Strategic Decision-Making: Adoption of Agricultural Technologies and Risk in a Peasant Economy

Mariam, Yohannes; Galaty, John and Coffin, Garth

12. June 1993

Strategic Decision-Making: Adoption of Agricultural Technologies and Risk in a Peasant Economy

Yohannes Kebede (also known Yohannes Mariam) [1/], John Galaty[2/], Garth Coffin[3/]

[1/] Washington Utilities and Transportation Commission, Olympia, WA, [2/] Professor, McGill University, Department of Anthropology, McGill University, Montreal, Quebec, CA
[3/] Formerly Associate Professor and Associate Dean, Faculty of Agricultural and Environmental Sciences, McGill University

Acknowledgement: This paper is based on the principal author's doctoral dissertation completed at McGill University in 1993.The financial support of the Rockefeller Foundation (African dissertation internship award), International Development Research Center, and McGill University, and technical support provided by the International Livestock Center for Africa (ILCA) for field work in Ethiopia is highly appreciated.

Abstract

Descriptive and logit analysis were employed to investigate the impact of social, economic and technical factors on decisions to adopt new agricultural technologies in the Ada and Selale districts of Ethiopia. Peasants follow sequential adoption of technologies. In both study areas, priority is given to adoption of crop production augmenting technologies followed by technologies that complement crop production (Ada) and contribute to increases in milk production (Selale). Producers of both regions require existence of certain pre-conditions prior to the adoption of technologies. Ada farmers require more pre-conditions related to livestock production while Selale farmers require more preconditions related crop production.

The impact of indigenous production knowledge and experience on adoption decisions was found not only positive but greater than most economic and social variables. The influence of most socioeconomic variables is greater on technologies that are proven to have a more certain outcome (e.g., fertilizer and pesticides) than on technologies which are either expensive or risky (e.g., cross-bred cows and improved seed).

Risk-averse behaviour of households reduces the probability of adopting new technologies in both study regions. Households may be willing to take more risks if they receive insurance from social networks, governmental and non-governmental organizations or are rich. The results from the Selale and Ada regions suggest that physical inputs and knowledge exert large and significant positive impacts on production when farmers adopt combinations of fertilizer and pesticides (Ada), or fertilizer and cross-bred cows (Selale).

Strategic Decision-Making: Adoption of Agricultural Technologies and Risk in a Peasant Economy

Introduction

Because of land and other resource constraints, increased food production in developing countries generally requires the introduction of new technologies to increase yield and productivity of resources. Various development initiatives of this nature have been frustrated by low adoption rates (Feder et al.1982; Hayami and Ruttan, 1985; Molnar and Clonts, 1983). Consequently, food production in many developing countries is not keeping pace with population growth (Stevens and Jabara, 1988).

Ethiopia is no exception. Several agricultural development strategies have been introduced to the peasant sector but the prospect for replacing the native livestock with a more productive cross-bred remains dismal. Demands for energy and construction material have depleted the vegetation cover in many areas, contributing to soil degradation and depletion.

Understanding the role of factors that influence adoption decisions is critical to successful agricultural development. In this regard, it is known that the reasons for low rates of adoption include social, cultural, economic, technical and environmental factors (Jamison and Lau, 1982). It is also known that differences in access to and diffusion of information may be important determinants of adoption decisions (Longo, 1990; Aklilu, 1974; Ayana, 1985; Feder et al.1982). Likewise, skill-enhancing factors, knowledge and resource characteristics and availability have been found to be important (Eisemon and Nyamete, 1988; Warren, et al.,1988; Molnar et al.1983).

Most studies of adoption of technologies do not examine the influence of production knowledge on adoption decisions. Where it is considered at all, most use only an indirect approach for assessing its impact through a proxy variable (e.g. management). Households operate in a complex socioeconomic environment which influences inter and intra-household-decision making processes (Mason and Halter, 1980; Eisemon and Nyamete et al.1988). Thus, it is difficult to assume that a management variable adequately reflects the role of indigenous knowledge.

Moreover, given the complementary input requirements of new technologies, most studies on the provision and impact of technologies tend to argue that a package approach to intervention strategies enable households to attain the maximum potential of technologies (Hayami and Ruttan, 1985). That is, they assume that farmers follow simultaneous adoption decisions (Jamison and Lau, 1982; Feder et al.1982). However, this pattern of adoption was not found to be the case in drought-prone areas of Ethiopia (Kebede et al.1990). Whether farmers follow a sequential or simultaneous pattern of adoption in the grain surplus regions of Ethiopia, however, has not been investigated.

Household studies in Ethiopia rarely examine information regarding the patterns and pre-conditions for adoption of technologies. This study attempts to provide evidence on pre-conditions and patterns of adoption, and to examine factors influencing decisions regarding adoption of cross-bred cows, fertilizer, pesticides and improved seeds in the Ada and Selale regions of the Ethiopian highlands.

An important aspect in the study of household decisions is the risk-taking behaviour of peasants (Roumasset, 1979; Valdes et al.1979). Therefore, the degree to which farmers are willing to take risk can be approximated from decisions they made. No matter what the decision-making environment is, the behaviour of households represented by their sensitivity to risky income influence adoption of new agricultural technologies (Kebede, et al. 1990).

The present study is conducted in Selale and Ada districts of the Central highlands of Ethiopia. Crop and livestock production technologies were introduced by different development agencies. The study is also expected to provide useful information to government and development agencies dealing with the provision of cross-bred cows. Thus, adoption of cross-bred cows was used as a criteria to group farmers in test and control categories.

Selale farmers were instructed that inputs necessary for the management of cross-bred cows were available in their locality, and that they should take full responsibility for the management of such cows. Farmers in the Ada area, however, joined the International Livestock Research Center (ILCA) technology diffusion program voluntarily because it provided a relatively risk-free environment (e.g., subsidized cost of feed). The approach to diffusion of technologies in the Selale region, therefore, is different from that implemented in Ada area. Comparative analysis of the two sites is hypothesized to reveal significant differences in the pre-conditions, patterns and determinants of adoption of a single or mixes of agricultural technologies. The findings of this study would provide valuable evidence on strategies of technological intervention to planners and policy makers of agricultural development that include new agricultural technologies as major components.

The Study Sites and Research Design

The research was carried out over a period of 17 months in 1990-1991. The research sites are Selale and Ada districts of the central Ethiopian highlands. These two sites have similar farming systems and belong to the high potential cereal-livestock zone (13, 19).

Selale is representative of the high altitude zone (more than 2000 metres above sea level) of the country. The major crops grown in Selale include oats, teff, barley, wheat, horse beans and field peas. The average farm size is 3.1 hectares, 30% of which is used as permanent pasture or grazing land with the rest cultivated. The average livestock holding is 3.5 cows, 1.8 oxen, 0.55 bulls, 1.8 young animals and 2.96 calves (13). Farmers have extensive experience in livestock production and the region has greater potential for increasing productivity of this enterprise than the Ada region.

Ada is characterized by mild weather and is representative of the country's large middle-altitude cropping zone (1500 to 2000 metres above sea level). The major crops grown include teff, wheat, barley, horse beans, chickpeas and field peas. The average farm size is 2.6 hectares. There is virtually no fallow land. The average livestock holding is 1.28 cows, 1.98 oxen, 0.50 bulls, 0.53 young animals and 0.84 calves (18). Compared with the Selale region, Ada farmers specialize more in crop than in livestock production. That is, Ada farmers have extensive experience in crop production. A summary of selected socioeconomic characteristics of farmers in both study sites (analysis of variance) is presented in Table 1.

The results suggest that the two regions exhibit statistically significant differences with respect to the: i) number of household members who are independent ii) number of years of

Table 1: Selected Characteristics of Selale and Ada Farmers

		Selale		**Ada**			
		N	Average	N	Average	F-Value	Prob>F[1/]
No. of Household Members who are:	Dependent	173	4.47	41	4.29	0.412	0.469
	Independent	207	1.75	48	1.5	4.52	0.03*
Education of Household Head (yrs)		55	2.5	23	3.6	5.671	0.001*
Experience (years):	Dependent	176	11.24	50	13.44	0.044	0.83
	Independent	176	24.58	50	27.88	4.173	0.04**
Income (Ethiopian birr) from Sale of:	Grain	203	230.27	49	828.6	65.46	0.006*
	Livestock & Livestock Products	194	451.4	22	203.11	1.09	0.058**
	Fuel wood	169	343.58	31	63.97	13.84	0.004*
Expenses (Ethiopian birr) for	Purchase of food	214	268.2	50	228.14	2.366	0.125
	Clothing	205	114.49	39	106.09	0.309	0.579
Milk production (in liters) per Month:	Local cows	193	56.9	35	42.6	6.79	0.05**
	Cross-bred cows	66	320.35	14	186.29	5.76	0.011*
Area under (hectares)	Crop	217	2.5	52	2.3	19.56	0.001*
	Grazing	208	0.8	37	0.2	26.29	0.006*
Livestock Number		165	10.89	16	5.18	0.69	0.016*
Crop Production ('00kg)		217	14.88	52	21.41	2.98	0.05**

1/ * and ** refer significance at 1 and 5 percent respectively; the F-values test differences in the average values of socioeconomic characteristics between Selale and Ada farmers.
2/ Household members who are capable of working without supervision are categorized as independent or "workers" (age 15-60) and those who have to be supervised are considered dependent or "consumers" (age <15 and >60).

education, iii) number of years of farming experience as an independent farmer, iv) number of livestock owned, vi) average income earned from the sale of grain, livestock and fuel wood, vii) crop and grazing area, viii) amount of milk produced per household, and ix) amount of grain produced (Table 1).

Ada farmers had more years of schooling and more years of farming experience. They gain most of their income from the sale of grain while that of Selale farmers from livestock and livestock products. The productivity of dairy cows (litres/month) is higher among Selale farmers while Ada farmers produce greater crop yields per hectare.

Determination of Sample Size

Several crop production technologies have been introduced in the study sites since the 1960's. However, introduction of cross-bred cows took place not only recently but was also implemented by different agencies with relatively different approaches to technological intervention strategies. Since this research was conducted to provide information on the feasibility of cross-bred cows husbandry, it was felt appropriate to compare farmers who have adopted cross-bred cows (test farmers) with those who did not (Control farmers). These farmers may have adopted any combination of crop-production augmenting technologies.

Households which received cross-bred cows and were selected for this study in the Ada and Selale areas numbered 26 and 89 respectively. Prior to selection of the control group, the sample size was determined according to the following procedure. The sample size (N) is given as:

$$N= (KV)^2/D^2$$

where D is the largest acceptable difference (in percent) between the estimated sample and the true population parameters. K is a measure of confidence (in terms of the number of deviations from mean) with which it can be stated that the result lies within the range represented by plus or minus D and V is the coefficient of variation of crop and/or milk yields (see Kebede, 1993). A confidence level of 95%, coefficient of variation of crop and milk yields of 96 percent and precision level of ± 20% resulted in a sample size of 89 farmers for the Selale region. For the Ada region, however, time and financial resources limit the number of test farmers to only 26. Comparison of average values of socioeconomic variables derived from a district-wide survey by the Ministry of Agriculture and average values of similar socioeconomic characteristics calculated from test farmers showed that the two data set are approximately the same. Therefore, the small sample size for the Ada region will not bias the foregoing analysis.

After determining the sample size, the need to use farmers who joined the International Livestock Center for Africa (ILCA) and FINNIDA (Finnish International Development Agency)/ MOA (Ministry of Agriculture, Ethiopia) programs as test groups necessitated the use of a systematic selection of the control group. A method was designed such that all test farmers were compared with farmers who exhibit similar socioeconomic characteristics (control farmers) but were different in ownership of cows (19). 116 and 26 control farmers were selected from Selale and Ada regions respectively.

The control farmers were to have a comparable number of oxen, cows, sheep/goat, family size, age (farming experience), education, annual farm income and farm size (crop and grazing) with the test farmers. Moreover, the two groups had to exhibit similar ethnic, climatic and geographical characteristics. To accomplish this task, a three-step procedure was followed.

Firstly, a group of farmers involving political leaders and elders in each peasant association were asked questions such as, "With whom do you think farmer "A" compares with respect to income, livestock holdings, living standard, etc., except that he does not own cross-bred cows?". A peasant association is a geopolitically delimited association of peasants covering an area of about 400 hectares. Political leaders are farmers who, through democratic election processes, were elected to take administrative positions within a peasant association.

Secondly, each test farmer was asked questions such as, "To whom do you think you are comparable with respect to income, livestock holding, family size, etc., except that you own cross-bred cows and the other farmer does not?". This method of identify a control farmer is difficult and socially controversial. Nevertheless, it would provide a clue to identifying control farmers. Discussions with group of farmers indicated that this method could be feasible if used in conjunction with step one.

Thirdly, 150 farmers who did not receive cross bred cows were interviewed with respect to the above socioeconomic characteristics. The results were compared with background socioeconomic data obtained from test farmers. Combination of the above three steps enabled identification of control farmers that were used in the present study.

The research involved interview, observation and participatory methods. Data collected from interviews include socioeconomic characteristics such as schooling, relatives, production knowledge, wealth, income, expenses, area, crops planted, number of livestock, milk yield, technologies adopted, etc. (Kedede, 1993).

The Empirical Model and Data

Various models of limited dependent and qualitative variables are used to examine adoption decisions. Most of these models involve modified forms of univariate logit or probit models (Feder et al. 1982; Shakya and Flinn, 1985). Probit models when the dependent variable is limited and continuous between 0 and 1, and logit models for discrete dependent variables (Maddala, 1983). The difference in the estimated results obtained from logit or probit models are not significantly different (Maddala, 1983). To examine the relative impact of production knowledge, information, wealth, age and other socioeconomic factors on adoption decisions, a multivariate logit model is chosen in this study.

Each household is confronted with a decision to adopt the new technology, partly or fully, in combination with other technologies or to continue using traditional practices. Denoting the probability of adoption (P), new technology (N), traditional technology (T), the probability of adopting a new technology by a household, given its economic, social and physical characteristics (X), $P(N|X)$, is given by:

$$P(N|X)= \exp(X\beta + U)/\{1+\exp(X\beta + U)\} \qquad \text{.....................} \quad (1)$$

where $-\infty < X\beta < \infty$, exp is exponent and U is the Disturbance term.

The probability of adoption of the traditional technology, $P(T|X)$, is therefore,

$$\begin{aligned} P(T|X) &= 1- P(N|X) \\ &= 1- [\exp(X\beta + U)/\{1+\exp(X\beta + U)\}] \\ &= 1/(1+\exp(X\beta + U) \qquad \text{.......................} \quad (2) \end{aligned}$$

The relative probability of adopting versus not adopting a new technology is given by:

$$\begin{aligned} P[(N|X)/(T|X)] &= \exp(X\beta + U)*[\{1+\exp(X\beta + U)\}/\{1+\exp(X\beta + U)\}] \\ &= \exp(X\beta + U) \qquad \text{....................} \quad (3) \end{aligned}$$

taking the logarithms of both sides,

$$\ln [P(N \mid X)/P(T \mid X)] = X\beta + U \qquad \text{......................} (4)$$

Where β is a vector of unknown parameters which can be interpreted as the net influence of the vector of independent variables on the probability of adoption of new technologies (Rahm and Huffman, and Kebede et al.1990). Equation (4) is the logarithm of odds choice, not the actual probability. Hypothesis testing for individual and joint influences of socioeconomic, technical and physical factors is carried out using the likelihood ratio (see Jamison and Lau, 1982).

Separate adoption equations are estimated for the Ada and Selale areas. These are:

$$A(C)_{s,a} = f[A(N_t), X_1, ... X_n \qquad \text{..} (5a)$$
$$A(F)_{s,a} = f[A(N_t), X_1, ... X_n \qquad \text{..} (5b)$$
$$A(P)_{s,a} = f[A(N_t), X_1, ... X_n \qquad \text{..} (5c)$$
$$A(S)_{s,a} = f[A(N_t), X_1, ... X_n \qquad \text{..} (5d)$$

where A(C), A(F), A(P) and A(S) respectively refer to adoption of cross-bred cows, fertilizer, pesticides and improved seed. The subscripts s,a indicate that the equations are estimated for Selale and Ada regions, respectively. The variable(s) $A(N_t)$ refers to technology(ies) which is (are) adopted earlier and which farmers believe to have influenced decisions regarding adoption of fertilizer, pesticides, cross-bred cows and improved seed technologies. Variables $X_1, ... X_n$ refer to social, economic, technical, etc. factors that are hypothesized to influence the adoption decision. These variables are family size, years of schooling, awareness, years of farming experience, number of relatives, purchase price (in Ethiopian birr), productivity, production and marketing knowledge, wealth (Ethiopian birr), expense (Ethiopian birr), off-farm income (Ethiopian birr), technologies adopted, input prices (in Ethiopian birr), veterinary services (Ethiopian birr), feed area (hectares) and farm size (hectares).

Measures of production and marketing knowledge are obtained from problem solving tests (Kebede, 1993). Wealth is measured as the sum of the market values of livestock and crop outputs without accounting for home consumption and seed requirements. Expenses include the sum of money spent to purchase consumer goods, to pay taxes and contributions, school fees and clothing. Off-farm income includes money earned from wage labour by working on plots of other farmers, to government agencies or in cities.

Producers were asked to rate the productivity of each technology compared to local livestock breeds or crop cultivars. These ratings were coded as high, average and low, and they were assigned values of 3, 2 and 1 respectively. Input prices include feed, insemination and other costs related to the management of cross-bred cows. Purchase prices apply only to crop production technologies because prices of cross-bred cows are fixed and producers consider the cost of managing the cows to be more important than purchase prices. Unlike other production increasing inputs such as fertilizer, investment in livestock production technology is risky because it cannot be adopted in a sequence of small amounts. This is typical characteristics of indivisible or lump-sum technologies. Thus, the rate of adoption of livestock production technologies is slow (Feder et al.1982).

Awareness is calculated as follows:

$$\text{Awareness} = [A_1 + A_2 + A_3]/3 \qquad \text{.................................} \ (6)$$

Where A_1 is the number of visits a farmer makes to the nearby city and A_2 is the number of days a household visits local markets. Both variables are calculated on yearly basis and divided by the highest number of visits in the sample. Owning radio (A_3) is given a value of 1 and 0 otherwise. A farmer who owns a radio is assumed to listen to news from outside the vicinity and is thus expected to have a 100 percent exposure to outside information compared to farmers who do not own radio. Although owning a radio is recorded as a dichotomous and city visits as discrete variable, the need to capture influences from these sources and, at the same time, to reduce the number of variables in the logit regression necessitated the construction of this index (Kebede et al. 1990). In other words, the values of A_1, A_2 and A_3 are constrained to lie between 0 and 1.

Risk-Taking Behaviour

The inherent behaviour to take risk is reinforced by the environment in which households operate. Peasants employ various ways of minimizing risk (Roumasset et al.1979). For instance households may pursue wage labour, ties with markets, strengthening social relationships, variable cropping patterns, and so on (Firth, 1969; Jodha and Mascarenhas,1983). Social relationships, scattered fields and storage provide both spatial and temporal buffers (Jodha and Mascarenhas, 1983). In their selection of alternative methods of reducing risk, households exhibit varying degrees of risk-taking behaviour.

Reactions of peasants to development strategies are, in part, explained in terms of risk-taking behaviour. Reluctance of peasants to adopt innovations is not due to irrational behaviour, as often assumed, but to their desire to maximize their security by minimizing their risk (Ortiz, 1980). Several factors influence risk-taking behaviour of households. These include wealth, social standing, rainfall and other social, cultural, economic and technical factors (Shahabudin and Mestelman, 1986; Dewalt and Dewalt. 1980).

Methods for analysing risk-taking behaviour of households range from those utilizing hypothetical gambling to those conditional on actual production decisions (Anderson et al.1977;

Barry, 1984; Binswagner,1980; Fleisher and Robinson; 1985). Most of these models are based on the assumption of rational economic or utility maximizing behaviour of households.

In this study, risk-taking behaviour is examined using information obtained from actual decisions made by households. It is hypothesized that the primary objective of farmers is to secure subsistence for maintenance of the family and the farming unit. Therefore, households follow the strategy of minimizing the risk associated with securing subsistence requirements. Crop diversification indices are calculated (Hardaker and Ghodake, 1984; Valdes et al.1979).

A crop diversification index (CDI) is calculated as :

$$CDI = 1-\Sigma_j L_j^2 \quad \text{.................................} \ (7)$$

where L_j is the proportion of land allocated to crop j. The index "CDI" has an upper bound of 1.0 and takes a value of zero for monoculture. Similar calculations are made for the composition of livestock. This measure generally increases with the degree of risk aversion (Hardaker et al.1984). One of the difficulties in measuring the degree of risk-taking behaviour in peasant agriculture is that choices of crops and livestock fulfils several functions, of which economics is one. Therefore, equations such as in (7) incorporate both physical possessions and non-economic attributes. A households wants a cow, ox, heifer, steer and sheep. Another household may possess a cow, ox, steer, heifer and goat. Both own the same classes of livestock. The choice of either goat or sheep could be religious, cultural requirement or resource constraint. Such features can be approximated by such physical measures of resource management.

In order to assess the influence of risk-taking behaviour (measured as CDI) and other socioeconomic variables on adoption of the four production technologies, four logit regressions are specified:

$$A(C)_{a,s} = f[\delta(X), A(N_t), X_1, \ldots X_n \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(7a)}$$
$$A(F)_{a,s} = f[\delta(X), A(N_t), X_1, \ldots X_n \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(7b)}$$
$$A(P)_{a,s} = f[\delta(X), A(N_t), X_1, \ldots X_n \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(7c)}$$
$$A(S)_{a,s} = f[\delta(X), A(N_t), X_1, \ldots X_n \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(7d)}$$

The definition of variables is the same as those in equations 5a to 5d, except that the risk taking behaviour ($\delta(X)$) is added.

Empirical Results

Patterns and Pre-conditions for Adoption

Prior to performing statistical analysis, frequency distributions of patterns of adoption of innovations for the Ada and Selale regions are calculated. The results are presented in Table 2.

The results show that at least eighty-five percent of households in both regions adopt fertilizer as their first choice. Most Ada producers adopt innovations in the following sequence: fertilizer, pesticides, improved seed and cross-bred cows. Selale producers adopt fertilizer, pesticides, cross-bred cows and improved crop varieties in that order. These patterns of adoption indicate that the primary goal of producers in both regions is to produce adequate grain through the adoption of crop production technologies.

This result confirms that the "package approach" to the provision of technologies is not a feasible strategy in the grain surplus regions of the Ethiopian highlands. This finding also support the hypothesis of sequentiality of decisions regarding goals and strategies in the study sites (Kebede, 1993).

Table 2. Patterns of Adoption of Innovations by Region

	Sequences of Adoption			
	First	Second	Third	Fourth
	percentages of farmers			
Ada Region				
Fertilizer	90	30	15	16
Pesticides	5	60	31	21
Improved seed	4	6	48	23
Cross-bred cows	1	4	8	38
Selale Region				
Fertilizer	85	15	10	13
Pesticides	9	74	28	21
Improved seed	1	2	5	28
Cross-bred cows	5	9	56	48

Source: Calculated from base-line data gathered from the study sites, 1990/91.

Success in adoption of agricultural innovations in LDCs is linked to the existence of pre-conditions or "modernizing" conditions (Molnar and Clonts,1983; Valdes et al.1979; and Hayami and Ruttan, 1985). For instance, adoption of fertilizer requires conditions such as accessibility of distribution centres, availability of credit, subsidies and favourable output prices (Table 3). When production constraints are binding, however, pre-conditions become irrelevant.

Producers of Ada and Selale regions have realized that the fertility status of their farm lands and production are declining. Adoption of fertilizer is a feasible strategy to reduce the risk of not producing enough grain to satisfy family food requirements. Regardless of the existence of pre-conditions, households may adopt innovations as the only solutions to ensure subsistence requirements. Furthermore, producers in the Selale and Ada regions adopt improved crop varieties if increases in production from these varieties is twice that of local cultivars and that they can sell their grain at fair market prices. With respect to livestock production, producers indicate availability of feed and veterinary services as the two important pre-conditions prior to adoption of cross-bred cows.

The adoption of innovations necessitates shifts in the allocation of financial and physical resources. For instance, the adoption of cross-bred cows requires growing forage. Faced with this dilemma, more than sixty percent of Selale farmers chose to reduce the area allotted to barley and oats. These two crops occupy the largest percentage of area per household (Kebede, 1993). The by-product of these crops is a good source of livestock feed. However, the market value of these crops is low compared to crops such as wheat, teff and beans. In the Ada area, fifty percent of the test and thirty percent of the control farmers would reduce the area devoted to barley.

Table 3. Pre-Conditions for Adoption and Importance of Products of Innovations

	Selale		Ada	
Categories	Test	Control	Test	Control
	Percentage of producers			
1. Adopt cross-bred cows if:				
a. Availability of Feed & veterinary serv.	45	68	85	87
b. Fair Price	39	51	71	77
c. Grow Feed	90	81	40	20
2. Adopt crop technology if:				
a. Increase in productionis the same as local cultivars	10	15	12	9
b. ≥ twice the local cult.	81	79	96	94
c. Price is good	78	85	89	92
d. Adequate distribution Centers	42	32	65	75
e. Credit/subsidies	78	69	81	78
3. If grow forage, then reduce area under:				
a. Barley+oat	74	61	50	30
b. Wheat	31	29		
c. Guaya	30	33		
4. Type of feed purchased:				
a. Wheat bran	15	11	35	23
b. Noug cake	5	14	5	6
c. a+b	80	75	60	71
5. If adopt cross-bred				
a. Reduce livestock no.	80	61	98	87
b. Increase livestock no.	6	11	-	-
c. No change in Livestock Number	14	28	2	13
6. Use of calves from Cross-Bred Cows for:				
a. Husbandry and traction	68	76	35	46
b. Fattening	15	22	32	29
c. a+b	17	2	33	25
Sample Size	89	128	26	27

The objective of introducing "more productive" animals or cross-bred cows is to reduce the large but less productive stock. The result indicates that most farmers (80%) intend to reduce the number of local cattle if they obtain cross-bred cows.

The adoption of cross-bred cows or crop production technology involves decisions regarding what use can be made from the outcomes of new innovations (e.g., higher crop or milk yield). Seventy percent of the Selale farmers prefer to use calves for husbandry or traction purposes. The results from Table 2 and 3 show that households follow sequential decision-making, and the pre-conditions for the choice of innovations is associated with enterprise-specific experience of farmers and regional potential (see also page 4-5).

Empirical results of Adoption Decisions

From practical and statistical points of view, it is difficult to analyse all factors that influence decisions to adopt innovations. Based on correlation analysis, therefore, a limited number of factors are selected to examine adoption decisions. Spearman's correlation analysis is performed for several variables. As a rule of thumb, if the correlation coefficient between \`x' and \`y' is ≥ 0.6, only one of variable is included in the logistic regressions (Moock, 1981). In lieu of parsimony and convergence, therefore, a maximum of 18 variables were selected to investigate decisions regarding adoption of each production technology (Madalla, 1983).

Adoption of Fertilizer and Pesticides

The adoption of fertilizer is positively influenced by economic factors (wealth and off-farm income), social factors (family size and relatives) and technical factors (farm size and productivity). Awareness, purchase price, market knowledge and expense are negatively correlated with the adoption of fertilizer (Table 4). The adoption of pesticides is positively influenced by economic factors (wealth and off-farm income), social factors (education and production knowledge) and technical factors (farm size) in both Selale and Ada regions (Table 4).

Ada producers have experimented with fertilizer, pesticides and other crop production increasing inputs. Consequently, they posses greater crop production knowledge than Selale farmers.

Farmers of this region have relatively greater access to credit, markets and infrastructure. Consequently, they received greater score on marketing knowledge. Furthermore, they are located closer to the political capital of the country. Several projects operate in the region compared to Selale. Consequently, the negative effects of some agricultural policies are less pronounced in Ada than in Selale. As a result of these situations, several factors exert positive and significant effect on adoption of fertilizer and pesticides in Ada compared to Selale region.

Increases in agricultural output can be expected if introduction of fertilizer is complemented by other crop production-increasing inputs such as pesticides and improved crop cultivars. Producers obtain these inputs either on cash or credit. Their ability to pay is dependent

Table 4. Results of Logit Regression of Adoption Decisions

	Fertilizer		Pesticides		Cross-bred Cows		Improved Seed	
Variables	Selale	Ada	Selale	Ada	Selale	Ada	Selale	Ada
Intercept	2.078	3.033	1.428	4.613	-1.092	-2.454	-1.578	3.044
	(6.679)*	(4.466)*	-1.432	(5.714)*	-1.303	(2.682)#	-1.708	(4.738)*
Family Size	0.626	-0.744	-0.116	1.816	-0.062	-0.04	-0.267	0.038
	(4.452)*	-0.4797	-0.089	(2.935)#	-0.079	-0.056	-0.466	(2.990)#
Education	0.173	0.091	0.603	0.065	0.228	0.555	0.037	-0.244
	(6.470)*	(3.971)#	(5.439)*	(5.213)*	(4.535)*	(6.908)*	-0.05	-0.132
Awareness	-0.195	-0.192	-0.063	0.43	0.502	0.722	0.581	0.988
	-0.256	-0.0125	-0.0286	-0.0425	(5.65)*	(4.175)*	(2.906)#	(6.129)*
Experience	-0.279	0.965	-0.019	0.779	0.362	0.476	-0.344	0.419
	(4.24)*	(4.260)*	-0.0025	(4.570)*	(4.682)*	(5.23)*	-0.848	(2.972)#
Relatives	0.269	0.268	-0.033	0.85	-0.058	-0.077	0.47	0.502
	(3.18)#	(3.21)#	-0.034	(2.851)#	(3.078)#	-1.017	(6.839)*	(5.584)*
Purchase price	-0.443	-0.31	-0.24	-0.816			-0.092	-0.976
	-1.259	(3.137)#	-1.064	(4.904)*			-0.14	(4.757)*
Productivity	0.602	-0.415	-0.14	0.654	0.45	-0.048	-0.018	-0.415
	(2.98)#	-2.03	-0.263	(6.824)*	(2.961)#	-0.94	-0.053	-0.7434
Production	0.624	0.563	0.715	0.945	0.674	0.471	-0.523	0.948
knowledge	-6.234	-4.735	(5.616)*	(4.900)*	(6.959)*	(4.516)*	-0.676	(8.450)*
Marketing	-0.83	-0.021	-0.301	-0.918			0.216	-0.822
knowledge	(4.635)*	-0.45	-0.374	(2.770)#			-0.464	-1.313
Wealth	0.77	0.134	0.526	0.122	0.191	-0.244	0.779	0.441
	(3.07)#	(3.102)#	(4.513)*	(3.42)#	(3.025)#	(3.304)#	(4.027)*	(3.417)#
Expense	-0.769	-0.917	-0.463	-0.115	-0.88	-0.847	-0.064	-0.45
	(4.36)*	(5.963)*	(3.072)#	(3.411)#	(3.524)#	(6.070)*	-1.02	-0.626
Off-farm	0.164	-0.41	0.256	0.219	0.42	0.344	-0.069	0.213
income	-1.97	(2.658)#	(3.988)*	(2.987)#	(3.53)*	(2.946)#	-0.76	-1.992
Farm/feed	-0.121	0.431	0.214	-0.531	0.795	-0.957	-0.212	0.391
area	-1.752	(4.35)*	(2.972)#	-1.971	(4.147)*	(6.412)*	-1.752	(4.723)*
Input Price					-0.308	-0.191		
					(3.098)#	-1.066		
Veterinary					0.852	-0.011		
					(4.878)*	-0.948		
Adoption of			0.37	0.713	0.125	0.521	0.433	0.62
Fertilizer			(2.997)#	(3.248)#	-1.9	(4.371)*	(2.973)#	(6.983)*
Adoption of					0.541	0.71	0.593	0.801
Pesticides					(3.41)#	(6.45)*	(4.09)*	(5.279)*
Adoption of					-	0.105	-	0.253
Improved seed						-1.593		-1.89
N	217	52	217	52	217	52	217	52
Chi-Square	47.4*	50.9*	52.6*	46.9*	49.1*	50.4*	47.8*	46.7*

* and # indicate statistical significance at 1 & 5 percent respectively.

on the amount of production obtained and market prices. In situations where the market price is low, awareness of these factors, purchase price and market knowledge reduce the probability of adoption.

Adoption of Cross-Bred Cows and Improved Seed

The results of adoption of cross-bred cows and improved seed varieties are presented in Table 4. Education, awareness, experience, production knowledge and off-farm income positively and significantly influence adoption of cross-bred cows in the Selale and Ada areas. Marketing knowledge is excluded from the model of adoption of cross-bred cows because prices of cows and milk are fixed. Therefore, limited use can be made of this knowledge. However, prices of crop technologies and crop outputs vary. Thus, knowledge of grain marketing affects adoption of crop production technologies.

The influence of wealth is positive and significant in Selale but negative and significant in the Ada region. The largest percentage of the wealth of Selale producers is embodied in livestock. Thus, wealth exerts a positive and significant influence on adoption of livestock related technologies. In the Ada region, however, the prospect for livestock production is limited. Therefore, producers don't want to risk their family survival by investing in livestock technologies.

The wealthier a producer, the less interest he will show for livestock husbandry, especially if the pre-conditions are not present (e.g., feed). This is true in the Ada region where feed is binding constraint. Feed and veterinary services exert a significant impact only on adoption of cross-bred cows in the Selale region.

Among the social variables, education, experience, production knowledge and awareness significantly influence adoption of cross-bred cows. Family size and number of relatives are negatively correlated with adoption. Several studies have documented that households who are actively involved in social networks are better insured against unforseen risks of failures or financial losses than households who are less involved in social networks and have few relatives (Barlett, 1980). Nevertheless, there is a limit to the insurance that relatives or networks can provide against risks of crop or livestock losses. Cross-bred cows or purchases of livestock, in general, are risky investments. Households may not be completely buffered from financial risk associated with adoption of cross-bred cows. Thus, they may decide to take responsibility for the consequences of their investment decision. Another interpretation for the negative effect of family size and relatives on the adoption of cross-bred cows is that if households invest in expensive innovations, they may not have sufficient financial or physical resources to participate in social-networks. They may not help relatives and provide subsistence requirements for their families. Therefore, increases in family size and relatives may negatively influence decisions regarding adoption of cross-bred cows.

Technical variables such as productivity of cows, veterinary services and availability of land to grow feed or grazing area positively and significantly influence adoption of cross-bred cows in the Selale area.

Adoption of Improved Crop varieties

The adoption of improved crop varieties is positively and significantly influenced by awareness, relatives and wealth in both study sites. Improved crop varieties are recently introduced in the Selale region. Their performance on fields of early adopters was not promising. Thus, adoption of this innovation may endanger the securing of subsistence. Family size, experience, productivity, and production knowledge reduce the probability of adoption of improved seed in the Selale region. Adoption of fertilizer and pesticides increase the probability of adoption of improved seed.

Research conducted in the Ada region argued that Ada farmers have access to most crop production technologies and that they show strong interest in adopting improved crop varieties (Belay, 1977; Gryseels and Anderson, 1983). Exposure and access to complementary inputs may have contributed to the positive and significant effect of family size, experience, productivity, production knowledge and number of technologies adopted on decisions to adopt improved seed varieties in the Ada region.

Sequentiality of adoption decisions holds in all logit regressions. That is, technologies that are adopted later are positively [and significantly] associated with those adopted earlier.

Risk and Adoption of Technologies

Before evaluating the impact of risk on adoption decisions, correlation analysis is performed to detect problems of multicollinearity. Selected variables were included in the logit regression. The results of logit regression are presented in Table 5.

Table 5. Risk and Adoption of Technologies

	Fertilizer		Pesticides		Cross-bred Cows		Improved Seed	
Variables	Selale	Ada	Selale	Ada	Selale	Ada	Selale	Ada
Intercept	4.182	3.413	1.201	3.942	2.122	0.954	2.428	1.923
	(5.772)*	(4.986)*	1.1131	(3.501)*	(4.803)*	(2.987)#	(5.437)*	(4.342)*
Family size	-0.096	0.92	-0.197	-0.429	-0.462	-0.14	-0.326	-0.096
	-1.082	(2.731)#	-1.036	(3.041)#	-0.129	-0.236	-1.899	(3.093)#
Education	0.213	0.021	0.029	0.422	0.328	1.055	0.529	0.211
	-1.572	-0.417	-0.249	(1.992)#	-1.425	(4.340)*	(3.012)#	(2.945)#
Awareness	-0.203	0.609	-0.211	0.821	0.001	-0.102	-0.197	0.138
	-1.426	(2.919)#	-1.209	(3.401)#	-0.09	-0.111	-1.728	-0.209
Experience	0.399	0.871	0.217	0.631	0.231	-0.029	0.001	0.591
	(2.941)#	(3.214)#	-0.932	(2.991)#	(2.981)#	-0.43	-0.039	(2.724)#
Relatives	0.609	0.508	0.31	-0.201	0.572	-0.392	0.004	0.09
	(4.002)*	(5.201)*	(2.997)#	-1.074	(2.721)#	(4.815)*	-1.009	-1.004
Production	0.322	-0.29	0.481	0.398	0.174	0.231	0.035	0.021
	(6.103)*	-1.109	(2.948)#	(3.757)#	(4.099)*	-1.031	(2.97)#	-1.679
Risk	-0.594	-0.509	-0.401	-0.648	-0.474	-0.571	-0.601	-0.415
	(2.833)#	(2.735)#	(2.949)#	(4.653)*	(2.859)#	(4.163)*	(3.01)#	(2.945)#
Wealth	0.95	0.216	0.925	0.092	0.408	-0.024	0.219	0.241
	(4.983)*	(3.321)#	(4.904)*	-1.751	(2.995)#	-1.311	(2.95)#	(4.91)*
Expense	-0.331	-0.731	-0.167	-0.329	-0.781	-0.268	-0.209	-0.921
	(2.949)#	(2.994)#	(3.092)#	-0.97	(6.902)*	-1.427	-1.781	(4.39)*
Off-farm	0.129	0.927	-0.124	0.001	0.177	0.255	0.227	0.401
	-1.999	(4.989)*	-1.3201	-0.077	-1.342	(2.972)#	(3.82)#	(3.023)#
Farm/Feed Size	0.241	0.724	-0.019	-0.459	0.991	-0.467	-0.182	0.647
size	(3.001)#	(2.91)#	-1.009	(6.997)*	(6.457)*	(2.958)#	-1.891	(6.783)*
N	217	52	217	52	217	52	217	52

* and # refer statistical significance 1 and 5 percent respectively.

The impact of most socioeconomic and technical variables on adoption of technologies approximates those obtained in previous sections. The risk diversification index exerts a negative and significant effect on adoption of most of the technologies.

The results from this study indicate that measures of risk-taking behaviour calculated from actual production decisions of households negatively influence adoption decisions. This is true not only because of the newness of innovations but also because of the environmental or resource constraints that inhibit peasants from attaining the maximum potential of innovations.

Risks from adoption of innovations can be reduced by social networks, the individual's socioeconomic status in a society and the government. In dryland agriculture, all producers are subjected to a common source of risk, namely rainfall variability. Under this kind of farming condition, the first two sources of insurances may not buffer peasants from risks. Governmental or non-governmental assistance should accompany innovations to mitigate the effects of risks, thereby increasing food production (Kebede, 1993).

Summary

Peasants follow sequential adoption of technologies. In both study areas, priority is given to adoption of crop production augmenting technologies followed by technologies that complement crop prodctution (Ada) and contribute to increases in milk production (Selale). Producers of both regions require existence of certain pre-codntions prior to the adoption of technologies. Ada farmers require more pre-conditions related to livestock production while

Selale farmers require more preconditions related crop production.

Education, wealth, number of relatives, productivity of technologies, off-farm income, extension contacts, feed area and/or farm size exert positive impacts on adoption of most agricultural technologies in both study sites. The impact of education, experience and production knowledge on decisions to adopt innovations is not only positive but larger than other variables. In regions where "modernizing conditions" or pre-conditions are lacking, adoption decisions are negatively influenced by several variables (e.g. improved seed in Selale and Cross-bred cows in Ada).

The results of this study indicate that: i) households follow sequential adoption patterns; ii) when technologies are risky or expensive, most farmers would like to have several conditions simultaneously before deciding to adopt (e.g. cross-bred cows compared to crop production technologies); iii) skill-augmenting factors, especially production knowledge and schooling, exert a consistently significant effect on adoption of all technologies; and iv) the magnitude and direction of effects of variables correspond to experience and region-specific potentials.

Success in adoption of technologies can be attained when i) intervention strategies recognize experience, enterprise and region-specific potentials, ii) the skills of producers match the requirements of technologies and iii) the risk of failure in crop or livestock production is mitigated by the government or development agencies.

References

Aklilu, B., Technological Change in Subsistence Agriculture: The Adoption and Diffusion of Fertilizer in Ethiopia's Minimum Package Areas, Ph.D. Dissertation, Boston University, 1974.

Anderson, J. R., J.L. Dillon and J.B. Hardaker. Agricultural Decision Analysis, Ames: Iowa State University Press, 1977.

Ayana, I., An Analysis of Factors Affecting the Adoption and Diffusion Patterns of Packages of Agricultural Technologies: A case Study in Two Extension Districts of Ethiopia. M.A. Thesis, Addis Ababa: Department of Economics, Addis Ababa University, June, 1985.

Barlett, P.F., Agricultural Decision Making: Anthropological Contribution to Rural Development (ed), New York: Academic Press, 1980.

Barry, P., Risk Management in Agriculture, Ames: Iowa State University Press, Iowa, 1984.

Belay, H.S., Problems, Practices and Strategies for Rural Development in Ethiopia, Debrezeit Agricultural Experiment Station. Addis Ababa: Addis Ababa University, 1977.

Binswagner, H.P., "Altitudes towards Risk: Experimental measurement in Rural India," American J. of Agricultual Economics, 62(1980):395-407.

Dewalt, B.R. and K.M. Dewalt, "Stratification and Decision making in the Use of New Agricultural Technology," In P.F. Barlett (ed), Agricultural Decision Making: Anthropological Contribution to Rural Development, New York: Academic Press, 1980, pp.289-320.

Eisemon, T.O., and A. Nyamete, "Schooling and Agricultural Productivity in Western Kenya," J. of East African Research and Development, 18 (1988):pp.44-66.

Feder, G., R.E.Just, and D. Zilberman, Adoption of Agricultural Innovation in Developing Countries.Washington, DC: World Bank Staff Working Paper No.549, 1982.

FINNIDA, Base Line Survey: Selale Dairy Development Pilot Project, Unpublished Report, Addis Ababa, 1989.

Firth, R., "Social Structure and Peasant Economy: The Influence of Social Structure upon Peasant Economies," In C. Wharton (ed), Subsistence Agriculture and Economic Development, Chicago: Aldine, 1969, pp.23-27.

Fleisher, B., and L.J. Robinson, Application of Decision theory and the Measurement of Attitudes Towards Risk in Farm management Research in Industrialized and Third World Settings. East Lansing: MSU International development paper No.6., 1985.

Gryseels, G. and F.M. Anderson, Research on Farm and Livestock Productivity in Central Ethiopian Highlands: Initial Results, 1977-1983, ILCA Research Bulletin Report No.4., Addis Ababa, 1983.

Hardaker, J.B. and R.D. Ghodake, Using Measurement of Risk Attitudes in Modelling Farmer's Technology Choices. Economics Program, Progress report 60. January, India, ICRISAT, 1984.

Hayami, Y. and V.W. Ruttan, Agricultural Development: An International Perspective, Baltimore: The John Hopkins University Press, 1985.

Jamison, D.T. and L.Lau, Farmer Education and Farmer Efficiency, Baltimore: The John Hopkins University Press, 1982.

Jodha, N.C., and A.C. Mascarenhas, Adjustments to Climatic Variability in Self Provisioning Societies: Some Evidences From India and Tanzania, ICRISAT Economics Program Progress Report No.4, India, 1983.

Kebede, Y., The Micro-Economics of Household Decision Making: The Case of Adoption of Technologies in Ethiopia. Unpublished Ph.D. Dissertation, Montreal, Departments of Agricultural Economics and Anthropology, McGill University, 1993.

Kebede, Y., K, Gunjal and G. Coffin, "Risk and Adoption of Agricultural Technologies in Ethiopia," Agricultural Economics, 4 (1990):27-43.

Longo, R.M.Juliano, "Information Transfer and the Adoption of Agricultural innovations," J. of the American Society for Information Science, 41 (1990):1-9.

Maddala, G.S., Limited-Dependent and Qualitative Variables in Econometrics. New York:Cambridge University Press, 1983.

Mason, R. and A.N. Halter, "Risk Attitude and the Forced Discontinuance of Agricultural Practices," Rural Sociology, 45(1980):435-447

Molnar, J.J., and H.A.Clonts, Transferring Food Production Technology to Developing Nations: Economic and Social Dimensions, (eds), Colorado: West View Press, 1983.

Moock, P.R., " Education and Technical Efficiency in Small Farm Production," Econ. Dev. and Cult. Change, 29(1981):723-739.

Ortiz, S., "Forecasts, Decisions, and Farmer's response to Uncertain Environments," In P.F.Barlett (ed), Agricultural Decision Making: Anthropological Contribution to Rural Development, New York: Academic Press, 1980, pp.177-202.

Rahm, M.R., and W.E. Huffman, "Adoption of Reduced Tillage: the Role of Human Capital and other Variables," Amer. J. Agr. Economics, 66(1984):405-413

Roumasset, J.A., "Unimportance of risk for technology design and agricultural development policy," In A. Valdes, G.M. Scobie, and J.L. Dillon (eds), Economics and the Design of Small-Farmer Technology, Ames:Iowa State University Press, 1979.

Shahabudin, Q., and S. Mestelman, "Uncertainty and Disaster Avoidance Behaviour in Peasant farming: Evidence from Bangladesh," J. of development Studies, 22(1986):740-752.

Shakya, P.B., and J.C. Flinn, "Adoption of Modern Varieties and Fertilizer Use on Rice in the Eastern Terrai of Nepal," J. of Agricultural Economics, 36(1985):409-419.

Stevens, R.D. and C.L. Jabara, Agricultural development Principles: Economic Theory and Empirical Evidence. Baltimore:The John Hopkins University Press, 1988.

Valdes, A., G.M. Scobie and J.L. Dillon, Economics and Design of Small Farmer Technology (eds), Ames: Iowa State University Press, 1979.

Warren, D.M., L. Jan Likkerveer and S.O.Titilola, Indigenous Knowledge Systems: Implications for Agricultural and International Development, Studies in Technology and Social Change, No.11. Ames: Iowa State University, 1988.