RISK PREFERENCES AND SOIL CONSERVATION DECISIONS OF SOUTH AFRICAN COMMERCIAL SUGARCANE FARMERS

By

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I certify that the work reported in this thesis is my own original and unaided work except where specific acknowledgement is made.

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ABSTRACT

In this study commercial sugarcane farmers' risk preferences are measured and tested, amongst other factors, as determinants of their soil conservation decisions. Motivation for this research stems from ongoing erosion on South African commercial farms, including sugarcane farms; recognition that agricultural economists have a poor understanding of factors affecting soil conservation; and because little positive economic research has been conducted linking risk preferences to environmental choice. This research also affords the opportunity to investigate both theoretically and empirically the effect of the range of the data on the Arrow-Pratt absolute risk aversion coefficient (AP); and to investigate factors affecting farmers' risk preference. Both of these are important topics for research.

The proposed conceptual model views farmers' soil conservation decisions in a system analogous to a demand system from which a probabilistic choice model of the adoption of soil conservation practices is developed. This model relates adoption of soil conservation technologies to the demand for soil conservation using derived demand theory. Consequently, soil conservation decisions are analysed in terms of both achieved soil conservation efficiency and farmers' choices of soil conservation measures. This conceptual model further advances previous research in that it provides a sound economic base for the analysis and it accounts for intra-farm variations in soil conservation decisions.

It is demonstrated that AP's must be adjusted for the range as well as the scale of the data for comparison of risk preferences across different risk situations. Although Raskin and Cochran's (1986) theorems adjust AP's for the scale of the data and are widely used in agricultural economic research, they only adjust correctly for the range of the data under special circumstances. It is demonstrated that in previous agricultural economic research AP's have been incorrectly adjusted for the range of the data and that the effect of the range on AP's has been often incorrectly interpreted as a wealth affect. It appears that informing agricultural economists of the sensitivity of AP's to the range of the data is important. An approach is proposed for adjusting AP's for both the scale and the range of the data.

Fifty three commercial sugarcane farmers from KwaZulu-Natal were surveyed by personal interview during May and June 1996 to elicit farmers' risk preferences and information on their soil conservation decisions. Arrow-Pratt absolute risk aversion coefficients are elicited using a direct elicitation of utility approach. Two farmers refused to participate in lottery games for religious or moral reasons. Of the remainder 57.2 percent were risk averse, 29.6 percent risk neutral and 13.2 percent risk preferring. On average they were risk averse although risk preferences vary significantly amongst individuals. Regression analysis indicates that on average sugarcane farmers are averse to a possible loss in wealth relative to initial wealth and they exhibit increasing absolute risk aversion although at a decreasing rate with increasing gamble range.

Technological information is used to assess KwaZulu-Natal commercial sugarcane farmers' intra-plot (panel) soil conservation relative to requirements of the Conservation of Natural Resources Act of 1983. Findings indicate that farmers consider enforcement of the Act to be unlikely and that 28 percent of farmers surveyed do not meet adequate intra-panel soil conservation standards. This partially reflects that a large proportion of farmers have not yet completed implementing their soil conservation plans. Nonetheless, policy makers should examine factors impeding adequate enforcement of the 1983 Act.

Multiple regression and principal component analysis techniques are used to analyse farmers' soil conservation decisions. Decisions are analysed in terms of achieved intra-field soil conservation adoption and soil conservation effort, and farmers' choices of soil conservation measures. Measurements of soil conservation efficiency are defined to be objective, be suitable for relative analysis, and reflect intensiveness of adoption. Extensiveness of adoption is captured by eliciting information for more than one field per farm. Achieved goodness of fit statistics are good compared to previous similar studies and indicate that intra-farm variations in soil conservation contain important information explaining soil conservation decisions. Findings generally support the conceptual exposition that the demand for soil conservation technologies is derived primarily from the demand for soil conservation. However, the demand for fire insurance does affect adoption of strip cropping, and hence soil conservation decisions.

Results indicate that although risk and risk preferences are not significant determinants of the quantity of soil conservation demanded by sugarcane farmers, they are significant determinants of their soil conservation decisions. Firstly, the rate at which more risk averse farmers tend to undertake extensive restructuring of sugarcane field layouts tends to be relatively slow. This verifies the hypothesis that risk averse farmers value an option to postpone capital intensive, irreversible investments. Secondly, relatively risk averse farmers are more likely to adopt strip cropping programmes. This finding is attributed to their aversion to income risk and not risk of excessive soil loss. The hypothesis that risk averse farmers adopt soil conservation practices to reduce risk of serious erosion is not supported.

It is concluded that farmers' abilities to assess soil conservation efficiency is poor, especially with respect to the partial contribution of conservation structures to achieved soil conservation efficiency; while farmers tend to implement soil conservation on steeper slopes first; and perceive minimum tillage and strip cropping programmes to be imperfectly compatible. Adoption of minimum tillage, trash mulching and strip cropping are primarily constrained by physical climatic, field and soil characteristics and to a lesser extent by farmers' management time and technical abilities. Implementation of improved soil conservation structures is constrained by financial constraints. Amongst other factors, education and use of extension information sources and adoption of land use plans are positively related to both conservation adoption and effort. Soil conservation policies must make farmers more aware of soil erosion. This is best achieved through provision of specific technical information, especially land use plans.

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1. INTRODUCTION

The objective of this research is to jointly study risk preferences and soil conservation decisions of KwaZulu-Natal commercial sugarcane farmers at the micro-level from an economic perspective. Although much research has been devoted to the theory of soil conservation choices, almost no positive economic research has been conducted on the implications of uncertainty and farmers' risk preferences for these choices. In this study farmers' risk preferences will be measured and tested in soil conservation decisions. The motivation for this research arises primarily from theoretical and regulatory purposes.

Estimated annual soil loss in KwaZulu-Natal is in the region of 100 million tons (Maher, 1996). Positive net erosion, that is a rate of soil loss greater than the rate of soil formation, will reduce the long term productivity of cropland resources and has a detrimental impact on environmental quality. Fuggel and Rabie (1992: 191) suggest that erosion is possibly the greatest environmental problem facing South Africa. Given topography, soil type and weather, farm practices determine the level of erosion. Since, farmers are the agents through which any reductions in erosion will be brought about, analysis of factors affecting farmers' soil conservation decisions will facilitate assessment of soil conservation policy options.

Although sugarcane is regarded as having good water and soil conserving properties, soils in South African sugarcane growing areas are mostly granular, leached, prone to crusting and have high rates of erosion once the natural vegetation is removed (Platford, 1987). Soil degradation and loss have been partially attributed to negating expected improvements in yield productivity from newly released varieties of sugarcane over the past two decades (Meyer *et al*, 1996). Despite good progress in conservation measures amongst members of the Sugar Industry reported in 1992 (Anonymous, 1992), McFarlane and Maher (1993) reported that only nine percent of completed requests for farm assessments conformed with the 1983 Act in all aspects. Further, Ardington, quoted in Fitz-Gerald (1996), recently drew attention to ongoing erosion on KwaZulu-Natal sugarcane farms.

In terms of the Conservation of Agricultural Resources Act of 1983 *ex ante* soil conservation requirements may be enforced by *ex ante* penalties, ie. farmers can be prosecuted for carrying out practices that could lead to soil erosion. Conservation committees, drawn from farmers' associations, government officers and other technical representatives, are responsible for applying the 1983 Act, under the guidance of the minister of agriculture (McFarlane and Maher, 1993). However, Maher, quoted in Fitz-Gerald (1996), contends that South African sugarcane farmers are not being held accountable for soil erosion on their farms by either the sugar industry or the Departments of Agriculture or Justice, resulting in too few farmers implementing adequate soil conservation.

Issues central to the economics of soil conservation are (a) externalities associated with erosion, and (b) the balance between present and future income. Problems with agricultural externalities, such as those associated with soil erosion, are their non-point source nature, the large number of polluters, the large number of victims, and their stochastic nature. Common law solutions are often impossible as proof of violation, identification of the culprit, and the amount of liability must be ascertainable. If landowners do not receive the full net social benefits of an erosion control investment, they will under invest in erosion control from a social perspective. Consequently, where externalities from soil erosion exist, soil conservation from a social perspective will always be suboptimal in the absence of government intervention.

Virtually all economists agree that, at least in theory, a farmer's soil conservation decisions are based on his estimates of his costs of the conservation investment versus the costs of loosing soil to erosion (Ervin and Ervin, 1982). When considering only on-site productivity damages and assuming a perfectly functioning and costless capital market, landowners theoretically receive adequate incentives through private markets to achieve socially optimal levels of soil conservation. In other words, if land prices reflect the value of conservation improvements, a landowner can obtain the undepreciated investment in terms of a higher price when property is sold (Featherstone and Goodwin, 1993). Landowners will then have equal planning horizons to society and soil conservation will be socially optimal (Gardner and Barrows, 1985).

Costs of information discovery on soil conservation efficiency may be high due to the generally indiscernible nature of most soil erosion, the masking effects of productivity improvements on soil degradation, and because costs and benefits change according to location. Costs of information discovery are likely to be inversely related to awareness of suboptimal soil conservation, which is commonly conceptualised as a precursor to implementing soil conservation measures (eg. Ervin and Ervin, 1982; Barlow, 1995). High costs of information on soil conservation efficiency may result in farmers being relatively less aware of the costs (benefits) of actual erosion (soil conservation). Soil conservation efficiency will then be suboptimal, even if farmland markets are efficient.

Hedonic pricing studies have tested the hypothesis that, even if farmland markets function efficiently, farmland prices may not account for the effects of past erosion or potential erosivity on future net returns to land if the costs of information discovery regarding soil conservation are high (Ervin and Mill, 1985). Ervin and Mill (1985), Gardner and Barrows (1985), King and Sinden (1988) and Palmquist and Danialson (1989) have all used hedonic pricing models but have found mixed results. Their findings generally suggest that conservation investment is more likely to be capitalised into land values when the need for soil conservation is highly apparent. It may be concluded that costs of information discovery are relatively lower, but not necessarily low, on land where the need for soil conservation is distinct. This echoes Bennet's (1945, as cited by Scotney, 1978: 1) observation that "The extent of damage [from soil erosion] greatly exceeds common understanding and the average person does not notice the far more serious effects of erosion represented by the less spectacular process of sheet washing."

Whereas several economic studies of farmers' soil conservation decisions have been completed in the United States (eg. Ervin and Ervin, 1982; Featherstone and Goodwin, 1993; Saliba and Bromley, 1986), only two studies have been completed in South Africa: Barlow and Nieuwoudt (1995) and Basson (1962). Although Barlow and Nieuwoudt's (1995) study encompassed KwaZulu-Natal sugarcane growers and is recent, data restrictions in their study necessitated measurement of soil conservation effort essentially in terms of farmer's own assessments, which, by their own admission, does not necessarily reflect conservation effectiveness (Barlow and Nieuwoudt, 1995). By way of contrast, technical information specific to sugarcane farming is used to objectively assess soil conservation effectiveness in this study.

Theoretically risk preferences may be important in explaining farmers' soil conservation decisions (Ardila and Innes, 1993). Although farmers' risk preferences are frequently included in normative economic studies of soil conservation decisions (eg. Kramer *et al*, 1985; and McSweeny and Kramer, 1986; Setia, 1987), these models assume that farmers know the correct probabilities of the events at risk and through specification of these risks essentially predetermine the effect of risk on decisions. In reality, farmers are confronted with a diverse array of information about soil conservation and consequently have subjective probability distributions of current and future income, wealth, and other attributes according to soil conservation practices adopted. How farmers deal with this complexity is important. Only a few positive economic studies have related uncertainty and farmers' attitudes towards risk to the economics of soil conservation. Those studies that have considered risk attitudes all constructed (potentially unreliable) indices of risk orientation using attitudinal questions. More precise measurement of farmers' risk preferences may facilitate understanding the role of risk preferences on farmers' decisions.

Further motivation for the elicitation of risk preferences is to facilitate future research. A measure of risk aversion may be needed to weigh alternative activities that involve risk. Rather than selecting levels that give desired quantitative results, researchers should select values that represent plausible levels of risk aversion to aid policy makers (Babcock *et al*, 1993). Developing appropriate methodology for assessing risk attitudes then becomes an important goal for research, and knowledge of the distribution of risk preferences within a (similar) population is important.

Young's (1979) review shows that the principal uses of elicited risk aversion coefficients are for (a) farm management extension applications, (b) technology adoption and rural participation applications, and (c) policy and predictive applications. He concluded that considerable heterogeneity in risk preferences among individuals; requirements of frequent updating of individuals risk preferences in response to changing objectives, information and attitudes; and time, cost and practical problems associated with elicitation of risk preferences are likely to limit their use in extension programs (Young, 1979). A review of application of risk research in farm management and extension programs over the past twenty five years by Patrick and DeVuyst (1995) confirms Young's views although they concluded that progress is being made in this regard.

Estimating the willingness of farmers to adopt a new technology or participate in rural development programs may be facilitated by knowledge of risk preferences. Risk preferences have been shown to be important in many decisions including grain marketing decisions (eg. Blakeslee and Lone, 1995), use of agricultural chemicals (eg. Babcock, 1992; Feder, 1979), producers' participation in farm commodity programs in the 1980's (Kramer and Pope, 1981), and choice of marketing strategies (eg. Johnson and Foster, 1994). Smith and Desvousges (1986) and Desvousges *et al* (1988, cited by Eom, 1992) verified the existence of averting behaviour to decrease health risks, and Eom (1992) found perceived health risk to be a primary determinant of consumers' choice of fresh produce. However, frequently other variables are more important in explaining these decisions.

Whilst farm management and development programming applications may not justify measurement of individuals' risk preferences, in the arena of policy and predictive applications such measures are sometimes justified (Young, 1979). To quote Anderson *et al* (1977: 312) "Policy makers will generally suffer fewer 'surprises' in program results if their economic models of farming behaviour include an adequate recognition of farming risks and farmers' attitudes toward them." Where farmers' risk preferences are non neutral, policies seeking to achieve production abatement or expansion, or environmental protection may be better achieved through affecting the farmer's risk environment. Knowledge of risk preferences facilitates understanding of policy on producer choices and is important in evaluating the consequences and merits of alternative policy measures. For example, *ex ante* forecasting of how uncertainty and irreversibility are likely to affect producers' responsiveness to agricultural technologies has implications for the design of environmental policies (Purvis *et al*, 1995; Oglethorp, 1995; Leathers and Quiggen, 1991). Likewise, risk management policy options are currently being considered to address the major criticisms with the existing system of commodity programs and deficiency payments in the U.S. (Chaherli and Babcock, 1995).

It is contended that the Arrow-Pratt absolute risk aversion coefficient (AP), defined as $-U''(x)/U'(x)$, has been reported in the literature without due consideration to the effect of the range and scale of the data on the coefficient. Scale of the outcome variable is affected by units of measurement (currencies, measures of pollution, etc...) and also inflation. Range of the outcome variable (ie. the magnitude of risk) is important because economic agents may differ in their attitudes towards small risks relative to large risks. Consequently, the magnitude of AP's conveys little information in the absence of a description of the stochastic distribution for which they are elicited.

Although agricultural economists appear to be well informed of the scale problem and Raskin and Cochran's (1986) theorems to adjust AP's for the scale of the data, the effect of the range of the data on AP's is less widely recognised and methodology for appropriately adjusting the AP has yet to be developed. This is highly evident in the literature where AP's are frequently reported with insufficient information to allow for appropriate adjustments for the range of the data; and previously elicited AP's have been employed in secondary studies without appropriate adjustment for the range of the data in the new study. To prove inappropriate comparison of AP's within a study or incorrect adjustment of AP's between studies is often impossible because adequate description of the stochastic income distributions is seldom reported. Two recent examples are, however, identified, which serve to confirm that informing economists of the effect of data range on AP's and developing methodology to adjust AP's for both the range and scale of the data are both important goals for research.

The specific objectives of this study are: a) to demonstrate the impacts of the scale and range of the data on AP's and to develop a methodology to standardise the expression of risk preferences, rendering it comparable across studies and utilisable in secondary studies without requiring prior adjustment; b) to elicit farmers' risk preferences and empirically analyse how risk characteristics affect revealed risk preferences; and c) to analyse the role of farmers' risk preferences in their soil conservation decisions from an economic perspective.

The analysis has six distinct features:

* it develops a conceptual framework of farmers' soil conservation decisions, based on the demand for soil conservation, within the expected utility framework;

* it develops an approach to adjust the Arrow-Pratt absolute risk aversion coefficient (AP) for both the scale and the range of the data;

* it uses a direct elicitation of utility (DEU) approach to elicit individual risk preferences over a series of hypothetical, dichotomous lotteries considered separately, systematically varying the level of monetary payoff to assess this effect on the pattern of revealed risk preferences;

* it analyses the distribution and structure of revealed risk preferences in the study population. Factors affecting revealed risk preferences are also examined;

* it assesses intra-field soil conservation efficiency of sugarcane farms through use of technological information specific to sugarcane farming. This provides scope for analysis of intra-farm variation in soil conservation efficiency and soil conservation decisions; and

* it uses micro-level data to test hypotheses regarding factors that affect sugarcane farmers' soil conservation decisions. Decisions are analysed in terms of soil conservation efficiency, and adoption of alternative soil conservation measures.

The analysis begins with a review of soil conservation models conceptualised in previous economic studies. Studies of both farmers' decisions to adopt soil conservation practices and those of farmers' achieved soil conservation efficiency are considered. A striking feature of these studies is that sound economic models are seldom conceptualised. The former set of studies usually conceptualize adoption of a soil conservation practices as a stimulus - response situation, where at or above a threshold level there is a response to adopt. Soil conservation efficiency models conceptualise soil conservation decisions as a psychological process starting with recognition of erosion, followed by a decision to adopt or not adopt soil conservation and the resultant consequences of the decision.

A sound economic framework for conceptualising soil conservation decisions in this study is provided by considering soil conservation measures as inputs in agricultural production, where the demand for these soil conservation measures is derived from the demand for the product. Accordingly, farmers adopt that bundle of soil conservation practices, and associated level of soil conservation efficiency, that maximises their expected utility. This framework is used to derive conceptual models for the analysis of both farmers' choices of soil conservation measures and their achieved soil conservation efficiency.

Because the research objectives require that farmers' attitudes towards risk be elicited, the analysis proceeds to consider measures of risk preference within the expected utility framework, in particular the Arrow-Pratt absolute risk aversion coefficient. Although some researchers (eg. Kachelmeier and Shehata, 1992) have adjusted measurements of risk preferences for the range of the data, these measures cannot be directly applied to stochastic efficiency techniques. From Pratt's (1964) derivation of the coefficient, it is demonstrated why the coefficient is sensitive to both the range and the scale of the data describing the risk situation. Examples of inappropriate reporting of AP's in previous research and inappropriate borrowing of AP's for use in secondary research are used to illustrate the significance of this finding. This result is further used to explain the difference between the relative risk aversion and Frisch coefficients.

Next, Raskin and Cochran's (1986) theorems are examined and an amendment is proposed to their first theorem to allow AP's to be adjusted for the range as well as the scale of the data. This amendment, although useful, is not ideal since not all risk situations may be described in monetary terms, for example health risks. Two approaches are subsequently suggested for reporting risk preferences: the first, similar to that proposed by Babcock *et al* (1993) entails adjusting the data to uniform range and scale prior to calculating an "adjusted absolute risk aversion" coefficient. This approach may be extended to multivariate utility analysis. The second approach, which is analogous to the first, requires reporting marginal utilities, normalised through expression as a percent of total utility, to provide a feel for risk preference.

A review of the empirical studies of farmers' soil conservation decisions and those eliciting farmers' risk preferences describes several aspects of problems encountered in past research. Despite considerable research, statistical results of the former branch of research are, without exception, poor, indicating that agricultural economists understand little about farmers' soil conservation decisions.

Despite consensus amongst authors of these studies that measures of soil conservation should be objective, reflect both effectiveness and extensiveness of whole farm achieved soil conservation, and allow for relative analysis; a striking feature of this body of literature is that soil conservation is measured differently in almost all studies. Despite progress, no measures have yet met all these criteria. Furthermore, these studies have all defined measures of whole farm soil conservation, neglecting potentially important information contained in intra-farm variations in soil conservation decisions.

New research should either attempt to improve on the previous approach, try a new approach, or, like this study, do both. Firstly, in this study, soil conservation efficiency is assessed over a unit of land, sufficiently small to be considered homogenous in both soil conservation adoption (the soil conservation measures used on that land) and soil conservation effort (the quality of soil conservation on that land). Information on intra-farm variations in soil conservation decisions, and hence extensiveness of whole farm soil conservation, is captured through multiple observations of soil conservation decisions from each farm. Secondly, soil conservation effort is objectively assessed relative to the requirements of the 1983 Act using technological information.

The review of empirical research on risk preferences reveals that several analytical methods have been developed to elicit risk preferences. The relative merits of each approach are discussed. It is demonstrated that failure to adjust AP's for the range of the data has caused problems for researchers when interpreting results of these studies. Most available literature indicates that a majority of farmers are risk averse, however, there is a wide range of risk preferences.

To relate the conceptual model of farmers' soil conservation decisions with what is known about their soil conservation decision-making environment and to evaluate the feasibility of implementing the model, chapter 4 provides information on the study population, soil conservation practices applicable to land under sugarcane, and soil conservation legislation in South Africa. This information was taken into account in specifying the research methodology.

To meet the empirical needs of the specified econometric models , a survey was developed eliciting farmers' risk preferences, soil conservation decisions and other data requirements. A direct elicitation of utility (DEU) through preset choices approach is employed to elicit farmers' risk preferences. Certainty equivalents are elicited for five hypothetical lotteries considered separately, systematically varying the level of monetary payoffs in order to assess this effect on revealed risk preferences. Information on adoption of soil conservation practices was elicited for both respondent's relatively steep and average gradient slopes for the land they operate to capture information on intra-farm variations in soil conservation decisions. Survey respondents were also asked their assessments of their own soil conservation to analyse farmers' abilities to assess soil conservation. A sample of 53 commercial sugarcane farmers from KwaZulu-Natal was surveyed by personal interview to provide data for the study. Principal components analyses and multiple regression techniques are used to analyse the data.

This thesis is organised into seven chapters. Chapter 2 presents a conceptual model of farmers' soil conservation decisions and develops an approach to adjusting AP's for both the scale and the range of the data. Chapter 3 reviews empirical evidence of each of the components considered in the conceptual framework. Chapter 4 describes the study population, soil conservation practices applicable to land under sugarcane, and soil conservation policy in South Africa. Chapter 5 presents the methodology used for assessing and analysing farmers' risk preferences and their soil conservation decisions, as well as the data collection process and descriptive statistics. The results of these analyses are reported and discussed in Chapter 6. Chapter 7 concludes by discussing implications of these findings for policy as well as for further research.

2. CONCEPTUAL MODELS

This chapter, much like most of the other chapters in this thesis, and for that matter this research, is divided into a section on farmers' risk preferences and another on farmers' soil conservation decisions. As explained in the previous chapter, these branches of research are connected through the research objective of determining the link(s), if any, between risk preferences and soil conservation decisions. Each of these sections requires separate conceptualisation, although within the same conceptual framework. Conceptual models describing farmers' soil conservation decisions and their risk preferences are presented in sections 2.1 and 2.2 respectively, both are contained within the expected utility framework.

2.1 A Conceptual Framework of Farmers' Soil Conservation Decisions

A striking feature of previous research on farmers' soil conservation decisions is that sound economic models of farmers' soil conservation decisions are seldom conceptualised. Section 2.1.1 presents a review and discussion of conceptual models used in previous economic research of farmers' soil conservation decisions.

The basic rationale for the conceptual exposition developed in this section is that soil conservation is an input in farming, and because soil conservation is achieved through the adoption of soil conservation practices, the demand for soil conservation practices is derived from the demand for the output, the production function and supply conditions of other factors. This is explored in section 2.1.2. Section 2.1.3 develops this description in formal terms within the expected utility framework. Soil conservation decisions are conceptualised in a model analogous to an input demand system. This model accounts for adoption of soil conservation technologies and interrelations between soil conservation technologies, the processes of implementing adoption decisions, and achieved soil conservation efficiency.

2.1.1 A Review of Soil Conservation Decision Studies

Soil conservation decision studies can be categorised as those analysing the adoption of soil conservation practices and those analysing achieved soil conservation effectiveness.

Adoption of Soil Conservation Practices.

Considerable research has been conducted on adoption of new technologies by agricultural producers. In general, these studies have focused on either a single technology or on a set of new technologies considered as a single unit. Adoption decisions are essentially conceptualised as stimulus - response situations where at or above a threshold level there is a response to adopt. The discrete nature of the decision and the varying nature of the threshold generate a non linear frequency distribution of the response. Bivariate probability models are used to analyse observed behaviour. Examples of soil conservation studies using this approach include Belknap and Saupe (1988), Rahm and Huffman (1984), Young and Shortel (1984), Van Vuuren *et al* (1995), and Traoré *et al* (1998). These models are best suited to understanding adoption rather than erosion control, since adoption does not necessarily correspond to effectiveness or extensiveness of use (Ervin and Ervin, 1982).

Formal derivation of these bivariate technology adoption probability models are derived in Rahm and Huffman (1984), from expected utility theory, and Featherstone and Goodwin (1993), from a present value decision model. Because a present value decision model only works well when anticipated costs and revenues from a prospective investment are relatively certain, and when sunk costs are reversible or insignificant (Purvis *et al*, 1995), and secondly, past research suggests that non pecuniary factors such as altruism (Colman, 1994), environmental quality (Bergstroom, 1989; Napier and Brown, 1993; Supalla *et al*, 1995 amongst others), peer pressure, or risk of prosecution for not meeting legislated requirements may significantly affect farmers' conservation decisions, it is argued that a conceptual model based on expected utility theory is more appropriate for the analysis of soil conservation decisions.

A shortcoming of these studies is that they treat adoption as a discrete phenomenon rather than a continuous one. Consequently, two farmers who have adopted a particular practice on ten and one hundred percent of their land respectively are considered to be equal adopters of that practice. Lee and Stewart (1983) demonstrated the use of a logit scale of the proportion of land units with that practice (in their case minimum tillage) adopted within a regression framework to elude this problem. Similarly, Featherstone and Goodwin (1993) used total annual expenditure on long-term conservation measures to provide a continuous measure approximating adoption of long-term soil conservation measures, which necessitated estimation using a simultaneous equations Tobit model.

A second criticism is that these studies usually fail to consider interrelationships between the adoption of different technologies, eg. van Vuuren *et al* (1995) considered six annual conservation practices independently of each other in bivariate logit models, and Featherstone and Goodwin (1993) aggregated expenditure across all long-term conservation investments. Soil conservation is achieved through the adoption of a set of soil practices and technologies which results in benefits of reduced soil erosion. This set, or bundle, of technologies is chosen not as a single input to be used or ignored but instead as one potential bundle out of which the producer could choose from some larger set of soil conservation technology bundles. Thus the adoption arena is an inherently multivariate one, and attempting univariate modelling excludes useful economic information contained in interrelated and simultaneous adoption decisions (Dorfman, 1996). The author is not aware of any research that has considered interrelationships between soil conservation practices.

Adoption of Soil Conservation *per se*

This second body of literature analyses the adoption of soil conservation as opposed to adoption of soil conservation technologies, eg. Ervin and Ervin (1982), Sindin and King (1990), Barlow and Nieuwoudt (1995) and Lynne *et al* (1988). The adoption decision is usually conceptualised as a process with three components: (1) antecedents (recognition of an erosion problem), (2) the adoption process (a decision whether or not to adopt soil conservation practice(s)), and (3) consequences (achieved soil conservation effectiveness). Separation into three (or more) stages serves to simplify the continuous and dynamic decision process (Sinden and King, 1990).

The second stage is conceptually equivalent to the soil conservation technology adoption studies considered in the previous section. Analysis of achieved conservation effectiveness, the third stage, is important if the ultimate goal of conservation policy is erosion reduction (Ervin and Ervin, 1982). A weakness of this body of literature is that a sound economic foundation to this conceptualization is predominantly absent.

The objective of these studies is to delineate significant determinants associated with adoption of a (bundle of) soil conservation practice(s). The adoption decision stages tend to be specified as functions of producer, physical, socio-economic, financial, and institutional characteristics. The three stages are usually estimated separately rather than sequentially or simultaneously because the final decision stage may occur a considerable period after the recognition stage and the separate effects of factors at each stage are usually of interest (Sinden and King, 1990). Definition and measurement of the dependent variables is uncertain, reflected in the lack of uniformity in their definition and measurement across these studies.

The two bodies of literature reviewed in this section both analyse farmers' soil conservation decisions. The first focuses on factors affecting the adoption of individual practices. The second focuses on the process of soil conservation decisions and consequently considers the adoption stage as an aggregate adoption of practices. If the ultimate goal of conservation policy is erosion reduction, then research must focus on achieved soil conservation efficiency and not technology adoption. Although the second approach is consequently more useful from a policy perspective, it however lacks sound economic foundation.

Based on the common point between the two categories of soil conservation studies, a theoretical link between the conceptual models is necessary to allow extension of the expected utility framework of the technology adoption studies to the process of soil conservation decisions. The next section considers the relationship between the demands for soil conservation and soil conservation practices as a bridge to this gap.

2.1.2 The Demand for Soil Conservation

A plausible model describing soil conservation decisions should, perhaps, begin by considering the demand for soil conservation to ensure a sound economic foundation. The link between demand for the product and demand for a factor of production is closest when the factor required is ridgedly and technically linked to the amount of product (Friedman, 1976: 153). Soil conservation is achieved through the adoption of soil conservation practices, ergo the demand for soil conservation practices is derived from the demand for the product. Although government legislation by way of the 1983 Act is designed to impose minimum constraints on the quantity of soil conservation demanded by farmers through imposing *ex ante* requirements enforced by *ex post* penalties, contraventions have been treated leniently (Adler, 1985; Maher quoted in Fitz-Gerald, 1996). Consequently, it is expected that government legislation has not played a large role in South African commercial sugarcane farmers' demands for soil conservation.

Demand for an uncertain outcome (soil conservation) depends on: (a) the farmer's subjective utility function of income, wealth, environmental quality and other attributes associated with soil conservation, eg. aesthetic appearance of land and compliance with laws;

(b) his subjective frequency distributions of future income, wealth and environmental quality; (c) the changes in these frequency distributions generated by the adoption of soil conservation technologie(s); (d) the cost of soil conservation; and (e) other factors and constraints to quantity of soil conservation demanded eg. competing uses for available resources and government enforced soil conservation requirements. The long term nature of implementing soil conservation decisions may constrain achieved soil conservation from equalling demanded soil conservation.

2.1.3 A Conceptual Model of Soil Conservation Decisions

The movement towards soil conservation is generally accomplished by the adoption of a combination of technologies which result in benefits of reduced soil erosion. This set of technologies is not chosen as a single input to be used or ignored but instead a one potential bundle out of many such bundles of soil conservation technologies which the producer could choose from some larger set. Thus the adoption decision is an inherently multivariate one, and attempting univariate modelling excludes useful economic information contained in interdependent and simultaneous adoption decisions.

Because soil conservation adoption and effort may vary within individual farms, soil conservation is defined specific to areas sufficiently small that adoption of a technology bundle may be represented as a discrete decision, resulting in the choice variable being of a qualitative nature. Extensiveness of whole farm soil conservation may be captured by recording multiple measurements for each farm. To capture the true nature of the decision process, all possible combinations of technology bundles of interest should be included in the decision set. If each technology bundle is thought of as a possible adoption decision by the farmer, the farmer will be expected to choose the one that maximises his expected utility.

Adoption of Soil Conservation Technology Bundles

The decision environment is represented in a probabilistic choice system (PCS). A PCS is defined in terms of a set of indexing alternatives, I; the finite choice sets from I, B; the measured and observed attributes of the alternatives, Z; and the measured and observed characteristics of the individuals, S. A utility function is assumed that accounts for a vector of probabilistic differences in tastes between individuals, μ, depending on $s \in S$. It is further assumed that variation in demand within the population is accounted for by differences in tastes between individuals. Through consideration of the cumulative density function of tastes in the population and application of the hypothesis of random utility maximization, a multivariate qualitative response probability model of individuals decisions may be derived. The choice probability $P(i|b,s)$ specifies the probability of choosing $i \in I$, given that a decision must be made from the choice set $b \in B$ and the decision maker has characteristics $s \in S$. A PCS is analogous to a conventional econometric specification of a demand system, with the functional specification of the demand structure and the distribution of errors combined to specify the distribution of demand (McFadden, 1981).

If B is the set of soil conservation technology bundles and K is a vector of constraints to adoption of B (eg. climate, suitability to sugarcane), then consider a choice set $b = \{0,1,...,m\} \in B$ of the soil conservation technology bundles available for intra-panel soil conservation on sugarcane panels within the population. By convention, technology bundle zero will represent adoption of none of the technologies being studied. Identification is accomplished relative to this technology bundle.

Alternative *i* has a column vector of observed attributes Z_i that describe and an associated utility $u_i = \alpha' Z_i$, where α is a vector of taste weights. Z_i describes both the distribution of net returns (both current and future) and other attributes (for example environmental quality and aesthetic appearance of the farm) to technology bundle *i*. Assume α to have a parametric probability distribution with parametric vector θ, and let $\beta = \beta(\theta)$ and $\Omega = \Omega(\theta)$ denote the mean and variance of α. Let $z_b = (z_1,...,z_m)$ denote the array of observed attributes of the available alternatives. Then the vector of utilities $u_b = (u_1,...,u_m)$ has a multivariate probability distribution with mean $\beta' z_b$ and covariance matrix $z'_b \Omega z_b$. Thus

$$U_i = \alpha' Z_i + e_i \qquad ...(2.1)$$

According to the random utility maximization hypothesis, choice is determined by maximising expected utility, ie. the individual adopts the *i*th technology bundle if $U_i \geq U_j$ for $j \in b$. The qualitative variable D_i indexes the decision: $D_i = 1$ if $U_i \geq U_j$ (the technology is adopted), and $D_i = 0$ if $U_i < U_j$ (the technology is not adopted).

The probability, $P(i|b,s)$, that D_i is equal to one can be expressed as a function of α:

$$\begin{aligned} P(i|b,s) &= P_r(D_i = 1) = P_r(U_i \geq U_j) \\ &= P_r(\alpha Z_i + e_i \geq \alpha Z_j + e_j) \\ &= P_r[e_i - e_j \geq \alpha(Z_j - Z_i)] \\ &= P_r(u_i \geq \alpha X_i) \\ &= F(\alpha X_i), \qquad ...(2.2) \end{aligned}$$

where $P_r(\bullet)$ is a probability function, u_{ij} is a random disturbance term, $D_i = Z_j - Z_i$ is a coefficient vector, and $F(\alpha X_i)$ is the cumulative distribution function F evaluated at αX_i. Thus the choice probability $P(i|b,s)$ for alternative *i* then equals the probability of drawing a vector u_b from this distribution such that $u_i \geq u_j$ for $j \in B$.

The vector of attributes z_i of an alternative in this formation is a function of the raw data (q,w_i,r,s) where (q,w_i) measure characteristics of the alternative and (r,s) characteristics of the individual and the background economic environment. Since any continuous utility function can be approximated on a compact set to any desired degree of accuracy by an appropriate linear specification, and z_i can incorporate complex transformations and interactions of the raw data, there is virtually no loss of generality in assuming the utility structure $u_i = \alpha' z_i$.

Adoption of Soil Conservation Technologies

If $n > 2$, ie. there is more than one technology (and hence greater than two technology bundles), analysis of adoption of technology bundles requires a multivariate analysis to consider possible interrelationships between adoption of different soil conservation practices. The issue of interrelated practices has important implications for statistical modelling in adoption studies. A multivariate qualitative response (QR) model specifies the joint probability distribution of two or more discrete dependant variables. Assuming that adoption of one soil conservation practice on a panel does not preclude or necessitate adoption of a different soil conservation practice on that same panel, the relationship between the number of soil conservation practices that may be adopted on that panel, s, and the number of possible soil conservation technology bundles that could be adopted on that panel, b, is provided by:

$$b = \sum_{i=1}^{n} \binom{n}{i} \qquad \text{...(2.3)}$$

For simplicity, consider n =2 (therefore b = 4): The joint distribution can be described by Table 2.1. where $P_{jk} = P(n_1 = j, n_2 = k)$, and $\Sigma P_{jk} = 1$.

Table 2.1 Joint distribution of two binary random variables.

	n_2	
n_1	0	1
0	P_{00}	P_{01}
1	P_{10}	P_{11}

(Amemiya, 1985: 311)

Then, assuming that each choice is made according to a binary probit model, $P(n_1 = 1) = \Phi(\beta'_1x)$ and $P(n_2 = 1) = \Phi(\beta'_2x)$. Having specified the probabilities of n_1 and n_2, the multivariate model is completed by specifying the joint probability $P(n_1 = 1, n_2 = 1)$, which in turn is determined if the joint distribution of n^*_1 and n^*_2 is specified. If it is assumed that they are jointly normal with a correlation coefficient ρ, then $P(s_1 = 1, s_2 = 1) = F_\rho(\beta'_1x,\beta'_2x)$, where F_ρ denotes the bivariate normal distribution function with zero means, unit variances, and correlation ρ.

The model conceptualised has thus far extended the soil conservation technology adoption model to a multivariate setting that accounts for interrelationships between soil conservation practices, including the process of adoption. The next section adapts the model to focus on achieved soil conservation instead of soil conservation technologies.

Adoption of Soil Conservation

Through assuming that all soil conservation practices are perceived by farmers to be essentially similar, the above multivariate QR model may be reduced to an ordered multinominal QR model for a single dependant variable, NPRAC, equal to the number of soil conservation practices adopted. If *n* is large, NPRAC may be assumed continuous, although bounded between zero (no soil conservation practices adopted) and *n* (all soil conservation practices adopted). NPRAC is a measurement of soil conservation adoption, similar to that used by Ervin and Ervin (1982).

If it is further assumed that farmers perceive soil conservation efficiency and other attributes achieved through adoption of any g, $g \le n$, soil conservation practices is equivalent to that achieved from adoption of g different soil conservation practices, then farmers' demand for soil conservation affects only the number of soil conservation practices which they adopt. Thus, NPRAC on the *j*th field of the *i*th farmer may be postulated to be a linear relationship of X_{ij} and a zero mean disturbance term, e_{ij}:

$$NPRAC_{ij} = X_{ij}\eta + e_{ij} \text{ ; s.t. } 0 \le NPRAC \le n \qquad ...(2.4)$$

The assumption that farmers perceive all technologies are similar is considered reasonable when, firstly, the primary attribute of all technologies is assumed to be soil conservation and secondly, all technology adoption decisions may be represented using dichotomous variables.

However, because soil conservation practices do vary in their contribution to soil conservation efficiency, the previous assumption is relaxed. Instead it is assumed that farmers can correctly assess achieved soil conservation efficiency, EFFORT, however other attributes are not important. This assumption is reasonable if soil conservation is the primary attribute of all soil conservation practices. Farmers will then adopt soil conservation practices due to their demand for soil conservation. Consequently, farmers' achieved soil conservation efficiency is postulated to be a linear relationship of X_{ij} and a zero mean disturbance term, e_{ij}:

$$EFFORT_{ij} = X_{ij}\nu + e_{ij} \qquad ...(2.5)$$

where EFFORT is a continuous measure of the *i*th farmers' soil conservation effort on his/her *j*th sugarcane field. Thus the demand for soil conservation is specified as a function of the attributes of soil conservation and the decision maker's tastes and decision making environments. This reflects that the demand for the final product is a joint demand for all the inputs.

2.1.4 Implications

This section developed a conceptual framework investigating farmers soil conservation decisions. The model is derived from expected utility theory and is analogous to a demand system for soil conservation and soil conservation technologies. It provides scope for analyses of interrelationships between soil conservation practices and of the adoption process.

This model does not reject the concept of a decision process conceptualised in studies such as those reviewed in section 2.1.1. It recognises that a change in decision may stem from any factor that affects the demand for soil conservation. For example, recognition of a soil conservation problem may affect the farmer's subjective relative price of soil loss; or increased environmental awareness is an example of a change in taste. Clearly, analysis of what causes change in awareness of perceptions is important, however such analysis falls within the domain of sociology and psychology rather than economics.

An advantage of this model is that it considers soil conservation decisions from adoption of technologies to adoption of soil conservation *per se* and the process of implementing adoption decisions. This provides scope for analysis of how factors affect soil conservation. The next chapter reviews empirical studies of farmers' soil conservation. This will provide insight to methodology required for analysis of soil conservation decisions. The focus of this chapter, however, now shifts to conceptualising a model of risk preferences.

2.2 A Conceptual Model for Risk Preferences Analysis

Most models of decision making under risk require knowledge of decision makers' risk preferences. This is true for both positive applications of risk theory that explain or predict behaviour under uncertainty for purposes of policy evaluation, and for normative approaches which advise decision makers which decisions they should make given their risk preferences. Risk aversion is a purely ordinal notation and is a property of risk preference analysis. Bernoulian models have been the mainstay of economic risk analyses and are based on the assumption that decision makers behave as if they maximise the mathematical expectation of utility, where utility is a function of the outcome variables and heuristics of the probability distributions. Hence, risk may be defined as a vector of variance, skewness, kurtosis and other higher moments of the probability distributions (Young, 1979; Buschena and Zilberman, 1994).

Expected utility (EU) models view decision making under risk as a choice between alternatives, each associated with probability distributions. Decision makers are assumed to have a preference ordering defined over the probability distribution for which the axioms of ordering, transitivity, continuity and independence are assumed to hold. Risky alternatives can be evaluated under these assumptions using the EU preference function (Buschena and Zilberman, 1994; Pope, 1982). The expected utility hypothesis (EUH) states that choices made under uncertainty are effected by the decision maker's preferences and expectations, and it provides a general decision rule - expected utility maximisation - which integrates information on these two factors to identify preferred choices (King and Robison, 1981).

Despite documented failings of expected utility and generalised expected utility frameworks (see Pope, 1982; Bar-Shira, 1992; Pratt, 1964; and Buschena and Zilberman, 1994, amongst others) both Pope (1982) and Robison (1982) concluded that EU is a useful, albeit not perfect, rational model of individual behaviour that describes a representative decision maker. Bar-Shira (1992) developed a nonparametric test of EUH but in most cases was unable to reject the hypothesis. He concluded that inconsistency with EU maximization is likely to be more common in laboratory experiments than in reality. This reflects the views of Pratt (1964). Most of the violations of expected utility hypothesis have been obtained with carefully planned experiments, thus it is unclear whether such violations should prohibit use of the expected utility hypothesis when studying real-world decisions (Bar-Shira *et al*, 1997). The general consensus from the literature is that EU is a good starting point for analysis under risk.

Section 2.2.1 discusses measurements of risk preference within the expected utility framework, concluding that the AP is appropriate, except that it is sensitive to both the scale and the range of the data. This chapter proceeds to develop an approach for adjusting the AP appropriately.

2.2.1 Measures of Risk Preferences

EU theory essentially defines risk aversion in terms of the concavity or convexity of the decision-maker's utility function at any particular point. Friedman and Savage (1948) showed that the local concavity or convexity of a von Neumann-Morgenstern utility function, u(x), indicates the local risk preference of the decision maker. A decision maker is described as locally risk averse, risk neutral or risk loving for a particular outcome level if $u''(x) <0, =0,$ or >0 respectively, where $u''(x)$ is the second derivative of $u(\bullet)$ with respect to outcomes (Machina, 1982). This measure merely indicates a decision makers risk preference, but is not an appropriate measure of risk aversion as $u''(x)$ is affected by linear transformations of x, and consequently its magnitude provides no insight into the severity of risk attitudes (Pratt, 1964).

Arrow (1974) and Pratt (1964) independently developed equivalent measures of risk preferences that allow for comparison of interpersonal preferences - the Arrow-Pratt absolute and relative risk aversion coefficients (r(x) or AP and RR respectively). Arrow developed them from the probability premium (Babcock *et al*, 1993), whilst Pratt worked from the risk premium (Pratt, 1964). A third and related measure of risk aversion, the partial risk aversion coefficient (PR), was developed by Menzes and Hansen (1970). These measures are invariant to positive linear transformations of x. A decision maker is defined a risk averse, risk neutral, or risk loving respectively if these measures are less than, equal to, or greater that zero (Menzes and Hansen, 1970; Pratt, 1964).

2.2.2 The Arrow-Pratt Absolute Risk Aversion Coefficient

The Arrow-Pratt absolute risk aversion coefficient (AP), defined as $-u''(x)/u'(x)$, has appeared extensively in the literature. Although AP's are invariant to linear transformations of U, they are not invariant to arbitrary rescalings of x or changes in the range of x, rendering AP's neither employable in secondary studies, nor comparable between studies without prior adjustment.

The impact of both scale and range on r(x) is perhaps best demonstrated using the initial work of Pratt. Pratt (1964, p.125) developed a relationship between the risk premium, the variance of the risky prospect and r(x) as being: $\prod(x,Y) = 0.5\sigma^2_Y r(x) + o(\sigma^2_Y)$, where $\prod(x,Y)$ is the risk premium given a level of wealth and a risky prospect Y, σ^2_Y is the variance of the risky prospect, r(x) is the AP at level of wealth x, and $o(\sigma^2_Y)$ are the higher order terms in the Taylor series expansion of the expected utility function around a mean of x. By rearranging the above expression to make r(x) the subject yields: $r(x) = 2[\prod(x,Y) - o(\sigma^2_Y)]/\sigma^2_Y$. Following Tsaing (1972), if the dispersion of the risk prospect is assumed small relative to wealth, then the term $o(\sigma^2_Y)/\sigma^2_Y$ may be neglected. Thus r(x) is approximately given by $r(x) \approx 2\prod(x,Y)/\sigma^2_Y$. (Note: this exposition is similar to that presented by McCarl and Bessler (1989) as part of their discussion on estimating an upper bound on the AP when the utility function is unknown).

These exact and approximate expressions of r(x) clearly indicate that r(x) is dependant upon both x and the risk situation, Y. Thus, the AP has associated with it a unit, the reciprocal of the unit with which Y is measured since the certainty equivalent is divided by the variance of Y. Because σ^2_Y and not E[Y] affects r(x), the magnitude of AP is not affected by the use of incremental rather than absolute returns, or *vice versa*. Furthermore, it is apparent that a change in σ^2_Y will affect r(x). For example, a mean preserving increase in risk, ie. σ^2_Y increases whilst x and the expected value of Y remain constant, will decrease r(x).

This discussion provides an explanation to McCarl's (1987) concern that if the magnitude of the AP is unaffected by use of incremental rather than absolute returns, as hypothesised by Raskin and Cochran (1986), then one could abandon the wealth concept and only look at income. Cochran and Raskin's (1987) reply agrees with McCarl, but writes off the anomaly as "an exercise in miscommunication" without explaining how AP's are a function of both initial wealth and stochastic income.

Given the sensitivity of AP to the scale of the data as well as the range of the data it is somewhat surprising that AP's have appeared in so many publications without also providing sufficient information about the source of the AP coefficients or the range and scale of stochastic wealth to allow comparisons with other studies (Cochran *et al*, 1985; Collender and Zilberman, 1985; Danok *et al*, 1980; Holt and Brandt, 1985; King & Oamek, 1983; King & Robison, 1981; King & Lybecker, 1983; Kramer & Pope, 1981; Lemieux *et al*, 1982; Love and Buccola, 1991; Love & Robison, 1984; Meyer, 1977; Rister *et al*, 1984; Tauer, 1985; Tauer, 1986; Wilson & Eidman, 1985; Ye and Yeh, 1995; Zacharias & Grube, 1984). A nonexaustive selection of reported values of AP's, many post Raskin and Cochran's (1986) paper, is presented in Table 2.2 to demonstrate the continued inconsistencies in magnitudes of elicited values.

Table 2.2. Arrow-Pratt absolute risk aversion coefficients elicited in previous studies.

STUDY	YEAR	VALUES OF AP ELICITED	
		ALMOST RISK NEUTRAL	STRONGLY RISK AVERSE
Dillon and Scandizzo	1978	-3.46	0.40
King and Robison	1981	-.001 to .0001	0.001
Collender and Zilberman	1985	.000000921	.000109
Cochran	1986		.0015
Tauer	1986	.0001 to .001	.001 to ∞
Antle	1987	mean of 3.272	
Preckel *et al*	1987	0.0000052	0.000037
Wiesensel and Schoney	1989	-.005	.005
Saha *et al*	1994	mean of 0.0075	
Oglethorp	1995	.000015	.000169
Torkamani and Hardaker	1996	.000001	.001
Bar-Shira *et al*	1997	mean of 0.0000045	

AP's are expressed in several studies to five decimal places (in one study to nine and in another to seven), and range from 12.17 (Chavas and Holdt, 1996) and 6.0 (Meyer, 1977) to .000000921 (Collender and Zilberman, 1985). Cochran (1986 p. 120) states "it appears reasonable to expect that the preferences of a majority of farmers will be represented with the interval -.0002 to .0015, when measured at after tax net farm annual income levels". However, Raskin and Cochran (1986) show that the relatively close values for AP of 0.0002 and 0.0003 yield a three fold difference on the marginal utility of the 10,001st dollar, and a 160 fold difference on the 50,001st dollar (Table 2, p. 206). Therefore, scale is very important.

Perhaps more surprising is the number of studies that have assumed AP values or used AP values from other studies as secondary data without adjusting appropriately for the scale and range of the data used in the primary study (eg. McSweeny and Kramer, 1986; Babcock *et al*, 1987; Lambert, 1990; Williams *et al*, 1993; Johnson and Foster, 1994; Backus *et al*, 1995 and Blakslee and Lone, 1995). Babcock *et al* (1993) provides a useful discussion on the need to consider the proportion of wealth at risk when selecting appropriate AP coefficients for examining the affect of risk preference on decisions. Subsequently, some researches (eg. Babcock and Hennessey, 1996) have selected AP's according to reasonable risk premia, whilst others (eg. Feuz *et al,* 1995) have been careful to compare elicited AP coefficients with those elicited for similar income distributions in previous research.

To prove that AP's are used incorrectly is impossible in most studies because information on the stochastic income distributions from which the AP's are elicited and applied tends to be inadequately provided. Nevertheless, two recent examples of misuse are identified: Botes *et al* (1994) and Simmons and Rambaldi (1997). The first study, which is reviewed in detail in the following chapter, compared AP's elicited for different stochastic income distributions according to their expected values and not the magnitudes of risk inferred by the distributions. As a consequence conclusions drawn on the structure of risk preferences within their study population may be incorrect. Simmons and Rambaldi (1997) adjusted average AP's elicited in Bond and Wonder (1980) according to the ratio of expected value of the stochastic income distribution of their study to those of the respective lotteries described in Bond and Wonder (1980). The procedure used is detailed on Simmons and Rambaldi (1997) p.164. Their calculated value was 9.633E-08. Section 2.2.5 indicates that AP's should instead be adjusted according to the ratio of standard deviations of the income distributions. Standard deviations of the lotteries in Bond and Wonder are easily calculated. If the distributions of wheat price and yield are assumed normally distributed and independent, then using data provided in Simmons and Rambaldi (1997) Table 1, p.163 it can be calculated that the standard deviation of expected income is $430857. The recalculated AP is equal to 3.484E-07: 3.6 times as large as that used by Simmons and Rambaldi (1997).

It is further noted that Simmons and Rambaldi (1997) calculated a n optimal hedging ratio of zero using their calculated AP but found that a ten fold increase in AP resulted in a hedge ratio of 0.81. This high level of sensitivity of their model to the assumed degree of risk aversion suggests that incorrect adjustment of AP's in this study had an important bearing on results and conclusions reached.

2.2.3 The Relative and Partial Risk Aversion Coefficients

The relative risk aversion coefficient, defined as x.r(x), is the elasticity of the marginal utility function and is unitless, however it is still susceptible to problems of marginal utility and returns being expressed in incommensurable units (Raskin and Cochran, 1986). The relative and partial risk aversion coefficients are more or less equivalent formulations of the same concept. Both are elasticities, and as such are unit free. The former measures the rate at which the utility of the outcome variable decreases with the level of that outcome variable, whilst the latter measures the same but is conditional on a given level of wealth (Bardsley and Harris, 1987). Consequently, the relative risk aversion coefficient is appropriate where both the stochastic (income) and non stochastic (initial wealth) components of wealth are changing proportionately, whereas the partial risk aversion coefficient is appropriate to describe situations in which initial wealth is fixed and income is variable (Bar-Shira *et al*, 1997).

2.2.4 The Frisch Coefficient

The Frisch coefficient, $\hat{w}$, is defined in equation (2.6) and is interpreted as the flexibility of the marginal utility of money (Frisch, 1959, p.183).

$$\hat{w} = (\delta w/\delta a)(a/w) \qquad ...(2.6)$$

where w = marginal utility of money, and

a = total expenditure.

Through mathematical manipulation of equation (2.6) Nieuwoudt and Hoag (1993) demonstrate that:

$\hat{w} = u''(y)/u'(y).a$, where y = money income,

$\therefore \hat{w} = -a$ (Arrow-Pratt absolute risk aversion coefficient)

$\therefore \hat{w} =$ -Arrow-Pratt relative risk aversion coefficient ...(2.7)

Equation (2.7) demonstrates that the Frisch coefficient and the Arrow-Pratt relative risk aversion coefficient are mathematically similar concepts. Both are elasticity concepts and both relate to the marginal utility of money. Further, Frisch coefficient values tend to range form -0.1 for the extremely wealthy to -10 for the extremely poor and apathetic, with -2 for the middle income bracket (Frisch, 1959), which is similar to Arrow's hypothesis that risk aversion is inversely related to wealth. However, risk preferences, and hence also risk aversion coefficients, are expected to change in response to a wealth preserving change in risk, whilst Frisch coefficient estimates for a population group tend to be similar across all commodities. This anomaly arises through failure to express risk preference measures as a function of the risk situation and emphasises the importance of providing sufficient information when reporting risk preferences.

2.2.5 Adjusting AP's for the Range and Scale of the Data

Raskin and Cochran (1986 p. 206) propose the theorem that if there is "a transformation of scale on x such that $w = x/c_1$, where c_1 is a constant,..then $r(w) = c_1 r(x)$," where r(x) = AP and x is the outcome variable. A second theorem (p. 207) shows that AP is unaltered by a shift of the range. Thus if $v = x + c_2$, where c_2 is a constant, then $r(v) = r(x)$.

The following demonstrates that theorem 1 requires that a transformation in either range or scale is independent of a shift in range. Consider a transformation such that $w = x/c_1$ that induces a shift in range such that $v = x + c_2$. From theorem 1, $r(w) = c_1 r(x)$, and $r(w) = c_3 r(v)$, where $c_1 = x/w$ and $c_3 = v/w = (x + c_2)/w$. Thus $(x/w)r(x) = ((x + c_2)/w)r(v)$. However, from theorem 2, $r(x) = r(v)$. This is true only if, $c_2 = 0$, which demonstrates that a transformation of range or scale must be independent of a shift in range.

The notion that range affects AP's is not new. Wiesensel and Schoney (1989), stated that AP's elicited for different income levels are not directly comparable. The notion that range affects AP's is also implied in McCarl and Bessler's (1989) approach to estimating an upper bound on AP when the utility function is unknown. Kachelmeier and Shehata (1992) suggested that risk preferences be measured as the ratio of the certainty equivalent to the expected value of the income distribution to permit comparison of risk preferences across lotteries of different range. Feinerman and Finkelshtain (1996) used a similar approach based on the probability premium. These approaches have a drawback in that results cannot be directly applied to some stochastic efficiency techniques, eg mean-variance programming models and stochastic dominance with respect to a function. Babcock *et al* (1993) also note that when the range of wealth distributions varies the risk premium, expressed as a proportion of gamble size (amount of wealth at risk), and the probability premium convey more information on risk preferences than does the AP. Consequently, they advocate consideration of these measures when selecting AP coefficients to demonstrate the effects of risk preferences on decisions. However, it is apparent from the range of AP's elicited, borrowed and assumed, even in recent studies, that many agricultural economists are unaware of the impact of range on AP's.

Section 2.2.2 indicated that AP's are not affected by the use of incremental rather than absolute returns, which suggests that theorem 2 in Raskin and Cochran (1986) is correct. However, it also demonstrates that σ^2_Y and not E[Y] affects r(x). Consequently, the conversion factor, c, in theorem 1 should be related to the standard deviations of x and w, rather than their expected values. Hence in theorem 1, an amendment is proposed that c_1 should equal σ_x/σ_w rather that x/w. Raskin and Cochran's first theorem may be applied if $\sigma_x/x = \sigma_w/w$, which is true for all scale transformations but is not necessarily true for range transformations.

Despite this suggested amendment to Raskin and Cochran's first theorem, not all risk situations may easily be adjusted to be represented in terms of dollar income or wealth to enable comparison and analysis, for example environmental risks. An approach is suggested entailing standardisation of the data to uniform scale and range prior to calculating an "adjusted Arrow-Pratt absolute risk aversion coefficient" (λ^*). For example, the negative exponential utility function, $U(x) = -\exp\{-\lambda x\}$, is assumed for simplicity since it has a constant AP = λ, and the distribution ($x_{min} \leq x \leq x_{max}$) is converted into a distribution ($0 \leq x^* \leq 1$) where x_{min} and x_{max} are the minimum and maximum values on the x-scale.

Let $\quad x^* = (x-x_{min})/(x_{max} - x_{min})$

$\therefore x = x_{min} + x^*(x_{max} - x_{min})$

where $\quad U(x) = -e^{-\lambda x}$ and $U(x^*) = -e^{-\lambda^* x^*}$

$$\therefore \lambda^* = \lambda(x_{max} - x_{min}) \text{ since } \lambda x_{min} = \text{constant} \qquad ...(2.8)$$

(Nieuwoudt and Hoag, 1993)

This simple transformation to equation (2.8) provides a unitless expression of the absolute risk aversion function, λ^*, by multiplying AP, λ, by the range of x. Clearly, changes in both the range and the scale of the data are accounted for. λ^* coefficients should then be reported with details of the risk situation and population characteristics, including wealth, for which they were elicited. Then, these local properties may be used to derive global properties of risk preferences for populations. Researchers will then be able to select appropriate λ^* coefficients for secondary studies or the interval approach to eliciting risk preferences, and through knowledge of the new risk situation, may calculate appropriate λ coefficients.

This approach may be extended to multivariate utility analysis. For example, the bivariate negative exponential utility function, $U(x,y) = -\exp\{-\lambda x\} - \exp\{-\theta y\}$ is standardised according to $x^* = (x - x_{min})/(x_{max} - x_{min})$ and $y^* = (y - y_{min})/(y_{max} - y_{min})$ to yield $U^*(x^*,y^*) = -\exp\{-\lambda^* x^*\} - c.\exp\{-\theta^* y^*\}$, where λ^* and θ^* are the adjusted-AP's with respect to x and y, and $c = \exp\{-\theta[x_{min}]\} / \exp\{-\lambda[y_{min}]\}$ (a constant). For example, it may be applied to environmental analyses where, say, both wealth and environmental risks may be important. Elicited values are consistent with the absolute risk aversion matrix, R, derived by Duncan (1977) (cited by Jeffrey and Eidman (1991) and defined by:

$$R = \left[-\frac{U_{ij}}{U_i} \right] = \frac{-\delta U(x)/\delta x_i \delta x_j}{\delta U(x)/\delta x_i}, \qquad \forall\ i,j = 1,2,\ldots,n \quad x = (X_1, X_2, \ldots, X_n)$$

R provides a complete representation of an agent's risk preferences for multiple attributes that is consistent with the Arrow-Pratt absolute risk aversion coefficient. The diagonal elements represent the agents absolute risk attitudes with respect to the *i*th risky attribute. The off-diagonal elements represent the agents attitudes towards risks involving pairs of attributes. In the multivariate case, the risk premium is a function of all elements in the ith row of R and the appropriate probability distributions. The general condition have not yet been established that allow analysis to predict multivariate risk-averse or risk-preferring behaviour based on the structure of R. However, If utility is additive (ie. $U(x_1, x_2, ...,x_n) = \Sigma U_i(x_i)$) the off-diagonal elements of R are all zero and R is a diagonal matrix. Given this, the approximate risk premium for the *i*th element is a function of the *i*th diagonal element of R and the variance and higher orders of the probability distribution. Alternatively, if the attributes are statistically independent then the covariances are zero and off-diagonal elements do not impact on the risk aversion coefficient. The multivariate approach has been extended to permit application of multivariate stochastic dominance techniques (Jeffrey and Eidman, 1991).

2.2.6 Marginal Utilities and Risk Preferences

Marginal utilities describe the choice situation and may be an answer to King's (1986) concern that a major problem with using stochastic dominance with respect to a function (SDWRF) is establishing an appropriate scale for measuring the absolute risk aversion. Table 2 in Raskin and Cochran (1986, p.206) shows that as the range of a risk situation increases, if the AP is held constant the marginal utility changes and *vice versa*. Thus reporting MU's provides a plausible feel for absolute risk aversion (Nieuwoudt and Hoag, 1993).

It may be instructive that the marginal utilities, used as weights, be reported for SDWRF studies. This may provide other researchers with some information about the choice situation. As shown in Table 2.3, marginal utility can be normalized, through expression as a percent of total utility, to show the weight of a change in x. This is equivalent to adjusting x to a unit distribution considered in the previous section. It is evident that relatively more risk averse agents attach a greater (lower) weight to outcomes in the left (right) side of the distribution, demonstrating decreasing marginal utility of the outcome variable under risk, which characterises risk aversion.

Table 2.3 Risk preference weights[1] on outcome x for a range of risk preferences.

x	$\lambda^* = 0.8$	$\lambda^* = 1.8$	$\lambda^* = 2.4$	$\lambda^* = 3.3$
0.0 to 0.1	14.08	19.74	23.72	29.07
0.1 to 0.2	12.97	16.48	18.58	20.94
0.2 to 0.3	11.95	13.78	14.56	15.08
0.3 to 0.4	11.00	11.50	11.40	10.86
0.4 to 0.5	10.13	9.60	9.09	7.82
0.5 to 0.6	9.34	8.03	6.86	5.63
0.6 to 0.7	8.60	6.70	5.49	4.06
0.7 to 0.8	7.93	5.59	4.30	2.92
0.8 to 0.9	7.28	4.68	3.37	2.10
0.9 to 1.0	6.72	3.90	2.64	1.52

[1] (Marginal utility/sum of marginal utility)(100) for $u(x) = -e^{-\lambda x}$

For instance, an agent with a certainty equivalent of 30 percent of the gamble range has an absolute risk aversion coefficient equal to $\lambda^* = 1.8$ when the data are scaled from zero to one. This assigns a weight of 19.74 to a unit on the 0% to 10% left extreme side of the outcome distribution and a weight of 3.9 to a unit on the 90% to 100% right extreme side. The area between two cumulative distribution functions (CDF's) to the right of a crossing must thus be considerably larger than the area to the left of the crossing, for the right side area to outweigh the left side area.

2.2.7 Summary and Implications

Whilst Raskin and Cochran (1986) have successfully made agricultural economists aware of the effect of the scale of the data on the AP, many still seem unaware of the effect of range. This discussion has focused on the abilities of the AP to convey information about risk aversion assumptions or measurements in research programs. It is shown that an amendment is necessary to Raskin and Cochran's first theorem if AP's are to be adjusted for the range as well as the scale of the data. It is imperative that sufficient information regarding the risk situation and the population are reported with elicited risk preferences.

Further, it appears important that risk preferences should be reported in a consistent manner such that studies can easily be compared to one another. It is shown that rescaling the data to a range of $0 < X^* < 1$ prior to calculating AP's, provides measures that can be compared across studies, even where the risk situation cannot be easily described in monetary terms.

This result may give an explanation for empirical findings regarding the magnitudes and structure of risk preferences of previous research, which is reviewed in second section of the next chapter. In the first section of chapter 3, however, the focus of this thesis returns to soil conservation, where empirical evidence from previous research of the impact of risk preferences and other factors on farmers soil conservation decisions is reviewed.

3. LITERATURE REVIEW

This chapter presents a review of those studies providing empirical insights into the issues raised in attempts to evaluate both factors affecting farmers' soil conservation decisions and the elicitation and analysis of farmers' risk preferences. The body of literature pertaining to soil conservation decisions is considered first in section 3.1, followed by that studying risk preferences in section 3.2.

3.1 A Review of Soil Conservation Decision Research.

Studies of farmers' technology adoption decisions have developed along two main branches. The first branch of the literature, reviewed in section 3.1.1, is concerned with empirical identification of the factors of characteristics correlated with adoption decisions and/or conduct analyses of factors affecting farmers' decisions using micro farm-level data. The current study belongs to this branch. The second branch concerns itself with building models of economic decision units faced with the possibility if adopting a new technology. Economic theory is employed to derive theoretical results predicting the qualitative effect of factors such as farm size, liquidity constraints, and risk attitudes on the decision to adopt or not adopt the technology. A non exhaustive selection of the empirical research in trying to understand farmers' soil conservation decisions from this branch is reviewed in section 3.1.2.

As far as this author is aware, Barlow (1995), is the only recent South African study of soil conservation from an economic perspective. Therefore, the present research has relied predominantly on soil conservation studies completed in the United States (U.S.).

3.1.1 Behavioural Economic Studies of Soil Conservation Decisions

The objective of these studies is to delineate significant determinants associated with adoption of (a bundle of) soil conservation (practices). Where adoption is conceptualized as a process, the stages of adoption are usually estimated separately rather than sequentially or simultaneously because the final decision stage may occur a considerable period after the recognition stage and the separate effects of factors at each stage are usually of interest (Sinden and King, 1990). The adoption decision stages tend to be specified as functions of producer, physical, socio-economic, financial, and institutional characteristics. Sociological and economic arguments are used to hypothesise relationships between these variables and adoption of conservation structures. Besides consideration of farmers' risk preferences, this discussion shall focus on how the dependant variables are defined, the empirical methodologies used in these studies, and the empirical results obtained.

Although the conceptual model developed in section 2.1 of the previous chapter integrated the demand for soil conservation technologies with the demand for soil conservation to describe farmers' soil conservation decisions, previous research has treated these areas of research separately. Consequently, literature reviewed from these branches of research are presented in separate subsections: studies analysing soil conservation technology adoption are considered next, followed by studies of soil conservation adoption in the following section.

Soil Conservation Technology Adoption Studies

Bultena and Hoiberg (1983) compared personal attributes of farm operators, farm characteristics, attitudinal orientation of the farmer, and the potential for soil erosion among early, late and non adopters of conservation tillage in Iowa. Farmers' risk preferences were captured from a four item scale that measured propensity to risk taking. Results indicate that older farmers and risk averse farmers are less likely to adopt minimum tillage. Farmers' perceptions of local acceptance and adoption of minimum tillage was found to be important, however, this may also approximate economic feasibility of adoption for the farming area.

Lee and Stewart (1983) analysed the relationship between landownership and the adoption of minimum tillage by cropland farmers during 1977-78 using a sample of 7649 farmers from across the U.S. An interesting feature of this study is the approach to model the explanatory variables using a logit scale in a linear model. Use of a logit scale allowed the dependant variable to reflect both adoption and extensiveness of adoption of minimum tillage on the landholdings, an improvement over earlier studies of technology adoption. Results indicated regional effects are most important in explaining adoption of minimum tillage; small operating size impedes adoption of minimum tillage more than separation of farm ownership from operation; and that adoption of minimum tillage is more likely on less erosive land, suggesting that soil conservation may be a secondary motivation in the adoption of minimum tillage.

Young and Shortel (1984) used a bivariate probability model to examine factors influencing adoption decisions of soil conservation structures using a sample of 14600 U.S.

farmers. They hypothesised that factors affecting adoption of non-structural practices will also affect the adoption of structural practices. A farmer was defined as an adopter if (s)he had invested in a soil conservation structure between 1975 and 1977. The estimated model showed poor fit of the data. Results indicate that younger male farmers with more education are more likely to adopt soil conservation structures; there is an inverse relationship between land rented out and conservation investments, although this relationship is offset when share leases are used; and investment in other land improving measures are positively related to investment in soil conservation structures, implying that land improvements are likely to be installed as a package.

Rahm and Huffman (1984) presented a model of adoption behaviour founded on maximisation of expected utility, from which they derived a probability of adoption model. They defined efficiency of adoption to be the difference between actual adoption and the estimated probability of adoption. Crossectional microdata from a survey of Iowa farms was used to explain differences in Iowa farmers' adoption of reduced tillage. The dichotomous definition of adoption of reduced tillage used fails to provide information on the extensiveness of adoption. Human capital variables were excluded from the probability of adoption model since adoption is not always feasible, but were included in an efficiency of adoption model since they are expected to increases the probability of farmers making the economically "correct" decision. Probit and linear regression techniques were used to estimate the two stage adoption model. Estimated equations showed poor fit of the data (R^2 statistics = 0.18 and 0.05). Results showed that the probability of adopting minimum tillage depends on soil characteristics, cropping systems and size of farming operation. Further, farmers' schooling enhances the efficiency of the adoption decision.

Norris and Batie (1987) noted that attributes other than soil conserving properties of soil conservation practices may affect adoption decisions. To examine this, their analysis consisted of two tobit models, the first modelling soil conservation effort, measured as farm expenditure on soil conservation (including maintenance and opportunity costs), and the second modelling adoption of minimum tillage measured as total acres planted under minimum tillage. These variables do not allow for analysis of the relative factors affecting these decisions, reflected in the result that farm size and farm income were found to be the most important explanatory variables.

Belknap and Saupe (1988) used maximum likelihood to estimate a probit model relating variables to the probability that a farm operator used conservation tillage using crossectional data from 529 randomly selected Wisconsin farmers. Farmers were defined as having adopted conservation tillage if conservation tillage was used on part of the farm. Independent variables were classified as being physical characteristics of the farm, farm business characteristics and human resource characteristics. Unlike Rahm and Huffman (1984), human capital variables were included in the adoption model to approximate psychological costs of adoption, attitudes and management objectives. Farmers' risk preferences were calculated from an index of their responses to questions on their attitudes towards risk. Results indicate that more risk averse farmers and those less aware of the damage of erosion on land values and crop productivity are less likely to adopt the use of no-plow tillage; adoption is more likely on larger farms and is less likely on rented land, steeper slopes and areas with cooler or wetter climates.

The next study, Gould *et al* (1989), also analysed the adoption of conservation tillage by 12240 farmers in southwest Wisconsin. Following Ervin and Ervin (1982) the adoption decision was conceptualised as a process in which farmers only consider adoption if they are aware of an erosion problem. The first stage of the analysis examined factors that influence farmers' level of awareness of soil erosion as a problem facing the agricultural sector. This was elicited by asking farmers whether they agreed with the statement, "Soil erosion is an important problem in this area." Responses were captured as a dichotomous variable equal to one if the respondent strongly agreed, otherwise zero. This was analysed in a probit model. The estimates model had a correct classification of 65 percent and revealed that farmers who have smaller farms, steeper soils, greater education, more experience, farm training, contact with soil conservation service personnel, and those who plan to continue farming full are likely to be more aware.

The second stage of the analysis used a model of conservation tillage adoption based on a Tobit model, where the dependent variable was defined as the proportion of planted acreage under conservation tillage and, thus, represented both adoption and extensiveness of adoption of conservation tillage. Results show that adoption of conservation tillage is greater on larger farms with dry and cold climates. Farm type also affected adoption according to expectations. Younger farmers with greater income and education and who are aware of erosion problems and spend less time in off farm employment and expect their farm to remain in their family also adopt more minimum tillage.

Van Vuuren *et al* (1995) used logistic regression analysis to determine what impact tenant, contract and land characteristics have on adoption of farm practices that enhance productivity and environmental husbandry on rented land. Six annual practices, including no-till planting, strip cropping and contour farming (all soil conservation practices), and five intermittent practices, including surface run-off control structures, were considered. Estimated equations tended to have poor statistical fit of the data but revealed that contract terms play an important role in promoting environmental husbandry on rented land. A disappointing feature of this study is that interrelationships between adoption of the different practices were not considered.

Most recently Traoré *et al* (1998) studied the adoption of conservation practices (conservation tillage and reduced chemical usage) by 82 Quebec potato farmers. They conceptualised adoption to be a two-stage decision process: awareness of environmental degradation is a precedent to adoption of conservation practices. Both awareness and adoption are captured in dummy variables (hence extents of awareness and conservation adoption are not captured) and analysed in models specified as logit models but referred to throughout as probit models. Predicted environmental awareness was included as an explanatory variable of adoption of conservation practices. The fit of the estimated models is poor (McFadden's R^2 statistics of 0.16 and 0.08 were achieved) but considered reasonable by the authors. Results indicate that awareness of environmental problems is raised by the level of education attainment, membership in producers' organisations, and participation in government sponsored farm programmes. The adoption of conservation practices by farmers was found to be positively influenced by the extent to which they [are predicted to] perceive environmental degradation to be a problem, their education level, and the availability of information on best management practices and negatively influenced by the expected crop loss to pests and weeds, and the perceived health threat of farm chemicals. It was concluded that policies promoting awareness of environmental degradation are important for encouraging adoption of conservation practices on potato farms.

Soil Conservation Adoption Studies

Ervin and Ervin (1982) was the first study to describe soil conservation decisions as a multi-stage process. They analysed data from a sample of 92 farmers in Missouri. Soil conservation was conceptualised as being determined by the following three stages: recognition of the erosion problem; the number of conservation practices adopted; and conservation effort reflecting effectiveness and extensiveness of practices adopted. This study was also the first behavioural study to consider risk preferences as determinants of soil conservation decisions. The survey incorporated a certainty equivalent approach to eliciting farmers' risk preferences, however, enumerator error caused the results to be questionable. A risk aversion index, constructed from responses to questions about the farmers' strength of preference for avoiding a risky situation, was used instead.

Conservation adoption was defined as the number of soil conservation technologies adopted on the farm (NPRAC). The authors noted that measurement of soil conservation effort presented measurement problems. The authors suggested use of total capital expenditure on soil conservation, however, the required data were not collected. The approach used defines effort as the reduction in soil erosion rates attributable to adoption of soil conservation practices. A problem with this definition is that a reduction of erosion by say two tonnes/ha on less erosive land may require more effort than reduction of erosion by four tonnes/ha on highly erosive land (Lockertz, 1991).

Multiple regression analysis was used to test hypothesised relationships. Statistical fit of the estimated equations to the data is poor with R^2 statistics all lower than or equal to 0.31. Results showed that NPRAC is positively influenced by education and farmers' perception of an erosion problem, and negatively related to farmer's age, degree of risk aversion and less likely on cash grain farms. Correlation analysis suggested that relatively more risk averse farmers are less likely to adopt long term conservation investments, but equally likely to adopt annual soil conservation practices. Effort is positively related to farm erosion potential (possibly reflecting definition of the dependant variable), farmer's education, perceptions of an erosion problem, and subsidy and cost sharing arrangements. Risk aversion was positively, but not significantly, related to effort.

The researchers concluded that soil conservation programmes should target homogenous groups of farmers according to their specific conservation needs. For example, while younger farmers need financial assistance, older farmers require technical advice and education programmes to promote awareness of erosion problems.

The next study, Saliba and Bromley (1986), defined conservation effort in terms of the universal soil loss equation. C is the ratio of soil loss from a slope under specific annual practices (eg, crop rotation, method of tillage) to that of an identical slope clean tilled continuous fallow, providing a measure of soil conservation effort attributable to annual management practices. P is a similar ratio that provides a measure of soil conservation attributable to long term conservation investments (eg. contouring, terracing and stripcropping). PxC provides a measure of soil conservation effort defined as the proportionate reduction in soil loss attributable to adoption of management practices.

Multiple regression techniques were used to estimate conservation effort, using a logit transformation of the dependent variables to ensure that predicted values will fall between 0 and 1. Results of the estimated equations show improvement relative to the effort equation of Ervin and Ervin (1982), indicated by R^2 statistics of 0.28, 0.33 and 0.58 for the C, P and CxP models respectively. Farm type, location and land characteristics variables predominantly accounted for the explained variation, although results show that income (debt) is positively (negatively) related to adoption of long term (annual) conservation investments, and farmers' beliefs about the effect of erosion on crop yields (land values) does (do not) affect their decisions.

Following a review of the literature Lynne *et al* (1988) concluded that agents' attitudes, values beliefs, and intentions are important determinants of their economic decisions. Consequently, they consider the decision making process to be a cohesive conceptual framework linking psychological process to economic decisions, ie. social situational factors, attitudes and social norms influence behavioural intentions and subsequently behaviour. This framework was used to analyse soil conservation decisions of 103 farmers in Florida, U.S. Like Ervin and Ervin (1982), the authors expressed desire to measure conservation effort in terms of expenditure on soil conservation, but data were not available. Consequently the number of practices adopted was used (similar to Ervin and Ervin's measurement of conservation adoption.) The independent variables encompassed both attitudes and beliefs regarding conservation, willingness to take responsibility for erosion externalities, and the general belief of being capable; tenure variables; values about profitability, the future and farming as a way of life; risk preferences (a qualitative variable coded 1 , 2, 3, or 4); income; credit; and a soil erodibility index.

A Tobit model was used for the analysis to recognise that this dependent variable takes on discrete values and has a lower bound of zero. Results suggest that the model has strong representation of behaviour in the sample, and indicate that conservation adoption is positively related to landownership, positive attitudes towards conservation, willingness to take responsibility for externalities, aversion to risk and soil erodibility; but negatively related to a belief in ability, value of profits, and after tax net farm income. Lynne *et al* (1988) conclude that consideration of psychology shows promise for the improvement of economic models of conservation behaviour.

Sinden and King's (1990) analysis of soil conservation by farmers in New South Wales, Australia, conceptualised a similar model of decision making to that of Saliba and Bromley (1986): Farmers' perception of the erosion status of the land depends on exogenous land characteristics and the farmer's personal characteristics; recognition of an erosion problem worth solving rests on their perception of land conditions, economic factors and the farmer's motivation to address the problem; and the decision to undertake conservation measures (FIXIT) rests on the perception and recognition stages and also institutional factors. FIXIT was defined as a binary variable equal to one if the farmer adopts soil conservation measures, otherwise zero. Logistic regression techniques were used to analyse the hypothesised model. Results show that economic constraints primarily prevent farmers from addressing erosion problems.

Featherstone and Goodwin (1993) analysed adoption of long term conservation improvements by 541 Kansas farmers. They conceptualised farmers' decisions as maximising their net present value, subject to constraints. This model was empirically represented using a simultaneous equations Tobit model to explicitly recognise that many of the variables that conceptually influence conservation investment, such as government payment receipts, net farm income, debt, and total crop and non crop acreage, are jointly determined with investment. Unlike Young and Shortel (1984) who defined investment in soil conservation using a dichotomous variable, Featherstone and Goodwin used total expenditures on long term conservation measures to provide a continuous approximation of adoption. However, despite having reviewed both Norris and Batie (1987) and Gould *et al* (1989) (the latter study comments on the advantage of relative analysis) investment expenditure was defined on a farm and not per acre basis. Consequently results are similar to those of Norris and Batie (1987) showing positive relationships between investment in soil conservation and farm size, farm income, farm debt, total assets and corporate ownership. Results must, therefore, be interpreted with caution.

The only recent economic analysis of South African farmers' soil conservation decisions, Barlow (1995), conceptualised a multi-stage process of soil conservation decisions. This process is commenced with awareness of the occurrence of erosion, followed by the perception that the erosion problem is worth solving. Subsequent decisions to adopt are analysed in terms of conservation adoption and conservation effort (similar to Ervin and Ervin, 1982).

Farmers' perceptions of their technical and financial abilities to effectively implement conservation measures were also analysed. Conservation adoption was defined as the ratio of the number of different types of soil conservation practices used on the farm to the maximum applicable for a particular farm enterprise mix, and was analysed using logistic regression techniques. Conservation effort was defined in terms of logarithmic transformation of farmers' own assessment of the percentages of their land protected with soil conservation practices and was analysed using linear regression techniques. This variable, perhaps, represents conservation extensiveness rather than efficiency of whole farm soil conservation.

Results show that conservation adoption is positively related to the farmer's technical abilities to implement soil conservation measures, farmers' willingness to invest his own capital in conservation, awareness of erosion's adverse impacts for productivity and visible erosion impacts. Conservation effort is primarily dependent on financial factors.

3.1.2 Economic Models of Soil Conservation Decisions

Burt (1981) applied control theory to study the economics of soil conservation in the Palouse area. He used a dynamic programming model to maximise the net present value of net returns over an infinite planning horizon. His results indicate that, firstly, high product prices exacerbate soil erosion problems and, secondly, that intensive wheat farming is the optimal choice in both the intermediate and long run despite greater soil loss from this option. This latter result is attributed to the extremely deep soil mantle of the Palouse region, thus the conclusion cannot be extrapolated to other areas, especially those with shallow soils. This study is important because it illustrates potential differences in optimal soil conservation decisions from farm level and social perspectives because some costs of soil loss are external to the farm.

Kramer *et al* (1983) recognised that a profit maximising objective does not necessarily represent farmers' decision objectives. Consequently they used a systematic quadratic risk programming model that included simultaneous consideration of uncertainty in both revenues and input supplies to study the influence of risk on farm level soil conservation decisions in southeast Virginia. The model maximised expected utility as a function of net returns less a risk premium.

Risk was incorporated using the variance-covariance matrices of returns based on average product prices paid to farmers over a thirty-one year period (1949-79) and adjusted for variance created by technological change. A variance-covariance matrix of available field hours for the same time period was included to approximate uncertainty in input supplies. Although not explicitly stated, the derivation of expected utility from a negative exponential utility function into a function of expected returns and variance of returns implies that the risk aversion coefficients used are the Arrow-Pratt absolute risk aversion coefficient. Values used ranged from 0.0 (risk neutrality) to a level of risk aversion of 0.002, however justification for this range of values is not provided.

Results indicate that risk aversion influences optimal production decisions, with implications for soil loss: forced reductions in soil loss generated substantial cuts in income that are directly related to the level of risk aversion; and the degree of risk aversion was found to influence the means by which erosion reductions were achieved. They concluded that uncertainty warrants further attention in future erosion control studies.

McSweeny and Kramer (1986) extended Kramer *et al*'s study to incorporate a government programme of cross compliance within the risk framework. The risk-reducing potential of government price and income support programs, as well as crop insurance, were explicitly recognised. Arrow-Pratt absolute risk aversion coefficients used were selected from a range of -0.0001 to 0.001 prescribed by King and Robison (but not adjusted for the range of the data). Notable differences were found across both different policies and different levels of risk aversion. Results suggest that cross-compliance might prove useful in inducing risk averse producers to adopt soil and nutrient loss control programmes. Important aspects of this study are the inclusion of options of endogenous risk reduction and that an effort was made to incorporate appropriate representation of farmers' risk preferences. A weakness of the last two studies is failure to consider on-farm costs of soil loss.

The next body of work, Klemme (1985), used stochastic dominance criteria to rank methods of tillage (conventional, minimum, till-plant and no-till technologies) in corn and soybean production under assumptions of risk. Cumulative probability distributions of net returns to each technology were calculated using the Indiana experiment plot yield data. An initial data analysis revealed that average net returns to land were lower for no-till relative to the other three systems, however, standard deviations were also lower. Results indicate that first-degree stochastic dominance does not exist in either corn or soybean production with respect to method of tillage when soil loss is ignored, with the exception of conventional tillage over no-till in rotation. Risk averse farmers who place low values on soil loss may select tillage intensive systems since they are generally stochastically dominant over no-till in the production of wheat and soybeans. Stochastic dominance rankings were affected towards favouring reduced tillage practices through the introduction of on farm costs of soil loss.

An expected value-variance framework was used by Tew *et al* (1986) to assess the risk efficiency of alternative tillage practices for irrigated corn production using data from an experimental site in Colorado. Three tillage systems were considered: conventional tillage, conservation tillage and minimum tillage. Two levels of herbicide application were applied to each tillage system, and irrigation was applied using high and low pressure delivery systems providing 12 production systems in total. The efficient set theorem, an extension of expected utility theory, was used to provide a criterion for choosing risk efficient alternatives from those considered in the analysis. Only those systems that included conservation or conventional tillage practices proved risk efficient. A criticism of this study is that it failed to consider the on-farm costs of soil loss.

Finally, Setia and Johnson (1988) used expected utility maximisation and safety-first decision criteria to analyse the effect of uncertainty on soil conservation systems for corn and soybeans in Illinois. Stochastic elements of the model represent variability in net returns from price and yield fluctuations. The models were estimated over a range of risk preferences, represented by confidence levels that a goal will be achieved. Hence a confidence interval of 50% (99%) implies risk neutrality (extreme risk aversion). Results were obtained using two discount rates, viz: 4% and 8%, and three planning periods (1, 10, and 25 years) to incorporate the dynamic nature of soil conservation. On farm costs of soil loss are included by considering costs to be a function of topsoil depth. Results indicate that soil conservation decisions should be affected by risk and farmers' risk preferences.

3.1.3 Discussion

Despite considerable empirical research and attention directed to the issues of technological adoption, a consensus has not yet developed regarding the social and economic conditions that lead farmers to conserve soil. Empirical results do show some consistency in that education, financial constraints and land characteristics seem to be important determinants of soil conservation decisions, however, statistical fit of the estimated models tend to be relatively poor, reflecting that agricultural economists have a poor understanding of factors affecting farmers' soil conservation decisions.

Whereas earlier behavioural studies defined technology adoption using dichotomous variables, more recent studies tend to define the dependent variable to reflect the extensiveness of adoption on farms for both annual practices and conservation investments. Consequently models of soil conservation have become statistically more demanding, advancing from bivariate probability models to Tobit models, which are better suited to relative analysis of adoption decisions. At this stage it seems important to note that, McCullagh and Nelder (1983), Madalla (1992: 345), and Gujarati (1995: 572), amongst others, present valid arguments against the use of Tobit analyses in studies where the dependent variable is not censored, clearly the case in the forementioned studies. These arguments are expounded upon in the discussion on appropriate methodology for the current study in Chapter 5 of this thesis. Suffice to say that according to these statisticians and econometricians, the results of the afore-mentioned studies may be biased.

Remarkable variation in measurement of farmer's soil conservation effectiveness is also evident. Aggregate adoption of soil conservation practices is commonly used, but provides no information on effectiveness and extensiveness of adoption. Effectiveness of soil conservation is represented in measures of soil conservation effort based on reductions in soil loss attributable to management practices (eg. Ervin and Ervin, 1982; Saliba and Bromley, 1988). Barlow (1995) captured extensiveness of adoption, but not effectiveness, in his measure of soil conservation effort. Expenditure on soil conservation (eg. Featherstone and Goodwin, 1993) reflects farmers' effort but not necessarily effectiveness of achieved soil conservation. Developing an objective measurement of soil conservation efficiency that measures both effectiveness and extensiveness of adoption, and allows for relative analysis is an important goal for economic research in soil conservation.

Although soil conservation practices are theoretically substitutes in erosion control, no studies have analysed interrelationships between the adoption of different soil conservation practices, nor intra-farm variations in soil conservation decisions and achieved soil conservation efficiency. Identification of a process of achieving farm soil conservation, say a sequential order to adoption of technologies, or other interaction between soil conservation decisions may advance empirical analysis of soil conservation decisions. Intra-farm variations in soil conservation adoption have been observed in previous studies (hence the objective to reflect extensiveness of adoption). Hence, it is also likely that there are intra-farm variations in achieved soil conservation effectiveness. Understanding why any trends in intra-farm soil conservation exist is important to understanding soil conservation decisions.

Economists investigating consumer demand have accumulated considerable evidence showing that consumers generally have subjective preferences for characteristics of products and that the demand for products is significantly affected by their perceptions of the products' attributes (Adesina *et al*, 1995). A noticeable trend in the soil conservation studies reviewed is increased consideration of psychological variables (eg, perceptions, awareness, attitudes and concerns) as determinants of soil conservation decisions. Farmer's psychology is clearly important in explaining conservation decisions, primarily due to the indiscernible nature of much soil erosion and the subjective nature of costs and benefits of soil loss and soil conservation respectively. Although these studies, in particular Lynne *et al* (1988), demonstrate that these variables improve statistical fit of the estimated models, this author cautions that they should not be included in economic studies at the expense of policy related variables. From a policy perspective, agricultural economists should seek to identify policy related variables which affect a shift in the demand for soil conservation or influence constraints to adoption.

Finally, economic criteria used to incorporate risk and risk preferences in economic models of decision making include stochastic efficiency, utility maximisation, expected value-variance analysis and safety-first criteria. Chronological analysis reveals a progression over time to provide a more holistic representation of the farmers' decision-making environments through incorporating sources of risk and endogenous risk reducing strategies. Although results suggest that farmers' risk preferences should be important determinants of their soil conservation decisions, the source(s) of risk considered and the algorithms used in mathematical programming studies essentially predetermine the relationship between farmers' risk preferences and their decisions.

Positive economic verification that risk and risk preferences influence soil conservation is rare. Those studies that have considered risk preferences have used crude indices of farmers' attitudes towards risk in lieu of economic measures of risk preferences, such as AP's. This may reflect high costs of eliciting farmers' risk preferences. More precisely elicited measures of risk preference are important to identify the role of uncertainty and risk preferences in soil conservation decisions. The following section reviews research that provides insight on approaches for eliciting and analysing risk preferences.

3.2 A Review of Studies Eliciting and Analysing Risk Preferences

Several analytical methods have been developed to express the underlying utility function and estimate the risk preference of the decision maker, including (a) direct elicitation of utility (DEU), (b) experimental methods (EM), and (c) econometric methods (ECM). DEU is commonly used. Utility functions are derived through interview procedures designed to determine points of indifference between certain outcomes and risky options. This requires the premise that decision makers can judge the point of indifference, or certainty equivalent, of a risky prospect in a hypothetical gambling situation. The experimental method is similar but provides financial compensation as a function of the responses made by decision makers in the elicitation survey. These studies have generally been carried out in populations with low per capita income and wealth eg. Binswanger (1980) in India, Kachelmeier and Shehata (1992) in China, and Grisley and Kellog (1987) in Thailand.

Direct elicitation of utility and experimental approaches differ in methodology essentially in only one respect: for DEU used hypothetical risk situations are used to determine risk preferences while EM creates real risk situations by providing financial rewards for responses. DEU and EM approaches may be subdivided into: (a) direct elicitation of single valued utility functions through eliciting certainty equivalents, (b) lottery choice tasks, and (c) the interval method.

Certainty equivalent tasks involve four components: the sure amount, an outcome denoted gain, an outcome denoted loss, and a probability level. The process usually involves providing the subject with three of the four components and finding a level of the fourth where the respondent is indifferent between the gamble and the sure amount (Cochran *et al*, 1990). Lottery choice tasks are similar. The process involves providing respondents with a choice of several lotteries for which all four components are provided. Risk preferences are inferred through the decision makers' choice of lottery.

The Interval Approach to eliciting risk preferences was developed by King and Robison (1981) and is founded primarily on stochastic dominance with respect to a function. The approach entails choice of appropriate risk preference levels (thus creating risk preference intervals) and risk situations. Risk situations are defined by distributions of income, say a reference income level of R50 000 with a standard deviation of 10 percent. Computer packages are used to elicit subsets of this distribution, each of which is stochastically dominant for one of the chosen risk preference levels. Respondents are required to choose between pairs of these income distributions to determine in which risk preference interval their risk preferences lie. By constructing interval measurements on the basis of information available at the end of each question, a decision maker can, in theory, be channelled into an ever narrowing risk-aversion interval through the selection of successive income distributions. Econometric methods infer risk attitudes by comparing actual economic behaviour with behaviour predicted by some empirically specified model such as profit maximisation. It is assumed that model specification is correct, consequently the residual is assigned completely to risk preferences.

This discussion focuses on empirical findings regarding the distribution of risk preferences within populations, conclusions regarding the structure of risk preferences in study populations, and how socioeconomic characteristics affect risk preferences. First, however, the impact of adjusting (not adjusting) AP's for the range of the data for each of these approaches is discussed in section 3.2.1. This is necessary for discussion of empirical results in these studies. Subsequently studies using DEU and EM approaches to eliciting risk preferences are reviewed in section 3.2.2 and econometric approaches are reviewed in section 3.2.3.

3.2.1 Impacts of Adjusting AP's for the Range of the Data

Intra-study comparisons of risk preferences elicited for lotteries of different range are common and are used to infer the structure of risk preferences within a population. This section considers the consequences of not adjusting AP's for the range of the data on interpretation of results. Two methodologies are discussed: certainty equivalent tasks (for which AP is calculated following elicitation of a response to a risk situation) and the interval approach (where a response is assigned to pre-determined risk preference interval).

Firstly, consider the implications of AP being sensitive to the range of the data for a certainty equivalent task where the range of each lottery is proportionate to its expected value, eg. Dillon and Scandizzo (1978) and Bond and Wonder (1980). As lottery range (the magnitude of risk) increases theory predicts that risk preferences will become more averse, however increases in wealth attributable to the lottery games will induce less risk averse behaviour (Pratt, 1964). The amendment to Raskin and Cochran's first theorem shows that if $E[x_1] < E[x_2]$ (ie. $\sigma_{X1} < \sigma_{X2}$) and if absolute risk aversion is held constant then $r(x_1) > r(x_2)$. In other words, failure to adjust AP's for the range of the data will bias findings towards decreasing absolute risk aversion as risk increases. This phenomenon may be incorrectly ascribed to reflecting Pratt's (1964) hypothesis that risk aversion decreases with wealth by less informed researchers.

The sensitivity of AP's to the range of the data also has important implications for the interval approach. Denote two reference income levels X_1 and X_2 for which corresponding sets of income distributions d_{1i} and d_{2i} are defined by mean incomes x_{1i} and x_{2i} and standard deviations of s_{1i} and s_{2i} respectively. Since $r(x_{1i}) = (s_{2i}/s_{1i})r(x_{2i})$ if $r(x_{1i}) = r(x_{2i})$ then $s_{1i} = s_{2i}$. Failure to adjust AP bounds on the risk intervals for the range of risk required for each income reference level suggests that corresponding income distributions across the different reference income levels will be risk preserving. Consequently, analysis of how elicited risk preferences change as income reference level increases captures only wealth affects from (often hypothetical) changes in wealth, unless the range of the data is adjusted appropriately for AP's.

3.2.2 Direct Elicitation of Utility and Experimental Approaches

Only three studies of farmers' risk preferences have been previously completed in South Africa, those by Lombard and Kassier (1991), Meering and Oosthuizen (1993), and Botes *et al* (1994). All these studies used DEU approaches. Consequently, the current research relies predominantly on international research.

Foreign Research

The first study in this section, Dillon and Scandizzo (1978), studied risk preferences of a sample of 103 subsistence farmers in northeast Brazil using a certainty equivalent task. An interesting feature of this study is that they used simulated but realistic farming problems rather than pure simulated gambles to elicit risk preferences. Gamble ranges varied according to whether the farmer was an owner (larger range) or a sharecropper and whether the gamble ensured subsistence or not. Risk preferences were measured using AP's (not adjusted for range), calculated under the assumption of negative exponential utility. Results indicated that most farmers are risk averse, increasingly so when subsistence was at risk, although a wide spectrum of risk preferences within the population was evident. The finding that owners tend to be more risk averse that sharecroppers may reflect that AP's were not adjusted for the range of the data. Gamble characteristics and socioeconomic variables were regressed upon the elicited risk premiums. Results indicate that gamble characteristics, level of income and perhaps other socioeconomic characteristics influence peasants attitudes towards risks.

Binswanger (1980) measured attitudes towards risk in 240 peasant households in India for both real and hypothetical gambles using a lottery choice task. This approach was preferred to that of Dillon and Scandizzo (1978) due to concern over respondent literacy (he desired a more simple experiment) and because he was concerned that the latter approach may lead to interviewer bias. Gambles were limited so that the lowest possible outcome was zero gain to confront moral problems involved in gambling and the experiment was designed to allow for long periods of reflection and opportunities for consultation; fixed neutral probabilities (ie P{win} = P{loss} = 0.5) using the toss of an unbiased coin were used to overcome probability preferences. Payoffs at their maximum exceeded monthly incomes of unskilled labourers, thus risks posed were significant. Risk preferences were measured as the partial risk aversion coefficient, calculated using a constant partial risk aversion utility function.

Results indicate that virtually all individuals are moderately risk averse with little variation according to personal characteristics, although wealth has a slight negative effect on risk aversion especially at low payoff levels. Distributions of risk preferences were more widely spread at low levels and for hypothetical gambles, suggesting that high payoffs and a games approach are more likely to elicit true risk preferences. Results support the hypothesis of increasing partial risk aversion with increasing payoff level.

Whereas the previous two studies elicited risk preferences from low wealth populations, an interesting feature of the study by Bond and Wonder (1980) is that they studied risk preferences of Australian farmers, a relatively high income population. They used a similar approach to Dillon and Scandizo (1978) to elicit risk preferences of 201 commercial Australian farmers. Results indicate that although aversion is the most prevalent risk attitude, there exists a wide distribution of risk preferences ranging from preference to aversion. No firm relationships were found between elicited risk aversion coefficients and socioeconomic variables.

Wilson and Eidman (1983) elicited and analysed risk preferences of forty five Minnesota swine farmers using the interval approach. The Arrow-Pratt absolute risk aversion coefficient was used to measure risk preferences, and was calculated assuming a negative exponential utility function. Two pilot studies of eleven students and twenty farmers respectively were conducted to determine appropriate risk preference intervals and reference income levels. Eight risk preference intervals were used with specific boundaries ranging from -0.0002 to 0.0003, and after tax net income of $16500, $31000 and $55000 were used as reference income levels.

Results indicated that 22 percent of farmers were risk preferring, 34 percent were risk neutral and 44 percent were risk averse. Increasing, constant, decreasing and mixed absolute risk aversion with increasing income reference level were all prevalent amongst the respondents, although decreasing absolute risk aversion was most prevalent, particularly in the lowest income group. Consistency checks indicated that approximately 25% of respondents demonstrated intransitivity. These results suggest that there is a trade off between the degree of accuracy demanded in the procedure and the transitive nature of the respondents. A discriminant analysis on three categories of risk preferences (risk preferring, risk neutral and risk averse) indicated that risk aversion is positively related to wealth (contradicting the finding that DARA (decreasing absolute risk aversion) and CARA (constant absolute risk aversion) are the most common risk preference structures), and diversification but negatively related to net income, age, education, debt and size of farming operation. However, the estimated discriminant function classified only 51 percent of cases correctly. This may indicate a problem in the elicitation procedure or that other variables also influence risk preferences. They concluded that personal interviews to explain the questioning process may improve the accuracy of the elicitation procedure.

Tauer (1986) used the interval approach to measuring risk preferences of 72 New York dairy farmers. Methodology used was similar to that of Wilson and Eidmann (1983). Eight risk preference intervals were selected, based on the work of King and Robison and preliminary testing, with specific boundaries ranging from -0.001 to 0.001 and two reference income measures of $15000 and $30000. There was replication at each of the two income levels to allow analysis of consistency of elicited risk preferences. Of the 151 respondents 79 failed consistency tests and were excluded from the analysis, suggesting that respondents have difficulty in distinguishing levels of risk from income distributions.

Results indicate that 26 percent of farmers were risk preferring, 39 percent risk neutral and 34 percent risk averse, and indicated evidence of decreasing absolute risk aversion, interpreted by the author that risk aversion decreases as wealth increases. Tauer (pp. 11) does caution that risk preference may be elicited because " In a survey it is very easy to choose the distribution with the largest single outcome", thus, "one may be sceptical that farmers would display this behaviour if the stakes were real". The Wilcoxon test was used to test for increasing or decreasing risk aversion with reference income level.

Logistic and linear probability models used to examine socioeconomic attributes on risk preferences, but explanatory power of the estimated models was low. Results indicated that risk aversion decreases with age and increases with education and wealth (contradicting the interpretation of DARA).

It is interesting to note that both of the above studies found that risk aversion increases with wealth and that DARA and CARA are most prevalent, suggesting that change in risk preferences across reference income levels is not a wealth effect. Section 3.2.1 showed that changes cannot be ascribed to changes in the size of the risk situation either since corresponding income distributions across reference income levels are risk preserving. This suggests that higher income levels tend to encourage less risk averse behaviour, possibly because the coefficient of variation for the distributions decrease as reference income increases. This may also be related to the hypothetical nature of the questions.

A similar study was conducted by Thomas (1987) for 30 Kansas farmers. Reference income levels used where \$50000, \$25000, \$0, -\$25000 and -\$50000. Eight risk aversion intervals were specified with specific boundaries of -0.0005, -0.0001, 0.0000, 0.0001, 0.0003, 0.0006, 0.0010 and 0.0050. Results indicate that the majority of farmers are risk averse, that absolute risk aversion is fairly constant across the reference income levels and that risk preferences are not significantly related to age. Elicited risk preferences were used to investigate the accuracy of farmers' own assessments of their risk attitudes. Farmers were asked to rate themselves on a scale of 1 to 8, where one is extreme aversion and 8 is extreme preference. Farmers were then categorised into two groups according to their ranking (1 to 4 and 5 to 8) representing those who consider themselves to be risk averse or risk loving respectively. Group means were calculated for the groups and compared. Results showed that the group of farmers who classified themselves as being risk averse were significantly more risk averse than the group who classified themselves as being risk loving. From this it was concluded that "some farmers apparently were capable of assessing their own risk attitudes" and that this should be further explored in future research.

Grisley and Kellog (1987) is another application of the experimental lottery choice approach used by Binswanger (1980). Risk preferences of 39 small semi-commercial farmers from two villages in Northern Thailand were elicited. A total of five sets of games, each with eleven choices of lotteries, with increasing real monetary payoffs were played over a period of five weeks. A further four games with hypothetical payoffs was also played to determine if revealed risk preferences are affected by the offer of real payoffs. Three of these games used lottery choices from games with real payoffs. In addition to measuring risk preferences in terms of the partial relative risk aversion coefficient the proportional insurance premium, defined as the difference between a risk neutral lottery and the lottery in question divided by the risk neutral lottery, was also used.

All the farmers surveyed were found to be risk averse and their preferences, on average, conformed to the hypothesis of increasing partial risk aversion. Farmers' risk preferences converged toward homogeneity as the magnitude of the monetary payoffs increased. Significant positive correlations were found between elicited risk preferences for corresponding real and hypothetical lotteries, suggesting that risk preferences can be elicited using hypothetical gambles. Aversion to risks was found to be negatively related to yield risk, indicating that less risk averse farmers are more prepared to take on more risky investments, and farm size, and positively related to wealth; enterprise diversification, indicating that more risk averse farmers engage in cropping diversification; and the farmer's mathematical ability, which suggests that farmers with better mathematical skills were more able to gauge risk. Stronger results in explaining risk preferences relative to previous studies must, however, be interpreted with care due to the small sample size.

Kachelmeier and Shehata (1992) used a certainty equivalent task to elicit individual risk preferences over a series of dichotomous lotteries with varying probabilities to win a monetary prize. The objectives of this study were twofold: a) to examine whether the level of monetary incentives influences the pattern of revealed risk preferences. Secondly, to examine the effect of the probability of winning on risk preferences. This study used certainty equivalent approach instead of a lottery choice task following a review by Treversky which concluded that lottery choices do not necessarily correspond to the preferences inferred from a lottery pricing task. It also allowed direct evaluation of the influence of probabilities on risk preferences. Each sequence of trials consisted of 25 lotteries using win percentages varying from 5 to 95 percent, in no discernable order. The measure of risk preference used is the ratio of a subject's certainty equivalent for that lottery to the lotteries expected value. Results indicate that respondents revealed increasing relative risk aversion with increasing real monetary prizes. There was also a pronounced sensitivity to different win percentages. Finally, they found that the effect of monetary prizes are real, albeit subtle.

Gunjal and Legault (1995) favoured a direct method of elicitation of risk preferences of Quebec farmers following observed inconsistencies of choices at various income levels under the interval approach in the literature. A lottery pricing task with hypothetical, but realistic farm alternatives was used for three income levels: $50,000; $100,000 and $150,000. An interesting feature of this study is that three point distributions were specified for the lotteries, ie. high, average and low returns. The assumption of symmetry within each distribution was made for simplicity. Following Binswanger (1980), a constant partial risk aversion utility function was assumed. The Delphi technique was used in elicitation of risk preferences. This is an interactive process usually involving several rounds with feedback of important group results after each round to obtain refined responses. Their justification of this technique was that in the real world, the decision maker often uses external information to see how his/her judgement concurs with others, thus the Delphi technique may generate more realistic results. In this study only two rounds were used. The sample consisted of 100 dairy and hog farmers in Quebec. Farmers were surveyed by personal interview on their farms.

Results indicate that in the second round risk aversion increased in the dairy sector but decreased in the hog sector. However, the differences between rounds were statistically non-significant at the ten percent level of probability and thus do not conclusively suggest that the Delphi technique resulted in any relative consensus for a particular investment decision by both dairy and hog producers. The results also indicate that there is a wide distribution of risk preferences among the survey population. The percentage of risk preferring farmers ranged from 8% to 23% depending on the level of investment. On average, however, both groups tend to be risk averse, with hog producers on average more risk averse than dairy farmers which may reflect the greater income stability of dairy farmers. Increasing partial risk aversion with investment size was evident for both sectors.

South African Research

Lombard and Kassier (1990) was the first economic study of South African farmers' risk preferences. They used the interval approach to elicit the risk attitudes of 52 farmers in the Western and Southern Cape using a similar methodology to Tauer (1986) and Wilson and Eidman (1983). Risk attitudes were measured, using the Arrow-Pratt absolute risk aversion coefficient, on a sixteen point scale ranging from -0.001 to 0.01 for each of five reference income levels, defined as after tax annual income levels of -R5000, R15000, R35000, R70000, and R110000. Results of the research indicate that risk preference, neutrality and aversion are all present in the sample population. Risk preferences, however, varied amongst different income levels for many respondents, suggesting some inconsistencies in elicited risk preferences. Like Tauer (1986) they concluded that there appears to be a tradeoff between accuracy of the risk interval and the consistency of choice.

Meering and Oosthuizen (1993) elicited risk preferences of irrigation farmers in the lower area of the P.K. le Roux dam of South Africa using an interval approach. An objective of this research was to examine the impact of increased risk on elicited AP's. Thirty-four farmers were inconsistent in their risk preferences and were omitted from the second survey. Questionnaires were compiled with distribution values around the levels of 0, R30 000, R60 000, R90 000, R120 000, R150 000 and R180 000. The variation of the distributions was taken to be 10% and 50% of the level concerned.

Results indicated increasing consistency in risk preferences at higher income levels which was attributed to clearer differences among distributions at higher levels. The number of risk averse farmers increased as risk increased. Most respondents were either strongly risk seeking or strongly risk averse, a deviation from previous research. This was attributed to the absolute risk aversion scale that was used, the bigger variations in distributions, and the research population. Results suggest that farmers may have difficulties in assessing the relative riskiness of different income distributions.

The most recent South African study, Botes *et al* (1994), elicited risk preferences of 52 irrigation farmers in the Winterton are of KwaZulu-Natal. An interesting objective of this study was to determine whether attitudes towards wealth risk are significantly different towards annual income risk. A similar methodology to that of Meering and Oosthuizen (1993) was used to elicit risk preferences. Risk intervals were selected based on Tauer's (1986) study, correctly adjusted for the scale of currencies using Raskin and Cochran's (1986) first theorem and an exchange rate of 1$ = R3. A rescaling factor of 10 was used to rescale the annual income measurement scale for wealth, justified by the same theorem. This produced risk intervals in the range of -0.00030 to 0.00170 (-0.00003 to 0.00017) for income (wealth). Income and wealth levels of R0, R60 000 and R120 000, and R250 000, R600 000 and R950 000 respectively were used as appropriate reference income and wealth measures.

Income distributions were calculated allowing for variation specified by standard deviations of 15% of the reference income level, which reflect variations in income and wealth levels experienced by farmers in survey population. Twenty distributions with six values each were generated for each of the income/wealth levels. Following Tauer (1986) the Wilcoxon test was used to test consistency of elicited risk preferences. Thirty of the farmers were found to be consistent in their risk preferences. The other farmers were excluded from the analysis. Results indicate that, firstly, most farmers are risk neutral, although some revealed extreme risk preferences; secondly, farmers are significantly more averse towards wealth than income risks; and thirdly, although there is some evidence of decreasing absolute risk aversion, no evidence could be found that risk aversion continually changed as the level of income/wealth changed from high to low levels. Thus the null hypothesis of constant absolute risk aversion was accepted.

This study is important because adjustment of AP's for the comparison of income and wealth risk preferences is essentially the first attempt in the literature to adjust AP's for the range of the data. However, the amendment to Raskin and Cochran's (1986) first theorem developed in the previous chapter indicates that the scaling factor, c, should be the ratio of risk between two gambles. Botes *et al* (1994) calculated the rescaling factor as the ratio of corresponding average wealth levels used to average income levels used (which equals 10). Ratios of the standard deviations for each corresponding set of wealth and income levels are 12, 10 and 12.9, suggesting that c should be approximately equal to 11.5. If $c < s_2/s_1$, then $r(x_1) < r(x_2)$, where s_1 and s_2 are the standard deviations of the income reference levels. Use of an incorrect rescaling factor thus places an upward bias on risk in the wealth risk aversion distributions relative to the income risk aversion distributions. The observed increase in risk aversion is, at least partially, due to increased risk, and not necessarily due to the nature of the risk. Consequently, the result that farmers are more averse to wealth risk relative to income risk must be interpreted with caution.

3.2.3 Econometric Approaches

Moscardi and de Janvry (1977) derived attitudes towards risk amongst peasants in Puebla, Mexico from survey data in a model of safety-first behaviour. Quantities of nitrogen fertiliser per hectare were expected to indicate risk aversion since it is agronomically the most important input for increasing yields in the area and is also the largest component of variable cost. The marginal productivity of nitrogen was estimated for each household from an estimated production function, and together with the coefficient of variation in yield, factor prices and product prices was used to calculate a measure of risk aversion, K. Results indicated that the distribution of K is biased towards risk aversion. Socioeconomic characteristics of the peasant households were regressed on K to explain differences in risk preferences. Results indicate that households that control more land and who have better access to credit and services are less averse to risk. Family size and education and age of the household head were not statistically significant in explaining risk aversion. Criticisms of this study are that constraints to use of nitrogen fertiliser, such as access to credit, will be reflected in K, although the affect on actual risk preferences may be different. Further, K provides no information regarding the magnitude of risk preferences.

Antel (1987) used a moments based approximation of the revenue function to econometrically estimate the distribution of attitudes towards risk for a population of farmers in India. The moments of revenue were specified as quadratic functions of preharvest human labour, animal labour, fertiliser and land. Fertiliser and labour were considered for elicitation of risk preferences, however, fertilizer use was found to be constrained by credit availability. The parameters of the distribution of risk attitudes were estimated using an instrumental variable approach developed in the same paper. The instruments were specified as variety, seasonal and annual dummy variables, output price, farmer's education, and rainfall variables. These variables are assumed to be exogenous to risk attitudes, but correlated with labour choices, and are thus appropriate instruments.

Both the Arrow-Pratt absolute risk aversion coefficient and downside risk aversion coefficient, DS, were estimated, where $DS = U'''(x)/U'(x)$. Results indicate that the population is characterised by both Arrow-Pratt risk aversion (mean estimated AP coefficient of 3.272) and downside risk aversion (mean estimated DS coefficient of 4.254) with considerable heterogeneity of both. By expressing risk aversion as the partial risk aversion coefficient, it was shown that results are comparable to those of Binswanger (1980) for a similar population. This study demonstrates that production survey data and econometric models can be used to estimate the distribution of risk attitudes in a producer population, however, results will only be reliable to the extent that both technology and behavioural models are well approximated. Despite the advances made by this study, the structure of risk aversion is imposed by the choice of utility function and that separation of production technology from risk preference estimation may introduce both inconsistency and inefficiency.

More recently, Saha *et al* (1994) developed a method to permit joint estimation of risk preference structure, degree of risk aversion, and production technology. The method is implemented by using the expo-power utility function, which imposes no restrictions on risk preferences structure and thus allows estimation of both the degree and nature of risk aversion. Estimation relies on the first order conditions of expected utility maximisation under output uncertainty. Empirical estimation of this method used farm level data from 15 Kansas wheat farmers over four years. Findings show that Kansas farmers are risk averse and their risk preferences are characterised by decreasing absolute risk aversion and increasing relative risk aversion with increasing wealth. Results further indicated that combined estimation of production function parameters with utility function parameters is more efficient than is the separate estimation of each.

Finally, Bar-Shira *et al* (1997) derived an econometric procedure for estimating Arrow-Pratt coefficients of risk aversion, including the absolute, relative and partial risk aversion coefficients, and the elasticity of absolute risk aversion with respect to wealth. Farmers from cooperative settlement (moshav) of farmers in the Arava region of Israel were studied. Each farm on the moshav is privately controlled, however marketing and input purchasing are done cooperatively. Strict rules of entry leads to a homogenous population in terms of preferences, hence it was considered reasonable to consider differences in wealth as the primary factor affecting risk preferences. The econometric model describes farmers' choices: because all labour is supplied by the households, farmers must select a portfolio of land allocations and leisure. By choosing different land allocations farmers are choosing different lotteries. Consequently individuals choices of their crop allocations and leisure consumption is indicative of their risk preferences. Expectations of future profit drives the decision process. Variation in risk attitudes across individuals is accounted for in the model by replacing a parameter in the model with a vector of socio-economic characteristics, such that risk aversion may vary across individuals but the elasticity of absolute risk aversion is kept constant. A two-stage instrumental approach was used to estimate the model.

The elasticity of absolute risk aversion with respect to wealth was calculated to be equal to -0.316. Consequently the hypotheses of decreasing absolute risk aversion and increasing relative risk aversion were accepted. These findings empirically verify Arrow's hypotheses. Results also indicated that farmers with higher levels of experience as well as farmers with better managerial abilities exhibit a lower degree of risk aversion; both results indicating that risk is a complicating factor which farmers with less experience or lower managerial ability try to avoid. Education and diligence were associated with greater risk aversion indicating that educated farmers better understand how to avoid risk and that harder working farmers can reduce risk *ex post*, thus appearing risk averse *ex ante*.

A positive feature of these studies is that measures of risk aversion are compared according to income, thus interpretation of decreasing absolute risk aversion with wealth is accurate because AP's were compared over individuals of different wealth levels. Developments in elicitation through ECM reveal a progression towards overcoming problems of constraining the functional form of utility and developing more efficient estimators of risk preferences. They also measure risk preferences based on actual decisions. Constraints of varied technology within the study population have also been overcome by Saha *et al* (1994) by specifying all inputs in production as capital. Disadvantages of this approach include that these studies are information intensive and they assign all estimation error to risk preferences.

3.2.4 Discussion

This section reviewed research that elicited farmers' risk preferences. It was shown that although AP's are affected by both wealth and the size of the risk situation, most researchers have interpreted considered changes in AP's across gambles exclusively as wealth effects. Further, adjustment of AP's for the range of the data is necessary for correct interpretation of these findings. No previous studies have appropriately adjusted AP's for the range of the data. Consequently, the studies reviewed provide little insight to the structure of absolute risk aversion in the study populations. Meering and Oosthuisen's (1993) results do, however, suggest increasing absolute risk aversion as risk increases and several studies found absolute risk aversion to be positively related to wealth - contrary to Pratt's hypothesis.

Elicitation procedures may be categorised as direct elicitation of risk preferences or econometric methods. The latter category are relatively less common but have shown considerable advancement over the past two decades. They remain data intensive and are criticised for the residuals being assigned entirely to risk attitudes when there exists a variety of other possible sources for such discrepancies. Risk preference are less costly to elicit using DEU techniques. Experimental techniques have been used for elicitation of risk preferences of peasant farmers, but budgetary constraints preclude their use for wealthy populations if meaningful questions are to be asked. Chronological analysis shows an early use of certainty equivalent tasks. Lottery choice systems became popular following Binswanger's study for eliciting risk preferences in low income populations, whilst the interval approach became common for eliciting risk preferences in high income populations. Results from all these studies indicate that respondents have increasing difficulty in distinguishing the level of risk implied by income or wealth distributions as the absolute risk aversion intervals became narrower. This implies a tradeoff between consistency and accuracy. Consequently, more recent studies conducted overseas have reverted to use of certainty equivalent tasks.

Results of all previous studies suggest that populations contain a broad distribution of risk preferences. Most respondents in low wealth populations have been classified as risk averse; risk neutrality and preference are prevalent in more wealthy populations. However, efforts to relate heterogeneity of risk preferences to socio-economic characteristics of respondents have met with limited success. Kachelmeier and Shehata's (1992) good results in explaining elicited risk preferences are entirely due to gamble, not respondent, characteristics.

Issues of previous empirical analyses must be jointly considered with knowledge of the study population to facilitate specification of a research methodology that is both feasible and appropriate. Consequently, the discussion presented in the following chapter describes the study population and their decision making environment.

4. THE STUDY POPULATION

The model of decision making conceptualised in the first chapter indicated that soil conservation decisions are characterised by what they have in common and how they differ. Common factors serve to define the set of possible soil conservation technology bundles and describe the decision making environment of all farmers. Description of this decision-making environment is necessary to evaluate the feasibility of implementing the conceptual models for analysis of heterogeneity in farmers' soil conservation decisions.

This chapter serves to describe the environment in which South African sugarcane farmers' soil conservation decisions are made. An overview of sugarcane production in South Africa is provided, followed by a description of the set of feasible soil conservation practices. Previous and current changes to this decision making environment attributable to South African soil conservation policy and institutions are then described. Finally, the suitability and feasibility of implementing the conceptual model using South African sugarcane farmers as a study population is discussed.

4.1 Introduction

The population of sugarcane growers in South Africa may be categorised as small-scale and developing farmers (mostly non-White) and large scale commercial (mostly White) farmers. Millers have developed areas for small growers (Maher and Platford, 1994), thus soil conservation on that land is only partially a function of the farmer's own decisions.

In South Africa, sugarcane is grown on about 400 000 ha under a wide range of climatic and soil conditions (Meyer *et al*, 1996). The sugarcane producing areas are situated mostly in the catchment areas of gently to steeply undulating land in KwaZulu-Natal (Tudor-Owen and Wyatt, 1991). Sugarcane may be rainfed or grown under irrigation. Rainfall varies widely in amount, intensity, and distribution, and drought and floods are relatively common in these areas (Maher, 1996).

Grey sandy soils (Entisols) are most extensive and account for 60% of the total area under sugarcane. The red soils (Oxisols) comprise the second largest group (19%), followed by the black Vertisols (13%) and brown Ultisol humic soils (8%). Many soils in the sugar industry are subject to various degrees of crusting, under both rainfed and irrigated conditions before crop canopy. Soil crusting is a precursor to soil loss through erosion because it limits water penetration into the soil (Meyer *et al*, 1996). Soils in sugarcane growing areas often have high rates of erosion once the natural vegetation is removed (Platford, 1987).

Production of sugarcane in South Africa is a monoculture, with a mean of eight crops before fields are re-established (van Antwerpen and Meyer, 1996). Historically cane production has involved intensive cultivation and with it potential degradation of the soil (Meyer *et al*, 1996). Sugarcane is a perennial, deep rooted, stool forming grass. Despite the fact that it is cultivated as a row crop, it has excellent soil and water conserving characteristics once the canopy is formed (The Experiment Station of the South African Sugar Association, 1974). It has been established that 85-90% of average annual soil loss occurs during the period where replanting takes place (Platford, 1987).

4.2 Soil Conservation Practices Applicable to Sugarcane Farming

Soil conservation practices applicable to sugarcane farming are categorised as intra-field soil conservation practices, which directly inhibit erosion from in-field areas, and soil conservation practices that either safely transfer runoff into natural watercourses or stabilise these watercourses.

4.2.1 Intra-field Soil Conservation Practices

The erosive power of water varies with the second power of its velocity and the volume of particles that can be carried in suspension varies with the fifth power of the velocity (The Experiment Station of the South African Sugar Association, 1974). Intra-panel soil conservation practices are those that serve to reduce runoff and decrease its in-field velocity, thus reducing soil erosion.

Conservation Terraces

Physical protection in the form of soil conservation structures has been the main way of providing soil conservation for agricultural lands in South Africa. Water carrying terraces are designed to intercept run-off water from the area immediately above and to convey it at an acceptable velocity to suitable discharge points, usually waterways. The alternative to water carrying terraces are spillover roads. Spillover roads do reduce in-field velocity of runoff, however they do not remove water from the in-field area. Terrace banks can be stabilised by cane, various grasses or, as in the case of broad base terraces, used as roads.

Spacing between conservation terraces (either water-carrying terraces or spillover roads), measured as the panel width or vertical interval (VI), is important to ensure that runoff does not exceed "safe" velocity. Optimum spacing of the banks depends on the ground slope, soil type and farm management practices. All slopes on which sugarcane is grown necessarily have soil conservation structures. Management decisions are the discrete choice between water carrying terraces or spillover roads and the panel vertical interval.

Construction of soil conservation structures require substantial capital investment, as do other conservation works. Subsequently, maintenance is required to keep them free of silt and debris (The Experiment Station of the South African Sugar Association, 1974; McFarlane and Maher, 1993, Platford, 1987). Plans to restructure soil conservation terraces on a sugarcane field are likely to be implemented when that panel is replanted. This is only necessary every 10 to 12 years because sugarcane can ratoon (Platford, 1987).

Trash Mulching

Mulches, such as trash, prevent surface crust formation under rainfall impact, thus enhancing water infiltration rates and reducing soil erosion. Laboratory and field experiments reported by Platford (1982) as cited by Meyer *et al* (1996), showed that strong crusts do not form under a mulch (eg. trash), and that trash retained 89% more soil and 58% more water than bare plots. Other advantages of trash mulching include the suppression of weeds, decreased wind erosion, improved soil fertility and reduced ratoon decline.

Trash mulching does, however, lower soil temperature which reduces ratoon vigour and stalk population. This limits use of trashing on the South Coast and high altitude areas of KwaZulu-Natal. Further, there is a clear trend in the industry towards burning at harvest compared to trash mulching, primarily because burning decreases extraneous matter at the mill, thus increasing cane quality; and because severely stressed cane infested with the stalk borer eldana may not ratoon through a trash blanket (Meyer *et al*, 1996; McFarlane and Maher, 1993).

Strip Cropping

Strip cropping (or strip replanting) means developing fields so that strips of cut or ploughed out cane alternate with standing cane. There should be an age or stage in growth difference of at least three months between adjacent strips. Soil loss is reduced through not exposing whole hillsides at replant or harvest, the stage where most erosion occurs. Strip cropping is a long term soil conservation measure. The strips are normal to the contour, and strip widths should not exceed the limits for acceptable soil protection. Other advantages of strip cropping include that it facilitates cutting cane at different stages on hillsides and the management of different cane varieties, which may have different optimum ages for harvest, bred for valley bottom and hilltop conditions. The fields also create fire breaks (Anonymous, 1996; McFarlane and Maher, 1993).

Minimum Tillage

Conventional tillage produces a large number of failure plains, pulverises soils and breaks down soil structure near the surface and creates a compaction layer at plough depth which reduces infiltration, leading to increased runoff. Soils are consequently more prone to wind and water erosion (Meyer *et al*, 1996). It has been shown that deep tillage of the soil before replanting is unnecessary in most soils of the South African Sugar industry (Moberly, 1972, cited by Meyer *et al*, 1996).

Chemical minimum tillage, in which glyphosphate (Roundup) is used to kill the old crop, reduces soil loss and increases yield relative to conventional methods of land preparation. Minimum tillage also increases soil organic matter content and reduce its bulk density and eliminates volunteer plants. The benefits vary according to soil type. Use is restricted in winter because the crop must have reached six leaf stage to be effective (Meyer *et al*, 1996; McFarlane and Maher, 1993). Following the removal of the patent rights to roundup in 1994, a range of similar products became available and resulted in a lower price for the product, which has reduced the cost of chemical minimum tillage (McCulloch and Stranack, 1995).

Platford's Nomograph

Figure 4.1 depicts a nomograph designed by Platford (1987) to compute widths of (vertical intervals between) panels in sugarcane fields to meet in-field soil conservation requirements defined in terms of the Conservation of Agricultural Resources Act of 1983.

The nomograph takes into account soil erodibility (slope gradient and soil structure) and adoption of soil conservation practices within that field. Predictions of soil loss for all the possible combinations of factors, using the Universal Soil Loss Equations, were used to prepare the Nomograph. The 45° lines in each quadrant represent the original standard recommendations, *viz*. conventional tillage, no strip replanting and terrace banks. The alternative lines in each quadrant account for the maximum effect that the various crop management factors can have. The slopes and positions of the lines are dependent on how much they reduce soil losses compared with the original standard practices (Platford, 1987). Cropping mix is not considered to affect soil conservation of sugarcane fields because production of sugarcane in South Africa is a monoculture (van Antwerpen and Meyer, 1996).

For example, if a field has a slope of 20%, the soil is classified as erodible; minimum tillage will be used, a strip planting programme will be carried out, and terrace banks will be built and the cane will be cut green leaving a trash mulch, then the panel vertical interval must be less than or equal to 13,5m, which corresponds to a panel width of 70m. However, If strip replanting is not carried out and the crop is burnt at the time of harvest, then a 10m vertical interval or a panel width of 52m would be required (Platford, 1987). The nomograph can also be used to check the adequacy of existing panels and crop management systems.

Clearly, practices that conserve soil allow for larger panel widths (vertical intervals). It is apparent from the nomograph that a slope on which many (few) technologies are adopted may still be unsatisfactorily (adequately) conserved if vertical interval between terraces is sufficiently large (small). This illustrates the conceptual difference between conservation adoption and conservation effort.

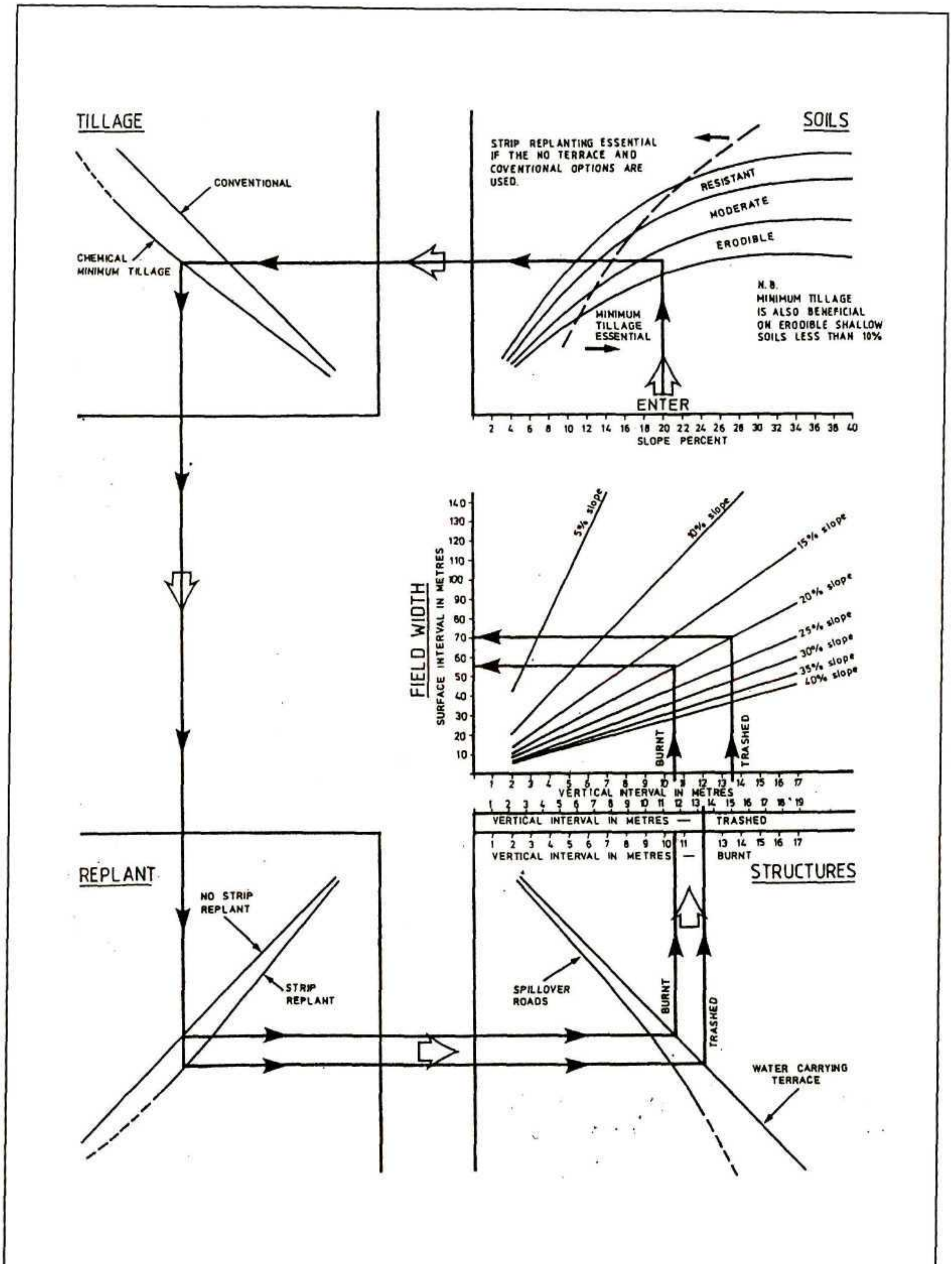

Figure 4.1 Nomograph to compute widths of panels in sugarcane fields (Platford, 1987: 153).

4.2.2 Other Soil Conservation Practices

Diversion terraces should be provided above all fields situated below such unconserved land as open veld, bush, homestead areas or labour compounds. These conservation works are usually bare or grassed canals which, like conservation terraces, have the soil removed from the canals and placed on the downslope side to form a bank. They are constructed along the-upslope edges of cultivated land to trap runoff. The water is conveyed to waterways or natural water courses. Maintenance is required to keep them free of silt and debris (The Experiment Station of the South African Sugar Association, 1974).

Waterways are hydraulically stable structures, protected either by vegetation or more durable materials and designed to safely convey runoff from erosion vulnerable in-field areas to natural water courses (McFarlane and Maher, 1993). The protection of stream banks is essential if severe erosion is to be avoided during heavy rains. Water courses can be stabilised by using indigenous grasses and trees (Tudor-Owen and Wyatt, 1991).

Good roads have hard wearing surfaces that are impervious to water. Consequently considerable runoff collects on roads so good drainage is important, not only to maintain the land around the road, but also to maintain the road itself. Roads (especially major roads) should follow crest lines, contours or conservation terraces, but this is not always possible and steep diagonal, boundary or slope-break roads may have to be constructed (The Experiment Station of the South African Sugar Association, 1974).

4.3 South African Soil Conservation Policy

The first comprehensive review of the soil erosion problem in South Africa was given in the report of the Drought Investigation Commission, 1923. The commission recommended State action in connection with soil erosion which would require farmer co-operation. The next significant event was the holding of a representative Soil Erosion Conference at Pretoria in 1929 which proposed establishment of a permanent Soil Erosion Advisory Council. This was established the following year and represents the first official granting of assistance to farmers for combatting soil erosion. The Council ceased to exist after 1933. However, in the same year the government approved a number of Soil Erosion Schemes which provided for subsidisation of erosion works.

These pioneer schemes were abandoned fifteen years later in favour of more comprehensive schemes in terms of the Soil Conservation Act, No. 45 of 1946. Concurrently, the Division of Soil Conservation and Extension was created to implement the provisions of the new Act. This Act conferred powers on the State to enforce conservation through use of penalties of fines or imprisonment or both, but the spirit of the Act was to encourage voluntary compliance with conservation requirements. The Act applied to all land, but in practice excluded areas reserved by the State for Bantu occupation from its provisions.

The Act provided for the establishment of a national Soil Conservation Board, primarily responsible for monitoring soil erosion and soil conservation throughout the country. Section 9 of the Act allows any defined area of land to be proclaimed a soil conservation district at the request of the landowners concerned. Section 26 of the Act provides that the State may of its own initiative proclaim any defined area of land as a soil conservation area. Such a proclamation obliges all landowners in the district to conserve, reclaim or improve his land, as may be necessary, overseen by a soil conservation committee. Soil conservation committees are predominantly constituted by local farmers, but the Minister may appoint up to one-third of the members at his discretion. Financial assistance granted for soil conservation schemes in terms of the Soil Conservation Act were primarily based on the cost of conservation works constructed, not conservation measures applied because soil conservation measures usually do not require significant capital investment. Financial assistance may take the form of loans, cash subsidies or special grants (Ross, 1963: 15-29; Adler, 1985).

The Act showed considerable initial success, however, by 1969 "progress had been far too slow" (Adler, 1985:34). The Soil Conservation Act was revised (Act No. 76 of 1969). In terms of this Act each owner or occupier of land is responsible for observing the general provisions of the Act. Subsequent prosecution of a number of malpracticers prompted many more farmers to seek advice in implementing conservation farm plans. By 1980 73% of agricultural land in South Africa had been planned in terms of the Soil Conservation Act, 1969 (Adler, 1985; The Experiment Station of the South African Sugar Association, 1974).

In 1983 legislation on control of soil erosion, noxious weeds and undesirable invader plants was combined in one Conservation of Agricultural Resources Act, No. 43 of 1983. The Act provided a necessary shift in the focus of soil conservation requirements from *ex post* penalties to *ex ante* prevention and imposed *ex ante* regulation enforced by *ex ante* penalties (McFarlane and Maher, 1993). In terms of the Soil Conservation Act of 1969 contraventions were treated leniently and only 36 prosecutions had been instituted in the period 1969 to 1983. It was also perceived that the previous maximum penalties did not serve as sufficient deterrents; consequently penalties under the 1983 Act were made considerably more severe (Adler, 1985). Further, for the first time, land users can be prosecuted for carrying out farming practices which could lead to soil erosion, although no signs of erosion might be visible (McFarlane and Maher, 1983).

Prior to the 1983 Act, soil conservation practices on sugarcane farms consisted predominantly of conservation terraces and grassed waterways. The spacing of these banks was based on a formula used in annually cropped areas and modified for the perennial crop of sugarcane. The requirements of the Act were not met on slopes over 12% for erodible soils, and over 22% for strongly structured soils when cultivated by normal ploughing. Consequently, minimum tillage, strip planting, trash mulching and terrace banks were used to control runoff from steep land (McFarlane and Maher, 1993).

4.4 Institutions Promoting Soil Conservation on Sugarcane Farms

In the coastal areas where predominantly sugarcane is grown, responsibility for technical planning, and the provision of plans and specifications, has been vested in the Experiment Station of the South African Sugar Association (SASEX). In areas where sugarcane forms only part of a mixed farming enterprise, as in the case in the Natal Midlands, the Department of Agricultural Technical Services and SASEX will be jointly responsible for providing these services. The individual cane grower may choose which organisation he approaches. The Department of Agricultural Technical Services is the sole authority on subsidies for soil conservation works (The Experiment Station of the South African Sugar Association, 1974).

Land use plans (LUP's) are designed to hold soil loss to acceptable levels while improving economies of the farm. The LUP combines factors such as agronomic practices, mechanisation, climate, soils, water and topography to obtain the best possible economic yield. Soil conservation provides the basis of all LUP's. LUP's have been found to increase yields, although this may not be attributable to the soil conservation. Savings are also made on infield haulage costs and fertiliser, through better siting of loading zones and roads. To produce a LUP costs about R3135 for a 100ha farm (less than 0.5% of average annual total revenue), while they have the potential to increase yield about 5% (Maher, 1996).

The South African Sugar Association has recognised that sugar growers need be made aware of the Conservation of Agricultural Resources Act of 1983, and consequently implemented programs advocating soil conservation in 1986 (McFarlane and Maher, 1993). The Lower Tugela Conservation Committee was the first to promote improved conservation of farmland through better farming practices. This was undertaken partially through a mass media approach incorporating dramatic illustrations of erosion (Hulbert, 1990).

Soil conservation committees are available to assess farms and make recommendations towards compliance with the 1983 Act. Recommendations on adoption of soil conservation practices by soil conservation committees and SASEX to South African sugarcane growers are based on Platford's nomograph (McFarlane and Maher, 1993) and allow for maximum possible autonomy in farmer choice of practices but ensure that requirements of the Act are met. Prior to 1989, Soil conservation committees were responsible for large regions, often covering three of four mill group areas. In 1989 South African Sugar Association initiated a move which gave grower groups the option of forming their own local environmental committees or continuing as conservation committees. The new structure gave growers closer contact with environmental control (McFarlane and Maher, 1993).

4.5 Discussion

Whole farm soil conservation efficiency is achieved on sugarcane land by adoption of intra-panel soil conservation practices that inhibit in-field erosion, augmented by other soil conservation practices that safely transfer runoff into natural watercourses and stabilise these watercourses. It is apparent that some intra-panel soil conservation practices involve annual decisions (and low capital investment) whereas others involve decisions taken every 10-12 years (with large capital outlays). Because panels are homogenous in management practices applied, the decision to adopt a soil conservation practices on a panel is a discrete choice and extensiveness of adoption within a panel is not an issue. Following Platford (1987), it appears reasonable to assume that panels are homogenous in soil conservation efficiency and soil conservation efficiency of individual panels can be assessed relative to the requirements of the 1983 Act using Platford's (1987) nomograph. It may be argued that the requirements defined by this technological information are not necessarily optimum for all situations. However, because recommendations on adoption of soil conservation practices by SASEX to South African sugarcane growers are based on this nomograph (McFarlane and Maher, 1993), assessment of soil conservation efficiency using this nomograph will provide measurement that is both objective and which has familiar interpretation for policy makers and members of the South African sugar industry. Consequently, farmers' soil conservation decisions on their sugarcane land are easily applied to the models conceptualised in chapter 2. It is expected that intra-field soil conservation efficiency will closely approximate whole farm soil conservation efficiency.

The introductory chapter has previously motivated that soil conservation on South African sugarcane farms is an important policy issue. However, relating soil conservation decisions to farmer characteristics, and in particular farmers' risk preferences, requires that farmers are responsible for their own soil conservation decisions. This chapter has indicated that small and developing sugarcane farmers have not necessarily been responsible for their own conservation practices, whereas commercial farmers have been provided autonomy in deciding which soil conservation measures they use. Consequently, this research investigates commercial farmers' soil conservation decisions.

Many of the behavioural economic studies of farmers' soil conservation decisions reviewed in the previous chapter found that considerable variation in farmers' decisions is accounted for by differences in land use or region. Clearly land use influences rates of erosion: rates of erosion are considerably higher on cultivated land as opposed to veld; and some soil conservation practices are not appropriate for some cropping systems or are not applicable in certain climatic regions. Analysis of a population with homogenous land use type and climate will abstract as far as possible from variation attributable to physical constraints and focus on variables subject to policy influence. It is previously noted that farm enterprise mix does not affect infield soil conservation efficiency of sugarcane land, thus restricting the analysis to sugarcane land is useful. Climate, however, does affect soil conservation decisions because use of certain practices is restricted where irrigation is used, and because trash mulching is less feasible at altitude and on the south coast of KwaZulu-Natal. Consequently, the study population was restricted to rainfed sugarcane land. The Eston, Sezela, and Mzimkulu sugar mill areas were selected to encompass the survey population due to their close proximity to each other and because sugarcane production in these areas is predominantly rainfed.

Analysis of choice requires heterogeneity in decisions. This chapter has indicated that sugarcane growing areas are prone to soil erosion. Despite government legislated soil conservation requirements there exists considerable scope for variation between farmers' use of soil conservation measures in their crop management systems. Government has also afforded commercial farmers considerable institutional and financial assistance to expedite soil conservation. The South African sugar industry further promotes soil conservation on sugarcane farms and provides further institutional support to sugarcane farmers. Consequently, it is *a priori* expected that heterogeneity does exist in both sugarcane farmers' use of soil conservation measures and achieved soil conservation efficiency.

This chapter has indicated that analysis of sugarcane farmers' intra-panel soil conservation decisions is feasible using the model conceptualised in chapter 2. Further, it is shown that the population of commercial sugarcane farmers with rainfed cane from the Eston, Sezela and Mzimkulu sugar mill areas of KwaZulu-Natal provide a suitable study population for this research. The analysis proceeds in the next chapter to specify the research methodology.

5. RESEARCH METHODOLOGY AND DATA COLLECTION

The objectives of the models specified are to determine the sets of factors which respectively influence farmers' risk preferences and their soil conservation decisions; and thereby determine the link, if any, between the two. The methodology employed is designed around the conceptual models developed in Chapter 2 with due consideration of issues raised in the literature review and knowledge of the chosen study population.

This chapter describes the methodology used to elicit farmers' risk preferences and specifies econometric models for the analysis of factors affecting elicited risk preferences in sections 5.1.1 and 5.1.2 respectively. Section 5.2. describes model specification of models used for analysing farmers' soil conservation decisions, including assessment of soil conservation effectiveness. A brief discussion on comparing the relative importance of covariates in regression models follows. A survey questionnaire was designed to collect the necessary data. Section 5.4 and 5.5 describe the data collection procedure and provides descriptive statistics of the survey sample respectively.

5.1 Methodology for Eliciting and Analysing Risk Preferences

5.1.1 Eliciting Risk Preferences

The literature review identified three general approaches to eliciting risk preferences, all of which may be adjusted appropriately to account for the sensitivity of AP's to the range and scale of the data. Despite criticisms that the entire residual is assigned to risk preferences, econometric estimation approaches have shown considerable advance in recent years and a trend of increasing popularity is evident. However, risk preferences are costly to elicit under the econometric approach (both in terms of data requirements and estimation procedure) relative to direct elicitation procedures.

The direct elicitation of utility (DEU) approach has been criticised on grounds of subjectivity involved in the identification of the utility function's functional form, individuals biases towards probabilities, preference for specific probabilities (for example, a 50:50 bet), and negative preferences towards gambling. Although the preceding remarks indicate *a priori* concern, Young (1979) stresses that the DEU approach must be judged according to its ability to produce results in accordance with actual economic behaviour.

A long standing controversy in the elicitation of risk preferences is whether actual monetary incentives are necessary to induce truthful preference revelations. Although evidence from the literature as reviewed by Gunjal and Legault (1995) suggests that monetary incentives fail to change respondents behaviour, their results were inconclusive in this regard. Possible reasons include that individuals may respond to hypothetical situations in such a way that minimise his cost of participating, including cost of his time, rather than reflecting his true preferences (Robison, 1982). Whilst preferences elicited using actual monetary payments may be more reliable, typical budgetary restraints may preclude the researcher from asking meaningful questions eg. low value can be attached to inferences made from risk preferences elicited from gambles of small monetary incentives (Kachelmeier and Shehata, 1992).

Tversky *et al* (1990) as cited by Kachelmier and Shehata (1992) provide evidence from a large number of preference reversal studies that lottery choices do not necessarily correspond to preferences inferred from a lottery pricing task. Further, the literature reviewed suggests that respondents may face difficulties in differentiating the level of risk implied by each pair of distributions. It is reiterated that Binswanger (1980) favoured a lottery choice task due to concern over low respondent literacy impeding a certainty equivalent approach.

In light of the above arguments, a direct elicitation of utility through preset choices approach was employed to elicit farmers' risk preferences. Budgetary constraints precluded use of actual monetary incentives. The survey population is characterised by high literacy and education, consequently respondents were expected to understand the elicitation of certainty equivalent procedure. Elicitation through preset choices was favoured over the Delphi process (see Gunjal and Legault, 1995) as only one round of questioning was feasible and lotteries were to be kept consistent across all participants to aid comparison of risk preferences.

Certainty equivalents were elicited for hypothetical lotteries considered separately. Survey respondents were presented with five hypothetical but realistic lotteries of the form (x_{max},x_{min},p), promising a monetary prize of x_{max} with probability p or x_{min} with probability 1-p. Lottery characteristics were varied to capture how changes to the risk situation affect revealed risk behaviour. Consequently, none of the information collected should be redundant. Table 5.1 summarises these lotteries. Lottery ranges varied from R20000 to R100000 and were chosen to represent significantly large income and wealth risks for the farmers to ensure meaningful response. Probability of a win (loss) was described as the flip of a coin to overcome probability preference, and all lotteries had positive expected values to encourage participation, despite the chance of a hypothetical loss in wealth in lotteries 2, 4 and 5. The games were always played in numerical order to ensure that successive games increased in risk faced (either gamble range increased or had negative "loss" values) to hold the respondents attention. Only five lotteries ($g = 1, ..., 5$) were used due to concern that respondents may quickly become bored with prolonged playing of these hypothetical games and because only one round of questioning was considered feasible.

Table 5.1 Characteristics of the hypothetical lotteries

Lottery (g)	x_{max}	x_{min}	Range	p
1	R20000	R0	R20000	0.5
2	R15000	-R5000	R20000	0.5
3	R40000	R0	R40000	0.5
4	R30000	-R10000	R40000	0.5
5	R75000	-R25000	R100000	0.5

To begin a trial respondents were required to choose between the hypothetical options of a specified lottery and a certain monetary amount, initially its expected value. Deductions (increments) from (to) the certain monetary alternative were made as appropriate and the question reasked. This was repeated until a point of indifference was reached, determining each subject's certainty equivalent for that gamble. Utility functions of the forms $U_g(x) = -e^{-\lambda_g x}$ and $U_g(x) = -e^{-\lambda_g^* x^*}$ were assumed, where $x^* = (x - x_{min})/(x_{max} - x_{min})$, normalising the x^* range from 0 to 1. Values of the Arrow-Pratt absolute risk aversion (λ_g) and adjusted Arrow-Pratt absolute risk aversion (λ^*_g) coefficients were calculated from the elicited certainty equivalents for all participants and for all lotteries by fitting the respective functions $f = 0.5 + 0.5e^{-\lambda(x_{max} - x_{min})} - e^{-\lambda(x - x_{min})}$ and $f = 0.5 + 0.5e^{-\lambda^*} - e^{-\lambda^* x^*}$.

5.1.2 Analysing Risk Preferences

Because risk preferences are elicited for hypothetical lotteries, it is necessary that the elicited risk preferences be subjected to tests before they are accepted and related to respondents' soil conservation decisions. Following Dillon and Scandizzo (1978) the elicited risk preference of the *i*th respondent is hypothesised to be a function of a) the risk of the prospect presented to him in the experiment and b) a socioeconomic component. The risk of the prospect may be defined by the moments of the probability distribution of the uncertain prospect (eg. Dillon and Scandizzo, 1978 and Grisley and Kellog, 1987) or some alternative measure, eg. Katchelmeir and Sehata (1992) used the prize level and the probability of a win. It is hypothesised that risk aversion is positively related to risk.

Literature reviewed indicates that there exists a large gap in knowledge and understanding regarding the socioeconomic component. The problem stems from the way in which risk attitudes are intimately associated with complex behavioural characteristics of the individual farmer and the difficulties in separating risk related responses from other forms of behaviour (Bond and Wonder, 1980) and because many socioeconomic variables are determined jointly with risk aversion (Binswanger, 1980). Even independent sources of risk are substitutes which gives rise to risk trading (Gabrial and Baker, 1980). Consequently, *a priori* expectations regarding sings of coefficients on the essentially endogenous covariates cannot be determined theoretically (Grisley and Kellog, 1987). Causality between risk preferences and independently determined socioeconomic factors is theoretically more sound, eg. Arrow's hypothesis that risk aversion decreases with wealth because wealth increases capacity to bear risk.

Previous research efforts to relate socioeconomic factors to risk preferences have tended to consider factors that are determined jointly with risk aversion eg. land rented by Binswanger (1980); income by Binswanger (1980) and Dillon and Scandizzo (1978); off-farm income by Bond and Wonder (1980) and Moscardi and de Janvry (1977); enterprise diversification by Grisley and Kellog (1987) and Wilson and Eidman (1983); solvency by Wilson and Eidman (1983); enterprise or farm size by Moscardi and de Janvry (1977), Grisley and Kellog (1987) and Belaid and Miller (1987); and membership of credit solidarity groups by Moscardi and de Janvry (1977); amongst other variables. Binswanger (1980) also included a "psychological" variable, LUCK, to capture how past experience impacts on a respondent's choice; Dillon and Scandizzo considered respondents ethical attitudes towards gambling; whereas Grisley and Kellog (1987) elicited measures of respondents abstract and mathematical abilities. Common covariates that are determined independently of risk aversion include wealth, age and education. Although the hypothesised relationship between wealth and risk aversion is clear, hypotheses linking age to risk aversion usually follow the argument that a relationship exists between age and wealth. Further, links between education and risk aversion are generally not rationalised in these studies.

Most researchers are cognisant of problems associated with uncertain causality between these variables and risk aversion, and hence refer to the estimated regressions or discriminant functions as correlation analyses. Nonetheless, the merit of conducting these analyses is questionable. They are usually rationalised as having predictive merit, however poor statistical fit of the estimated equations lends little support for this. Binswanger (1980) considered his own analysis to have merit because of its exploratory nature. Bond and Wonder (1980), however, explain that hypotheses cannot be tested for variables where causality is uncertain, whilst Wilson and Eidman (1983: 181) commented of their own results that "All we can say about these results is that some associations between risk attitudes and socio-economic variables were obtained".

It is clear from this discussion that the objective of ratifying the elicited risk aversion coefficients is best achieved by relating them to risk characteristics of the lotteries for which they are elicited rather than socioeconomic characteristics of respondents. An appropriate model is specified in this section. Because previous studies have emphasised the merits of relating socioeconomic factors to risk preferences for exploratory and predictive purposes, a similar analysis is conducted in this study. However, because it is external to the focus of this thesis this correlation analysis is presented in appendix B.

The econometric model specified examines the impact of gamble range and risk of a loss in wealth on revealed risk preference. Panel data sets usually consist of observations over a number of individuals, say I = 1, 2, ..., I, over several time periods, say t = 1, 2, ..., T. Following Kachelmeier and Shehata (1992) repeated measures from the same individual, in this case the λ^*_{ig}'s, $g = 1, 2, ..., G$, are used in place of time periods. Clearly, systematic differences between individual subject's risk preferences would induce correlated errors in ordinary linear regression testing gamble characteristic effects in panel data. Consequently, individual subject effects are included in the model as dummy variables. such that the (i,g)th observation on the general dummy variable model can be written as:

$$\lambda^*_{ig} = B_{1i} + \sum_{k=2}^{K} \beta_k X_{kig} + e_{ig} \qquad ...(5.1)$$