Chapter 2

LITERATURE REVIEW

"Change is inevitable in a progressive society.
Change is constant."

Benjamin Disraeli.

2.1 INTRODUCTION

One of the components (subsystems) of any development system is technological development or change. Whether positive or negative, change is inevitable in any part of the world and is part of the development of life. The transfer and adoption of newly developed technologies were and will always be part of the development system of mankind. Sunter (1996) said that the rules of the "game" are going to get very strict and that the person or institution that do not adapt to new technologies will experience increasing penalties for failure that will end up in bankruptcy.

It is well-documented that the "Western" agricultural model went through a technological explosion. With the liberalisation of national and international trade and markets, the farmers who do not adapt to these changes by adopting new the technologies of modern agriculture, would not be able to compete in the marketplace of this liberalised world (Nell, 1997). The agricultural development strategies followed by most governments in less developed countries who have interests in agricultural planning, vary to a large degree, but can be regrouped as the "Western" model of development. This is generally equated with increased production and the need to increase the production level of small farmers (Gibbons, De Koninck & Hasan, 1980).

During the first three decades after the Second World War the gap in agricultural productivity widened sharply between developed and developing countries (Third World). Technological breakthroughs in this period concentrated mainly on grain technologies (Hayami & Ruttan, 1985) and high-potential areas with favourable climatic conditions (Otsuka & Delgado, 1995). During the same period the development of livestock technologies were neglected mainly because the returns obtained on crop technology were much more spectacular than those of livestock technologies (De Boer, Knipscheer & Kartamulia, 1992). Nevertheless, the development and adoption of livestock technologies remain important for livestock farmers. Vink (1986) stated that research on agricultural development in Sub-Saharan Africa has taken little note of the problems of the livestock sub-sector despite its importance in terms of the availability of resources.

Ten years ago Spies (1987) pointed out that agricultural development will be characterised by a transformation from an agrarian agriculture with a very high dependency on quality and quantity of natural resources, to a commercial agriculture which will be more dependent on new technologies, quality of farmers and the availability of capital. He also stated that the emphasis will fall on the development of black emerging commercial farmers and that the need for "effective technology transfer" in the South African agriculture will increase in future. Long-term growth in agricultural production will depend on the implementation of healthy long-term strategies which will stimulate entrepreneurship and technological innovation. Agriculture is not a machine but a vibrant pulsing socio-economic system, particularly in countries where a considerable part of the annual per capita income is generated from the agricultural sector, as is the case in South Africa.

Although some research has been done on livestock production in developing areas of South Africa (Afful, 1997; Anim, 1997; Fényes, 1982; Naledzani, Ortman & Lyne, 1989;

Nkosi & Kirsten, 1993 & Vink, 1986), very little attention was given to livestock technology transfer and adoption and even less to livestock veterinary technology transfer and adoption in the former rural homeland areas. Very little is known about the characteristics of black emerging small ruminant farmers adopting livestock veterinary technologies in South Africa. This is very strange for a country where most of its land is not suited for crop production and most of the agricultural land is therefore used for livestock production.

This chapter will attempt to provide an insight on how technology development functions as a subsystem within the total development system, as well as how the economies of countries and the lives of people all over the developing world are affected, especially on communities and its effect on the development of new technologies. The variables (predictors) contributing to the transfer, diffusion, adoption and usage of new technologies will be identified by the existing literature on agricultural technology transfer and adoption and discussed from the point of view of this study. This is done in three main sections. The **first section** discusses the role of agricultural technological change in developing countries, the **next section** deals with the methodologies and the mathematical models (discrete choice models) used by other researchers on the identification of farmer characteristics and predictors on technology transfer and adoption studies and the last section identifies predictors (variables) contributing to technology transfer, adoption, progress and usage reported in the literature.

2.2 THE ROLE OF AGRICULTURAL TECHNOLOGICAL CHANGE IN DEVELOPING COUNTRIES

Technological change can become a major vehicle in agricultural development reaching far beyond the more immediate goals of increasing production and satisfying food and nutritional needs as well as the alleviation of poverty (Birowo & Qasem, 1987a). Only by using a properly integrated multidisciplinary, holistic approach as an overall development strategy system can its full potential for achieving growth and equity goals be achieved. New technologies must be planned and developed on a multidisciplinary partnership basis, with the participation of the end users (farmers) (Borlaug, 1988). Owens (1993) shares this view in stating that the development of new technologies must be planned and developed in participation with the end users (farmers), which will make the technology transfer process more impact-orientated and increase its adoption rate. Appropriate public policy and institutional changes (reforms) must accompany and support this strategy.

Leaver (1994) emphasises the importance of a holistic multidisciplinary approach of technology transfer in a sustainable agricultural development system. It is essential to identify problems and solutions with the participation of farmers on the adoption of the new technologies. Gibbon (1994) shares the viewpoint of Leaver in that he argues that agricultural research institutions remain dominated by the prevailing Western scientific paradigm. Farmers or potential users of technology, as well as all the disciplines involved in development of a specific technology, must become involved in research planning or decision-making. Low (1990) came to the same conclusion from his experience that all the elements necessary for technology transfer and adoption can be available, but if an integrated or multidisciplinary approach to research, extension and support services is not followed, the technology transfer and adoption process will not be sustainable.

According to Clark and Juma (1991) the history of contemporary development has shown that technological change is not deterministic and therefore its evolution can be governed in order to achieve certain social goals. Pehu (1994) goes further by stating that the scientific community, those setting research priorities and the target group where biotechnology is going to be applied, must have a say in the way biotechnology is going to be applied. Düvel (1994a, 1994b) goes even further and indicates that the adoption of new technologies is hardly possible if there is a perceived incompatibility between the innovation (technology) and the needs of an individual.

Experiences over the last 30 years have demonstrated the importance of institutional reforms related to the agricultural sector to implement new technologies (Norton & Alwang, 1993). These reforms have been proven important not only to production incentives and to the distribution of economic gains, but also on the types of technologies produced and adopted. Land reform, improved credit policies, marketing system development, non-discriminatory pricing policies, and incentive systems to reduce environmental externalities are important institutional changes that are crucial for the success of the technology transfer and adoption system. Bembridge (1987) stated that "[n]ew technologies are not gifts of nature and institutional changes do not magically appear". Bembridge (1987) also recommended institutional reform and advancing technology by improving draught power, evaluating intercropping systems, integrating crop and livestock production, and developing technology for improving plant and weed control to narrow the "gap" between farmer yields and potential yields in Transkei.

2.2.1 The role of the technological subsystem in the developmental system

Development is a total system, open or closed, which consists of certain developmental actions (parts) that synergistically generates a higher energy than it would have, had the different parts been functioning on their own. If synergy exists between technology, tenure, infrastructure and financial institutions, the total developmental system will foster entrepreneurship and sustainable agricultural progress or development (Groenewald, 1993). The technological development subsystem is an integral part of the total developmental system. The Practice Model of Development that was developed by Wessels (1996) provides a significant, broader frame of mind from which practical developmental programmes could be adapted to suit different needs.

Three of the most important constraints to agricultural development in West Africa reported by Sanders, Shapiro and Ramaswamy (1996) are:

- "inadequate adoption and diffusion of the substantial achievements of public investment in agricultural technology research over the last 20 years;
- the failure of economic policies to encourage output and investment in the agricultural sector; and

- the inability of farmers to acquire capital either from their own savings or from the private or public sectors to finance the increased input purchases necessary for technological change in agriculture."

These constraints are interrelated. Higher inputs are required to increase yields. An economic environment in which profits can be made at an acceptable level of risk, the provision of adapted agricultural technologies, and the evolution of input and product marketing systems are necessary conditions to encourage farmers to purchase more inputs (McMillan et al., 1997; Mahmud & Muqtada, 1988).

Development is all about growth and change in order to provide a better way of life. To achieve this in agricultural development, the spendable income of farmers must increase. Welch (1978) stated that "agricultural development is knowledge in use". Sanders, Southgate and Lee (1995) feel that developing countries need to increase their yields (crops) or reproduction levels (livestock) – total production per hectare – and that many productivity-increasing technologies are more sustainable than area-expansion technologies in developing countries. Water and soil retention techniques, irrigation, adequate management techniques, including breeding, feeding, veterinary and medication, are examples of adequate technologies needed in low-income (low rainfall) countries. Policy reviews such as the structural-adjustment programmes, to reduce price distortions and to strengthen property rights are essential to guarantee the success of new technology adoption which may result in a more productive and sustainable agricultural sector. Poor property rights and inefficient price signals discourage farmers throughout the developing world, from adopting land conservation measures or technologies that are essential for sustainable agricultural development. Stacy, Van Zyl and Kirsten (1994) share this view and stated that a "package of prime movers" is necessary to sustain agricultural development and increase the quality of life for those involved in the advantage of new technologies.

2.2.2 Policies and constraints regarding technology transfer and adoption

Raikes (1994) stressed the importance of agricultural policies that must be in place to assist with the transformation process of new technologies. Chopra (1986) examined the impact of the Green Revolution in four states of India, analysing the reasons for success in Punjab and Haryana and its failure in the western Uttar, Paradesh and Bihar regions. He came to the conclusion that in the case of the first two states, the administrative support in the form of policies to support the adoption of new technologies by the government has contributed directly to the successful development of technology and its transfer and adoption processes.

Blackie (1987) felt that a responsive and productive agricultural sector in Sub-Saharan Africa can be developed by using government policies to regulate rather than to manage the delivery of services essential to agricultural development and technological change. Central to this process is the effective participation of the small-scale farmer in determining agricultural policies. Sanders and Shapiro (1998) feel that it is the responsibility of governments to draft supportive policies to assist farmers to introduce new technologies if they are not in a position to adopt these technologies on their own. The policies of the public sector must be directed in such a way that infrastructure can be extended. The maintenance of agricultural research and investment in water research technologies will all help to reduce risk for emerging farmers (Sanders et al., 1996). Clark and Juma (1991) argue that an understanding of the strategic dynamics of the major new technologies must form an integral part of the policy-making process. The development of biotechnology for the Third World must include a dimension of long-term environmental stability that must be incorporated into policy formulation and implementation.

According to Mijindadi (1995), four major elements are critical in the agricultural technology transfer process, namely:

- Identification of the problems and needs of potential end users – technologies must be relevant to identified needs.

- Testing and adaptation of new technologies to the local environment of the users – technical, social, environmental and economic issues must be addressed. This is essential for profitability (incentives) and sustainability;

- Existence of government or official regulations to provide decision mechanisms for approval and release of new technologies to users – technologies must be well proven and authenticated.

- Effective operation of a communication process – approved technologies must be passed on to users, through an extension services system.

Two other factors also aid the technology transfer process, namely:

- Provision of regular training on the use of innovations.
- Incorporation of technology related services in extension programmes.

The success of new technologies will be determined by its adoption rate (Sarch, 1993). The adoption of new technologies is an ongoing process in developing agriculture. It was found that after the initial adoption of new agricultural technologies during the Green Revolution in Asia, farmers increased their expected income dramatically until 1980. Thereafter there was a stagnation in the income levels of rice farmers due to a decline in the real price of rice and a decline on rice research for the development of new improved cultivars (Jatileksono & Otsuka, 1993; Otsuka, Gascon, & Asano, 1994; Otsuka & Delgado, 1995).

Stacy *et al.* (1994) found that the adoption of new technologies increases the productivity of land and labour. However, adoption behaviour differs across socio-economic groups and over time. Wealth derived from the adoption of new technologies enables further adoption that affects the dynamic pattern of aggregate adoption. Differential rates of technology adoption by different socio-economic groups disappear once the process is sufficiently advanced.

According to Birowo, Gondowarsito and Harrison (1989) the following factors were basic constraints to rapid adoption of new technologies or innovations:

- Inappropriate transport infrastructure.
- Limited access to information.
- Insufficient human capital.
- Aversion to risk.
- Lack of credit.
- Social acceptability of introduced, albeit imposed, change.

The explosion of both technology innovations and development and means of communication, as well as the provision of information, made the transfer process highly sophisticated and is increasing at an almost exponential rate in developed countries. The usefulness (value) of new technologies (innovations) and their marginal cost (cost of the technology and transaction cost), in relation to the needs and wants to be satisfied, determines their rate and extent of adoption by the farmers. A discrete science has evolved in studying the process of agricultural technology transfer and means to improve its rate of adoption by farmers (Finlayson, 1995). Besides the actual cost of a certain technology, other costs are involved in obtaining it – transaction costs, which, for instance, are related to transport costs. These costs will vary depending on the location of the farm, transport infrastructure and access to information and suppliers of inputs. It is therefore important to keep transaction costs in mind when studies are done on technology transfer and adoption.

2.2.2.1 Transaction costs and Von Thünen's theory

According to Vink (1986) transaction costs can be divided into three stages (sections), namely *ex anté*, actual and *ex post* transaction costs. ***Ex anté* costs** are the costs involved in obtaining an input which include, for instance, transport to and from the supplier of medication or to the markets. **Actual costs** are those costs incurred during the transaction itself, such as commission at the livestock auction kraals, value-added tax payable with the purchase of the medication, etc. ***Ex post* costs** are those costs for the second party who, for instance, have to transport the animals from the auction to the farm. There are always two parties involved and the costs are never equally shared between the parties. According to Vink (1998) the farmers always come off second best, as they are the party who are always on the weaker negotiating side of the transaction.

Pearce and Turner (1990) elaborate on the bargaining side of transaction costs by stating: "Such costs include those of bringing the parties together, organising often widely distributed and difficult-to-identify sufferers, the actual bargain itself and so on. If the transactions costs are so large that any *one* party's share of them outweighs the expected benefits [incentives] of the bargain, that party will withdraw from the bargain, or not even commence it. Moreover, it seems likely that transactions costs will fall on the party that does not have the property rights. But transactions costs are real costs – we have no reason for treating them differently to other costs in the economy. Thus, if transactions costs are very high all we appear to be saying is that the costs of the bargain outweigh any benefits. In that case it is *optimal* that no bargain occurs." This resembles the situation found in Qwaqwa where farmers sometimes have to travel long distances to obtain technological inputs, services or information on livestock veterinary technologies.

One of the first analysis on the relationship between the differences in spatial location was developed by J. H. von Thünen in his book *Der Isolierte Staat*, written in 1826 (Barlowe, 1978). This theory clearly illustrates the negative effect of increased transport costs (*ex anté*) with respect to adoption of inputs, services, information and use of markets. As farmers are allocated further away from the supplier centres, the cost to obtain new technologies increases, decreasing the possible incentives and the adoption of these technologies. Many countries where new agricultural technologies are promoted, tried to achieve maximum adoption of these technologies by removing some of the actual costs of new technologies (direct subsidies) and others by introducing extension services (to reduce the transaction costs of information).

2.2.3 Livestock technology transfer and adoption

McMillan *et al.* (1997) found that when new disease-free areas are opened to mixed and livestock farming and new livestock technologies have not been transferred and adopted, after a decade the income decreases to about half of the initial income and more efficient farmers will migrate to other frontier areas where technologies and infrastructure are available. Improvement in livestock technology is more complicated than in crop production. The usage of gradual improvements, which include "best-farmer" practices and other on-farm technology improvements result in a slow production growth. Sanders and Shapiro (1998) referred to Ruttan (1991) who pointed out that the diffusion of "best-farmer practices" leads to very slow rates of production growth, namely one to two per cent, whereas science-based changes can increase production growth up to three or four per cent. They further suggest that new technologies should be developed in order to promote better integrated crop-livestock systems and more intensive livestock systems to obtain rapid growth rates and to respond to the increasing demand for animal food products for the needs of the growing population.

The shift to more intensive technologies also implies an improved management of natural resources (land, water and natural veld or grazing) compared to extensive strategies (low-input systems) (Sanders et al., 1996). The introduction of livestock production systems, intensive in the higher rainfall areas and extensive in the lower rainfall areas, in combination with improved technologies can contribute much to sustainable agricultural development in Sub-Saharan Africa.

De Boer et al. (1992) listed the following factors (constraints) which limited technology transfer for livestock in Indonesia:

- Their longer production cycle (18 to 24 months with cattle).
- Lack of clear and observable animal responses to treatment.
- Inability of the research extension and banking systems to work closely together to develop a profitable "package".
- The smaller role of livestock in generating family income.

- Employment and consumption relative to crops.
- The multiple role animals play in the complex farming systems of Indonesia.

The diffusion of innovations or technologies should be left to more efficient channels of communication, which will increase the adoption rate. Bembridge and Schimming (1991) also made similar recommendations concerning the technology transfer process to increase the adoption rate of new technologies for Karakoel farmers in the Rehoboth district of Namibia.

The approach "Seeking Innovations" in livestock farming, where the poor small farmers adopt new improved innovations (technologies) from the wealthier larger farmers, had great positive results. This approach can be described as a successful way in transferring new technologies to farmers who need it the most (Holden, 1992).

2.2.3.1 Transfer and adoption of livestock veterinary technologies

Nagy, Sanders and Ohm (1988), in their on-farm trails and in whole-farm modelling results, found that all the applicable or available technologies would need to be adopted together as a package before economic incentives and risk levels will be adequately adopted by the farmer. They stated that the principal reason for the failure to adopt new technologies as a package, is the complexity of the large initial financial, human capital, managerial and labour requirements. Researchers must develop new technologies that, at an early stage, will provide sufficient economic incentives at low risk, with lower financial, human capital, managerial and labour requirements that will be more attractive to farmers. Supportive programmes in the initial stages of technology transfer and adoption are essential if the farmers do not have the necessary resources for technology adoption. These support programmes must include the following:

- Credit programmes to help the farmers with business capital.
- Farm management information, especially on the efficient utilisation of the new technologies to be adopted.
- Development of input and product markets (Nagy, Sanders & Ohm., 1986).

Empirical evidence indicated that farmers do adopt new technologies not as packages but sequentially en route to the adoption of the total package (Byerlee & Hesse de Polanco, 1986). If a total health programme is not adopted by the small ruminant farmer he/she may experience reproduction and growth problems or even high mortality rates. These farmers must also be assisted with the necessary support programmes as indicated (Swanepoel & Hoogenboezem, 1995).

Bhattacharyya *et al.* (1997) studied the rate of adoption of Trichomoniasis vaccine amongst range cattle farmers in Nevada, which is one of the few studies on the adoption of medication technologies that could be found. Their results showed that the use of computers (for information flow), consulting of veterinary surgeons and herd size were the most important predictors for the adoption of this vaccine. They also found that cooperative extension programmes enhance the rate of adoption.

2.2.4 Technology transfer and adoption in South Africa

The aridity index (see Table 1.1) of South Africa indicates that 90 per cent of the country is arid and semi-arid, which is perhaps one of the main reasons why agricultural development went through difficult stages in the past. South Africa has furthermore the unique situation in Africa concerning agricultural development, because approximately 95 per cent of the agricultural production is produced by highly technical developed commercial farmers who operate in a free market with nearly zero subsidies. In the South African agricultural system, farmers can be grouped into three levels of technology adoption, namely high technology → high management; high technology → low management; low technology → low management (Nell, Viljoen & Lyne, 1997). Bembridge (1991b) stressed that future technology transfer strategies in South Africa should be based on a target approach to reach progressive, low-access, and resource-poor farmers. Emerging and small-scale black farmers have to be established and provided (equipped) with new technologies as well as management skills to make the best use of these new technologies to compete in a free national and international market (Central Statistical Services [South Africa, Republic], 1985, 1991a; Kirsten, 1994).

Kirsten (1994) gave a total historical background of the approaches to agricultural development in the former “homelands” of South Africa. This background explains the problem encountered with agricultural development as well as the initiatives of the Development Bank of Southern Africa (DBSA) concerning the establishment of Farmer Support Programmes (FSP) at 35 different locations, primarily in the former “homelands” and KwaZulu/Natal. The main philosophy of these FSP's was to supply appropriate support services (transferring the “total new technology package”) as well as infrastructure and appropriate institutional support, to black emerging and small-scale farmers with a very low average educational level. It was expected that by providing support services, these farmers would have the opportunity to be exposed to and adopt new technologies. This would hopefully remove or alleviate restricted technical, system-related constraints, allowing a more efficient utilisation of agricultural resources, with a concomitant increase in economic activity and income levels in less developed areas of the country. Van Rooyen (1993) took an overview of the FSP from introduction in March 1987 to 1992, and came to the conclusion that during this period 55 000 people from the former homelands were supported by the 35 FSP's. He also expected that FSP's would expand into a major development strategy in the South African agricultural sector, especially in the rural homelands. With the change of government in 1994, this expectation experienced a major setback in the sense that the Development Corporations, which were the facilitators of the FSP's, were disbanded and their activities carried over to the different provincial Departments of Agriculture who, in most cases, did not have not the capacity to progress with the FSP's. Thus the technology transfer programmes experienced a major setback in the former homeland and rural areas (Claassens, 1998).

The FSP's, which were seen by Van Rooyen (1993) as a huge success were, in fact, not as successful as anticipated because of the absence of one of the major aspects of a successful total support system, namely the holistic approach to development as well as an institution to coordinate such a programme (Kirsten, 1994; Stilwell, 1997).

Düvel (1991) is perhaps the only researcher who did research on the psychological aspects of technology (innovation) transfer and adoption in South Africa. The agricultural development situation and economic realities in South Africa called for an approach that is priority-orientated, purposeful and efficient. He developed a "revised extension programme model" and offers the biggest scope for improvement in extension directly influenced by a new approach towards behaviour change. In 1994 he developed a model of technology transfer in agricultural development on the assumption that certain "intervening" variables influence adoption behaviour directly, while the influence of more independent variables only show its effect via the intervening variables (Düvel, 1994a). In a further study in 1994 he also developed a model to determine adoption behaviour and found that personal and environmental factors are the independent variables, while needs, knowledge and perception are the intervening variables and adoption of practices and efficiency are the dependent variables. Non-adoption of new technologies can be traced back to unwilling (a lacking need) or incapable (related to aspects of perception and knowledge) to adopt (Düvel, 1994b).

2.4.1 Livestock veterinary technologies in South Africa

External parasite remedies, internal parasite remedies, antibiotics and vaccines are the four main groups of veterinary medicines used by livestock farmers. External parasite remedies were the first of the four major medication groups to receive attention by the veterinary services in the early stages of their formation in South Africa. Scab was the first disease reported in the history of South Africa (Halterley & Litt, 1969). According to Rolando (1990), Europeans were the first to find the new ecto-parasites which were responsible for high losses in livestock production in Natal in 1874. The colonial administration soon realised the need to control these parasites. Samuel Wiltshire was the first veterinary surgeon who came to South Africa for this purpose. He was appointed by Sir Walkins Pitchford from the Natal Colony to assist livestock farmers in combatting East Coast Fever, a tick-transmitted disease (Lawrence, De Vos & Irvin, 1994). The first dipping-tank was installed in 1902 on the farm Baynesfield in Natal. Henning Otto was the first veterinary surgeon sent to the Orange Free State in 1897 to assist livestock farmers in combatting "Rinder pest". The first diseases identified amongst small ruminants in the Free State were scab, blue tongue and quarter evil.

The only study done in South Africa on the attitude of farmers towards livestock medication technologies (internal parasite remedies), was done by Joubert, Van Wyk and De Wet (1994) amongst commercial sheep farmers in the Northern Free State, Northern and North-Western Cape. They found that internal parasites, diseases and external parasites gave the most important problems in their sheep production systems. They also reported that these farmers regard internal parasites with visible effects as the most important ones, and reacted accordingly. In a study done in Namibia on Karakoel sheep, Bembridge and Schimming (1991) found that only 48 per cent of the farmers made adequate provision for disease control and preventative measures. No studies are reported on the adoption of antibiotics in South Africa.

2.3 MODELS AND METHODOLOGIES USED IN THE PAST IN THE TECHNOLOGY TRANSFER AND ADOPTION PROCESS

Two main approaches are followed on the mathematical evaluation of technology transfer and adoption. The first approach is to determine the effect, incentives or the estimation of economic implications of new technologies on the profit of the enterprise or the farm. Operational research techniques are mainly used for these estimations, which require accurate basic information on production levels, production costs, etc. in order to obtain a realistic estimation (solution). The other approach is to determine the variables (predictors) influencing the adoption as well as the rate of adoption of new technologies. In the last approach econometric models (discrete choice models) are used. The rest of this section will deal with econometric models used by other researchers on technology transfer and adoption studies.

2.3.1 Econometric models

Discrete choice (mathematical or econometric) models, in particular the logit, probit, tobit and multinomial logit models, have been widely used to determine the composition of explanatory variables (predictors) influencing the adoption process of new technologies by farmers. Literature suggests that the farm, the farmer and institutional factors drive farmers to adopt new technologies (Bhattacharyya et al., 1997; Feder, Just & Zilberman, 1985; Nichola, 1994; Wheeler & Ortmann, 1990). Factors such as the financial and socio-economical impacts of new technologies, effects of new technologies on the risk (increasing or decreasing) of the farm, available resources, and technology transfer programmes also have an effect on the decision of the farmer to adopt new technologies (Feder et al., 1985).

When the objective is to identify the socio-economic variables that influence both adoption and intensity (percentage) of adoption, the probit and the tobit models are preferred (Adesina & Zinnah, 1993; McDonald & Moffit, 1980; Nichola & Sanders, 1996). Different approaches towards adoption models that were used in the past were described by Nichola (1994). He refers to the "Innovation Assessment Lag" of Linder, Fisher and Pardey (1979) where the modelling of adoption is seen as a problem of decision-making when there is uncertainty and where learning can occur. This approach assumes that when a new technology becomes available, the farmer does not know if the adoption will be profitable or not, but the uncertainty can be reduced by waiting and gathering information from other farmers adopting the technology. Adoption in this context is, therefore, a function of the subjective belief of the farmer about the profitability (incentives) of the new technology with adjustments as more information and returns on the new technology becomes available.

Feder et al. (1985) surveyed various of the more important studies that attempted to explain patterns of adoption behaviour either theoretically or empirically. They came to the conclusion that most aggregate adoption models are dynamic and derive the behaviour of the diffusion process over time analytically. They referred to Mansfield (1961) who derived a S-shaped diffusion path assuming that the driving force of the diffusion process is imitation. They also referred to a number of studies (Lekval & Wahlbin, 1973; Lerviks, 1976; Hernes, 1976) which have extended Mansfield's approach and showed that the diffusion process can be described quite accurately by compact mathematical formulas such as a logistic curve or other specific sigmoids.

Most of the studies on technology adoption as well as that done by Feder et al. (1985)

were based on the dichotomous qualitative dependent variable ("adoption" or "non-adoption"). Feder et al. (1985) referred to Schutjer and Van der Veen (1977) who concluded that adoption cannot be represented adequately by a dichotomous qualitative variable in cases where a package of new technologies is evaluated for adoption. A farmer who is classified as an "adopter" can, for instance, only use one per cent of the new technology and 99 per cent of traditional technologies on his farm. The dichotomous qualitative dependent variable can only be used in those cases where only one or a specific technology is analysed for adoption and where the extent of adoption is not important to the researcher.

Many econometric studies on adoption have focussed on directional impacts of certain explanatory forces rather than their quantitative importance. Feder et al. (1985) referred to the studies of Rochin and Witt (1975) and Parthasarathy and Prasad (1978) in this context. An outcome can, for instance, be significant, but the quantitative impact of the variable is unknown. A model must therefore be developed to estimate the coefficients and determine the p-values (i.e. $\leq$0,15) of the predictors.

The linear probability model could be estimated by ordinary least squares. According to Gujarati (1988), the following problems may, however, arise:

- The disturbance cannot be normally distributed.
- The disturbance is heteroskedastic.
- The possibility of $E(P_i)$ lying outside the 0–1 range.
- Estimated standard errors will be biased.
- The usual t- tests, etc., cannot be relied upon in small samples.
- The R^2 values will generally be lower.
- It will fit a line with a negative intercept, so that for certain low levels of explanatory variables (X_i), it will yield a negative $E(P_i)$.
- A linear function implies that a given rise in explanatory variables will always result in the same rise in P_i.
- Ordinary least square estimation will still yield unbiased estimators of b_1 and b_2,.

According to Gujarati (1988), one will, in reality, expect that P_i is non-linearly related to X_i. At a very low level of utility or incentive of the new technology the farmer will not adopt the new technology, but at a sufficiently high level of utility or incentive, say, X* of the new technology, the farmer will most likely adopt the new technology. Any increase in utility or incentive beyond X* will have little effect on the rate of adoption at both ends of the utility or incentive distribution.

What is needed is a (probability) model that has the following two features: (1) As X_i increases, $P_i = E(Y = 1 \mid X_i)$ increases but never steps outside the 0-1 interval, and (2) the relationship between P and X_i is non-linear. This sigmoid curve resembles the cumulative distribution function of a random variable. One can easily use the cumulative distribution function to model regressions where the response variable is dichotomous, taking 0-1 values (Gujarati, 1988; Thomas, 1996).

Different econometric probability functions or cumulative distribution functions that present a sigmoid curve can therefore be used in the analysis of the adoption process, such as logit, multinomial logit, probit (normit) and tobit analysis. Nichola and Sanders (1996) stated that these discrete choice models are fairly widespread, and referred to Feder et al. (1985), Akinola and Young (1985), Akinola (1986) and Adesina and Zinnah (1993). The practical question now is: Which cumulative distribution function should be used? The cumulative distribution functions most commonly chosen to represent the 0-1 response models are (1) the logistic or logit model and (2) the normal or probit (normit) model. Gujarati (1988) made a comparison between the logit and the probit models and stated that these two formulations are quite comparable, but the main difference is that the logistic curve has slightly flatter tails than the probit, and the curve approaches the axes more quickly than the logistic curve. Therefore, the choice between the two is a matter of mathematical convenience and availability of computer programmes. According to Gujarati (1988) the **logit** model is generally used in preference to the probit model. These two models can only be used when the adoption process is dichotomous (adoption and non-adoption), but a strictly dichotomous variable is often not sufficient for examining the extent and intensity of adoption. A study on adoption with full adopters, partial adopters and non-adopters, a multiple choice situation (dummy dependent variables), can be better accommodated by a multinomial logit function

(Annexure B) (Bhattacharyya et al., 1997 Feder et al., 1985; Park & Kerr, 1990; Studenmund, 1997).

Binary or dummy variables are used to estimate qualitative and non-direct quantifiable variables (dependent and explanatory) in a regression analysis (Nell, 1978; Ramanathan, 1992; Studenmund, 1997). The binary dependent variable can be used to analyse full adopters, partial adopters and non-adopters, and the binary explanatory variables can be used to analyse risk-aversiveness, kind (tenure) of farm, human capital endowments, institutions, information sources, etc.

2.3.2 Conventional and adapted adoption definitions

In the mentioned studies adopters are conventionally defined as farmers who use a specific technology during the survey period. In the theory on technology transfer and adoption the assumption is made that the supply of a new technology (inputs or services) is elastic. However, according to Nichola and Sanders (1996), scarcity of inputs or services can result in a less elastic or even inelastic supply of inputs. Increased costs to obtain new technologies, for instance, caused increased transaction costs for those farmers allocated further away from input or service centres, and can also lead to a less elastic supply function. The absence of subsidies in South Africa makes the classical Von Thünen model of regional economics (Barlowe, 1978; O'Kelly, 1988) relevant to understand the adoption differences between farmers. The price of outputs decreases and that inputs (services) increases as farmers settle further away from input or output markets, which is a continuous relationship as the profitability or incentives of new technologies decreases. The cost of information on new technologies also rises due to increased transportation costs to obtain this information. Many of the variables discussed in this chapter are proxies for decreasing profitability. As farmers are located further away from the urban centre or institutions, it becomes more difficult and expensive to get information on the advantages or incentives of new technologies. If the technology is locally available, farmers who want or need it, will use it. However, if the technology is not locally available and extra transport costs have an increasing effect on the price of the technology, farmers who want to adopt it, may become non-adopters because they cannot afford it any more.

For these reasons Nichola and Sanders (1996) concluded that the traditional definition of adopters and non-adopters is too restrictive. They argued that under these circumstances the definition of adopters should include would-be or potential adopters. According to them, most diffusion studies have a too narrow definition of adoption when inputs or services are subsidised and rationed as has generally been the case where the state has been promoting the introduction of new technologies, especially for poverty alleviation purposes. In most of the former homelands of South Africa, inputs and veterinary surgeon services were subsidised up to 1994. Because subsidies were stopped, two types of adopters should be used in defining an adopter, namely those actually adopting and those saying that they would have adopted these technologies if they could have obtained these inputs or services (potential adopters).

Henry, Klakhaeng and Gottret (1995) used a logit regression model, following the methods of Hosmer and Lemeshow (1989) to overcome the limitations of the traditional ordinary least squares regression model. This was done to include the estimation of relationships that include dichotomous dependent variables (adoption *versus* non-adoption) (Gujarati, 1988). Grisley and Shamambo (1990) also used a logit model to predict the adoption rate of a bean cultivar. They used tabular and linear correlation methods to identify the characteristics of the households and farms studied and the extent of adoption and diffusion.

Kleynhans and Lyne (1984) analysed factors that had a negative effect on the adoption of technologies. They used selective socio-economic variables that they defer to a discriminant analysis to make a distinction between adopters and non-adopters of new technologies. Swanepoel and Darroch (1991) have also used a discriminant analysis to separate full and partial adopters in their research to determine the characteristics of full adopters of new technologies. Latt and Nieuwoudt (1988) used a discriminant analysis to identify plot size effects on the broad commercialisation concept. The robustness and less stringent assumptions of discriminant analysis and the interpretability of the results tend to favour its use in this regard. The discriminant analysis can also be used, but the disadvantages of its linearity result in that the natural flow of adoption as expressed by a discrete choice model with its S-curve, cannot be estimated. A further disadvantage is that it cannot accommodate categorical variables.

Hosmer and Lemeshow (1989) suggested the following model-building strategy for the logistic regression:

- The first step is to conceptualise all the possible explanatory variables which may contribute to adoption. The number of variables must be minimised because the resultant model is more likely to be numerically stable, and more easily generalised. The more variables included in the model, the greater the estimated standard errors become, and the more dependent the model becomes on the observed data.
- Explanatory variables that have a logical linkage to the contribution of the adoption of the technology in the study are included in the list of variables. The selection process should begin with a careful univariate analysis of each variable. From this list, possible predictors with a p-value of $\leq 0{,}15$[1] are determined by means of different statistical tests[2] for inclusion in the econometric models to be estimated.
- Upon completion of the selection of the possible predictors (p-values of $\leq 0{,}15$), the multivariate analysis using one or more discrete choice models with all the identified variables can be performed.
- The variables from the econometric models with a p-value of $\leq 0{,}15$ are selected by means of a stepwise regression, as predictors contributing to the different adoption levels estimated.
- The analysis ends with the prediction of the correctness of the classification of the different adoption groups.

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1 A p-value of $\leq 0{,}25$ is suggested by Hosmer and Lemeshow (1989), but due to the relative large number of variables (34) and the relative low sample size (in some adoption groups as little as 13) and after discussion with Joubert (1998), it was decided to use a cut-off of $\leq 0{,}15$.

2 For the continuous variables the t-test and Mann Whitney tests will be used and for the selection of the categorical variables the Chi-square and Fisher Exact tests.

2.4 VARIABLES (CONSTRAINTS) PREDICTING TECHNOLOGY TRANSFER AND ADOPTION

In this section an attempt is made to identify variables contributing to agricultural technology transfer and adoption. Literature on the adoption of livestock veterinary technologies is very scarce and therefore available literature applicable to the transfer and adoption of crop technologies will also be used as a guideline, amongst others, to identify possible predictors and predictors of livestock veterinary technologies, bearing in mind its differences. The observed rates of adoption indicate that the transfer of new technologies in Third World countries has only been partially successful. The conventional approach is that the constraints, discussed in this section, are the main obstacles in the rapid adoption of new technologies (Feder et al., 1985).

2.4.1 Human capital endowments

The variable "human capital endowments" are perhaps one of the most important groups of predictors of new technology adoption. It includes amongst others, age, family size, level of education, gender, experience, knowledge, management (technical, economical and financial), farming efficiency (technical, economical and financial), farming skills, gender, level of entrepreneurship and creativity.

According to Pinstrup-Andersen and Pandya-Lorch (1997) poverty is one of the main obstacles of sustainable agricultural intensification and development. The International Food Policy Research Institute (IFPRI, 1997) as well as the World Bank (1996) found that seventy to eighty per cent of the 1,3 billion absolutely poor people in the world live in rural areas. These people do not have sufficient human capital capacity (endowments), managerial skills, income or access to credit to purchase and manage appropriate technologies in order to develop a sustainable level of production, protect the natural resources, or rehabilitate degraded resources (Pinstrup-Andersen & Pandya-Lorch, 1994). According to Fényes (1982), Kirsten (1994) and Vink (1986) the same applies for the black South African small-scale farmers in the former "homelands".

Wheeler and Ortmann (1990) as well as Roché (1988) argued that the most important success-determining factors for adopting new technologies are those relating to the human capital endowments (level of education, experience, knowledge, and farming efficiency) and economic status (wealth [i.e. assets], income, land size, and credit use) of the farming household. Formal education and experience are strongly related to knowledge and adoption of production technologies. Bentley (1987) found that although the average formal education of the farmers in the northwest of Portugal was only three to four years schooling their high farming skills helped them to adopt new technologies at a high rate because they responded rationally to economic incentives. The farmers in most Sub-Saharan African countries and most low income Asian and Latin American countries have, in contrast, only gained marginal productivity because of a lack in knowledge.

According to Pinstrup-Andersen and Pandya-Lorch (1997), poor nutrition and health during early childhood have a direct negative effect on the cognitive development of the human brain, which results in low productivity during adulthood. Efficient farming becomes knowledge intensive, and poorly educated farmers cannot take advantage of the rapid evolving technologies to increase the productivity of their farming operations. Pinstrup-Andersen and Pandya-Lorch (1997) suggest that "... developing countries must invest much more in the human resource development of their people, particularly smallholder farmers".

Throughout agricultural history women have played an important role in farming, especially in the cases where the head of the family (the man) earns off-farm income. In the case of Africa, a number of authors (i.e. Gasson, 1994; Jiggins, 1986; Malena, 1994; Sanders et al., 1996) found that women play an even more important role in agriculture than men. Norton and Alwang (1993) reported that in many African countries male farmers tend to be involved in livestock farming, while the women are in charge of crop production.

2.4.1.1 Education and training

2.4.1.1.1 Education

Development of the educational level of a population is required if countries have to domestically produce, adapt, transfer and receive new technologies. According to Lyne (1985), improved education services enhance the adoption of new technologies. Venter, Vink and Viljoen (1993) came to the same conclusion, namely that the low level of educational training is the most limiting factor on technology adoption among small-scale commercial farmers in Venda. Norton and Alwang (1993) concluded that countries that are unable to develop the skills and the knowledge of their farmers and their families find it difficult to develop anything else. The development and utilisation of new technologies and institutions are critically dependent on an educated and developed workforce.

Education is positively correlated to technical progress achieved, although not very strongly (Gibbons et al., 1980). For instance, seventy-five per cent of Malaysians attended secondary schools, whereas only 52 per cent of their counterparts in Aceh in Indonesia attended secondary schools. This also contributes to the difference in technical progress between the two regions, with clear advantage for the most educated farmers (Gibbons et al., 1980). The low educational level of the small-scale farmers in Latin America is perhaps one of the most serious constraints in the process of new technology transfer and adoption and the ability to attain higher income (Peres, 1995). The Programme to Develop Entrepreneurship Abilities in Rural Youth (PROJOVEM) was implemented in Brazil in the beginning of 1997 with the main aim to prepare rural youngsters to manage small farms in a competitive and sustainable way and thus increase the level of income of their families. This programme also comprises the adoption and correct management of new technologies (Peres, 1997).

2.4.1.1.2 Training

Training is one of the most critical factors of the technology transfer process. Cederroth and Gerdin (1986) examined the responses of two local communities in Lombok to the

Green Revolution. In the Karang Sari village, which is situated close to the capital, where the people are not so bound to the traditional way of living and are more informed/trained about technical changes required by the high yielding varieties of rice, the latter was easily accepted. In the Suren village, which is situated much further from the capital, where the people are much more bound to the traditional way of living and not so informed/trained about technical changes required by the high yielding varieties of rice, the introduction of this rice seed was a catastrophe.

Kohnert (1990) feels that the "training and visit" extension approach that is used in development through modernisation, failed in its main goal to transfer technology to the African smallholder in order to increase agricultural production. After five years of experience with the "training and visit" system in West Africa the main goal failed, as innovations were developed by agricultural research stations without due consideration of the particular constraints of the different systems of production and target groups. Claassens (1998) stated, however, that training and visits by the veterinary surgeon, animal health officers and extension officers to enhance the technology transfer and adoption programmes at the sheering sheds in Qwaqwa, played an important role in training the small ruminant farmers in the correct use and adoption of medication technologies up to 1994.

Nagy *et al.* (1988) pointed out that one of the important sections of a support programme for technology adoption is farm management training and demonstration. There are many technologies available that require a greater educational level than that of the farmers. In these cases more educational and training projects are needed to develop the desire for new technologies and its implementation by the farmers (Pritchard, 1986).

In Gambia they adopted the Community-based Experimentation and Extension (CBEE) approach which provides training for the farmers in improved ways of experimentation of new technologies to enable them to proceed with technology development, adoption and management of new technologies on their own (Owens, 1993). The success of the CBEE programme, to a very great extent, depends on the skills and abilities of the field staff or extension officers.

2.4.1.2 Management skills

According to Penning de Vries and De Wit (1987), the fact that potential food production in Sub-Saharan Africa by far exceeds its current production levels, is the main reason why serious agricultural research is being done to develop improved varieties of crops, new husbandry and management technologies that in turn can offer farmers new technologies, better means of production and management. Charreau and Rouanet (1986) pointed out that there are many technologies available for soil and water management as well as agronomic technologies which are not used because of the lack of management skills. Pinstrup-Andersen and Pandya-Lorch (1997) also found that because of the lack of management skills, the farmers in most Sub-Saharan African countries and in most low income Asian and Latin American countries, have only gained marginal productivity. If applied and managed correctly, they can have a significant impact on agricultural production.

In 1976 a total of 10 146 families were settled in the Mahaweli Ganga Development Project in Sri Lanka. After three years it became apparent that the project's objectives were getting awry. After an assessment of the reasons for that situation it was found that the settlers had an acute absence of productive and managerial human skills. In other words, they were not able to adopt and manage the new technologies transferred to them (Kahn, 1982). Peres (1995) feels that the only way in which these problems can be overcome is by giving the small-scale and emerging farmers competence to manage their farms, whereas the agricultural school system in Latin America could improve the standard of living as well as the managerial skills of the peasants. The development of techniques for small farm management is of utmost importance in order to help with the agricultural development of the small-scale farmer.

Future technologies will need to include improvements in resource management (soil fertility, water, veld and capital management) (Sanders *et al.*, 1996). In Sub-Saharan Africa the most successful technology change took place in Burkina Faso, Mali, and Senegal where the introduction of new cultivars was very successful due to improved crop management techniques adopted by the farmers. It can therefore be concluded that when farmers start to use more complex management systems and the results are positive, they will be more open to further improvements, especially if the overall economic environment for increased crop production is favourable.

2.4.1.3 Level of entrepreneurship and creativity

Gibbons et al. (1980) concluded that once the regional and ethnic variables are held constant, progress in entrepreneurship emerges as the most discriminating expression of the Green Revolution. The entrepreneurial farmer will adopt new technologies at a higher rate than the non-entrepreneurial farmer. Entrepreneurship explains the largest proportion of the variances in farmer participation (technical progress) in new technologies. It is the active, well-informed entrepreneurial farmer, the one who seeks credit, subsidies, new technologies, etc. who first adopts new technologies. They also found an existing inherent positive relationship between entrepreneurship, farm size and technology adoption.

Mills (1994) reported that the level of entrepreneurial activities and skills of small-scale fish farmers played a major role in the adoption of new fish technologies and in the expansion of fish farming activities in Sub-Saharan Africa, especially in Malawi. In comparing black commercial farmers with black subsistence farmers, Nicholson and Bembridge (1991) found that the level of innovative and entrepreneurial skills of the commercial farmers were much higher than those of the subsistence farmers, even though the commercial farmers are farming on poor subsistence land. According to Bembridge (1991a) the availability of credit and entrepreneurial skills had a direct effect on innovativeness and yield per hectare. In the same study it was found that innovativeness can be predicted by the level of understanding of a practice. The urge among small-scale avocado farmers in Venda to increase their entrepreneurial and managerial skills in order to improve the implementation of new technologies to increase their productivity, was evident in the study done by Bembridge (1992).

Clarke (1996) is of the opinion that initiative, the desire to succeed, the ability to determine priorities, tenacity and persistence to face obstacles and willingness to move into action distinguishes the entrepreneur from the non-entrepreneur. Research shows that the entrepreneur:

- enjoys identifying, evaluating and developing opportunities;
- responds quickly to changes;
- has energy and drive;
- has confidence in his or her own ability;
- is enthusiastic and focuses on the positive;
- is an excellent communicator;
- has good social interactions;
- has knowledge and experience in the field of farming practice he or she is in;
- is self-disciplined and committed towards making new technologies work; and
- enjoys good health.

2.4.2 Farm size/herd size and annual income

Reed and Salvacruz (1995) came to the basic premise that large farmers have a greater margin of risk-taking and greater access to capital (spendable money) which enables them to shift to new technologies sooner than the smaller farmers. This increases the gap between these two groups of farmers, which implies that the channels for credit to modern inputs for small farms should be improved. If the infrastructure and the necessary assistance (access to credit) are in place the misconception that a large farm structure is essential for the adoption of new technologies, is proven wrong. Henry *et al.* (1995), in their study on the adoption of new cassava varietal technology in Thailand, found that the adoption was higher on relatively large farms and in more fertile areas. This finding was also in line with those of Feder *et al.* (1985) in a comparative adoption analysis. Latt and Nieuwoudt (1988) found the same in a study in three rural regions in KwaZulu/Natal. Farmers with larger plots were able to sell more produce and they made more use of improved technologies. Swanepoel and Darroch (1991) came to the same conclusion from research done in the same province, as they found that the adoption of new technology packages were higher among farmers who belong to older "clubs"[3], have less formal savings, receive more visits from extension officers, have larger farm sizes and a higher rand monetary value on livestock. Larger farms reduce transaction costs, which increases the economic advantage and incentives of new technologies.

Gibbons et al. (1980) reported that of the 97 million agricultural holdings in Asia in the early 1960's, 45 million (46%) were under one hectare in size and 21 million (21%) were between one and two hectares (see also United Nations, 1976). The larger farmer entrepreneurs had the capacity and ability to exploit new technologies and aid at a higher rate than the small farmers. The net return per unit of cultivated land to technical progress and Government Agricultural Aid (GAA) (physical infrastructure; extension; receipt of inputs; receipt of credit or subsidies; assistance with marketing/processing; membership in agro-based organisations), has been greater for larger farmers.

One of their final conclusions was that in order to develop farmers to a level where they are able to exploit new technologies, land development and redistribution programmes must be designed to give every farming family access to enough land to enable them to produce enough to rise above the poverty line.

Gibbons et al. (1980) came to a final conclusion that technology transfer, adoption and progress on their own cannot improve the returns of small farms. These techniques can also not be used on their own, to overcome the pre-existing inequalities in the distribution of farm size and tenure. They said that "GAA and technical progress are largely responsible for the increasing inequality evident in both study regions, because of their impact, they favour the larger farmers". GAA and technical progress actually aggravated the pre-existing inequalities (enlarging the "gap" between "poor" and "rich farmers").

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[3] Farmers form a group through which they buy inputs and market outputs in order to get discounts and obtain higher prices for their products because their bargaining power increases.

In Malaysia where technology transfer was more successful, the net results in relative and absolute terms were much higher than in Indonesia. The average "small" farm in Malaysia generates a surplus of approximately 17 guintals in comparison with Aceh (Indonesia) of less than one guintal and even the "large" farms only generates seven guintals. In Aceh the purchase per hectare of all inputs drops remarkably with an increase in farm size, while in Malaysia it rises. These facts again enlightens the effect of better technology transfer (Gibbons *et al.*, 1980). Griffin (1974) found in his study in Java and in the Philippines that larger farms in Java tend to use more inputs, while in the Philippines he found the opposite. In the Philippines "fertiliser is largely a substitute for land", meaning that an increase in the use of fertiliser produced better results than land expansion.

Inequalities in farm size will always exist in any free economy. People are not the same, therefore equal development will never occur (Ruttan & Hayami, 1984). Gibbons *et al.* (1980), however, do not agree because they found that farm size is relatively unimportant when it comes to the usage of agricultural aid (extension, infrastructure, inputs, credit, assistance with marketing and membership in agro-based organisations). Where new technologies are available and the opportunity exists, farmers take advantage of it and adopt and use it. The early adopters are normally those who get the highest remuneration for adopting new technologies (Binswanger & Von Braun, 1993).

Kleynhans and Lyne (1984) concluded that the arable land area per permanent family member was the most important factor that had a positive effect on technology adoption and that the number of cattle owned by the family was the second most important socio-economic factor influencing technology adoption. The contrary was found by Otsuka and Delgado (1995) who stated that although socio-economic factors such as farm size and tenure are often considered as critical determinants of technology adoption, there is no evidence to support such views (see also David & Otsuka 1994; Otsuka *et al.*, 1994).

In his study on the effects of new technologies on farm equity, Shand (1987) found that technology in itself is scale-neutral. Shand also referred to studies done by Hayami

(1981), Kalirajan and Shand (1982) and Vyas (1982) who came to the same conclusion. There were substantial income gains to the farmers arising from crop intensification and the introduction of new production technologies which were obtained without any significant alteration of distributional equity of farm income.

2.4.3 Traditional farming practices

The historical "Trás-os-Montes" farming systems in Portugal have been sustained and developed through indigenous knowledge and not by "modern" science and technology. Portela (1994) argues that the development of indigenous knowledge can be used to sustain the natural resources and will not damage the natural resources and environment like "modern" technology. In a traditional farming system the farmers use their knowledge to generate their own technologies and transfer it amongst themselves very effectively.

In a research done by Sanders *et al.* (1996) where new technologies and traditional technologies were modelled, they compared three situations: (1) perfectly inelastic land supply – severe land degradation and population pressure; (2) moderately inelastic land supply by introducing time, cost of travel and moderate population pressure, and (3) perfectly inelastic land supply which was modelled by fixing the supply of bush-fallow land at 3,5 ha per farm. In all three cases the new technologies resulted in significantly higher annual net farm income, which indicates that it is very difficult to "turn the clock back" in a modern economy like South Africa.

2.4.4 Extension

Extension visits or availability of extension services is perhaps the single variable (predictor) that emerged significantly in most of the research work on technology transfer and adoption. According to Mijindadi (1995), the following lessons may be found useful from experiences concerning technology transfer of Nigeria's extension services:

- Effective extension services with a good extension approach and well-trained and experienced extension officers would put pressure on the research systems to become more farmer demand-orientated and transfer new technologies more efficiently.
- Extension advice on its own cannot develop a nation's agriculture.
- A combination approach to extension services must be followed.
- Specific extension programmes for women and using a group extension approach has been shown feasible and helpful.
- For an extension programme to be sustainable, a total political commitment at the very top is essential.

A strong technical institutional basis is essential if agricultural extension services in African countries are to be sustainable in the long run and assist in the technology transfer and adoption process.

Of the six types of GAA to paddy and rubber smallholders considered in the research, extension programmes were, according to Gibbons et al. (1980), identified as the most important type of aid, but the small farmers targeted, rated their impact as very low. Unfortunately the shortage of trained and experience extension personnel resulted in the small portion of smallholders reached by the programmes of the Green Revolution. This in turn resulted in the uneven distribution of technology transfer and adoption amongst the small farmers. The availability of extension services was positively correlated with technical progress. Wellard and Copestake (1993) concluded that where governments in Sub-Saharan Africa had effective extension services, the technology transfer and adoption processes were very succesful and the quality of life has increased at a remarkable rate.

The availability of appropriate technology and extension services is essential in the establishment of profitable agricultural enterprises (Binswanger & Deininger, 1996). Kirsten (1994) referred to Eicher and Baker who came to the conclusion that over the past 20 years in Africa, most extension services and officers have been poorly equipped and undertrained, when compared to their counterparts in Asia or Latin America. Most extension services in Africa are orientated toward technical problems and ill equipped towards farm management or social aspects that are necessary for technology transfer and adoption. Nagy *et al.* (1988) found that experienced extension officers are one of the most important components of technology transfer and adoption support programmes.

2.4.5 Attitude towards risk

Birowo *et al.* (1989) reported that risk-aversion was one of the basic constraints towards adoption of new technologies in Indonesia. According to Sanders *et al.* (1996), profitable agriculture is essential if one wants to hasten the adoption and diffusion of new intensive technologies. In their modelling on intensive technology introduction they found that risk-aversion had a minimal effect on intensive technology introduction in the cases analysed, the most likely reason being the low risk-level of the technologies introduced. Binswanger (1980), on the contrary, found that farmers who are risk-averse will seek risk-reducing strategies and technologies to adopt in their farming systems. That is why small-scale farmers and emerging farmers will implement technologies that do not necessarily give maximum net returns (Dillon, 1986). Sanders et al. (1996) concluded that farmers who consider adopting new technologies, tend to be pessimistic about possible yield gains until they have more information on the results of new technologies. This factor may be more important than risk-aversion as an impediment to higher diffusion rates.

2.4.6 Access to credit

An important aspect of a support programme is the functionality of credit programmes to adopters of new technologies (Nagy *et al.*, 1988). Farmers without cash and no access to credit will find it very difficult to attain and adopt new technologies. The nature of livestock production systems is not as capital intensive as crop production systems, which makes the availability of credit to buy veterinary technologies less important than for crop technologies, especially medication technologies where the medication to be purchased is not so capital intensive. However, if the farmer wants to purchase registered or graded rams, access to credit can play a more important role.

According to Pinstrup-Andersen and Pandya-Lorch (1997) there is, however, an urgent need for effective credit and savings institutions in rural areas to enable small-scale farmers and emerging farmers to invest in new modern technologies and sustainable agricultural intensification. Birowo and Qasem (1987b) further argued that extended credit policy made it possible for farmers in Indonesia to increase input purchases (mainly fertiliser and pesticides) and an appropriate price policy (subsidies) stimulated farmers to adopt new rice technologies.

Desai, Gupta and Singh (1988) came to two major conclusions in their study on technology adoption in India, namely that agricultural progress and the volume of credit are positively related, and credit repayment among cooperatives is positively related to the level of agricultural progress. Charreau and Rouanet (1986) stressed that the availability of credit is a precondition for persuading farmers to adopt new technologies. In the Ukraine the major constraint in adopting new technologies by farmers is the access to credit or financing (Sohatsky, 1995). This finding is shared by Coetzee, Kirsten and Van Zyl (1993) as well as Venter *et al*. (1993) who found that credit was much more important to emerging commercial farmers (who have adopted more modern technologies) than to subsistance and sub-subsistance farmers in South Africa.

One of the main problems in South Africa is the cost of credit as well as the relatively high transaction costs of production loans obtained through the South African Land Bank to acquire new technologies in crop and livestock production. The interest rate on production loans (between R5 000 and R60 000) is at present higher than 20 per cent. With such high cost it is very difficult to repay debt under the current agricultural circumstances in South Africa (Van Zyl, 1997).

2.4.7 Information sources for decision-making

Acquisition of information is one of the important aspects in adoption studies (Feder & Slade, 1984). Bhattacharyya *et al.* (1997) refer to Putler and Zilberman (1988) and Zepeda (1990) who reported that farmers in the United States of America using computers as information source, tend to adopt new technologies at a higher rate than farmers not using computers. Bhattacharyya *et al.* (1997) did a study on the rate of adoption of *Trichomoniasis* vaccine amongst range cattle farmers in Nevada, and found that cooperative extension programmes enhance the rate of adoption.

2.4.8 Infrastructure and institutions, input and output markets

Both Pinstrup-Andersen and Pandya-Lorch (1997) and Venter *et al.* (1993) reported that inadequate infrastructure and marketing facilities are the key barriers to technology adoption and usage. Pinstrup-Andersen and Pandya-Lorch (1997) also indicated that the poorly performing agricultural extension systems, the declining investment in agricultural research, inadequate infrastructure and marketing facilities and a lack of incentives to appropriately used inputs had a negative effect on the adoption of technologies. Venter *et al.* (1993) came to the same conclusion that the absence of the mentioned infra-structure contributes a great deal to a low level of technology adoption in Venda.

To facilitate the introduction of new technologies, governments must assist the potential types of useful research and extension institutional support programmes (Nagy *et al.*, 1986:66). This will help to expand the technology transfer process and spread it in the shortest possible time to the highest number of farmers. Nagy et al. (1988) rated the subsidisation of inputs and development of the input and output market, as well as functional infrastructure, as important components of support programmes for technology transfer and adoption.

A highly-developed infrastructure for information flow, a functional interactive system of region-based input and output markets and favourable consumption incentives are essential components of a good technology transfer programme and agricultural growth (Mellor, 1990).

Pinstrup-Andersen and Pandya-Lorch (1997) further stressed that governments must provide the infrastructure needed for emerging and small-scale farmers to deal in their disadvantages on a free national and international market, otherwise these farmers will face a constant deterioration of their farming operations. They concluded by saying that adoption and use of new technologies alone will not be sufficient for the emerging and small-scale farmers in the developing world to survive the rapid change in technologies, but they must also be provided with appropriate policies that go hand in hand with new technologies. Van Zyl and Kirsten (1992) came to the same conclusion that production oriented policies that imply technological change and commercialisation of production by rural households, as well as the necessary infrastructure, will provide a long-term impact for all the food security risks.

According to Sanders and Shapiro (1998), improved economic policy, infrastructure and institutional structures have a positive effect on the adoption, diffusion and utilisation of new technologies through increased incentives. The Sub-Saharan African countries need to find new approaches (incentives) as well as technologies to counter the price collapse problem, especially of staple food crops in good production years.

2.5 CONCLUSION

Technology forms an integral part of a total agricultural development system. If it was not for the development and adoption of new technologies in agriculture, the world would have been starved today, as predicted by economists two centuries ago. With the present population growth rates, especially in the developing world, the implementation of improved technologies and bioengineering are essential in increasing the world's food production and supporting the ever-increasing world population growth.

The discussion of technology transfer and adoption on the international arena, and especially in the developing world (Asia, Latin America and Sub-Saharan Africa), in most of the cases showed a great improvement in food production and poverty alleviation, but also a lack of a holistic approach to ensure sustainable agricultural development programmes. The Green Revolution in Asia, on the one hand, was very successful in the sense that it improved agricultural food production, but the absence of ecologists on its programmes had a degrading effect on the natural environmental resources (land and water). Again the absence of a total system (holistic) approach placed a question mark on the sustainability of the Green Revolution. Belloncle (1989) stressed a commonly held view that when innovations (technologies) are technically feasible, sociologically acceptable, and economically profitable, as well as functional infrastructure and effective institutional structures, African farmers will quickly adopt them. Gibbons et al. (1980) found that if productive incentives of new technologies are implemented and available, farmers will adopt it and use it. Policy changes and institutional reform have to accompany and support technology diffusion programmes to ensure satisfactory adoption levels.

The conclusion on the literature on technology transfer and adoption with women farmers was that the importance of women farmers and their specific role in the developing agriculture was not acknowledged in the planning and development stage of new technologies. A further aspect that was uttered was the importance of the training of women extension officers to assist women farmers with extension services (Jiggins, Maimbo & Masona, 1992) . The relevance of traditional agriculture was also discussed and the main conclusion was that it can play an important role in an underdeveloped economy and in livestock medication technologies where the necessary herbal plants are available in the area of farming.

South Africa is situated in a unique position in Africa concerning technology planning, development, transfer and adoption in the sense that roughly 86 per cent of the agricultural produce are produced by commercial farmers with highly developed technologies and the other 14 per cent by developing and subsistence farmers who are not in the position to obtain and use these highly developed technologies due to a lack of knowledge and financial capacity and not always having the necessary infrastructure and institutional structures available to support them (Fényes, Van Zyl & Vink, 1988).

From the literature review it is evident that the lack of research on livestock veterinary technologies, and especially adoption of veterinary technologies, are of great concern and need more research. It is evident from the discussion in this chapter that knowledge regarding variables on livestock veterinary technologies is very low. In the following chapters the focus will be on identifying these variables.

The theoretical description of the models that will be applied in the analysis of the data will be described in Chapter 3 as well as the conceptualisation of the explanatory variables that will be used in the models.