ADOPTION OF HYBRID MAIZE SEED, FERTILIZER AND MACHINERY TECHNOLOGIES BY COMMUNAL FARMERS IN KWAZULU-NATAL

BY

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

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ABSTRACT

This study investigates the characteristics of technology adoption by small-scale farmers, notably the factors influencing the adoption of hybrid maize seed, inorganic fertilizer and machinery technologies. The study also on the basis of socio-economic and institutional factors, identifies the dimensions of small-scale farmers. Data for the study were obtained from a sample survey of 160 households in the Amangwane and Amazizi wards, located in the Okhahlamba magisterial district of KwaZulu-Natal during August 2000. The chief aim of this study is to generate empirical information that can be used to devise programs to encourage small-scale farmers to adopt agricultural technologies. The motivation of the research emanates from the fact that there is limited empirical information as to the actual adoption patterns of agricultural technologies by small-scale farmers. The nature and relative importance of factors associated with technology adoption is time and location specific. The study by using more recent and broader information builds on previous studies in order to complement technology adoption research on small-scale farmers. Understanding what factors influence the adoption of farm technologies and categories or dimensions of small-scale agriculture should provide information on policy options to stimulate technology adoption and improve growth in agricultural productivity.

A categorical dependent variable was specified to identify farmers' adoption pattern of hybrid maize seed and fertilizer. Seventy-two farmers were adopters of both hybrid seed and fertilizer, 56 were adopters of either hybrid seed or fertilizer while 32 farmers were non-adopters. The results of binary logistic regression analysis indicate the adoption of hybrid maize seed and fertilizer is positively associated with, in order of importance, larger farms, older household heads, more value of livestock and better access to information sources.

An index that indicates farmers' status of adoption of machinery technologies was constructed using a principal component analysis technique. The analysis showed that the adoption of machinery technologies can be represented by the single index which could be used as a dependent variable. A principal component regression analysis was subsequently used to determine factors contributing to the adoption of the machinery technology index. The results indicate that adoption was higher for (1) older and male headed households in general and residents of the Amangwane ward in particular; (2) operators of more arable land, owners of more livestock and earners of more non-farm income; and (3) households with large family labour, and households that made use of extension services and information sources. These results are consistent with hypothesised relationship between technology adoption and the predictors and are supported by previous empirical findings.

Priority should be given to policies that alleviate the tenure insecurity problem on arable land and this inturn promotes a land rental market. This would involve an institutional change and legal infrastructural support services. Arable land holding is highly skewed within the communal setting and the state needs to address this equity issue on arable land through redistribution or reform policies. The state needs also to invest in public goods that alleviate the problems of private investors for example by encouraging credit providers or promoting rural financial markets to alleviate liquidity constraints and enhance adoption. Investment in farmer training and education should therefore, be seen as priority if higher adoption rates and an improvement in income are to be achieved. Inadequate and poor extension and information services imply an urgent need for the formation of community and farming associations and for the provision of extension services to groups of farmers. Investment in these areas may reduce the cost of technology transfer programmes.

The results of a principal component analysis to identify the dimensions of small-scale farmers in communal areas of KwaZulu indicate that farmers fall into distinct categories. Component 1 is an emerging commercial and a more mechanised household while component 2 is a land-less farm household that is more educated and earns more non-farm income largely from contractor services. Component 3 is a non-farm female headed household that depends on income from land renting and non-farm jobs. Component 4 is a small intensive garden farmer, headed by a relatively educated female who has access to institutional services. Component 5 is relatively less educated, a female- headed and land-poor household that rents land and produces intensively.

It is concluded that a single policy measure cannot do justice to the needs of all of the farmers since it would affect different households differently. An integrated and a comprehensive programme is needed that would promote agriculture; facilitate income transfer or safety nets to alleviate poverty and the relief of short-term stress; address the problems of tenure insecurity; overcome the gender inequalities in accessing resources; and restructure institutional supports by providing rural finance, and an extension and legal infrastructure.

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CHAPTER 1. INTRODUCTION

The objective of this research is to study the adoption of land-saving and machinery technologies by small-scale farmers in communal areas of KwaZulu-Natal. The study also identifies the dimensions (categories) of small-scale farmers based on socio-economic and institutional factors. The final goal is to contribute to the knowledge of the ways in which encouraging technology adoption would increase agricultural productivity. This study was prompted by a recognition that empirical information about existing adoption patterns in subsistence agriculture in South Africa was limited. It is evident that the nature and relative importance of factors associated with technology adoption are time-and location-specific, especially in dynamic socio-economic and political milieus. The study builds on previous studies to supplement empirical technology adoption research on small-scale farmers in South Africa by using more recent and broader information from a sample survey.

Schuh, cited by Eicher and Staatz (1990:144) attributes the rising food output and decline in the real price of food not only to natural resource endowment but also to the use of new agricultural technology. Technology, if not the only factor, is one of the most important interactive factors for increased agricultural productivity. Schumpeter, cited by McInerney *et al* (1984:379) states that technological innovation is an 'engine' of economic development, and that a technology component lies at the core of most development schemes. The success of any technology transfer program, however, is a function of the available physical and institutional infrastructures.

The adoption of a new agricultural technology is a central feature of the transformation of farming systems in the process of economic development. Technology adoption has drawn much attention to the fact that the majority of the population of the less developed countries derive their livelihood from agriculture, and because technology offers an opportunity to increase production and income. Several studies have empirically established that technology has for many years been a major contributor to productivity growth (Manning, cited by Rauniyar, 1990:1). The role of technology in achieving a sustained increase in current food production, especially for Sub-Saharan Africa (SSA) is emphasised by Swaminathan, cited by Rauniyar (1990:1-2). The adoption of hybrid maize seed and fertilizer by commercial farmers and the consequent yield increase in Southern Africa is seen as a success story (Hassan *et al*, 1999).

Maize production has had the most rapid growth in Sub-Saharan Africa. This has been largely due to higher yields resulting from a better understanding of improved technologies for maize production (Rauniyar, 1990). Hybrid maize seed is increasingly becoming the dominant maize cultivar type sold in the formal market of Eastern and Southern Africa (Hassan *et al*, 1999). But, there is a substantial gap between maize yields achieved by small-scale farmers and by experimental stations and extension demonstration plots. The maize yield in developing countries for the period 1993-1995 was 55 per cent less than the industrial countries' maize yield (Morris, 1998:14).

Data for this study were obtained from a sample of 160 households in the Amangwane and Amazizi wards in the Okhahlamba Magisterial district of KwaZulu-Natal. Eighty sample households from each ward were interviewed using a structured questionnaire. A stratified random sampling technique as suggested by Lyne (1981:3-12) was employed to draw sample households. Binary logistic regression, principal components analysis (PCA) and principal components regression (PCR), and ridge regression (RR) techniques were used for data analysis. Section 1.1 presents an overview of small-scale subsistence agriculture in KwaZulu-Natal. Sections 1.2 and 1.3 present respectively the objective of the research and the organization of the thesis.

1.1. An Overview of Small-Scale Agriculture in KwaZulu-Natal

KwaZulu-Natal province stretches along the eastern seaboard of South Africa and covers a total area of 9.2 million hectares (Figure 3.1) with a population of 8,417 thousands (21 per cent of the total South African population) in 1996 (STATSA, 2001). Prior to 1994 the province was split into two regions; Natal and the self-governing homelands of KwaZulu. Agriculture and property rights in these two regions were distinct. Natal was dominated by commercial agriculture and private land tenure, and KwaZulu by subsistence agriculture and communal land tenure. After South Africa's first democratic elections in 1994, the two provinces were merged under one provincial administration. This has had no effect on agriculture and property institutions in the province. Land tenure arrangements in the rural areas of KwaZulu are still administered by tribal authorities. Tenure to arable land is insecure in the communal areas/homelands (Thomson, 1996:88-92).

There are 414,000 farming units in the former homelands of KwaZulu-Natal (NDA, 2001). Despite population pressure and the small size of farms, a considerable proportion of arable land in communal areas is left fallow because of an inefficient land rental market. To date, the less developed areas are net importers of food, and despite population pressure and high rates of unemployment are characterised by extensive rather than intensive land use (Lyne, 1996). Lyne also states that small-scale farmers have limited access to factors of production, credit and information, and markets are often constrained by inadequate property rights and high transaction costs. However, it is argued that small-scale agriculture has the potential to become a major source of employment and political stability (Delgado, 1999).

Although agriculture contributed only 3.2 per cent to gross domestic production in 2000, it is important to note its backward and forward linkages to the national economy. Maize is the staple food crop of the population and the most important crop covering the largest area (25 per cent of the total arable land) followed by wheat. Subsistence farmers produce an average of 500 000 tons of maize each year while annual commercial production over the past ten years was 8.2 million tons. KwaZulu-Natal provides 3 per cent of the dryland maize production while the Free State accounts for (34 per cent), North West (32 per cent) and Mpumalanga (24 per cent) (NDA, 2001). Maize is planted from October to December. Land preparation is accomplished by using tractor power although in some areas draft animals are still used. Tractors and other cultivating equipment may be hired from contractors. After harvesting, maize fields are considered communal in the homelands and cattle are allowed to graze the fields. The local chiefs decide when cattle must be removed from the fields to facilitate planting a new crop. Planting dates are determined by the availability of tractors, draft cattle, the onset of rainfall and tribal chiefs' decisions.

Since the deregulation of the maize industry in 1997, there has been no subsidy or any other direct form of financial assistance to farmers (NDA, 2001). Past efforts to improve homeland agriculture such as the farmer support programme of the 1980's focussed on the provision of extension, credit programmes, irrigation projects and technical inputs. The farmer support programmes were, however, phased out since then (Ortmann and Lyne, 1995). Small-scale farmers currently finance their inputs, machinery and farm chemicals from sales of crop and livestock, wage remittances, pension payments, off-farm incomes and informal credit.

1.2. Objective of the Study

The assessment of subsistence agriculture in KwaZulu-Natal provides evidence of low agricultural productivity, high rates of unemployment and rural-urban migration. Small-scale agriculture, however, has the potential to become a major source of employment and political stability (Delgado, 1999). Lyne (1996) also argues that agriculture, should and could, make a contribution to economic growth in the homelands of South Africa. The central theme of this study is to generate empirical information that can be used to devise programs to encourage small-scale farmers adopt agricultural technologies. The study rests on the premise that adoption of technological innovations combined with the relevant infrastructure and institutional services could change the current situations prevalent in subsistence agriculture. The hypothesis that the adoption of agricultural technologies by small-scale farmers is influenced by individual and farm attributes, socio-economic factors, and infrastructure and institutional facilities is tested in this study. Successful interventions using the generated information will significantly improve agricultural productivity of the small-scale farmers.

The specific objectives of this study are (a) to identify the factors associated with the adoption of hybrid maize seed, fertilizer and machinery technologies by small-scale farmers; and (b) to identify the dimensions of small-scale farmers based on socio-economic and institutional factors.

1.3. Organization of the Study

This thesis is organized into six chapters. Chapter 2 presents a review of the theoretical and empirical research results of technology adoption behaviour. Chapter 3 describes the research methodology used for analysing the determinants of technology adoption by farmers and the socio-economic dimensions of small-scale agriculture, and the hypotheses and definition of variables used in the empirical models. Chapter 4 presents the general characteristics of sample population using descriptive statistics. The results of the empirical analyses are reported and discussed in Chapter 5. Chapter 6 concludes by discussing the implications of these findings for policy and future research.

CHAPTER 2. LITERATURE REVIEW OF ADOPTION BEHAVIOUR

2.1. Background

The adoption of technical innovations by agricultural producers is an essential prerequisite for the economic prosperity of developing countries. Technical innovations such as high yielding, disease and pest resistant, and stress tolerant crop varieties, pesticides, herbicides and machinery contribute significantly to economic development. Since their introduction in the mid 1960's, the high-yielding wheat and rice varieties accounted for about 40 to 50 millions tons of additional grain each year in the Third World (Lipton, 1989).

The appearance of high-yielding grain varieties had important effects on the theory as well as on the practice of agricultural development. Several authors note that the new grain/fertilizer innovations were highly divisible, allowing them to be incorporated into existing systems of small-scale agriculture (Either and Staatz, 1990). High yielding varieties, it is argued, promoted both employment and output objectives.

Considerable empirical evidence is also available on mechanisation (i.e., tractors, planters, harrows, etc.) and its impact on agriculture in developing countries. In South Africa, the numbers of tractors in use were 88, 000 in year 1998. However, there were almost 175,557 in 1981 tractors, this was the maximum number recorded so far (FAO, 2000). This decline is partly due to a drop in area under maize and higher tractor prices. The growth rate of threshers in South Africa between 1961 and 1998 is estimated at 1.6 per cent. Although there are equity issues, mechanization contributes to output and employment in any given country and especially if successful mechanisation is achieved, may partly or wholly offsets the high national opportunity costs of importing tractors, fuel and parts (Ruthenberg, 1985: 71). In developed countries, however, machines do substitute labour. For households with low yields, as in subsistence agriculture in KwaZulu-Natal, a complementary relationship between labour and machinery use has been reported (Nieuwoudt and Vink, 1989). This and other evidence documented in the literature have generated much interest in the adoption issue. An in-depth analysis and understanding of adoption and diffusion processes facilitates the progress of developing countries towards sustainable economic development.

2.2. Definition of Terminology

This section highlights terminologies which are used in the thesis.

Adoption: the use of a particular innovation by individuals/ farmers at a point in time or during an extended period of time (Nkonya *et al*, 1997).

Adoption rates: the percentage of area planted with improved seed or the percentage of area fertilized in a given region (Griliches, 1957).

Intensity of adoption: the level of adoption of a given technology. The average hectare planted with improved seed (the percentage of each farm planted with improved seed) or the amount of chemical fertilizer applied per hectare (Nkonya *et al*, 1997).

Adoption process: the process by which technological advance is assimilated. Generally, it includes awareness, interest, evaluation, trial or 'mental acceptance' and finally actual practice or adoption (Basabrain, 1983).

Technology/ innovation: the solution and overcoming of problems; a new way of doing something (Brow, 1983). Conceptually, technology is viewed as an upward shift in the production function. Broadly speaking, innovations may be classified according to whether they raise the productivity of all resources equally, in which case they are called 'neutral', or whether they save one particular resource rather than another, when they are classified as 'biased'. The following classifications according to Hill and Ray (1987) are worth mentioning:

Land-saving: technical innovations that allow a reduction of land input per unit of output. In general, this term applies to bio-technical innovations such as the introduction of high yielding varieties, improved methods of plant protection and nutrition. A technology can also be land neutral or land consuming.

Labour-saving (machinery): technical innovations that allow a reduction of labour input per unit of output. Examples of such innovations are the use of herbicide or of mechanization. Labour- saving is analogous to land-saving technology. A pure labour-saving technology is the substitution of capital for labour while in practice, there is an innovation with a mixed effect. A technology can also be labour-consuming or labour-neutral.

Capital-saving: a technical innovation that allows a reduction in the capital input per unit of output. An example is the use of artificial insemination by dairy farmers. Similarly, a technology can be capital neutral, bringing little change in capital investment as in the case of chemical fertilizer or a new seed variety or it can be capital intensive as in the case of the introduction of new machinery or a new type of milking parlour.

A technological package: a package of several technologies which may be adopted simultaneously or independently depending upon whether or not the specific practice is complementary. Technologies can be considered *divisible* (e.g., improved crop seeds, fertilizers, farm chemicals, agricultural services, etc.), and *non-divisible or lumpy* (e.g., a tractor, harvester, planter, management etc.).

2.3. Concepts of Needs, Behavioural Change and Technology Adoption

A need is viewed as a difference between what is, and what ought to be; it always implies a gap. The fulfilment of a need would further the welfare of the organism (Basabrain, 1983:46-47). The importance of understanding human needs is in the actions they initiate, once they are felt on the part of the individual. Leagans, cited by Basabrain (1983) states that only felt needs motivate the individual to take action for satisfaction. These actions induce behavioural changes in the individual.

According to Leagans' behavioural differential model, the adoption of any new idea or practice involves some form of change in the individual (Basabrain, 1983). It is the understanding of the behavioural change that is the central to an understanding of adoption behaviour, which essentially seeks to explain why individuals will choose to change their existing behavioural pattern (Basabrain:66-67).

Leagans, cited by Basabrain (1983:6-7), argues that there are always forces acting upon people which create needs or a disequilibrium between them and their environment. As stated by Leagans, "the essence of behavioural change results from the interaction of two states of opposing forces: Change incentives and change behaviours, which create tensions that motivate action and result in change". On the one hand, incentives motivate individuals to change their behaviours within their environmental context. These incentives may include innovativeness, rising education, the desire for social improvement, and the availability of technology. The inhibitors, on the other hand, motivate individuals to retain their established behavioural pattern or to resist change. Inhibitors may be traditional values, low education, lack of resources, and low income status. Furthermore, Leagans claims that besides determining incentives and disincentives, the force between them is important as this force finally determines the cumulative force that affects the total behavioural change (Basabrain, 1983: 66).

Technology adoption is simply defined as the act by which a person begins using a new practice to replace an old one. The process of adoption is actually more complex than this statement explains. Rogers views the process as "the mental process through which an individual passes from hearing about an innovation to final adoption" (Basabrain, 1983:51-52). Leagans supports Roger's concept of adoption as a type of 'learning experience' (Basabrain, 1983).

Feder *et al* (1985:256) argue that for rigorous theoretical and empirical analysis a precise quantitative definition of adoption is needed. At the level of the individual farm they define it as "the degree of use of a new technology in the long-run equilibrium when the farmer has full information about the innovation and its potential." Aggregate adoption is measured by the level of use of a specific new technology within a given geographical area or population.

Roger's definition of adoption implies that the adoption process involves levels or stages. It has been recognized that the adoption of innovation is not an instantaneous or abrupt 'metamorphosis' but is rather a product of sequence of events and influences operating through time (Basabrain, 1983:53).

Although researchers generally recognize that adoption is the result of a sequence of events and not a random behaviour, there is little evidence as to exactly *how many stages* there are in the adoption process. The five-stage model of the adoption process which is summarized as in Figure 2.1 below has however been widely used in the area of adoption-diffusion studies (Basabrain, 1983:55-58):

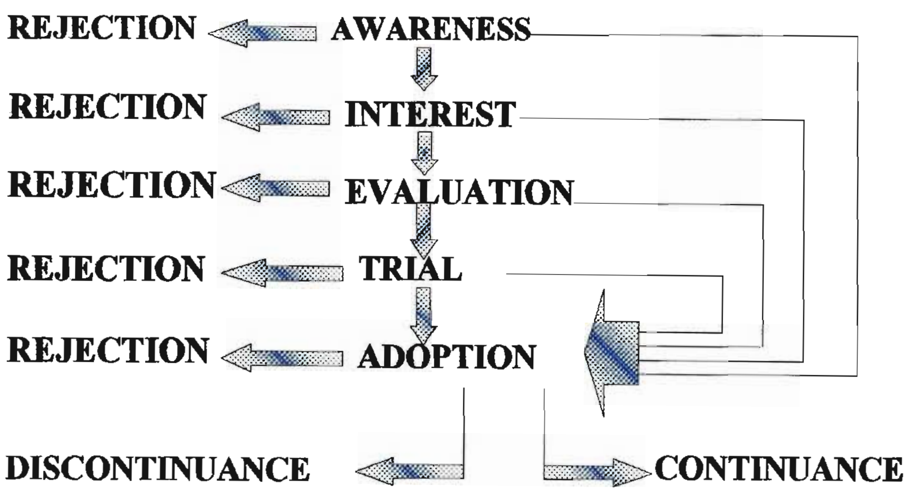

Figure 2.1. A Paradigm of Adoption Process (Adapted from Basabrain, 1983)

1. Awareness stage: the individual learns about the new idea, practice or product;

2. Interest stage: the individual develops an interest in the idea and imagines it applied to his own situation, but does not have enough information to judge.

3. Evaluation stage: the individual has already collected some information about the idea or practice; he is in the process of mental trial

4. Trial stage: the individual uses the innovation on a small scale.

5. Adoption stage: the individual decides to continue the full use of the innovation.

It is evident that at each stage on the continuum the individual deepens his commitment to the innovation and improves his understanding. In doing so, there is at each stage a possibility of rejection of the innovation by the individual. Finally, the model assumes that some time after adoption an individual may continue or discontinue with the innovation (Basabrain,1983:60).

The adoption of a new practice is affected by groups of factors which interact during the mental activity that individuals pass through prior to adoption. The " mental process" nature of adoption behaviour implies that the phenomenon cannot be directly observed and manifestations of the process must satisfy research objectives. Inconsistencies in the definition of adoption may therefore, result. For instance, a farmer who uses fertilizer may be termed an adopter of fertilizer according to a certain researcher, but the same farmer may be a non-adopter of some other innovation, for example insecticide or herbicide. The step-wise adoption of a technological package hypothesis has been supported by some authors. Byerlee and Hesse de Polanco (1986:519) demonstrate that farmers in the Mexican Altiplano have rationally followed a step-wise approach to the adoption of a technological package that reflects the characteristics of each component and the interactions between them. Proponents of the package argue that a package is needed to capture the positive interactions between several components. Walker states that farmers are convinced by a technological package because they will realize the large yield differences between the traditional method and improved practices (Byerlee and Hesse de Polanco, 1986:519).

Definitional inconsistency arising from different research situations has resulted in varied and often contradictory sets of hypotheses and observations concerning adoption behaviour. In most studies, adoption variables are categorized simply as "adoption" or "non-adoption" where adoption is seen as dichotomous. However, "knowing that the farmer is using a modern variety may not provide much information because he may be using 1 or 100 per cent of his acreage" (Feder *et al,* 1985:283). Similarly, with respect to the adoption of fertilizer, a farmer may be applying a small amount or a large amount per hectare. Feder *et al* (1985:283) argue that adoption often cannot be represented adequately by a dichotomous qualitative variable. Following a comprehensive review of the literature on technology adoption, Schutjer and Van der Veen, cited by Feder *et al* (1985:283) concludes that "the major technology issues relate to the extent and intensity of use at the individual farm level rather than to the initial decision to adopt a new practice".

The focus of main-stream research on adoption is on the identification of factors influencing the nature and extent of the adoption process. Rogers claims that the problem is to learn why, provided with 100 different innovations conceived simultaneously, only ten will spread while 90 will be forgotten (Basabrain, 1983:45). The adoption process is considered to be a function of the characteristics of the innovation and of the individual. The next section presents a review of the individual and innovation characteristics influencing adoption.

2.4. Factors Influencing Technology Adoption

2.4.1. Technology Characteristics

Although it is not known with certainty, the economic potential of a new technology in terms of anticipated yields, cost of production and profit seems important for its adoption. Griliches (1957) and Hiebert (1974) have shown the profitability of an innovation to be the most important factor in the adoption process. Tesfai on the other hand concludes that profitability is a necessary but not sufficient condition for adoption by peasant farmers (Basabrain, 1983: 93). Mosher and Upton, as cited by Ruthenberg (1985:28) state that a new technique must promise a substantial increase in yield (i.e.,40 to 100 per cent) or major reductions in costs to be acceptable to most farmers.

Perceived profitability and risk are the two variables strongly indicated by economic theory to be important for adoption (Chilot *et al*, 1996). Parikh and Bernard (1987) in Bangladesh and Shapiro *et al* (1991) in the mid-west USA empirically show that an individual's subjective beliefs about profitability and risk can significantly affect the adoption behaviour of farmers. The profitability and riskiness of a technology, in turn, are a function of elements of the agro-climatic and socio-economic environments, such as rainfall and prices.

In the study of hybrid corn in the corn belt of the USA, Griliches (1957) found the rate of adoption to be linked to the relative environmental suitability of the State concerned. The compatibility of a technology with the farming circumstances has been observed to influence adoption decisions. For instance, in the opinion of the author, Ethiopian Vertisol farmers rejected a profitable plough (broad bed maker, BBM) because it was too heavy for oxen and could not be used during the extended planting dates of farmers who manage a mix of crops.

Besides profitability, four innovation characteristics namely, 1) riskiness, 2) divisibility (as in the case of a high yielding variety) or initial capital requirements, 3) technical complexity and 4) availability are hypothesized as influencing the adoption process (Byerlee and Hesse de Polanco, 1986). Byrnes, as cited by Byerlee and Hesse de Polanco (1986) hypothesises similar, but not identical, characteristics consisting of observability, comparability, profitability, reliability and trialability. Rogers and Shoemaker (1971) reported the characteristics consisting of relative advantage (profitability), compatibility, complexity, trialability and observability. Monu (1981) states that the compatibility of the innovation with the existing cultural patterns, its relative advantage over existing innovations, the institutional support which the innovation receives, the distribution systems available and the method of dissemination of information about the innovation will influence its adoption.

2.4.2. Characteristics of the Individual

Adoption study in the sense of individual characteristics focuses on identifying the personal, psychological, economic, socio-cultural and educational attributes of the target individual so as to explain observed differences in various aspects of adoption behaviour. By convention, individuals within a given population are classified into five categories, according to the date of adoption, as innovators (venturesome), early adopters (respected), early majority (deliberate), late majority (sceptical) and laggards (traditional) (Hill and Ray, 1987: 292-293).

The characteristics of the individuals belonging to the various categories have been well documented in past literature. Opio-odongo (1980) summarized three African studies, Basabrain (1983:76) compiled a similar table of international studies, and Hill and Ray (1987:292-293) recently tabulated the findings of several British studies. The following summary of major variables based on Wheeler (1989) and Hill and Ray (1987) under broad headings are included so as to illustrate the types of variables considered in the literature:

Personal Characteristics: age, gender, etc

Social Characteristics: family size, social status, society norms and expectations, etc

Psychological Characteristics: adoption inclination, susceptibility, attitude, achievement, ingenuity, leadership role, risk aversion, empathy, cosmopolitan, etc

Economic factors: income, wealth status, farm size, access to credit, transaction costs etc

Educational and communicational factors: formal education, level of literacy, experience, exposure to extension, knowledge about the innovation, urban contact, contact with scientific information sources, etc.

Definitional inconsistencies and the time-specific nature of the relationships between the various factors and adoption behaviour, have resulted in little agreement among authors as to the theoretical and observed (empirical) relationships. Ruttan, cited by Feder *et al* (1985) claims that these inconsistencies and a lack of generalisations are attributable to the widely differing social, political and economic environments into which the innovations have been introduced and the studies made.

2.4.3. Explanatory Factors

A review of the empirical work in a number of key explanatory factors affecting adoption behaviour is summarised below.

(a). Farm size

Land is an important asset in the farming business and a major source of wealth for the farmer. Farm size is one of the first factors on which the empirical adoption literature focussed. Whether farm size is positively or negatively associated with technology adoption may have policy implications as cutting up farms into small units as in land reform may affect technology adoption. Wheeler (1989:13) states that there are observed reports in the literature on the positive, negative and neutral relationship between land size and adoption behaviour, while there are theories which support all the observed relationships. Roeling *et al*, cited by Ruthenberg (1985) reported a positive correlation between adoption rate and farm size and they also find that there are 'laggards' and 'progressive' farmers in all farm size categories. This would justify the neutrality hypothesis.

Feder *et al* (1985:271) finds that larger farmers may be at an advantage in that they can more easily bear the fixed costs attached to the implementation of innovation. The adoption of lumpy inputs such as machinery may thus be associated with larger farmers. Hayami (1990:419) shows that the pattern of modern variety diffusion paths sharply contrasts with the diffusion pattern of tractors. In the case of the latter, large farmers achieved distinctly faster and higher rates of adoption. This means that tractor technology is indivisible and lumpy, and requires a large farm size for efficient operation.

Larger farmers are also quicker to adopt divisible innovations, such as seed and fertilizer, since there are economies of size in transaction costs and management opportunity costs (Feder *et al,* 1985). This is because both large and small farmers spend the same time and effort in acquiring and evaluating information about a new technology, learning how to use it and making the purchase transaction. Fertilizer and seed technologies are also complementary to tractors, as increased use in fertilizer is often correlated with increased mechanization. For an increase in the net return of $ 20 per hectare, the new technology might be quite advantageous for a 10-hectare farmer but not for a 1-hectare farmer. Experimentation with the new technology may involve the unknown risk of requiring an additional investment, a risk which only larger farmers may be able to take (Perrin and Winkelmann, 1976).

Small farmers may face higher input costs since quantity discounts may be available, or government subsidies for information, credit or inputs may favour large farmers (Perrin and Winkelmann, 1976). Similarly, Binswanger, Gafsi and Roe show that large-scale farmers adopt lumpy technologies more easily because they have relatively better access to capital and credit, and the capacity to bear risk (Hassan, 1998:122). Feder *et al* (1985), regarding modern seed varieties and fertilizers, find that small-scale farmers at least initially lagged behind other farmers in adoption. Hassan (1998:123) observes that in Kenya the average lag between the time of release of a seed variety and its initial adoption was approximately two years for large scale farmers and eight years for smallholders. He reports that access to information, extension, and credit, which is substantially better for large-scale than for small-scale farmers, may explain differential rates of adoption.

Feder *et al* (1985:273) report that farm size is a surrogate for a large number of important factors such as access to credit, information, inputs, capacity to bear risk and the wealth of a farmer which are likely to influence adoption behaviour. As the influence of these factors varies in different areas and over time, so does the relationship between farm size and adoption. Therefore, large farmers may tend to adopt quickly due to the proxy factors rather than to the large farm size per se. Hayami (1990) in his summary, also reported that "there was one village where there was a significant lag of small farmers behind large farmers in the adoption of modern variety". Perhaps fixed information costs declined as the benefits became clearer and made adoption less costly to small farmers once larger farmers had adopted the new technology. Besides, since technology transfer programmes in Asia were run by the government, extension services, fixed information and management costs were born by the government.

Chitere (1985), and Shaw and da Costa (1985) have reported a positive relationship between adoption and farm size. Empirical evidence from KwaZulu suggests that both the adoption of farm technology and the production of surpluses are positively correlated with farm size and renting or borrowing of land (Kleynhans and Lyne, 1984; Nieuwoudt and Vink, 1989; Thomson and Lyne, 1991). Large farm sizes enhance technology adoption because management and information costs are fixed but returns to information and technology are proportional to scale (Welch, 1978).

On the other hand, an inverse relationship between farm size and the adoption of modern inputs is reported by several researchers. The rationale for this argument is that small-scale farmers may farm more intensively to meet subsistence needs. Hayami (1990: 419) states that 'little empirical evidence indicates that the use of modern rice varieties has been monopolized by larger farmers in Asia'. On average, small farmers were quicker to adopt improved varieties than were large farmers. Feder *et al* (1985) report that small farmers have been observed to irrigate more efficiently and to use more low-cost family labour. Norman *et al* (1982) in Nigeria and Nkonya *et al* (1997) in Tanzania reported a negative correlation between farm size and the rate of nitrogen fertilizer applied. The alleged reason was that farmers with more land tended to grow their crops on more fertile lands and fallowed areas with less natural fertility (i.e., when land is not constrained, a positive relationship might hold). Perhaps the inverse relationship between technology adoption and farm size is attributed to the fact that government reduced private fixed transaction costs by providing information, credit and extension. Or else there are special resources (such as irrigation, cheap labour, and subsidies) at the disposal of small scale farmers. Otherwise, very small farm sizes tend to preclude scale economies and limit potential returns to innovation and higher product prices (Nieuwoudt and Vink, 1989; Lyne and Niewoudt, 1991).

From a third perspective, a biological technology is essentially 'neutral' with respect to farm size or farm tenure. This suggests that no significant influence on adoption behaviour results from farm size. Ruttan, cited by Hayami (1990), after a summary of micro studies in Asia, concludes that "neither farm size nor tenure has been a serious constraint to adoption of high-yielding varieties and an important source of differential growth in productivity". Ruttan and Binswanger, cited by Ruthenberg (1985:51) state that although differential rates of adoption by farm size and tenure have been observed, available data show that within a short time of a technological introduction, lags in adoption rates associate with farm size or tenure have typically disappeared. On the basis of evidence obtained from the Indian Punjab and rice farms in Phillippines, they conclude that no serious adoption differences have caused any significant yield differences between small and large farmers.

Feder and Slade (1984:320) reported some complementary results in line with the above view that although larger farmers may adopt earlier, small farmers tend to catch up and eventually operate on the same footing. Perrin and Winkelmann (1976:889) state that the lag reduces over time as community experience increases and information about the new technology becomes more common, the transaction costs fall and unknown risks likewise. Perhaps, once larger farmers have adopted the new technology fixed information cost declines as the benefits become clearer making adoption less costly to small farmers. Thus, size effects are likely to be observed at an early phase of the adoption cycle. The neutrality view does not take into account the fixed costs of information, transaction and management costs that favour large farmers.

(b). Economic status

Any technology adopter incurs a cost in acquiring a new technology. Feder *et al*, cited by Wheeler (1989:15) state that there must be an availability of finance if the decision-maker is to be able to bear cost of the technology. It is hypothesized that healthy economic status will result in an increased capacity to bear the potential risk associated with the new technology and in this way will stimulate adoption. It is also more likely that wealthier farmers are able to finance the cost of a new technology. Off-farm activities and credit access provide finance for implementing and maintaining the new technology whereas an asset base (herd size or any other asset) represents an increased capacity to take risk. Savadogo *et al*, and Adesina, cited by Adesina *et al* (2000) have shown that non-farm income positively influence adoption of technologies. This is because having non-farm income may allow farmers to meet capital costs, and may also reduce adverse consequences of risks in experimenting with new technologies. Sanders *et al* (1996:128) report that farmers' indebtedness (i.e., willingness to take credit) is positively related to the adoption of a sorghum variety in Sudan.

Basabrain (1983) states that wealth is seen as a surrogate both for factors such as income and credit availability (liquidity), and for increased capacity to accumulate information. Voh and Monu, cited by Wheeler (1989:16) reported that economic status referred to as 'level of living' has positively affected the adoption of a technology. Chilot *et al* (1996) report a similar positive impact of wealth on the probability of adoption of improved seed and weedicide. Authors such as Chitere (1985), Chilot *et al* (1996), Freeman *et al* (1996) and Hassan (1998) have reported that availability of credit has positively influenced the adoption of new farm practices, and inputs such as fertilizer, herbicide and dairy feed in Kenya and Ethiopia. Feder *et al*, cited by Wheeler (1989) report a general consensus among authors that finance has an important influence on adoption behaviour, although the evident profitability of the new enterprise will induce even the smallest farmers to mobilize funds from whatever sources are available.

(c). Human capital

Human capital is the cumulative knowledge acquired in the form of informal or formal education, and experience. Feder and Slade (1984:312) reported that "improved knowledge regarding a new technology through the accumulation of a stock of information (i.e., with economic return) over time is hypothesised to be one of the main dynamic elements of technology adoption processes". Welch (1978) contends that education reduces cost of information and improves allocation efficiency, while demand for education increases with farm size as returns to education are scale proportional (large scale implies broader scope for applying information). He concludes on the positive ties between technical dynamics and the allocative role of farmer schooling from studies conducted in both developed and developing countries. Feder and Slade (1984), Sanders, *et al* (1996), Chilot *et al* (1996), Nkonya *et al* (1997) and Hassan (1998) have found that better formal education, concrete experience, and exposure to extension services are important sources of information gathering in that they contribute to comprehensive knowledge about the innovation and thereby stimulate technology adoption. Feder and Slade (1984:318) conclude that a higher endowment of human capital promotes adoption by improving resource allocation efficiency and productivity. Feder *et al* (1985) report that educated farmers adjust to input price change, their input levels approach optimal level faster, and they apply modern inputs efficiently. This suggests that more educated farmers are early adopters. They add that several other studies have explicitly verified the link between early adoption and education.

Kislev and Shchori-Bacharch (1973) more explicitly argue that the production function associated with new technology incorporates an efficiency factor which is positively related to the level of knowledge. In the learning by doing literature, knowledge is represented by cumulative output which increases over time, thus raising the level of knowledge and efficiency and rendering the new technology attractive to an increasing number of producers. Hiebert (1974:764) states that an adoption decision is a decision made under uncertainty, where the farmers have different and incomplete information about the new techniques and hence are uncertain about the techniques. As the adoption process proceeds, farmers obtain additional information which reduces uncertainty and the possibility of making allocation mistakes. Skills which enable the recipient to "decode" information are thus, shown to increase the likelihood of adoption.

(d). Labour availability

Labour availability is an often-mentioned variable which affects farmers' decisions about the adoption of new agricultural practices or inputs. Labour shortage may encourage labour-saving technology and on the contrary, discourage labour-intensive technology. Feder *et al* (1985: 277) report that a higher rural labour supply leads to the greater adoption of intensive rice varieties in Taiwan and that shortages of labour explained the non-adoption of high yielding variety (HYV) in India. Most studies seem to agree that the operative constraint in African farming systems is the peak-season labour scarcity. Celis *et al* (1991:215) reported that households that have adopted the highest level of technology (i.e., oxen, hybrid seed and fertilizer) have used more family labour than those which adopted the lowest level (traditional method). This shows that labour availability or the liquidity to hire labour is important if a higher level of technology adoption is to be attained.

Theoretical work on labour bottlenecks and labour supply uncertainty in peak seasons seeks to explain the adoption of machinery techniques. Several authors conclude that "mechanisation can make operations more timely and allow increased production and reduced labour demand and, sometimes, more double cropping and multiple cropping" (Feder *et al*, 1985). In KwaZulu-Natal households are using both land-saving and machinery technologies. Despite an increasing rural population and society viewing it as inappropriate, households tend to adopt machinery rather than land-saving farm technologies, because in the absence of an efficient rental market the private opportunity cost of agricultural land is extremely low. Thus, divergencies between private decisions and those considered desirable by society can be ascribed to missing and imperfect markets (Lyne, 1996). Although land is scarce relative to labour, the relative scarcity of land is not reflected in price since there is no efficient land market. Consequently, farmers adopt land-saving technology although society views it as inappropriate.

(e). Supply constraint

An adoption pattern is explained by the supply of complementary inputs. Feder *et al* (1985) contend that high yielding varieties (HYV) and fertilizer must be available for most farmers to adopt improved seed and realise the high yielding potential of the seed. Beyond the simultaneously introduced complementary inputs, it is further argued that other complementary innovations must also be considered. Feder *et al* (1985) report that HYV fertilizer packages are more profitable and less risky if water supply is assured and regulated. They conclude that innovation complementarity and adoption decisions should be jointly examined. Nichola, cited by Sanders *et al* (1996:126) reports that the principal constraint on the rapid and wider adoption of a high-yielding sorghum variety in Sudan was the inadequate quantities of high-quality seed and sufficient fertilizer provided by input suppliers. There would evidently have been 51 per cent more adopters if all farmers who wanted to buy seed had been able to obtain it.

(f). Institutional factors

Factors such as access to credit, extension advice, legal and regulatory institutions, and other sources of information are hypothesised as influencing farmers' technology adoption decisions. Thomson (1996:46) contends that institutions, by affecting property rights and transaction costs, have the effect of either facilitating or retarding economic growth. Basabrain (1983) reports that the level of knowledge about the innovation, extension contact and contact with other sources of information influence adoption of innovations. Hassan *et al* (1998:151) reported that more farmers in the medium and high-potential areas in Kenya adopt fertilizer since they had relative access to institutional credit and extension services. Keregero, cited by Nkonya *et al* (1997) and Kleynhans and Lyne (1984) report a similar result in that the adoption of technology was increased by farmer-officer and officer-farmer visits. Moor and Nieuwoudt (1998) found that access to extension and training positively influenced yield (total output). This suggests that better informed farmers are more likely to make yield-enhancing management decisions.

Households which are cooperative members behave very differently from non-members: as the former use more hired labour which is required by the new technology. Cooperatives apparently help integrate workers with the market and stimulate the development of activities that achieve a high return for each hour of labour performed (Celis *et al*, 1991:244). Adesina *et al* (2000) and Caveness and Kurtz, cited by Adesina *et al* (2000) also report that the adoption of alley farming in agroforestry technologies is higher for farmers belonging to farmers' groups and for those who have contact with extension agencies in the southwest of Cameroon and Senegal. Poor infrastructure limits the extent to which technological change promotes the full use of labour, land, capital and education (Celis *et al*, 1991). The 'frontier model' as well as the 'diffusion model' critically depend on a number of physical and institutional infrastructures (Ruttan, cited by Ahmed and Donovan, 1992).

(g). Land tenure

Several studies argue that tenurial arrangements may play an important role in the adoption decision. Views are not unanimous, however, and the subject is one of considerable controversy. Bahduri, cited by Feder *et al* (1985) develops a model showing that credit-provider and land-owner landlords in India may not permit the adoption of yield increasing innovations. The alleged reason is that adoption will reduce the tenants' indebtedness to the landlord, and that the income from lending declines more than the increase in output shares. Scandizzo, cited by Feder *et al* (1985) also concludes that landlords will be reluctant to adopt land-saving innovations if interest charges and price margins are high. However, several authors, Newbery (1975), Ghose and Saith (1976) and Srinivasan (1979) criticize the Bahdur's analysis by stating that landlords have no monopoly power and that they favour the adoption of yield increasing technologies. Scandizzo's (1979) model was also criticized on a number of factual and methodological points. It was shown that usurious interest rates serve to tie the tenant to the land rather than serving as means of extracting profits. Thus, under semi-feudal conditions, landlords *will not be reluctant* to adopt yield-increasing technologies subject to the usual profitability and risk.

Newbery, cited by Feder *et al* (1985) constructs a model that implies sharecropping could hinder the adoption of innovations. The alleged reasons are that production and labour markets are subject to uncertainties and that a new technology increases the supervision cost of tenants' inputs. Bell (1972), however, reports that tenants' attitudes towards adoption depend not on the form of the existing lease but on the profitability and riskiness of the technology. He concludes that whenever a technology is attractive to the tenant, it will also be attractive to the less-risk-averse landlord. Bardhan, cited by Feder *et al* (1985) presents a model with endogenous wage determination and allocation of land between self-cultivation and sharecropping. He reports that 1) the percentage of the area under tenancy increases if land-saving technology is introduced thus contradicting Newbery's report; 2) market imperfection for complementary inputs with HYV technology leads to a lower percentage of area under tenancy, and 3) the higher labour intensity of the crop induces a higher incidence of tenancy.

The effects of tenure arrangements and proportion of farms rented for the adoption of HYV have been considered in a number of empirical studies. Conflicting and confusing empirical results have been recorded on the relationship between technology adoption and tenure. Parthasarathy and Prasad, cited by Feder *et al* (1985) conclude that tenants have a lower tendency to adopt HYV's than owners, and less familiar fertilizers were used less by small farmers and tenants. Nitrogen fertilizer use was however the same for tenants and owners. Likewise, other empirical results show no clear relationship between tenure and adoption (Feder *et al*, 1985). Vyas, cited by Feder *et al* (1985) argues that adoption HYV in India shows that tenants were not only innovative as land owners but sometimes used more fertilizer. Uchendu (1978) reported that the tradition of multiple interests that many Africans enjoy on the same piece of land remains a major obstacle to the adoption of technical innovations. Feder *et al* (1985) concluded that conflicting empirical results on the relationship of tenure and adoption are in accordance with the unsettled debate in the theoretical literature about the relationship between tenancy and adoption. This suggests that there may be many factors yet to be considered appropriately.

Migot-Adholla *et al* (undated) and Place and Hazell (1993) report that tenure security directly affects variable input use because of improved access to cheaper institutional credit. Hayes *et al* (1997) in Gambia, and Moor and Nieuwoudt (1998) in Zimbabwe report that tenure security positively enhances long-term investments, the planting of trees on plots and the application of higher levels of inputs. It is contended that the increasing individualization of land rights (i.e., rights to sale and the use rights it implies) even under customary tenure is associated with a higher propensity to make investments, which in turn has a positive effect on yields. Tenure security is expected to enhance access to credit (i.e., collateral) and to encourage investment in fixed improvements (i.e., ability to internalise benefits) (Thomson and Lyne, 1995:178). Kille (1993) reports that on-farm investment and farm productivity are determined by exclusive and secure property rights. Lyne (1989:14) states that the underutilisation of arable land does not involve high opportunity costs as the land market is incomplete (partly due to tenure insecurity). In the absence of an efficient market, rural households adopt time-saving rather than land-saving farm technologies because the private opportunity cost of agricultural land is extremely low (Lyne,1996:191). Farm size are, however, extremely small in KwaZulu and society views land as a constraint. Small improvements in tenure security and contract enforcement can stimulate the rental market for arable land, leading to more intensive land use and welfare gains for contracting parties (Thomson, cited by Lyne, 1996). The incidence of investments in farm implements, tractors and fencing is also higher among lessees (Thomson, 1996). The adoption of seasonal inputs is expected to be higher for owner operators than for tenants because lease arrangements involve moral hazards.

(h). Gender

The gender of the farmer is hypothesized as influencing the decision to adopt a given technology. Women have the problems of legal ownership of land (in case they have ownership, it is biased in favour of men), low social status and cultural barriers, and lack of education (Lipton *et al*, 1996:338). Hassan *et al* (1998:127) claim that female farmers are expected to place more emphasis on the post harvest qualities of new varieties than men do, because women usually perform post harvest operations. Female headed households in Zambia are less inclined to adopt hybrid maize and fertilizer technologies (Celis *et al*, 1991:198). Fabiyi *et al*, cited by Adesina *et al* (2000) in southwest Nigeria find that male farmers are more likely to use alley farming than women. Adesina in Cote d' Ivoire and Matlon in Burkina Faso, cited by Adesina *et al* (2000) reported that female rice farmers are less likely to use chemical fertilizers. The presence of a male-decision maker in a household positively influenced the adoption of maize production technologies (Bembridge and Williams, 1990). Women face less certainty than men when attempting to enforce a contract in a tribal court. In Latin America, a husband's representation to contract is often required even after the woman reaches majority age (Leutner,1999:164). Delgado (1997) reports that although most women and men have land use rights, women unlike men are not directly involved in the allocation of use rights. The tenure insecurity of women reduces their incentive to invest in time and resources, and adopt more sustainable practices. He also states that women face higher transaction costs (i.e., a market and information), receive less education than men, face mobility restrictions and less credit accessibility, which in turn may have implications for their adoption of new technologies.

(i). Age of the farmer

The commonly held view is that elderly farmers resist change, very young ones are less inclined to undertake drastic change, and middle-aged ones are the most tolerant of the adoption of new practices. Copp and Brown, and Gross and Taves, cited by Basabrain (1983) report results which support this line of argument. Age may, however, mean that a farmer has accumulated enough information through longer experience and experimentation, and hence age is thought to increase the likelihood of adopting a new technology (Hassan *et al,* 1998:127). Nell (1998:149) reports that the older goat and sheep farmers of Qwaqwa in South Africa adopted relatively more of internal parasite remedies because long years of experience are probably needed to diagnose internal parasites. Matungul, *et al* (2001) similarly reported that older and more experienced household heads tend to have more contacts, face lower transaction costs and use more marketing channels.

On the other hand, attitude towards risk may be affected by age; Older farmers may be more conservative or resistant to change than younger ones. Celis *et al* (1991:196) report a negative relationship between the age of household head and modern technology. Kille (1993) finds a negative relationship between farm productivity and the age of the household head. Similarly, Bagi, Gould *et al*, and Polson and Spencer, cited by Adesina *et al* (2000) have shown that younger farmers tend to be more innovative because of their long-term planning horizons and lower risk aversion. Nkonya *et al* (1997) report that farmer age does not significantly influence the adoption of improved maize seed and nitrogen fertilizer in Tanzania. Empirical evidence indicates a positive, negative or no (zero) relationship between age and the adoption of farm practices (Basabrain, 1983:77-78).

Generally, the evidence shows that the observations and hypotheses of adoption studies on the nature of adoption behaviour are location and time specific. The pattern of barrier complexity moreover varies from one farming environment to another. Therefore, any program aimed at the transfer of farm technology must take account of the micro-and macro level factors affecting farmers and, additionally, the quality of extension (i.e., institutions and infrastructures) and the characteristics of the innovation.

CHAPTER 3. DESCRIPTION OF VARIABLES AND METHODS

Section 3.1.1 presents a short justification of the dependent variables while the hypotheses about independent variables are presented in section 3.1.2. Section 3.2 presents a survey which includes a description of study areas, sources of information, and data collection and sampling techniques. Section 3.3 highlights methods of data analysis which include how the potential and possible predictors of technology adoption are selected, and the analytical techniques such as logistic regression, principal components analysis (PCA), principal component regression (PCR) and Ridge regression (RR).

3.1. Selection of Variables

The selection of the explanatory variables is based on the extensive literature review done in chapter two of this document. The results of previous adoption studies of small-scale farmers in South Africa as well as outside South Africa were considered. The first section of the present chapter describes the dependent variables followed by explanatory variables influencing technology adoption.

3.1.1. Dependent Variables

3.1.1.1. Land-Saving Technology Score

This is a dichotomous dummy dependent variable indicating whether a farm household used hybrid maize seed and fertilizer during the survey season. Two dummy dependent variables were specified to account for individual adoption decisions when using fertilizer and hybrid maize seed. Firstly, LDS_1 (Y_1) equals 1 for the adopters of **either** hybrid maize or fertilizer or both and 0 for non- users.

Secondly, LDS_2 (Y_2) equals 1 for the adopters of **both** fertilizer and hybrid maize (full adopters- a simultaneous decision) and 0 for non-adopters. In the latter case, the adopters of a single technology (i.e., either fertilizer or hybrid maize seed) are excluded from the analysis. LDS_2 (Y_2) is specified to test the simultaneous nature of farmers' decision to adopt hybrid maize seed and fertilizer. On the basis of the decision to use hybrid maize seed and chemical fertilizer, sample households can be classified as:

Non- adopters (NA):- those farmers who did not use hybrid maize seed or chemical fertilizer at all

Partial- adopters (PA):- those farmers who use either fertilizer or hybrid maize seed.

Full adopters (FA):- those who use both technologies simultaneously.

3.1.1.2. Machinery Technology Adoption Indices

Data as to farmers' use (hire) and ownership of machinery technologies (a tractor, plough, planter and harrow), and contractor expenditure for these inputs were gathered. Principal components were extracted to create a few indices to represent the dimensions of machinery technology adoption by small farmers in communal areas of KwaZulu-Natal. The second component, TK_2 (hereafter called index of machinery technology adoption) represents technology adoption and hence was specified as a dependent variable for use in subsequent analysis (See Chapter 5, section 5.2.3). An adopter of machinery technology has a positive and high value while a non-adopter has a negative and low value of TK_2.

3.1.2. Explanatory Variables

This section describes the selected socio-economic variables influencing the adoption of land-saving and machinery technologies for the specified models. The explanatory variables could be classified as either continuous or categorical, depending on the method of approaching or measuring a variable. For example, a variable describing access to extension can be specified by the number of visits by an extension officer within a year or whether or not a farmer is visited by the officer. The following explanatory variables were used as predictors contributing to the adoption of land-saving and machinery technologies.

3.1.2.1. Quantitative Variables

These variables take numerical value in a real interval when measured accurately (Ramanathan, as cited by Nell, 1998). They include the age and education of the respondent; quantity of family labour available for farm work; non-farm income; monetary value of livestock and the area of operated arable land.

3.1.2.2. Qualitative Variables

These variables may take a numerical value one or zero and are often called nominal or categorical variables. They are the respondent's ward and the gender of the household head. Qualitative variables may also take a numerical value zero, one, two and more and are scores created by summing one or more dummy variables. They are scores for the use of extension and other information services.

(a). The respondent's residential ward (WAD)

Amangwane is a relatively large and unplanned whereas Amazizi is a small and planned or settlement ward. Although the two wards are adjacent to each other, arable allocated land size is relatively larger and is located near homesteads in Amangwane while Amazizi residents have small garden plots next to homesteads whereas allocated arable land is far from the homesteads. Residents of Amangwane can protect their property rights to arable land and supervision is less costly as arable lands are next to homesteads. It is hypothesized that farmers in Amangwane tend to adopt more land-saving and machinery technologies than their Amazizi counterparts. The variable ward equals zero for residents of Amangwane and one otherwise and a negative relationship is expected between ward and technology adoption .

(b). Age in years of the respondent (AGE)

It is expected that age represents a proxy for innovativeness. It is perceived that younger farmers may be more innovative, quicker learners of new techniques, have longer planning horizons and be less risk averse than older farmers. On the other hand, older and experienced households would have had more contacts with extension officers that can reduce transaction costs involved in adopting technologies, more time to accumulate capital and credibility in large networks although they are less innovative and risk averse. Empirical evidences indicate positive, negative and no (zero) relationship between age and adoption of farm practices (Basabrain, 1983). Age of respondent is therefore expected to be inversely or positively related to the adoption of a technology.

(c). Gender of the household head (GEN)

Gender is a categorical variable and equals one if the household head is a female and zero if male. The gender of the farmer is hypothesized to influence the decision to adopt a given technology. Delgado (1997), citing Quisumbing *et al* and Saito, Mekonnen and Spurling reports that women in general have less access to equipment, extension, information, informal and formal credit, and technology than men. Other constraints on women include social and cultural barriers such as mobility restrictions, less secure land tenure, inadequate female extension agents and male extension workers bias against visiting female farmers. In their study on marketing problems facing smallholder farmers in rural KwaZulu, Matungul *et al* (2001) reported that female farmers face higher transaction costs than their male counterparts. The hypothesis is that female farmers in the study areas will have little incentive to adopt farm technologies and a negative relationship is expected.

(d). Number of years of formal education (EDU)

This is a measure of human capital. As discussed in the chapter describing the survey data, the educational level of the respondents is not high and it is not expected to be high in the rural areas. Nonetheless, the ability to read and write is expected to positively reduce information and transaction costs and to bear on efficient management such as responding timeously to changes in the price of inputs and adjusting to optimum input levels. Kille (1993), citing Feder *et al* states that education plays a positive role in determining adoption the rates of new technology in developing agriculture. A higher educational level is therefore hypothesized as positively influencing technology adoption.

(e). Quantity of family labour available (FML)

Family labour is the ratio indicating the amount of family labour available per household member. Family labour is expressed in terms of household labour equivalents. This is calculated as the square of the household labour equivalents. That is, FML= adults (≥ 18 and ≤ 60)- wage employed and self employed + 0.5 [children + pensioners] /Household size. The numerator (family labor equivalents) is squared to capture the effect of complex cooperation in farm production. Low (1986), as cited by Fenwick and Lyne (1999) states that complex cooperation describes the increasing efficiency in production as more family labor becomes available. The denominator controls for differences in household size. Labour availability is one of the important factors for the high level of adoption of improved technologies. For households with low yields, there is a complementary relationship between labour and machinery use. Although machinery technologies are possible substitutes for labour, the adoption of machinery technologies such as cultivation by oxen and tractor demands labour especially during the harvest seasons. It is hypothesized that larger quantity of family labour available per household member reduces heavy reliance on expensive hired workers especially during harvest seasons and therefore more labour availability (liquidity) will be positively related to the adoption of the technologies.

(f). Non-farm income (NFI)

The monthly cash income earned (e.g., pensions and wage remittances from self-and wage employed members) is a variable which shows the availability of a reliable income source and a liquidity factor. There are two contradictory views on non-farm income wether it positively or negatively influences the adoption of technology. Low (1986) states that the transfer of household time from farm to off-farm work reduces farm output and hence creates a negative relationship between adoption and non-farm activity. On the other hand, Lyne and Nieuwoudt (1991) argue that such transfer need not necessarily result in reduced output. Since labour has close substitutes (e.g., machines, draught animals, herbicides and insecticides), increased off-farm earnings could alleviate on-farm liquidity constraints. In addition, studies in KwaZulu show that wage remittances are positively correlated with the production of surplus (Nieuwoudt and Vink 1989; Lyster, 1987:137) and the adoption of farm technology (Kleynhans and Lyne, 1984). Since the opportunity cost of working on the farms of educated household members in rural KwaZulu is high, their wage income in urban and neighboring commercial farms is greater. It is therefore expected that there will be a positive relationship between technology adoption and non-farm income.

(g). Monetary value of livestock in Rand (LIV)

Livestock is a continuous variable indicating the monetary value of all livestock, both cattle and small-stock owned by the farm household. The average price of cattle is estimated at R800 while for that of small-stock is R275 (Stock Owners, 2001). Availability of capital is one of the important factors to influence technology adoption, as this is a cost in itself. The ownership of livestock signifies wealth status and a source of finance. Farmers who have more value in the form of livestock may be better able to finance the cost of technology adoption. It is therefore hypothesized that ownership of livestock is positively associated with the adoption of technology.

(h). Area of operated arable land in hectares (AL)

The area of allocated land actually operated (including rented land) was measured, and used as a proxy for farm size. Land size has been found to be a proxy or surrogate for a number of factors (i.e., finance, inputs, information and wealth) which are likely to influence technology adoption. There is much debate on the issue of the relationship between farm size and technology adoption and this, in turn, results in conflicting sets of hypotheses about the adoption behaviour. A small farm size strategy advocates a policy of dividing large farms into small farms. It argues that productivity per hectare is higher on small farms, and that smaller farmers have adopted technologies at an equal pace or even faster than large farmers thereby implying an inverse relationship between technology adoption and farm size. The small farm strategy,however, does not take into account specialised resources such as irrigation, institutional credit and extension services. Very small farm sizes preclude scale economies, limit potential returns to innovation, and have a negative impact on the responsiveness of food production to higher product prices (Nieuwoudt and Vink, 1989; Lyne and Nieuwoudt, 1991). In contrast, a larger farm strategy argues that gains from agricultural innovations are proportional to farm size as large farms have more incentive from diverse sources for adopting a new technology (Welch, 1978). Although farm sizes are small, the land rental market is inactive, rural infrastructure services are inadequate, and transaction costs are high in communal areas, some of the farmers have managed to invest in technical inputs and agriculture. The development of the hypothesis about the relationship between technology adoption and farm size is based on the underlying historical, and current economic and social environment. Since operators of larger arable tracts of land have an advantage over operators of smaller arable land sizes, and eventually are expected to adopt technologies, a positive relationship was hypothesized. The positive relationship is expected to be stronger for machinery than for the land-saving as the latter are highly divisible(fixed costs are confined to information and transaction costs).

(i). Use of extension services (EXT)

This is the sum of five dummy variables (i.e., a composite score ranging from zero to five) which explains use of extension services. They are: awareness of extension officer's name; farmer- extension officer and extension officer-farmer visits; field day participation; and access to agricultural training. Extension is one of the important factors for the adoption of improved agricultural technologies (Pinstrup-Anderson and Pandya-Lorch, 1997; Ojo and Evbuomwan, 1997). This is because use of extension is expected to provide an important information source to the farmer and reduces fixed information costs. The greater the composite score (access to extension services), the better will be the ability of the farmer to make decisions and hence adopt a technology. It is expected that a positive relationship between use of extension services and the adoption of technology.

(j). Use of other sources of information (INF)

This is the sum of four categorical variables (i.e., a composite score ranging from zero to four) that can explain use of other important sources of information. They are: a farmer's membership of a farming association; ownership of a television set; analysis of farm's soil; and purchase of farming literature. Helleiner (1975) has reported that farmers' relationship with other information sources about new technology can play an important role in determining adoption. A household which has a membership of a farming association behaves differently from one which does not have membership because the organization of farmers into associations exposes farmers to new information, facilitates interaction and reduces technology demonstration costs. The higher value of the composite score, the better will be the availability of information to farmers to help them adjust to changing circumstances. Use of information is therefore expected to bear positively on technology adoption .

3.2. The Survey

3.2.1. Description of the Study Areas

The study was conducted in the Upper Tugela Catchment which lies within the Okhahlamba magisterial district of KwaZulu-Natal Province. The study area borders the Drakensberg mountain range between the towns of Winterton and Bergville. It comprises two tribal wards: a betterment planned ward of Amazizi and a larger unplanned ward of Amangwane as shown in Figure 3.1. "Betterment planning" was a government program which separated arable and residential allotments, and which relocated households to village settlements, while the remaining land was set aside for grazing (Davenport, 1987). As part of "Betterment planning", households are often far removed from their allotted arable lands. In addition to this land, most households have been allocated a small garden next to their homesteads. Two sub-wards were chosen in each ward. Moyeni and Dukuza were chosen from the Amangwane ward and Okhombe and Maphophomeni from the Amazizi ward.

While respectively 90 per cent and 95 per cent of the Amangwane and Amazizi areas fall under bioclimatic group 4 (Highland sourveld) which has good potential for agriculture, the remainder falls under bioclimatic group 6 (Moist tall grassveld). The study areas are heavily stocked with cattle (KDC, 1981). Serious droughts are rare, but growth retarding dry spells do occur. The area experiences a mean annual rainfall ranging from 800 mm in group 6 to 1500 mm in group 4. Mean annual temperatures range from 13 °C in group 4 to 18 °C in group 6 (Van Heerden, 1974).

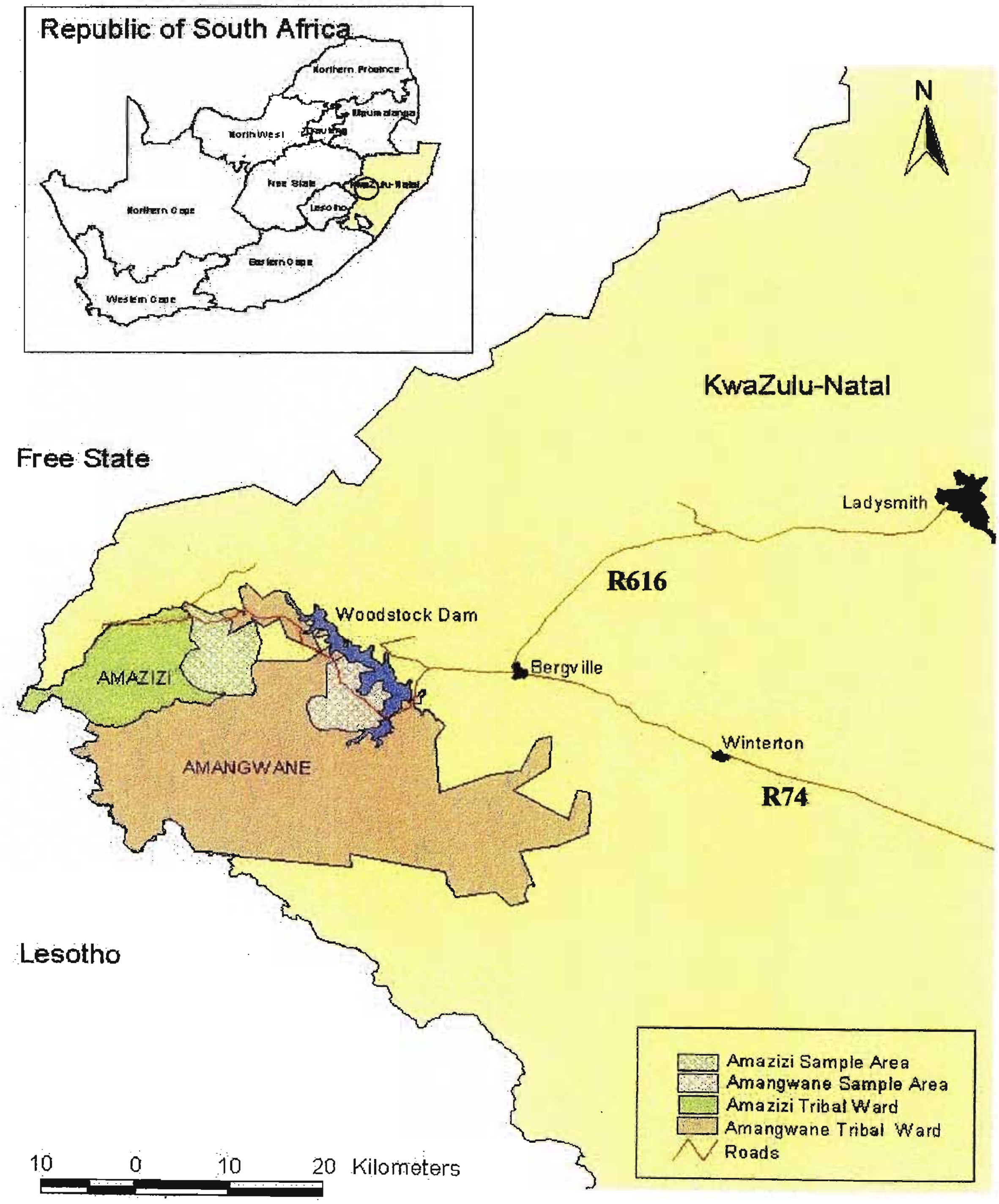

Figure 3.1. Map showing the location of study area in KwaZulu- Natal

3.2.2. Information Sources

The collection of farm level data to determine constraints (predictors) contributing to the adoption of land-saving and machinery technologies was based on the adoption-diffusion theory and empirical work. Empirical evidence on technology adoption and diffusion suggests that the adoption behaviour of farmers is a function of attributes related to farms and farmers, and the technology itself (Mafuru *et al*, 1999), the farming objective (CIMMYT, cited by Mafuru *et al*, 1999), and the available institutions and infrastructure (Hayami and Ruttan, cited by Nell, 1998). On the basis of extensive literature on technology adoption and the reality on the ground, a questionnaire was developed and farmers were interviewed to obtain relevant information. Data collected from the cross-sectional sample survey were used in the modelling of adoption of land-saving and machinery technologies.

3.2.3. Sampling Procedure and Data Collection

A stratified random sampling procedure as described by Lyne (1981) was used to draw sample households. Random sampling is the most basic form of probability sampling which gives an equal chance of probability to the sampling units and also requires that all sample units are listed and sampling is carried out on a homogeneous population, one which is not known to be highly heterogenous (Steel and Torrie, 1980:560). This may, however, limit the sample's usefulness in further statistical analysis. These problems may be overcome by stratified random sampling.

Stratified random sampling involves classifying the target population into non-overlapping sub populations called strata, each of which is internally homogeneous (Cochran, 1953:65). Random samples are then drawn independently from each stratum. The target population is often divided into strata along geographical lines for administrative convenience. Stratification may result in a gain in precision of targeted population characteristics provided that variability within the stratum is less than between strata (Barnett, 1974: 83-84).

Stratification was made along the geographical boundaries of the Amangwane and Amazizi wards each representing one stratum. Two sub-wards from each ward, Moyeni and Dukuza from Amangwane and Okhombe and Maphophomeni from Amazizi were chosen. Finally, households from each sub-ward were selected for the interview. A total of 160 households (40 from each of the four sub-wards) were selected for the field survey. The total number of sampled households accounts for 7% of the total household population in the two wards. Data were collected by means of a structured questionnaire during the months of August and September 2000 (See Appendix E). Local women enumerators who are matriculated and can read and speak English were recruited to interview the sample households. The questionnaire was directed to the individual male or female- head of the household.

3.3. Data Analysis

The SPSS (1995) computer software was used for data processing in order to determine farmer characteristics and possible predictors and to identify the influential variables of the specified dependent variables in the various models used. In order to prevent the inclusion of two or more highly correlated independent variables in a specific model that could violate the assumptions and lead to unreliable estimates, the independent variables were tested to identify possible correlations between them. All variables were tested using the Pearson correlations test. Other techniques such as Condition Index and Variance Inflation Factors were also used to detect multicollinearity between variables.

3.3.1. Determination of Possible Predictors

The explanatory (independent) variables hypothesized to influence the adoption of hybrid maize seed, chemical fertilizer and machinery technologies were placed in two categories, quantitative and qualitative. The explanatory variables defined and hypothesized in section 3.1.2 were tested for statistically significant differences between the different adoption groups of land-saving technologies, using one of the following statistical tests depending on their type and distribution as described by Siegal (1956):

the **t-test** to determine significant differences between two continuous variables with normal distribution;

the **Mann-Whitney test** to determine significant differences between two continuous variables with skewed distributions,

The **Chi-square test** in the analysis of categorical variables with larger frequencies;

The **Fisher's exact probability test** in the analysis of categorical explanatory variables, with small frequencies or where data have low expected scores.

The age of household head variable is the variable with a normal distribution and therefore the mean is to be used as a summary statistic. All other variables have skewed distributions and hence the median is used as it is a more representative criterion for this type of data set (Steyn, Smit, and Du Toit, 1994). Following Siegal (1956), the t- and Mann-Whitney tests respectively were used to determine the differences between the groups of nine of the continuous variables with normal and skewed distributions. The Chi-square test was used to determine the differences between the groups for categorical variables, ward and gender.

3.3.2. Determination of Significant Predictors

The identified possible predictors for each specified dependent variable (adoption model) were included in the most adequate discrete choice model. Those variables that statistically significantly differentiate adopters and non-adopters of land-saving technologies based on a single variable test (i.e., t, Mann-Whitney and Chi-square) were selected for a further logistic regression analysis. The binary logistic model described in appendix A is used to determine the factors influencing the adopters and non-adopters of land-saving technologies. A binary logistic model was selected since the dependent variables (users of hybrid seed and fertilizer) considered in this study were measured qualitatively as categorical variables (with values of 0, 1), and not quantitatively, as percentage of adoption (continuous variables). In this model, the direct entry method of binary logistic regression was used to identify the predictors contributing significantly ($P \leq 0.20$) to the adoption of land-saving technologies.

In the case of machinery technologies whereby index of machinery technology, TK_2 is specified as a dependent variable (i.e., a continuous variable) all possible predictors were included although only nine predictors were significantly correlated with the dependent variable. Due to a multicollinearity problem, principal components (PCA), principal components regression (PCR) and ridge regression (RR) analyses were used to determine predictors contributing to the adoption of machinery technologies. The details of the derivation of PCA, PCR and RR procedures are presented in appendices B, C and D while highlights of these techniques are presented in section 3.3.3.

3.3.3. Analytical Techniques

A set of four analytical techniques was used to analyze the survey data. A binary logistic regression model was employed to determine socio-economic factors that differentiated one group of farms from another for land-saving (i.e., hybrid maize seed and fertilizer) technologies. Factor analysis, particularly, principal component analysis, was used to develop an index of technology adoption for machinery technologies and to purge the multicollinearity problem from the explanatory variables. Subsequently, the principal component regression (PCR) technique was also used to identify socio-economic factors influencing the adoption of machinery technologies.

Logit Analysis

The relationship between farmers' use or non use of fertilizer and hybrid maize seed and socio-economic conditions was analyzed using a logit model. The rationale for using the logit model was that the dependent variable assumes 0 or 1. Ordinary least square (OLS) regression could not be used as it would lead to inefficient parameter estimates (Maddala, 1992; Gujarati, 1995:544). The criticism of OLS regression stems from the fact that the predicted values of the dependent which takes 1 or 0 may lie outside the 0 and 1 interval. Aside from econometric limitations, functional forms other than OLS would better fit the dichotomous dependent variable. Logit and probit have been widely used to overcome the problems arising when using the linear models. These models force the predicted probabilities to lie within the limits of (0, 1).

A Logit model takes a logistic distribution whereas the probit model takes a cumulative normal distribution. Logit's logistic distribution assumes a variance of $\Pi^2/3$ and probit's normal distribution has a unit variance. A choice between the two models is a matter of computational convenience (Gujarati, 1995:568). The great merit in logit is that the parameters are linear, and thus the estimation is computationally simpler. The logistic regression model is presented in Appendix A. The estimates only require a transformation in an exponential form to arrive at the probabilities.

PCA and Factor Analysis

A continuous index of the adoption of machinery technologies was constructed to account for two basic situations. In the first situation, the degree of adoption was to be addressed. A farmer might have adopted only one or a few from a number of technological practices available. For instance, a farmer might have adopted only a tractor without a planter and harvester while a complete mechanisation set includes a tractor, planter and harvester. The farmer will have adopted 33 per cent of the complete set. The continuous variable reflecting adoption should therefore account for such behavior. The second issue was related to the contention in the literature that adoption is a process of moving toward a position of an equilibrium. If this is true, a cross sectional view of farmers at a given time should reveal that farmers are at various stages of the adjustment process. The various stages may approximate a continuum. In this case, let $T_1, \ldots T_5$ represent five technological components of adoption. A value of one is assigned when a farmer adopts a component at any level, and a value of zero if he does not. If the adoption process is sequential, then a hierarchical pattern of farmers would exist as shown in Table 3.1.

Table 3.1. Sequential adoption pattern of technology adoption

T_1	T_2	T_3	T_4	T_5	Score
0	0	0	0	0	0
1	0	0	0	0	1
1	1	0	0	0	2
1	1	1	0	0	3
1	1	1	1	0	4
1	1	1	1	1	5

Source: (Rauniyar, 1990)

For adoption data such as those in Table 3.1, a technique called **scalogram** analysis could have been employed to test the hypothesis that adoption formed a sequential pattern (unidimensional). However, this technique has two limitations. The input data must be categorical, that is, adoption- non-adoption rather than a continuous variable reflecting the degree of adoption. The second limitation is that if the null hypothesis of unidimensionality is rejected, scalogram analysis provides information neither of the number of dimensions nor of the structure. Factor analysis suffers neither limitation (Rauniyar, 1990).

The central aim of PCA and factor analysis (FA) is to reduce the dimensionality of a data set while retaining as much as possible of the variation present in the data set. The reduction is achieved by transforming to a new set of variables, the PCs or factors respectively, which are orthogonal and ordered so that the first few retain most of the variation present in all the orthogonal variables (Jolliffe, 1986:116). The weights of the variable are called 'factor loadings' and proxy variables are called 'factors' or 'principal components'. The variables with large loadings in a factor are considered as representative variables in that particular factor.

Both techniques may be thought of as aimed at presenting some aspect of the covariance matrix (or correlation matrix) as well as possible, but PCA concentrates on the diagonal elements whereas in FA, the interest is in the off-diagonal elements. Consequently, in PCA if any individual variable is almost independent of all other variables, there will be a PC corresponding to each such variable, and the PC will be almost equivalent to the corresponding variable. In contrast, a common factor in FA must contribute to at least two of the variables, so that it is not possible to have a *'single variable'* common factor. Instead, such factors appear as specific factors (error terms) and do not contribute to the dimensionality of the model. Thus, for a given set of data, the number of factors required for an adequate factor model will be no larger, and may be strictly smaller than the number of PC's required to account for most of the variation in the data (Jolliffe, 1986:122-24). A fundamental difference between the two techniques is that FA attempts to achieve a reduction from p to m dimensions by postulating a model relating x_1, x_2, ..., x_p to m hypothetical variables. There is no such explicit model underlying PCA, although some statisticians argue that using PCA implies an implicit model (Jolliffe, 1986: 116). Because *a priori* expectations about relationships between adoption decisions are uncertain, no particular model may be postulated. Consequently, a PCA technique presented in Appendix B is used in this study in lieu of factor analysis.

Principal Component Regression (PCR)

When severe multicollinearity precludes reliable estimation of OLS, the use of biased regression estimators forms a second class of approaches to overcoming this problem. This class includes ridge regression, shrinkage estimators, and also approaches based on PCA. The best-known approach of this kind is known as PCR (shown in Appendix C), and simply uses the PCs of the predictor variables instead of the predictor variables themselves. PCR as suggested by Kendall (1957), Nieuwoudt (1972), Jolliffe (1986) and Maddala (1992), was used to rid the explanatory variables of multicollinearity and to re-estimate the regression coefficients for the original variables. In this case, by deleting a subset of PCs, especially those with small variances, much more stable estimates of βi (the original regression coefficients) can be obtained (Jolliffe, 1986:132). Regressions on estimated PCs-excluding one or more minor principal axes are calculated and converted to original variables on either the original or standardized scale. Estimation using this procedure results in a trade-off between the model's ability to reproduce the estimation data (R^2) and an improved interpretability of the estimated coefficients.

Ridge Regression (RR)

RR is one of several methods that have been proposed to remedy multicollinearity problems by modifying the method of least squares to allow biased estimators of the regression coefficients. When an estimator has only a small bias and is substantially more precise than an unbiased estimator, it may well be the preferred estimator, since it will have a larger probability of being close to the true parameter (Neter *et al*, 1996:411). Figure 3.2 shows that estimator **b** is imprecise, whereas estimator $\mathbf{b}^R$ is much more precise but has a small bias. The probability that $\mathbf{b}^R$ falls near the true value of β is much greater than for the unbiased estimator **b**.

The ridge standardised regression estimators are obtained by introducing into the least squares normal equations a biasing constant $K \geq 0$ as shown in the Appendix D.1. The constant K reflects the magnitude of bias in the estimators and usually varies between 0 and 1. When $K > 0$, the ridge regression coefficients are biased but tend to be more stable (i.e., less more variable) than ordinary least squares estimators (Neter *et al*, 1996:412). The bias component of the total mean squared error (MSE) of the RR estimator $\mathbf{b}^R$ increases as K gets larger (with all $\mathbf{b}_k^R$ tending toward zero) while the variance component becomes smaller. There always exists some value of K for which the RR estimator $\mathbf{b}^R$ has a smaller total MSE than the ordinary least squares estimator **b**.

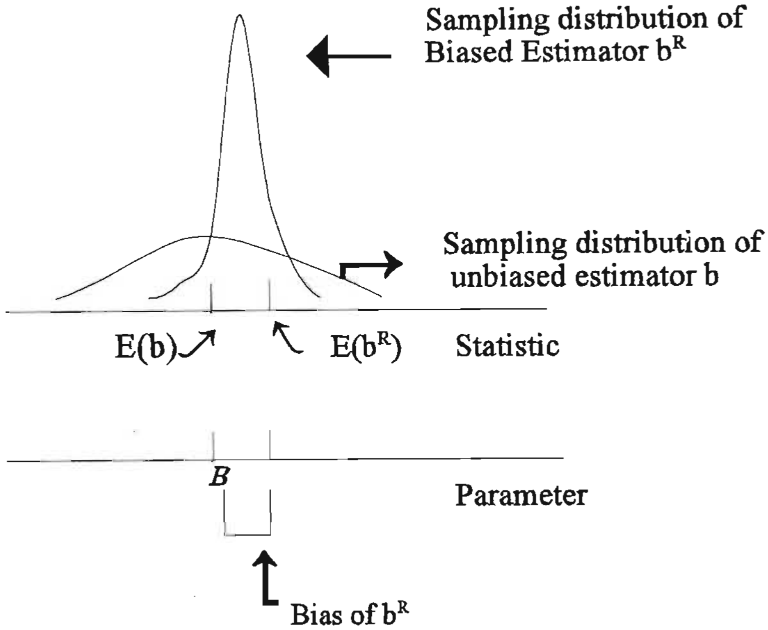

Fig 3.2. Biased estimator with small variance may be prefarable to Unbiased estimator with large variance.

A commonly used method of determining the optimal biasing constant K is based on the *ridge trace* and the *variance inflation factors (VIF)* as presented in appendix D.2. The former is a simultaneous plot of the values of the p-1 estimated ridge standardized regression coefficients for the different values of K while the latter are the diagonal elements of the inverse of the simple correlation matrix for dependent variables. Therefore, by examining the ridge trace and VIF values, the smallest value of K will be chosen where the regression coefficients first become stable in the ridge trace and the VIF values become sufficiently small. In this study the appropriate biasing constant and hence the final model RR coefficients were derived by examining the ridge trace and VIF, using SPSS and Mathematica computer software programmes, respectively.

CHAPTER 4. DESCRIPTION OF THE SURVEY DATA

4.1. Introduction

The characteristics of the households sampled within the study areas where the adoption of farm technologies was investigated, are important. It is also important to know what personal farm and demographic characteristics the sample farmers have and to what extent they were exposed to new technologies. The external circumstances, be the physical, socio-economic or cultural under which the farmers are operating have to be described to be included in the diffusion programs. The flow of information is an important link in the adoption-diffusion process. The rate and level of adoption is determined by *the sender* of the message about the technology (i.e., extension officers, co-farmers, the media, and family) and by *the recipients* of the message who are the farmers with their specific characteristics. Co-factors are the location they are in and the available infrastructure (Von Thűnen's theory) (Nell, 1998).

The following sections present the household demographic, and farm characteristics of the sample farmers, and availability, accessibility and functioning of extension services, infrastructure, and formal and informal institutions. The data described in this chapter are processed from a sample survey conducted in the Amangwane and Amazizi tribal wards of the Okhahlamba magisterial district in KwaZulu-Natal.

4.2. Household Demographic Characteristics

This section is aimed at describing the general characteristics of the sample farmers by using qualitative and quantitative measures. The discussion mainly focuses on those explanatory variables influencing the adoption of farm technologies, as identified in the previous chapter. Age is the only variable that has a fairly normal distribution and therefore the mean will be used as a summary statistic for this purpose. All the remaining variables have skewed distributions and the median is used to summarise the information, mainly because the median is a more representative criterion than the mean in data sets with skewed distributions (Styne, Smit and Du Toit, 1994).

The results in Table 4.1 show the household level demographic features in addition to the occupation of household members. The median family size for the total sample is nine and it ranges from 2 to 16 persons per household. The age of the household head in the sample varies between 29 years to 99 years, with a mean of 58 and a coefficient of variation of 24.6 per cent. Sixty-six per cent of households are male headed; this means that 34 per cent are female headed households. Eighty-nine per cent of the female headed households are Widowed; this forms 30 per cent of the total sample. The dependency (consumer-worker) ratio is expressed as the number of consumers to the number of workers. The median dependency ratio for the sample farmers is one, and this indicates that every working person in a given household supports one dependent family member.

Table 4.1. The demographic characteristics of sample households, 2000.

Particulars	Overall, N= 160
Median household size	9
Median family farm labour available per member	2.04
Median dependency (C-W) ratio	1
Male headed households %	66.3
Female headed households %	33.8
Widowed head households %	30
Mean age of the household head in years	58 (145)
Median education level of household heads	4 (157)
Median number of wage earners	0 (159)
Median number of self-employed members	0 (159)
Median number of unemployed members	2 (159)
Median number of pensioners	1
Median number of students	3
Median number of infants	0

Note: Numbers in brackets indicate valid cases.

4.2.1. Education and Occupation of Household Head

Since the personal characteristics of the household head are relevant in explaining the adoption of a technology, in-depth statistics on the level of education and occupation of the household head are summarized in Table 4.2. Although the educational variable is composed of different personal characteristics, educational qualifications in this case focus on the level of attainment of formal schooling. The median educational level of household heads is grade four. Nearly twenty seven per cent of the household heads have no formal education whereas 41.4 per cent and 31.8 per cent of the household heads have attained respectively a formal schooling level between grades 1 and 6, and grades 7 and 12. Overall, nearly forty per cent of the household heads are pensioners and 22 per cent are unemployed. Cross *et al* (1995) report that the unemployment level in KwaZulu is high, with 58 per cent of the economically active population not formally employed. Since the income from subsistence agriculture does not sustain the family, households earn their income from diverse sources like self-and wage-employment and pension, in addition to income from crop and livestock sales. Results in Table 4.2 indicate the diversified nature of the income sources for the fact that 39 per cent of the household heads are pensioners, and 39 per cent are engaged in self-and wage- employment. Nearly 14 per cent of the total household members are engaged in wage and self-employment activities.

Table 4.2. Educational levels and job status of the household heads, 2000.

Educational level	Overall, N = 160 (%)	Job status (Occupation)	Overall, N = 160 %
No education	27 (157)	Self employed	21
Grade 1-6	41	Wage employed	18
Grade 7-12	32	Unemployed	22
		Pensioners	39
		Housekeeper	0.6

Note: Number in bracket indicates valid cases

4.2.2. Demographic and Educational Characteristics of Members

There are more *de facto* female members than male members in the sample households. More female than male members belong to the working age group (18-59) inclusive. Twenty-three per cent of male household members and 21 per cent of female members are below 18 as shown in Table 4.3. The summary statistic shows that there is almost an equal proportion of a working group to a dependent's group. This is indicated by the dependency ratio of unity in section 4.2.

Table 4.3. Demographics of sample household members by age-group and gender, 2000

Particulars	Overall, N= 160	
	N	%
Median male members	4	48
Median female members	5	52
Median males aged 60 & above	0	3
Median females aged 60 & above	1	6
Median males aged 18 to 59 years	2	22
Median females aged 18 to 59 years	2	24
Median males less than 18 years	2	23
Median females less than 18 years	2	21
Educational level and proportion of sample households		
No education excluding infants %	9	
Primary % (N =155)	42	
Junior % (N = 155)	23	
Matriculation % (N = 155)	26	
Total	100	

The educational level of the members is an important factor in examining labour mobility in the households. Evidence from rural KwaZulu shows that better educated members have a higher opportunity cost if they stay in the subsistence agricultural sector (Fenewick and Lyne, 1999).

Therefore, migrant labourers (young, relatively well educated men) could earn more income from off-farm employment in commercial farming and from the service oriented industrial sectors. This shows that improvement in labour quality, and thereby productivity, is associated with education. The schooling level of household heads and other household members varies from no education to grade 12. Nine per cent of the family members excluding infants have no formal education. Forty-two per cent of household members have reached a primary level of schooling and only 26 per cent have attained the twelfth grade. Figure 4.1 compares the proportion of the family members at various schooling levels. It can be seen that there is no significant difference between the educational levels of household members in the different wards. Even after accounting for school children, the median number of educated members between the wards is not statistically different.

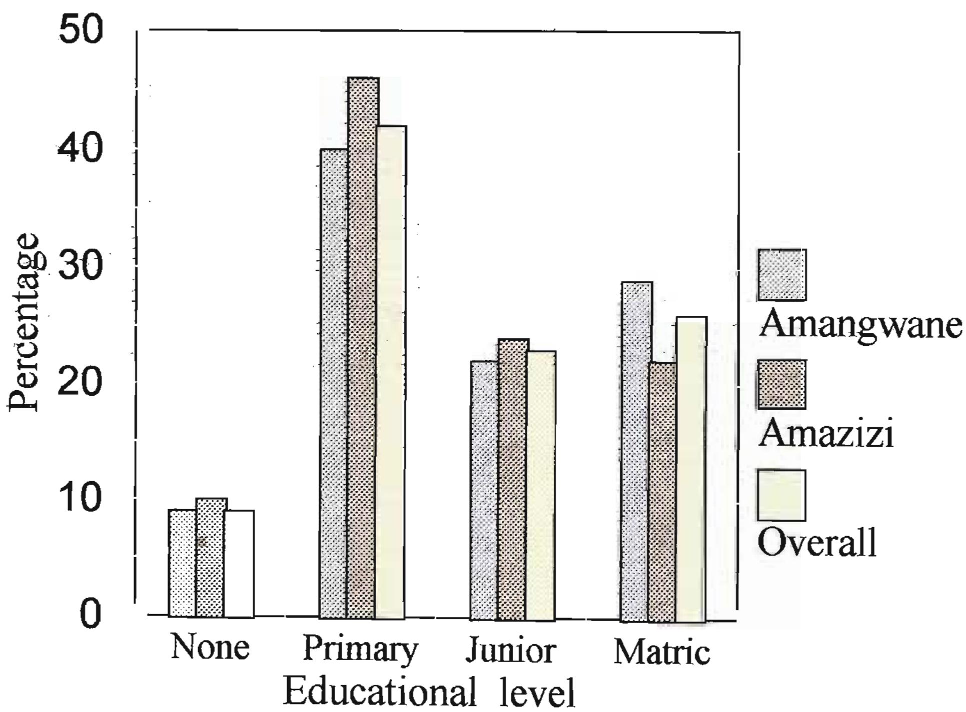

Fig. 4.1. Educational level of members

4.2.3. Asset Ownership and Investment

Asset ownership and investment in fixed improvements for the sample farmers are shown in Table 4.4. Owners of fixed assets have a better wealth position and therefore can afford to adopt farm technologies. Ownership of fixed assets is highly skewed. This is common in subsistence farming where the accumulation of capital in the form of assets is difficult for the majority of households. The skewed distributions of asset ownership or unequal access to farm equipment is attributable to a number of historical, socio-economic and political factors.

The results in Table 4.4 show that the on-farm investment by the sampled farmers in fixed improvements is minimal. Nearly 47 per cent of sampled farmers fenced off their arable land to protect agricultural investment from stray animals. Fencing of land is seen as an important act of privatising land. The proportion of fencing was identical for the different wards for the year of the study. Thomson (1996:95), however, reported that there are higher incidence of fencing and lower incidence of employed guards in Amangwane as households can police their fences and crop themselves. In addition to liquidity problems, the concomitant problem of tenure insecurity in the communal areas of KwaZulu might have prevented farmers from making investments in fixed improvements. Thompson (1996:134) reports that tenure is insecure in communal areas of KwaZulu-Natal (this means that the breadth, duration and assurance aspects are not satisfied). This insecurity problem adds an element of risk and is a disincentive to investment in agriculture. Hayes *et al* (1997) report in a study made in Gambia where land is a scare resource and customary tenure arrangement is common, that tenure security enhances long-term investments, which in turn enhances the yield. Therefore, alleviating the problem of tenure insecurity along with other institutional provisions and state investment in infrastructure may stimulate farmers' investment in fixed improvements and thereby improve productivity.

Table 4.4. Asset ownership pattern and investment in fixed improvement, 2000.

	Overall, N = 160				
Asset	N	%	Fixed investment	N	%
Car	29	13.1	Irrigation	1	0.6
Motor bike	2	1.3	Water trough	2	1.3
Television	37	22.9	Fencing	75	46.9
Freezer	44	24.6	Lime application	5	3.1
Tractor	14	8.8			
Plough	25	14.4			
Planter	19	11.9			
Harrow	13	6.9			

4.3. Households' Enterprise and Farm Characteristics

Land in the study areas has a good potential for both crop and livestock production and agriculture in general (KDC, 1981). Farm households produce various crops and keep different species of livestock. Crop and livestock enterprises are described in the next sub-sections.

4.3.1. Crop Enterprises

Maize is the staple food crop for the residents of Amangwane and Amazizi wards. Results in Table 4.5 show that maize is the dominant crop (which is grown by 87 per cent of the sample households) followed by vegetables (16.9 per cent), beans (14 per cent) and potatoes. Nearly equal proportion of farmers grow maize in the Amangwane and Amazizi wards. About 42 per cent of the sample households plant fruit trees around their homesteads.

Table 4. 5. Crops grown and technical input used in the Amangwane and Amazizi wards, 2000.

Crops	N = 160	Particulars	N = 160
	%	Hired tractor %	70
Maize	86.9	Hired plough %	70
Potatoes	10	Hired planter %	54
Beans	14.4	Hired harrow %	33
Vegetables	16.9	Purchased hybrid seed %	57
Fruit trees	41.9	Purchased fertilizer %	67

4.3.2. Livestock Enterprises

Cattle in rural KwaZulu play a significant role in the household economy. Although Tapson and Rose (1984) argue that cattle on communal lands are kept primarily for milk production with social exchange, drought exposure and consumption as secondary reasons, there is a variety of natural, social and economic reasons for keeping stock by households. In general, livestock serve as the most important asset and as a source of finance and security against crop failures and other misfortunes (Chilot *et al*, 1996).

The results in Table 4.6 show that 43 per cent of sample households in the Amangwane and Amazizi wards do not own cattle. Lyne (1989: 23-24) has reported that livestock ownership is skewed, with a few people owning most of the stock while 40 per cent of rural households in the former KwaZulu own no stock. Nearly 80 per cent of the total sampled households do not own draught oxen. The majority of cattle and small-stock owners keep stocks of between 1 and 10 head. The median number of cattle kept by sample farmers is two. About 60 per cent of households do not own small-stock (i.e., sheep, goats and pigs). Nearly 35 per cent of farmers own between one and 10 head whereas four per cent own between 11 and 20 small-stock. Less than three per cent of the households own in excess of 21 head of both cattle and small-stock. The median number of draft cattle and small-stock owned by the farmers is zero. This is not surprising owing to the fact that the majority of farmers (i.e., 80 and 60 per cent, respectively) do not have any draught cattle and small-stock.

Table 4.6. Livestock number and species kept by sample farmers, 2000.

Number of	Overall, N=160	
	%	Median
Total cattle 0	42.8	2
1- 10	49.7	
11- 20	5	
21- 44	2.5	
Draught cattle 0	80	0
1- 5	15	
6 -10	5	
Small-stock 0	60.4	0
1- 10	34.6	
11 -20	3.8	
21-36	1.3	

4.4. Household Income

Liquidity is one of the important factors that influence farmers' capacity to invest in farm technology. Farm households in the survey areas acquire their income from various sources such as sales of crops and livestock, monthly wage remittances, and transfer payments (pension). During the study season data on crop income were not collected because the farmers did not harvest crops due to the poor season. The data for livestock sales are not reliable as most farmers did not report their income accurately. This study therefore reports only the households' monthly non-farm income from wage remittances and pension as shown in Table 4.7.

The median monthly non-farm income of the sample farmers is R600. This low income is not surprising the fact that 53 per cent of the population in KwaZulu-Natal lives in poverty (Marcus *et al* , 1995). With a mean monthly per capita income of R126 in the rural areas of KwaZulu (1992), the province had the third highest incidence of poverty in the country and 60 per cent of the population lives below household subsistence level (May, 1995; Marcus *et al*, 1995). Non-farm income is greater for farmers in the Amangwane ward than in Amazizi. Small farmers in KwaZulu-Natal are severely constrained by low levels of liquidity which restrict investment both in farm inputs and hired labor (Fenwick and Lyne, 1999). The Strauss commission (1996) also argues that the growth and development of small-scale agriculture are constrained by liquidity levels. It can be concluded that the problem of liquidity, *ceteris paribus*, constrains technology adoption.

Table 4.7. Median non-farm income for Amangwane and Amazizi sample households, 2000.

Particulars	Overall, N=160
Non-farm income in R, N = 151	600
Remitted income in R, N = 142	300
Pension income in R , N =160	500

4.5. Farm (Arable Land) Size

The size of the arable land holding in the study areas is generally small. Results in Table 4.8 indicate that while 59 per cent of farmers operate on an area of arable land less than or equal to 1.0 ha, 41 per cent of farmers operate within the range of 1.1 to 10.2 ha. A small proportion (8 per cent) of the households have been allocated arable land of 3 ha and above. The median allocated arable land for the residents of the unplanned Amangwane ward is 1.75 ha while it is only 0.75 ha for residents of the planned Amazizi ward. Nieuwoudt and Vink (1989) argue that the small size of land holdings in KwaZulu has a negative impact on the responsiveness of food production to higher product prices.

Of the total allocated arable land, 52 per cent is cultivated whereas 40 per cent was left idle during the study season. This suggests that arable land is underutilized. Knight and Lenta (1980), Lyne (1989) and Lyster (1990) respectively reported that 27, 22 and 20 per cent of arable land was left idle in various study areas of KwaZulu. Only 18 ha (22 per cent) of the total area of idle land for sample farmers is leased out indicating that the land rental market is not active because of tenure insecurity, the lack of legal and institutional support, and the lack of a physical infrastructure. An efficient land market requires security of property right; and transaction costs must be small (Nieuwoudt, 1990).

Since these requirements are not met in the study areas, the land rental market is incomplete and land use is inefficient. The implication is that there is less likelihood of agricultural investment and wider scale technology adoption by small-scale farmers.

Table 4.8. Farm size and its use by sample farmers of Amangwane and Amazizi wards, 2000.

Particulars	Overall, N= 160
Median allocated arable land in ha	0.86
Median cultivated land in ha	0.26
Median fallow land in ha	0.2
Median leased out land in ha	0
Median operated land in ha	0.81
Percentage of land cultivated	52
Percentage of land fallowed	40
Percent of leased out land	8
Arable farm size ≤ 1 ha, in %	59
1.1 - 10.2 ha , in %	41

4.6. Institutional Facilities

An institution is a set of norms and ideals which is imperfectly (hence, subject to dramatic change) reproduced or internalized through habituation in each succeeding generation of individuals. Institutions may refer to the broader laws, regulations and social norms (including land tenure arrangements) that guide economics decisions. An institution serves as a stimulus and guide to individual behavior (Dugger, 1979). Wanmali and Islam (1997) argue that hard infrastructure like roads provides the framework with which soft infrastructure (i.e., input and output markets) can be made available in less developed countries. Likewise, agricultural support institutions could create a framework for the technology transfer process as their presence accelerates technology adoption and their absence retards it. Since the technology adoption process involves a major change in existing structural and institutional arrangements, an in-depth description of the accessibility of institutions is of paramount importance. The next sub-sections describe farmers' use of credit and institutional facilities such as extension, information sources, and their tenure arrangements

4.6.1. Use of, Sources and Demand for Credit

Since technology it-self is a cost, the availability of external finance for the household is an important factor in the transfer of technology. Sample households have little access to formal credit. The results in Table 4.9 show that a significant proportion of farmers have obtained credit from informal sources like friends and relatives and furniture stores. The credit is not necessarily used for technical inputs. There is evidence that various institutions like KwaZulu Department of Agriculture (KDA), Development Bank of Southern Africa (DBSA) and KwaZulu Investment and Finance Corporation (KFC) and the LIMA rural development foundation were involved in assisting emerging farmers in KwaZulu by promoting a strategy of comprehensive agricultural support services in which they identified potential areas for agricultural production. The farmer support program initiated in the mid-1980s aimed at promoting structural change, from subsistence agriculture to commercial production (Lyne and Ortmann, 1991).

Seasonal loans from KFC (now Ithala bank) have been phased out in the study areas (Lyne and Ortmann, 1991). According to Thomson (1996), credit schemes should have been started as of 1994/95 cropping season. This survey indicates that almost no agricultural credit is being provided and that farmers have little or no access to formal credit institutions. For small-scale farmers, the high transaction costs in obtaining credit are prohibitive because infrastructure (roads, telecommunications, postal services etc) are is inadequate and poor. Matungul et al (2001:353) reported that high transaction costs face by households in communal areas are the result of poor physical infrastructure as well as a weak institutional environment (communication skills and contract enforcement). Yet, 53 per cent of the respondent farmers showed an interest for credit. Some farmers (six per cent) did not plant their fields because of cash constraints. It can be concluded that the problem of liquidity is one of the serious constraints to small-scale farmers' adoption of technology.

Table 4.9. Sources and use of credit in the Amangwane and Amazizi study areas, 2000

Particulars	Overall, N= 160
KFC (Ithala) %	0.6
Bank %	1.3
Farming association %	0.6
Informal lenders %	2.5
Friends %	16.3
Relatives %	12.5
Furniture store %	54.4
Credit use %	30
Demand for credit %	52.5

4.6.2. Extension Services and Other Information Sources

Extension is one of the most important components of technology transfer (Pinstrup-Andersen and Pandya- Lorch, 1997; Ojo and Evbuomwan, 1997 and Nagy, Sanders and Ohm, 1988). Although extension service is important, the majority of respondents made little use of extension services. The results in Table 4.10 indicate that 41 per cent of respondents are aware of an extension officer's name, 14 per cent have been visited by the officer and 16 per cent of respondents have visited the officer. The number of visits paid by an extension officer varied from 0 to 17 (only a single farmer got this maximum visit); *84 per cent* of the farmers did not receive visits from officers during the year. This explains why the median number of visits by either of the parties is zero. The mean visit by extension officers per year is 1.1 (Matungul *et al*, 2001:350). Farmers' participation at a field day, and access to agricultural training was also very limited. There are 4 and 5 extension personnel in the Amazizi and Amangwane wards, respectively (Thokozani, 2001). Majority of the extension officers or personnel are male.

Eight per cent of the farmers are members of a farming association. This result is in line with a report by Lyne and Ortmann (1991) that during the implementation of the comprehensive farmer support programme in KwaZulu-Natal, the issues of promoting and assisting farmer associations and cooperatives were addressed inadequately. Only twelve per cent of farmers purchased agricultural literature,15 per cent got their soil analyzed and about 22 per cent of farmers own television set. The results indicate that farmers' access to information sources is very limited. A positive link was reported between the percentage of cultivated area being fertilized and membership in a cooperative in Zambia and Cameroon (Jha *et al*, 1991; Adesina *et al*, 2000). This suggests that farmers' associations reduce private information costs and speed up delivery time.

Table 4.10. Access to extension and other information sources for sample farmers, 2000.

	Overall, N = 160		
Particulars	%	Particulars	
Farming association membership	8	Households that visited an extension officer %	16
Purchase of literature	12	Number of visits by officer (median)	0
Soil sample analysis	15	Number of visits by farmers (median)	0
Televison ownership	22	Field day participation %	24
Awareness of extension officer	41	Attendance of special training %	6.3
Households visited by extension officer %	14		

4.6.3. Land Tenure

The state (Ingoyama trust board) legally owns land in study areas and land is administered by the local tribal authority. The nature of tenure is communal: households are allotted parcels of arable land for cropping, which becomes communal grazing in the winter season. Security of land tenure, by definition, involves the breadth, duration and assurance aspects of the rights to land. Tenure is insecure in communal areas of KwaZulu-Natal (Thomson, 1996:314). This is because crop farmers have no fully exclusive rights to land against stock owners, land rental contracts among lessors and lessees are not legally enforceable; and the time needed to recover the cost of a particular investment is uncertain. The duration of property rights (wether the investor can control the land long enough to recover the investment) is an important source of uncertainty. Thomson (1996) argues that tenure security depends on both the actual and the perceived rights of individuals. These include whether or not farmers perceive rights to cultivate for the whole year, fence-off their arable land, and claim compensation for crops damaged by stray animals. Data on the farmers' perceived rights to arable land were not conclusive enough to be used for analysis. Thomson (1996:95) reported that lower incidence of damage by stray livestock and guards, and higher incidence of fencing in Amangwane. This suggests households in Amangwane are able to protect their property rights to arable land.

When tenure security elements are not satisfied, farmers may have little incentive to adopt technologies. Technologies that have a long gestation period- irrigation, application of lime and watershed development- require both secure property rights and collective action, and these are not fulfilled in communal areas of KwaZulu. The small proportion of investment in irrigation, pasture and lime reported in section 4.2.3 may indicate the disincentive of tenure insecurity, *ceteris paribus*. Matungul (2001:353), citing Thomson, and Kille and Lyne, reported that farmers with insecure tenure tend to lack both incentives and the ability to finance fixed improvements or new technologies that could enhance their production efficiency. Hayes *et al* (1997) report that tenure security, represented by complete transfer rights significantly affects the propensity to make fixed investments. Similarly, according to Barghouti and Hazell (2000), technologies are not likely to be adopted and maintained if there are no secure property rights, and collective action is missing regardless of their profitability and scientific soundness. The high-yielding seed varieties of the green revolution were not affected by the security of property rights since they could be captured within a single season. Their use was not, therefore, dependent on secure property rights and collective action (Barghouti and Hazell, 2000). In communal areas of KwaZulu, although some of the farmers are using seed technologies, tenure insecurity remains as a major constraint to agricultural investment.

4.7. Conclusion

The level of education of the sample households is generally low with nearly one fifth of the total household heads having no formal education. The mean age of household heads is high since younger and relatively well educated members are migrant workers. In the sample households, the proportion of male headed households is greater than the female. The majority of female heads of the households are widows. Female headed households have poor access to resources, education little use of extension, and technology. Likewise, women still suffer discrimination under the new subsidized housing scheme (SAGI, 1998:12). Conversely, KwaZulu community is a typical example of patriarchal society whereby males have more access to, use of and control over resources.

Small farm sizes and tenure insecurity are disincentives to agricultural investment. Household income is low and liquidity is a constraint to productivity growth of the farmers. The inaccessibility of financial institutions is another barrier for the majority of the sample households. Sample farmers have access to the informal sources of credit whereas the formal sources of credit currently are inaccessible because of high transaction costs and farmers may not be creditworthy. Some farmers, however, have shown their demand for institutional credit. Sample households are constrained by inadequate infrastructure facilities such as a dearth of extension facilities (fewer extension visits to and from farm households), and inadequate information services since forming and sustaining cooperatives and community associations is inadequately addressed during the implementation of the comprehensive farmer support programmes. Last but not least is the poor physical infrastructure of roads, telecommunication networks and postal services. The situation in Amangwane and Amazizi, like other areas of KwaZulu, is such that there cannot be effective transfer and adoption of farm technologies which could possibly alleviate the primary agricultural production problems.

CHAPTER 5. EMPIRICAL RESULTS AND DISCUSSION

Sections 5.1.1 and 5.1.2 present a descriptive analysis, while the results of a logit regression analysis for the adoption of land-saving technologies are presented in Section 5.1.4. Sections 5.2.2 and 5.2.3 respectively present correlation test results and indices for technology variables using PCA. The results of the OLS regression model and PCA for the explanatory variables to get rid of multicollinearity are presented in sections 5.2.4 and 5.2.5, respectively. The results of a correlation test to limit the number of important PCs is presented in section 5.2.6. Sections 5.2.7, 5.2.8 and 5.2.9 respectively present results of PCR, RR and discussion of results for machinery technology adoption, TK_2. Finally, the socio-economic dimensions of the small-scale agriculture in communal areas of KwaZulu-Natal are presented in section 5.3.

5.1. The Adoption of Land-saving Technologies

5.1.1. Hybrid Maize Seed

Maize is the main staple food grown by 87 per cent of the sampled farmers. During the study period about 57 per cent of the sampled farmers purchased improved maize seed. Households purchased hybrid maize seeds from private shops, seed stores and farmers. On average, sample farmers applied 24 kg/ha of hybrid maize seed and invested R24, as shown in Table 5.1.

5.1.2. Chemical Fertilizers

Sixty-seven per cent of the sampled farmers used fertilisers during the year 2000. The types of fertilizer farmers used were SAAIFOS, 2-3-2 formulation and LAN. Sampled farmers applied fertilizer to crops such as maize, vegetables and potato. The results in Table 5.1 indicate that households from the study area, on average, applied 151 kg/ha as compared to 133 kg/ha in the neighboring communal wards of KwaZulu-Natal (i.e., Amaci, Khanyile and Hlabisa) while farmers in Swazi and Zambia respectively applied 59 and 50 kg/ha.

On average, farmers in SSA applied 15 kg/ha of fertilizer in 1992/93, compared with 205 kg/ha in East Asia (Pinstrup-Andersen *et al*, 1997). In Southern Africa, fertilizer applications range from 0.9 kg in Botswana to 60 kg per hectare of arable land in South Africa. Sample farmers applied higher amounts of fertilizer than farmers in SSA but far lower amounts than South African commercial farmers. Input application is low because of poor liquidity resulting from thin markets, poor infrastructure (i.e., physical as well as communicational), an inefficient marketing system and high transaction costs.

5.1.3. Characteristics of Adopters versus non-Adopters

Of the total one hundred and sixty sample households, 72 (45 per cent) adopted hybrid maize seed and fertilizer simultaneously, 56 (35 per cent) adopted either hybrid maize seed or fertilizer while 32 (20 per cent) were non-adopters. The mean and median characteristics of the nine continuous and three categorical variables for the farmers in different adoption groups is summarized in Table 5.2. On the basis of univariate tests, the same six predictors differentiate adopters and non-adopters in both models, LDS_1 and LDS_2 excluding the gender variable which is significant at ($p \leq .15$) only for model LDS_2.

However, the level of significance of the predictors in differentiating the groups varies (See Table 5.2).

Table 5.1. Technical inputs use by sample farmers, other wards and selected SSA countries, 2000.

Particulars	Study areas N =160	Other wards in KwaZulu N =292	South African commercial farmers	Swaziland N =136	Zambia N = 330
Hybrid maize seed %	57	na.	100	89	28
Fertilizer use %	69	na	100	89	49
Hybrid maize in kg/ha	24 (141)	na	22	18	na
Fertilizer in kg/ha	151(147)	133	692	59	50
Average farm size in ha	1.3	1.46	large	1.87	na

Source: (Own survey; Lyne & Ortmann, 1991; Combud, 1998; Rauniyar, 1990; Celis *et al*, 1991 and Hassan *et al*, 1999). Numbers in parentheses indicate valid cases; na- indicates data not available; Other wards include: Amaci, Khanyile and Hlabisa wards.

LDS_1: Adopters of land-saving technologies are distinguished from non-adopters by variables such as mean age of the household head, the median sources of information score and the area of operated arable land at the 1% probability level, followed by non-farm income, the value of livestock and ward.
LDS_2: Adopters are distinguished from non-adopters by the following variables; median value of livestock , the area of operated arable land, the information sources score and non-farm income at the 1% probability level, followed by ward, age and gender of the household head.

The results of univariate analyses as in Table 5.2 suggest the following: 1) that Amangwane residents are more likely adopters of hybrid maize seed and fertilizer compared to their Amazizi counterparts; 2) older and male household heads, who operate more arable land are more likely adopters of maize seed and fertilizer; and 3) adopter households earn more non-farm income, have more liquidity in the form of livestock and have made use of various information sources. To isolate the partial effects of individual explanatory variables multivariate analyses using a binary logistic regression models were estimated using predictors that showed significant group differences based on univariate analyses.

Table 5.2. Characteristics of adopters (A) and non-adopters (NA) for LDS_1 and LDS_2 models and statistical significance of possible predictors ($p \leq 0.15$).

Variable	**LDS_1**= 1 if fertilizer or seed or both; 0 otherwise			**LDS_2** = 1 if fertilizer and seed; 0 otherwise		
	NA	A	*P*-value	NA	A	*P*-value
Ward (1= Amazizi, 0 = Amangwane)	63	47	**.114** [3]	63	38	**.018** [3]
Median arable land in ha	0.75	0.93	**.094** [2]	0.75	0.94	**.047** [2]
Median operated land in ha	0.69	0.92	**.012** [2]	0.69	0.94	**.004** [2]
Mean age of the household head	51	60	**.003** [1]	51	58	**.032** [1]
Gender of the head (1=F, 0= M)	41	32	.358 [3]	41	25	**.108** [3]
Median education of the head	6	4	.267 [2]	6	4	.215 [2]
Median family labour per member	3.18	2.89	.908 [2]	3.19	3.13	.674 [2]
Median non-farm income in R	500	655	**.019** [2]	500	800	**.010** [2]
Median value of livestock in R	813	2400	**.021** [2]	813	2950	**.004** [2]
Credit use (1=Y, 0=N)	25	31	.490 [3]	25	25	1.00 [3]
Median extension (0-5) score	1	1	.740 [2]	1	1	0.5282
Median information (0-4) score	0	0	**.005** [2]	0	0	**.005** [2]

where: [1] t - Test

[2] Mann- Whitney Test

[3] Chi-square Test

5.1.4. Logit Model Results

A binary logistic regression analysis was found suitable for determining the socio-economic factors contributing to the adoption of land-saving technologies. The results in Table 5.3 indicate that, of the 6 potential predictors that distinguish the groups based on univariate tests, four predictors were retained in the final logit model ($p \leq 0.20$). The variable non-farm income was dropped from the logit analysis as it was collinear with the other predictors. The dummy variable ward was excluded from the final model because it captured the effects of other predictors such as farm size, information and livestock. However, the negative sign of the coefficient of ward suggests that farmers in the Amazizi ward are less inclined to adopt than the Amangwane farmers who may be able to protect their property rights to arable land. The result is consistent with the hypothesized relationship between technology adoption and ward. The variable, gender, is not included in the final model because the inclusion of gender reduces the significance (t-values) of the other predictors and caused the overall classification to decline to 78%. On the basis of univariate test as shown in Table 5.2, the significant association between gender and technology adoption supports the hypothesis that female farmers are less inclined to adopt.

The results of the logistic regression model are good, given that the variation in the sample data is relatively small. The small variation is attributed to the fact that farmers experience similar constraints. This phenomenon reduces correct classification rates and t-values.

5.1.4.1. LDS $_1$ (0 = non-adopters; 1 = adopters of fertilizer or hybrid maize seed, or both)

If a cut-off point is shifted to 0.75 (proportional to size) and the predicted probability of > 0.75 is assumed to define adoption, the model correctly classifies the overall adoption category of 73%. The model correctly classifies 78% of adopters and 54% of non-adopters. Following Maddala (1977:121), all variables with t-values greater than 1.0 are retained in the final model. The age of the household head followed by the area of operated arable land, information sources and livestock make a significant contribution to the model in Table 5.3. The model Chi-square statistic is statistically highly significant while the goodness of fit and -2 log likelihood statistics indicate a significant fit in the overall model.

Table 5.3. Logit results - Adopters (A) versus non-Adopters (NA) for sample farmers, 2000.

(Dependent variables: LDS_1 and LDS_2).

Variable	LDS_1; A=128, NA=28		LDS_2 ; A= 65, NA=28	
	Parameter	t-values	Parameter	t-values
Area of operated arable land in ha	0.4137	2.198***	0.6377	2.674 ***
Household head's age in years	0.0397	2.322***	0.0349	1.837**
Monetary value of livestock in R	0.0001	1.219*	0.0002	2.000**
Sources of information (0-4) score	0.8193	1.870**	0.7936	1.633*
Constant	-1.2049	-1.202	-1.5816	-1.401
Goodness of fit	127.75		83.14	
Model X^2	25.91***		27.99 ***	
-2 log likelihood	115.08		85.79	
Overall % correctly classified	73		80	
% adopters correctly classified	78		82	
% non-adopters correctly classified	54		75	

***, ** and * denote significance at the 1, 10 and 20 per cent of probability levels, respectively. The cut-off points respectively are 0.75 and 0.65 for LDS_1 and LDS_2.

5.1.4.2. LDS_2 (0 = non-adopters; 1 = adopters of both fertilizer and hybrid maize seed)

The LDS_2, as a dependent variable, accounts for the simultaneous decision aspect of adopting both fertilizer and hybrid maize seed by households. If a cut-off point is shifted to 0.65 (i.e., proportional to size) and a predicted probability of > 0.65 is assumed to define adoption, the model correctly classifies the adoption category of 80%. The model correctly classifies 82% of adopters and 75% of non-adopters. Following Maddala (1977:121), all variables with t-values greater than 1.0 are retained in the final model. The results on Table 5.3 indicate that the variable area of operated arable land, followed by the monetary value of livestock and age of the household head variables make significant contributions to the model. The model Chi-square statistic is statistically highly significant.

The relationship of the predictors (area of operated arable land, age, livestock, and access to information sources) in the final model with the dependent variable LDS_2 is similar to the relationship explained for the dependent variable, LDS_1. When the dummy variable ward is included in the logit analysis, its coefficient has a t-value greater than one and carries a negative sign, as expected. Since ward captures the effects of the other variables (e.g.,operated arable land size, livestock and information) and reduces their significance levels, it was excluded from the final model. The result from a univariate test in Table 5.2, however, suggests that farmers in Amazizi ward are less inclined to adopt than their Amangwane counterparts because residents of the Amazizi ward cannot protect their property rights and may face high transaction costs.

5.1.5. Discussion

Age has a positive and highly significant coefficient, indicating that land-saving technology adoption is associated with older and experienced household heads. The results in Table 5.2 show that adopters are older (60 years) and non-adopters are relatively younger (51 years). Compared to younger household heads, older and experienced household heads may have had closer contact with extension officers and greater credibility in larger networks that can reduce the transaction costs and therefore older age enhances adopting land-saving technologies. A commonly held view is that younger people are more inclined to adopt a new technology but the contrary finding of this study is supported by others. A contributing factor leading to this finding is that the average age of the household heads is very high while younger members in the household could influence decisions taken. The finding is supported by Matungul, *et al* (2001) who reported that older and more experienced household heads tend to have more contacts, face lower transaction costs and use more marketing channels. Nell (1998:149) similarly reported that older goat and sheep farmers of Qwaqwa in South Africa adopted relatively more internal parasite remedies because long years of experience is probably needed to be able to diagnose internal parasites.

The coefficient for operated arable land area was positive and a highly statistically significant predictor of adoption, indicating that farmers operating more land may have a greater incentive to adopt technology. The median operated arable land size of adopters is greater (0.92 ha) than that of non-adopters (0.69 ha). This supports the hypothesis that a large farm size encourages technology adoption. Very small farm sizes preclude scale economies and limit potential returns to innovation and higher product prices (Lyne and Nieuwoudt, 1991). Likewise, Welch (1978) reported that larger farms enhance technology adoption, as returns to information, management and technology adoption are scale dependent. Feder *et al* (1985:271) also report that fixed-costs attached to the implementation of the technology may be more easily born by large farms. The implication is that policies should facilitate or promote a rental market to enable farmers to acquire more land and to provide them with an incentive to invest in agriculture. Thomson and Lyne (1991) suggest that the development of an efficient land rental market could bring both equity and efficiency advantages. Uchendu (1970: 485) reported that the African tradition of multiple land holding interests on the same piece of land was a major obstacle to technology adoption and he also reported a progressive reduction of right-holders as technology was adopted by an agricultural economy. The long-term implication is that customary tenure system in KwaZulu should evolve towards allowing a more exclusive and private system of land ownership for higher adoption rates and a productivity growth of small-scale farmers.

The finding that the coefficient of information sources score is positive and significant supports the view that use of different information sources enhances probability of technology adoption. Membership of farmers' associations significantly affects the probability of adoption of alley cropping and agroforestry technologies in Senegal and Cameroon (Caveness and Kurtz, 1991; Adesina *et al*, 2000). A zero median score of information sources (Table 5.2) between adopters and non-adopters implies that the majority of the sample farmers make use of different information sources. For instance, a small proportion of households were members of a farming association, have purchased literature, had had a soil sample analyzed or owned a television set. This may clearly shows that non-adopting households have poor access to important information sources (Chapter 4). Information costs (Delgado, 1997) and high transaction costs (Low, 1986; Lyne, 1992; Coetzee, 1995; Fenwick and Lyne, 1999) adversely affect farmers' access to markets for inputs, products and contractor services. Barnes and Morris (1997) contend that the institutional environment in KwaZulu-Natal is not only inefficient, but also far from transparent, often inequitable, and resistant to change. Organizing farmers into associations exposes them to technology, facilitates interactions for technology experimentation and management, reduces demonstration costs, and increases economies of scope for technology diffusion. The state should support administratively and financially for several years when organizing farmers.

The significant livestock coefficient indicates that adoption is positively associated with owners of more livestock (Rand value). Adopters have a greater median number of livestock (four) than non-adopters (two). The positive sign of the coefficient is consistent with the hypothesis that wealth increases the probability of technology adoption. Livestock serve as the most important asset in that it presents accumulated wealth, a source of income and security against crop failures and other misfortunes (Crotty,1980; Chilot, *et al*, 1996; Hatch, 1996) and, moreover, it reflects farmers' potential financial or liquidity positions.

The coefficient of gender was not statistically significant base on multivariate analysis and its t-value was less than 1.0. The univaraite test result, however, suggests that female headed households are less inclined to adopt the technologies than male headed households. Women farmers in Southwest Nigeria, Cote d'Ivoire, Burkina Faso and Cameroon are less likely to adopt alley farming and chemical fertilizer technologies (Fabiyi *et al*, 1991; Adesina, 1996; Malton, 1994; Adesina, *et al*, 2000). Delgado (1997), citing Quisumbing, however, reports that, given equal access to resources and human capital, female farmers can achieve yields equal to or higher than their male counterparts. Delgado (1997) reported that women in Sub-Saharan Africa (SSA) face problems of tenure insecurity, limited access to extension services and technologies, and high transaction costs. The result suggests a need to develop appropriate female targeted programmes, provide farmers access to resources, and to reorganize the extension services that discriminated against women. Current extension service efforts to target women (community garden schemes, KFC's small seasonal loan) should be further strengthened and expanded on sustainable basis. The formation of a female-technology team may bring them to the economic mainstream.

5.2. Adoption of Machinery Technology

5.2.1. Use and Ownership of Machinery Technology

The results in Table 5.4 show that nearly 9 per cent, 14 per cent, 12 per cent and 7 per cent of sampled farmers respectively own a tractor, plough, planter and harrow, indicating that machinery ownership is highly skewed and that a majority of farmers rely on contractor services. Residents of Amangwane invested more (R351) for contractor services than did their Amazizi counterparts who invested R127. Thomson (1996) reported that delay of service and the high price charged for contractor services limited the use of machinery technologies.

Table 5.4. Farm machinery use and ownership by sample farmers, 2000.

Particulars	Overall, N=160	Particulars	Overall, N =160
Hired tractor %	70	Tractor owners %	8.8
Hired plough %	70	Plough owners %	14.4
Hired planter %	54	Planter owners %	11.9
Hired harrow %	33	Harrow owners %	6.9
Contractor expenditure in Rand	233 (142)		

Note: Number in bracket shows valid cases

5.2.2. Correlations Test for Selection of Technology Variables for PCA

Results in Table 5.5 show pair-wise correlations between the technology variables X_1, X_2 ... X_9. Preference was given to those technology variables that are significantly correlated because the derived first and second principal components contribute a greater proportion to the total variance. The high correlations among technology variables suggest technologies are used simultaneously.

Table 5.5. Pair-wise correlation matrix between technology variables for sample farmers, 2000.

Technology variables		X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
Number of tractors owned	X_1	1								
Number of ploughs owned	X_2	.660**	1							
Number of planters owned	X_3	.433**	.685**	1						
Number of harrows owned	X_4	.321**	.564**	.603**	1					
Contractor expenditure in R per household [c]	X_5	0.053	.168*	.177*	0.15	1				
Hired tractor (1 =Y, 0 =N)	X_6	-.440**	-.292**	-.193*	-.207**	.361**	1			
Hired plough (1 = Y, 0 = N)	X_7	-.440**	-.460**	-.316**	-.265**	.207**	.859**	1		
Hired planter(1 = Y, 0 =N)	X_8	-.201*	-.204**	-.357**	-.224**	.194*	.679**	.652**	1	
Hired harrow (1 = Y, 0 = N)	X_9	-.168*	-.139	-.172*	-.168*	.157	.460**	.460**	.62**	1

** and * Correlation is significant at the one and five per cent levels of probability, respectively.

[c] Contractor expenditure includes mean price paid for contractor services (e.g., a plow, tractor, planter and harrow) and an opportunity cost estimate was substituted for owners.

5.2.3. Indexing and Specification of Technology Variables

A PCA was performed on the technology variables with the aim of reducing these into simple technology indices that could represent the variations in machinery technology adoption. The results in Table 5.6 show the component loadings of the first and the second principal components extracted from the machinery technology variables. The loadings of the first and second principal components form the coefficients of linear equations from which farmers' 'component scores' for adoption status were calculated. The first (TK_1) and the second (TK_2) technology indices respectively contributed 43 per cent and 22 per cent to the total variance. The first component accounted for most of the variation in technology variables because there is a great deal of covariation in hiring of contractors. The percentage contribution to the total variance of the first and the second principal components extracted, compare well with the 25 per cent of the "performance index" in Nieuwoudt (1977: 77-78). In another adoption study conducted in the Amaci areas of KwaZulu, the first principal components contributed 84 per cent, 47 per cent and 52 per cent for machinery, land-saving and general innovations respectively (Kleynhans and Lyne, 1984).

The results in Table 5.6 show two important dimensions with the first index, TK_1 explaining ownership versus hiring of machinery technology, and the second, TK_2 explaining the adoption versus non-adoption patterns of machinery. The index TK_1 has values ranging from -1.098 to 3.988 and the index, TK_2 has values ranging from -1.457 to 3.978. Since there is not enough *apriori* information about why farmers own or hire machinery technologies, the index TK_1 was not considered in this study. The second index, TK_2 is considered because it represents technology adoption. Larger and positive values for the index TK_2 signify adoption whereas relatively small and negative values explain non-adoption. TK_2 is specified as a dependent variable to be used for subsequent analysis. Explanatory variables that influence adoption of machinery technology are identified using econometric techniques in subsequent sections.

Table 5.6. Characteristic vectors of the first and second technology adoption indices extracted from machinery technology variables, 2000.

Variables	TK_1	TK_2
Number of tractors owned	0.656	0.317
Number of ploughs owned	0.705	0.553
Number of planters owned	0.605	0.53
Number of harrows owned	0.545	0.527
Contractor expenditure per household in R	0.138	0.631
Hired tractor (1= Y, 0= N)	-0.777	0.476
Hired plough (1= Y, 0= N)	-0.844	0.292
Hired planter (1= Y, 0= N)	-0.733	0.406
Hired harrow (1= Y, 0= N)	-0.573	0.398
Eigen value	3.845	2.016
% of variance explained	42.72	22.4

5.2.4. OLS Regression Model for TK_2

The following model relating the machinery technology adoption index to socio-economic variables was hyphotesized.

$$\mathbf{TK_2 = \beta_1\,WAD + \beta_2\,AL + \beta_3\,GEN + B_4\,AGE + \beta_5\,EDU + B_6\,FML}$$

$$\mathbf{+\,\beta_7\,NFI + \beta_8\,LIV + \beta_9\,EXT + \beta_{10}\,INF + \epsilon_i} \qquad \mathbf{(1)}$$

where TK_2 is the second index explaining adoption versus non-adoption of the machinery technologies whereas the explanatory variables are as defined in Chapter 3; β_i's are the coefficients to be estimated and ϵ_i is the disturbance term.

The initially estimated OLS regression model for TK_2 following SPSS (1995) was:

$$TK_2 = -.566 - .319\,WAD + .120\,AL - .510\,GEN$$
$$(-.2.047)^{**} \quad (2.051)^{**} \quad (-.3.040)^{***}$$
$$+ .0099\,AGE - .0154\,EDU - .0354\,FML + .000165\,NFI$$
$$(1.490)^{*} \quad (-.616) \quad (-.800) \quad (.942)$$
$$+ .000028\,LIV + .00070\,EXT + .158\,INF \qquad (2)$$
$$(1.693)^{*} \quad (.010) \quad (1.498)^{*}$$

where adjusted R^2 = 25%, t- values are shown in parentheses, and *** ,** and * indicate significance at the 1%, 10% and 15% probability levels, respectively.

The Condition Number (CN) is the square root of the ratio of the largest eigenvalue to the minimum eigenvalue. Multicollinearity is moderate to high when the value of CN is between 20-30 and it is serious as the value of CN is greater than 30 (Gujarati,1995:338). In equation 2, the CN is 20.46 suggesting a moderate to high multicollinearity in the data set. The variables such as EDU (education) and FML (family labour available for farm work) have unexpected signs. Results of the pair-wise correlations among the socio-economic variables in Table 5.7 also show the presence of multicollinearity and, therefore, using an OLS regression model is inappropriate.

Table 5.7. Pair-wise correlations between socio-economic variables, and the dependent variable, 2000.

Variables	TK_2	WAD	AL	GEN	AGE	EDU	FML	LIV	NFI	EXT
TK_2 -index of machinery adoption	1									
Ward (1= Amazizi, 0 =Amangwane)	-.210**	1								
Operated arable land in ha	.346**	-.264**	1							
Gender of head (1= F; 0= M)	-.235**	0.053	-.152*	1						
Household head's age	.168*	-0.07	0.09	.180*	1					
Education of household head	-0.02	-0.04	0.01	-.217**	-.446**	1				
Family labor per member	0.066	-0.118	0.124	0	.292**	-0.04	1			
Value of livestock in R	.286**	-0.09	.466**	-.236**	-0.06	0.105	0.1	1		
Non-farm income in R	.309**	-0.101	.178*	-0.06	.293**	.004	0	.188**	1	
Extension services (0-5) score	.213**	-0.111	0.177	-0.113	-0.01	0.03	0	.238**	0.102	1
Information services (0-4) score	.274**	-.144*	0.03	-0.05	0.034	.229**	0	0.101	.254**	.257**

Note: ** and * indicate correlation is significant at the 1% and 5 % probability levels, respectively.

5.2.5. Principal Component Analysis (PCA)

PCA converts the original set of variables into a new set of uncorrelated variables called principal components (PCs), which are linear combinations of the original variables. PCs extracted from standardized socio-economic variables (ZWAD, ZAL etc.) to cope with this problem are summarized in Table 5.8. PC_1 distinguishes households that score high values on variables measuring farm size, gender, education, liquidity, wealth and use of extension from those that score low values on these variables-a larger emerging commercial farmer while PC_2 distinguishes households that score high values on variables measuring education, age, farm family labour and liquidity from those that score low values on these variables. PC_3 distinguishes households that score high values on variables measuring information use, farm size, wealth and liquidity from those that score low values on these variables. PC_4 distinguishes households that score high values on variables measuring tenure security, farm family labour, non-farm income and wealth from those that score low values on these variables.

Standardised variables are expressed in terms of deviations from their means (change of origin) and divided by their sample standard deviation (change of scale); thus the standardised variables have a zero mean and unit variance (Gujarati,1995:182). Standardized variables therefore are independent of the original units of measurement, and their coefficients show the relative importance of the variables, which is important for policy purposes.

Table 5.8. Principal components extracted from the standardized socio-economic variables, 2000.

Standardized variables	Principal components									
	PC_1	PC_2	PC_3	PC_4	PC_5	PC_6	PC_7	PC_8	PC_9	PC_{10}
Ward (1= Amazizi, 0 = Amangwane)	**-0.36**	**-0.3**	0	0.694	0.301	0.326	**0.286**	-0.11	0.184	0.04
Area of operated arable land in ha	**0.669**	**0.29**	-0.4	0.09	-0.27	-0.21	0.127	-0.11	0.415	0.09
Household head (1= F; 0= M)	**-0.53**	0.27	0.19	0.02	-0.33	-0.34	**0.592**	0.19	-0.1	0
Age of household head	-0.14	**0.86**	0.11	0.139	0.115	0.07	-0.12	0	-0.12	0.408
Education of household head	**0.439**	**-0.6**	0.17	-0.13	0.314	-0.23	0.146	**0.32**	0	0.311
Family labor per member	0.118	**0.53**	-0.31	**-0.38**	0.576	0.19	0.271	0.16	0.06	-0.17
Non-farm income in Rand	**0.431**	**0.36**	0.45	0.468	0.103	-0.21	-0.23	**0.33**	0.02	-0.22
Monetary value of livestock in R	**0.706**	0	-0.4	0.315	0.02	-0.11	0.239	-0.2	-0.41	0
Extension services (0-5) score	**0.464**	0.02	0.24	-0.11	-0.41	0.695	0.144	0.23	0	0.04
Information sources (0-4) score	**0.39**	0.1	0.73	-0.16	0.145	-0.04	0.21	**-0.5**	0.05	0.04
Eigen value	2.14	1.18	1.21	1.02	0.91	0.89	0.73	0.58	0.39	0.35
Percentage of variance explained	21.37	17.66	12.12	10.25	9.09	8.92	7.34	5.79	3.97	3.54

5.2.6. Correlations Test

Following Jolliffe (1986) and Maddala (1992: 285), a correlations test was run to limit the principal component regression into a subset of principal components that are uncorrelated. The PCs extracted from the socio-economic variables, especially those that are significantly correlated with the dependent variable, TK_2 were used for further analysis to determine the socio-economic variables influencing machinery technology adoption. The results in Table 5.9 show that TK_1 is significantly correlated with PC_1 and PC_2 while TK_2 is correlated with PC_1, PC_2, PC_7 and PC_8.

Table 5.9. Pair-wise correlations between the technology indices and extracted principal components for the standardized socio-economic variables.

PCs	PC_1	PC_2	PC_3	PC_4	PC_5	PC_6	PC_7	PC_8	PC_9	PC_{10}
TK_1	.239***	-.128*	0.1	0	0	0	0.071	-0.1	-0.1	0.1
TK_2	.426***	.217***	0	0	0	0	-.153*	-.130*	0	0

*** and * denote correlation is significant at the 1 and 15 per cent probability levels, respectively.

5.2.7. Principal Component Regression (PCR)

PCR as described in appendix C was used to deal with the multicollinearity problem (Maddala, 1992:285; Swanepoel, 1997). The PCs extracted for standardised predictor variables are used to restate equation (2) in terms of original variables purged of multicollinearity. In this case, by deleting a subset of the PCs, those with small variances, much more stable estimates of *βi*-can be obtained (Jolliffe, 1986:132). Although the four components (PC_1, PC_2, PC_7 and PC_8) together explain 52% of the variation in the explanatory variables, there is no a necessary relationship between the order of principal components and the degree of correlation with the dependent variable, TK_2. Following Maddala (1992:285), TK_2 is regressed on a subset of the principal components (i.e., PC_1, PC_2, PC_7 and PC_8) as per equation 3. Although PC_7 and PC_8 contribute a small proportion to the total variance, they are included in PCR because they are significantly correlated with TK_2 and have t-values greater than 1.0 (Maddala, 1977). These two PCs contribute to the model and stabilize the coefficients.

$$TK_2 = .438\,PC_1 + .205\,PC_2 - .145\,PC_7 - .123\,PC_8 \qquad (3)$$

se	(.070)	(.070)	(.070)	(.070)
t	(6.275)***	(2.939)***	(-2.076)***	(-1.767)**

where adjusted $R^2 = 28\%$, F-value = 23.05***, degrees of freedom = 120, t-value is in parenthesis, and ***, and ** denote significance at the 1 and 5% probability levels, respectively.

Standardised dependent variable, TK_2 could also be estimated using OLS regression of TK_2 on the standardised explanatory variables as follows:

$$TK_2 = \beta_1 ZWAD + \beta_2 ZAL + \beta_3 ZGEN + \beta_4 ZAG + \beta_5 ZEDU$$

$$+ B_6 ZFML + \beta_7 ZNFI + \beta_8 ZLIV + \beta_9 ZEXT + \beta_{10} ZINF \quad (4)$$

Following Chatterjee and Price (1977:176), the βi- coefficients of the original equation were estimated from equation **3** coefficients and loadings of PC_1, PC_2, PC_7 and PC_8 from Table 5.8 as follows:

$$B_i = \sum_{j=1}^{K} a_{ij} c_{ij} \quad (5)$$

where a_{ij} = estimated component loading for variable i in PC_j, c_{ij} = estimated coefficient for PC_j from equation 3, and k = number of PCs retained. For example, the standardized coefficient β_1 = **(-.360 x .438) + (-.260 x .205) + (.286 x -.145) + (-.072 x -.123) = -.244**

Substituting these expressions in to equation **(4)** gives the estimated standardized machinery technology adoption regression model as:

$$TK_2 = -.244\ ZWAD + .343\ ZAL - .286\ ZGEN + .134\ ZAG$$

$$+ .0038\ ZEDU + .0998\ ZFML + .225\ ZNFI$$

$$+ .291\ ZLIV + .159\ ZEXT + .213\ ZINF \quad (6)$$

Results in Table 5.10, column 5 show the estimated *βi* coefficients for the standardized machinery technology adoption model and the magnitudes of the coefficients indicate the relative importance of each explanatory variable in influencing the dependent variable, TK_2. Area of operated arable land (ZAL) is the most important explanatory variable followed by monetary value of livestock (ZLIV), ZGEN (gender), ZNFI (non-farm income), ZWAD (ward), ZINF (other information sources), ZEXT (extension), ZAGE (age of the household head) and ZFML (family labour available for farm work). Policies aimed at the transfer of farm machinery technologies should give emphasis to the variables in order of their importance as shown by the magnitude of the *βi* coefficients.

Table 5.10. Results of the PCR of socio-economic variables for the Amangwane and Amazizi sample farmers.(**Dependent variable**: TK_2- an index of machinery technology adoption).

Variable	Symbol	Expected sign	Regression coefficients	Beta coefficients	t-values
Operated arable land size in ha	AL	+	0.2099	0.343	6.588***
Monetary value of livestock in Rand	LIV	+	5.1E-05	0.291	5.457***
Gender of household head (1=F, 0=M)	GEN	-	-0.5798	-0.286	-4.755***
Non-farm income in Rand	NFI	+	0.00051	0.255	5.268***
Ward (1=Amazizi, 0 =Amangwane)	WAD	-	-0.4663	-0.244	-6.526***
Other information sources (0-4) score	INF	+	0.2724	0.213	4.732***
Extension services (0-5) score	EXT	+	0.13523	0.159	4.234***
Age of the household head in years	AGE	?	0.00891	0.134	2.177***
Family labour available per member	FML	+	0.05289	0.0998	2.284***
Education of household head in years	EDU	+	0.00102	0.0038	0.064
Constant			-1.415		
Adjusted R^2	0.28		F-value	23.05***	

*** denotes significance at the 1 per cent probability level.

Variances and therefore standard errors, and t-values of the βi coefficients are estimated following Gujarati (1995:70) as:

$$\operatorname{var}(B_i) = \sum_{j=1}^{k} (a_{ij}^2 * \operatorname{var}\ (c_{ij})) \qquad (7)$$

where a_{ij} = estimated loading for variable i in PC_j, Var (c_{ij}) = variance of the estimated coefficient of PC_j from equation **(3)**, and k = number of PCs retained for further analysis, in this case, PC_1, PC_2, PC_7 and PC_8. Lastly, the regression coefficients in equation **(6)** are multiplied by $S_{TK\ 2} / S_{Xi}$ (standard deviation of TK_2 divided by standard deviation of the relevant explanatory variable) to express the amended OLS model for the of adoption of machinery technologies in original scale (Chatterjee and Price, 1977:178; Swanepoel, 1997: 45), as per Table 5.10.

Comparing coefficients of equation **(2)** and the amended regression coefficients in Table 5.10 column 4, adjusted R^2 has improved from 25 per cent to 28 per cent whereas the t-values increased significantly. The low R^2 is expected, given the trade-off with the increased interpretability of the data. Moor and Nieuwoudt (1998) reported an adjusted R^2 of 30 per cent for a study that used a principal component regression technique. The signs of most of the amended OLS regression coefficients are consistent with a priori expectations as shown in Table 5.10. The explanatory variables, education and availability of family labour per member, have the expected positive signs in the amended regression model. The regression coefficient estimates in Table 5.10, column 4 are biased as some information was lost by dropping some of the principal components. The new estimates, however, are more precise as they have smaller mean squared errors than the OLS estimates in equation **(2)** (McCallum, 1970; Chatterjee and Price, 1977:175; Doran, 1989:106).

5.2.8. Ridge Regression (RR) for TK_2

Following Maddala (1992:280) and Neter *et al* (1996:411) ridge regression was used as an alternative procedure to PCR to deal with the problem of multicollinearity in the original equation (2). RR overcomes the multicollinearity problem by adding a biasing constant, $K \geq 0$ to the least squares normal equations and then by estimating the standardized ridge estimators (Neter *et al*, 1996:412). A careful examination of the *ridge trace*, which is a graph of the beta coefficients against the biasing constant, K, and the values of VIF help to determine the value of K which stabilizes the beta coefficients. The results in Table 5.11 show that the ridge estimators first stabilized when the value of the biasing constant, K (Hoerl and Kennard, 1970) equals 0.05 and the values of VIF for the regression coefficients are close to one (unity) as shown in Table 5.12. The value of K= 0.05 was then used to determine the final beta coefficients. The results of ridge regression of socio-economic variables on TK_2 are presented in Table 5.13. The signs of the explanatory variables retained in the final model agree with a priori expectations. The coefficients of education, family labour and extension services were non-significant and hence were excluded from the final RR model. The standardized coefficients of ridge regression in Table 5.13 suggest that gender of the household head (GEN) is the most important variable influencing TK_2 followed by area of operated arable land (AL), LIV (monetary value of livestock), WAD (ward), AGE (age of the head), NFI (non-farm income) and INF (information sources).

Comparing PCR and RR results, the beta coefficients and t-values of RR are generally smaller in magnitude than the beta coefficient and t-values obtained by using PCR. The adjusted R^2 obtained using RR is lower (25 per cent) than when using PCR (28 per cent). The RR results in general support the findings of PCR.

Table 5.11. R-square and the Beta Coefficients for different Values of the biasing constant, K

K	R^2	WAD	AL	GEN	AGE	NFI	LIV	INF
0	0.31	-0.1675	0.1957	-0.2515	0.1492	0.0823	0.1603	0.1238
0.01	0.31	-0.1661	0.1946	-0.2486	0.1468	0.083	0.1593	0.1225
0.02	0.31	-0.1648	0.1935	-0.2457	0.1446	0.0837	0.1584	0.1213
0.03	0.31	-0.1635	0.1925	-0.2429	0.1424	0.0843	0.1575	0.1201
0.04	0.31	-0.1622	0.1914	-0.2403	0.1404	0.0849	0.1566	0.1189
0.05	**0.31**	**-0.161**	**0.1903**	**-0.2376**	**0.1384**	**0.0854**	**0.1558**	**0.1177**
0.1	0.31	-0.1551	0.1853	-0.2255	0.1296	0.0873	0.1516	0.1125
0.15	0.31	-0.1497	0.1807	-0.2148	0.1222	0.0885	0.1478	0.1078
0.2	0.31	-0.1448	0.1763	-0.2052	0.1158	0.089	0.1442	0.1037
0.25	0.3	-0.1402	0.1721	-0.1966	0.1103	0.0892	0.1409	0.1 01
0.3	0.3	-0.1359	0.1682	-0.1889	0.1054	0.089	0.1377	0.0966
0.35	0.299	-0.132	0.1644	-0.1818	0.101	0.0886	0.1347	0.0935
0.4	0.296	-0.1283	0.1609	-0.1753	0.0971	0.088	0.1319	0.0907
0.45	0.29	-0.1248	0.1575	-0.1693	0.0935	0.0873	0.1292	0.0881
0.5	0.29	-0.1215	0.1542	-0.1638	0.0902	0.0865	0.1266	0.0857
0.55	0.29	-0.1185	0.1511	-0.1586	0.0872	0.0856	0.1241	0.0834
0.6	0.29	-0.1156	0.1481	-0.1539	0.0844	0.0847	0.1217	0.0813
0.65	0.28	-0.1128	0.1453	-0.1494	0.0819	0.0837	0.1195	0.0793
0.7	0.28	-0.1102	0.1425	-0.1452	0.0795	0.0828	0.1173	0.0775
0.75	0.28	-0.1077	0.1399	-0.1413	0.0772	0.0818	0.1152	0.0757
0.8	0.27	-0.1054	0.1374	-0.1376	0.0751	0.0808	0.1132	0.074
0.85	0.27	-0.1031	0.1349	-0.1342	0.0731	0.0798	0.1112	0.0724
0.9	0.27	-0.101	0.1326	-0.1309	0.0713	0.0788	0.1093	0.0709
0.95	0.27	-0.0989	0.1303	-0.1278	0.0695	0.0778	0.1075	0.0695
1	0.26	-0.097	0.1281	-0.1248	0.0678	0.0768	0.1058	0.0681

Table 5.12. VIF values for regression coefficients and R^2 for different biasing constants K- Machinery technology adoption using seven predictors.

K	$(VIF)_1$	$(VIF)_2$	$(VIF)_3$	$(VIF)_4$	$(VIF)_7$	$(VIF)_8$	$(VIF)_{10}$
0	1.114	1.411	1.125	1.643	1.27	1.408	1.229
0.01	1.087	1.363	1.099	1.571	1.231	1.36	1.194
0.02	1.062	1.317	1.073	1.504	1.194	1.315	1.161
0.03	1.037	1.274	1.048	1.442	1.159	1.272	1.128
0.04	1.013	1.233	1.024	1.384	1.126	1.231	1.098
0.05	**0.99**	**1.195**	**1.001**	**1.33**	**1.094**	**1.193**	**1.069**
0.1	0.886	1.029	0.897	1.107	0.957	1.027	0.941
0.15	0.8	0.898	0.808	0.941	0.847	0.897	0.837
0.2	0.726	0.792	0.733	0.814	0.756	0.792	0.751
0.25	0.662	0.706	0.668	0.714	0.681	0.706	0.678
0.3	0.607	0.634	0.612	0.633	0.618	0.634	0.616
0.35	0.558	0.574	0.562	0.567	0.564	0.574	0.563
0.4	0.516	0.522	0.519	0.512	0.517	0.522	0.517
0.45	0.478	0.478	0.48	0.465	0.476	0.478	0.477
0.5	0.445	0.439	0.446	0.426	0.441	0.44	0.442
0.55	0.414	0.406	0.416	0.392	0.409	0.406	0.411
0.6	0.387	0.376	0.388	0.362	0.381	0.376	0.382
0.65	0.363	0.35	0.363	0.336	0.355	0.35	0.357
0.7	0.341	0.326	0.341	0.313	0.333	0.327	0.335
0.75	0.321	0.305	0.321	0.292	0.312	0.306	0.314
0.8	0.302	0.287	0.302	0.274	0.294	0.287	0.296
0.85	0.286	0.269	0.285	0.257	0.277	0.27	0.279
0.9	0.27	0.254	0.27	0.242	0.262	0.254	0.264
0.95	0.256	0.24	0.255	0.229	0.248	0.24	0.25
1	0.243	0.227	0.242	0.216	0.235	0.227	0.237

Table 5.13. Results of ridge regression of socio-economic variables for sample farmers.

(**Dependent variable**: TK_2-index of machinery technology adoption).

Variables	Symbol	Regression coefficients	Beta coefficients	t-values
Area of arable land operated in ha	AL	0.1164	0.1903	-2.099***
Gender of the household head (1= F, 0 = M)	GEN	-0.4818	-0.2376	-3.059***
Monetary value of livestock in R	LIV	0.000025	0.1558	1.809**
Age of the household head in years	AGE	0.00911	0.1384	2.016***
Ward (1= Amazizi, 0= Amangwane)	WAD	-0.3071	-0.1609	-2.099***
Monthly non-farm income in Rand	NFI	0.0002	0.0853	1.059
Other information sources (0-4) score	INF	0.1504	0.0724	1.520 *
Constant		-0.4931		-1.384
Adjusted R^2	0.25	F	5.359***	

***, ** and * denote significance levels respectively at the 1%, 5% and 10 % probability levels.

5.2.9. Discussion

The coefficient of ward (WAD) was statistically significant. The result implies that residents of the Amazizi ward are less inclined to adopt machinery technologies. Presumably this is the case because residents of Amazizi ward have fields far away from their homesteads, making supervision costly. They also have the problem of protecting their property rights to arable land. Policies should improve the assurance component of tenure security (e.g., enabling farmers to protect their property rights to arable land). The positive and highly significant coefficient of arable land (AL) indicates that households who operate more land are more likely adopters of machinery technologies. Welch (1978) reported a similar result namely that a large farm enhances technology adoption, as returns to information, technology and management are scale dependent. In contrast, very small farm sizes preclude scale economies and limit potential returns to innovation and higher product prices (Lyne and Nieuwoudt, 1991). Policies should therefore improve farmer access to more arable land for a higher adoption rate. Firstly, the promotion of arable land rental markets may encourage agricultural investment and bring more land under production. The following efforts could improve land rental markets: (1) legal enforcement of contracts, (2) extension services to bring contracting parties together and (3) property transfer rights. Currently, a median of 0.2 ha of arable land is left idle. Thomson (1996) reported that a small increment in tenure security and contract enforcement has a pronounced impact on the rental market for land, leading to more intensive land use and welfare gains for contracting parties. Secondly, policies should also redistribute arable land because land ownership in the communal areas is highly skewed (i.e., a few proportion of the farm households own most of the arable land).

The coefficient of gender (GEN) is significantly related to machinery adoption, indicating less likelihood of female farmers adopting machinery technologies. Delgado (1997) reported that women have less access to equipment, extension, information, credit and technology than men. On the other hand, given equal access to resources, female farmers can achieve yields equal to or greater than their male counterparts (Delgado, 1997, citing Quisumbing). The result suggests that policies and programs must enable female farmers to get better access to resources for instance by reorganizing the extension services and other institutional services that discriminate against female so as to target the female farmers. In this way female farmers can be brought into the economic mainstream.

The positive and significant coefficients for family farm labour (FML) and liquidity (NFI) suggest that machinery adoption is associated with labour availability or liquidity to hire labour. This complementary relationship may be attributed to the fact that current rates of machinery adoption do not wholly substitute for labour. Nieuwoudt and Vink (1989) reported a complementary relationship between labour and machinery use by small-scale farmers in KwaZulu-Natal. Celis *et al* (1991:215) also reported that households that adopted the highest level of technology (i.e., oxen, hybrid seed and fertilizer) have used more family labour than those which adopted the lowest level or a traditional method.

The coefficient of non-farm income (NFI) was positive and significant, indicating that liquidity facilitates machinery technology adoption. Savadogo *et al* and Adesina, as cited by Adesina *et al* (2000) reported that non-farm income positively influenced the adoption of new technologies. Further, Nieuwoudt and Vink, and Ortmann and Lyne, cited by Lyne (1996) reported a positive correlation between off-farm incomes and investment in agriculture among rural households in the homelands. Fenwick and Lyne (1999) reported that small farmers in KwaZulu are severely constrained by low levels of liquidity which restrict investment in farm inputs and hired labour. Besides, the inaccessibility of lending institutions because of high transaction costs worsens the situation of emerging farmers and their ability to finance a technology. The positive and significant coefficient of livestock (LIV) shows that owners of a large number of livestock are more likely adopters of machinery technologies. The result is consistent with the hypothesis that wealth enhances technology adoption. In addition to source of income, livestock provide security against crop failures and other misfortunes in Ethiopia (Chilot *et al*, 1996). Policies should, therefore, target farmers by investing in physical and institutional infrastructures and hence promoting rural financial markets (i.e., promote opening up of rural cooperative banks) which might help alleviate liquidity constraint and enhance technology adoption. In this case, the state should strengthen the policy environment, improve legal and regulatory framework and adopting appropriate governance arrangements of financial markets.

The positive and significant coefficient of age (AGE) indicates that age is positively associated with machinery technology adoption. The result suggests that older and more experienced household heads compared to younger household heads, may have had better access to extension officers and credibility in larger networks which could reduce the transaction costs involved in adopting machinery technologies. A commonly held view is that younger people are more inclined to adopt a new technology but the contrary finding of this study is supported by authors such as Matungul *et al* (2001) and Nell (1998). A contributing factor leading to this finding is that while the average age of the household heads is very high, younger members in the household could influence decisions taken.

The positive and significant coefficient of extension services (EXT) suggests that farmers' exposure to extension services contributes to better knowledge about the technology and thereby stimulates technology adoption. This finding supports the hypothesis that getting access to extension service positively influences the adoption of machinery technology. The median score of extension services is one. This indicates that most of the farmers have little access to extension services. Hassan (1998:151) reported that more farmers in medium and high potential areas in Kenya adopt fertilizer, as they have better access to extension and credit services. Ferrer (1999) also found that use of information from extension services is an important determinant of achieved soil conservation adoption, in particular on relatively steeper slopes. Policies should therefore aim at improving small-scale farmers' access to extension services.

The positive and significant coefficient of information sources (INF) suggests that better informed farmers are likely adopters of machinery technology. This result supports the hypothesis that claims access to information is equivalent to access to capital and in this way enhances technology adoption. Adesina *et al* (2000) reported that farmers' access to other information sources (e.g., farm associations) positively influenced adoption. In contrast, information costs (Delgado,1997) and high transaction costs (Fenwick and Lyne,1999) adversely affect access to markets for inputs, products and contractor services. Lyne and Ortmann (1991) reported that the comprehensive farmer support programmes were not able adequately to promote or assist farmer associations and cooperatives. Further, Barnes and Morris (1997) contend that the institutional environment in KwaZulu is not only inefficient, but also far from transparent, often inequitable, and resistant to change. The state should alleviate the problems of access to information sources (i.e., institutional problems) primarily by investing in infrastructure. This will reduce transaction costs and stimulate private institutions that work with small farmers.

5.3. Socio-Economic Dimensions of Small-Scale Agriculture

Due to historical, economic, social and political factors, small-scale farmers developed almost entirely as a separate mode of agriculture in South Africa. These farmers in general have problems of insecure and fragmented land rights, small farm units, overstocking and the deterioration of land while they also lack support infrastructure, water supplies, transport and communication networks, financial support, extension and research (Singini and van Rooyen, 1995). Nieuwoudt and Vink (1989) identified four dimensions of small-scale agriculture and they argue that a single policy measure affects the different dimensions of farmers differently. This study builds on the previous findings to identify the dimensions of small-scale farmers with more recent information. The hypothesis that there are discrepancies within the small-scale farming environment, and that households have different dimensions ascribable to natural, socio-economic and political factors, is tested. Lyne (2001) contends that classifications of farmers, and subsequent policy interventions based on socio-economic characteristics, are more significant than classifications based on only physical factors such as soil types or land use. Identifying the dimensions of small-scale farmers in communal areas of KwaZulu will assist policy makers, researchers and extension specialists in the future planning and implementation of comprehensive and integrated rural development programmes.

The principal components analysis of the socio-economic characteristics of the surveyed data are presented in Table 5.14. The different factors extracted represent different dimensions of small-scale farmers in communal areas of KwaZulu. The grouping of the original variables into components can be seen by the magnitude of factor loadings. The dominant loadings are presented in *bold* font style in Table 5.14.

(a). Component one

This represents an emerging commercial farmer who operates a larger area and who is more mechanised. The household is headed by a male who owns machinery (that is, a tractor, plough, planter or harrow) and a large number of livestock. The farmer uses extension and information, and purchases technological inputs such as fertiliser, chemicals and hybrid maize seed. Although the household owns a car, it also uses public transport. This is shown by a relatively large coefficient in component 1. The first component accounts for nearly 17 per cent of the total variation in the socio-economic variables. Low and Kamwi (1998) and Low et al (1999) have reported a household of this nature (which is named as a commercial family farm, CFF) a study conducted in Kavango region of northern Namibia. This is the household owning 11 heads of cattle and above. The CFF operates with marketed assisted objectives, substitutes hired labour with capital, purchased more of less labour- intensive technology (Low et al, 1999).

Nieuwoudt and Vink (1989) reported a similar finding that increased farm production is associated with the demand for all farm resources, including labour and capital. In this study, although a similar conclusion can be drawn about capital use, few data were available about labour use, as farmers did not harvest their crops because of unfavourable weather during 2000. This kind of household will benefit from policies that promote agriculture.

(b). Component two

This represents a land-less household that has a high educational level of the head, a larger number of wage earners and no allocated arable land. The household has a car, tractor, and plough and does not rely on public transport. The farmer operates a bank account and also earns more non-farm income as shown by the positive and large magnitude of loadings. Since farming is a less important activity, the household does not invest in agriculture especially in technological inputs such as fertiliser, hybrid maize seed, chemicals and machinery. There are two reasons for not investing in agriculture. Firstly, the household has little access to arable land and high transaction costs (including risk) prohibit contracting more arable land. Fenwick and Lyne (1999) report that lack of access to viable arable land and the absence of a land rental market due to tenure insecurity are disincentives to agricultural investment. Secondly, since the household has a tractor and plough, and more wage earners, whose opportunity cost of staying in agriculture is high, it has the incentive to be a contractor and to specialise in service providing activities.

The results of the study indicate although the household has lack of access to arable land, (both allocated and through rent), it is headed by educated head (human capital) and other capital resources (machinery). Thus, this household is currently involved in service-giving activities rather than agriculture (crop production) as described by component 2. A policy prescription is to improve basic infrastructure and support services so that the household can specialise in providing services (e.g., agricultural contractor or non-agricultural business). Alternatively, enable the household to have access to viable sizes of arable land by promoting land rental markets. The improvement of roads could also promote better labour mobility and more lucrative employment. The second component explains ten pre cent of the total variation in the variables.

(c). Component three

This is a female headed, large, *non-farm household* dominated by wage earners and which earns mostly non-farm income. The farmer 'owns' arable land but rents land out as shown by the negative loading for the variable *hectare of land rented* in Column 4. Although this farmer has relatively better access to arable land, she did not make use of inputs like crop seeds and extension, information and other institutional services. The economic implication is that in situations some households lack access to resources and their earnings from agriculture are trivial, the household will look for alternative off-farm employment. A migrant labourer, in the short-run, could secure better income from off-farm jobs in commercial agricultural and industrial sectors. This household will benefit from better economic conditions in the non-agricultural sectors. Policies that create jobs in these sectors are, thus, important. The same policies that benefit households in component 2 will also benefit those in component 3.

(d). Component four

Component 4 is a small and a highly intensive garden farmer *headed by a female* with good education, who makes use of credit, extension and information as indicated by positive loadings. The farmer purchases potato and vegetable seeds, and chemicals, as shown by large and positive loadings. The farmer is also a typical lessor, as indicated by a negative loading for the area of land rented variable. The household has neither livestock nor wage earners. The lack of livestock and wage earners indicates that the household may not be wealthy and that lack liquidity may be a constraint.

Table 5.14. Principal components for sample of households in Amangwane and Amazizi wards, 2000 (N = 160).

Variables	Principal Component					
	1	2	3	4	5	6
Allocated arable land in ha	**.528**	**-.309**	**.362**	.185	**-.377**	**-.360**
Hectare of land rented in (+) or out (-)	-.139	.010	**-.253**	**-.494**	**.328**	**.409**
Number of cars owned	**.260**	**.685**	-.153	-.080	.010	-.120
Number of tractors owned	**.474**	**.340**	.030	-.069	-.097	**.480**
Number of ploughs owned	**.733**	.127	-.155	-.176	-.148	**.258**
Number of harrows owned	**.591**	.098	-.004	.121	.016	**.291**
Number of planters owned	**.774**	.120	-.086	-.105	-.163	.095
Number of freezers owned	**.157**	**.556**	**-.377**	.142	.224	-.148
Used transport (1= Y, 0 = N)	**.325**	**-.446**	**-.269**	-.170	**.414**	-.212
Operate a bank account (1= Y, 0 = N)	.090	**.388**	.212	.173	.242	-.184
Household head (1= F; 0 = M)	**-.326**	-.078	**.356**	**.306**	.058	.209
Education of head in years	.069	**.465**	-.043	**.346**	**-.299**	-.115
Household size	.149	-.046	**.591**	-.089	.112	.070
Number of wage earners	-.075	**.340**	**.586**	.079	**.375**	-.110
Monthly non-farm income in Rand	**.308**	**.401**	**.453**	-.148	**.462**	-.040
Livestock number	**.559**	**.255**	-.118	**-.357**	**-.339**	**-.273**
Credit use (1= Y, 0 = N)	.027	-.183	.130	.159	-.169	**.267**
Extension services (0-5) score *	**.454**	.020	-.097	**.240**	-.010	**-.362**
Information sources (0-4) score **	**.467**	.098	.163	**.342**	.164	.045
Fertilizer cost in Rand	**.674**	**-.370**	.211	-.032	.086	.070
Hybrid maize seed cost in Rand	**.424**	**-.461**	**-.249**	-.111	**.438**	-.132
Purchased potato seed (1= Y, 0 = N)	.132	-.151	**-.340**	**.429**	**.303**	-.121
Purchased vegetable seed (1= Y, 0 = N)	.039	.018	**-.397**	**.616**	.113	.127
Purchased chemicals (1= Y, 0 = N)	**.397**	**-.254**	.038	**.425**	.066	**.430**
Machinery expense in Rand	**.445**	**-.363**	.185	-.159	.033	-.155
Percentage of variance explained	16.7	10.3	8.1	7.1	6.1	5.7

*A sum of five dummy variables: if a farmer knew an extension officer's name, visited the officer, was visited by the officer, participated on field day and attended special training (0-5).

** A sum of four dummy variables: membership of a farming association, television ownership, analysis of a soil sample and purchase of farming literature (0-4).

Providing specialized information on the growing of crops appears important as a policy prescription. The farmer has comparatively advantageous resources- skill/education and information and invests in intensive garden farming by renting out part of her land. Policies that promote an active land rental market will improve the livelihood of this intensive farmer because renting land generates income. The policies are the following: (1) legal enforcement of commercial contracts, (2) provide extension services that bring together contracting parties (ie., reduce search costs), and (3) improve tenure security by providing permanent rights of exclusion from arable land. The promotion of rural financial markets (i.e., rural cooperative banks or saving clubs) or other institutional support services that alleviate capital constraints may also improve her livelihood.

(e). Component five

Component 5 is a land-poor household which is headed by a less educated household head who rents in land, and is an intensive producer who purchases hybrid maize and potato seed. The household uses public transport, has more wage earners, earns more non-farm income, and operates a bank account but owns no livestock. In another study, Low and Kamwi (1998) reported three groups of households in Kavango, of which, one group is without cattle that constitute 44% of sample households. They argue that households without cattle are under strong pressure to seek non-farm production opportunities. The proportion of non-farm income for no cattle owning households accounts for two thirds of the total production. The household makes little use of capital, allocated arable land or institutional services such as extension, credit and education. This household resembles component 3 in characteristics such as the number of wage earners and non-farm income. The household captured by component 3, however, has better access to allocated arable land while component 5 has access only through a rental contract. This result supports the finding that an active land rental market alleviates the shortage in land, creating both efficiency and equity advantages to contracting parties (Thomson *et al*, 1996). Prior to 1994, there was virtually no rental market for crop land. Thomson and then Lima rural development foundation have made concerned efforts to improve the rental market in the study areas. The efforts are reinforcing penalties for stray livestock (to strengthen tenure security), ensuring that rental contracts to be upheld in tribal courts (to reduce risk) and introducing extension staff to reduce private transaction costs of negotiating and drafting rental contracts.

Crookes and Lyne (2001) reported the prevalence of a longer term (a mean of 3.9 years) land rental contract, a large area of arable land under contract and a land rental contract entered into between lessors and strangers. This situation was not encountered in earlier studies. The implication is that households in components 3 (being a lessor) and 5 (being a lessee) could benefit from policies that promote an active land rental market. This conclusion is deduced from the fact that a median of 0.20 ha of arable land is kept idle in Amangwane and Amazizi wards despite population pressure and small arable land holdings. Alternative policy options, which need a long-term commitment, include land reform and the promotion of a market for land (i.e., property transfer rights).

(f). Component six

This household is headed by a land-poor female farmer who rents land in as shown by a positive loading for the area of rented in land variable. She is an intensive producer on the rented land and involved in contractor services since she owns a tractor, plow and harrow. The household has no livestock, makes little use of extension services but has marginal makes some use of informal credit from relatives and friends. This finding supports the idea that female-headed households, especially in less-developed areas, such as the former KwaZulu, have relatively little access to the use and control of resources (e.g., land ownership, extension services and education). The implication is that female targeted educational and training programs, credit and extension facilities would be desirable. Policies should enable farmers to get more access to arable land. This could be achieved by stimulating the land rental market- a short-term option or by implementing land reform towards a private type of land ownership system-a long-term option. A reorganization of extension services could provide an opportune time to address past gender discrimination in extension. Although the provision of pensions should go some way towards provision of financial support for this disadvantaged sector of society, coherent poverty alleviation policies and coordinated programmes designed to strengthen the asset base of the poor are recommended. For example, community garden and irrigation schemes, small non-fam enterprise and social asset development.

CHAPTER 6. CONCLUSIONS AND POLICY IMPLICATIONS

A binary logistic model was fitted to determine factors influencing the adoption of land-saving technologies, namely, the use of hybrid maize seed and fertilizer. The rationale for using a logit model was that the dependent variable scored a value of 0 or 1. LDS_1 and LDS_2 were specified as dependent variables for land-saving technologies. In the former case, adopters of **either** hybrid seed or fertilizer or both scored a value of one whereas non-adopters scored a zero value. For LDS_2, adopters of **both** hybrid maize seed and fertilizer scored a value of one whereas non- adopters scored a zero value. These dependent variables were used in a further analysis. The result showed that adoption of hybrid maize seed and fertilizer involves both step-wise and simultaneous decisions.

The result of principal component analysis for the adoption of machinery technologies showed that a total of nine technology variables namely, investment on technological inputs including ownership and/or hiring of a tractor, plough, planter and harrow could be represented by a few indices. The first index, TK_1 explains ownership versus hiring of the machinery technologies. The second index, TK_2 explains adoption of the machinery technologies. The second index was used as a dependent variable in a further analysis. The result also showed that the decision to adopt machinery technologies is a simultaneous decision. An implication for this result is that the adoption of machinery technologies can be improved if emphasis is placed on adoption of a group of the technologies rather than a single technology.

The next objective of the study was to determine socio-economic factors influencing the adoption of land-saving and machinery technologies by smallholder farmers. The hypothesised socio-economic variables were regressed on the second index (TK_2) of machinery technologies and the categorical dependent variables, LDS_1 and LDS_2 for land-saving technologies, respectively. Since a multicollinearity problem among the explanatory variables was detected, PCR and RR techniques were used to identify factors influencing the adoption of machinery technologies. The conclusions and policy implications from the logistic regression analysis for the adoption of land-saving, and PCR and RR analysis for machinery technologies are presented in terms of ten explanatory variables. In the statistical models, the following variables had a significant effect on the adoption of land-saving and machinery technologies.

Residential ward of the household

While the ward variable was represented as a dummy predictor of the adoption of a technology, the concept of a residential ward was included mainly for the following reason: fields in Amangwane ward are adjacent to homesteads and farmers are able to protect their property rights to arable land and supervise their property at relatively low cost. This shows that tenure is less secure for the residents of Amazizi ward. The coefficient of the ward variable was statistically significant implying that the residents of Amangwane are more likely adopters of machinery technologies than their Amazizi counterparts. The ward variable was excluded from the land-saving technology model owing to a multicollinearity problem.

Area of allocated arable land

The concept of farm size was represented by the area of arable land operated in hectares by the household. The positive and statistically significant coefficient of operated arable land implies that a large farm size favours the adoption of both land-saving and machinery technologies. Despite intense population pressure, arable land is underutilised because the private opportunity cost of (unused) agricultural land is extremely low even though average farm sizes are extremely small. This has been one of the important factors discouraging agricultural investment. Land is essentially a constraint in KwaZulu from societal point of view. This is not the case for subsistence farmers in Swaziland, where land is not a constraint (Rauniyar, 1990).

The operators of larger arable land spread the fixed costs of production over a larger output and this in turn lowers average costs (economies of size) to a greater extent than small farms. In addition, returns to information, technology and management are proportional to scale, so large farms have greater incentives to adopt new technology. The result implies that operators of larger farms have incentives to adopt technology, at least in fixed and transaction costs. This could mean that the state should design policies that enable farmers to get access to more land. The policy implications are (1) promote a land rental market which requires institutional support such as legal enforcement of commercial contracts and extension services; and (2) not to resettle farmers on units that are very small or which are not marketable.

Gender of the household head

The coefficient of gender was statistically significant for machinery technology adoption implying that female headed households are less inclined to adopt. Gender was excluded from the land-saving technology model because of collinearity. The low adoption for women may be because women have little access to resources and other necessary facilities. The policy prescription, therefore, is the reorganisation of the extension and other institutional services that discriminate against females so that target female farmers may be brought into the economic mainstream. There is a need to further strengthen the recently launched community garden schemes and other women targeted programmes.

Age of the household head

This is measured by the number of years attained by the head of household. The coefficient of the age variable is positive and statistically highly significant for the adoption of land-saving and machinery technologies. In comparison with younger household heads, older and more experienced household heads may have had more contacts with extension officers and greater credibility in larger networks, which could reduce the transaction costs involved in adopting technologies. A commonly held view is that younger people are more inclined to adopt a new technology but the contrary finding of this study is supported by others. A contributing factor leading to this finding is that while the average age of the household heads is very high, younger members in the household could influence decisions taken. Policies should be implemented which aim at providing training to improve farmers' skills.

Availability of family labour

The concept of family labour was measured by the amount of available labour per member of the household. The quantity of family labour was not significantly related to land-saving technologies. However, it was positively and significantly related to the adoption of machinery technologies. This result indicates a complementarity between the use of family labour and machinery for households with low yields. The implication is, therefore, that labour availability or liquidity will enhance small-scale farmers' technology adoption, by off-setting labour shortages in harvest seasons or when hired labour is expensive.

Value of livestock

The concept of capital (liquidity) is also represented by the monetary value of livestock owned by the household. The coefficient of the livestock variable was positive and statistically significant for both land-saving and machinery technologies. The results suggest that farmers who have more livestock are more likely adopters. The result obtained is consistent with the hypothesis that the availability of capital in the form of livestock enhances technology adoption. The implication is that owners of livestock are better off, since they are able to sell their stocks for financing technology inputs or for backing up their sustained use of improved technologies. So far, the needs of the poorest who have no source of cash income are not addressed. Policies to be implemented should alleviate the liquidity problems facing non-adopters of technologies, transform subsistence agriculture, and improve the quality of life. The provision of advice and support by public and other institutions should include micro-scale activities such as peri-urban agriculture and small-scale livestock.

Non-farm income

This variable was represented by two sources of income: (1) monthly wage remittances from members of the household, and (2) monthly pension payments. The coefficient of non-farm income was positive and statistically significant for the index of machinery technology adoption. Although non-farm income was excluded from the land-saving model because of collinearity, a univariate test result suggests that NFI is related to the adoption of land-saving technologies. The results imply that farmers in a better liquidity position can finance inputs such as hybrid maize seed, fertilizer and machinery. However, low level of liquidity is one of the constraints to technology adoption and growth for most small-scale farmers. Investment in an infrastructure will stimulate rural financial markets by reducing transaction and information costs. Policies should focus on strategies that alleviate the problem of infrastructures and improve farmers' liquidity and access to technology. The state must promote rural financial markets so that farmers could access credit. There is also a need to train and educate the adult to improve employment prospects and reduce private transaction costs and improve creditworthiness.

Extension services

This variable was a sum of five dummy variables: (i) a farmer's awareness of an extension officer's name, (ii) a farmer's visit to an extension officer, (iii) an extension officer's visit to the farmer, (iv) a farmer's participation in a field day, and (v) access to special agricultural training. The coefficient of extension services was positively and significantly related to the index of machinery technology adoption. The result showed that extension was one of the important components of the adoption process and that it stimulated technology adoption. However, the median score on the extension index was low (one, on the 0 to 5 score), indicating that most farmers make little use of extension services. The policy prescription is to reorganize and strengthen the extension services in terms both of quality and population coverage.

Other information sources

This variable was represented by four dummy variables that could stimulate technology adoption. The variables include, whether or not a household (1) purchased agricultural literature, (2) obtained a soil analysis, (3) was a member of a farming association and (4) owned a television. The coefficient of information was positive and statistically significant for both land-saving and machinery technologies. The result supports the premise that access to information sources is equivalent to access to capital and stimulates technology adoption. However, the median score of use of information sources was low (zero, on the 0 to 4 score), indicating that most farmers in KwaZulu-Natal make little use of information sources. Inadequate access to information could emanate from (1) lack of investment in infrastructure that leads to high information and transaction costs (little incentive to farm), which in turn adversely affect access to markets, inputs and machinery services, and (2) lack of farming associations and the scattered nature of small farmers. Investment in infrastructure and the organisation of small-scale farmers into farming associations, would stimulate private institutions and reduce the high transaction costs of dealing with small and often scattered individual rural households. Policies should promote sustainable cost-reducing programmes by mobilising farmers and transforming inefficient and inequitable institutional arrangements.

A further analysis was conducted to study dimensions of farm households. The results from a PCA revealed that small-scale farmers in the Amangwane and Amazizi wards of KwaZulu belong to different socio-economic categories. Among these are:- (1) emerging commercial farmers and capitalised family farms; (2) land-less household, and a service provider; (3) non-farm, large female headed households which have access to arable land but earn income by renting land and working off-farm; (4) small highly intensive garden households headed by educated female with access to extension and information; (5) land-less farmer who farm intensively by renting in land and rely partly on casual employment; and (6) land-less households which farm intensively by renting in land, in addition to providing contractor services. Variations within small-scale agriculture have emanated from historical, socio-economic and political factors.

The existence of distinct dimensions/ categories of farmers implies that farmers follow different patterns of technology adoption and make different responses to policy interventions. The results indicate that a single policy measure aimed at alleviating the problem of small-scale farmers would affect the various dimensions of farmers differently. Different strategies are therefore needed for households under different situations. For example, a policy that promotes agriculture is appropriate for an emerging commercial farmer while, a safety net program is more appropriate for a resource- poor household. The results also imply that the classification of farmers according to social, economic and institutional variables is more significant than one based on only physical factors. These results are supported by previous studies. The socio-economic classification shows a more tangible target farming population and it will assist planners, decision-makers and extension personnel in the implementation of development programmes.

A comprehensive and an integrated rural development program which aims at alleviating the problems of small-scale farmers by taking into account the different farmer categories may better address both efficiency and equity objectives. Policies should include programmes such as: 1) promoting agriculture (e.g., appropriate technology, technical and managerial training and input-output market development; 2) facilitating income transfer or safety nets for poverty alleviation and the relief of short-term financial stress; 3) addressing the problems of tenure insecurity by changing institutions that promote land rental markets and land transfer rights and hence encourage investment; 4) alleviating the gender inequalities in using extension and information services, and accessing resources; and 5) restructuring institutional supports such as providing extension, information and legal infrastructure.

SUMMARY

In this study small-scale communal farmers' technology adoption patterns are investigated. The study also classifies small-scale farmers on the basis of socio-economic and institutional factors. Data on factors associated with the adoption of land-saving and machinery technologies were obtained from a sample of 160 households in the Amagwane and Amazizi wards of KwaZulu-Natal during August 2000. Smallholder farmers' crop yields and productivity are generally low and the potential for attaining higher yields and productivity has been demonstrated elsewhere. The final goal of this study was to contribute to the current understanding of ways to increase growth in agricultural productivity. In subsistence and less-developed agriculture, growth in agricultural productivity could be achieved by encouraging farm level technology adoption. The technologies described in this study are technologies currently available in use by small-scale farmers in communal areas of KwaZulu-Natal. Conceptually, technology is viewed as an upward shift in the production function.

The literature indicates that adoption behaviour is a function of farm and farmer attributes, the characteristics of the technology, the farming objective whether subsistence or commercial, the available institutions and infrastructure. The nature and the relative importance of the factors influencing technology adoption patterns may vary across regions and over time. This research project draws on previous limited adoption studies undertaken for small-scale agriculture using a more recent and broader information base. The study hypothesised that the poor performance of small-scale agriculture in the communal areas of KwaZulu-Natal is a function of the low level adoption of agricultural technologies and that this in turn is a function of the socio-economic and institutional environment in which the farmers are working. Identifying the factors that influence the farmers' adoption of agricultural technologies may assist policy makers, researchers, development planners and

extension specialists, and private institutions.

The study also investigated the dimensions of small-scale agriculture on the basis of socio-economic and institutional variables. This segment of the study hypothesised that although small-scale farmers, in general, have the problem of small farm units, lack of liquidity, support infrastructures, transport, communication networks and extension, there are distinct dimensions of farmers who need different policy interventions. It was argued that the different categories of farmers have formed over time in response to natural, social, economic and political factors. Given the different dimensions of farmers, a single policy would affect different farmers differently. Identifying the distinct dimensions of farmers would give a better understanding of small-scale farmers and assist future rural development interventions such as technology transfer and institutional supports.

A set of four analytical techniques was used to analyse the data collected from a cross-sectional sample survey. A binary logistic regression model was used to determine the factors influencing the adoption of land-saving technologies. A principal components analysis (PCA) was used to create indices that (1) explain the adoption of machinery technologies, (2) reduce multicollinearity in socio-economic variables, and (3) identify the socio-economic dimensions of small-scale agriculture. Principal components regression (PCR) and ridge regression (RR) analyses were used to handle the multicollineartiy problem in the data set and subsequently to determine socio-economic factors influencing the adoption of machinery technologies. The types of predictor variables and their definition as well as the hypothesised relationships with technology adoption behaviour of small-scale farmers were also presented in Chapter 3.

Chapter 4 presents general information about the study population by using descriptive statistics. The study population is characterised by large family size, small arable farm units, low levels of schooling, liquidity problems, poor access to formal credit (inaccessibility of financial institutions), inadequate access to extension and information services. The distribution of arable land holding is highly skewed since a small proportion of farmers own most of the arable land. Resource ownership, which includes livestock and farm machinery is also skewed. Despite intense rural population pressure and small land holding, the results showed that a median of 0.2 hectares of arable land is left idle. Poor physical (e.g., roads, input and output markets) and institutional (i.e., secure tenure) infrastructure is limiting and farmers have little incentive to invest in technical inputs and agriculture.

In the first section of Chapter 5, the results of logistic regression analysis confirmed that the adoption of land-saving technologies was determined in the following order of importance by:(a) farm size, (b) age of the household head, (c) value of livestock (liquidity effect), and (d) use of information. The results of principal components regression analysis revealed that the adoption of machinery technologies is associated with operated arable land, which is the most important explanatory variable, followed by monetary value of livestock, gender, non-farm income, ward, use of information and extension, the age of the farmer and the quantity of family labour available for farm work. As an alternative to PCR, ridge regression analysis was also used for machinery technology adoption model. The results of RR revealed that the adoption of machinery technologies is associated with operated arable land, which is the most important variable, followed by gender, monetary value of livestock, ward, age of the farmer, non-farm income and use of information.

A principal components analysis was used to identify the dimensions of small-scale agriculture in Amazizi and Amangwane wards of KwaZulu-Natal. The results revealed that farmers belong to several dimensions and hence a single policy measure aimed at alleviating the problem of the small-scale farmers would affect the different dimensions of farmers differently. The implication is that classification of farmers on the basis of socio-economic and institutional factors is more significant to identify dimensions of farmers. The identification of the dimensions apparently may help to effectively target farmers and design programmes that address both efficiency and equity objectives.

This study concludes that small-scale farmers' adoption of agricultural technologies is associated with attributes related to farm and farmer, socio-economic and institutional factors. Policies should enable farmers to get access to more arable land by either promoting land rental markets and reforming the tenure structure. The state must promote rural financial markets to solve the problem of liquidity and improve farmers' access to finance. There is a need to organise farmers into farming associations to transfer technologies, and provide extension and information services to groups of farmers rather than to individual farmers.

The results also suggest that the identified dimensions of farmers must be targeted by designing holistic and integrated rural programmes such as: 1) promoting agriculture (e.g., appropriate technology, technical and managerial training and input-output market development; 2) facilitating income transfer or safety nets for poverty alleviation and the relief of short-term financial stress; 3) addressing the problems of tenure insecurity by changing institutions that promote land rental markets and land transfer rights and hence encourage investment; 4) overcoming the gender inequalities in using extension, information and education services, and accessing resources; and 5) restructuring institutional supports such as providing extension, information and legal infrastructure. Since the

Amangwane and Amazizi wards are far removed from markets and main roads, the state should invest in roads, telecommunications, and postal services.

Future research on the adoption of agricultural technologies for small-scale agriculture should take account of risk attitudes of farmers, profitability of technologies and input supply constraints. Further, this study could address neither the factors influencing adoption of technologies over time nor factors associated with the intensity of technology adoption. The study of adoption over time accounts for different categories of farmers who adopt agricultural technologies at various paces.

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APPENDIX A: LOGIT MODEL

The theory of technology adoption shows a traditional sigmoid (*S*) curve trend in the sense that the technology adoption process has at first a slow increasing trend with time, and as soon as the adopter starts to use or implement new technologies and the utility or incentives obtained are sufficiently realized by the farmer, the adoption process accelerates. After the implementation of a set of new technologies, the acceptance process declines until new technologies appear again.

The standard cumulative logistic distribution function is given by:

$$Pi = E(Y=1|X1) = \frac{1}{1+e^{-(ao+BiXi)}} \qquad \text{(A.1)}$$

where Pi is the probability that a farmer will "adopt" or " not adopt" new technologies, given the values of the vector of the explanatory variables X (x_1, x_2, x_3 ....x_n). The β is a vector of parameters to be estimated (b_1, b_2, b_3 ...... b_n) and *e* represents the base of the natural logarithm OR:

$$1 - Pi = \frac{1}{1+e^{(ai+BiXi)}} \qquad \text{(A 2)}$$

The ($\alpha_0 + \beta_i X_i$) function ranges from $-\infty$ to $+\infty$, P_i ranges between 0 and 1, and P_i non linearly related to ($\alpha_0 + \beta_i X_i$). Note that Pi is nonlinear not only in X but also in the β_i's (See A.2). This means that the ordinary least square (OLS) procedure cannot be used to estimate the parameters. The maximum likelihood (ML) estimation can be applied to eliminate this problem, as it generates consistent coefficient estimates (Gujarati, 1995).

If P_i, the probability of adopting a technology, is given by (A.2), then $(1-P_i)$ is the probability of not adopting new technologies and can be written as:

$$1-Pi=\frac{1}{1+e^{(ai+BiXi)}} \qquad (A.3)$$

$$A.2 \,/\, A.3 = e^{(ai+BiXi)} \qquad (A.4)$$

Equations (A. 2 / A.3) which is simply Pi / (1- Pi) is the odds ratio in favor of adopting new technologies.

If the natural log of (A.4) is taken, the result is the following function:

$$Li = \ln\left(\frac{p}{1-pi}\right) = ai + BiXi \qquad (A.5)$$

where Li is the log of the odds ratio of the dependent variable (Gujarati, 1995). The logit model will be used with the analysis of land-saving technology (hybrid maize seed and fertilizer) adoption. The logit model will be estimated by maximum likelihood method using SPSS 9.0 ©.

APPENDIX B. PRINCIPAL COMPONENT ANALYSIS (PCA)

PCA is a transformation technique with which a set of complex set of relations can be reduced to simple canonical form. The purpose of PCA can also described as an effort to economize on the number of variables (Jolliffe, 1986). Principal components are obtained by transforming the observed variables as follows:

$$TK_1 = a_{i1} X_1 + a_{i2} X_2 + ... + a_{ip} X_p$$

where p variates X_1, X_2 . . . X_p are observed on n individuals/ households; a_{i1} , a_{i2} , ... a_{ip} are coefficients calculated so that TK_1, the first principal component, makes the greatest contribution to the variance (or correlation) as contained in the ***p*** number of the original variables; the second TK_2 is chosen to be uncorrelated with the first, and to have as large a variance as possible, etc. The X variates are thus transformed to new uncorrelated variates, which account for as much variation as possible in descending order (Nieuwoudt, 1977: 277). For detail derivation of the principal components (See Maddala, 1992: 293-303).

APPENDIX C. PRINCIPAL COMPONENT REGRESSION (PCR)

A solution often suggested for a multicollinearity problem is the principal component regression, which is presented as follows. For k explanatory variables, we can consider linear functions of these variables:

$$Z_1 = a_1 x_1 + a_2 x_2 + \dots\dots\dots + a_k x_k$$

$$Z_2 = b_1 x_1 + b_2 x_2 + \dots\dots\dots + a_k x_k \quad \text{etc.} \qquad \textbf{(1)}$$

Suppose we choose the a's so that the variance of Z_1 is maximized subject to the condition that $a_1^2 + a_2^2 + \dots\dots + a_k^2 = 1$. This is called normalization condition. It is required, or else the variance is increased indefinitely. Z_1 which is the linear function of the x's has the highest variance (subject to the normalization rule) is known as the first principal component.

The process with the aim of maximizing the variance of the linear function Z subject to the above normalization condition such that sum of squares of the coefficients of the x's equals 1, produces K linear functions $Z_1, Z_2 \dots\dots\dots Z_k$. These are called principal components of the x's. They can be ordered so that $Var(Z_1) > Var(Z_2) > \dots\dots > Var(Z_k)$

Z_1, the one with the highest variance is called the first principal component (FPC), Z_2 with the next highest variance is called the second principal component and so on. These principal components have the following features :

1. $Var(Z_1) + Var(Z_2) + \dots\dots + Var(Z_k) = Var(x_1) + Var(x_2) + \dots\dots + Var(x_k)$

2. Unlike the x's , which are correlated, the z's are orthogonal or uncorrelated. Thus, there is a zero multicollinearity.

If we have a dependent variable Y a linear function of the x's and the x's are plagued by the problem of multicollinearity, there is a point in using the principal components only if we regress Y on a subset of the Z's (Maddala, 1992:285). The PCs extracted from the observed socio-economic variables were first standardized to have unit variance.

Following (Jolliffe, 1986; Maddala, 1992), an equation was specified to determine factors that influence adoption of machinery technologies (TK_2) by small-scale farmers. TK_2 is the second index that accounts for machinery adoption (See Chapter 5 section 5.2.3).

$$\mathbf{TK_2\ (Y_2) = \mathit{f}(\text{ a subset of } Z_i\text{'s or PCs }) \quad (i = 1, 2., \ldots n) \qquad (2)}$$

where:

TK_2 is the dependent variable, and

PCs (Z's) are the subsets of principal components extracted for standardized socio-economic variables.

APPENDIX D.1. RIDGE REGRESSION AND ESTIMATORS

Consider the following least squares normal equations for the ordinary multiple regression model:

$$\mathbf{X'X\,b = X'Y} \qquad (1)$$

The least squares estimators are obtained from

$$\mathbf{b = (X'X)^{-1}\,X'Y} \qquad (2)$$

Following (Neter *et al*, 1996:278-279), after standardizing and transforming using a correlation transformation of the Y and X's, equation **(1)** can be expressed as follows:

$$\underset{(p-1)}{\mathbf{X}}{}'\underset{(p-1)}{\mathbf{X}} = \underset{(p-1)x(p-1)}{r_{xx}} \qquad (3)$$

where $\mathbf{r}_{xx}$ is a correlation matrix of the X variables, whereas

$$\underset{(p-1)x}{\mathbf{X}}{}'\underset{1}{\mathbf{Y}} = \mathbf{r}_{YX} = \begin{bmatrix} \mathbf{r}_{y1} \\ \mathbf{r}_{y2} \\ \cdot \\ \mathbf{r}_{y,\,p-1} \end{bmatrix} \qquad (4)$$

$\mathbf{r}_{yx}$ is the vector of the coefficients of simple correlation between Y and each X variable. It now follows from **(3)** and **(4)** that the least squares normal equations and estimators of the regressions coefficients of the standardized regression model (Neter *et al*, 1996:279) are as follows:

$$r_{XX}\ \mathrm{b} = \mathbf{r}_{YX} \tag{5}$$

$$\mathrm{b} = \mathbf{r}^{-1}_{XX}\, r_{YX} \tag{6}$$

where

$$\underset{(p-1)\times 1}{b} = \begin{bmatrix} b'_1 \\ b'_2 \\ \cdot \\ b'_{p-1} \end{bmatrix} \tag{7}$$

The regression coefficients b'_1, ... b'_{p-1} are called *standardized regression coefficients*. The ridge standardized regression estimators are obtained by introducing into the least squares normal equations a biasing constant $K \geq 0$ in the following form

$$(\boldsymbol{r}_{xx} + \mathbf{KI})\ \mathbf{b}^R = \boldsymbol{r}_{YX} \tag{8}$$

where **I** is the $(p\text{-}1) \times (p\text{-}1)$ identity matrix while $\mathbf{b}^R$ is the vector of the *standardized ridge regression coefficients* b_k^R:

$$b^R = \begin{bmatrix} b_1^R \\ b_2^R \\ \cdot \\ b_{p-1}^R \end{bmatrix} \tag{9}$$

Solving the normal equations in **(8)** yields the ridge standardized regression coefficients:

$$\mathbf{b}^R = (\boldsymbol{r}_{xx} + \mathbf{KI})^{-1}\ \boldsymbol{r}_{YX} \tag{10}$$

APPENDIX D.2. VARIANCE INFLATION FACTORS (VIF)

The Tolerance for variable X_k is $(TOL)_k = 1 - R_k^2 \quad k = 1, 2, 3 \ldots, p\text{-}1.$ (11)

where R_k^2 is the R-square when X_k is regressed on the other independent variables in the model including the constant. The variance inflation factor in the ordinary least equation for variable X_k is the inverse of the tolerance and measures how much the variance of the standard regression coefficient, b_k is inflated by collinearity. That is,

$$(VIF)_k = 1/(TOL)_k \qquad (12)$$

The VIF value for $\mathbf{b}_k^R$ measures how large the variance of $\mathbf{b}_k^R$ is relative to what the variance would be if the predictor variables were uncorrelated. Following Neter *et al* (1996:415), VIF values for the ridge regression coefficients $\mathbf{b}_k^R$ are the *diagonal elements* of the following $(p\text{-}1) \times (p\text{-}1)$ matrix:

$$(r_{xx} + KI)^{-1}\ r_{XX}\ (r_{xx} + KI)^{-1} \qquad (13)$$

A sufficiently small value of VIF for $\mathbf{b}_k^R$ is desirable when choosing the stable coefficients (Neter *et al*, 1996). Further, the smallest value of the biasing constant, K where the regression coefficients first become stable in the *ridge trace* should also be examined for decision.

APPENDIX E: HOUSEHOLD SURVEY QUESTIONNAIRE, 2000

UNIVERSITY OF NATAL

DEPARTMENT OF AGRICULTURAL ECONOMICS

Ward:____________________ **Interviewer**:____________________

Sub-ward:____________________ **Date:** ____________________

The information obtained in this questionnaire is strictly confidential and will be used for research purposes by LIMA staff and researchers at the School of Agricultural Sciences and Agribusiness, University of Natal. The findings will inform government of ways in designing programmes aimed at improving farming efficiency and household welfare. Respondents do not have to answer questions – answers are voluntary. The respondent should be a male or female household head.

Respondent's Name:______________________________ Household No.:__________

1. FARM CHARACTERISTICS

	Arable land						
	Allocated land cultivated	Allocated land leased out	Allocated land left idle	All arable land	Land rented in*		
					1	2	3
No. of arable plots cultivated now and in the past							
Size (ha)							
Slope/Soil depth							
Aspect							
Waterlogging problem (**Y** or **N**)							
Distance to irrigation water (specify units)							
Arable land quality**							
Change of boundary **(Y/N)**							
If farm boundaries changed, is the farm **larger** or **smaller**?							

* **Record the lessee's 3 most important rental contracts**

** **1 Poor; 2 Below Average; 3 Average; 4 Good; 5 Excellent**

Missing values score = -1

2. HOUSEHOLD COMPOSITION

2.1.

Respondent	Gender (M or F)	Age (years)	Occupation[1]	Cash income (R/Month)	Cash remitted (R/month)	Disability and pension payments (R/month)	School standard passed
1. Male head	M						
2. Female head	F						
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							

[1]Occupation should be categorised as: Wage Employed (**WE**); Farmer (**F**); Self-employed (**SE** – e.g. taxi driver, shopkeeper etc.); Housekeeper (**H**); Pensioner (**P**) if paid pension; Disabled (**D**) if paid a disability grant; Unemployed (**U**) if work seeking; Student (**S**); Infant (**I**) if too young to attend school; or vagrant (**O**).

2.2 If the household head is female, is she widowed? (**Y** or **N**) ________

2.3 How many family members work on the farm at planting time? ____________

2.4 Does any family member have a bank account? (**Y** or **N**)_______________

If **YES**, where is the nearest account held? (town) _______________

3. LIVESTOCK

Livestock	No. possessed by all household members	Gross income from sales in past year (Rand)
Drought cattle		
Other cattle		
Small stock		

3.1 Did the household produce any dairy products over the past year? (**Y** or **N**) ______

If **YES**, were any sold? (**Y** or **N**) _____

If **YES**, what was the gross income from dairy sales over the past year? R_______

4. CROPS GROWN DURING LAST YEAR

Crops	Grown during past year (Yes or No)	Sold during past year (Yes or No)	Gross income (Rand)
Maize			
Potatoes			
Beans			
Vegetables			
Fruit			

4.1. Has the household planted all of its arable land this season? (**Y** or **N**)______

If **NO**, list (in order that the respondent mentions them) the main reasons for not cultivating all of their arable land (e.g.risk of drought, lack of cash to buy inputs, no ploughing services in the area, cattle damage crops etc.) ____

____

____

5. FARMING EXPENSES

5.1 Agricultural inputs used *this past* season

Purchased input	Used (Yor N)	Quantity used specify unit	Total cost in R	Input provided by the landlord or sharecropper (R)	Amount of down payment in R
Fertilizer					
Seed: Maize					
Beans					
Potatoes					
Vegetables					
Others					
Hired : Contractor					
Farm equipment					
Drought power					
Labour					
Veterinary medicines					
Transport services					
Livestock feed					

5.2. Indicate the type of input purchased and Rand amount allocated to the crop, this past season.

Purchased input	Used (Y or N)	Crops grown				
		Maize	Potatoes	Beans	Vegetables	others
Pesticide	a					
	b					
Herbicide	a					
	b					
Fertilizer	a					
	b					
	c					
	d					

6. ASSETS

6.1 Does the household own any of the following in working order?

Item	Number	First year acquired	Item	Number	First year acquired
Motor vehicle			Knapsack sprayer		
Tractor			Maize mill		
Plough			Fridge/Freezer		
Planter			Television		
Harrow					

6.2 Have you ever hired any farm implements and machinery for your farm?

(Y or N) ________

If **YES**, which farm implements and machinery, and when did you *first start* using them?

Item	Number	First year acquired	Item	Number	First year acquired
Motor vehicle			Knapsack sprayer		
Tractor			Maize mill		
Plough			Fridge/Freezer		
Planter			Television		
Harrow					

7. ON-FARM IMPROVEMENTS

7.1 Has the household invested in any of the following?

Item	**Y or N**	Year of investment	Item	**Yor N**	Year of investment
Irrigation			Lime application		
Water troughs			Storage silos		
Fencing arable land			Other (specify)		
Pasture					

8. CREDIT USE

8.1 Has the household used credit for agricultural inputs in the past two years?

(Y or N) _____

If YES, from whom did they get the credit? (tick where appropriate):

KFC/Ithala ________ Bank________ _____

Co-op ________ Informal lender (e.g. shopkeeper)______

Relative________ Friend/Neighbour _____

Tenant_______ Lessor ______

8.2 If the household did NOT use credit for agricultural inputs, would it like to?

(Y or N) ______

If YES, what has prevented the household from using credit? (tick where appropriate):

Not creditworthy________ Interest charges are too high ______

Cannot use land as collateral ________ Credit is too risky ______

8.3 Have any household items (e.g. furniture, fridges, TV's etc) been bought on credit in the past two years? (Y or N)________

9. EXTENSION AND INFORMATION

9.1 What is the name of your local extension officer? _________________

9.2 How many times did the extension officer visit you this past growing season since planting? _________________

9.3 How many times did you visit the extension officer this past growing season since planting? __________________

9.4 Has any member of your family attended the following?

(tick where appropriate):

Agricultural field days ______

Agricultural training courses ______

9.5 Are you a member of any of the following: (tick where appropriate)

Farming association ______ Cooperative ______

9.6 Does any member of your family purchase farming books or magazines? (e.g. Farmers Weekly)

(Y or N) ________

9.7 Have you had soil samples taken and analysed ? (Y or N)________

THANK-YOU