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12. April 1993

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Acknowledgment: 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

An aggregate measure of production efficiency involving crop and livestock enterprises is examined in the Selale and Ada regions of Ethiopia using Data Envelopment Analysis (DEA). In general, farmers in regions more suitable to crop production (Ada) tend to attain higher production efficiency compared to farmers in regions suitable to livestock production (Selale).

This implies that Ada farmers produce agricultural outputs with a minimal outlay of inputs. DEA results also reveal that farmers who adopted cross-bred cows (refrred as test farmers) are more efficient than those who have not adopted (referred as control farmers) in both study sites. Analysis of the contribution of socioeconomic variables to measures of production efficiency indicated that the magnitude of knowledge-related variables (i.e. production knowledge and schooling) are relatively higher compared to physical or other non-physical variables. This finding implies that sustainable increases in production efficiency and attainment of food self-sufficiency could be attained if development strategies design methods of incorporating indigenous production knowledge of peasants in the planning process.

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Introduction

Agriculture is the major economic sector of Ethiopia. It employs 80% the total population and contributes 90% of the country's foreign exchange earning. Strategies of development designed to benefit the poor, therefore, have to focus on agriculture. Several intervention strategies have been implemented in peasant agriculture since the 1960's (2,16,17,27). However, their impact on agricultural output and living standards of the rural poor was short lived.

Methods of attaining food self-sufficiency in the agricultural sector of Ethiopia include increases in area cultivated, productivity of land or both. The first possibility is difficult to achieve in the highlands because of the high density of livestock and human population, and landscape that requires huge financial expenditure to be harnessed. Thus, strategies that focus on methods of increasing the productivity of land and other resources while conserving those which are over-utilized are preferred.

Implementation of intervention strategies should be preceded by ex-ante holistic evaluation of their social, cultural, environmental and economic impacts. In the absence of holistic analysis, policy makers and planners should gather evidence from disciplinary studies regarding the economic, social or cultural impacts of intervention strategies or technologies.

Planners in LDCs rely on economic or technical feasibility of intervention strategies in designing long-term development plans. Researchers, employ various kinds of statistical and mathematical tools to assess the feasibility of agricultural technologies. Analysis of production efficiency is an important aspect of economic and technical analysis of agricultural projects.

Depending on the choice of tools, the empirical results of production efficiency may be different. Consequently, policy makers can introduce error in the planning process if the results of efficiency analysis are not reliable.

Parametric statistical tools have been employed to examine production efficiency (10). The present study is the first application of non-parametric methods of production efficiency analysis (known as Data Envelopment Analysis or DEA) to examine production efficiency of peasants in Ethiopia.

Peasants employ several inputs in the production of crop and livestock outputs. Farm inputs include traditional (e.g. land and labour) or new technologies. Research in the peasant agriculture has focused on the impact of a technology on production rather than selective combination of technologies. Adoption of a single or mixes of production technologies are anticipated to have a differential impact on production efficiency of smallholders (7). Specifically, selective mixes of production technologies are hypothesized to exert greater influence on the level of production efficiency compared to a single technology or traditional inputs. The present study investigates the distribution of relative production efficiency and socioeconomic factors that influence this distribution within and across regions, and the impact of selective mixes of agricultural technologies on the measures of production efficiency among peasants of the Central highlands of Ethiopia. The study is expected to focus on the feasibility of cross-bred cows husbandry.

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 choice of inputs or technologies and the resulting efficiency of production. The findings of this study would provide valuable evidence on strategies of technological intervention to planners and policy makers of agricultural development in LDCs.

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 meters 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 in the region posses extensive experience in livestock production compared to those in the Ada region.

Ada is characterized by mild weather and is representative of the country's large middle-altitude cropping zone (1500 to 2000 meters 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 socio-economic 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 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

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).

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.[1] 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 obtained from this study 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

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[1] 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 (Casely et al. 1982).

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?".[2]

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.[3] Nevertheless, it would provide a clue to identifying control farmers.

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.

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[2] 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

[3] Evaluating the economic well-being of other farmers would force farmers to think as if they were intruding into private life of others. This is not a socially acceptable norm. However, options were explored with groups of farmers and they suggested that this method could be feasible if used in conjunction with step one.

Methods of Analysis

Resources are allocated relative to the constraints imposed by the structure of production technology and by the structure of input and output markets, and relative to goals of the producer.[4] Investigation of efficiency and its measurement were made by Koopmans and Debreu (20,21,7). Efficiency analysis often involve statistical and mathematical modeling.

Farrell (1957) decomposed private efficiency into technical and allocative components. He also provided indexes of technical, allocative and overall private efficiency (11,12). Farrell's measure of technical efficiency has been generalized to allow for disproportionate input reductions and/or disproportionate output increases by Fare and Lovell, and Fare and Grosskopf (8,9). Association of optimal size with input-output vectors satisfying constant returns to scale was examined by Forsund and Hjalmarsson, Banker, and Banker, Charnes, and Cooper (1,14).

Charnes et al. (1978) formulated Data Envelopment Analysis (DEA) (4,23,24,25,26). In DEA the best practice frontier is constructed from observed inputs and outputs as a piecewise linear technology. Depending on the depth of the study, DEA has the ability to incorporate technical parameters that may not be captured by parametric production efficiency methods.

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[4] A producer is said to be technically efficient if production occurs on the boundary of the producer's production possibilities set, and technically inefficient if production occurs on the interior of the production possibilities set (Fare, Grosskopf and Lovell, 1985). A technically efficient producer is said to be structurally efficiency if production occurs in the uncongested or 'economic' region of the boundary of the production possibilities set, and structurally inefficient if production occurs in a congested or 'uneconomic' region of the boundary of the production possibilities set (Fare, et al., 1985).

The fractional linear program for n decision-makers is the ratio of total weighted output of decision maker j divided by its total weighted input:

$$\text{Maximize } Z_j = \sum_{j}^{n} U_{kj}Y_{rj} / \sum_{i}^{m} V_{ij}X_{ij} \qquad \text{..............} \quad (1)$$

where Y_{kj} is output k produced by decision-maker j , X_{ij} is input I used decision-maker j, U_{kj} and V_{ij} are weights. The decision-maker will choose these weights subject to the constraint that no other decision-maker would have an efficiency greater than one if it used the same weights.

$$\sum_{j}^{n} U_{kj}Y_{kj} / \sum_{i}^{m} V_{ij}X_{ij} \leq 1 \qquad \text{................} \quad (2)$$

Furthermore, the weights have to be non-negative. That is:

$$U_{kj}, V_{ij} \geq 0 \qquad \text{..................} \quad (3)$$

Similar to many mathematical or statistical models, DEA has some limitations. DEA requires that all inputs and outputs to be specified and measured. DEA assumes that each unit of a given input or output is identical to all other units of the same type. It assumes constant returns to scale. Finally, the input and output weights produced by DEA cannot be interpreted as values in the economic sense.[5]

The objective of this research is to measure the efficiency of individual producers who are engaged in the production of crop and livestock simultaneously. Farmers which can attain the highest production level from minimum input use will have a score of 1 or 100 percent efficiency. All other farmers will be compared relative to the farmer with a maximum efficiency.

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[5] This assumption is not a shortcoming of the procedure but rather in the interpretation of results.

Thus, the measure lies between 0 and 1. The production surface of the most efficient units will form the envelop or the gauge on the basis of which others will be compared. Efficiency measure of other farms or units, therefore, lies on or below this envelope.

DEA would not restrict individual decision making units from using various levels of inputs and attaining different levels of output (28). Thus, it is possible to compare units producing different levels of output given the choice and use of inputs. DEA assumes that the production units produce one or several homogeneous outputs.

In Ethiopian agriculture, crop and livestock production are intertwined. The assumption of homogeneous outputs does not hold if physical units of measurements are used. Therefore, physical outputs are multiplied by their respective market prices. The outputs include crop, milk, butter and live animals. That is market prices are used to convert outputs into similar units. The physical inputs required to produce milk are cows, labour, feed, veterinary services and related expenses. Size of crop area, seed, labour, fertilizer, pesticides and oxen inputs are necessary to produce cereals. Thus, there are ten production inputs.

Let X_{ij} be the amount of input I used by farmer j in the production of milk or crops. Similarly, let Y_{kj} be the level of output k produced by farmer j. These measures of inputs and outputs are assumed to be greater than zero. Each producer possesses different level of managerial skill. The weights for inputs and outputs are chosen such that optimal solution will be found. For instance, U_{kj} is the unit weight of output k produced by farmer j. Similarly, V_{ij} is the unit weight of input I used by farmer j. The unit weights are defined via the constraints which are specified in the problem.

The linear fractional program in equation (1) is transformed into a linear program, called DEA, is given (primal) as :

$$\text{Maximize } Z_j = \sum_{j}^{n} U_{kj}\, Y_{rj} \qquad \text{.................. (4)}$$

Subject to

$$\sum_{k=1}^{n} U_{kj}Y_{kj} - \sum_{i=1}^{m} V_{ij}X_{ij} \leq 0 \text{ ; } j= 1,2,3, ..., n \qquad \text{.................. (5)}$$

$$\sum_{i=1}^{m} V_{ij}X_{ij} = 1 \qquad \text{.................. (6)}$$

$$U_{kj} \geq 0;\ k=1,2... .q \qquad \text{.................... (7)}$$

$$V_{ij} \geq 0;\ I= 1,2,..., m \qquad \text{............................... (8)}$$

The problem is solved for 267 farmers (all test and control farmers in both study regions), ten input and four outputs.

Analysis of production efficiency scores would not provide evidence regarding factors that cause variation in efficiency. To guide extension agents, researchers and policy makers, it is essential to identify factors that influence production efficiency.

Production efficiency scores lie between 0 and 1. Formulation of a regression equation with a truncated continuous dependent variable (efficiency score) may result in a predicted output that may lie beyond the interval 0-1 (22). Therefore, a linear probabilistic model was selected to examine factors explaining differences in production efficiency. The model is given as:

$$P_i = F(X_i) = \frac{1}{1 + e)^{-(\alpha + \beta Xi)}} \qquad \text{.................................. (9)}$$

Taking the logarithms of both side,

$$\ln (P_i) = \alpha + \beta X_i + U_i \qquad \text{(10)}$$

where the P_i's are truncated dependent variables, α and β are unknown parameters, X_i's are independent variables and U_i's are disturbance terms.

Description of Variables

The research involved interview, observation and participatory methods (19). Variables in the objective function of (4) include market value of crop, milk, butter, and live animals. Variables that form the constraint set include crop area (hectares), fertilizer and pesticides expenses (Ethiopian birr), oxen inputs(oxen-days), seed (kg), labour for crop production (man-days), number of milking cows, roughages (kg), labour for dairying (man-days), use of atela or by product of brewing (in litre), feed and veterinary expense (Ethiopian birr), concentrate fed (in kg), farming experience (years), area of stubble feeding and grazing areas (hectares).

Variables that are anticipated to cause variation in production efficiency include years of farming experience, number of years of schooling, number of visits by extension agents, worker:consumer ratio (the ratio of independent to the number of dependent members of the family), region (0-1 variable), number of technologies adopted and production knowledge.[6]

There is no hard and fast rule to measure or quantify production knowledge. Studies in cognitive psychology have demonstrated the usefulness of measuring knowledge using problem solving tests or comprehension ability (5,7).

[6] The regional dummy is expected to reflect the impact of the comparative advantage of each region on the viability of crop and livestock enterprises.

Problem solving tests were constructed to measure agricultural knowledge and skills related to current production technologies and practices. The tests were intended to examine the kinds of solutions households provide to crop and livestock production problems based on their agricultural knowledge. For instance, farmers who plant barley were presented with the following problem solving task:

> Your barley plants are stunted exhibiting yellowish colour and do not grow tall enough to produce good seed. What are the possible causes of this problem? How may it be prevented?

The information used in solving such problems come from schooling, contacts with extension agents, friends, relatives and experience. Answers obtained from problem solving tests are scored to compare variations in knowledge of farmers within and between regions. The basis for scoring are answers obtained from group discussions with farmers of different age-groups. The premise behind this basis for scoring is that experience and indigenous knowledge vary by age. Answers from group consensus are believed to reflect solutions to actual problems of farming in the study regions. A score of 1 to 10 is prepared and individual farmers response are ranked relative to the answers given by the group.

Empirical Results of Data Envelopment Analysis (DEA)

Aggregate measures of efficiency such as DEA rely on very few assumptions. It has the ability to incorporate both crop and livestock enterprises in a single model. In so doing, it is possible to compare all farmers relative to those whose efficiency measures 1.00. The results of DEA are presented in Table 2.

Table 2. Percentage of Producers Grouped by Efficiency Scores obtained from Data Envelopment Analysis

Ranges	Efficiency Mid-point	Selale Test Farmers	Ada Test Farmers	Selale Control Farmers	Ada Control Farmers	All Selale Farmers	All Ada Farmers
0.00-0.5	0.255	2.2	0	6.1	0.4	7.6	1.8
0.51-0.6	0.555	2.3	5.5	6.3	4.4	4.6	9.4
0.61-0.7	0.655	10.5	6	11.2	3.7	9.2	1.9
0.71-0.8	0.755	17	15.3	12.5	11.1	11.2	10.1
0.81-0.9	0.855	13.4	13.7	18.8	18.5	16.6	11.3
0.91-1.00	0.955	55.6	69.5	45.1	61.9	50.8	65.5

The results indicate that a large percentage of Ada farmers received higher production efficiency scores than Selale farmers. The percentage of test farmers whose efficiency score lies between 0.9 and 1 is 56 and 70 for test farmers in Selale and Ada regions respectively. Ada is a predominantly crop production region. The region is closer to major markets, has better access to markets and other infrastructural facilities 9 roads, means of transport, etc.) compared to Selale. Moreover, a cash crop called teff (*Eragrostis Abyssinica*) is widely cultivated in this region. These factors may enable Ada farmers to earn greater cash income from crop farming compared to Selale farmers. Furthermore, the availability of infrastructures and attractive market prices may increase the incentive to produce greater output with minimal outlay of inputs. Test farmers in Ada region are provided with cross-bred cows in a relatively risk-free environment compared to farmers in the Selale region. These factors may have contributed to greater efficiency scores among test farmers compared to the control group. Similar differences in efficiency scores are observed among control farmers between Selale and Ada regions, and between all Selale and all Ada farmers.

The results also confirm that test farmers in both regions are more efficient than control farmers. Crop specific production efficiency scores computed using parametric production efficiency analysis methods showed that test farmers are more efficient than control farmers (19). These results suggested that strategies that are designed to increase production efficiency may help to alleviate food shortages in the Ethiopian highlands.

Peasant production structure in Ethiopia involves a mixture of crop and livestock enterprises. These enterprises are complementary and competitive. They are complementary because output from one enterprise helps to boost production in the other enterprises. They are competitive because they compete for the limited physical and financial resources of peasants. Thus, it would be instructive to examine the association of production efficiency scores by major components of crop and livestock enterprises. Table 3 presents the relationship of efficiency scores with selected socio-economic characteristics of farmers.

The results indicate that producers who own large number of livestock obtain greater production efficiency score compared with farmers who own few livestock. Farmers who cultivate greater farm size are those who owns large number of livestock. Thus, producers who own large number of livestock and cultivate relatively large farm size are more efficient than those who own few livestock and cultivate smaller farms.

Experience while households are under parents supervision did not exert significant impact on production efficiency. This may be due to the incremental or cumulative characteristics of experience. That is, the experience after households become independent include experience prior to becoming an independent farmer. As observed, experience after becoming an independent farmer exert significant impact on production efficiency.[7]

Production efficiency increases with increases in crop area, number of cows, production knowledge, number of livestock, worker:consumer ratio and grazing area. Greater increases in production efficiency is observed when worker:consumer ratio is >1.5, grazing area is >1.5

[7] Experience under parents supervision and after becoming an independent farmer had a correlation coefficient of 0.05 and the correlation was statistically insignificant. That is why both variables were included in the regression analysis.

Table 3. Relationship Between Selected Socioeconomic variables and Production Efficiency

Production Efficiency Score	Worker:Consumer Ratio	Area of:		Number of:		Production Knowledge	
		Crop	grazing	Cows	Livestock	Crop	Livestock
0.4	0.62	1.2	1.3	1	2.1	5.6	4.6
0.5	0.62	1.5	1.4	2.3	2.25	5.71	5.7
0.6	0.67	1.52	1.41	2.31	2.5	5.72	6.8
0.7	0.78	1.8	1.46	2.4	3.2	6.45	6.9
0.8	0.98	2.5	1.7	2.38	3.8	7.78	7.9
0.9	1.22	2.7	1.81	2.45	6.5	8.33	8.9
0.95	1.5	2.8	1.93	2.5	7.67	9.1	9.4

hectares, crop area is >3 hectares, number of cows is >3 and when production knowledge is >7 (see Table 3).

Explaining Differences in Production Efficiency

Results of logistic regression of factors influencing production efficiency are presented in Tables 4 and 5. All variables exert a positive and significant impact on production efficiency scores of test farmers. The impact of education, production knowledge and number of technologies adopted is greater than other variables in both study sites. These factors relate to skills of decision making that incorporate indigenous knowledge and knowledge gained from secular education. Thus, if production efficiency in peasant agriculture is to be increased, skills that augment or complement new agricultural technologies should be focused on.

The findings also indicate that the number of technologies that exert greater impact on production efficiency differ between the study regions. The empirical results consistently indicate that adoption of one or two technology(ies) greatly influence production efficiency in Selale region while adoption of two or more technologies exert greater impact on production in the Ada region. Sustainable increases in production efficiency, therefore, requires an appropriate mixes of technologies to match the skills and experiences of decision makers.

Region tend to affect the enterprise in which it has greater comparative advantage. Extension education do not significantly contribute to production efficiency. It may imply that the methods of delivery or contents of extension education have to be changed or modified so that it would exert positive and significant impact on production decisions.

Table 4. Impacts of Selected Variables on Measures of Efficiency [1/]

	Selale region		Ada region	
Variables	Test	Control	Test	Control
Intercept	1.015	2.118	1.102	2.07
	(2.454)**	(2.6)**	-1.963	(2.92)**
Depenexp	0.151	0.211	0.211	0.341
	-1.784	-1.91	(3.022)**	(3.17)**
Indepexp	0.651	0.443	0.793	0.503
	(2.987)**	-1.65	(4.98)*	(3.1)**
Education	0.355	0.183	0.489	0.179
	(4.376)*	-1.76	(2.273)**	-1.09
Extension Education	0.211	0.017	0.231	0.022
	-1.99	-1.61	-1.481	-1.8
Worker:consumer Ratio	0.584	0.437	0.444	0.394
	(2.97)**	(3.09)**	(3.124)**	(3.667)**
Region	0.454	0.51	0.011	0.231
	(3.981)**	(3.01)**	-1.544	(2.957)**
Production Knowledge	0.894	0.803	0.987	0.901
	(4.312)*	(4.4)*	(3.101)**	(4.8)*
One Technology	0.514	0.193	0.455	0.274
	(3.15)**	-1.172	(3.784)**	-1.04
Two Technologies	0.629	0.31	0.631	0.511
	(4.98)*	(2.954)**	(6.874)*	(4.48)*
Three technologies	0.401	0.297	0.622	0.531
	(2.91)**	-1.46	(3.12)**	(3.98)**
N	216	214	52	50
Chi-Square	48.7*	52.01*	47.4*	46.9*

1/ Values in parenthesis are t-statistics.

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

Table 5. Impacts of Selected Variables on Measures of Efficiency[1/]

Variables	All Selale farmers	All Ada farmers
Intercept	1.015	2.102
	(4.454)*	(2.963)**
Depenexp	0.151	0.211
	-1.784	(3.022)**
Indepexp	0.351	0.493
	(3.987)**	(4.98)*
Education	0.255	0.389
	(2.376)**	-1.973
Extension education	0.111	0.201
	-1.49	-1.981
Worker:cons.ratio	0.384	0.344
	(2.97)**	(2.124)**
Region	0.454	0.011
	(2.981)**	-1.544
Production Know.	0.894	0.987
	(4.312)*	(6.101)*
One Technology	0.314	0.355
	(3.15)**	(2.984)**
Two Technologies	0.429	0.631
	(2.98)**	(4.874)*
Three technologies	0.31	0.618
	(2.91)**	(4.12)*
N	216	52
Chi-Square	55.8*	46.9*

1/ Values in parenthesis are t-statistics.
* and ** indicate statistical significance at 1 and 5 percent respectively.

Summary

The aggregate efficiency scores indicate that Ada farmers are more efficient than Selale farmers. Test farmers of both study sites are more efficient than control farmers. Intervention strategies in one enterprise help boost production in complementary enterprises. Increases in crop production from the use of fertilizer and pesticides increase household income which in turn boost livestock production. The converse also holds true. This may be the reason for higher efficiency scores of test farmers who adopted on or two technology(ies) (Selale) and at least two technologies (Ada) compared to control farmers.

Many LDCS heavily invest in extension education. As the present study demonstrates extension education doesn't exert significant impact on production efficiency. Thus, it may be necessary to find ways of modifying or improving the contents or delivery mechanisms of extension education so that it will significantly contribute to increases in production efficiency.

Skill related variables greatly contribute to variations in production efficiency. The result also indicate that intervention strategies should focus on methods of integrating indigenous production knowledge and secular education with skill embodied in new agricultural technologies. It is only when this combination is compatible with conducive socioeconomic conditions that sustainable increases in production attained (19).

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