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Analysis of Soil and Water Conservation Techniques in Zimbabwe: A Duration Analysis

By

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ABSTRACT:

This study investigates factors explaining the divergences in the amounts of time taken by farmers to adopt Soil and Water Conservation Technologies (SWC) in Zimbabwe. Previous studies suggest that informational problems limit the farmer's ability to correctly anticipate the long-term productivity consequences of current land use practices and that farmers possibly undergo stages of learning and updating their knowledge of the distributions of the benefits and costs of SWC. Several factors that potentially influence the time taken to adopt SWC technologies were identified and included in a duration model. The results suggest that the longer a household has gone without adopting any SWC technology, the more likely they are to adopt in the following year. The results also suggest that adoption is more likely in the first five years of the management life of the farmer. The distributions of the times taken to adopt individual SWC technologies differ considerably.

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CHAPTER 1 - Introduction

This study is motivated by the increasing need to promote better resource management (soil in particular) in Zimbabwean smallholder agriculture. This need arises, as in other developing countries, because current agricultural practices can lead to excessive soil erosion and insufficient water retention. Whitlow (1987) and Stockwell and Elwell (1988) present evidence that this has happened in Zimbabwe and other countries in Africa. Since soil erosion and low water retention can cause long-term crop yields to decline, it is important that effective counter-active measures be developed. Research (Chuma and Hagmann, 1995; Hagmann, 1994; Moyo and Hagmann, 1994; Munyati, 1997) suggests that currently available soil and water conservation techniques are feasible and can increase crop yields and water retention. While it is promising that technical means are available for increasing yields and thus potentially increasing the welfare of smallholder farmers, it is important to study the economic and social context under which soil and water conservation techniques are implemented (or not implemented).

For example, while the effort to conserve soil on a technical basis appears feasible, individual efforts may be overwhelmed by steadily increasing demands for food for the growing human population. This may be one reason why not all farmers adopt soil and water conservation techniques. This raises several questions. Why do some farmers not adopt techniques that would appear to be in their benefit? Why do some farmers adopt more quickly than others do? What are the mechanisms by which information about the benefits of soil and water techniques is transmitted through small holder societies and how does this affect adoption? This study attempts to explain and predict the divergences in the time it takes to adopt soil and water conservation after the establishment of a farm household between smallholder farmers in Zimbabwe.

There are numerous factors that potentially influence the adoption decision of a farm household. These may include resources, preferences, technology and institutions. Different factors may have a profound influence on the incentives for, and capacity of, farm households to invest in soil and water conservation (SWC). The relative importance of each factor may vary over time and across households.

Understanding such divergences between farm households is of crucial importance in devising effective and efficient government policy for promoting use of soil and water conservation techniques. This study analyzes the importance of selected factors on the time it takes households to adopt SWC using duration analysis, a fairly new technique in the analysis of technology adoption data.

Chapter 1 presents the background to this research problem, a formal problem statement, further justification for this research and the specific objectives for the study.

1.1 Background

Concern for the health of the global environment has increased in recent years. Resource degradation associated with agriculture has been identified as a problem of particular worldwide concern (Napier et al, 1994b). Brown (1984) and Sabel-Koschella (1988) have presented evidence that reveals the seriousness of the soil erosion problem. Globally, 25 billion tons of sediment from arable lands is said to be lost into the oceans, compared to only 2 billion tons per year before settled agriculture began. In Zimbabwe, estimated losses from arable lands are put at over 50 tons per hectare annually (Elwell and Stocking, 1988). An erosion survey in Zimbabwe (Whitlow, 1987) showed about 13% of the country and 26% of the communal areas as moderately to severely eroded. Elwell and Stocking (1988) also reported estimates of nitrogen, phosphorus, and potassium losses of up to 50% of the amount applied in fertilizers.

About 57% of the Zimbabwean population lives in the rural areas (Moyo et al., 1993) and the majority (75%) of these live and farm in the semi-arid parts of the country. These are areas in Natural Regions IV to V and some marginal parts of Natural Region III. The areas are characterized by unreliable rainfall with an annual average of about 600mm.[1] Drought-induced crop failure on average occurs in one out of every four years. The soils are generally sandy and infertile. High water losses

[1] Zimbabwe is divided into 5 Natural Regions (Natural Farming Areas). Natural Region I, receives the highest rainfall, suitable for intensive crop farming, Natural Region II, suitable for intensive livestock and crop farming, Natural Region III, Semi-intensive livestock and crop farming, Natural Region IV, Extensive farming, and Natural Region V, very low rainfall, suited to extensive livestock farming.

from arable lands through surface runoff and soil loss through sheet erosion further diminish the low agricultural potential of these areas. Soil and Water Conservation (SWC) is of paramount importance under these conditions.

Awareness of the importance of SWC in Zimbabwe has evolved over the past century. The introduction of the plough early in the past century triggered a drastic change in farming systems and practices, virtually eradicating indigenous knowledge in SWC (Hagmann and Murwira, 1996). Consequently, degradation became so severe that from the 1940s the colonial administration forced smallholder farmers to implement externally developed conservation works. These included the digging of contour ridges, destocking and the abolishment of gardens in wetlands (streambank cultivation), which were governed by the Native Husbandry Act of the 1950s.

Contour ridges are a conservation technology originally designed for commercial farming areas designed for commercial farming areas. These areas are normally sited in high rainfall areas with heavier soils. Thus the contours are aimed at stopping erosion by limiting runoff while draining excess water off fields. During the liberation struggle (1976-1980), farmers were encouraged by the freedom fighters to destroy or stop maintaining contour ridges, which were seen as a symbol of white oppression (Hagmann and Murwira, 1996).

Hagmann and Murwira (1996) have noted that there is a common perception amongst farmers that the natural resource base has dwindled drastically over the last two decades and that the situation will continue worsening unless stringent measures of resource management are put in place. The most recent piece of legislation governing land affair in Zimbabwe is the *Communal Lands Act* of 1982, which repealed the Tribal Trust Lands Act of 1979. This resulted in the power to use and occupy the communal lands resting with district councils who would act in consultation with members of the Village Development Committees (VIDCOs). This stripped traditional leaders who used to enforce laws on SWC, of their powers. Most people realize the need for resource management, including soil and water conservation, but feel helpless to organize themselves properly to define and implement appropriate conservation measures.

Effective institutions are essential for implementation of SWC techniques. In Zimbabwe, complexity, weak leadership, and lack of cooperation characterize institutions at local levels (Hagmann and Murwira 1996). Weak leadership and lack of cooperation are in part caused by tensions between those in favor of modern democratic institutions and those in favor of more traditional leaders and institutional structures. Given this situation, successful SWC implementation will depend on successful communication with local institutions and policies aimed at increasing their capacity (Hagmann and Murwira, 1996). The ITDG food Security project suggests that strengthened local institutions enhance the sustainability of development activity that promotes SWC (ITDG, 1997).

The Deutsche Gesellschaft für Technische Zusammenarbeit GmbH (GTZ), an international aid agency, have collaborated with the Zimbabwean Department of Agricultural Technical and Extension Services (Agritex) in a project entitled "Conservation Tillage For Sustainable Crop Production Systems" (ConTill) to revive interest in the importance of soil and water conservation. The Intermediate Technology Development Group has also been working to promote SWC through a "Food Security Project". Both projects have been following participatory approaches to developing and promoting SWC techniques from 1991 onwards. GTZ and ITDG proposed to field test participatory approaches in Masvingo province in Zimbabwe. Participatory approaches are based on the principle of promoting stronger participation by farmers in planning and implementing agricultural extension and research programs in the rural areas. These approaches also emphasize the strengthening of local institutions as vehicles for any developmental activities. In both projects, farmers have developed several options for SWC. Other SWC techniques were developed on station and offered to farmers for testing. Most of the options that have been developed have their origin in traditional farming practices, but are adapted to present farming systems (Hagmann and Murwira, 1996).

1.2 The problem and justification of the study

The research problem of this thesis is to explore the divergences in soil and water conservation adoption behavior among farmers in Chivi communal lands, Zimbabwe.

Soil and water conservation (SWC) has played an important role in the development of smallholder agriculture in Zimbabwe. As mentioned in an earlier section, the introduction of the plough early this century triggered a drastic change in the farming system and in practices, virtually eradicating indigenous technical knowledge in soil and water conservation (Hagmann and Murwira 1996).

After independence in 1980, the focus on conservation in extension under the new government lost out to the drive towards yield maximization. At present, there is growing concern about continuing degradation and alternative SWC techniques are being studied. Notable efforts to promote SWC have been through government cooperation with Non-Governmental Organizations (NGOs). ITDG and GTZ have been following what are known as participatory approaches to developing and promoting SWC techniques from 1991 onwards.

Despite the attractiveness and apparent superiority over contours of these participatory approaches to SWC, not all households have been quick to adopt SWC and some households still have not adopted any techniques at all. Table 1 reports, as an example, the adoption of SWC techniques developed by farmers and researchers in the ITDG Food Security Project (ITDG, 1997).

The poorest adoption is for techniques developed on research stations with adoption rates over the period 1991-1997 as low as 0.31% for Fanya juu terraces. The most popular techniques appear to be the 'revived traditional practices', which have adoption rates as high as 62%. However, the adoption rates for these techniques could still be improved. Some farmer innovated techniques also have managed to gain popularity (infiltration pits; 65%), whilst some have failed (rock catchments; 1%, modified contour ridges; 3%). These divergences are due to both technical aspects of implementation and socio-economic characteristics of the communities and individuals involved.

In this study, we are concerned mostly with socio-economic dimensions of SWC adoption, which may include resource ownership, risk and time preferences and attitudes. Technical constraints are outside the scope of this study. This is justified because much of the literature on soil conservation in Zimbabwe has been devoted to technical aspects whilst fewer studies have examined the social and economic factors that influence SWC adoption.

Table 1.1: Adoption of SWC techniques for field Crops by farmers in Ward 21, Chivi

Technology	**Source of Innovation**	**Adoption by number of households (Total 1300 households) 1991-1997**
Tied Ridges	Chiredzi and Makoholi Research Stations, Harare Institute of Agricultural Engineering at Mutoko	450
Infiltration pits	Farmer innovation (Mr. Phiri from Zvishavane)	850
Rock catchments	Farmer innovation (Mr. Phiri from Zvishavane)	14
Modified contour ridges	Farmer designed	40
Mulching and ripping	Agritex/GTZ Contill project	5
Fanya juu terraces	Agritex/GTZ Contill project	4
Winter ploughing	Revived traditional practice	800
Intercropping	Revived traditional practice	450
Termite soil as fertilizer and moisture retainer	Revived traditional practice	800

Source, ITDG (1997) Total number of households in project area approximately 1300

A detailed study of the social and economic factors involved in SWC adoption is warranted because if conservation practices are to be successful they need to be integrated into the structural, social, cultural and economic context in which they take place. Knowledge of the socio-economic aspects is essential to develop policies and interventions that will lead to successful adoption of SWC techniques. In addition, the few studies that have concentrated on social and economic aspects have been qualitative or descriptive in nature. Previous quantitative studies have been mostly done in a static framework. Static analysis of adoption does not allow for households adopting at different rates over time. A more quantitative approach in a dynamic framework is warranted that will allow for rigorous testing of socio-economic factors to determine which factors are important and which factors are not.

This study assumes that effective measures and policies to promote SWC techniques depend not only on an understanding of the social and economic aspects of rural communities but also on understanding the processes and therefore understanding of the time to adoption of these practices. The diffusion of innovation theory provides a framework for understanding the process by which technologies are adopted in a society or economy. Rogers (1983) defined the process of diffusion as "the process by which an innovation is communicated through certain channels over time among members of a social system". Rogers (1983) highlights mass media channels as being essential to diffuse initial information about an innovation. Following that, interpersonal channels are essential to gain adoption/rejection of an innovation. Diffusion of innovations is hypothesized to follow a normal, bell-shaped or an S-shaped curve when adopters are plotted on a frequency basis or cumulative frequency basis respectively against time. Based on the innovativeness[2] of individual or any decision-making unit, diffusion studies on agricultural practices grouped farm populations into five categories namely: innovators, early adopters, early majority, late majority, and laggards.

Although diffusion theory provides a useful framework for understanding how technology is dispersed it does not identify the details of socio-economic factors that may influence who adopts more quickly. Advocates of the diffusion model tend to see adoption behavior as strongly influenced by information and past experience (Hansen et al, 1987; Napier, 1991). The diffusion model also focuses on aggregate behavior rather than individual behavior.

Another reason that we are interested in looking at the time to adoption is that resource degradation is a process that takes place over time. This means that one might predict the time when rural communities reach critical resource deficiencies, thresholds and irreversibilities. Since adoption is a process that takes place over time

[2] Rogers and Shoemaker (1971) define innovativeness as the degree to which a household or other decision-making unit is relatively earlier in adopting new ideas than other members of a system. Innovativeness is assumed to be a randomly distributed human characteristic (Rogers, 1983).

we would want to know whether the rates of adoption are fast enough to counter rates of resource degradation. One cannot determine this using a static model. The importance of timing of adoption led to a departure in this study from common approaches of studying socio-economic factors affecting SWC adoption, which depend on static choice models (Lapar and Pandey, 1999). Instead the timing of adoption motivated the use of a duration modeling approach, where the dependent variable is the "time to adoption" for individual households.

1.3 Research Objectives

The purpose of this study is to identify economic, social and institutional factors that influence adoption rates of farmers living in the rural areas in Zimbabwe. To address this broad research purpose a number of specific objectives were set for the study. The objectives are:

1. To identify the current practices available in soil conservation and to present descriptive statistics on the extent of adoption measured by the numbers of farmers practicing the technique, and timing of adoption.
2. To determine how long the process of SWC adoption takes at the individual and community levels.
3. To estimate the effect of various factors, i.e. socio-economic, attitudinal and sources of information, on the time it takes a household to adopt a SWC technology.
4. To provide estimates of the time it takes households to adopt a SWC technology.
5. To provide simulations of the probability of adoption in any given time period to demonstrate the impact of changes in a factor, i.e. socio-economic, attitudinal and sources of information characteristics of households holding all other factors constant.
6. To suggest possible policy responses and avenues for future research into SWC in light of research findings of this study.

By analyzing the timing of adoption and the effect of socio-economic characteristics on the length of time to adoption, it is hoped that such knowledge will better inform change agents on strategies that are best for development.

1.4 Thesis Structure

Chapter 2 includes a review of economic theory pertaining to soil conservation. In addition, a review of the debate surrounding economic analysis of soil conservation, policy, and suitable technology is provided. A brief review of literature of studies of the adoption process is also presented. Chapter 3 includes an overview of the study area and questionnaire, and a discussion of the general activities in SWC in the area. Chapter 4 discusses the conceptual and empirical frameworks that shape the analysis. It begins with outlining some economic theory and links the theory with duration analysis. It then provides an overview of duration analysis, the concepts of duration distribution and dependence. The section concludes with specification of the empirical model. In Chapter 5, the results of duration analysis are presented. Chapter 5 also includes simulations. Chapter 6 summarizes the results, and then provides concluding remarks on policy recommendations for future SWC strategies, limitations of the study, and some suggestions for future research.

CHAPTER 2 - Literature Review

2. 1 Overview

This chapter begins with a discussion of definitional and analytical issues encountered in the economic evaluation of SWC. Next, the chapter discusses the benefits and costs of SWC leading into a discussion of the two main analytical approaches to the assessment of SWC; namely the evaluation and the adoption schools. A brief review of past empirical studies of the adoption process follows. The chapter concludes with a review of the debate surrounding policy and suitable technology in SWC.

2.2 Definitions of Soil Conservation

Soil conservation averts the damage caused by soil erosion. The analysis of soil conservation is confounded by different interpretations of conservation – namely absolute, standards-based, and efficient, or economically optimal conservation (Erenstein, 1999). The different interpretations imply different degrees of erosion control with significant implications for the analysis. Absolute and optimal conservation remains largely hypothetical in view of the costs and complexities involved respectively.

The first interpretation, absolute conservation, suggests that the soil resource should not erode at all (Erenstein, 1999). This view can also be labeled soil conservation fundamentalism (Seckler, 1987) or Buncian conservation (van Kooten, 1993). Such views revolve around stewardship and a strict precautionary principle. Maintenance of an absolute conservation approach implies that there is no (accelerated) soil erosion, which makes it an infeasible approach. The other three approaches to soil conservation suggest that soil erodes at a slower (or equal) rate than without conservation.

The second approach to soil conservation is the standards-based approach. This approach uses T-values. The T-value is defined as the maximum rate of soil erosion consistent with economic production into the indefinite future (Crosson, 1985). The T-value for the United States, for example, is estimated to be 11 tons per ha per year (Pagiola, 1994b). There is widespread criticism on the T-value both on technical and economic grounds. On technical grounds the criticism is two-fold. First, the T-value is ambiguous because it is based on the rate of topsoil formation, and not the actual rate of soil formation from consolidated parent materials, which is a much slower process than the former (Crosson et al, 1985). Second, the relationships among soil quality, erosion and productivity are far too complex and variable among soils and regions to be captured in a simple rule of thumb for an entire region or country (Crosson, 1997). This makes it difficult to develop standards that are broadly applicable.

Thirdly, soil conservation may be viewed in terms of economic efficiency or optimality. The basic premise of this view is that it is not worth preventing soil erosion unless the benefits gained are larger than the costs incurred (Erenstein, 1999). This means that the marginal benefits of avoided erosion losses are just balanced by the additional conservation effort (Erenstein, 1999). Although there is much to say for optimal conservation, there are serious methodological difficulties in applying it (Stocking, 1987; Upstill and Yapp, 1987). The optimal level of soil conservation will depend on the shape of the cost curves for soil erosion and conservation (Carlson and Zilberman, 1993). In practice, most of the required data are rarely available. Consequently, most empirical economic assessments of soil conservation have focused on aggregate rather than marginal figures (Blyth and MacCallum, 1987).

2.3 Economics of Soil Conservation

The costs of soil conservation are usually obvious and therefore seldom overlooked (Troeh, Hobbs and Donahue, 1991). Soil conservation reduces the cumulative on-site damage by soil erosion. However, in many instances the damage caused by soil erosion is largely imperceptible and the short-term benefits of soil and water conservation may also be imperceptible. Hence the returns of SWC are not readily identifiable, because conservation merely preserves productive potential that would otherwise be lost. Weather variations, more fertilizer, new crop varieties, and improved crop management may mask lowered potential of soils to produce crops. It takes a perceptive person to properly balance the obscure costs of inaction against the obvious costs of acting to conserve soil. Soil conserving practices often provide long-term benefits in exchange for immediate costs (Troeh, Hobbs and Donahue, 1991).

Another factor that may inhibit adoption of SWC or prevent it from being applied at an optimal level is that SWC can create positive externalities. That is, many people may benefit from a single landowner's conservation practices. For example, soil that is held on a field neither muddies the water of a stream nor becomes sediment on other land. People living downstream therefore benefit from soil conservation practices upstream. Therefore to adequately address the problem there is a need to assess the economic implications of conservation and to acknowledge the private and social dimensions. Soil erosion is a serious problem in a number of localities but the greatest question often posed is whether counteraction in the form of soil conservation is warranted. Some groups argue in favor of soil conservation without questioning cost effectiveness. Others assert that if soil conservation were economically attractive, farmers would take care of it themselves (Kerr and Sanghi, 1993; van Kooten, 1993:235). However, the latter view ignores off-site externalities.

2.3.1 The Benefits of Soil Conservation Practices

Soil conservation yields many kinds of benefits. The present section discusses these in turn. Some conservation practices may produce an immediate profit; some may lead to a delayed profit, and some may produce no monetary profit but may have aesthetic or other non-monetary effects (Troeh, Hobbs and Donahue, 1991).

Conservation tillage is one of the soil conservation practices that produce an immediate benefit by reducing energy input thereby reducing costs (Troeh, Hobbs and Donahue, 1991). Conservation tillage may also result in savings through reduced demand for machinery. Wittmus *et al.*, (1975) report savings of 18% for machinery and 64% for fuel by a corn farmer in Nebraska. Soil conservation may also lead to soil moisture retention, which would be especially useful in semi-arid areas. Contour tillage might make an average of 50mm more available for plant growth on sloping lands during the growing season (Troeh *et al.*, 1991). Fertilizer, tillage, water management, and pest control practices should increase profits the same year they are applied. However, several years may be required to repay the investment cost of SWC practices such as terracing, revegetating grazing land, replanting forests and soil reclamation.

Soil loss results in the loss of productive potential. Reduced yield potential resulting from soil loss has been stated to range all the way from 0 to 100% (Troeh *et al.*, 1991). The yield reduction depends greatly on the amount of erosion and the nature of the topsoil, subsoil, and soil parent material. Soil erosion is seldom uniform across a large area of land. The value of soil conservation for preserving productive potential may vary for different parts of a single field.

The losses due to soil erosion may also vary because the value of the soil itself varies over space. Hence, the value of lost soil, one particular cost of soil erosion may also vary and so will the benefits of SWC in terms of reductions in soil loss. Reasons that the value of each ton of eroded soil varies include differences in soil clay, organic matter, and nutrient contents.

In addition to loss prevention, several types of soil and water pollution can be reduced by soil conservation practices (Troeh *et al.*, 1991). Sediment and the chemicals often associated with it are prime examples. Soil conservation practices can keep most of the soil and chemicals in the fields where they are useful.

2.3.2 Costs of Soil Conservation Practices

The costs of conservation practices can be difficult to evaluate. The costs of some practices are highly variable, making it difficult to estimate the costs in particular circumstances. Furthermore, direct payments do not reflect the management input of the landowner and other persons who provide the required technology. Opportunity costs are a means of considering many of the less obvious costs of conservation. For example, one must forgo the opportunity to grow a crop on the area where a grassed waterway is planted. The opportunity to make a profit is real, even though a gully might destroy it later (Troeh *et al.*, 1991).

Most conservation practices involve out-of-pocket direct costs and less tangible indirect costs. Building terraces involves large direct costs, usually in expectation that more intensive use will increase profit and repay the costs. On the other hand, opting for less intensive landuse (*e.g.* land retirement) involves little or no direct costs but has indirect costs in the form of lower gross returns from the land.

Long-lasting conservation practices are logically considered investments. A drainage project, for example, is not expected to repay its total cost the first year. Sometimes the installation cost exceeds the gross returns from the crop of any one-year. It may take several years to repay the cost and make a profit. A conservation practice is a good investment if it produces a satisfactory rate of return over a long enough lifetime. Most water management, land reclamation, and terracing projects are installed in anticipation of long-term profits.

2.3.3 Paying for Soil Conservation

People are usually willing to pay for a conservation practice that produces short-term profits (Troeh *et al.*, 1991). Other practices that require long terms to produce profits are adopted more cautiously, especially if large investments are required. The person paying for the practice must be assured of stable conditions for a long enough time to make the benefits worth more than the costs. An owner-operator is more likely to invest in such practices than an operator with a short-term lease. Aesthetic, legal, and moral considerations may motivate the use of some practices in spite of unfavorable economics. Some individual landowners may pay for such practices but group or public action is more common. Flood control, drainage projects, and irrigation developments are examples of other practices that commonly require group action (Troeh, Hobbs and Donahue, 1991).

Governmental units at any level may want to encourage conservation projects that benefit large numbers of people. The benefits from some projects may be so diffuse that individuals or small groups would not likely install them but they may be feasible as government projects. A government has several ways of encouraging the application of soil conservation practices. It can provide technical assistance. It can allow tax credits or other benefits to those who apply the practices. It can provide low-interest loans or pay part or all of the costs itself to finance the practices. Governments also have the option of establishing legal requirements and enforcing them through the court system. Finally, the government can provide information on

SWC and the potential damages that may occur in the long-term through investments in research and development.

2.4 Economic Assessments of SWC

The assessment of SWC poses considerable analytical challenges that have been tackled in varying ways. The different analytical approaches can be broadly grouped into two main schools of economic analysis: (1) the evaluation school and (2) the adoption school. Each school focuses on different aspects of soil conservation and each is, to a certain degree complementary to each other (Erenstein, 1999). The evaluation school tries to quantify the economic impacts of different conservation alternatives or between conservation and alternative investment. By quantifying the benefits and costs of SWC, this approach aids policymakers and farmers to determine the best course of action to follow. However, even if an economic evaluation is empirically valid, the adoption of soil conservation measures may still be uncertain. Only in the case that farmers were operating under perfect markets with the sole objective of maximizing efficiency would such an economic analysis suffice (Pagiola, 1994a: 34). Therefore, an adequate understanding of the socio-economic factors influencing soil conservation behavior is also needed. The adoption school addresses this dimension. The subsequent subsections discuss these two methods in detail.

2.4.1 Economic Evaluation of SWC

The evaluation school tries to quantify the economic impact of different soil conservation scenarios. However, attempts to evaluate SWC are often curtailed by data limitations. The steps in this approach are to choose the mode of costing erosion, and then go on to choosing the mode of economic analysis. Alternative approaches for costing erosion include the non-demand curve approaches, which have been characterized as; the dose-response approach, replacement cost, mitigation behavior, and the opportunity cost approach. The demand curve approaches include; expressed preferences, revealed preferences, hedonic pricing and the travel cost method (Erenstein, 1999). Demand curve approaches have the advantage of providing a welfare measure but have tended to be ignored in terms of costing erosion. Alternative approaches for analysis are broadly classified into discrete (cost-benefit analysis) and continuous (optimization models) approaches.

The dose-response approach is most frequently used to assess on site costs of soil erosion (Erenstein, 1999). This approach links a biological response to an environmental stress based on a production or damage function (Walker, 1982; Turner et al., 1993). It provides a means to estimate, 1) the damage incurred by non-action, and 2) the averted damage of mitigating action. Soil erosion is commonly taken as the dose with the productivity effects as the response. However, the complex nature of the underlying soil erosion process implies there are generally no clear dose-effect relations. In addition, site specificity and data limitations add further problems to implementation of this approach (Erenstein, 1999).

The replacement cost approach is occasionally used as an alternative. This technique tries to estimate the cost of restoring a damaged asset (Turner et al., 1993; 113). It can be applied to assess both on-site and off-site costs of soil erosion. The replacement cost approach is not without problems, particularly when applied to erosion-induced nutrient loss. It may overestimate the on-site costs as it implies soil conservation in the absolute sense; all nutrient loss is considered undesirable and needs to be compensated (Pearce and Warford, 1993). Yet, the marginal productivity impact of the nutrient loss varies across nutrients, crops, soils, and management levels. The approach may also underestimate the on-site costs of soil erosion as it singles out only one aspect of the incurred degradation: it is only a partial reflection of the total on-site impact (Erenstein, 1999). Fertility replenishment may therefore not be enough to compensate all the erosion induced productivity loss (Lal, 1987a).

Other non-demand curve approaches include mitigation behavior and the opportunity cost approach. Mitigation behavior is based on aversive expenditures, i.e. preventive costs. Mitigation behavior will generally be some form of standards-based conservation, using the most cost-effective way of meeting a particular conservation standard and it can be applied to assess both the on-site and off-site costs of soil erosion (Erenstein, 1999).

The opportunity cost approach circumvents the controversial valuation of the environmental benefits and costs. Instead, the benefits of degrading activity are used as a benchmark for what environmental benefits would have to be surpassed to make the activity worthwhile. For example, the benefits in relation to erosive land use within a watershed could be used as a benchmark to mirror the joint downstream impacts within the same watershed. Alternatively, the costs of soil conservation within the watershed could be used as a benchmark (Erenstein, 1999).

Each measure is imperfect in some way. Erenstein (1999) points out that, to compound the issue, the different measures are not directly comparable. Many only provide a partial–yet occasionally overlapping – measure of the true cost of soil erosion. Further, each measure reflects different soil erosion scenarios (ignore, prevent, cure) whereas their application may reflect different–implicit or explicit-definitions of conservation (i.e. absolute, standards-bases, efficient, or optimal). Erenstein (1999) concludes by stating that although all existing methods are typically imperfect and open to criticism, following a method that is open for external debate is preferable to covering the difficulties.

The various evaluation methods that may be used to perform economic analysis of SWC can be typified as discrete and continuous methods. The discrete approaches try to quantify the economic impact of a specific predetermined set of conservation scenarios (e.g., cost-benefit analysis (CBA)). For continuous approaches, the set of scenarios is conceivably unlimited (e.g., optimization models).

CBA is a discrete approach and mainly revolves around the efficiency interpretation of soil conservation. CBA may calculate a *benefit/cost ratio* by dividing probable benefits by estimated costs. A *benefit/cost ratio* of 1.0 or larger may suffice to cause a practice to be installed. A ratio smaller than 1.0 is likely to end consideration of a project. Erenstein (1999) suggests that estimating the benefits side of soil and water conservation is one of the problems of applying CBA. For example, one of the greatest on-site benefits relates to averted yield loss, but information for accurate quantification is typically lacking. The use of discounting in soil conservation CBA is another controversial issue, particularly for some non-economists. They view discounting as 'penalizing' the future benefit stream of soil conservation investments, whereas current investments remain relatively unaffected.

Optimization models provide a continuous approach in line with the optimal interpretation of conservation. The model maximizes a specified objective function subject to a number of constraints. One frequent approach uses mathematical programming either in a static (Seitz et al., 1979; Zinser et al., 1985; Deybe, 1990; Carcamo et al., 1994) or a dynamic setting (Miranowski, 1984; Baffoe et al., 1987; Orazem and Miranowski, 1994). The static models typically have a soil loss constraint, which subsequently can be tightened or slackened to assess the impact of changing conservation standards. Static models fail to recognize endogenous incentives for soil conservation: the higher erosion induced yield loss the bigger the incentive for adoption (Miranowski, 1984; Miranowski and Cochran, 1993). Dynamic models typically do include some estimate of erosion induced productivity loss.

Several modifications can be incorporated into optimization models to make them more realistic (Erenstein, 1999). Stochastic programming incorporates stochastic elements into the optimization model. It presents a form of sequential and adoptive modeling that may be more consistent with farmer behavior. However, it has only sporadically been applied to soil conservation (Lopez-Pereira et al., 1994). Multi-criteria programming provides another approach to make optimization models more realistic. In most standard applications, models optimize one objective, typically maximizing utility (efficiency). Yet in the real world, multiple objectives are the rule rather than the exception. Multi-criterion programming allows for the simultaneous optimization of more than one objective, however its application to soil conservation is relatively limited. The most influential application of optimization modeling to soil conservation is by McConnell (1983). The model maximizes the net value of the farm with input use as a control variable and soil depth as a state variable. An earlier application by Burt (1981) used the proportion of land used under wheat as a decision variable and topsoil depth and organic matter content as state variables. Notwithstanding, McConnell's model has been variously adapted. Optimal control methods determine the privately optimal path of soil degradation (or the optimal cropping strategy to employ, etc.) in each period of time as a function of prices and biophysical conditions (van Kooten, 1993). However, a major shortcoming of such dynamic optimization techniques is that they still are only applied in abstract stylized settings under specific assumptions (Pagiola, 1994a). The data limitations and the nature of analysis influence the choice. Although models provide a powerful analytical tool, their strength in the end hinges on the underlying assumptions. Erenstein (1999) states, "The economic evaluation of soil conservation eloquently highlights the analytical dilemma of opting for a 'messy' empirical or 'clean' theoretical approach".

2.4.2 Study of Adoption Behavior to Assess SWC

The economic evaluation approach aids policymakers and farmers to determine the best course of action to follow by quantifying the benefits and costs of SWC. However, even if an economic evaluation were implemented successfully the adoption of the soil conservation measures would still be uncertain. An economic evaluation would suffice, only in a case where farmers were operating under perfect markets with the sole objective of maximizing efficiency (Pagiola, 1994a: 34). This is not the case, and there are numerous factors that potentially influence the decision to adopt a soil and water conservation technology. Therefore, an adequate understanding of the socio-economic factors influencing soil conservation behavior is also needed. The adoption school tries to explain and predict the divergences in soil conservation behavior of economic agents. Studying the adoption behavior of a community is tantamount to assessing the criteria for increasing the likelihood that SWC technologies will be taken up by households. The numerous factors that potentially influence the adoption decision of the farm household include resources, preferences, technology, and institutions. An analysis of conservation behavior also helps to predict future conservation behavior of households. The extreme socio-economic site-specificity of soil conservation both warrants and entangles the study of adoption behavior (Erenstein, 1999). Most adoption models have not explained farmers' behavior well or are not very useful (Miranowski and Cochran, 1993; Camboni and Napier, 1994).

Adesina and Zinnah (1993) distinguish two types of paradigms of technology adoption and diffusion: the innovation-diffusion paradigm and the economic constraint paradigm. These emphasize different aspects of adoption behavior, for instance, the advocates of the diffusion model proposed by Rogers (1983) tend to see adoption behavior as strongly influenced by information and past experiences (Hansen et al., 1987; Napier, 1991). Advocates of the farm structure model emphasize the role of the farm household's resources. Nowak (1987) suggests that such perspectives are bound to be more useful if they are regarded as being complementary. Therefore, despite considerable effort there is still very little known about who conserves the soil. The present section will discuss the two perspectives in detail.

Rogers (1983) defined an innovation as: "an idea, practice, or object perceived as new by an individual or other unit of adoption". Alavalapati (1990) points out that the perceived newness of the idea is the focal point and that it matters little whether or not an idea is 'objectively' new. Rogers (1983) also defined the process of diffusion as "the process by which an innovation is communicated through certain channels over time among members of a social system". Mass media channels are essential to diffuse initial information about an innovation. Following that, interpersonal channels are essential to gain adoption/rejection of an innovation.

Innovativeness is the degree to which a household or other decision-making unit is relatively early in adopting new ideas than other members of a system (Rogers and Shoemaker, 1971). Innovativeness is assumed to be a randomly distributed human characteristic (Rogers, 1983). According to the innovation diffusion theory, innovativeness follows a normal, bell-shaped or an S-shaped curve when adopters are plotted on a frequency basis or cumulative frequency basis, respectively, against time. Based on the innovativeness of the individual or any decision making unit, the diffusion studies on agricultural practices grouped farm populations into five categories namely: innovators (2.5%), early adopters (13.5%), early majority (34%), late majority (34%), and laggards (16%).

The innovators are characterized by the following: venturesome, cosmopolites, networked with other innovators, financial resources, understand complex technical knowledge; cope with uncertainty (Rogers, 1983). The early adopters in turn are respectable, more local than innovators, and have strong opinion leadership. The early majority interacts frequently with peers; seldom hold positions of opinion leadership, interconnected to the system's interpersonal networks and go through a long period of deliberation before making an adoption decision. The late majority may adopt as a result of economic/social necessity due to the diffusion effect. The diffusion effect is "the cumulative increasing degree of influence upon an individual to adopt or reject an innovation, resulting from the activation of peer networks about an innovation in a social system". They are skeptical and cautious and have relatively scarce resources. The members of the last category, the laggards are the most local, have a point of reference in the past, suspicious of change agents and innovations, and have few resources.

The framework described above leads us to hypothesize that social, personal, and communication characteristics of a household will largely influence his/ her adoption process. These general characteristics of adopter categories will have implications in designing development strategies. Chatoe and Gilbert (1997) examine literature on the diffusion of innovations and discuss the various limitations of using this framework to model the adoption decision of farmers. Their main question is whether the diffusion innovations framework is appropriate for modeling the adoption behavior of farmers. The first step towards answering this question is to check if the adoption curves for the technique in question look anything like the sigmoid innovation diffusion curve. The innovation diffusion curve is also regarded as an artifact of underlying assumptions. These include the assumption of a fixed constituency of potential adopters, the assumption of no outflow of individuals that have adopted, the assumption of atomic technologies, and the assumption of structural similarity.

These assumptions lead to several questions, for instance, "Is it true that the number of farmers eligible for a given technique remains more or less constant over its lifetime?" The assumption of a fixed constituency encourages sigmoid adoption curves. The assumption of no outflow makes it impossible for farmers who have adopted a technology to revert to their old practices. The assumptions suggest models in pursuance of the innovation diffusion model at a number of levels of detail and sophistication. These include simple prediction by curve fitting, sophisticated prediction by behavioral determinants using aggregate data and simulation of the adoption process.

The advocates of the farm household structure emphasize the role of farm household resources in influencing the adoption process (Erenstein, 1999). The availability of land, labor and capital resources constrains the farm household's feasible set of activities. Implementing soil conservation may thereby imply substantial opportunity costs. The household's objectives and attitudes determine whether these costs are compatible with utility maximization (Erenstein, 1999). Compatibility is more likely when implementing conservation implies short-term results and reduces risk. Also, compatibility may depend on technology factors because neither conservation or production technology is homogenous. This may imply significant differences between the different conservation technologies as well as their technological compatibility with current production practices. The compatibility of conservation with utility maximization may also depend on institutional factors, which encompass a highly influential set of external conditioning variables. Of particular relevance for institutional compatibility are the market imperfections and the corresponding institutional adaptations. The security of rights can be influential in this respect.

Despite the apparent failure of currently available theories and empirical studies to explain adoption behavior fully, one thing has become very clear: many factors potentially influence the adoption of soil conservation practices at the farm level (Camboni and Napier, 1994; Napier *et al.*, 1994b). The subsequent discussion briefly reviews these in terms of technology, the farm household and prevailing institutions. Though the factors are discussed separately, most of them interact and together determine conservation behavior. For example, the composition of farm household assets tend to reflect farm household preferences and the institutional setting; the high time preference of farm households may reflect scarce resources and the institutional setting; etc (Erenstein, 1999).

2.4.2.1 Technology Factors

Technology may enter the decision to adopt a SWC technology in two distinct ways (Erenstein, 1999). First, SWC technology is not homogenous. Second, the current production technology on the farm may have different implications for a given conservation technology. Different conservation technologies exist, with corresponding implications for their efficiency, feasibility, complexity, predictability, and divisibility (Reardon and Vosti, 1992).

The efficiency of technologies is likely to be affected by the timing and magnitude of initial investment, recurrent costs and corresponding benefits – which may be technology specific (Erenstein, 1999). The feasibility of technological options typically depends on the required supporting environment – *e.g.*, in terms of the provision of specific equipment or inputs. Complexity increases the learning costs for farmers, whereas predictability reduces the risks associated with adoption. Divisibility may have a twofold effect. First, if the technology is divisible, a farmer can adopt and implement it in incremental steps thus potentially reducing both risk and the level of economic investment needed. Second, the technology may require a certain scale of implementation that may transcend the farm boundary and thereby require collective action, thus complicating the adoption process. The implications of a given conservation technology are also affected by current production technology. On the one hand, conservation and production technologies may not be entirely compatible – *e.g.*, the width of terraces may prohibit mechanized land preparation. This implies the need to adapt at least one of the two technologies upon conservation adoption. On the other hand, conservation and production technologies may be complementary – *e.g.*, soil conservation also implies reduced loss of inputs through reduced runoff. The complementarities also give rise to a paradox: conservation competes with productive technology for resources, but also can increase the returns to productive investment (Reardon, 1995).

2.4.2.2 Farm Household Resources

The farm household makes decisions relating to land use and therefore soil conservation. The decision to adopt SWC is therefore likely to reflect resource endowments and preferences of the farm household. Farm households only have a limited set of resources (land, labor and capital). Soil conservation requires the use of resources – either directly in terms of investment and maintenance of requirements (e.g., capital and labor) or indirectly in terms of foregone production (e.g., land to locate structures). However, these conservation requirements are likely to compete with alternative household use of resources for production and consumption. Therefore, resource availability constrains the feasible set of activities of the farm household.

Given a set of resource constrains, both the absolute level and timing of resource requirements are of importance. For instance, the household's labor used for production and consumption activities are likely to be divided between on-farm, off-farm, home, social, and leisure activities. *Labor* needed for conservation activities implies displacement from other activities and thereby represents an opportunity cost in terms of utility forgone. The timing of the labor needs is likely to influence the magnitude of these opportunity costs. This opportunity cost will be high during peak periods of agricultural on-farm and other on-farm and off-farm employment opportunities (Kerr and Sanghi, 1993). Consequently, the slack agricultural season tends to correspond with much off-farm activity (Reardon and Vosti, 1992).

It is often hypothesized that farm resources are positively correlated with adoption in general, and soil conservation in particular. In this regard, farm *size* has received substantial attention. The size of the farm has been considered as a surrogate for a large number of potentially important yet confounding factors (Feder et al., 1985). A larger holding is typically associated with access to financial and technical support systems, as well as economies of scale. Farm size may also affect preferences (*e.g.*, attitude towards risk).

Farm household resources have both quantitative and qualitative dimensions (Erenstein, 1999). The quality aspect is particularly relevant for the land resource. Land quality has a profound influence on conservation adoption, as it affects both the need for conservation and its opportunity cost. Adoption of SWC technology may be linked to *human capital* – *i.e.* the knowledge and skills embodied in the household members. Human capital is expected to influence learning costs – a potentially large and fixed cost of adoption. These costs are likely to vary over households, depending on their knowledge base and skills (*e.g.*, learning ability; management capacity). In this regard, Stiglitz (1988) distinguishes between (1) learning by doing and (2) learning to learn. Learning by doing stresses the investment in knowledge upon technology adoption. This implies that it may pay to adopt a technology in a dynamic setting when on static consideration alone it would not. Learning to learn stresses the investment in skills. This implies it may pay to adopt a technology neither for its current or prospective returns, but for the benefits that will accrue in the adoption of future technologies. Education has been hypothesized to facilitate diffusion of new technology. This is because education enhances one's ability to receive, decode and understand information, and information processing and interpretation is important for performing or learning to perform many tasks. The process of education can thus be viewed as an act of investment in people.

2.4.2.3 Farm Household Preferences

The decision to adopt SWC technology is co-determined by the farm household's preferences as reflected in the household's objectives and attitudes. Farmers generally pursue a set of objectives – for instance, profit maximization, to provide for food and other household needs, to avoid becoming indebted, to obtain acceptable returns for the applied resources, and to achieve an adequate balance between work and leisure. Relevant attitudes include time preference, risk preference, and stewardship motivations. Both objectives and attitudes are inherently subjective and specific for each household, and jointly determine the preferred set of production and consumption activities. The household is assumed to choose the combination of these activities that will maximize utility, given the constraints imposed by available resources, technology and institutions. Within the process of maximizing utility, if conservation is an objective for the household, conservation may compete with other objectives for limited resources.

For resource-poor farmers, sheer survival today may be a more pressing problem than conservation of the resource base for a distant future (Blaikie, 1985; Conway and Barbier, 1990). Farmers are sometimes assumed to be practicing a form of 'myopic optimization'[3] resulting in strong preference for short-term effects (Feder *et al.*, 1985). This may contrast starkly with the several years normally needed to achieve significant benefits from traditional conservation investments (Napier *et al.*, 1991).

It is generally acknowledged that developing country farmers tend to be risk-averse, and may have short planning horizons and hence high discount rates. (See Anderson and Thampapillai, 1990: 11-13 for various references). Conservation typically poses a risk dilemma as it affects risk in two opposing ways (Erenstein, 1999). On the one hand, soil conservation reduces risk. Soil conservation halts the decay of an income stream: it is a preventive investment that avoids and undesirable and uncertain future outcome. Further, soil conservation tends to reduce agricultural production risks by conserving water – often a limiting factor (Anderson and Thampapillai, 1990; Reij, 1994). On the other hand, soil conservation increases risk. It is generally acknowledged that innovations – whatever their nature – entail risk. Feder *et al.* (1985) distinguish between subjective risk (*e.g.*, yield is more uncertain with an unfamiliar technique) and objective risks (*e.g.*, in relation to weather and availability of inputs). In the case of soil conservation, this problem of risk is exacerbated by the time-scale observability problem (Reardon and Vosti, 1992). A complicating factor is that risk preference is difficult to measure and is closely associated with other factors, leading to identification difficulties in empirical associations observed in cross-sectional data (Feder *et al.*, 1985; Norris and Batie, 1987, in Anderson and Thampapillai, 1990).

2.4.2.4 Institutional Factors

Institutional factors provide an important set of external conditioning variables for the conservation decision (Erenstein, 1999). There are various definitions of institutions which include: 'a set of behavioral rules that govern and shape the interactions of human beings, in part by helping them to form expectations of what other people will do' (Erenstein, 1999). Hoff *et al.* (1993) consider an economic institution to be 'a public system of rules that define the kinds of exchanges

[3] Myopic optimization is very close to having a very high discount rate.

that can occur among individuals and that structure their incentives in exchange.' According to Bromley (1982b), 'institutions are collective conventions and rules that establish acceptable standards of individual and group behavior.' Hayami and Ruttan (1985) consider institutions as the rules 'that facilitate co-ordination among people by helping them form expectations which each person can reasonably hold in dealing with others.'

The required institutional arrangements for efficient allocation of resources include: 1. Complete set of markets; 2. Perfectly competitive markets; 3. No externalities; 4. No public goods; 5. Fully assigned property rights; 6. Perfect information; 7. Producers maximize profit, consumers utility; 8. Long-run average costs are non-decreasing; 9. No transaction costs; 10. All relevant functions satisfy convexity conditions (Perman *et al.*, 1996). The standard neo-classical analysis assumes that these requirements exist, and thereby concentrates on technology, resources and preferences. However, in the analysis of soil conservation in developing countries, may be inappropriate, as both the problem and the setting imply substantial divergences from the necessary conditions.

The set of markets in developing countries is typically incomplete and their structure and performance imperfect (Erenstein, 1999). Factor market imperfections affect the adoption decision directly. For instance, soil conservation investments may be embodied in the land resource. To recapture soil conservation investments upon selling the land requires a functioning land market to recognize such investments (Kuyvenhoven *et al.*, 1996). Land values should reflect that value of averted long-term erosion-induced productivity losses (Miranowski and Cochran, 1993). Institutional interrelationships may affect the decision to adopt a SWC technology indirectly. For instance, a functioning labor market may alleviate a missing credit market as off-farm work substitutes for credit (Reardon *et al.*, 1994).

Property rights are one of the most frequently highlighted institutional factors influencing soil conservation adoption (Bromley, 1982a; 1982b; Napier, 1992). Economic theory suggests that insecure property rights lead to a premature depletion of resources. If a farmer cannot capture the future gains that arise from conservation decisions, he or she will have no incentive to conserve. In the extreme, farmers without security of tenure are interested in maximizing their short-term investment in seed, fertilizer and labor for the crop that is in the ground (Barbier, 1990). There are different types of property rights: 1. Private; 2. State; 3. Communal (with conventions governing use); and 4. Open access (without conventions governing use). Conventional wisdom holds that soil erosion/degradation is most likely under open access, as no one will have the incentive to invest in soil conservation. Communal management of resources can be successful – notably when institutional arrangements adequately relate private incentives to collective benefit and impose the necessary sanctions from within to prevent free-riding (Turner *et al.*, 1993).

2.5 Evaluating Empirical work on Adoption

The economic literature on adoption of innovations in agriculture has been studied intensively since Griliches' (1957) pioneering work on adoption of hybrid corn in the USA. The majority of adoption research subsequent to this has been concerned with answering the questions: (a) what determines whether a particular producer adopts or rejects an innovation, and (b) what determines the pattern of diffusion of the innovation through the population of potential adopters (Linder *et al.*, 1982; Feder *et al.*, 1985; Lindner, 1987; Tsur *et al.*, 1990; Leathers and Smale, 1992; Feder and Umali, 1993; Saha *et al.*, 1994; Marsh *et al.*, 1995; Rogers, 1995).

Empirical research on adoption of soil and water conservation techniques is made difficult by the extreme socio-economic site-specificity of soil conservation. The research problems are exceedingly complex and uni-causal models generally founder (Blaikie and Brookfield, 1987). Most adoption models have not explained farmers' behavior well or are not very useful (Miranowski and Cochran, 1993; Camboni and Napier, 1994). Therefore, despite considerable effort there still is very little known about who conserves the soil (Lockeretz, 1990). Lockeretz (1990) provides a critical review of the major shortcomings of the soil conservation adoption literature. Some problems are methodological, others analytical such as the difficulty in defining and measuring conservation adoption (Miranowski and Cochran, 1993). Another problem is the difficulty of comparing and interpreting results of different studies (SRAPTF, 1993). The empirical problems of studying soil conservation adoption in particular are compounded by the complexity of explaining farm household behavior in general, particularly in developing countries.

Risk has often been considered as a major factor reducing the rate of adoption of an innovation (Lindner *et al.*, 1982; Lindner, 1987; Tsur *et al.*, 1990; Leathers and Smale, 1992; Feder and Umali, 1993). However the issue of risk in adoption has rarely been addressed adequately (Ghadim and Pannell). The missing link is usually the dynamic nature of adoption decisions involving changes in farmers' perceptions and attitudes as information is progressively collected. Gadhim and Pannell (1999) model the adoption of a new crop as a dynamic decision problem spanning at least several years. The model allows for generation of potentially valuable information and the impact of that information is on personal perceptions of the innovation.

Studies that employ econometric techniques have tended to concentrate on models explaining the decision to adopt versus non-adoption rather than explain why some farmers quickly adopt techniques and why some farmers are reluctant to adopt immediately, even if the technique is clearly profitable. Logit and probit models are well-established approaches in the literature on adoption of technology. In general, the data used refer to a given point in time, resulting in static models of adoption. The dependent variable 'adoption or non-adoption' does not pick up adoption over time as it does not allow for farm households' different waiting times (De Souza Filho *et al.*, 1999). Zhao and Zilberman (2000) have pointed out that a dynamic adoption model that adequately accounts for the sunk cost and the uncertainty involved in the adoption process can explain the observed reluctance of farmers to adopt SWC technology. Their dynamic adoption model is an application of Real Option Theory (ROT) in technology adoption. Zhao and Zilberman (2000) argue that if an investment is irreversible and its future benefits are uncertain, it may pay to wait for new information before making the investment. Since many new technologies require significant capital (including both physical and human capital) investment, and it is difficult to undo the investment, a farmer may be very cautious in adopting a new technology if the future benefit of the technology is uncertain. The farmer would have an incentive to wait for new information until the expected profitability of the project surpasses a certain value, called option value. Real Option Theory shows that the option value is increasing in the level of uncertainty. Zhao and Zilberman (2000) test the ROT through the structural estimation of stochastic dynamic decisions using a method of generalized maximum entropy. The method estimates all the parameters in the dynamic decision, including those of the instantaneous profit function, transition matrix (stochastic process, and discount rate. Option value can then be evaluated based on the estimated parameter values (Zhao and Zilberman, 2000).

The present study follows De Souza Filho *et al* (1999) by analyzing the influence of potential determinants of technology adoption within an appropriate dynamic econometric framework, namely duration analysis, used widely in labor economics. Although this technique has obvious advantages in the analysis of technology adoption there are only a few examples in the technology adoption literature and it would seem, even fewer in the particular context of agricultural technology adoption. De Souza Filho *et al.*, (1999)'s work appears to be the first published application to agricultural production. In the application of duration analysis to analyzing labor there is a lot of micro-foundation given for the job-search and employment duration models. However, there is no sound theoretical basis on which to specify structural relationships and interdependencies among variables explaining the time taken to adopt a technology.

The major advantage of duration analysis over the logit, probit and tobit methods is that it can deal with both cross-section and time series data. As a result, this kind of analysis can capture both cross sectional and temporal changes in the farm household's characteristics, costs of adopting the innovation, output price, environmental characteristics, and other explanatory variables. Adoption and diffusion can, therefore be investigated together within a dynamic process.

2.6 Soil and Water Conservation: Suitable Policy and Technology

Halbach, Runge and Larson (1987) pose this question: How do we apply scientific knowledge to improve conservation policy while recognizing political reality? This problem is captured by three interlinked adages: all politics is local, all conservation is local; all conservation is political (Halbach *et al.*, 1987). Public conservation interventions go back to the 19th century in the USA and the early 20th

century in tropical colonies. But government intervention so far has proven largely unsuccessful (Erenstein, 1999) with Africa showing a dismal record of soil conservation (Fones-Sundell, 1992).

Soil conservation is characterized by numerous market failures including imperfect information, spatial and temporal externalities, and the potential for economies of scale and irreversible damage (Erenstein, 1999). These failures are likely to be exacerbated in developing countries by typically missing, incomplete and imperfect markets. A question then is whether the public sector can be expected to offer effective interventions. For some, the mere existence of market failures implies the need for public interventions. For others, particularly absolute conservationists, intervention is a matter of common sense. However, intervention in soil conservation is only justified if the expected benefits of intervention to society are larger than the related costs. According to the advocates of efficient conservation, market failure only identifies the potential area for intervention: *i.e.* it is a necessary but not sufficient condition for public intervention (Stiglitz, 1987).

The traditional public intervention in SWC implicitly or explicitly recognizes the market failures underlying soil conservation (Erenstein, 1999). Farmers are seen to under-invest in conservation, and the government assumed to know better, tries to redress that. Intervention is based on the premise that conservation technology works – it is just a matter of getting farmers to adopt. Persuasion alone on grounds of stewardship, environmental concern, social good are never likely to be very effective in the face of private costs (Nowak, 1988). That leaves economic incentives and direct regulation (Turner *et al.*, 1993). Economic incentives have traditionally focused on different forms of subsidies, which include direct handouts (cash, food, inputs, and capital goods), credit and different degrees of cost sharing (Erenstein, 1999). The direct regulation approach has been based on standards stipulating dos and don'ts and attaching penalties to non-compliance. Unfortunately, the traditional mode of conservation intervention has not been very successful. Table 2.1 shows a hypothetical dichotomy of views between the farmer and the conservationist. The use of incentives and sanctions appear to be fraught with difficulties, especially in developing countries.

Table 2.1 A dichotomy of views

	Conservationist	Farmer
Emphasis	Conservation	Productivity
Planning Horizon	Long-term (cumulative degradation, investment)	Short-term (making ends meet)
Focus	Regional (externalities)	Farm (no externalities)

Adapted from Erenstein (1999).

The major problem with these approaches is that they do not question whether or not the available technologies work. Traditional conservation technology has contributed to the lack-luster success of conservation intervention. The technology is characterized by a number of biases (Erenstein, 1999) namely: (1) *conservation bias* - a conservation-first approach which tends to favor technical effectiveness over economic efficiency; (2) *developed country bias* - despite various efforts of researchers to highlight the need for appropriate technology in developing countries, the transfer of techniques of soil erosion measurement, conservation technologies and policies from the USA continues unabated (Blaikie and Brookfield, 1987); (3) *favorable land bias* - there has been a tendency to neglect steep lands with research stations typically located in relatively flat areas; (4) *paradigm bias* – up to recently, there has been a genuine lack of innovation in the conservation technology development process. Instead of more radical fundamental changes, the same old technological approach was used (Erenstein, 1999).

The new approach to public intervention has been to acknowledge first, the diverging viewpoints of conservationists and farmers and then to incorporate socio-economic considerations in the development of soil conservation technologies. Upon harmonizing the conservationist and farmer perspective it is useful to assess what can be learned from farmers in terms of soil conservation. Farmers have managed their soil resource for millennia and generally speaking are still in business (Erenstein, 1999).

A key to successful conservation intervention lies in harmonizing the views of conservationists with those of farmers (Erenstein, 1999). Therefore, understanding and addressing the farmers' preferences and constraints is crucial. Erenstein (1999) emphasizes a multidisciplinary, participatory and flexible approach to soil conservation intervention by the government. Erenstein (1999) further emphasizes the need to focus on soil productivity and not conservation *per se* and suggests the incorporation *ex ante* of farm household and institutional considerations in conservation technology development.

In terms of technology development, conservation is more likely to be compatible with household utility maximization whenever the technology outputs are short term, tangible and relevant, competitive, institutionally feasible and predictable. Also, conservation is more likely to be compatible with household utility maximization if the technology itself is cheap, simple, divisible, easy to maintain, compatible with the farm system, institutionally feasible and flexible.

The present chapter has highlighted the important factors (household resources, technological and institutional etc) that may play a considerably important role in influencing the soil and water conservation behavior of farmers. The subsequent chapters incorporate this in an empirical model to determine their statistical importance.

CHAPTER 3 - Survey Methods, Study Area Background, and Data Collection

3. 1 Overview

The first section of Chapter 3 describes the study area. This is followed by a discussion of the survey methods that were used for this study, the sample, the survey instrument and the state of soil and water conservation practices at the site. The chapter is concluded by presentation of variable statistics and a description of the SWC practices.

3.2 The Study Area

The Chivi communal area is located in Masvingo Province in southeastern Zimbabwe. The study area falls within Natural Region III, an area characterized as having semi-intensive livestock and mixed farming. The region receives 650-800mm annual rainfall, mostly during infrequent heavy storms, and drought occurs on average three years in every five. The high population density of up to 70 people per square km and a population growth rate of around 3% per annum combine to produce enormous land pressure. Average landholdings are around 1.2 hectares per farmer and they are getting smaller. Individual smallholdings typically contain of one or two cropping fields that are generally cultivated in the rainy season. Maize is the most frequently planted crop. Other crops planted include cotton, groundnuts, and sunflower. In addition to cropping fields, smallholders also establish garden plots in which they plant fruit and vegetables that are utilized primarily for household consumption. Before the 1990/1991 drought, less than half the population owned cattle. It has been estimated that up to 90% of cattle died during the drought (ITDG, 1997). Subsistence agriculture forms the mainstay of the livelihood of most families in Chivi. Other significant livelihood strategies include trading in clothes and food, sale of agricultural surplus, gold panning, crafts, and pottery production. Remittances from family members working in the urban centers are increasingly vital for rural families' survival (ITDG, 1997).

Chivi is commonly perceived as being poor, backward, drought-prone and environmentally degraded (Scoones et al, 1996). The immediate impression of Chivi can differ dramatically, depending on the time of the year and the quality of the rainy season. In the dry season, the area is dry and dusty, with squalls of wind blowing across the sparse brown landscape. But with adequate rainfall, the environment can be transformed with lush grass in the valleys, vigorously growing crops in the fields and green trees covering the hillsides. The Chivi communal area is comprised of several administrative Wards including Chivi Office, which is the administrative center for the whole Chivi District. This study area encompasses seven villages in Ward 25, southeast of Chivi Office. The area was selected because there has been considerable work in soil and water conservation research by IES carried out there, through which this particular study was being funded and administered. However, no studies on the adoption of SWC had been carried out in this particular area. The total area of the Chivi communal land is 3,534 km^2.

The government agency, Agritex, employs one Agritex 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. Currently, there are several non-governmental organizations, which include, ITDG, GTZ, CARE and IES that also offer the same kind of services provided by Agritex. The ITDG Food Security Project and the Agritex/GTZ Conservation Tillage Project have particularly been instrumental in promoting SWC in Chivi. The ITDG Food Security Project was initiated in 1990 to explore methods for involving community members in technology development. In its initial phases, the project identified the following as priority needs: water for crop production, animal draught power and equipment, suitable dry land crop varieties, water for vegetable production, fencing for protection from livestock, soil and water conservation, and pest management. The GTZ Conservation Tillage Project was implemented between 1988 and 1996 as a co-operation between Agritex and GTZ and was funded by the German Ministry of Economic Co-operation. The primary objective was to assess the soil and water conservation yield merit of several tillage systems with a view to develop sustainable crop production systems for smallholder farmers in different Natural Regions of Zimbabwe. Ward 25 in Chivi was selected as the study area as SWC had recently taken importance in the area. The residents of the area had also not been surveyed too frequently. Another consideration was the high frequency of smallholders with knowledge of SWC techniques and experience in implementation.

3.3 Survey Methods

3.3.1 Informal Survey

An Informal survey was carried out to obtain preliminary information about soil conservation. Specifically, an overview of the techniques being practiced by the farmers in the district was obtained from the informal survey. This included discussions with key informants and farmers. Key informants included government extension workers in Ward 25, UZ-IES staff in Harare and in the area, and other NGO workers in the area. Information from household surveys by previous researchers was also important in designing some of the survey questions.

Participatory Rural Appraisal (PRA) discussions followed the discussions with key informants and individual farmers. The PRA was used to identify relevant issues in soil and water conservation for the target community and to record the evolution of SWC practices in the community. The PRA yielded information about when the various techniques in SWC were first introduced into the community. The PRA was extremely useful for developing the survey instrument. This included identifying the villages to sample the relevant practices to include on the survey instrument, and the relevant sources of heterogeneity in the sample. It was also useful for cross-checking survey responses and providing additional insights.

3.3.2 Formal Survey

The questionnaire encompassed two main sections that fulfilled the majority of the quantitative data requirements for this analysis (*Appendix 3*). The first section provides a profile of the household, which is the sampling unit for the study. Following the PRA, the data for the first section of the questionnaire was grouped under household characteristics, household resources, household preferences, objectives and attitudes, and institutions. The presence of various practices, which include contours, Fanya-Juu, tied ridges, mulching etc. on farmers' fields made up the second section of the questionnaire.

The second section of the questionnaire was also designed to obtain information on labor usage, maintenance requirements and the timing of SWC activities during the year. Following the development of the questionnaire, four enumerators were trained over a period of three weeks. The questionnaire underwent some modifications during this process. The questionnaire was pilot tested on twenty farmers and was further modified a number of times. One of the enumerators was employed for the purpose of questionnaire administration. The household survey was conducted over a period of two and a half months between November 1999 and January 2000. The questionnaire length enabled single visits to each household. However, in some cases, additional visits were made for verification of information after supervisory checks on data consistency.

3.3.3 Sample Selection Methods

The sample was selected with the help of UZ-IES field staff who were asked to provide the sampling frame. This sampling frame was based on the extent of coverage in terms of geographical area of the GTZ/Agritex and IES projects. This was mainly because one of the aims of the analysis was to determine the influence of participatory approaches to soil conservation technology development on SWC technology adoption. The projects had covered about seven villages in Ward 25. Stratified random sampling with seven strata based on the number of adopters of SWC registered with IES within each village was used to select the households in the sample.

Table 3.1. Number of Households in Final Survey Sample by Village

Village	Households
Puche	19
Pedzisa	50
Mbaimbai	26
Mukwazvure	14
Guti	36
Nduna	29
Nyengera	26
Total	**200**

There were a total of 182 farmers practicing one or more of the SWC technologies and 18 farmers who had never adopted a single technique. The structure of the sample in the group of 200 farmers according to village is presented in Table 3.1.

3.4 Description of Collected Data

The practices used for conserving soil are many and varied. Some practices are expensive and some only require new habits; some are permanent and some are temporary; some are limited to very specific conditions whereas others are widely useful, although none have universal application (Troeh, Hobbs and Donahue, 1991). Some of the techniques currently in practice are summarized in Table 3.2. The amount of erosion reduction varies from one practice to another and from one set of circumstances to another. Various factors influence or determine the feasibility of implementing a particular technique. For example, stone bunds may be viewed as a low cost mode of erosion control, but this will only be true where the stone resource is not scarce. In addition, the issue of property rights may limit access to the stone resource, and this may be a severely limiting factor in situations where the stones are scarce. On average, labor requirements for tied ridging are slightly higher than for conventional tillage practices (Chuma and Hagmann, 1995). However, the labor requirements may vary greatly from farmer to farmer depending on the farmer's resources (e.g., available implements) and on the farmer's specific practices in the conventional tillage technique and managerial skills (Chuma and Hagmann, 1995).

According to measurements, the contour layout may occupy up to 22% of the arable area on some farms in Zimbabwe (Hagmann, 1994). In Chivi and Zaka, the area occupied was about 12.3%. This would likely deter some farmers from implementing these structures on their farms. Also, the experience of an adaptive on-farm trial program of the Agritex/GTZ project revealed that the assumption of rill erosion being effectively controlled through the contour layout did not hold true for the areas under investigation at the time. Initial shortcomings in the implementation of the layout as well as bad maintenance were found to create rills, which through subsequent cropping, developed into undulating depressions in the fields below.

Table 3.2. Examples of SWC Technologies in Practice

Mulching The practice of spreading around or over a plant with a mixture of wet grass, leaves or crop residues. Mulching increases yields of all crops by lowering soil temperatures, enhancing soil life, structure and fertility, conserving soil moisture, preventing direct impact of the rain (erosion control).
Intercropping. The growing of two or more crops simultaneously on the same field. Two or more crops grown together cover the ground better and/or longer than a single crop. More raindrops are intercepted, runoff is slowed and erosion is markedly reduced.
Strip Cropping. Strip cropping divides a field into long narrow parcels that cross the path of the erosive force of water or wind. The strips with more vegetative cover slow runoff, reduce wind velocity, and catch soil eroded from the more exposed strips. Thus the average soil loss may be reduced to as little as one-fourth of what it would be without the strips.
Vetiver. Type of deep-rooting grass that can be planted along waterways, on contours. Typically used for rill reclamation.
Crop Rotation. Two or more crops alternating on the same land. A rotation may control erosion and plant diseases. A crop rotation often provides more continuous cover than is possible when the same annual crop is grown year after year.
Winter Ploughing The practice of ploughing the land during the fallow season. This practice increases soil moisture retention, which in turn leads to reduced soil erosion.
Contours. Contour ridges combined with storm drains have formed the standard mode of SWC in Zimbabwe over the past century. This layout is designed to carry the maximum storm water runoff from a bare soil produced by a storm and drain it safely out of the field into a waterway. This layout is generally considered as highly effective for protecting land from rill erosion (Hagmann, 1994). Sheet erosion between contour ridges, however, is still considered to be a major constraint to good crop yields in smallholder agriculture (Elwell, 1985).
Fanya-Juu. The Fanya-juu has been proposed as an option for improving the existing contour layout. The Fanya-juu system was developed in Kenya during the early 1950s. Fanya-juu is a Kiswahili word, which means, "throw uphill". It consists of a bund along a contour line made of soil and or stones with a ditch at the lower side. It reduces the velocity of overland flow and consequently soil erosion. In Zimbabwe, the tendency has been to implement the Fanya-juu by modifying existing contour ridges. The advantage of the Fanya-juu over the contour ridges is that it requires less maintenance and that it increases water retention. Farmers exposed to the system at the onset of the GTZ/Agritex project in Zimbabwe revealed a high potential for adoption of the Fanya-juu. The farmers highlighted that their benefit from adopting these would be a gain in land (the present contour layout occupies up to 22% of their land), and the fact that this encourages water retention instead of draining it.
Tied Ridges. Conservation tillage technique. Tied ridges are furrows which are blocked at intervals along their length, forming basins which hold rain water reducing runoff and soil loss. This also greatly increases soil moisture.
Stone Bunds. Stone bunds or stone Lines are barriers of stones placed at regular intervals along the contours of farms. The size of stone bunds varies, depending on the availability of stone and the topography.
Infiltration pits. A farmer innovated technique that involves the construction of pits in the highest contour level of the fields. The catch rainwater thereby reducing runoff and serve as water reservoirs.
Tree Planting. Properly managed trees provide excellent erosion control even on steep land. In agro forestry systems farmers use trees by deliberately combining them with agricultural crops.

The Fanya-juu has been proposed as an option for improving the existing contour layout. The Fanya-juu system was developed in Kenya during the early 1950s. Fanya-juu is a Kiswahili word, which means, "throw uphill". It consists of a bund along a contour line made of soil and or stones with a ditch at the lower side. It reduces the velocity of overland flow and consequently soil erosion. In Zimbabwe, the tendency has been to implement the Fanya-juu by modifying the already existing contour ridges. The advantage of the Fanya-juu over the contour ridges is that it requires less maintenance and that it increases water retention. Farmers exposed to the system at the onset of the project in Zimbabwe revealed a high potential for adoption of the Fanya-juu. The farmers highlighted that their benefit from adopting these would be a gain in land, and the fact that this encourages water retention instead of draining it.

3.4.1 Current SWC Practices

3.4.1.1 A Review of the Data for SWC Collected on Adoption

Several interesting facts came out from the PRA discussions. This section briefly outlines these. Popular techniques include crop rotation, contours, winter ploughing and composting. Contours were forcibly enforced during the 1950s. However, implementation of which was also associated with rewards during the colonial period. For example, if a farmer implemented these correctly he could be rewarded with either a bigger farm in the agro-ecologically better areas or a Master Farmer status (PRA discussion, 1999). The farmers also saw contours as an effective way of defining field boundaries. Crop rotation was viewed as desirable since it diversified household's sources of food whilst increasing average yields per acre compared to the situation of only one annual crop. Winter ploughing is a technique, which increases the moisture retention properties of soils. These result in reduced erosion by reducing soil vulnerability to the erosive force of wind and increased crop yields per unit of land.

Table 3.3. Adoption of Various techniques by 200 sampled farmers in Chivi (Ward 25)

Average Number of Techniques per Household = 5			
Technique	Number of Households	Percent	Year of First Adoption
Contours	149	75	1946
Stone Bunds	80	40	1960
Infiltration pits	42	21	1990
Rotation	158	79	1950
Strip	87	44	1960
Ridges	36	18	1991
Mulch	38	19	1970
Winter	147	74	1950
Vetiver	35	18	1990
Tree Planting	81	41	1962
Fanya-Juu	34	17	1992
Compost	120	60	1963

3.4.2 Factors to Explain Adoption

It is hypothesized that both the economic environment and the non-economic environment of the farmer and the farm characteristics are important to the adoption process. The full list of potential determinants that the data permits for consideration is presented in Table 3.4. These factors are directly related to those discussed in Chapter 2. The discussion in Chapter 2 highlights the importance of factors related to the technology itself (YIL_COST), farm household resources (CATTLE, SIZE, CULTIV, PLOUGH, NOHSE, and HIGHEDUC), farm household preferences and attitudes (RETURNS, FUTURE and HRISK), institutional (GROUP1, GTZAG), property rights (OWNEST), sources of information (PAPMAGS, RADIO, EXTAGS) and social participation (SOCIAL, LEADER, TRIPS).

Table 3.4. Definitions of Explanatory Variables

EXTERNAL ENVIRONMENT
GROUP1: dummy variable, =1 if farm household was established before independence
GTZAG: dummy variable, =1 if the GTZ/Agritex project was operating when household was started, 0 otherwise.
FARM HOUSEHOLD RESOURCES
CATTLE: number of cattle owned by farmer as an indication of wealth.
SIZE: farm size in acres.
CULTIV: =1, if farmers owns, 0 otherwise.
PLOUGH: =1, if farmer owns, 0 otherwise.
OWNEST: = 1, farmer owned land at the time the household was established, 0 otherwise.
YIL_COST: =1, the first adoption was for contours which entail an immediate loss of cultivable land, hence yield, 0 otherwise.
FARM HOUSEHOLD CHARACTERISTICS
AGEHEAD: age of the head of the household in years.
GENDER: sex of the head of household, =1 if male, 0 if female.
NOHSE: number of persons living at homestead.
HIGHEDUC: dummy variable, =1 if any person living at the homestead received secondary school education or higher, 0 if not.
FARM HOUSEHOLD ATTITUDES AND OBJECTIVES
RETURNS: dummy variable, =1, if farmers aims to obtain acceptable returns to the resources he employs, 0 if not.
FUTURE: dummy variable, =1, if farmer believes that soil conservation will assure good yields in the future, 0 if not.
HRISK: dummy variable, =1, if farmer has low risk aversion, 0 if not.
FARM HOUSEHOLD SOCIAL PARTICIPATION AND SOURCES OF INFORMATION ON SWC
SOCIAL: dummy variable, =1, if farmer belongs to a farming related club, 0 otherwise.
LEADER: dummy variable, =1, if farmer holds a leadership position in any club, 0 otherwise.
TRIPS: dummy variable, =1, if farmer attends field trips outside of their village, 0 otherwise.
FARMERS: dummy variable, =1, if farmer obtains information on SWC from other farmers, 0 otherwise.
PAPMAGS: dummy variable, =1, if farmer obtains information on SWC from papers and magazines, 0 otherwise.
RADIO: dummy variable, =1, if farmer obtains information on SWC from the radio, 0 otherwise.
EXTAGS: dummy variable, =1, if farmer obtains information on SWC from extension agents, 0 otherwise.

3.4.2.1 Preliminary analysis of factors affecting adoption

Some descriptive statistics of the variables are shown in Table 3.5. Adopters are classified according to their duration in four categories. Adoption is defined as the decision to take up a particular technique or more and implementing it or them on the field. Since we are interested in why some farmers adopt faster than others some notable differences are revealed in table 3.5. For example, a visual inspection of table 3.5 reveals that adopters where on average older (mean age 57.4, compared to 40 for non-adopters), somewhat more outgoing (social 0.3 compared to 0 for non-adopters). Non adopters in the sample do not attend field trips, do not own cattle, had smaller farm sizes, own no cultivators and most of them own no ploughs. Farmers who adopted in shorter times (1-10 years) owned land at the time of household establishment, had more cattle, tended to be male headed, held leadership positions, read papers and magazines, and listened to the radio. It remains to be seen whether these differences are significant in a statistical sense. The empirical framework for statistical analysis is presented in Chapter 4 and the results in Chapter 5.

Table 3.5. Sample Means for the Variables in the Adoption of the First Technology Model

VARIABLE	SAMPLE N=200	Adopters 1-10 years N=136	Adopters 11-20 years N=28	Adopters 21-30 years N=12	Adopters 31-40 years N=6	Non-Adopters N=18
CATTLE	2.3	2.6	1.6	2.4	3.1	0
SIZE	3.3	3.6	3.0	3.4	3.7	1.4
CULTIV (0,1)	0.1	0.2	0.1	0.3	0	0
PLOUGH (0,1)	0.6	0.6	0.6	0.4	1	0.1
AGEHEAD	47	44.4	53	63.5	68.5	40
GENDER	0.7	0.8	0.6	0.4	0.7	0.7
NOHSE (0,1)	7.1	7.1	7.7	8.3	6.5	5.3
HIGHEDUC (0,1)	0.7	0.7	0.6	0.6	0.7	0.7
SOCIAL (0,1)	0.3	0.3	0.3	0.3	0	0
LEADER (0,1)	0.3	0.4	0.3	0.1	0	0.1
TRIPS (0,1)	0.4	0.4	0.5	0.4	0.7	0.1
FARMERS (0,1)	0.1	0.1	0.1	0.1	0	0.1
PAPMAGS(0,1)	0.1	0.1	0	0	0	0.2
RADIO (0,1)	0.5	0.6	0.4	0.3	0.3	0.5
EXTAGS (0,1)	0.3	0.3	0.1	0.3	0	0.1
RETURNS((0,1)	0.4	0.4	0.6	0.3	0.5	0
FUTURE (0,1)	0.8	0.4	0.4	0.4	0.8	0.2
HRISK (0,1)	0.2	0.2	0.1	0.3	0.3	0.2
LRISK (0,1)	0.8	0.8	0.9	0.7	0.7	0.8
GROUP1	0.6	0.4	0.7	1	1	1
GTZAG	0.2	0.3	0.1	0	0	0
OWNEST	0.3	0.4	0.1	0.2	0.2	0.1
YIL_COST	0.5	0.5	0.5	0.4	0.7	0.8

CHAPTER 4 – Conceptual and Empirical Framework

4.1 Conceptual Framework

This study uses a duration model, described as a dynamic econometric framework, to analyze the importance of socio-economic factors in influencing the time taken by a farmer to adopt a SWC technology (De Souza et al, 1998). Common approaches to modeling the adoption process include the logit and probit models. These analyses have been argued to dissociate adoption from diffusion (De Souza et al, 1998) by not allowing for the fact that households spend different lengths of time before they decide to adopt from the time they learn of a technology. One of the ways in which the dynamic nature of technology adoption has been captured has been to model the diffusion process by evaluating the cumulative adoption process at the aggregate level (Feder and Umali, 1993). One problem with this aggregate approach is that there is relatively little micro-foundation given for the diffusion process and hence, it is difficult to account for the heterogeneity in the underlying sample of farm households (De Souza et al, 1998).

In technology adoption, the theoretical basis on which to specify structural relationships and interdependencies among the variables explaining the time taken to adopt a technology is still weak (De Souza et al, 1998). This study uses the duration model, which has been widely applied in labor economics. The major advantage of duration analysis is that it can be applied to both cross-section and time series data. The use of the duration model comes at some cost, however, because it gives no theoretical linkage between an economic theory of adoption and an econometric model of duration as there is in most models. For example, the random utility model is linked to logit or probit models, and the theory of job search in labor economics leads naturally to an econometric duration model (Kiefer, 1988).

Heckman and Singer (1984) attempt to make a linkage between the duration model and the random utility model but they do not indicate how any of the possible distributions for the durations can be derived from theory. This analysis concentrates on establishing a viable econometric model to explain the time taken to adopt technologies and providing some stylized facts about the time taken to adoption of technology with which theoretical work ultimately has to be confronted.

4.2 Empirical Framework

4.2.1 Overview

Analysis of duration is a new but rapidly growing area in econometrics. The variable of interest in the analysis of duration is the length of time that elapse from the beginning of some event until its end (for example unemployment) or until the measurement is taken. Heckman and Singer (1984) favor the use of continuous time models in analyzing discrete choices made over time. Conventional discrete choice models such, as the logit and probit, when defined for one time interval are of a different functional form when applied to another time unit, if they are defined at all (Kiefer, 1988).

Continuous time duration models are invariant to the time unit used to record the available data. A common set of parameters can be used to generate probabilities of events occurring in intervals of different length. Economists have recently found it convenient and fruitful to study duration data by reasoning in terms of hazard functions rather than data densities (Heckman and Singer, 1984). The hazard function is a simple transformation of the density function. The attraction of the using the hazard function comes from the fact that interesting properties of data, such as duration dependence, are most easily defined and understood in terms of hazard functions. Duration analysis has proven to be an ideal setting for some applications, especially in labor economics, which link economic theory and econometric methods tightly together. However, there are weak links between economic theory and duration models studies on the adoption of agricultural technology.

4.2.2 Distributions and Duration Dependence

Probability theory plays a fundamental role in duration analysis. Instead of focusing on the time length, one can consider the probability of its end, or as it is the same, the probability of transition to a new state (Burton, Rigby, and Young, 1997). The spell is defined as the amount of the time that it takes for an event to begin or end (Kiefer, 1988). In a technology adoption study, a pertinent question is: what is the probability of a household adopting a certain technology very shortly after time t, given that it has not adopted by that time? (Burton, Rigby, and Young, 1997). The answers are generated by the hazard function, defined as the probability of a spell being completed at duration *t*, given that it has lasted until *t*.

Let $f(t)$ be a continuous probability density function of a random variable *T*, where *t*, a realization of *T*, is the length of a spell. The corresponding cumulative distribution is given by

(1) $$F(t) = \int_0^t f(s)ds = \Pr(T \le t).$$

Equivalently, the distribution of T can be expressed by

(2) $$S(t) = 1 - F(t) = \Pr(T \ge t)$$

which has been termed the *survival function*. *S (t)* gives the probability that a spell is of length at least *t*, that is, the probability that the random variable *T* exceeds *t*. The hazard, as defined above, can be expressed as *Pr* $(t \le T \le t + \Delta \mid T \ge t)$, where Δ is the next short interval of time after *t*. The limiting value of this probability divided by Δ, when Δ tends to zero, gives the hazard function:

(3) $$h(t) = \lim_{\Delta=0} (\Pr(t \le T \le t + \Delta \mid T \ge t)) / \Delta$$
$$= \lim_{\Delta=0} (F(t + \Delta) - F(t)) / \Delta S(t)$$
$$= f(t) / S(t)$$

The hazard function specifies the instantaneous rate of completion of a spell at *T=t*, conditional upon survival to time *t*. The cumulative distribution, survival and hazard are equivalent ways in which the distribution of *T* can be expressed. Roughly *h(t)* is the rate at which spells will be completed at duration *t*, given that they last until *t* (Burton, Rigby, and Young, 1997).

The hazard function provides a convenient definition of duration dependence (Kiefer, 1988). *Positive duration dependence* exists at point t^* if $d\lambda(t)/dt > 0$ at $t = t^*$. Positive duration dependence means that the probability that a spell will end shortly increases as the spell increases in length. Negative duration dependence exists at t^* if $d\lambda/dt < 0$ at $t = t^*$. Negative duration dependence means that the probability that a spell will end shortly decreases as the spell increases in length. See Kiefer (1988: 652) for illustrations.

4.2.3 Specification

Several techniques are available for analyzing duration data. Some techniques assume nothing about the underlying distribution of failure times. These are called nonparametric techniques. Semi parametric methods make minimal, but nonetheless substantive assumptions about the underlying distribution of durations (Greene, 1997). Finally, there are parametric models of durations, which make explicit distributional assumptions for the duration data. The literature contains a variety of choices for parametric duration models, which include exponential (a popular choice), Weibull (another popular choice), normal, inverse normal [inverse Gaussian; see Lancaster (1990)], F, gamma, and many others. All of these are distributions for a nonnegative random variable. Their hazard functions display very different behaviors. The hazard function for the exponential distribution is constant, that for the Weibull is monotonically increasing or decreasing depending on p, and the hazards for lognormal and log-logistic distributions first increase, then decrease (Greene, 1997).

The exponential distribution is one of the widely used distributions for modeling duration data. It is simple to work with and to interpret. It is often an adequate model for durations that do not exhibit much variation (in much the same way that the linear regression model is simple and adequate if the data do not vary enough to reveal important non-linearities (Kiefer, 1988)). The summary of the properties of the distributions is shown in Table 4.1. The exponential distribution is sometimes termed *memoryless*, because the hazard function is constant and so reflects no duration dependence. The Weibull distribution can be thought of as an exponential distribution on a rescaled time axis. The 'trick' of finding a transformation of duration so that the transformed durations are exponentially distributed is quite useful in interpreting models and in developing specification diagnostics. The final distribution under consideration is the log-logistic distribution. This is an example of a *non-monotonic* hazard. Once the parametric distribution of T has been chosen, estimation of parameters follows maximum likelihood procedures. Specification analysis after the model has been fitted may also be used to reveal whether or not the model or distribution chosen adequately describes the data.

Table 4.1 Some Survival Distributions

Distribution	***Hazard Function***	***Survival Function***
Exponential	λ,	$S(t)=e^{-\lambda t}$
Weibull	$\lambda p(\lambda t)^{p-1}$	$S(t)=e^{(-\lambda t)^p}$
Lognormal	$f(t)=(p/t)\phi[p\ln(\lambda t)]$	$S(t)=\Phi[-p\ln(\lambda t)]$
	[$\ln t$ is normally distributed with mean $-\ln\lambda$ and standard deviation $1/p$]	
Log-logistic	$\lambda(t)=\lambda p(\lambda t)^{p-1}/[1+(\lambda t)^p]$	$S(t)=1/\left[1+(\lambda t)^p\right]$
	[$\ln t$ has a logistic distribution with mean $-\ln\lambda$ and variance $\pi^2/(3p^2)$	

The main interest for studying the time taken to adopt SWC technologies is to learn the effect of a set of covariates, *(X)* on the hazard rate of adoption and the duration. Hence the hazard rate described in the previous section could be rewritten as

(4) $$h(t,X,\beta)=\lim_{\Delta\to 0}(\Pr(t\le T\le t+\Delta \mid T\ge t,X,\beta))/\Delta$$

where β is the unknown coefficient vector, and the corresponding survival function is

(5) $$S(t,X,\beta)=1-F(t,X,\beta)=\Pr(T\ge t\mid X,\beta)$$

Unlike the ordinary least squares method, the coefficients of covariates in the hazard function do not have a clear interpretation as a partial derivative of the hazard or the duration. The interpretation depends on the specification. Two special cases, the *proportional hazard rate* and the *accelerated life-time models*, are easy to interpret. In the proportional hazard specification, the effect of covariates (X) enters as a multiplicative effect on the hazard function. The accelerated lifetime model, which is the class of log-linear models for *T*, is characterized by the multiplicative effect of covariates on time rather than on the hazard function (Kalbefleisch and Prentice, 1980). The Weibull regression model is both the proportional rate and the accelerated life-time models (Kalbefleisch and Prentice,1980). The corresponding hazard and survival functions are

(6) $$\lambda(t,X,\beta)=\frac{1}{\sigma}t^{\frac{1}{\sigma}-1}\exp(-X'\beta)^{\frac{1}{\sigma}}\text{, and}$$

(7) $$S(t,X,\beta)=\exp\left\{-\left[t\exp(X'\beta)\right]^{\frac{1}{\sigma}}\right\}$$

where $(1/\sigma) > 0$ is the shape parameter. This form guarantees the necessary non-negativity without imposing restrictions on β. The partial derivative of $\lambda(t,X,\beta)$ with respect to t is

(8) $$\lambda(t,X,\beta)=\frac{1}{\sigma}\left(\frac{1}{\sigma}-1\right)t^{\frac{1}{\sigma}-2}\exp(-X'\beta)^{\frac{1}{\sigma}}$$

This result means that the hazard rate is constant, increasing, or decreasing over time as $\sigma=1, \sigma<1, or \sigma>1$, respectively. The partial effect of X on $\ln\lambda(t,X,\beta)$ is

(9) $$\frac{\partial\ln\lambda(t,X,\beta)}{\partial X}=-\left(\frac{\beta}{\sigma}\right)$$

Hence, β is the (negative) constant proportional effect of X on the hazard rate, but re-scaled by the parameter σ (Kalbefleisch and Prentice, 1980). In other words, the marginal effect of covariates on the hazard rate is smaller (bigger) when the hazard rate is decreasing (increasing) over time. The corresponding linear model interpretation is

(10) $$\ln t = X'\beta+\sigma\varepsilon$$

where ε is the error term with type 1 extreme value distribution. The partial effect of X on $\ln t$ is

(11) $$\frac{\partial \ln t}{\partial X}=\beta$$

Therefore, β is also the constant proportional effect of the covariates on the length of time for completing a spell.

The parameters β and σ of equations (10) and (11) can be estimated by maximum likelihood (ML) methods. Let $\delta_i=1$ if the i^{th} spell is completed and $\delta_i=0$ otherwise. Then, the log-likelihood function for a sample of n independent spells $\{t_i\}_{i=1}^{n}$ with corresponding covariates $\{X_i\}_{i=1}^{n}$ is given by

(12) $$\ln L(\beta,\sigma) = \sum_{i=1}^{n} \delta_i \ln f(t_i, X_i, \beta, \sigma) + \sum_{i=1}^{n} (1-\delta_i) \ln S(t_i, X_i, \beta, \sigma)$$

That is, completed spells contribute to the density term $f(t, X, \beta, \sigma)$ and censored spells contribute to the probability $S(t, X, \beta, \sigma)$. Given that the density function is the product of the hazard function and the survivor function, the log-likelihood function can be rewritten as:

(13) $$\ln L(\beta,\sigma) = \sum_{i=1}^{n} [\delta_i \ln \lambda(t_i, X_i, \beta, \sigma) + \ln S(t_i, X_i, \beta, \sigma)]$$

4.2.3.1 Incorporating Heterogeneity

The problem of heterogeneity in duration models essentially can be viewed as the result of incomplete specification (Greene, 1997). Individual-specific covariates are intended to incorporate observation specific effects. But if the model specification is incomplete and if systematic individual differences in the distribution remain after the observed effects are accounted for, then inference based on the improperly specified model is likely to be problematic. Heckman and Singer (1985) have shown that if heterogeneity is present and we do not control for it, the parameter estimates of the hazard function will be biased toward negative duration dependence. Lancaster (1985) also found that the effect of heterogeneity in the Weibull model causes the ML estimator $\hat{\sigma}$ to be biased upward, *i.e.* to bias downward the estimated hazard function duration dependence and the ML estimator $\hat{\beta}$ is biased toward zero.

There are several reasons for an analysis to consider heterogeneity (Li and Huffman, 1999): First, the duration, that is, the realization of T, may have been recorded with error. Second, there may be a measurement error in the covariates X. Third, if the covariates X fail to account fully for the true differences among individuals, omitted regressors will cause heterogeneity.

There are a number of ways of extending duration models to account for heterogeneity. One direct approach is to model heterogeneity in the parametric model (Li and Huffman, 1999). Let V, distributed as gamma with unit mean represent the effect of heterogeneity, which is independently distributed with X and T, multiplying the hazard function. For the Weibull distribution of duration, the survivor function is given by:

$$(14) \quad S_m(t,X,\sigma,\beta,\theta)=\int \exp\left(-\int_0^t v\lambda(z,X,\beta,\sigma)dz\right)f_v(v)dv$$

$$=\int \exp\left(-v[t\exp(-X'\beta)]^{\frac{1}{\sigma}}\right)f_v(v)dv=\left(1+\theta[t\exp(-X'\beta)]^{\frac{1}{\sigma}}\right)^{\frac{-1}{\sigma}}$$

where θ is the variance of V. The hazard function is derived by differentiating $-S_m(\cdot)$ with respect to t giving

$$(15) \quad \lambda_m(t,X,\beta,\sigma,\theta)=[S_m(t,X,\beta,\sigma,\theta)]^{\theta}\left(\frac{1}{\sigma}\right)t^{\left(\frac{1}{\sigma}\right)-1}[\exp(-X'\beta)]^{\frac{1}{\sigma}}$$

Note that

$$(16) \quad \lim_{\theta\to 0}\lambda_m(t,X,\beta,\sigma,\theta)=\left(\frac{1}{\sigma}\right)t^{\left(\frac{1}{\sigma}\right)-1}[\exp(-X'\beta)]^{\frac{1}{\sigma}}=\lambda(t,X,\beta,\sigma)$$

which is the hazard function without heterogeneity. Hence, θ can capture the sensitivity of the hazard function to unmeasured heterogeneity; and the effect of heterogeneity is larger when θ is further away from zero. Given the above hazard and survivor functions, the likelihood function can be constructed to find the ML estimators $\hat{\beta},\hat{\sigma}$, and $\hat{\theta}$. Note that the value of σ cannot simply indicate the time dependence of the hazard rate.

4.2.4 Empirical Specification

The endogenous variable is the length of time that passes between the establishment of a household and adoption of SWC. In the analysis of duration data for an innovation, the date for the start of the duration of each individual is required. The start of the duration can be set either at the time when the technology was first introduced or if the household was created after that at the time of its creation. In this case, there was no clearly defined date for soil and water conservation technology: soil and water conservation technology has always been 'available' to farmers. The approach in this study was to ask the farmer when their household was established; *i.e.,* when they got married or if they were single never having been married before;

when they left home. However, for some individual techniques there were some well-defined start dates, i.e., the time when these were first introduced. The approach for individual techniques therefore was to set the start date at the time the technique was first introduced or the time the household was created, whichever was the latest. The formula for calculating the dependent variable, the time taken to adopt a SWC technique, is given by the following:

(17) $T_{AT} = E - S_{HS}$

(18) $T_{IT} = E - S_I$, for $S_I > S_{HS}$

(19) $T_{IT} = E - S_{HS}$, for $S_{HS} > S_I$, where,

T_{AT} = The time to the adoption of any SWC technique.

T_{IT} = The time to the adoption of an individual technique.

E = The time when the household adopted a (an individual) technique.

S_{HS} = The time when the household was started.

S_I = The time when the individual technology was first introduced.

The survey relied on farmer recall data and asked questions about when they got married, or left home (indicating the start date for the duration), and when they adopted their first soil and water conservation technology (the end date for the duration). Some of the farmers had not adopted any soil and water conservation technology at the time of the survey but they represented a relatively small proportion (9%) of the sample. This meant that these spells were unknown. The procedure for analysis will be to right-censor their durations at the time the data was collected.

The exogenous variables are as outlined below and have been defined in section 3.5. The empirical specification of the $X_i(t_i)'\beta$ part of the hazard function $\lambda(\cdot)$ is:

$$X_i(t_i)'\beta = \beta_0 + \beta_1 GROUP1_i(t_i) + \beta_2 GTZAG_i(t_i) + \beta_3 SIZE_i(t_i) + \beta_4 CULTIV_i(t_i) + \beta_5 PLOUGH_i(t_i) + \beta_6 OWNEST + \beta_7 AGEHEAD_i(t_i) + \beta_8 GENDER_i(t_i) + \beta_9 NOHSE_i(t_i) + \beta_{10} HIGHEDUC_i(t_i) + \beta_{11} FUTURE_i(t_i) + \beta_{12} HRISK_i(t_i) + \beta_{13} LEADER_i(t_i) + \beta_{14} TRIPS_i(t_i) + \beta_{15} PAPMAGS_i(t_i) + \beta_{16} RADIO_i(t_i) + \beta_{17} EXTAGS_i(t_i) + \beta_{18} YIL\_COST_i(t_i) + \beta_{19} VILLAGE_i(t_i)$$

(20)

The equation for predicting duration using both the Weibull and Weibull with gamma heterogeneity specification will be given by:

(21) $predictedT = \exp(X'\beta)$

A brief discussion of the expected signs based on economic theory and previous studies in equation (20) follow. The signs are summarized in Table 5.1.

The dummy variable GROUP1 denotes the pre-independence period which is the period 1980 and before. GTZAG is also a dummy variable that indicates the period in which the GTZ/Agritex project was operating. The coefficient β_1 is therefore expected to be positive, whilst that on GTZAG, β_2 is expected to be negative. This is due to the fact that the presence and access to sources of technical knowledge and information is hoped to improve the profitability of a technology during initial periods through impact on the farmer's knowledge. Farmers in the post-independence period generally had greater access to technical knowledge and information. Thus farmers in the post-independence period are expected to have accurate expectations of the distribution of the profitability of a technology. This would in turn reduce the number of years it would take them to adopt a technology (Ghadim and Pannell, 1999).

Farm resources are hypothesized to be positively correlated with adoption in general and soil conservation in particular. The coefficients β_3, β_4, β_5 and β_6 are therefore expected to be negative. The size of the farm is considered as surrogate for a large number of potentially important yet confounding factors (Feder *et al.*, 1985). A larger holding is typically associated with access to financial and technical support systems as well as economies of scale (Napier and Sommers, 1993). Farm implements like the plough and cultivator necessarily facilitate easier and faster completion of certain tasks. Property rights are one of the most frequently highlighted institutional factors influencing soil conservation adoption (Bromley, 1982a; 1982b; Napier, 1992). Economic theory suggests that insecure property rights lead to a premature depletion of resources. If a farmer cannot capture the future gains that arise from conservation decisions, he or she will have no incentive to conserve. In the extreme, farmers without security of tenure are interested in maximizing their short-term investment in seed, fertilizer and labor for the crop that is in the ground (Barbier, 1990).

Table 4.2 The expected signs on the coefficients

Variable Name	Expected sign on coefficient
EXTERNAL ENVIRONMENT	
GROUP1 (β_1)	+
GTZAG (β_2)	-
FARM RESOURCES	
SIZE (β_3)	-
CULTIV (β_4)	-
PLOUGH (β_5)	-
OWNEST (β_6)	-
HOUSEHOLD CHARACTERISTICS	
AGEHEAD (β_7)	+
GENDER (β_8)	-
NOHSE (β_9)	-
HIGHEDUC (β_{10})	-
ATTITUDES	
FUTURE (β_{11})	+
HRISK (β_{12})	+
SOCIAL PARTICIPATION	
LEADER (β_{13})	-/+
TRIPS (β_{14})	-/+
PAPMAGS (β_{15})	-/+
RADIO (β_{16})	-/+
EXTAGS (β_{17})	-
YIL_COST (β_{18})	+
VILLAGE (β_{19})	-/+

-/+ means the expected sign on the coefficient is indeterminate.

Age may influence risk aversion, with the traditional view being that older farmers are more risk averse (Ghadim and Pannell, 1999). If this is true, this will mitigate against adoption. The coefficient β_7 is thus expected to be positive.

Morris and Doss (1999) suggest that technology adoption decisions depend primarily on access to resources. If men tend to have better access to resources than women, technologies are not going to benefit men and women equally. If men have better access to resources than women, they are likely to adopt technologies quicker than women would. The coefficient β_8 is expected to be negative.

Labor is often viewed as a major constraint to the adoption of technologies (Erenstein, 1999). Labor availability is generally embodied in the size of the household. It is expected that larger households will have greater labor availability. The coefficient β_9 is expected to be negative. Education has been hypothesized to facilitate the adoption of technologies. This is because education enhances one's ability to receive, decode and understand information. Information processing and interpretation is important for performing or learning to perform many tasks. The coefficient β_{10} is expected to be negative.

It is often argued that developing country farmers tend to be risk averse, have short planning horizons and hence high discount rates and these mitigate against adoption of SWC technologies. Some SWC technologies may require relatively long time periods for the realization of the benefits of soil and water conservation making the benefits of soil and water conservation uncertain. The coefficients reflecting this; β_{11} and β_{12} are therefore expected to be positive. It has been found in many studies of agriculture that social participation in formal or informal organizations influences adoption behavior. Social participation may expose individuals to wider ranges of ideas, which may either cause him/her to form a favorable or unfavorable attitude toward an innovation (Alavalapati, 1990). The coefficients β_{13} and β_{14} are thus expected to be either negative or positive. The premise is that farmers who are exposed to systems outside the social systems (through the radio, papers and magazines, and extension agents) are more likely to know more about SWC technologies and adopt quicker, but the other side to this is that, this may also shape unfavorable attitudes towards the practices and lead to non-adoption or slower adoption. The coefficients β_{15} and β_{16} in this respect are therefore expected to be either positive or negative.

Contact with extension agents is expected to help farmers obtain accurate expectations of the distributions of the benefits and costs of soil and water conservation. This may in turn lead them to adopt quicker relative to a farmer without this privilege. The coefficient β_{17} is expected to be negative. The discussion in chapter 2 highlights the importance of the role of the government in providing information about the imperceptible damages and uncertain benefits of soil erosion and soil and water conservation respectively. If this coefficient turns out to be positive, this will indicate that the particular policy of the government is working. Some soil and water conservation techniques may entail loss of land that would otherwise have produced a crop yield. This can thereby be regarded as a cost to implementing a technique. Consequently, techniques that do not result in any loss of land that would otherwise be planted to crop result in lower implementation costs. It is expected that farmers that adopted quicker most likely took up techniques that involved less costs. The coefficient β_{18} on the variable YIL_COST is expected to be positive.

The present chapter has highlighted the absence of economic theory to determine the relevant functional form for empirical analysis. This therefore remains open and in this case will be determined through non-parametric analysis in Chapter 5. The chapter has also described in detail the empirical model and outlined the relevant variables in the model, which will be the core of Chapter 5.

CHAPTER 5 – Model and Results

The chapter reports a non-parametric analysis of the duration data for the times to adoption of SWC technologies. In the absence of theory to aid in determining the relevant functional form for analysis, these methods may be useful for this purpose. On the basis of the selected functional form, the chapter reports the analysis of the time taken to adopt the first SWC technology. The chapter finally looks at the time taken to adopt particular individual techniques, and following this, some model simulations. The chapter then concludes with a summary of the results.

5.1 Non-Parametric Analysis

Parametric models are attractive for their simplicity. But by imposing as much structure on the data as they do, such models may distort the estimated hazard rates of adoption (Greene, 1997). It may be that a more accurate representation may be obtained by imposing fewer restrictions. However, even if we could obtain accurate representations of the hazard rate of adoption by farmers, the effect of socio-economic variables on the hazard rate would remain undetermined. The approach in this analysis therefore, is first, to obtain non-parametrically the most accurate structure, which will then be imposed on the data in order to investigate the importance of socio-economics in determining the relevant hazard rates of adoption for different households. There is evidence, as will be shown later from the existing data based on a preliminary plot of the data for a monotone increasing hazard formulation. This suggests a Weibull specification for this analysis.

The main task of this study is to model the dynamics of the adoption of SWC technologies by farmers. The most basic view of this consists of a graph of the number of farmers who have adopted a technology at particular times after its initial introduction, or after their initial establishment on the farm, whichever event is the latest. Based on Rogers (1984)'s innovation diffusion theory, we would expect this plot to be bell-shaped or sigmoid on a frequency or cumulative frequency basis respectively. Figures 5.2 to 5.4 present plots on a frequency basis of the number of farmers adopting the first technique, contours, crop rotation and vetiver respectively after certain times (in years) have elapsed. The figures clearly indicate that the adoption of SWC does not follow a bell-shaped pattern (see Appendix 2). They follow distributions that are highly skewed to the left. The pattern followed for vetiver adoption appears different from the rest, however. Contours and crop rotation techniques have been available for farmers to adopt for a long period of time (as far back as the 1950s) whereas vetiver has been introduced only recently (i.e., 1991). Therefore contours and crop rotation techniques have been there long enough for the distribution pattern of adoption to be affected by outflows of farmers from the area over time through deaths and emigration and there also have been inflows due to immigration and births. Hence it should not be expected that the patterns of adoption in the current sample should follow the sigmoid curve proposed by Rogers (1981).

The discussion in Chapter 2 indicated that there are several underlying assumptions that build up the 'typical' innovation diffusion curve. In particular, the assumption of a fixed constituency, which is required to encourage normal shaped adoption. It is highly unlikely in reality however that the number of farmers eligible to adopt SWC techniques remains constant over time. Duration model analysis allows for adoption profiles that differ from this.

For purposes of the duration analysis it is necessary to identify the most appropriate profile for the distribution of the times for the adoption of SWC technologies. Non-parametric procedures can be used to obtain accurate representations of the distribution of the times for the adoption of SWC technologies in the sample. The commonly used non-parametric techniques in duration analysis are the *life table* estimator or the *Kaplan-Meir estimator*.[4]

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[4] Let h_j be the number of completed spells of duration t_j, for $j = 1\ldots K$. In the absence of ties the h_j are all equal to one. Let m_j be the number of observations censored between t_j and t_{j+1}; m_k is the number of observations with durations greater than t_j, the longest complete duration. Let n_j be the number of spells neither completed or censored before duration t_j

$$n_j = \sum_{i \geq j}^{K} (m_i + h_i).$$

The hazard $\lambda(t_j)$ is the probability of completing a spell at duration t_j, conditional upon the spell's reaching duration t_j. A natural estimator for $\lambda(t_j)$ is

$$\hat{\lambda}(t_j) = h_j / n_j,$$

The methods assume that observations are homogeneous in the probability distribution over duration times, with the exception of the measured covariates (Kiefer, 1988).

Homogeneity for purposes of this analysis was achieved roughly by grouping farmers according to village of residence, or age. In addition, it was assumed that any censoring in the data was unrelated to the duration values themselves. This analysis followed the *life table* approach. For a life table, the time line is split up into fixed intervals, typically one-year intervals. A survival rate is then calculated for each interval[5]. Figures 5.5 – 5.11 show the estimated survival rates for the seven villages in the sample. The X-axis is scaled in artificial time, from 0 to 14, 0 to 30, 0 to 35, 0 to 35, 0 to 35, 0 to 45, and 0 to 45 for Mukwazvure, Mbaimbai, Nduna, Pedzisai, Nyengera, Guti, and Puche farmers respectively. The *life table* estimate of the survivor function is plotted to give a step function, where the estimated survival probabilities are constant between consecutive adoption times and fall after each of these adoption times. The life table and survival function for Mukwazvure farmers are shown in table 5.1 and figure 5.5 respectively. The survival functions for the other villages are shown in Appendix 2. It is clear from all the graphs that over time, the probability of a household adopting a SWC technology becomes greater. That is, the longer a household has gone without adopting a technology, the more likely they are to adopt in the next time period, in this case, in the next year.

The corresponding estimator for the survivor function is: $\hat{S}(t_j) = \prod_{i=1}^{j}(n_i = h_i)/n_i = \prod_{i=1}^{j}(1-\hat{\lambda}_i)$ which is the *Kaplan-Meir* or *product-limit* estimator.

[5] Let λ_i be the probability of completing a spell in the ith interval, conditional upon entering the ith interval. A natural estimator for λ_i is the fraction of those entering the intervals that complete their spells during the interval. The estimator adjusts for censoring by subtracting one-half of the number of observations censored during the ith from the number entering the interval in calculating the fraction of completed spells. This estimator will be labeled λ_i^a. Then the life table is estimated by $S_i^a = \Pi(1-\lambda_j^a)$. The life table estimator differs from the Kaplan-Meir estimator for the survival function in that the intervals for which the hazards are calculated depend on the data for the Kaplan-Meir estimator.

Table 5.1 Life table hazard and survivor estimates for Mukwazvure farmers

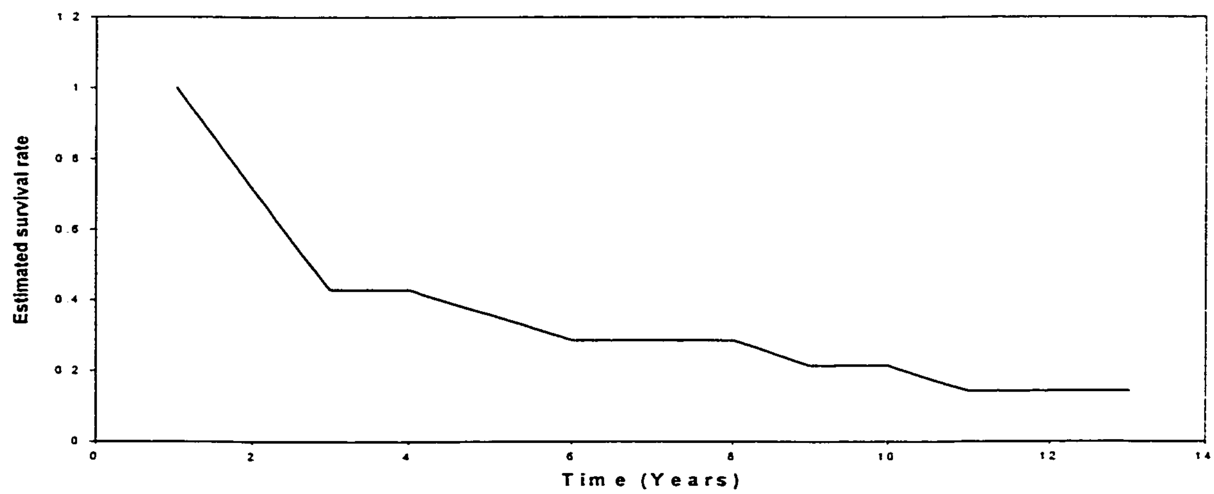
Survival	Enter	Censored	At Risk	Exited	Survival Rate	Hazard Rate	Integrated Hazard
0 – 1.3	14	0	14	8	1	0.6154	0
1.3 – 2.6	6	0	6	0	0.4286	0	0.8472
2.6 – 3.9	6	0	6	1	0.4286	0.1399	0.8472
3.9 –5.2	5	0	5	1	0.3571	0.1709	1.0297
5.2 – 6.5	4	0	4	0	0.2857	0	1.2528
6.5 – 7.8	4	0	4	1	0.2857	0.2198	1.2528
7.8 – 9.1	3	0	3	0	0.2143	0	1.5404
9.1 – 10.4	3	0	3	1	0.2143	0.3077	1.9456
10.4 – 11.7	2	0	2	0	0.1429	0	1.9456
11.7 – 14	2	0	2	2	0.1429	1	2

The average duration before adoption of the first SWC technology appears to vary by village. Specifically, the villages ordered by average durations from shortest to longest are Mukwazvure, Mbaimbai, Nduna, Pedzisai, Nyengera, Guti, to Puche. There is no clear explanation for this pattern. The estimate of the survivor function is similar if the data is grouped according to age. The graph is shown in figure 5.12. Average durations also vary by age category. More specifically, the age categories ordered by average duration from shortest to longest are 31-50, 20-30 and 51-99. Of interest however, is the fact that age appears to have a not so straightforward effect overall. Farmers who are 30 years old or younger generally have higher survival rates than farmers from 31 to 50 years old.

This suggests that at a given duration, farmers below 31 years of age have a lower probability of adopting in the next time period than farmers who are 31 to 50 years old. Farmers older than 50 years old also have higher survival rates, the longer the duration than farmers from 31 to 51 years old suggesting also, that, at a given duration, farmers above 50 years old have a lower probability of adopting in the next time period than farmers who are 31 to 50 years old. From this information it appears that if age were to be plotted against the probability of adoption, age would have a quadratic effect, with the probability of adoption increasing up to age 50 and then falling from there onwards.

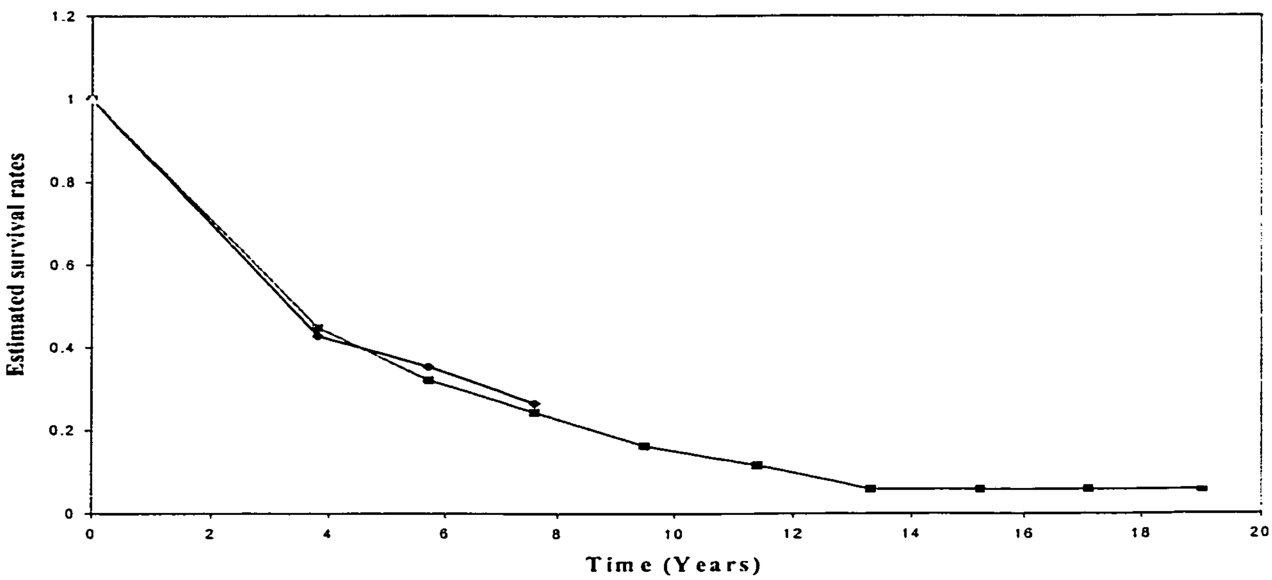
Two statistics, the Log-rank and Generalized Wilcoxon, were computed for testing homogeneity of the survival distributions across the strata. The tests for homogeneity were significant indicating that there is no homogeneity across the strata, which is to be expected since the socio-economic variables have not been included. What is clear from the various plots however is that, the longer the duration, the higher the probability of adoption in the next time period. This suggests a functional form for which the hazard rate increases monotonically. The Weibull model is one such model. Kiefer (1988) demonstrates how the appropriate functional form can be determined using the plot of the integrated hazard. The integrated hazard for Mukwazvure farmers is shown in figure 5.13 along with a plot of the hazard. A common approach to determining the functional form is to turn the plot of the hazard into a plot of the integrated hazard. To interpret the plot we obtain we use the fact that a plot for the exponential distribution is a straight line (Kiefer, 1988). A convex integrated hazard implies that the hazard itself is increasing – positive duration

Figure 5.5 The estimated survival rates for farmers in Mukwazvure



dependence – while a concave integrated hazard implies a decreasing hazard or negative duration dependence. Figure 5.13 suggests that the Weibull model may be adequate for this analysis since it indicates a monotonically increasing hazard.

Figure 5.12 The estimated survival rates for farmers in different age categories



5.2 Parametric Duration Model Estimation

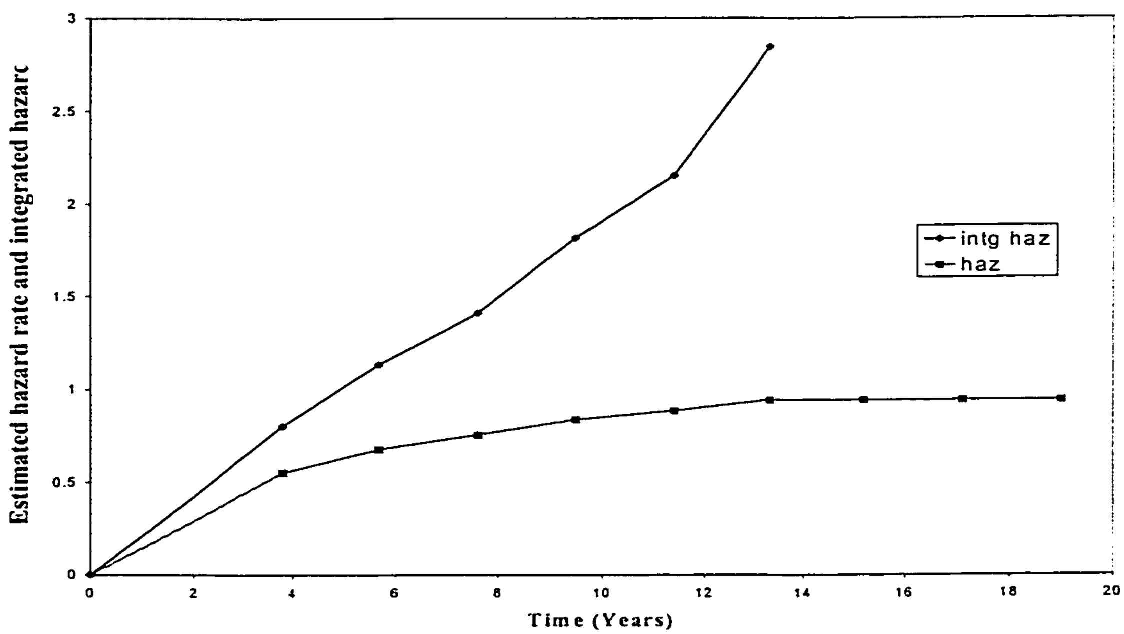
5.2.1 Results

A total of five models were considered for analysis. Table 5.2 summarizes these models. All the five models were fitted by the maximum likelihood method.

Table 5.2 Summary of models

MODEL NUMBER	MODEL DESCRIPTION
ONE	Weibull model of the time to the adoption of a technology with all the uncorrelated variables included.
TWO	Model One with Gamma heterogeneity
THREE	Weibull model for the adoption of contours
FOUR	Weibull model for the adoption of crop rotation
FIVE	Weibull model for the adoption of vetiver

Figure 5.13 Estimates of the Intergrated hazard and hazard rates for Mukwazvure farmers



The model of the time to the first adoption is modeled with and without heterogeneity effects. The dependent variable for all the models is the natural logarithm of the length of a household's spell before adopting SWC techniques measured in years. The heterogeneity effect θ is represented by gamma heterogeneity, giving a mixed model. The heterogeneity effect θ was found to be significantly different from zero at the 5 % level of significance.

5.2.1.1 Time to the first adoption of a SWC technology

In table 5.3 the signs of the estimated coefficients with the exception of trips are all as expected across the specifications of the hazard rate model. Both models have significant explanatory power as indicated by the chi-square statistics. Some of the coefficients are not significant at all in the hazard rate model. These include GTZAG, YIL_COST, NOHSE, TRIPS, RADIO, FUTURE, and some of the village dummies. PLOUGH is marginally important in model one but unimportant in models two and three. The dummy variable indicating Nduna village is not significant in model one but is significant in model two. Most of the coefficients in model two, except for SIZE, EXTAGS, HRISK and one of the village dummies, NDUNA are significantly different from zero at the 1- percent level of significance.

For the model without heterogeneity (model one, Table 5.3), the estimate for σ, $\hat{\sigma}$ is 0.84, and it is statistically significantly different from zero at the 1-% level of significance. The estimate is also significantly different from one at the 1-% level of significance. This implies an increasing marginal effect of the length of time for a household that has not yet adopted any SWC techniques, on the household's hazard rate of adoption. Other things being equal, as the length of time a household has gone without adopting increases, the household's hazard rate for adoption increases. However, due to the slightly concave shape of the hazard, the marginal increase of the hazard rate of adoption over time is decreasing.

Table 5.3 Estimation Results – Models One and Two

VARIABLE	Without Heterogeneity (t-ratios in parentheses)	With Heterogeneity (t-ratios in parentheses)
INTERCEPT	0.98 (1.67)*	0.40 (0.76)
GROUP1	0.78 (3.40)***	0.65 (2.80)***
GTZAG	-0.22 (0.85)	-0.08 (0.76)
SIZE	-0.09 (2.20)**	-0.09 (2.26)**
PLOUGH	-0.30 (1.80)*	-0.24 (1.38)
OWN_EST	-0.55 (3.24)***	-0.67 (3.81)***
YIL_COST	0.21 (1.31)	0.09 (0.57)
AGEHEAD	0.02 (2.6)***	0.02 (3.16)***
HEADSEX	-0.33 (1.90)*	-0.44 (2.60)***
NOHSE	0.005 (0.23)	0.02 (0.65)
LEADER	-0.65 (3.90)***	-0.54 (3.05)***
TRIPS	0.16 (0.82)	0.05 (0.24)
RADIO	-0.20 (1.15)	-0.20 (1.17)
EXTAGS	-0.44 (2.11)**	-0.44 (2.24)**
FUTURE	-0.06 (0.20)	0.01 (0.6)
HRISK	0.45 (2.08)**	0.50 (2.4)**
MBAIMBAI	0.32 (1.26)	0.28 (1.03)
GUTI	0.60 (1.82)*	0.97 (2.97)***
NDUNA	0.54 (1.29)	0.91 (2.35)**
PEDZISAI	0.58 (1.88)*	0.92 (2.86)***
NYENGERA	0.39 (0.92)	0.59 (1.49)
MUKWAZVURE	0.27 (0.59)	0.48 (1.07)
σ	—	0.76 (2.07)*
θ	0.84 (12.92)***	0.61 (6.69)***
λ	0.15 (0.13, 0.17)	0.22 (0.17, 0.28)
P	1.18 (0.99, 1.36)	1.65 (1.17, 2.13)
MEDIAN	5 (4.11, 5.43)	4 (3.23, 5.33)
MODEL DIAGNOSTICS	$LnL_u = -276.2599$ $LnL_R = -310.0442$ $\chi_{0.01}(21) = 67.57$	$LnL_u = -272.3915$ $LnL_R = -308.1961$ $\chi_{0.01}(21) = 71.61$

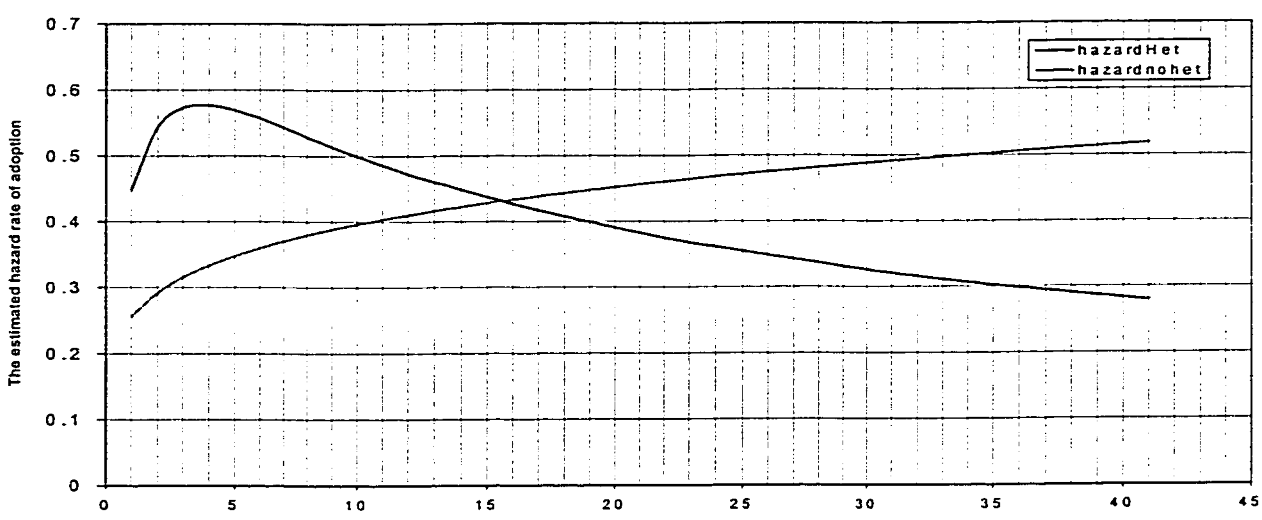
*, **, *** means significant at the 10%, 5% and 1% levels of significance respectively.

This suggests that adoption tends to occur earlier in the management life of the farmer. The relationship between the time that elapses before adoption and the predicted hazard rate of adoption for a representative male farmer is graphed in Figure 5.14. The covariates are set equal to sample means and dummy variables set to zero.

The hazard rate model with gamma heterogeneity (model two, table 5.3) gives a different picture. In Figure 5.14, the pattern of the predicted hazard rate for adoption is also graphed. The relationship is now such that other things being equal, as the length of time a household has gone without adopting increases, the household's hazard rate increases, but this time it increases only up to 3 and a ½ years after establishment, remains constant in the next year and then eventually starts to decrease. This suggests that in the first 3 years of establishment farmers possibly undergo stages of learning and updating their knowledge of the distributions of the benefits and costs of SWC (McWilliams et al., 1999).

Every year that a farmer passes through in the first 3 years, a new stage of learning brings him closer to adopting a SWC technology. The costs of holding out increase in each subsequent year such that with each additional year, the conditional probability of adopting starts to fall. The estimated parameter $\hat{\theta}$, measuring the effect of heterogeneity, is 0.76 and is statistically significantly different from zero at the 5% level of significance. Hence heterogeneity across individuals seems to exist in the hazard and survivor functions. The inclusion of gamma heterogeneity tends to reduce the intercept and the effects of GROUP1 and LEADER while it strengthens the effect of other coefficients.

Figure 5.14 The estimated hazard rate of adoption with and without gamma heterogeneity for the representative male farmer (with all other dummy variables set to zero)



5.3 Model Selection

Given the substantial differences in the estimation results between the model without gamma heterogeneity and with gamma heterogeneity, a choice must be made between the two. The Weibull model without gamma heterogeneity is a special case of the mixed model (with gamma heterogeneity). This can be verified by looking at equations (15) and (16) in section 4.2.3 where it can be seen that when θ is zero, the hazard function collapses to the one without heterogeneity. This means that model two is nested in model three. The parameter estimate $\hat{\theta}$ is 0.76 and is significantly different from zero at the 5% level of significance. The LR statistic for testing the validity of the restriction of θ to zero is $\chi_{0.01}(1) = 7.7368$ and it is greater than the critical chi-square value, leading to the rejection of the null hypothesis at the 1-% level of significance. The restriction on θ as implied in the model without heterogeneity is invalid. The main purpose of this analysis is to predict the behavior of farmers with respect to the time taken to adopt SWC technologies. The goodness of fit test was carried out for both the models without and with heterogeneity.

Table 5.4 In sample predictions using the models with and without heterogeneity

DURATION (YEARS)	ACTUAL	PREDICTED		CORRECTLY PREDICTED	
		No Heterogeneity	With Heterogeneity	No heterogeneity	With heterogeneity
0 – 5	114	76	107	76	107
5 – 10	29	57	46	29	29
10 - 15	21	24	23	21	21
15 – 20	11	14	14	11	11
20 – 25	7	12	5	7	5
25 – 30	7	9	3	7	3
30 – 35	6	3	0	3	0
35 - 40	3	1	2	1	2
40 – 45	2	2	0	2	0
More	0	2	0	0	0
TOTAL	200	200	200	157	178
% CORRECT PREDICTIONS WITHOUT GAMMA HETEROGENEITY IS 79% % CORRECT PREDICTIONS WITH GAMMA HETEROGENEITY 89%					

Although both models were found to predict in sample quite well (79% for the model without heterogeneity and 89% for the model with heterogeneity), the differences between the actual observed durations and the predicted durations for individuals were statistically significant with the model without heterogeneity indicating smaller differences overall. Table 5.4 shows the results in detail. The remainder of the discussion focuses on the model without heterogeneity.

The model highlights that the time taken to adoption of the first SWC technique is largely explained by variables relating to the external environment

(GROUP1), property rights (OWN_EST), gender (HEADSEX), age (AGEHEAD), and social participation (LEADERS). The other significant variables in the model are related to economies of scale (SIZE), geographical location (GUTI, PEDZISAI), preferences (HRISK), ownership of farm implements (PLOUGH), and contact with extension agents (EXTAGS). The variables GTZAG, YIL_COST, and NOHSE are not significant.

Farmers whose households were established during the colonial period (indicated by variable GROUP1) took longer to adopt than households established post-independence by 78%. In part, if not the whole, the reluctance to practice SWC appears politically motivated. Farmers whose households were established post-independence were fortunate in that there was force free assistance with technical knowledge and information through the government extension department and Non-Governmental Organizations (NGOs). Farmers with access to technical services and information are likely to have accurate expectations of the distribution of the profitability of an innovation. This in turn reduces the number of years required before full adoption takes place (Ghadim and Pannell, 1999). The variable GTZAG relates to this but it was not significant. This variable indicates households that were established during or after the GTZ/Agritex project was implemented. The reason it turns out that we cannot distinguish households established before this period and households established during and after this period is the fact that even though the project was present, there may have been inadequate household contact and coverage by the project itself.

Holding all other factors constant, older farmers are likely to have spells that are 2% longer than those for younger farmers. Age may influence risk aversion; with the traditional view being older farmers are more risk averse (Ghadim and Pannell, 1999). If this is true, this probably mitigates against adoption. The coefficient on HRISK is positive and significant. Farmers that are highly risk averse will take longer (45% more time) to adopt SWC technologies than farmers that are moderately to lowly risk averse.

The estimated coefficient on the variable OWN_EST indicating whether or not a farmer owned land at the time their household got established suggests that farmers owning land from the time their household got established have a duration before adoption which is 55% shorter than the counterparts who start to own land some time after the household has been started. Property rights are one of the most frequently highlighted institutional factors influencing soil conservation adoption (Bromley, 1982a; 1982b; Napier, 1992). Economic theory suggests that insecure property rights lead to a premature depletion of resources. If a farmer cannot capture the future gains that arise from conservation decisions, he or she will have no incentive to conserve. In the extreme, farmers without security of tenure are interested in maximizing their short-term investment in seed, fertilizer and labor for the crop that is in the ground (Barbier, 1990). It should however be noted that farmers in Zimbabwe's communal lands do not obtain title deeds to the land they farm on, they only have claim to the land (therefore "own" the land) for as long as they continue to reside in the same village.

A male-headed household reduces the time to adoption relative to female-headed households by 33%. Morris and Doss (1999) suggest that technology adoption decisions depend primarily on access to resources. If men tend to have better access to resources than women have, technologies are not going to benefit men and women equally. The current situation in Zimbabwe is such that on average in the rural areas, men tend to have better access to resources than women have.

Increasing farm size by 1 acre reduces by 9% percent the time before adoption. This supports the hypothesis by Feder *et al.* (1985); Napier and Sommers (1993). These authors suggest that the size of the farm is considered as surrogate for a large number of potentially important yet confounding factors to adoption. In addition, a larger holding is typically associated with access to financial and technical support systems as well as economies of scale. Therefore farmers with larger farms are likely to take less time to adopt SWC technologies. Farmers that hold leadership positions in any social organizations will have durations 65% shorter than farmers that do not. Contact with extension agents shortens the time to adoption by 44%. Another interesting result is the fact that there appear to be significant village differences in the time taken to adoption with farmers in Guti and Pedzisai being observed to have durations that are 60% and 58% longer respectively than farmers in

Puche. There does not appear to be any significant differences between farmers in Nyengera, Nduna, and Mukwazvure and Puche though. The reason for this pattern is not clear, but may largely be related to soil types and topographical features which this analysis did not consider.

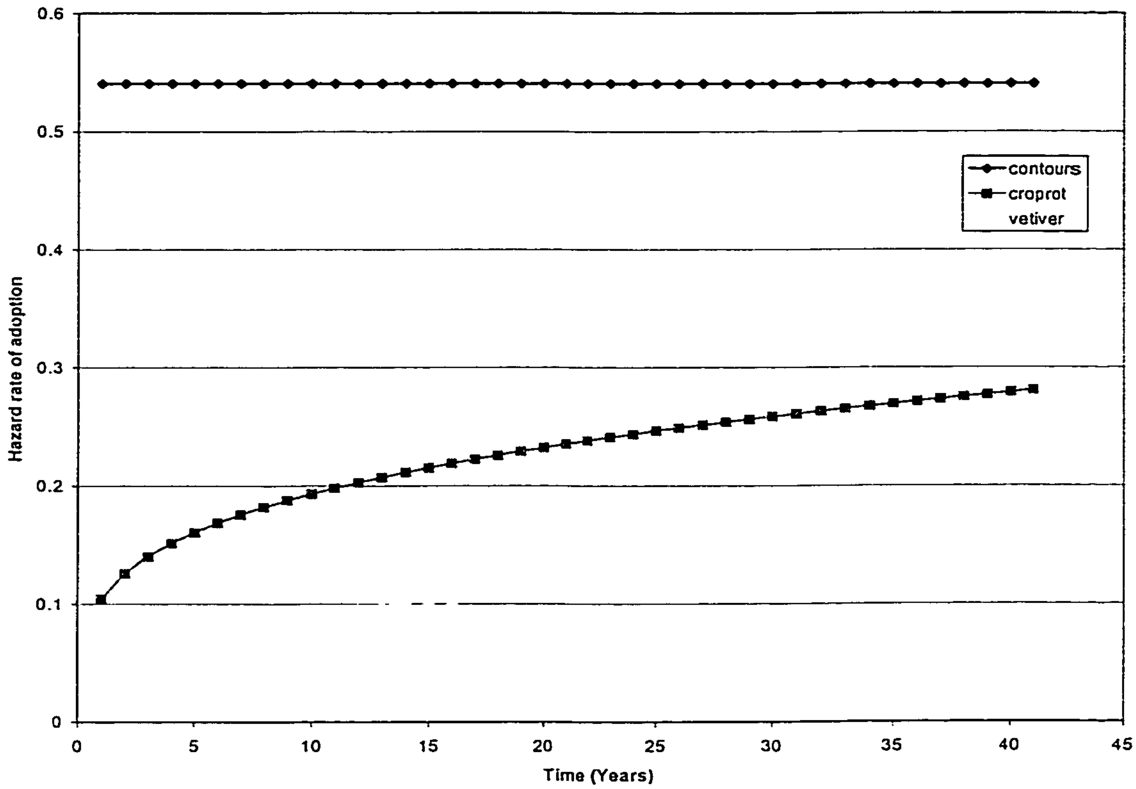
5.4 Time to the Adoption of Individual Techniques

This section looks at the adoption of individual SWC technologies particularly contours (introduced before 1980), crop rotation (popularized in the 80's) and the planting of vetiver grass (introduced in the 90's). Contours were a highly unpopular soil and water conservation in the days before independence. However, years after independence the contour remains synonymous with the term soil conservation. A great number of households throughout the communal areas in Zimbabwe still construct contours on their farms. Crop rotation is one of the techniques that were highly popularized by the government extension services in the mid-80s. The planting of vetiver grass was also introduced to this particular group of farmers in the early 90's.

The estimates of σ for the three models were found to be 0.99, 0.79 and 0.48 and significantly different from zero at the 1-% level of significance for contours, crop rotation and vetiver respectively. The estimates for the crop rotation and vetiver models are also significantly different from 1 at the 1% level of significance whilst the estimate for contours is not significantly different from one. These results imply that the adoption of crop rotation and vetiver is characterized by positive duration dependence whilst that of contours has no duration dependence.

The results for crop rotation and vetiver mean that the longer a household has gone without adopting contours, the more likely they are to adopt contours in the next time period, whilst the probability of a household adopting contours is the same in all time periods. The result for contours is entirely plausible since it implies an exponential distribution for the time to adoption of contours, which is a special case of the Weibull distribution when $p = 1$. The graphs in figure 5.15 indicate that for the representative farmer, the adoption of contours exhibits no duration dependence and those for crop rotation and vetiver grass exhibit positive duration dependence.

Figure 5.15 The hazard rate of adoption of individual techniques for the representative farmer



The model for contours (Table 5.5) highlights that the time to adoption of contours is largely explained by the possession of certain farm implements (PLOUGH), the age of the household-head, risk preferences (HRISK), property rights (OWNEST), social participation (LEADER) and gender (HEADSEX). The other important variables relate to the time period in which the household was established (GROUP1), and the village where the household is located (NDUNA, PEDZISA and NYENGERA). Older farmers take longer to adopt by 3%. Most of the older farmers likely started their households before independence or were at least old enough to witness the brutal force with which their parents had been forced to construct these on their farms.

The effect of force is captured by the variable GROUP1, which is positive and significant. Farmers established before independence took longer (46%) to adopt contours. The results indicate that farmers who are highly risk averse take 59% more time to adopt contours. If farmers own land at the time their household is established time to adoption is shortened by 45%. Farmers who own a plough adopt faster, the time shortened by 48% relative to those that do not. Male-headed households also adopt faster (47%) than female headed households.

Table 5.5 Estimation results for Contours, Crop Rotation and Vetiver

VARIABLE	CONTOURS	CROP ROTATION	VETIVER
INTERCEPT	1.24 (1.95)*	3.69 (7.13)***	5.43 (5.3)***
GROUP1	0.46 (1.96)**	-0.53 (2.11)**	0.50 (1.34)
SIZE	-0.04 (0.99)	-0.05 (0.99)	-0.009 (0.20)
PLOUGH	-0.48 (2.50)***	0.08 (0.41)	-0.14 (0.44)
OWNEST	-0.45 (2.19)*	-0.10 (0.53)	0.41 (1.57)
AGEHEAD	0.03 (2.84)***	-0.02 (2.68)***	-0.03 (1.93)**
HEADSEX	-0.47 (2.28)**	0.10 (0.62)	0.14 (0.52)
NOHSE	0.04 (1.48)	0.02 (0.68)	0.04 (0.97)
LEADER	-0.67 (3.48)***	-0.59 (3.19)***	-0.35 (1.46)
TRIPS	0.28 (1.30)	0.19 (0.95)	-1.07 (2.36)***
RADIO	-0.20 (0.93)	-0.25 (1.36)	-0.23 (0.82)
EXTAGS	-0.45 (1.88)*	-0.78 (4.06)***	0.01 (0.04)
FUTURE	-0.27 (0.89)	-0.07 (0.36)	-0.38 (1.30)
HRISK	0.59 (2.48)***	0.25 (1.19)	-0.16 (0.56)
MBAMBAI	0.44 (1.37)	-0.07 (0.24)	1.07 (1.41)
GUTI	0.66 (1.59)	-0.43 (1.35)	-0.26 (0.56)
NDUNA	1.14 (2.33)**	-0.40 (1.08)	0.11 (0.16)
PEDZISAI	0.94 (2.045)***	0.03 (0.10)	-0.94 (2.03)**
NYENGERA	0.94 (1.81)*	0.13 (0.34)	-1.03 (1.42)
MUKWAZVURE	0.17 (0.32)	-0.43 (0.97)	-1.29 (1.40)
σ	0.99 (10.71)***	0.79 (12.33)***	0.48 (5.37)***
λ	0.08	0.13	0.03
P	1	1.26	2.08
MEDIAN	8	6	33
MODEL DIAGNOSTICS	$LnL_U = -282.6821$ $LnL_R = -333.5778$ $\chi_{0.01}(19) = 101.7914$	$LnL_U = -219.5868$ $LnL_R = -289.9156$ $\chi_{0.01}(19) = 140.657$	$LnL_U = -70.2219$ $LnL_R = -246.9430$ $\chi_{0.01}(19) = 353.4420$

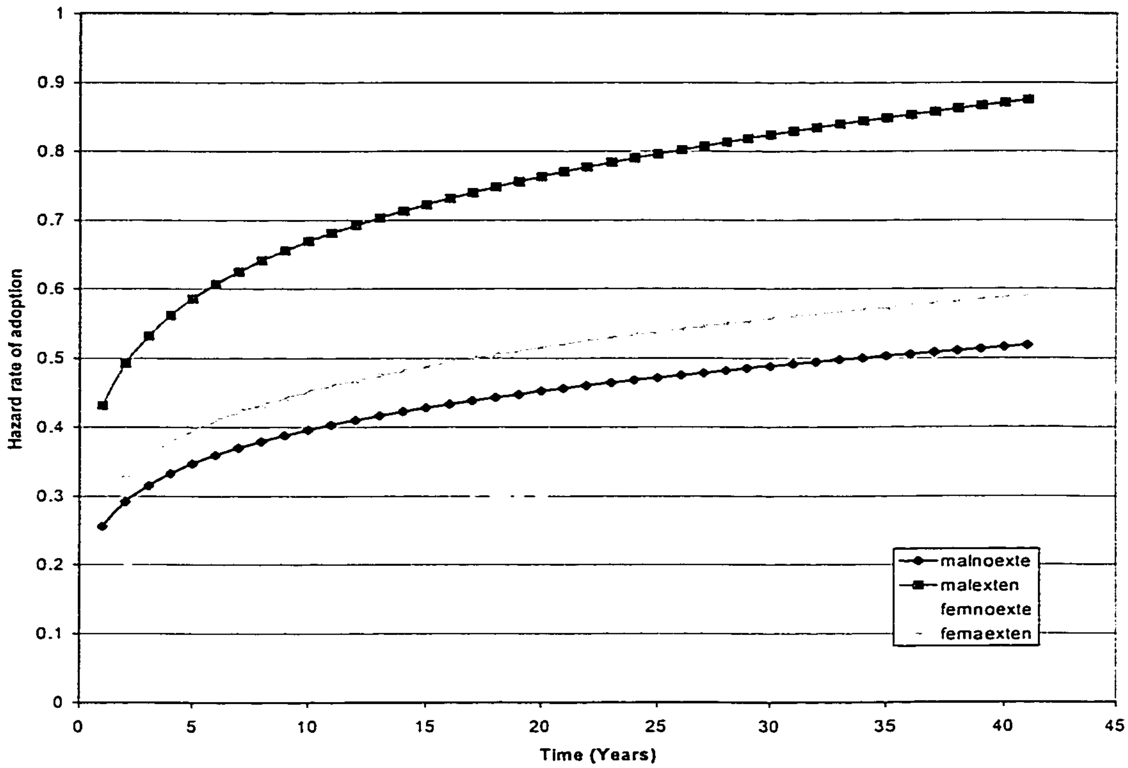
The model for the time to adoption of crop rotation highlights that the time to the adoption of crop rotation is largely explained by the age of the household head (AGEHEAD), the time period in which the household was established, social participation (LEADER), and contact with extension agents (EXTAGS).Social participation (TRIPS), village of residence (PEDZISA) and the age of the household head largely explain the adoption of vetiver. This makes sense as the introduction of vetiver was coupled by efforts to revive indigenous institutions through the creation of various social groups in which farmers could belong, and thus encourage a participatory approach to development. The median time to adoption of crop rotation is 6 years. The model results also indicate that older farmers will adopt vetiver faster than younger farmers. Farmers that are leaders and have contact with extension agents will also take a shorter time to adopt crop rotation.

The median predicted time to the adoption of vetiver is 33 years. The adoption of vetiver is also characterized by positive duration dependence. The results of the model indicate that older farmers will take a shorter time to adopt vetiver than younger farmers. Farmers that also attend field trips will adopt faster (1.07 times faster than farmers that do not). Farmers living in Pedzisai village will adopt faster (94%) than their counterparts in Puche village. This is largely explained by the fact that Pedzisai was the point of the first introduction of the technique in 1991 through the GTZ/AGRITEX, ConTill project.

5.5 Model Simulations

The results allow a prediction of the hazard rate in a given time period for a farmer with a specific set of socio-economic characteristics. In particular, they allow us to investigate the influence of extension on the time taken by households to start practicing SWC. The effect of extension on the adoption of agricultural technologies has been a subject of interest amongst economists and sociologists for a long time. Around, the world, considerable funds are invested by governments, aid bodies, and agribusiness in extension (Marsh, Panell and Lindner, 1995). To illustrate, the time paths of the hazard rate for two farmers, a male farmer and a female farmer are presented in Figure 5.16. Basically, at any given time, the hazard rate for the female farmer is lower than that for a male farmer. This suggests that more attention should be paid to gender related factors when encouraging the adoption of SWC technologies. The graphs also indicate that extension effort encourages earlier adoption by both male and female farmers.

Figure 5.16 The role of gender and extension agents in SWC adoption

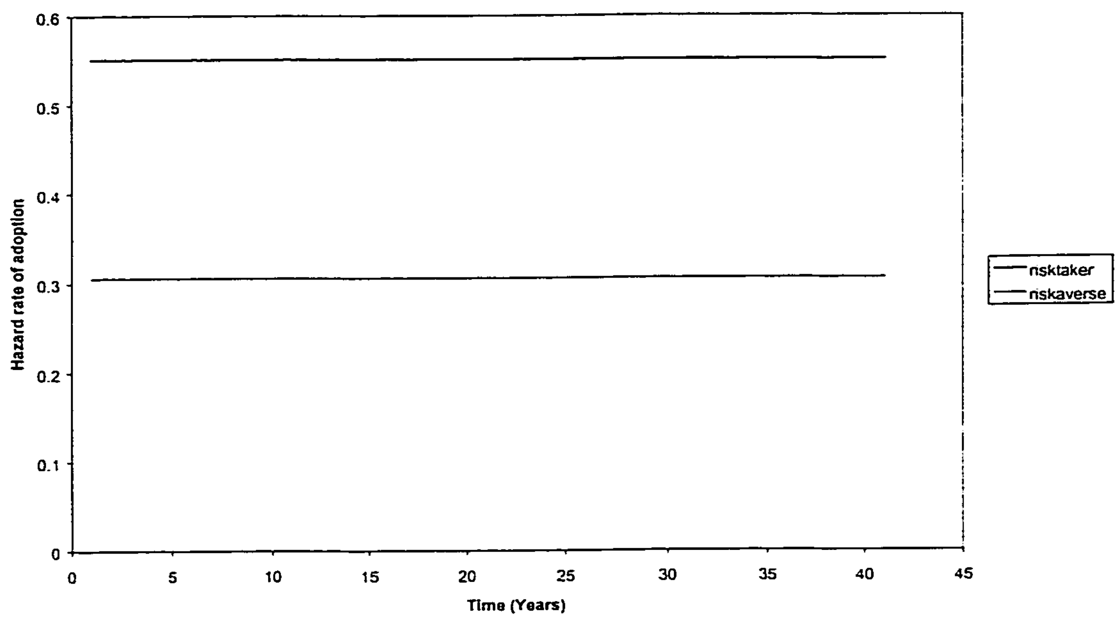


Extension clearly encourages earlier adoption and could in addition be tailored to target female headed households as the graphs indicate that extension alone can improve the plight of the male farmer even to the extent that it surpasses that of a male farmer with no contact with extension agents.

The results of the model for the time to the first adoption indicate that farmers that are risk averse will take longer to adopt SWC technologies. The model results for individual techniques indicate that techniques that may be characterized as high-risk techniques may not encourage early adoption of SWC technologies. The risks associated with crop rotation and vetiver grass are very low compared to contours. The riskiness of contour arises mainly from the considerable chunk of land that has to be excluded from planting (farmers are not allowed to cultivate crops along the contours). Figure 5.17 shows how this affects the time to adoption of contours, which are relatively a risky technique.

The model also allows the estimation of the amount of time that will be taken by the two farmers to adopt SWC technologies. This time taking the same two farmers, and using $prdT = \exp(X'\beta)$ will allow us to predict the number of years to adoption by the two farmers. The female farmer is predicted using this expression to spend 6 years before they adopt any SWC technology.

Figure 5.17 The influence of risk preferences on the hazard rate of adoption of contours



If this same female farmer had started their household before 1980 they would have spent 13 years before adopting any technology. The male farmer is predicted to spend 4 years before they adopt any SWC technology. If this same farmer had started his household before 1980, he would have spent 8 years before adopting. A female (male) farmer owning land at the time they started their household will spend about 4 (2) years before they adopt any SWC technology. Owning land does significantly reduce the time taken to adoption relative to the scenario where they do not.

5.6 Summary

The decision to adopt high yielding varieties and crop-management technologies in developing countries is a somewhat easier decision to make than for adoption of SWC techniques as these technologies typically produce economic returns within a production cycle. On the other hand, a relatively longer time period is required for the realization of the benefits of soil conservation making the benefits of soil conservation uncertain. Informational problems limit the farmer's ability to correctly anticipate the long-term productivity consequences of current land use practices (Lapar and Pundey, 1999). McWilliams *et al* (1999) suggest that farmers possibly undergo stages of learning and updating their knowledge of the distributions of the benefits and costs of SWC. Every year that a farmer passes through a new stage of learning may bring him closer to adopting a SWC technology.

The adoption of Soil and Water Conservation techniques for the farmers in Ward 25, Chivi is characterized by positive duration dependence, that is, the longer a household has gone without adopting any SWC technique, the more likely they are to adopt a SWC technology in the following year. The results of the analysis indicated that most of the adoption tends to occur early in the management life of the farmer, i.e. the first five years.

The results of the study suggest that in the context of Ward 25 in Chivi, the number of years to adoption of the first SWC technique was shortened if the farmer was more integrated with farmers' organizations, had contact with extension agents, if the farmer's household was established after independence, owned land at the time household was established, owned more land, was male, and lived in Puche village. On the other hand, the time to adoption is lengthened if the farmer is older and is highly risk averse.

The results of the analysis indicate an important contradiction in the sense that the presence of an active SWC project (indicated by the variable GTZAG) did not appear to have influenced the lengths of time taken by households to adopt their first techniques yet the variable indicating contact with extension agents shortened these times significantly. Extension agents would supposedly disseminate the knowledge and information generated by the SWC project. This creates ambiguity for policy implementation as it is not clear as to why the agent that generates the knowledge and information appears not to be important, whilst the agent that passes this information on to the farmer is important. This could be attributed to the nature of the data that was available for analysis. There were relatively fewer households (approximately 44 out of 200 households) that were established after the GTZAG project was implemented. It could be that insufficient variation in the data could be a major determinant of this result. Whereas the variable EXTAGS is measured in such a way that it is not restricted to a particular time period.

The results of the analysis also indicate substantial differences in the time taken to adopt different techniques from the time they are first introduced. Not only that, but contour adoption is characterized by no duration dependence, that is the probability of a farmer adopting contours remains the same throughout his/her management life. The median time to the adoption of contours was found to be 8 years, crop rotation, 6 years and vetiver 33 years. The analysis only examined the socio-economic factors that may account for these differences. Important factors that have not been considered are to do with the characteristics of the techniques themselves and the topographical location of the farm.

For contours the most important factors are related to the age of the household head, risk preferences and property rights. For crop rotation, the most important factors relate to age, extension and social participation. Risk preferences play an important role in the adoption of contours, which are a relatively riskier technique and do not differentiate earlier adopters from late adopters in the adoption of crop rotation and vetiver. For vetiver, the most important factor is social participation, this makes sense as the introduction of this technique was coupled by efforts to revive indigenous institutions through the creation of various social groups in which farmers could belong, and thus encourage a participatory approach to development.

In all the models considered, the mass media variable, RADIO is negative and insignificant. The innovation diffusion model (Rogers, 1983) highlights the mass media as being important for technology diffusion through a society. The results of the analysis indicate that earlier and later adopters in Chivi cannot be differentiated based on whether or not they listen to the radio or read newspapers and magazines even though the sign on the coefficient was negative.

The results of the analysis mostly agree with the discussion of Chapter 2. For example, even though the distributions of the durations on a frequency basis were not bell-shaped, factors such as leadership and risk characteristics were found to be important in differentiating earlier adopters from late adopters and with the same direction of influence. The mass media variable as pointed out earlier turned out to be unimportant for this particular sample. Also, some of the influences of components of household resources and preferences were as expected. These included farm size, and farm implements. The coefficient on the size of the household was positive and insignificant. The direction of the influence of this variable is not what was expected, as it implies that larger households take longer to adopt SWC technologies, but since this effect is not statistically significant, it not a cause for concern.

The present chapter has provided an empirical analysis of the factors that are important in determining the time to the adoption of SWC technologies. Chapter 6 provides a summary of the thesis and concludes with policy implications of the research findings and recommendations for further research.

Chapter 6 - Conclusions

Chapter 1 began by posing a number of questions: why do some farmers adopt SWC technologies more quickly than others do? What are the mechanisms by which information about the benefits of soil and water conservation technologies is transmitted through smallholder societies and how does this affect adoption? The discussion in Chapter 2 proceeded to indicate how these questions could be answered using previous literature. The discussion in Chapter 2 highlighted the possible importance of social participation, mass media, household resources and preferences, technological factors and institutional factors in influencing the adoption process and decisions. This helped provide some hypotheses for the empirical analysis in Chapter 4. Chapter 3 provided a description of the methods of data collection, data collected and a preliminary analysis of the adoption data.

The analysis in Chapter 5 highlighted the importance of property rights, economies of scale, risk preferences, gender, extension agents, age and social participation in determining the time to adoption of SWC technologies. These results were consistent with several of the findings of past studies. The adoption of SWC technologies, in general, exhibits positive duration dependence, that is, the longer the household has gone without adopting a SWC technology, the more likely they are to adopt in the next time period. The results of the analysis also indicate that households are more likely to adopt SWC technologies in the first 5 years of their management life. The time to adoption of a SWC technology is shortened if, the farmer owns land, the farmer has a larger farm, the farmer is male, and has contact with extension agents. On the other hand, the time to adoption is lengthened if the farmer is highly risk averse and older.

6.1 Policy Implications of the Findings

As the social and environmental benefits of moving to more sustainable farming systems are gaining increasing recognition, policymakers are concerned about finding cost-effective ways of promoting the adoption of sustainable agricultural practices (Burton, Rigby, and Young, 1997). The research has shown that targeting households in their first 5 years of establishment will yield the most success. To persuade substantial numbers of farmers that conversion is an economically viable option will be a challenge but may be worthwhile in the long run. This study has highlighted the importance of property rights, economies of scale, risk preferences, gender, and age in determining the time taken to adopt SWC technologies.

The effect of extension on adoption has been a subject of interest. Studies on the size of returns to extension investments have failed to yield consensus as to the size of these returns (Huffman, 1978; Feder et al., 1987; Huffman and Evenson, 1993). This research study has not produced a quantifiable measure for the size of these returns nor did it have available the amount of investment into extension. What the analysis has managed to indicate, however, is the fact that extension does appear to have considerable influence on the amount of time that farmers will take to adopt SWC technologies. The results of the analysis indicated that farmers who have contact with extension agents took 44% less time to adopt a SWC technology than farmers who did not have contact with extension agents. These results indicate that investment by the government and non-governmental organizations into extension will be worthwhile if the indirect benefit that may accrue from averted damage warrants this.

The effect of investment in research has not been adequately addressed in this study. The variable hypothesized to represent indicate this was not significant in the analysis and this may have been due to insufficient variation in that variable. Specifically, the results imply that the presence of a large research project in SWC was not important in determining the amount of time taken to adopt SWC by farmers. This variable may have been incorrectly defined and measured. The fact that contact with extension agents was significant and that the presence of the project was not, may indicate as mentioned in chapter 5, that there was inadequate reach or coverage of households by the project and by the extension agents themselves. This leads us to suggest that government and/or NGO projects should aim both at generating knowledge and information and ensuring adequate dissemination of this information through extension agents.

The study has also highlighted the importance of risk preferences in determining the amount of time taken to adopt a SWC technology. Risk preferences may cause farmers to differ in their beliefs about the costs and benefits of the different SWC techniques. The results suggest that risk averseness will lengthen the amount of time taken to adopt SWC technologies. Perhaps, the government and NGO research departments could address this problem by allowing farmers to participate in the research process through trying some of the innovations themselves. The value of these trials as indicated in a study by Ghadim *et al* (1999), is the generation of valuable information, which could lead to reductions in uncertainty about a technique's long-term profitability. Through these trials, farmers also stand to develop skills valuable to making the technique a success.

The results of the analysis indicate substantial divergences in the amount of time taken by male and female-headed households to adopt SWC technologies. This is a cause for concern. Women have been disadvantaged as a result of local customs and traditions. There is historical evidence to indicate that modern institutions have also acted in the past to estrange women. The Native Land Husbandry Act (NLHA) of the 1950s allowed widows with children to be eligible for only one-third the land men could hold and all other categories of women were barred from getting land. At present, such conditions are less stringent for women, but they still exhibit a bias in favor of men. A key action for the government to take may involve creating conditions for equality in terms of access to resources. As well, research and extension efforts may need to be modified by deliberately targeting technologies that are particularly suited to the resources that are available to women.

The study may support the potential importance of a democratic approach to selecting and implementing appropriate SWC techniques. This was highlighted by the result for contours, which indicated that farmers whose households were established during the time when contours were forced upon the people tended to adopt them much later than other techniques (such as crop rotation and vetiver) which were introduced under a more democratic regime and have less political connotations.

6.2 Recommendations for Further Research

A number of areas of future research are prompted by this study. A number of the factors examined in the analysis vary over time, and these include age, marital status, size of land, etc. However, these were treated as being fixed in this analysis . The model could be extended to incorporate the fact that some socio-economic factors vary over time. This analysis could also be extended to include other external variables like farm-level prices and general economic conditions, which have not been included in this study. Other variables that would be of importance include, soil and vegetation types and the topographical location of the farm.

Second, the decision to adopt a particular SWC technique may be a choice amongst multiple techniques or, choice of a particular technique may be influenced by the other techniques that have been chosen. It may be well worth the time to extend the model into a multiple-choice model and thus examine choices as they are made over time.

Third, the costs of adopting SWC have not been modeled explicitly in this analysis. The main constraint to this was data availability. One suggestion is to improve over the data that was available for this study by perhaps improving on the data collection techniques. The modeling of costs explicitly would be useful both in the original model and in a dynamic multiple-choice model. Dynamic multiple-choice models appear to be gaining popularity, but these appear difficult to implement and require advanced simulated maximum likelihood techniques. A potentially important variable for this analysis is the number of adopters in a period where the farmer has not adopted a SWC technique. The number of adopters in a period where a farmer has not adopted provides an additional source of information about the costs and benefits of adoption. This variable could have also been included in the model.

Fourth, this study served as a means of obtaining initial information, which may serve as a starting point for examining the links between duration analysis and economic theory for technology adoption formally. Finally one might want to link a dynamic adoption model with a model of dynamic resource degradation. This would enable us to link the two and determine critical points for resource degradation and implementation of mitigative measures. At present, there are very weak linkages between technology adoption and duration analysis in term of economic theory. There is no doubt however as to the usefulness of this technique in the analysis of economic data.

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Appendix 1 -- Economic Theory and Duration Distributions

This section provides a brief example illustrating that economic theory can be used to obtain implications for duration distributions in particular settings. The job-search model, which leads to an exponential distribution for durations, will be considered. Individuals in the model are assumed to occupy only two states, employment and unemployment, because attention will be focused only on one transition, which is the transition from unemployment to employment. State e is employment and u is unemployment. Workers are allowed to change states at any time t. The unemployed draw wage offers w from the distribution p(w). Unemployed workers receive offers at a constant rate η, that is, the probability that the worker will get an offer in any short interval with length Δ is $\eta\Delta$.

Offers are drawn independently from the density p(w). Individuals know the offer distribution p(w) but do not know the location of each firm in that distribution. Assume that vu, the instantaneous utility associated with being unemployed, does not depend on either the outstanding wage offer w or the offer distribution p(w), and is constant over the duration of the spell of unemployment. Assume that the utility associated with being employed is a function of the wage paid, e = ve(w), but not of the offer distribution. Further assume that ve/dw > 0; higher wages are preferred to lower. The worker receives offers at random intervals and decides, when an offer is received, whether to accept the offer or to continue searching. It is clear that an unemployed worker will accept or decline a job immediately upon receiving a draw; that is, there is a wage w* such that offers greater than or equal to w* will be accepted and lower offers will be declined. This follows because the expected discounted utility of being employed is an increasing function of the wage received, while the utility of being unemployed does not depend on the outstanding wage offer. If a worker prefers employment at wage w to unemployment, he will prefer employment at higher wages as well. The reservation wage w* is the wage at which the worker will be indifferent between accepting the offer w* and declining the offer. The probability that an offer is acceptable is given π, the probability of a wage offer equaling or exceeding w*, namely

$$\pi = \int_{w^*}^{\infty} p(w)dw.$$

The transition rate from unemployment to employment is then given by the product of the offer arrival rate and the probability that an offer is acceptable; this transition rate is the probability of leaving unemployment at any moment given that the individual is still unemployed up to that moment. In other words, it is the hazard function for the distribution of unemployment durations

$$\lambda = \eta\pi .$$

Observe that the duration of unemployment does not appear in this expression for the hazard rate. Consequently, the implied distribution of durations of spells of unemployment is exponential

$$f(t) = \lambda \exp(-\lambda t).$$

The model has several interesting features. First, it is possible to use the optimality equations to develop restrictions on the effects of interindividual variations in offer distributions p(w) on the reservation wage w* and therefore the hazard λ. For example, individuals with higher mean offers can be expected to have higher acceptance probabilities per draw, other things being equal. This kind of prediction can be used to obtain implications for coefficients of a parameterization of λ as a function of explanatory variables. Thus, the variable "mean wage offer" or a suitable proxy is expected to have a positive effect on λ, the conditional probability of becoming employed. Those predictions can be checked as an informal specification test. Second, the model is extremely simple to estimate, as will be seen. Third, the multi-state extension is straightforward. Kenneth Burdett et al (1984) estimate a three state dynamic discrete choice model of labor turnover; the present simple model is a special case.

The implication of an exponential distribution of unemployment durations, however, is not robust to economically plausible changes in assumptions. Changes over time in the arrival rate of offers η, the offer distribution p(w), or the utility associated with unemployment (for example due to exhaustion of unemployment insurance benefits) will lead to a different duration distribution. A variation leading to non-exponential distributions can be as follows. This model will be the same as the previous model but will focus on spells of employment. Spells of employment are assumed to end at layoff or on receipt of a better offer. The probability that a worker will be laid off is assumed to depend on seniority. In particular, workers face layoffs in inverse order of seniority. This model leads to a prediction of a declining hazard for employment duration. The prediction holds up in a weibull model fit by Burdett et al (1985) and in a variety of other studies.

Appendix 2

Figure 5.2 The distribution of the time taken to adopt contours

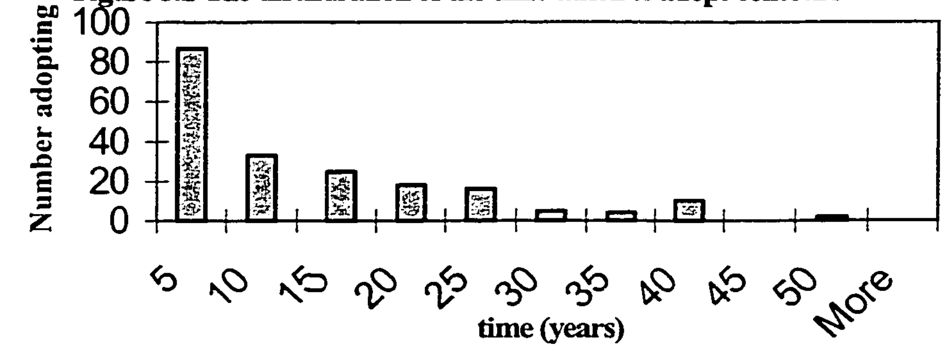


Figure 5.3 The distribution of the time taken to adopt crop rotation

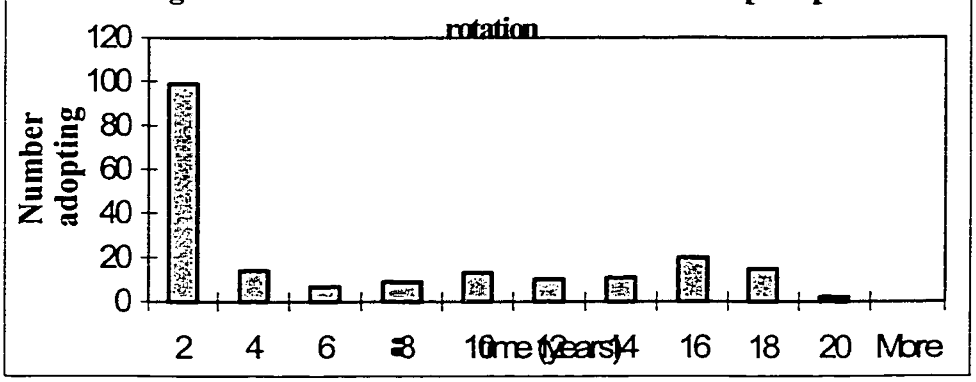


Figure 5.4 The distribution of the time taken to adopt vetiver

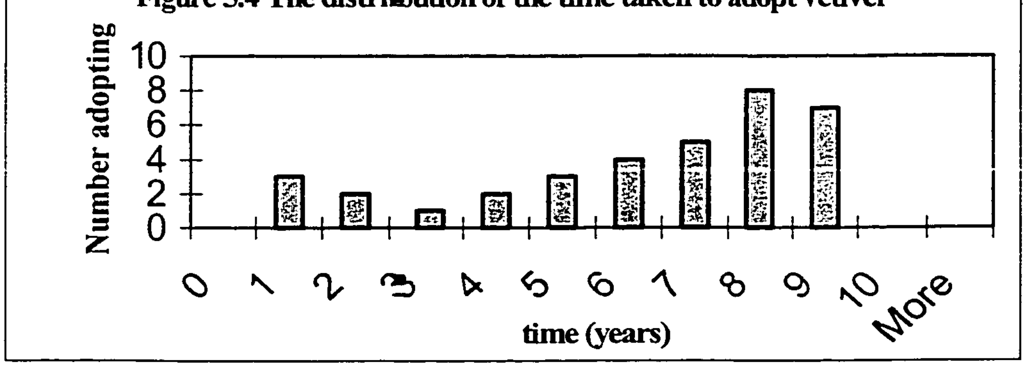


Figure 5.6 The estimated survival rates for Mbaimbai farmers

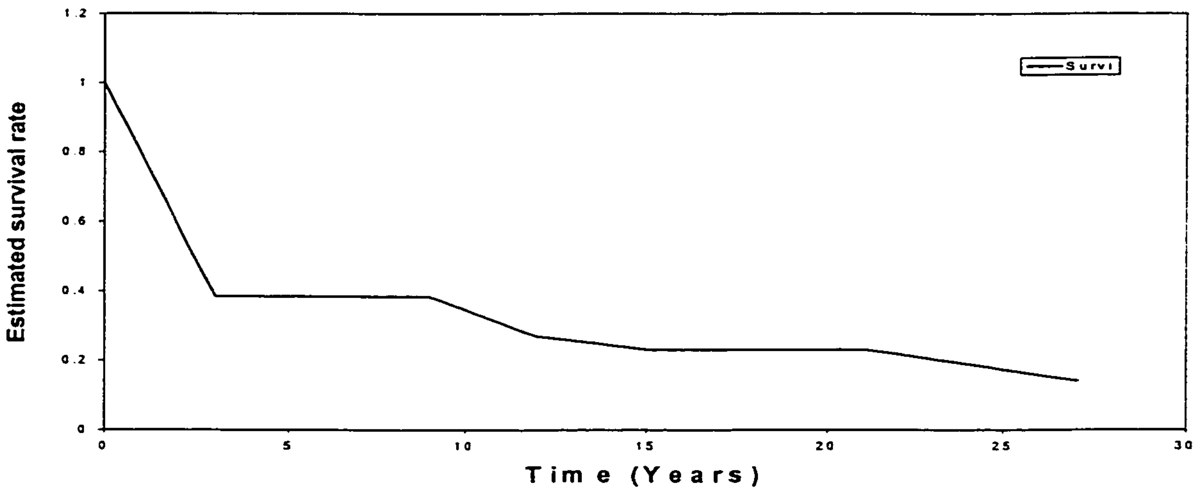


Figure 5.7 The estimated survival rates for Nduna farmers

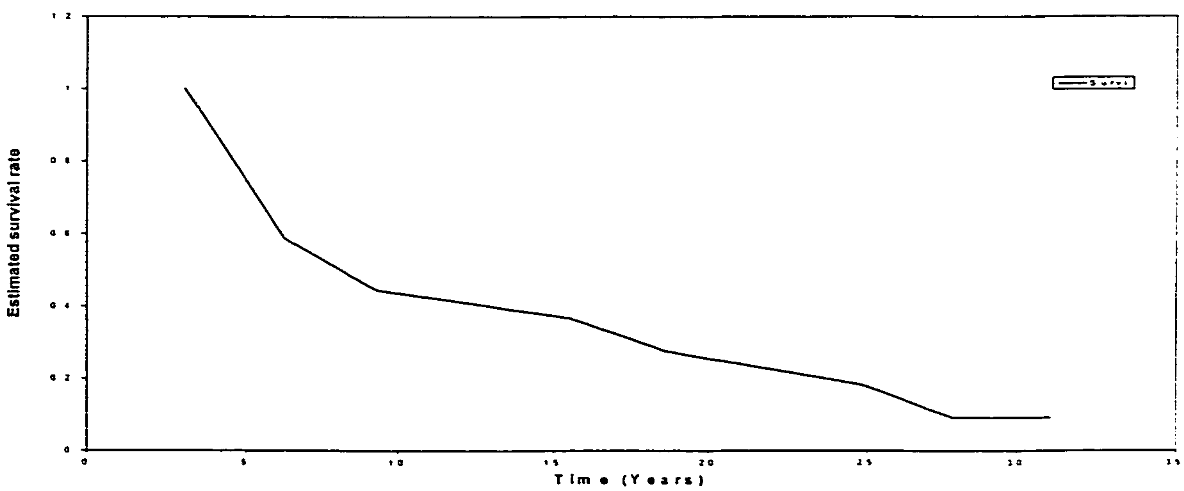


Figure 5.8 The estimated survival rates for Nyengera farmers

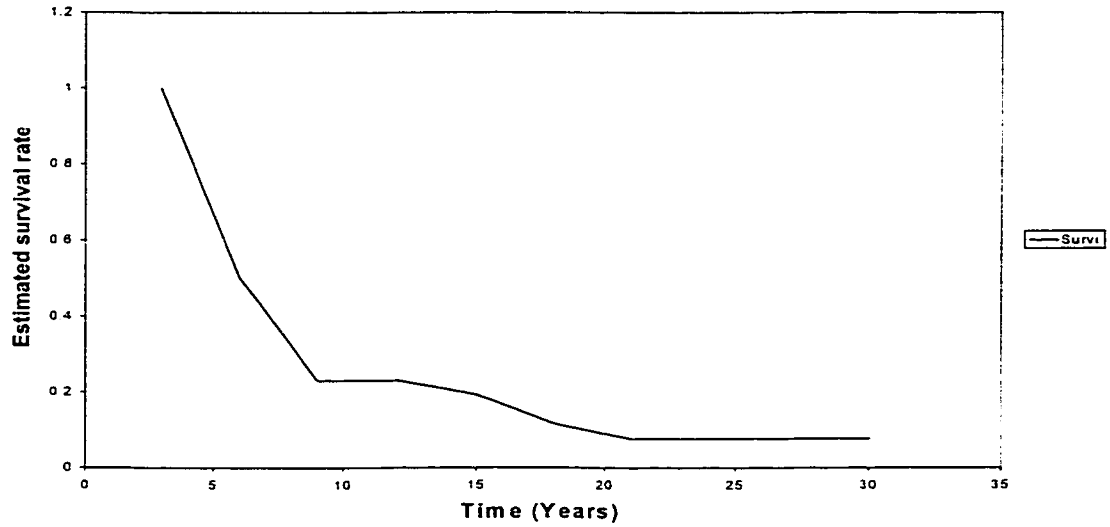


Figure 5.9 The estimated survival rates for Pedzisai farmers

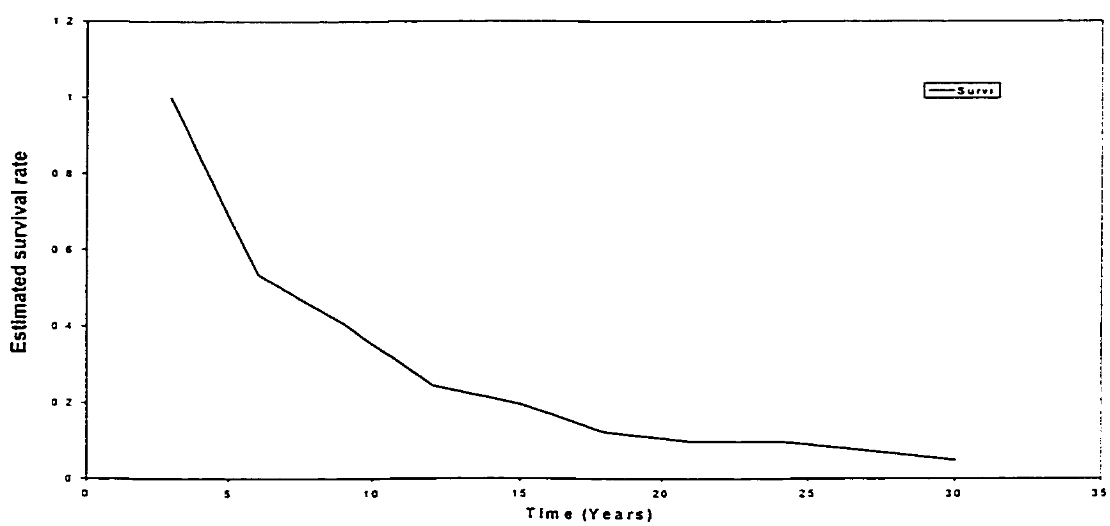


Figure 5.10 The estimated survival rates for Puche farmers

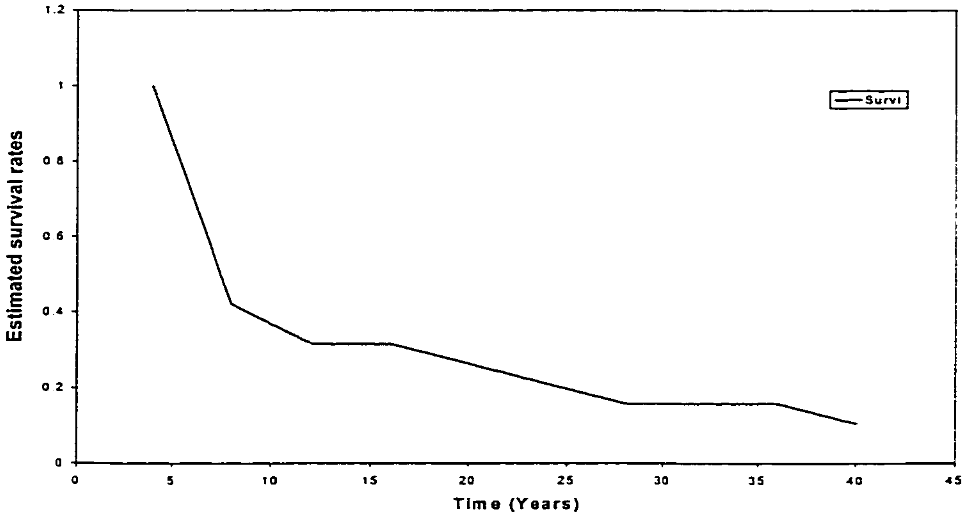
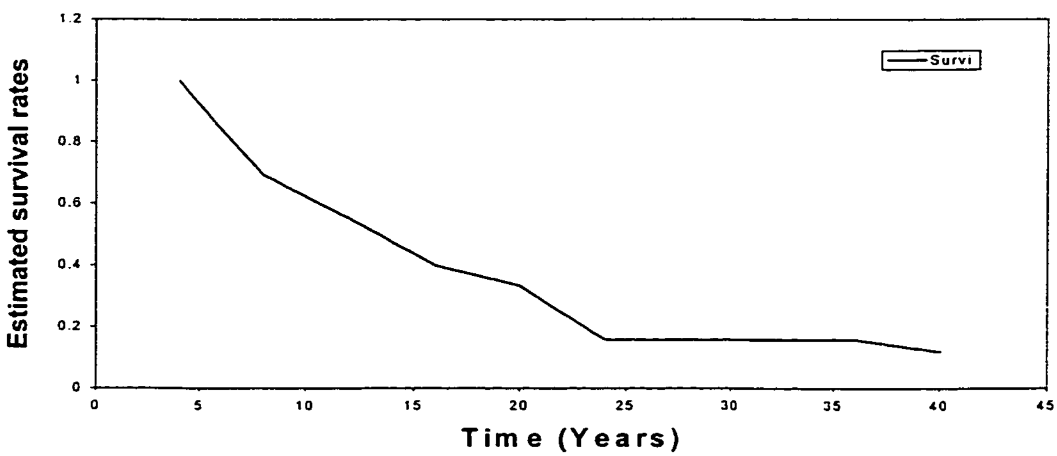


Figure 5.11 The estimated survival rates for Guti farmers



Appendix 3 – The household survey questionnaires

Questionnaire #1

Your household is being visited today as part of a study to learn about the different techniques you practice in Soil and Water Conservation. By participating in this survey you will be assisting a Zimbabwean student Lorraine Dzuda who is studying at the University of Alberta in Canada. This study is part of the requirements for a Masters degree in Agricultural Economics. The information collected from the study will also help us to understand which techniques are important to you in conserving soil and water and why. Participation is voluntary and your responses will be kept confidential. The appropriate District and Village leaders have given permission for this study to be carried out.

Name of Village---

Family Name--

Number of respondents---------------------------------------

Interviewer's name---

Time taken for interview--------------------------------------

Supervisor's Observations

How many errors were found in checking the questionnaire?----------------------

Is the survey satisfactory? Yes....1 No...2

The wages of the enumerator will be reduced by $20 for every survey that is unsatisfactory.

Household Characteristics

1. *(Interviewer should observe the type of respondents' house and circle the appropriate number(s))*

   Pole and Dagga plus thatch ...1

   Brick plus thatch ...2

   Pole and Dagga plus tin ...3

   Brick plus asbestos ...4

   Brick plus tin ...5

2. (*Interviewer should record the sex of the respondent*)

Male ...1

Female ...2

3. *What is your age?(circle the appropriate)*

0-25years

26-50years

51-100years

Above 100years

4. *What is your level of education?(circle the appropriate)*

Primary school.......0

Secondary school....1

High School.........2

Advanced............3

5. *Are you married? (If yes, go to 6, if no proceed to 7)*

6. *In which year were you married?*

Please provide the season of the year as well. The seasons are defined on CARD NUMBER 1..

Year----------Season------------(*Early Cropping (chirimo)...0 Late Cropping...1, Harvest(zhizha)...2 or Fallow...3)*)

7. *How many members are there in your household?* ----------

Name	Sex	Age	Relation to head	Education	Occupation
1. -------	-----	-----------	-------------	--------------	-------------
2. -------	-----	-----------	-------------	--------------	-------------
3. -------	-----	-----------	-------------	--------------	-------------
4. -------	-----	-----------	-------------	--------------	-------------
5. -------	-----	-----------	-------------	--------------	-------------
6. -------	-----	-----------	-------------	--------------	-------------
7. -------	-----	-----------	-------------	--------------	-------------
8. -------	-----	-----------	-------------	--------------	-------------
9. -------	-----	-----------	-------------	--------------	-------------
10. -------	-----	-----------	-------------	--------------	-------------
11. ------	------	------------	--------------	--------------	-------------
12. -------	-----	-----------	-------------	--------------	-------------
13. -------	-----	-----------	-------------	--------------	-------------
14. -------	-----	-----------	-------------	--------------	-------------

	Name	Sex	Age	Relation to head	Education	Occupation
15.	------	-----	--------	----------	-----------	----------
16.	------	-----	--------	----------	-----------	----------
17.	------	-----	--------	----------	-----------	----------
18.	------	-----	--------	----------	-----------	----------
19.	------	-----	--------	----------	-----------	----------
20.	------	-----	--------	----------	-----------	----------

Material Possessions, Farm Power and Livestock

1. *Please tell me about the following material possessions. Indicate yes, or no. Time of acquisition to be given in YEAR ONLY.*

a) Do you own,

i) a radio? ………….If yes, when did you first acquire it? ……………………

ii) Chairs? ………….If yes, when did you first acquire them? ………………………….

iii) A table? ………….If yes, when did you acquire them? ……………………….

iv) Sofa? ………….If yes, when did you first acquire them? ……………………….

v) Bed? ………….If yes, when did you first acquire them? ………………………..

vi) Wrist watch? ………….If yes, when did you first acquire one? ……………………….

vii) Bicycle? ………….If yes, when did you first acquire one? ……………………….

viii) Any motorized vehicle? ………….If yes, when did you first acquire it? ……………………….

2. *Please tell us about the following farm implements.(Indicate yes or no). Time of acquisition to be given in YEAR ONLY.*

a) *Do you own,*

i)a plough? ………….If yes, when did you first acquire it? ………………$…………

ii)harrow? ………….If yes, when did you first acquire it? …………………$………

iii) hoe? ………….If yes, when did you first acquire it? ……………………$……

iv) a cultivator? ………….If yes, when did you first acquire it? ……………$……………

v) a caterpillar? ………….If yes, when did you first acquire it? ……………$……………

b) Do you have access to a ridger? (indicate yes or no)

c) If yes, where can you get it? ………………………………….

3.Do you own any agricultural land at present? If yes, skip 4 and proceed to 5, if no go to 4, then proceed to 8.

Yes.......1

No........0

4.Where do you grow your crops then?

i)On land rented for a season

ii)On land rented for more than one season.

5.When did you acquire this land? Please provide specifics like season and year. Use card number 1 to check the season definitions.

Year--------------Season................Total Acreage owned then..........

6.How many acres of agricultural land does your household own at present?----------------

7.How has your acreage changed over the years? Insert the relevant number corresponding to the appropriate explanation on CARD NUMBER 2 in the increase/decrease column. The seasons are as defined on CARD NUMBER 1.

Year	**Season** ***(Early Cropping...0 Late Cropping...1, Harvest...2, Fallow...3)***	**Acreage**			
		Increased through	**Increased by how much?**	**Decreased through**	**Decreased by how much?**

8. *Which of the following livestock do you own? Circle the relevant response.*

a) Do you own,

i) Donkeys yes...1 no...0, *If yes, how many?...............*

ii) Cattle yes...1 no...0, *If yes, how many?...............*

iii) Oxen yes...1 no...0, *If yes, how many?...............*

iv) Goats yes...1 no...0, *If yes, how many?...............*

b) When did you first own,

i) Donkeys? ***Year..........Season..........****How many?...........How did you acquire them?...............*(use CARD NUMBER 3 to insert the relevant number).

ii) Cattle? ***Year...........Season..........****How many?............How did you acquire them?*...............(use CARD NUMBER 3 to insert the relevant number).

iii) Oxen? ***Year.............Season.............****How many?.......... How did you acquire them?*
...............(use CARD NUMBER 3 to insert the relevant number).

iv) Goats? ***Year.............Season.............****How many?.......... How did you acquire them?*
...............(use CARD NUMBER 3 to insert the relevant number).

9. How has your livestock ownership changed through the years? Insert the number corresponding to the relevant explanation on CARD NUMBER 4 in the relevant increase or decrease column. (Seasons to be entered in the tables as Early Cropping...0, Late Cropping...1, harvest...2, fallow...3). The seasons are defined in terms of maize. Early Cropping is from November to December, Late Cropping from January to February, Harvest from March to April and Fallow from May to October.

Year	Season	Which livestock type has changed in numbers?							
		Donkeys increased through	Donkeys decreased through	Cattle increased through	Cattle decreased through	Oxen increased through	Oxen decreased through	Goats increased through	Goats decreased through

Social Participation and Communication Characteristics

1. *We are interested in knowing about your participation in village/outside village clubs, associations, organizations, and institutions. These could be trade, political, professional, or religious related.*

1a. *Are you a member in any of these organizations?* No...0
Yes...1 (go to 1b)

1b. *Are you a member in;*

only one organization 1

more than one organization 2

1c. *Do you hold a leadership position in the organization(s)?* No...0

Yes...1

2. *Do you ever attend field trips to other farms outside of your village and ward?--------------- (If no, proceed to question 5).*
3. *How many field trips have you attended in the past year. Circle the appropriate.*

1-2 trips

3-4 trips

5 and above

4. *Who organized these field trips?* ....
5. *We would like to get an idea of how your participation in social organizations has changed over the years. Indicate, J----joined, Q------quit.*

	Year										
Organization	Before 1990	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999

6. *How often do you participate in the following mass-media source?*

Mass media source	Nature of ownership	How often do you read/watch/listen?		
Do you,		(2)	(1)	(0)
a) Read newspapers	Subscriber...1			
	Non-----------0	daily	occasionally	never
b) Read farm	Subscriber...1			
Magazines	Non-----------0	daily	occasionally	never
c) Read books on	Owner---1			
Agriculture	Borrower..0	regularly	occasionally	never
d) Listen to rural	Owner----1			
Radio programs	Borrower---0	daily	occasionally	never
e) watch television	Owner----1			
	Borrower....0	daily	occasionally	never

Farm Household Preferences

Household Goals and Objectives

We would like to find out about your goals and objectives in your daily farming life. Please tell us whether you strongly agree, agree, disagree, undecided, or strongly disagree with each of the following statements.

1. I farm mainly to provide for food and other household needs	SA	A	UD	D	SD
2. I aim to obtain acceptable returns to the resources that I employ	SA	A	UD	D	SD
3. When I plan my work I try to achieve an adequate balance between work and leisure	SA	A	UD	D	SD

Household Time Preferences

(The enumerator should now tell the respondent about the following hypothetical situation). Let us suppose that you had volunteered for a Donor Agency. In appreciation, the Donor agency offers to give you 10 buckets of maize today or you can choose to receive 10.5 buckets a year from now. We will assume that you are guaranteed through a contract to receive the grain at the time you choose to collect it. Which would you choose: *(The enumerator should emphasize that these are hypothetical choices and are not being considered as a future project plan by any or government agency).*

Question 1

A. 10 buckets of maize now

B. 10.5 buckets of maize 1 year from now.

Question 2

Now suppose the donor agency is offering to give 10 buckets of maize now so you can choose to receive 11 buckets 1 year from now. Which would you choose?

A. 10 buckets of maize now

B. 11 buckets of maize a year from now.

Question 3

Now suppose the donor is offering to give 12 buckets of maize a year from now or you can choose to receive 10 buckets today.

A. 10 buckets today

B. 12 buckets of maize a year from now

Question 4

Are there any responses you would like to change?

Household Risk Preferences

Now suppose the donor agency offers you an alternative deal. You may choose to receive 10 buckets of maize today. Alternatively, you may draw a twig from two twigs in my closed fist. If you choose the longer twig you will receive 15 buckets of maize. If you choose the shorter one you will receive 5 buckets. Which would you choose?

Question 1

A. 10 buckets for certain

B. 15 buckets if you pull out the longer twig or 5 buckets if you pull out the shorter one.

Question 2

Suppose the donor's deal was different. You can still have 10 buckets of maize today OR instead, you are given two chances to pull out a twig. Now, if you choose the longer twig in at least one of the chances, you will receive 15 buckets of maize. If you choose the shorter one in each chance you will receive 5 buckets of maize. Which would you choose?

A. 10 buckets of maize for certain

B. 15 buckets of maize if you pull out the longer twig in at least one of the chances or 5 buckets if you pull out the shorter twig in both of the chances.

Question 3

Suppose the donor's deal was different. You can still have 10 buckets of maize today OR you are given three chances to pull out a twig. Now if you pull out the longer twig in at least one of the chances, you will receive 15 buckets of maize. If you choose the shorter twig in all of the chances you will receive 5 buckets of maize. Which would you choose?

A. 10 buckets of maize today

B. 15 buckets of maize if you pull out the longest twig in at least one of the chances or 5 buckets if you pull out the shorter one in all of the chances.

Awareness and Stewardship Motivations

We would like to find out if you are aware any soil conservation programs that are occurring or have occurred in you area. Please tell us the ones that you are familiar with (i.e. programs by Agritex or NGOs. Farmers may provide the names of key people if they do not know the organizations by name). Meanwhile, the enumerator should tick the program corresponding to those listed in the prop card.

Program 1........................

Program 2........................

Program 3........................

Program 4........................

NONE.............

23. *What is your source of information about these activities? Circle all those that apply.*

Ward/Village meetings........................1

Radio...2

Extension agents..............................3

Neighboring farmers.......................4

Papers, Magazines...........................5

Any other (specify).........................6

24. *We are interested in your attitude towards the following statements on soil conservation. Please tell me whether you strongly agree, agree undecided, disagree, or strongly disagree over each statement.*

Statement	SA	A	UD	D	SD
1.Soil conservation will assure us of good crop yields in the future	1	2	3	4	5
Statement	**SA**	**A**	**UD**	**D**	**SD**

2.Soil conservation programs give the opportunity to the farmers to develop rapport with officers of developmental departments.	1	2	3	4	5
3. We have not yet noticed that those who practice soil conservation are better off.	1	2	3	4	5
4.There is little work done and more propaganda made about soil conservation.	1	2	3	4	5
5. The government should enforce soil conservation.	1	2	3	4	5

Questionnaire #2

Soil and Water Conservation Techniques

1. a) Have you previously been surveyed about soil conservation?...........If yes, when?.................(Response here should be given in YEAR ONLY. b) Do you practice soil and water conservation?.................(Indicate yes or no).
2. b) In the table provided in the following page, please tell us about all the techniques that you practice and the season and year in which you started doing them (Interviewer should circle the relevant technique from those provided in the table and in addition fill in the time when they were started, Also fill in the rest of the table. Seasons are defined as Early Cropping (chirimo)...0, Late Cropping...1, Harvest (zhizha)...2, Fallow...3. The seasons are defined in terms of maize. Early Cropping is from November to December, Late Cropping is from January to February, Harvest from March to April and Fallow from May to October.

Have you ever heard of,	**When did you first hear of this technique? (Year Only)**	**From whom did you learn of this technique?**	**Do you practice the technique?**	**When did you adopt the technique *(Year and Season)***	**Which special implements (if any) do you require for this technique?**
Contours ***(makandiwa)***		Other Farmers Agritex NGO Field day Other			
Stone Bunds *(matombo)*		Other Farmers Agritex NGO Field day Other			
Infiltration Pits *(matura emvura)*		Other Farmers Agritex NGO Field day Other			
Crop Rotation *(kuchinjanisa mbeu)*		Other Farmers Agritex NGO Field day Other			
Strip Cropping *(kusanganisa mbeu)*		Other Farmers Agritex NGO Field day Other			

Tied Ridging *(mariji ane matayi)*		Other Farmers Agritex NGO Field day Other			
Mulching *(kufukidza)*		Other Farmers Agritex NGO Field day Other			
Winter ploughing		Other Farmers Agritex NGO Field day			
Vetiver grass *(vhativha)*		Other Farmers Agritex NGO Field day Other			
Planting trees		Other Farmers Agritex NGO Field day Other			
Fanya-juu		Other Farmers Agritex NGO Field day Other			

Compost		Other Farmers Agritex NGO Field day Other			

3. Please fill in the following table, which will aid us in characterizing the techniques. Seasons are defined as Early Cropping (chirimo)…0, Late Cropping…1, Harvest (zhizha)…2, Fallow…3. The seasons are defined in terms of maize. Early Cropping is from November to December, Late Cropping from January to February, Harvest from March to April and Fallow from May to October. The first column responses will be given in terms of days. For the second column, lets define labor as the number of men/women/children required to complete a task. Thus High would correspond to more than 10 people, moderate to 5-10 people and low less than 5 people. Therefore we would have; High…….greater than 10, Moderate……..5-10, and low………less than 5 people. We will then define hired labor as the number of extra men/women/children from out of the household required to complete a task. Frequency of maintenance will be defined as very frequent……..more than four days a week, moderate……..2-4 days a week, Infrequent……less than once a week.

Do you practice?	**How many days do you take to establish this technique?**	**How many people will be working at this task?**	How many people do you hire?	**Does the technique require frequent maintenance?**
		High Moderate Low	None Less than 2 people 3-5 people More than 5 people	Very Frequent Moderate Infrequent
		High Moderate Low	None Less than 2 people 3-5 people More than 5 people	Very Frequent Moderate Infrequent

		High Moderate Low	None Less than 2 people 3-5 people More than 5 people	Very Frequent Moderate Infrequent
		High Moderate Low	None Less than 2 people 3-5 people More than 5 people	Very Frequent Moderate Infrequent
		High Moderate Low	None Less than 2 people 3-5 people More than 5 people	Very Frequent Moderate Infrequent
		High Moderate Low	None Less than 2 people 3-5 people More than 5 people	Very Frequent Moderate Infrequent
		High Moderate Low	None Less than 2 people 3-5 people More than 5 people	Very Frequent Moderate Infrequent
		High Moderate Low	None Less than 2 people 3-5 people More than 5 people	Very Frequent Moderate Infrequent
		High Moderate Low	None Less than 2 people 3-5 people More than 5 people	Very Frequent Moderate Infrequent

4. For each of the techniques that you indicated as those you practice, please briefly indicate (I) if you face any problems with them, and (ii) If you do, what those problems are. The problems could be; (1) lack of knowledge, (2) lack of relevant implements, (3) lack of money, (4) too time consuming, (5) unable to see benefits, and (6) any others which have not been mentioned.

a) Technique 1(insert the name of the technique).............................do you face any problems?.....................(indicate yes or no)

If yes, which problems do you face?........................(insert the relevant number from the choices mentioned above, specify the problem if it has not been mentioned.

b) Technique 2 (insert the name of the technique).............................do you face any problems?.....................(indicate yes or no)

If yes, which problems do you face?........................(insert the relevant number from the choices mentioned above, specify the problem if it has not been mentioned.

c) Technique 3 (insert the name of the technique)..............................do you face any problems?.....................(indicate yes or no)
If yes, which problems do you face?........................(insert the relevant number from the choices mentioned above, specify the problem if it has not been mentioned.

d) Technique 4 (insert the name of the technique)..............................do you face any problems?.....................(indicate yes or no)
If yes, which problems do you face?........................(insert the relevant number from the choices mentioned above, specify the problem if it has not been mentioned.

e) Technique 5(insert the name of the technique)..............................do you face any problems?.....................(indicate yes or no)
If yes, which problems do you face?........................(insert the relevant number from the choices mentioned above, specify the problem if it has not been mentioned.

f) Technique 6 (insert the name of the technique)..............................do you face any problems?.....................(indicate yes or no)
If yes, which problems do you face?........................(insert the relevant number from the choices mentioned above, specify the problem if it has not been mentioned.

g) Technique 7 (insert the name of the technique)..............................do you face any problems?.....................(indicate yes or no)
If yes, which problems do you face?........................(insert the relevant number from the choices mentioned above, specify the problem if it has not been mentioned.