood=$5/headload	(1.52)	(4.28)	(0.21)	(0.13)
Wage rates, Adult=$30/day, Child=$10/day				
Pole=$15/pole	0.42	0.87	0.12	0.14
Fuelwood=$3/headload	(0.48)	(1.25)	(0.08)	(0.05)
Pole=$40/pole	1.08	2.23	0.32	0.35
Fuelwood=$5/headload	(1.22)	(3.21)	(0.20)	(0.13)

a. Value in parenthesis represent standard deviations.

Benefit-cost ratios that are greater than 1 indicate economically acceptable investments, whereas benefit-cost ratios below 1 suggest that woodlot investment are not economically profitable. Also, unlike NPVs, BCR estimates indicate profitability relative to the size of the investment. In general, where BCR estimates are greater than 1, NPV estimates are greater than 0. However, because averages are being reported, this is not always the case. For NPV estimates, large negative numbers greatly affect averages, as absolute amounts are included. For BCRs, the same highly negative net present value estimates would cause the benefit-cost ratio to approach zero. This relative profitability estimate would not effect the averages as much as the negative absolute amounts for NPVs. Accordingly, we find several cases, where average NPV estimates are negative, while BCRs are greater than 1.

At the 10% discount rate, social BCR estimates for individual woodlots appear to be profitable with low wage rates and woodlot output prices, this was not the case for the net present value estimated under the same sensitivity analysis criteria. At the 35% discount rate, the only deviation from NPV results occurs at the private level with individual woodlot estimates where low to medium wage rates and low output prices are employed in the sensitivity analysis. NPV estimates for both of these sensitivity analysis criteria at the 35% discount rate are negative, while BCRs are greater than 1. Finally at the 50% discount rate, private BCR estimates for cooperative woodlots estimated with mid range wage rates and low output prices yield a BCR estimate that is slightly greater than one, while NPV results indicate negative returns to woodlot investment.

Several general trends and conclusions are evident from above results. First, generally speaking, prices on the order of those in Schedule B are required for woodlot owners and cooperatives to derive positive economic returns. This is a significant finding, as prices such as those indicated in Schedule A are not uncommon in the Mutoko communal area. Further, analysis incorporating commercial market pole prices indicates that access to commercial markets will have a very significant positive impact on economic returns to woodlot production. It should be noted however, that currently there are significant barriers to entry to this market, namely the absence of adequate harvesting and transport equipment. Second, subsidies were successful in allowing individuals, and to a greater degree cooperatives to establish woodlots that yielded positive economic returns. Analysis clearly indicates that without the provision of substantial subsidies, individual and cooperative woodlots in many cases would have exhibited negative economic returns. In addition, subsidies allowed households with high rates of time preference to experience positive returns on woodlot investments.

Chapter 5 – Socioeconomic and Biophysical Explanators – Regression Models and Results

Chapter 5 explores the final two research questions of this thesis "What factors influence variation in economic returns to tree growing?, and "What characteristics are associated with individual and cooperative tenures?. Two econometric models are presented. Section 5.1 presents an ordinary least squares model, Model A, which examines the socioeconomic and biophysical factors influencing economic returns to woodlot investments. In Section 5.2, Model B, a binomial logit model is presented that investigates characteristics associated with individual and cooperative woodlots.

5.1 Model A - Factors influencing economic returns to tree growing

To determine what factors are influencing variability in financial performance, net present value per tree is the continuous dependent variable for Model A.[59] Hypothesized explanatory variables include: tenure type, secondary benefits, tenure security, socioeconomic indicators and the biophysical rate of tree growth associated with each woodlot. Model A is specified by the following equation:

MODEL A: $NPV/tree_i = \alpha\beta 0 + Tenure\beta 1 + SecBen\beta 2 + TenSec\beta 3 + Socioecon\beta 4 + Growth\beta 5 + \varepsilon t$;(4)

where $NPV/tree_i$[60] is the value of the dependent variable on the i^{th} observation, α is a constant, βs are coefficients on each explanatory variable and ε_t is a random error term.

A potential problem in estimating this model stems from the way in which financial estimates in Chapter 4 were derived. Recall that a lack of data on actual harvest levels resulted in project benefits being estimated similarly for all woodlots in the sample based on average harvest levels. Therefore, the only source of variability in the financial returns is with respect to costs. This lack of variability in the dependent variable may prove problematic for regression analysis.

Table V.1 provides a summary of the explanatory variables for Model A, and their expected signs.

---

[59]Net present value estimates are divided by the number of trees originally planted in the woodlot to account for variation in economic returns that arise from differences in woodlot size. Some average spacing is assumed for the total sample of woodlots, allowing NPV/tree to represent the economic returns for a consistent area of land.

[60] NPV estimates for private economic returns using wage rates of $22.5 and $7.5 Zimbabwean dollars (1997) per day for adults and children respectively, and output prices of $40 per pole and $5 per headload of fuelwood at a 35% discount rate are utilized. These estimates are divided by the corresponding number of trees originally planted in each woodlot in the sample.

Table V.1: Factors influencing economic returns, hypothesized explanatory variables

Independent variable and abbreviation	Variable description	Expected effect on economic returns
Tenure Type *(Tenure)*	Individual or cooperative ownership *(Tenure, 0 = Cooperative, 1=Individual)*	+/-
Secondary Benefits *(Wind)*	Trees utilized to shelter crops or gardens from wind *(Wind, 0 = no windbreaks, 1=yes windbreaks)*	-
Tenure Security *(Yrs.)*	Years household or cooperative has been established on the current plot of land *(Yrs-continuous variable)*	+
Socioeconomic Indicators *(Gender, Edu, Income(Cattle, Plough, Agyield))*	Percent of household members or tree growing cooperative which are women *(Gender – continuous)*,	+/-
	Level of education of the household head or leader of the tree growing cooperative *(Edu, 0 = primary school or less, 1=more than primary school*,	+
	Total income of household or total household income for leader of tree growing cooperative. Income is comprised of: number of cattle *(Cattle-continuous)*, number of ploughs *(Plough-continuous)*, and number of bags of agricultural yield *(Agyield-continuous)*	+
Biophysical Growth Indicator *(Surv, MAI)*	Survival rate, percent *(Surv-continuous)*,	+
	Mean annual increment of surveyed stand *(MAI-continuous)*	+

The expected sign of tenure as it relates to economic returns is undetermined. Economic return estimates from Chapter 4 indicate that cooperative woodlots yield higher returns under the set of defined harvesting decisions. However, whether this is so in the presence of other explanatory variables is unknown and will be tested.

The sign of the secondary benefit variable *wind* is expected to be negative. In cases where nonmarket values can be captured efficiently, there will be a disincentive to harvest the tree crop to capture market values. When smallholders or cooperatives use the trees in their woodlots as windbreaks to shelter crops or gardens, the nonmarket value of the resource may exceed the market value, implying that nonmarket values captured in financial economic return estimates (represented by NPV/tree) will be relatively small. It is hypothesized that tenure security is positively correlated to NPV/tree. The economic rationale for this hypothesis is that the longer a household or cooperative has been established on its current plot of land, the more likely it is to make significant investments in tree growing. The assumption is that longevity of tenure implies some perception of future security.

Socioeconomic indicators such as: gender, education and income levels are embodied in the third explanatory variable. The sign of the gender variable may be either positive or negative. The two primary outputs of *E. camaldulensis* woodlots are poles for building (associated with traditional male roles), and fuelwood for cooking and heating (associated with traditional female roles). This implies a considerable incentive for both genders to invest in growing and harvesting trees.[61] It is expected that the smallholder or cooperative leaders' level of education will be positively related to NPV/tree. Smallholders who are highly educated are likely to have spent more time in school

Plate 5.1: *Eucalyptus* and sisal plants, used in conjunction to slow erosion

[61] Women may in fact be responsible for making decisions regarding tree planting and how to bare the cost of planting trees (Bruce and Fortmann, 1989). Because women are the primary fuelwood gatherers they are hypothesized to have a heightened awareness of household demand for woodland resources.

learning about agriculture and tree growing. Relative household wealth implies that smallholders may be less risk averse and therefore more willing to take land out of its' current productive use to plant trees. Higher or lower levels of household wealth will also imply less or more reliance on the secondary benefits of trees, impacting what proportion of the total woodlot stock is harvested.

It is expected that both the survival rate (i.e. the percentage of the total number of trees planted that survived) and the mean annual increment (MAI) of the stand will be positively related to NPV/tree.[62] The higher the percentage of trees that survived for a given set of inputs, the greater the potential economic returns are expected to be. Higher mean annual increments imply that primary woodlot outputs can be harvested sooner, indicating higher net present value per tree. Table V.2 presents descriptive statistics for the continuous variables discussed above.

Table V.2: Descriptive statistics for variables in Model A[a]

Variable	Mean	Standard Deviation	Min	Max	Units
NPV/tree	-1.29	8.60	-45.57	5.11	1997 $ZWD
Yrs	22.61	17.25	1	80	Years
Gender	53.59	20.84	0	100	Percent women
Cattle	5.76	4.49	0	22	Quantity
Plough	1.19	0.60	0	3	Quantity
Agyield	44.64	32.58	0	165	Bags
Surv	75.82	20.10	17.33	100	Percent
MAI/ha	41.81	85.45	0	688.21	M^3/ha

a. N=101 for all variables in this table.

5.1.1 MODEL A - Estimation results

Estimation results for Model A are presented below in Table V.3.

Table V.3: Estimation results – Model A

	OLS Estimation Results	
Independent Variable	Coefficient	T-Stat
Tenure	-3.3462	-1.914***
Wind	-2.134	-1.069*
Yrs	-0.1109	-0.185
Gender	-0.0055	-0.150
Edu	-0.6918	-0.355
Plough	-3.1562	-1.461**
Surv	0.0327	1.048*
MAI/ha	0.0094	1.398**
Constant	3.8916	1.024
R-squared	0.1088	

*** 95% level of significance
** 90% level of significance
*75% level of significance

62 See *Appendix B* for a detailed presentation of the estimation of mean annual increment for each woodlot surveyed and a presentation of summary stand growth statistics.

Overall the model does not perform particularly well. Tenure is significant at the 95% confidence level and negative, indicating that cooperative woodlots yield higher economic returns. This finding is likely due to the lack of variability in the dependent variable and the fact that cooperative woodlots are so much larger on average than individual woodlots. The secondary benefit, using trees as windbreaks, is negative as expected and significant at the 75% confidence level. This finding indicates that where woodlot owners employ trees as windbreaks economic returns from the harvest of primary woodlot outputs will be lower. Numbers of years of residence, gender and education level are negative and statistically insignificant. Little can be determined from these results.

Number of ploughs was chosen as the asset variable that provided the best empirical results. Number of cattle and bags of agricultural yield both had negative signs and were insignificant; therefore they were dropped from the regression. The sign of this variable is negative, a somewhat unexpected result indicating that wealthier households should expect lower returns from woodlots. This finding may imply that households and cooperatives have lower rates of time preference than were initially hypothesized to be relevant to this region, however, given the lack of statistical confidence this result should be interpreted with caution. These results are more likely to indicate that wealth indicator variables were poorly chosen in that they are not good proxy variables for household wealth.

Biophysical variables; survival rate and mean annual increment per ha have the expected signs and are significant at the 75% and 90% confidence intervals respectively. This finding indicates that faster rates of growth are associated with higher economic returns.

5.2 Model B - Characteristics associated with tenure type

The second research objective of this Chapter is to address the question: "What characteristics are associated with individual and cooperative tenures?". Tenure is the dichotomous dependent variable in Model B. Potential explanatory variables for Model B include: utilization of secondary benefits, woodlot age and socioeconomic indicators. Model B is specified by the following equation:

MODEL B: $Tenure_i = \alpha\beta 0 + +SecBen\beta 1 + TenSec\beta 2 + Socioecon\beta 3 + \varepsilon t\ ;$ (5)

where *Tenure*$_i$ is the tenure type of the dependent variable for the i^{th} observation, α is a constant, βs are coefficients on each explanatory variable and ε_t is a random error term. Table V.4 provides a summary of the explanatory variables for Model B and their expected signs.

Table V.4: Characteristics associated with tenure type, hypothesized explanatory variables

Independent variable and abbreviation	Variable description	Expected effect on probability of being individual woodlot
Secondary Benefits *(Wind, Fodder, Grain)*	Trees utilized to shelter crops or gardens from wind *(Wind, 0 = no windbreaks, 1=yes windbreaks)*.	+
	Household or group utilizes leaves from E. camaldulensis to feed livestock *(Fodder, 0=no fodder, 1=yes fodder)*.	+/-
	Household or group utilizes leaves to line grain bins *(Grain, 0=no grain, 1=yes grain)*	+/-
Woodlot Age *(Woodage)*	Years the individual or cooperative woodlot has been established on the current plot of land *(Woodage-continuous)*.	+
Socioeconomic Indicators *(Gender, Edu, Income (Cattle, Plough, Agyield))*	Percent of household members or tree growing cooperative which are women *(Gender - continuous)*.	+/-
	Level of education of the household head or leader of the tree growing cooperative *(Edu, 0 = primary school or less, 1=more than primary school*.	+/-
	Total income of household or total household income for leader of tree growing cooperative. Income is comprised of: number of cattle *(Cattle-continuous)*, number of ploughs *(Plough-continuous)*, and number of bags of agricultural yield *(Agyield-continuous)*	+/-

Data were gathered regarding secondary benefit usage and frequency of usage for all woodlots in the study sample. Three non-timber values: windbreaks, fodder and the utilization of eucalypt leaves for the lining of grain bins were assumed to be the main secondary benefits associated with *E. camaldulensis* in this region.[63] It is expected that utilization of woodlots for windbreaks will be positively correlated to individual woodlots.[64] Given the often location specific nature of non-timber values (e.g. windbreaks) and the inherent difficulties associated with benefit distribution in cooperative groups, it is hypothesised that individual woodlot owners are more likely to take advantage of the non-timber benefits offered by eucalypt trees.

Individual smallholders often plant trees around or near cropping fields allowing the trees to be used as windbreaks, whereas cooperative woodlots are often located in remote areas far from

[63] It is noteworthy that other that the non-timber benefits noted above, rural peoples are known to use *E. camaldulensis* for a variety of other uses. These include: medicine, fodder for bees, ornamentation, shade, tannin/gum/latex, resin/gum/latex, for the suppression of undergrowth, to kill aquatic snails that transmit *Bilharzia* and as living fences (Rocheleau *et al.*, 1988).

[64] The primary value of trees as windbreaks or shelterbelts is the protection/blockage from wind, which has negative effects on crop or garden output. The trees will theoretically protect crops and vegetables from wind to the extent that soil erosion will be slowed and crops will thus have a higher potential survival rate. In the dry regions of sub-Saharan Africa where soils are typically low in nutrient value, it is essential to farmers that the top soil remain to provide what fortification it can to the crops in question (Verinumbe, 1987).

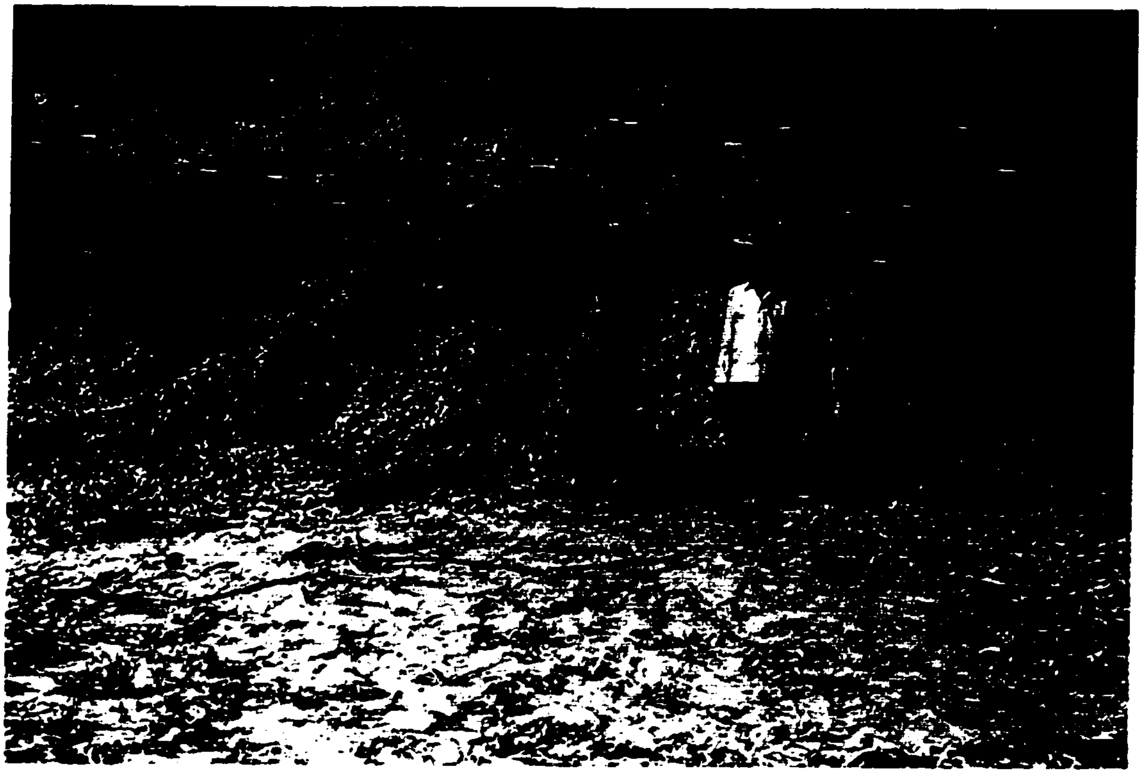

Plate 5.2: Recently felled *E. camaldulensis* pole and fuelwood

members cropping fields. The expected signs of the other two commonly observed secondary benefits: using leaves for livestock fodder and lining grain bins to protect grain from destruction by weevils are unknown but could potentially vary between tenure types. [65]

It is expected that woodlot age will be positively correlated with the likelihood of a woodlot being individually owned. Although NGOs and GOs have long been promoting the establishment of cooperative woodlots in the Mutoko region, data gathered during surveying indicate that individual woodlots have been established for a longer period of time in this region. There are a number of factors that may be attributed to this fact, including time for extension services and supplies to reach cooperative groups, the transactions costs associated with organizing etc.

---

[65] Allelopathic compounds in the leaves serve to repel weevils and other pests that destroy grain stores. This is a significant benefit of these trees for two reasons. First, the sale of cash crops to the Grain Marketing Board (GMB) is the major source of cash income for smallholders on the Mutoko communal lands. If grain stores are destroyed by pests, the primary source of income for the household, which often serves to pay for school fees and other primary needs is lost. Second, in Mutoko where the incidence of drought is frequent, it often occurs that smallholders must store grain for longer that one year. Eucalypt leaves serve as insurance that the grain stores will last, and the food value of the crops will be retained. This is a substantial benefit as it guarantees food stores and the maintenance of the nutritional value of the grain over time.

The sign of the gender variable is not known *a priori*. Women may represent a landless segment of society. If this is the case, it is likely that they will organize to form cooperative tree growing groups in the absence of having the opportunity to establish individual woodlots on their own and. In addition, NGOs and GOs often explicitly target women's groups when looking for organized factions to establish woodlots. However, it may be the case that individual households undertaking tree-growing projects may also have a high proportion of women. Because women are the primary gatherers of fuelwood, they may have strong incentive to invest in household level tree planting activities.

The expected signs of level of education and wealth with respect to the probability of a woodlot being individually owned are not known *a priori*.

Table V.5 presents descriptive statistics for the continuous variables in Model B.

Table V.5: Descriptive statistics for variables in Model B[a]

Variable	Mean	Standard Deviation	Min	Max	Units
Woodage	6.91	5.67	1	32	Years
Gender	53.59	20.84	0	100	Percent women
Cattle	5.76	4.49	0	22	Quantity
Plough	1.19	0.60	0	3	Quantity
Agyield	44.64	32.58	0	165	Bags

a. N=101 for all variables in this table.

5.2.1 MODEL B - Estimation results

Estimation results for Model B are presented in below in Table V.6.

Table V.6: Estimation Results - Model B

	Binomial Logit Estimation Results	
Independent Variable	Coefficient	T-Stat
Wind	2.8821	1.700***
Fodder	-0.2830	-0.724*
Woodage	1.2001	2.122***
Gender	-0.9638	-1.641**
Edu	1.5785	0.833*
Plough	-0.8862	-0.247
R-squared	0.1984	
Percent correct predicted	86.14%	

*** 95% level of significance
** 90% level of significance
*75% level of significance

Overall estimation results for Model B are good. Pseudo R-squared and percent correct predicted are both relatively high for a binomial logit model.

Wind is positively related to individual woodlots, whereas fodder is negatively related to individual woodlots. Both wind and fodder are significant at the 95% level. Grain was dropped from the regression as there was not strong theoretical reason for its inclusion and it did not enhance the overall fit of the model. As was hypothesized, individual woodlots are more likely to utilize trees as windbreaks given that woodlots are situated close to individual cropping fields. The finding that households with individual woodlots were not likely to use leaves for fodder indicates that cooperatives are more likely reliant on this secondary benefit.

As expected, woodlot age was positively associated with individual woodlots, despite extension efforts to promote cooperative woodlots in the region during the past 20 years. Findings with respect to the socioeconomic variables indicate that cooperatives are more likely to have a higher proportion of women. The gender variable is negative and significant at the 90% confidence interval indicating that high percentages of women are a characteristic of cooperative tree-growing groups. Education level is positive and significant at the 75% confidence interval, indicating that more highly educated smallholder's own individual woodlots. The only wealth variable included in the final model was *Plough* as it yielded the best estimation results. The sign of this variable is negative and not significant.

Chapter 6 – Summary and Conclusions

The final chapter presents a brief summary of the research study and a discussion of the conclusions offered by the analysis of both quantitative and qualitative data. Possible implications for rural afforestation policy are discussed. Finally the limitations of the research project will be presented and possible suggestions for future research discussed.

6.1 Summary

Pressures on woodland resources on the communal lands in rural Zimbabwe have influenced the land use portfolios of individual smallholders and cooperative groups. Several NGO and GOs have participated in the promotion of tree crops such as *E. camaldulensis* for the provision of building poles, fuelwood and other non-timber values. These afforestation projects have resulted in a number of individual smallholders and cooperative groups investing scarce resources in tree growing. Whether or not these investments offer positive economic returns is a question that policy makers should address if afforestation is to be a goal of future land use policies in sub-Saharan Africa.

One of the interesting foci of afforestation programs such as the RAP is the emphasis on the provision of incentives to plant trees cooperatively. However, although cooperative tree growing groups do exist in the Mutoko communal area, their frequency is not consistent with the extension efforts and subsidies offered by local NGOs and GOs. Estimates of private economic returns indicate that both individual and cooperative woodlots are profitable. However, social benefit-cost estimates indicate that mid range output prices are required to yield positive acceptable rates of return. When taking into account woodlot size (i.e. economies of scale), cooperative woodlots, which are generally much larger than individual smallholder's woodlots yield the highest economic returns at the private level. However, at the social level mid-size individual woodlots (between 50 and 100 seedlings planted) yield the highest returns, while cooperative woodlots are not economically profitable. This finding indicates that subsidies have played a major role in the establishment of cooperative woodlots. We can conclude from this that subsidies to cooperatives are providing the proper incentives to motivate them to organize and plant trees, however, the preference of individual smallholders in the Mutoko communal area to establish woodlots independently is a fact that can not be ignored.

It should be noted that two factors are likely to be influencing the findings of this analysis such that cooperatives appear to produce more favourable returns than they might in reality. First, the analysis is weak in that it bases cooperative harvesting patterns (and hence the estimation of benefits) on harvesting patterns observed largely for individual woodlots. This has likely resulted in the overestimation of the number of poles and headloads of fuelwood that cooperative groups are actually harvesting. Second, the logistics and group dynamics associated with cooperative tree growing ventures are not in any way captured in this analysis. Discussions with cooperative leaders, as well as group members at large indicated that there are considerable transactions costs associated with not only organizing labour to complete necessary management tasks, but also with the distribution of the benefits from the woodlot once the trees reach harvestable size.

In order to understand better the factors motivating economic return estimates, regression analysis was conducted to determine significant explanatory variables. Findings indicated that economic returns on a per tree basis were positively influenced if the woodlot was cooperatively owned, if trees were not utilized as windbreaks, if the tree growing unit was not relatively wealthy and if the biophysical performance of the tree crop was strong. It should be noted however that this model did not perform well econometrically and therefore the results should be broadly interpreted.

A second regression was estimated to explain the characteristic features of individual and cooperative woodlots. Estimation results indicate that the use of trees for windbreaks, but not other secondary benefits such as fodder for livestock characterize individual woodlots. In addition we found that individual woodlots are generally older than cooperatives and have a lower proportion of women.

6.2 Policy implications

Some policy implications can be drawn from this analysis. Even when considering the potential for overestimation of benefits for cooperative woodlots, the main finding that subsidized cooperative woodlots are highly profitable at the private level indicates that there is a financial rationale for cooperative groups to organize to grow trees under subsidized conditions. Assuming that subsidies continue to be provided, one can expect that further cooperative tree-growing groups may be established in the future. However, from a policy standpoint these findings may indicate that extension support and efforts are currently not far-reaching and/or accessible enough to influence a wide range of existing cooperatives or individuals that might be willing to form a cooperative tree growing group.

It may be the case that a simple economic assessment of primary woodlot benefits and socioeconomic characteristics, such as was provided in this paper is not likely to provide the full picture regarding why cooperative woodlots are not more prevalent. It is likely that the provision of financial incentives is only a part of what is required of rural afforestation extension packages. What may be equally, or perhaps more important is the provision of institutional support to set up and manage cooperatives throughout the duration of their tenure. The fact that so few cooperatives have harvested trees may be indicative of internal distribution issues with respect to woodlot benefits, or other institutional issues. Given that the some of the socioeconomic characteristics of these individual households and tree growing groups can be identified, this information may contribute to a better understanding of the institutional and governance issues that face these groups.

Finally the role that the biophysical performance of the tree species plays in influencing the economic returns that the smallholder or group observes is noteworthy. This finding although intuitive has not been extensively highlighted in the rural afforestation literature and speaks to the importance of choosing fast growing species if the smallholder or group is to observe benefits in a time frame consistent with rates of time preference observed in rural Zimbabwe. This is a significant finding, as the both NGOs and GOs in Zimbabwe are increasingly focusing afforestation efforts on indigenous species that have very long rotation ages. Thus, although the planting of *Eucalyptus* is controversial, its widespread adoption provides us with important information that may lead us closer to understanding the economic incentives that might motivate smallholders and cooperatives to plant indigenous trees.

6.3 Limitations and recommendations for further study

One of the limitations of this study was lack of breadth of values incorporated into the benefit-cost estimates due to limited time to complete surveys and the wide range of information that would have been required to estimate nonmarket values. As information provided in Chapter 3 indicates, there is an extremely wide range of nonmarket values in addition to other costs and benefits which are both challenging and time consuming to quantify. Secondly, as has been stated numerous times throughout the preceding text, the estimated returns for cooperatives must be cautiously interpreted given the fact that few cooperative woodlots have harvested any trees from their woodlots. Should a similar study be conducted in 5 years time, it is anticipated that a considerable number of cooperative tree growing groups will have harvested some portion of their woodlots, providing a wider range of data to base harvest estimates on. Finally, a number of the socioeconomic variables chosen for this analysis, namely education indicators and asset variables proved to be relatively poor indicators of actual household and cooperative socioeconomic characteristics.

With respect to further research in this area, a potential extension of this work may be to build on the economic return estimates for woodlots with estimates for other activities in the individual smallholder or cooperative's portfolio such growing stable food crops, tending vegetable gardens and livestock herding. To fully understand the land use changes that both smallholders and cooperative groups are making, and to assess the incentives motivating these changes is crucial to understanding what motivates the decision to employ land in tree production. Another potential extension of this work is the analysis of economic returns, socioeconomic explanators and biophysical performance of other tree crops commonly observed in the region. Finally, a sociological analysis of property rights, institution and governance issues surrounding woodlot establishment under various tenure types would contribute to better understanding land use change and household and cooperative group decision making in rural Zimbabwe.

References

Adams, Jennifer. 1991. "The Rural Labour Market in Zimbabwe", *Development and Change*, vol.22:297-320.

Adeyoju, S. Kolade. 1984. "Some Tenurial and Legal Aspects of Agroforestry", In *Social, Economic, and Institutional Aspects of Agroforestry*, J.K. Jackson editor. Tokyo: United Nations University.

Ahmed, P. 1989. "Eucalyptus in agroforestry; its effects on agricultural production and economics", *Agroforestry, Systems*, vol.8, no.1:31-38.

Anderson, Dennis. 1987. *The Economics of Afforestation: A Case Study in Africa*. World Bank Occasion Paper Number 1.

Ara, Ismat and N.S.M. Yahya. 1990. "Profitability of *Eucalyptus camaldulensis* plantation in Bangladesh", *Bangladesh Journal of Forest Science*, vol. 19, no. 1&2:45-55.

Arnold, J.E.M. 1984. "Economics Constraints and Incentives in Agroforestry", In *Social, Economic and Institutional Aspects of Agroforestry*, J.K. Jackson editor. Tokyo: United Nations University.

Avery, Thomas E. and Harold E. Burkhart. 1994. *Forest Measurements, Fourth Edition*. New York: McGraw-Hill Inc.

Babu, Ram, M.C. Agarwal, M.K. Vishwanatham and P. Joshie. 1986. "Economics and benefit-cost ratio of the *Eucalyptus* plantation for fuel purposes in denuded lands of Doon valley", *Soil Conservation in India*, vol.20, no.1:319-322.

Bacon, P.E., C. Stone, D.L. Binns, D.J. Leslie, and D.W. Edwards. 1993. "Relationships between water availability and *Eucalyptus camaldulensis* growth in a riparian forest", *Journal of Hydrology (Amsterdam)*, vol.150:541-561.

Banks, P.F. 1981. "The Planting of Woodlots for Fuelwood Requirements of the Tribal Trust Land Populations in Zimbabwe-Rhodesia: A Review of Past and Future Development", *South African Forestry Journal*, vol. 117, no.6:13-15.

Barrows Richard and Michael Roth. 1989. *Land Tenure and Investment Incentive in African Agriculture: Theory and Evidence*. Land Tenure Center Paper No. 136. University of Wisconsin-Madison. Madison: Land Tenure Centre.

Besley, Timothy. 1995. "Property Rights and Investment Incentives: Theory and Evidence from Ghana", *Journal of Political Economy*, vol. 103, no. 5:903-937.

Blair, Harry W. 1986. "Social Forestry: Time to Modify Goals?", *Economic and Political Weekly*, vol.21, no.30:1317-1321.

Bradley, P.N. and K. McNamara eds.. 1993. *Living with Trees: Policies for Forestry Management in Zimbabwe*. World Bank Technical Paper 210. Washington DC: World Bank.

Brokensha, David and Jack Glazier. 1973. "Land Reform among the Mbeere of Central Kenya", *Africa*, vol.43:182-206.

Bruce, John W., Louise Fortmann, and Calvin Nhira. 1993. "Tenures in Transition, Tenures in Conflict: Examples from the Zimbabwe Social Forest", *Rural Sociology*, vol. 58, no. 4: 626-642.

Bruce, John W. and Louise Fortmann. 1989. *Agroforestry: Tenure and Incentives*. Land Tenure Center Paper No. 135. University of Wisconsin-Madison: Land Tenure Center.

Bruce, John W. and Shem E. Migot-Adholla editors. 1994. *Searching for Land Tenure Security in Africa*. Washington DC: World Bank.

Calder, Ian R., Robin K. Hall, and K.T. Prasanna. 1993. "Hydrological impact of *Eucalyptus* plantation in India", *Journal of Hydrology (Amsterdam)*, vol.150:635-648.

Campbell, B., Clarke, J., Luckert, M., Matose, F., Musvoto, C., and Scoones, I. 1994. "Local Level Economic Valuation of Savanna Woodland Resources: Village Cases from Zimbabwe", *Hotsprings Working Group*, January, Unpublished Report.

Cernea, M. 1981. *Land Tenure Systems and Social Implications of Forestry Development Programs*. World Bank Staff Working Paper No. 452. Washington DC: World Bank.

Cernea, M. 1988. "Land Tenure Systems and Social Implications of Forestry Development Programs, In *Whose Trees? Proprietary Dimensions of Forestry*, Louise Fortmann and John Bruce editors. Boulder: Westview Press.

Clarke, Jeanette. 1994. *Building on Indigenous Natural Resource Management: Forestry Practices in Zimbabwe's Communal Lands*. Harare: Earthware Publishing Services.

COOPIBO. 1992. *Community based tree nursery groups in the Mutoko Communal Lands of Zimbabwe*. Seminar paper Participatory Extension Methods and Sustainable Agriculture. Mutoko, Zimbabwe.

Central Statistical Office (CSO). 1992. *Census 1992: Zimbabwe Preliminary Report*. Harare: Central Statistical Office.

Dasgupta, Agit K. and D.W. Pearce. 1980. *Cost-Benefit Analysis: Theory and Practice*. London: The Macmillian Press Ltd.

Dixon, John A., L. Fallon Scura, R.A. Carpenter and P.B. Sherman. 1994. *Economic Analysis of Environmental Impacts, 2nd Edition*. London: Earthscan Publications Ltd..

FAO. 1979. *Eucalypts for Planting*. Rome: Food and Agriculture Organization of the United Nations.

FAO. 1992. *Economic Assessment of Forestry Project Impacts: FAO Forestry Paper 106*. Rome: Food and Agriculture Organization of the United Nations.

Feder, Gershon and Tongroj Onchan. 1987. "Land Ownership Security and Investment in Thailand", *American Journal of Agricultural Economics*, vol. 69, no. 2:311-320.

Filius, A.M. 1982. "Economic aspects of agroforestry", *Agroforestry Systems*, vol. 1:29-39.

Fortmann, L. 1985. "The tree tenure factor in agroforestry with particular reference to Africa", *Agroforestry Systems*, vol. 2, no. 4:229-251.

Fortmann, L. and John Bruce. 1988. *Whose Trees? Proprietary Dimensions of Forestry.* Boulder: Westview Press.

Fortmann, Louise and John Bruce. 1991. *You've got to know who controls the land and trees people use: gender, tenure and the environment".* Harare: Centre for Applied Social Sciences, University of Zimbabwe.

Fortmann, L. and John Bruce. 1993. "Tenure and gender issues in forest policy", In, *Living with Trees: Policies for Forestry Management in Zimbabwe,* edited by P.N. Bradley and K. McNamara. Washington DC: World Bank.

Fortmann, L. and Calvin Nhira. 1992. *Local Management of Trees and Woodland Resources in Zimbawbe: A Tenurial Niche Approach.* Harare: University of Zimbabwe, Centre for Applied Social Sciences.

Fortmann, L. and D. Rocheleau. 1985. "Women and agroforestry: four myths and three case studies", *Agroforestry Systems,* vol. 2, no.4:253-272.

Francis, Paul. 1987. "Land Tenure Systems and Agricultural Innovation", *Land Use Policy,* vol. 4, no. 3:305-319.

Gavin, Sarah and Marcel Fafchamps. 1996. "Land Tenure and Allocative Efficiency in Niger", *American Journal of Agricultural Economics.* vol. 78. No. 2:460-471.

Gluckman, Max. 1945. "African Land Tenure", *Rhodes-Livingstone Institute Journal,* vol. 3:1-12.

Goebel, Allison. 1997. "Here is our Land the Two of Us: Women, Men and Land in a Zimbabwean Resettlement Area", 36 p. *Department of Rural Economy Staff Paper No. 97-07.* Edmonton: Department of Rural Economy, University of Alberta.

Govaerts, M. 1989. *Agricultural production and farmer cooperation in Mutoko communal land, Zimbabwe: Mutoko communal land, agricultural data 1987-1988 agricultural season.* Leuven: COOPIBO.

Gregersen, Hans, Sydney Draper and Dieter Elz eds. 1989. *People and Trees: The Role of Social Forestry in Sustainable Development.* Washington, D.C.: The World Bank.

Gwaai Working Group. 1997. *Local Level Valuation of Village Woodlands and State Forests: Cases from Matebeleland South in Zimbabwe.* IES Working Paper 7. Harare: Institute for Environmental Studies, University of Zimbabwe.

Haley, David and Martin K. Luckert. 1990. *Forest Tenures in Canada: A Framework for Policy Analyis, Information Report E-X-43.* Ottawa: Forestry Canada.

Hayes, Joseph, Micheal Roth and Lydia Zepeda. 1997. Tenure Security, Investment and Productivity in Gambian Agriculture: A Generalized Probit Analysis", *American Journal of Agricultural Economics",* vol. 79, no. 5:369-382.

Hill, D.B., T.C. Weber. 1995. "Apiculture and forestry (bees and trees)", *Agroforestry Systems,* vol.29:313-320.

Hoskins, M.W. 1980. "Community forestry depends on women", *Unasylva,* vol. 32, no.130: 27-31.

Hyami, Y, and V. Ruttan. 1985. *Agricultural Development: The International Perspective.* Baltimore: John's Hopkins Press.

Jackson, J.K. editor. 1984. *Social, Economic, and Institutional Aspects of Agroforestry.* Tokyo: United Nations University.

Jayawickrama, K.J.S., J.E. Schlatter V., and R. Escobar R. 1993 "Eucalypt plantation forestry in Chile", *Australian Journal of Forestry,* vol.56, no.2:179-192.

Jodha, N.S. 1986. "Common Property Resources and Rural Poor in Dry Regions of India", *Economic and Political Weekly,* vol. XXI, no. 27:1169-1181.

Kaiser, H.F. 1988. "Forest Development in the Congo: *Eucalyptus* plantations offer promise to a nation that has faced hard times", *Journal of Forestry,* vol.86, no.10:40-42.

Kihiyo, Vincent B.M.S.. 1996. "Economic Evaluation of Rural Woodlots in a Developing Country: Tanzania", *Journal of Environmental Management,* vol. 46, no.3:271-279.

Laarman, J.G. and A. Contreras H. 1991. "Benefits from the development assistance projects in forestry: does the available evidence paint a true picture?", *Unasylva,* vol. 42, no. 164:45-54.

Lisanework, N and A. Michelsen. 1993. Allelopathy in agroforestry systems: the effects of leaf extract of *Cupressus lusitanica* and three *Eucalyptus* spp. on four Ethiopian crops", *Agroforestry Systems,* vol.21:63-74.

Livingstone, Ian. 1986. "The Common Property Problem and Pastoralist Economic Behavior", *Journal of Development Studies,* vol. 23, no. 10:5-19.

Makamuri, Billy. 1995. *Making Sense of Social Forestry: A Political and Contextual Study of Forestry Practices in South Central Zimbabwe.* Published Ph.D. Dissertation, Vol. 438. Tampere: University of Tampere.

Malik, R.S. and S.K. Sharma. 1990. "Moisture extraction and crop yield as a function of distance from a row of *Eucalyptus tereticornis* ", *Agroforestry Systems,* vol.12:187-195.

Mandondo, Alois. 1993. *Management and Growth and Survival of Eucalyptus camaldulensis in Murewa and Mutoko Districts of Zimbabwe.* Unpublished M.Sc. Thesis: University of Zimbabwe.

Mandondo, Alois. 1995. "Ownership and Management of *Eucalyptus camaldulensis* Woodlots in North-eastern Zimbabwe", *South African Journal of Forestry,* vol. 174:9-15.

Mathur, R.S., S.R. Sagar and M.Y. Ansari. 1984. "Economics of *Eucalyptus* plantations - with special reference to Uttar Pradesh", *Indian Forestry,* vol. 110, no.2:97-109.

Mehretu, Assefa and Chris Mutambirwa. 1992. "Gender Differences in Time and Energy Costs of Distance for Regular Domestic Chores in Rural Zimbabwe: A Case Study in the Chiduku Communal Area", *World Development,* vol.20, no.11:1675-1683.

Mensforth, Lisa J., Peter J. Thorburn, Steve D. Tyerman and Glen R. Walker. 1994. "Sources Of water used by riparian *Eucalyptus camaldulensis* overlying highly saline groundwater", *Oceologia,* vol.100:21-28.

Migot-Adholla, Shem E., George Benneh, Frank Place and Steven Atsu. 1994. "Land, Security of Tenure, and Productivity in Ghana", In *Searching for Land Tenure Security in Africa*, J. Bruce and S.E. Migot-Adholla editors. Washington: World Bank.

Moyo, S., P. Robinson, Yemi Katerere, Stuart Stevenson and Davison Gumbo. 1991. *Zimbabwe's Environmental Dilemma: Balancing Resource Inequities.* Harare: ZERO.

Moyo, S., Phil O'Keefe and Michael Sill. 1993. *The Southern African Environment: Profiles of the SADC Countries.* London: Earthscan.

Murombedzi, James. 1990a. *Communal Land Tenure and Common Property Resource Management: An evaluation of the potential for sustainable common property resource management in Zimbabwe's communal lands.* Harare: University of Zimbabwe, Centre for Applied Social Sciences.

Murombedzi, James. 1990b. *The Need for Appropriate Local Level Common Property Resource Management Institutions in Common Tenure Regimes.* Harare: University of Zimbabwe, Centre for Applied Social Sciences.

Mvududu, S. 1991. *Forestry Commission Linkages with Non-Governmental Organizations in Forestry Research and Rural Afforestation Development: The Case of Zimbabwe.* ODI Agricultural Administration Network Paper #24. London: ODI.

Osemeobo, Gbadebo J. 1989. "An Impact and Performance Evaluation of Smallholder Participation in Tree Planting, Nigeria", *Agricultural Systems*, vol. 29, no. 2:117-135.

Osemeobo, Gbadebo J. 1990. "Why People Don't Grow Trees: A Case Study of Nigerian Smallholders", *Quarterly Journal of International Agriculture*, vol. 29, no. 3:303-319.

Ostrom, Elinor. 1995. "Designing Complexity to Govern Complexity", In, *Property Rights and the Environment: Social and Ecological Issues* edited by Susan Hanna and Mohan Munashinghe. Washington DC: The International Bank for Reconstruction and Development/ The World Bank.

Pearse, Peter. 1990. *Introduction to Forest Economics.* Vancouver: University of British Columbia Press.

Peters, Charles M. 1996. *The Ecology and Management of Non-Timber Forest Resources, World Bank Technical Paper Number 322.* Washington DC: World Bank.

Philip, Michael S. 1994. *Measuring Trees and Forests: Second Edition.* Wallingford: CAB International.

Phillips, Joseph M. 1994. "Farmer Education and Farmer Efficiency: A Meta-Analysis", *Economic Development and Cultural Change*, vol. 43, no. 1:149-165.

Place, Frank, Michael Roth and Peter Hazell. 1994. "Land Tenure Security and Agricultural Performance in Africa: Overview of Research Methodology", In *Searching for Land Tenure Security in Africa*, J. Bruce and S.E. Migot-Adholla editors. Washington: World Bank.

Place, Frank. 1995. *The Role of Land and Tree Tenure on the Adoption of Agroforestry Technologies in Zambia, Burundi, Uganda and Malawi: A Summary and Synthesis.* Joint paper between the Land Tenure Center and International Center for Research in Agroforestry. Madison: University of Wisconsin-Madison, Land Tenure Center.

Pohjonen, Veli and Timo Pukkala. 1988. "Profitability of establishing *Eucalyptus globulus* plantations in the Central Highlands of Ethiopia", *Silva Fennica,* vol. 22, no.4:307-321.

Poore, M.E.D., and C. Fries. 1985. *The Ecological Effects of Eucalyptus.* FAO Forestry Paper #59. Rome: Food and Agriculture Organization of the United Nations.

Price, Colin. 1989. *The Theory and Application of Forest Economics.* Cornwall: T.J. Press Ltd.

Raintree, John B. 1991. *Socioeconomic attributes of trees and tree planting practices, Community Forestry Note No. 9.* Rome: Food and Agriculture Organization of the United Nations.

Rocheleau, D., F. Weber and A. Field-Juma. 1988. *Agroforestry in Dryland Africa.* Nairobi: International Centre for Research in Agroforestry (ICRAF).

Roth, Michael and John W. Bruce. 1994. *Land Tenure, Agrarian Structure and Comparative Land Use Efficiency in Zimbabwe: Options for Land Tenure Reform and Land Redistribution.* Land Tenure Centre Research Paper #117. Madison: Land Tenure Centre, University of Wisconsin-Madison.

Runge, C.F. 1992. "Common Property and Collective Action in Economic Development", In, *Making the Commons Work: Theory, Practice and Policy* by Daniel W. Bromely. San Francisco: ICS Press.

Sanginga, N. and M.J. Swift. 1992. "Nutritional effect of *Eucalyptus* litter on the growth of maize (*Zea maize*)", *Agriculture, Ecosystems and Environment,* vol.41:55-65.

Saxena, N.C. 1991. "Crop losses and their economic implications due to growing of *Eucalyptus* on field bunds - a pilot study", *Agroforestry Systems,* vol. 16, no. 3:231-245.

Saxena, N.C. 1992. "Eucalypts on farmlands in India: what went wrong?", *Unasylva,* vol.170:53-58.

Scoones, Ian and Frank Matose. 1993. "Local woodland management: constraints and opportunities for sustainable resource use", In, *Living with Trees: Policies for Forestry Management in Zimbabwe,* edited by P.N. Bradley and K. McNamara. Washington DC: World Bank.

Scott, Anthony D., and James Johnson. 1983. *Property rights: developing the characteristics of interests in natural resources, Resource Paper No. 88.* Vancouver: University of British Columbia, Department of Economics.

Sedjo, Roger A. 1983. *The Comparative Economics of Plantation Forestry: A Global Assessment, A Research Paper from Resources for the Future Inc.* Baltimore: Johns Hopkins Press.

Shepherd, Gill. 1992. "Forest Policies, Forest Politics", In, *Forest Policies, Forest Politics: ODA Agricultural Occasional Paper 13,* edited by Gill Shepherd. London: ODI.

Stone, S.W., S.C. Kyle and J.M. Conrad. 1993. "Application of the Faustmann principle to a short-rotation tree species: an analytical tool for economists, with reference to Kenya and *leucaena*", *Agroforestry Systems*, vol. 21:79-90.

Verinumbe, I. 1987. "Crop production on soil under some forest plantations in the Sahel", *Agroforestry Systems*, vol. 5:185-188.

Wade, Robert. 1992. "Common Property Resource Management in South Indian Villages". In, *Making the Commons Wok: Theory, Practice and Policy*, edited by Daniel W. Bromely. San Francisco: ICS Press.

Watson, Leslie, Eloise C. Murray and Lesley Just. 1996. "Gender and the Value of Trees in Mutoko Communal Area, Zimbabwe", 22 p. *Department of Rural Economy Staff Paper No. 96-19*. Edmonton: Department of Rural Economy, University of Alberta.

Young, Anthony. 1990. *Agroforestry for Soil Conservation*. Oxford: C.A.B. International, International Council for Research in Agroforestry.

Yudelman, Montaque. 1964. *Africans on the Land: Economic Problems of African Agricultural Development in Southern, Central and East Africa, with Special Reference to Southern Rhodesia*. Cambridge: Harvard University Press.

Zimbabwe Forestry Commission. 1996. *Forestry Commission Annual Report*. Harare: Zimbabwe Forestry Commission.

Appendix A: E. camaldulensis in northeastern Zimbabwe: Woodlot Valuation Survey

1. Household Code ______________ *2. Interviewer's Name* ______________________

3. Date ______________________ *4. Approx. survey time* ______________ *min.*

*5. Current Ownership Category*______ *6. Original Ownership Category* ____________

A student named Pamela Jagger from a University in Canada is working on a research project with the help of the University of Zimbabwe. She is trying to find out why rural farmers decide to plant gum trees. To learn about the decisions that farmer's make we want to ask you questions about how you manage your woodlot and about your household. We also would like to count and take some measurements of the trees in your woodlot. The measurements will not in any way disturb your trees and will help us to understand how quickly your trees are growing. Local people are assisting Miss. Jagger. It is hoped that this study will contribute to better understanding how farmers in rural Zimbabwe manage their woodlots. Names will not be included in the study. We will be grateful for your assistance in answering the following questions.

Section I - Woodlot Management and Labour Use

7. How many **different** times has your household (or the members of your tree-growing group), planted gum trees in your woodlot? *All trees planted in the same calendar year are one planting.*

   3. One 4. Two 5. Three6. More than three

7a. How old are your gum trees *(approximate age in years)*?

Planting number	Age in years
First planting	
Second planting	
Third planting	

7b. (i)How many seedlings did you plant in your woodlot each time you planted trees? *(approximate number)*
(ii)How many trees lived each time you planted seedlings? *(approximate number)*

Planting number	Number of seedlings planted	Number of trees that lived
First planting		
Second planting		
Third planting		

8. What season was it when your household (or the members of your tree-growing group), planted your seedlings?

Planting number	Dry Season	Wet Season
First planting		
Second planting		
Third planting		

We want to ask some questions about the oldest gum trees in your woodlot. From this point, please answer all of the following questions about your oldest trees.

9. Where did your household (or the members of your tree-growing group), get the seedlings for your woodlot from?

3. Forestry Commission
4. A local Tree Nursery Group
5. Grew them at a TNG that you are involved in
6. AGRITEX
7. A local NGO (e.g. COOPIBO)
8. Local school
9. Other (specify)____________________

9a. Did you pay any money for your seedlings?

1. No (*Go to 9c*)
2. Yes

9b. How much money did you pay for each gum tree seedling? ____________________cents

9c. Did your household (or the members of your tree-growing group), get any advice on how to grow gum trees?

1. No (*Go to 10*)
2. Yes

9d. If your household (or the members of your tree-growing group), got advice on tree growing from someone else, who was it?

3. Forestry Commission
4. A local Tree Nursery Group
5. The leader of **your** tree growing cooperative
6. AGRITEX
7. A local NGO (e.g. COOPIBO)
8. Local school
9. Another farmer
10. Member of a tree growing group
11. Other(specify) ________________

9e. How many hours did you spend getting advice on how to grow gum trees?
____hours

10. Did your household (or the members of your tree-growing group), clear your land before planting your gum trees?

1. No (*Go to 11*)
2. Yes
3. Land was already cleared (*Go to 11*)

10a . (i) Which members of your household (or tree-growing group), helped to clear the land?
(ii) How many days did it take your household (or tree growing group), to clear the land?
(iii)How many hours per day did each person work?

Member of household or group	Number of workers	Number of days clearing	Number of hours worked per day
Adult male			
Adult female			
Children			

*An adult is defined as any person over the age of 15.

11. Did your household (or the members of your tree growing group), plough your land or dig holes before you planted your seedlings?
Ploughing is defined as land preparation that happens before you plant seedlings.

1. No (***Go to 12***) 2. Yes

11a. What season did your household (or the members of your tree-growing group), plough your land and/or dig holes in?

3. Dry Season 4. Wet Season

11b. (i) Which members of your household (or tree-growing group), helped to plough the land and/or dig holes?
(ii) How many days did it take your household (or tree growing group), to plough the land and/or dig holes?
(iii)How many hours per day did each person work?

Member of household or group	Number of workers	Number of days ploughing/digging holes	Number of hours worked per day
Adult male			
Adult female			
Children			

12. During the first three years you had your woodlot did your household (or the members of your tree growing group), put organic matter on your seedlings or young trees?

1. No (***Go to 13***) 2. Yes

12a. What did you use for organic matter?

3. Manure 4. Leaf litter 5. Other(specify)______________

12b. Which year(s) after planting did you put organic matter on your seedlings or trees?

3. Year 1 4. Year 2 5. Year 3

12c. What season(s) did you (or the members of your tree-growing group), apply organic matter in?

3. Dry Season 4. Wet Season 5. Both wet and dry

12d. (i) Which members of your household (or tree-growing group), helped to put organic matter on your seedlings or young trees?
(ii) How many days in each season did it take your household (or tree growing group), to put organic matter on your trees or young seedlings?
(iii)How many hours per day in each season did each person work?

Member of household or group	Number of workers	Number of days, dry season	Number of hours worked per day dry season	Number of days, wet season	Number of hours worked per day wet season
Adult male					
Adult female					
Children					

13. During the first three years you had your woodlot did your household (or the members of your tree growing group), weed your seedlings or young trees?
Weeding is defined as actions that take place to combat weeds after seedlings have been planted. Weeding may include the use of an ox-drawn implement e.g. plough which indirectly achieves weeding.

1. No (*Go to 14*) 2. Yes

13a. Which year(s) after planting did your household (or the members of your tree growing group), weed your seedlings or young trees (circle all appropriate responses)?

3. Year 1 4. Year 2 5. Year 3

13b. What season did your household (or the members of your tree growing group), weed your seedlings or young trees?

3. Dry Season 4. Wet Season 5. Both wet and dry

13c. (i) Which members of your household (or tree growing group), helped to weed your seedlings or young trees?
(ii) How many days in each season did it take your household (or tree growing group), to weed your trees or young seedlings?
(iii)How many hours per day in each season did each person work?

Member of household or group	Number of workers	Number of days, dry season	Number of hours worked per day, dry season	Number of days, wet season	Number of hours worked per day, wet season
Adult male					
Adult female					
Children					

14. During the first three years you had your woodlot did your household (or the members of your tree growing group), water your seedlings or young trees?

1. No (*Go to 15*) 2. Yes

14a. Which year(s) after planting did you water your seedlings or trees (circle all appropriate responses)?

3. Year 1 4. Year 2 5. Year 3

14b. How many times in each year did your household (or the members of your tree growing group), water your seedlings or young trees?

Year	Number of times watered
First year after planting	
Second year after planting	
Third year after planting	

14c. For one watering, how many buckets or containers of water did it take to water all of the seedlings or young trees in your woodlot? ___________________

14d. How big is the bucket or container you use to water your trees?

3. 5 litres 4. 20 litres 5. Other (specify) ____________

14e. Where did you get the water you watered your seedlings or young trees with?

3. River 4. Bore hole 5. Water piped into homestead
6. Other (Specify) ____

14f. (i)Which members of your household (or tree growing group were involved in gathering water and watering your seedlings or young trees?
(ii)How many minutes did it take your household (or the members of your tree growing group), to gather water and to water all of the young seedlings or trees in your woodlot one time?

Member of household or group	Number of workers	Number of minutes to gather water and water seedlings or young trees one time
Adult male		
Adult female		
Children		

15. Did your household (or the members of your tree-growing group), replace dead seedlings?

1. No (***Go to 16***) 2. Yes

15a. Which year(s) did your household (or the members of your tree-growing group), replace dead seedlings?

3. Year 1 4. Year 2 5. Year 3

15b. How many seedlings did you replace each year (approximately)?

Year	Number of seedling replaced
First	
Second	
Third	

15c. Where did you get the new seedlings?

3. Forestry Commission
4. A local Tree Nursery Group
5. Grew them at a TNG that you are involved in
6. AGRITEX
7. A local NGO (e.g. COOPIBO)
8. Local school
9. Another farmer
10. Other(specify) __________

15d. Did you pay money for the new seedlings you used to replace the dead ones?

1. No (***Go to 15f***)
2. Yes

15e. If yes, how much money did you pay for each new seedling?__________________cents

15f. (i) Which members of your household (or tree growing group), helped to replace your dead seedlings?
(ii) How many days did it take your household (or tree growing group), to replace your dead seedlings?
(iii) How many hours per day did each person work?

Member of household or group	Number of workers	Number of replacing seedlings	days dead	Number of hours worked per day
Adult male				
Adult female				
Children				

16. Did you do any of the following things to your trees after they were on your land for more than three years? (Choose as many as apply)

3. Applying organic matter
4. Weeding
5. Watering
6. Replacing dead seedlings

(***If none go to 17***)

16a. Which years did you do these things? (Check appropriate boxes)

Year	Organic matter	Weeding	Watering	Replacing dead seedlings
Fourth				
Fifth				
Sixth				
Seventh				
Eighth				
Every year				

17. When you planted your trees did you dig firebreaks to protect your trees from fire?

1. No (***Go to 18***)
2. Yes

17a. (i) Which members of your household (or tree-growing group), helped to dig fire breaks?
(ii) How many days did it take your household (or tree growing group), to dig your fire breaks?
(iii) How many hours per day in each season did each person work?

Member of household or group	Number of workers	Number of days digging fire breaks	Number of hours worked per day
Adult male			
Adult female			
Children			

18. Has your household (or members of your tree growing group), ever applied chemical pesticides to your trees to protect them from termites? *Chemical pesticides include disused oil.*

1. No (***Go to 19***)
2. Yes

18a. How many times have you put pesticide on your trees to control termites?

3. Once a year
4. Only one time during the life of the trees
5. Only when the termites are bad
6. Other (specify) ________________

18b. If you have applied chemical pesticides to your trees, where did you get the pesticides from?

3. Forestry Commission
4. AGRITEX
5. A local NGO
6. Bought at a store
7. Other(specify)________________

18c. Did you have to pay for the chemical pesticides you put on your gum trees?

1. No (***Go to 18e***)
2. Yes

18d. How much did you have to pay for one container of pesticide? ________________$ZWD

18e. How many times could you apply chemical pesticides to your trees with one container of pesticide? ________________________________

18f. (i) Which members of your household (or tree-growing group), helped to put chemical pesticides on your gum trees?
(ii) How many days did it take your household (or tree growing group), to put pesticides on your trees?
(iii) How many hours per day did each person work?

Member of household or group	Number of workers	Number of days applying pesticides	Number of hours worked per day
Adult male			
Adult female			
Children			

19. Have you used traditional methods to stop termites from eating your gum trees

1. No (***Go to 20***)
2. Yes

19a. Which traditional method(s) have you used?

3. Ashes
4. A mixture of indigenous plants and water
5. Onions planted at base of trees
6. Other(specify)__________

19b. How often do you practice these methods of termite control?

3. Once a year
4. One time during the life of the trees
5. Only in years when termites are bad
6. Other (specify)________________

19c. Each time you used traditional methods to control termites,
(i) Which members of your household (or tree-growing group), helped to do the work?
(ii) How many days did it take your household (or tree growing group), to prepare the termite control and put it on or around your trees?
(iii) How many hours per day did each person work?

Member of household or group	Number of workers	Number of days worked to control termites	Number of hours worked per day
Adult male			
Adult female			
Children			

20. Did you build fences around your individual trees to protect them from cattle and goats?

1. No (*Go to 21*)
2. Yes

20a. How many of your young trees did you protect this way? ________________________

20b. How many times did you replace each of these fences? ________________________

20c. What building material did you use to make the fences?

3. Sticks and bark from indigenous woodland
4. Branches or sticks from other trees in your woodlot
5. Other (specify)____________________________

20d. Each time you protected the trees in your woodlot with fences,
(i)Which members of your household (or tree-growing group), were involved in gathering the building material for these fences?
(ii)How many days did it take your household (or the members of your tree growing group), to gather the building material and build the fences to protect your young trees?
(iii)How many hours per day did each person work?

Member of household or group	Number of workers	Number of days to gather and build fences	Number of hours worked per day
Adult male			
Adult female			
Children			

21. Do the gum trees have a fence around them? ***(May be observed)***

1. No (***Go to 21a***)
2. Yes (***Go to 21b***)

21a. Has there ever been a fence around the woodlot?

1. No (*Go to 22*) 2. Yes

21b. What is the fence built out of?

3. Poles and barbed wire 4. Brushwood 5. Permanent hedge
6. Other(specify)________________________

21c. Where did the material for building the fence come from?

3. The Forestry Commission
4. AGRITEX
5. A local NGO
6. Purchased from a store
7. Gathered from indigenous woodland
8. Other ________________

21d. Did your household (or the members of your tree growing group), have to pay for the materials to build your fence?

1. No (*Go to 21g*) 2. Yes

21e. How much did your household (or the members of your tree-growing group), have to pay for the fencing material? ____$ZWD

21f. What year were the building materials purchased? ______________________________

21g. (i)Which members of your household (or members of your tree-growing group), worked to build the fence around your woodlot?
(ii)How many days did the members of your household (or the members of your tree growing group), work to build the fence around your woodlot?
(iii)How many hours per day did each person work?

Member of household or group	Number of workers	Number of days building fence	Number of hours worked per day
Adult male			
Adult female			
Children			

21h. How many times has the fence around your gum trees been repaired? ________________

21i. Each time you repaired your fence,
(i)Which members of your household (or members of your tree-growing group), worked to gather the materials and repair the fence around your woodlot?
(ii)How many days did the members of your household (or the members of your tree growing group), work to gather the materials and repair the fence around your woodlot?
(iii)How many hours per day did each person work?

Member of household or group	Number of workers	Number of days gathering materials and repairing fence	Number of hours worked per day
Adult male			
Adult female			
Children			

22. Has your household (or the members of your tree growing group), ever harvested any of the trees from your woodlot?

1. No (*Go to 23*) 2. Yes

22a. One harvest is all of the trees harvested in one calendar year.
(i) When were the trees harvested (approximate year and month)?
(ii) Which member(s) of your household (or tree-growing group), did the harvesting?
(iii) How many people helped with the harvesting?
(iv) How many poles were harvested from each harvest?
(v) How many head loads of fuelwood were harvested from each harvest?
(vi) If poles were harvested, what were they used for?
(vii) How were the poles or fuelwood transported (head load, shoulder load, scotch cart, ox and yoke, or other)?
(viii) Which member(s) of your household (or tree-growing group), transported the wood?
(ix) How many people helped with the transport?
(x) How many hours did it take to harvest and transport the wood from each harvest?
(xi) Were the poles or fuelwood sold?
(xii) If the poles or fuelwood were sold, what was the price per pole or price per head load?

Harvest Number	H-1	H-2	H-3	H-4	H-5	H-6	H-7	H-8	H-9	H-10
When were trees harvested (date)?										
Who did the harvesting?										
How many people helped with harvesting?										
How many poles harvested?										
How many headloads of fuelwood?										
What were the poles used for?										
What was the method of transport?										
Who transported the harvested poles and/or fuelwood?										
How many people helped with transport?										
How many hours did transport take?										
Were poles or fuelwood sold?										
What was the price per pole or headload of fuelwood?										

23. Do you have a bee keeping basket or wooden box by your gum trees?

1. No (*Go to 24*) 2. Yes

23a. How many bee keeping baskets or boxes are there at this woodlot?
________________ baskets or boxes

23b. Did you have to pay for your bee keeping baskets or boxes?

1. No (*Go to 23d*) 2. Yes

23c. How much money did you pay for each bee keeping basket or box that you have?
________________$ZWD

23d. Did anyone give you advice on bee keeping?

1. No (*Go to 23g*) 2. Yes

23e. Who gave you advice on bee keeping?

3. Forestry Commission 4. AGRITEX 5. Local NGO
6. Another farmer 7. Local school 8. Other(specify)________

23f. How many hours or days did your household (or the members of your tree-growing group spend getting advice on bee keeping? ________________hours

23g. How many years has your household (or tree-growing group) kept bees for?
________________ years

23h. How much honey do you get each time you harvest the honey from your baskets or boxes?
________________Kg's

23i. Each time you use harvest and honey,
(i)Which members of your household (or tree-growing group), are involved in harvesting the honey?
(ii)How many days do the members of your household (or tree-growing group) work each time you harvest honey?
(iii)How many hours per day does it take for each person to do the work?

Member of household or group	Number of workers	Number of days worked to harvest honey	Number of hours per honey harvest
Adult male			
Adult female			
Children			

23j. Do you sell the honey that you harvest from you bee keeping baskets or boxes?

1. No (*Go to 24*) 2. Yes

23k. Where do you sell the honey that you harvest?

3. Sell in the local village 4. Sell in Mutoko Township
5. Sell outside of Mutoko District 6. Other (specify)________________

23l. How do you transport the honey that you sell?

3. Head load
4. Scotch cart
5. Bus
6. Other (specify) ___________

24. Did you plant your gum trees so that they could shelter your crops or your garden from the wind?

1. No
2. Yes

25. Do you use the leaves from your gum trees to feed your goats or cattle?

1. No (*Go to 26*)
2. Yes

25a. How many times have you used the leaves from your gum trees to geed your livestock? (approximate number) ___________________________________times

26. Do you use the leaves from your gum trees to line your grain bin so your grain is protected from weevils? (*Go to 27*)

1. No
2. Yes

26a. How many times have you used the leaves from your gum trees to line your grain bin? (approximate number) ___________________________________times

27. Before you planted your woodlot what did you use the land where your woodlot is for?

3. Livestock grazing
4. Vegetable garden
5. Crop field
6. Other(specify) _______________

<u>Section II: Tenure Perceptions and Socio-economic Information</u>

For Individual woodlot owners only

28. Has one farmer always owned the trees in your woodlot?

1. No
2. Yes (***Go to 29***)

28a. How long were the trees in your woodlot owned by a cooperative or group before your household took ownership?___________________________________months

28b. Why has there been a change in woodlot ownership?

3. Lack of co-operation among group members
4. Cheaper for one farmer
5. Donation
6. Other (specify)___________

29. Has your household ever hired labour to work in your woodlot?

1. No (***Go to 30***)
2. Yes

29a. If you hired labour.
(i)Did you hire adult males, adult females or children?
(ii)How much did you pay each type of worker for one day of work?

Type of worker	Wage rate for one day of work
Adult male	
Adult female	
Children	

30. How many years has your household been in the village? ________________________years

31. Do you expect to be on this piece of land forever?

1. No   2. Yes

32. What is the gender of the respondent? **(OBSERVED)**

3. Male   4. Female

33. What housing type is the main house?

3. pole and dagga   4. brick and thatch   5. brick and asbestos
6. pole and asbestos   7. Other(specify)________________________

34. In which of the following categories does the age of the person most involved in the woodlot (in years) fall?

3. Under 25   4. 26-49   5. Over 50

35. How many members in your household are male? ________________________

36. How many members of your household are female? ________________________

37. How many members of your household are under the age of 15? ______________

38. What is the highest level of education or training that that the person most involved in the woodlot project has completed?

3. Never attended school   4. Primary school (grades 1 to 7)
5. Secondary school or diploma   6. Other(specify)________________

39. Have all of your children gone to primary school?

1. No   2. Yes   3. Only some

40. How many of each of the following do you have?

Item	Number in household
Cattle	
Ploughs	
Bags of Agricultural Yield per year	

41. Do you receive cash remittances from relatives in the city?

1. No (***Go to 52***)   2. Yes

41a. If yes, how many times a year do you receive them?

3. More than once a month
4. Monthly
5. Four times a year
6. Twice a year
7. Once a year
8. After more than a year

41b. How much money do you usually receive each time money is sent?

3. Less than $50
4. Between $50 and $250
5. Between $250 and $500
6. Between $500 and $1000
7. More than $1000

For Cooperative or group woodlot owners only

42. Has a cooperative or group always owned the trees in your woodlot?

1. No
2. Yes (*Go to 43*)

42a. How long were the trees in your woodlot owned by an individual farmer before your cooperative or group took ownership? ______________________________ months

42b. Why has there been a change in woodlot ownership?

3. Cheaper for more than one farmer
4. Donation
5. Other (specify)____________

43. Has your tree-growing group ever hired labour to work in your woodlot?

1. No (*Go to 44*)
2. Yes

43a. If you hired labour,
(i)Did you hire adult males, adult females or children?
(ii)How much did you pay each type of worker for one day of work?

Type of worker	Wage rate for one day of work
Adult male	
Adult female	
Children	

44. How old is your cooperative or tree-growing group? ______________________ years

45. Do you expect your cooperative or group to own the land where your woodlot is forever?

1. No
2. Yes

46. In which of the following categories does the leader of your tree growing group (in years) fall?

3. Under 25
4. 26-49
5. Over 50

47. How many members in your cooperative or tree growing group are male?____________

48. How many members of your cooperative or tree-growing group are female? ____________

49. How many members of your cooperative or tree-growing group are under the age of 15?

____

50. What is the highest level of education or training that that the person most involved in the woodlot project has completed?

3. Never attended school
4. Primary school (grades 1 to 7)
5. Secondary school or diploma
6. Other(specify)________________

51. How many of each of the following do the members of your cooperative or tree growing group collectively have?

Item	Number in Group
Cattle	
Ploughs	
Bags of Agricultural Yield per year	

Section III: Tree Height and Circumference Measurements

52. How close are the gum trees planted to the household? **(OBSERVED)**

3. Near (less than 500 m from homestead)
4. Far (more than 500 m from homestead)

53. Pick 10 randomly selected gum trees that were planted in the same year. Make the following observations and measurements. Trees should be selected from the centre of the planting row if trees are planted as a living fence. When trees are not planted as a living fence but rather as a group, or in several distinct groups, a woodlot will be defined as 10 or more gum trees that occur within a 20m x 20m area. Trees to be measured should be randomly selected making sure that they were all planted in the same year. The 10 trees should be selected from a centre planting line if possible. **Note: Coppiced shoots under 10 cm at DBH should not be measured.**

***E. camaldulensis* Tree Height and Basal Circumference Measurements**

Tree Number	Number of times harvested?	Number of coppiced shoots?	Basal circumference in cm	Height in metres
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

54. Measure the distance between the 10 selected trees.

Spacing Between Randomly Selected Trees

Tree Numbers	Spacing in metres
1 and 2	
2 and 3	
3 and 4	
4 and 5	
5 and 6	
6 and 7	
7 and 8	
8 and 9	
9 and 10	

55. Please make any notes regarding comments the person being interviewed has made, or unusual aspects of the woodlot or tree planting which seem interesting.

Appendix B: Methods - Stand Volume and Mean Annual Increment Estimation

Stand volume and mean annual increment (MAI) for each woodlot in the study sample were estimated using methods presented in Philip (1994). Stand structure of the species *E. camaldulensis* is characterized as plantation type managed by coppice. For forest inventory purposes the commercial value of *Eucalyptus* is its' value as small roundwood and saw timber (Philip, 1994). In the Mutoko communal area the economic potential of *E. camaldulensis* is realized through use of small roundwood and saw timber for building poles in the construction of household dwellings, fences etc., and also for use as fuelwood. Although small branches and leaf litter are utilized for other purposes, these components are not quantified as they are challenging and time consuming to measure. For the purposes of this analysis, stand volume is a function of the primary stem or stems and will not include estimates of branch wood, dry matter distribution (leaf litter) or bark.

Estimation of individual tree volume is based on the following equation:

$$v_i = g_i h_i f \; ; \qquad (6)$$

where v_i is the volume of an individual tree (m^3), g_i is the basal area of tree i (m^2), h_i represents the height of tree i (m), and f is a constant which standardizes for the form or shape of the tree bole.

From the centre of each planting line or woodlot, ten trees were selected for measurement. When trees with multiple stems were observed, each of the four largest stems over 10 centimetres were measured. In cases where none of the stems were equal to or greater than 10 cm's at diameter breast height (dbh), only the largest stem was measured.[66] Where trees were forked from ground level, dbh was measured for each stem; trees that forked above 1.3 metres were measured as single stems. Direct methods were employed for both dbh and height measurements. Dbh was estimated using a girth tape at 1.3 m over bark.[67] Because bark on *E. camaldulensis* is thin it was assumed unlikely to bias measurements. Where course bark had the potential to bias measurements it was scraped off with a knife prior to measuring. Measuring from soil level at a central point at the base of the tree to 1.3 m with a measuring stick identified breast height. When necessary, litter and tree debris were removed from around the main stem to maintain consistency in measurements.

[66] Diameter breast height is measured at 1.3 metres from the base of the tree.

[67] Girth or diameter tapes measure tree circumference. Tape graduations are based on the relationship between the diameter and circumference of a circle, which provide a direct reading of tree diameter (Avery *et al.*, 1994). Theoretically girth tapes are biased and yield overestimated results. However, in field tests it has been proven that calipers, which are the other common direct measurement tool, yield estimates which are biased to the same degree (Philip, 1994).

Basal area estimates based on dbh are required for volume calculations (Avery *et al.*,1994). Dbh measurements were converted to basal areas using the following equation:

$$BA_i = \Pi(\frac{dbh_i}{200})^2 ; \quad (7)$$

where BA_i is the basal area of each stem i in m^2, and dbh_i is diameter of each stem i at breast height in cm's.

Height was measured using aluminum height rods supplied by the Zimbabwe Forestry Commission. Measurements required that one person raise the height rods to the highest living point on the tree, while an observer noted when the rod was in line with the top of the tree. The process required two actions to be taken to ensure consistency. First the highest living point on the tree had to be observable from a point level with the location where the tree was planted. Second, for all trees measured the observer had to be an equal distance away from each tree to ensure heights were being observed from similar angles. These conventions were followed whenever possible. It is noteworthy that wind sway, one of the most common sources of error in tree height measurement was a significant factor in Mutoko.[68] Philip (1994) suggests that errors in measurement resulting from wind sway can be overcome by averaging readings taken at the extremes of the sway both towards and away from the observer. Although this solution is theoretically sound, wind in the study area generally blew in one direction on any given day. Thus, measurements were conducted at times when the wind either slowed or stopped. Although the amount of time required to gather measurements was increased, results are likely to have a lower margin of error.

Height estimates are based on Lorey's mean height which is often employed in allometric equations, particularly when the sample includes a number of trees under three years of age.[69] Lorey's mean height *(Lmh)* is a standardized height figure that is defined as:

$$Lmh = \Sigma h_i g_i / \Sigma g_i ; \quad (8)$$

where h_i is height and g_i is basal area.

[68] The majority of surveys were conducted in the month of August which is the windiest month of the year in northeastern Zimbabwe.

[69] Lorey's mean height employs the concept of a weighted average. Trees with a large basal area contribute more to the mean than trees with a small basal area. Average height weighted by basal area takes into account the low basal areas associated with young woodlots (Philip, 1994).

To estimate the volume for the average tree in each stand surveyed, allometric equations that rely on the assumption that the tree takes on the shape of a cone were used to translate basal area and height measurement into volumes. Assuming a cone shape implies that the tree has even taper all the way up the trunk, the form factor (f) 0.3 was used in volume estimations. Average volume per tree is based on the following equation:

$$v = ((0.3)(BA)(Lmh)). \qquad (8)$$

For the purposes of comparison, volume and mean annual increment estimates were calculated on a per hectare basis. Data gathered on spacing between the ten trees measured allowed for the estimation of the number of trees per hectare for each woodlot. To estimate actual stand volume per ha for each woodlot, the above formula *(v)* is multiplied by the total number of trees per ha in woodlot, adjusted for mortality. MAI per hectare is estimated by dividing volume per hectare by stand age. Table B.1 provides an overview of the summary statistics for both individual and cooperative woodlots.

Table B.1: Summary statistics, tree measurement data

	Individual woodlots (n=81)	Cooperative woodlots (n=20)
Average number of trees per ha	2423.44 (2496.30)[a]	5333.19 (4397.39)
Average volumes per ha(m^3)	274.43 (500.29)	92.09 (152.45)
Average MAI per ha (m^3)	47.82 (94.01)	17.46 (21.09)
Average Spacing (m)	2.84 (1.66)	1.81 (0.91)

a. Values in parenthesis indicate standard deviations.

As the above table indicates, average number of trees per hectare is much higher for cooperative woodlots than for individual woodlots. This may be attributed to the fact that more stringent spacing regimes are adhered to in cooperative woodlots. Regardless of more efficient spacing, volume per hectare and MAI per are much greater for individual woodlots than cooperatives. This may be related to better environmental growing conditions for trees in individual woodlots (i.e. soil conditions, access to water etc.).