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EFFECTS OF ANIMAL TRACTION ON SUBSISTENCE LEVEL FARMING IN BOURKINA FASSO : PRODUCTION FUNCTION ANALYSIS

BARK PYEONG-MU*

ABSTRACT

This study was concerned with the following two major hypotheses within the setting of subsistence level farming in Bourkina Fasso : the introduction of an animal traction (AT) program has a positive effect on the productivity per unit land area, and the AT program, known as a labor-saving technology, is also an innovative technology. The study used a functional analysis. From the analysis of results the author concludes:

1. In the case of corn and peanuts, labor, capital and animal traction variables are statistically significant and positive. In the case of millet production, the labor variable is only significant, while in the case of sorghum production the capital variable is most significant,

2. The results show some substitutability between millet and sorghum crop productions,

3. The translog production function estimates for millet suggest several implications such as there exist different levels of technology use between AT and non-AT farms, and there exist not only different shapes of production functions but also different input factor orientations between AT and non-AT farms,

4. Within the context of translog production function in the case of millet production, the results indicate that the production process of non-AT farms seems to be heavily dependent upon labor input and that of AT farms relies on labor, capital and animal power input, and

5. The study draws an inference that in the case of millet production, an AT program may be considered an innovative technology.

I. Introduction

The sub-Saharan African countries have been experiencing chronically low

*Senior Research Scientist, Center for Science and Technology Policy(CSTP), Korea Advanced Institute of Science and Technology(KAIST), P. O. BOX 150, Korea.

agricultural productivity and declining per capita food production. Prospects for rural development in the region appear to be much poorer than in the rest of the developing world. Furthermore, it is likely that this trend is part of a long-term trend. The food crisis in sub-Saharan African countries will likely persist, and it will probably require those poorest countries to be heavily dependent upon enormous quantities of food imports from the rest of the world.

One of the reasons for the failure to improve the productivity of the agricultural sector in the region is, perhaps, that the agriculture of subsistence level farming in this area is still in a traditional stage and well behind the level of technology enjoyed by the rest of the world (Wharton). In this particular set of rural areas, the sub - Saharan African countries, there has been a dramatic increase in development assistance since 1970. Despite foreign assistance including the establishment of regional research centers, very little, if any, has gone to farmers' fields "with any major impact on farm yields for cereals in west African countries"(*Singh et al.).*

The use of animal traction (AT) has been recognized as technology which is appropriate for subsistence level farming in an area where most of the farming operations are labor intensive. One of the major purposes of development programs in these regions is to increase agricultural production and rural incomes in the area through the introduction of an animal traction (AT) program (Barrett *et al.*). The use of animal draft power is thought to enhance farm produtivity by alleviating major labor constraints resulting in 1) an increase in labor productivity, 2) relieving seasonal labor bottle-necks, and 3) increases in yields.

Utilization of animal power is generally considered as the first step toward modernization in the setting of a highly traditional agricultural production system such as exists in the sub-Saharan region. Nevertheless the results of recent efforts toward modernization of the agricultural production system supported by foreign donors and local African governments seem to be inconclusive (Sargent). It is therefore of interest to further evaluate the economic effects of animal traction technology on agriculture of the region. The purpose of study is to provide an attempt in that direction by undertaking an in-depth study of the following issues :

1. whether the introduction of AT has a positive effect on yield per unit of land area, and

2. whether an AT program, known as a labor-saving technology, is an innovative technology or whether it is a simple substitute for labor.

The uniqueness of the study lies in the fact that this is the first serious empirical work that examines,with the help of farm (micro) level data gathered through household surveys in Bourkina Fasso, the econmics of animal traction using rigorous econometric analysis. The findings will fill an important empirical gap in our existing literature on the subject, particularly for the African LDCs. Second, it is hoped that the results of the analysis will have certain implications relevant to public policy concerning the program including research and development.

Ⅱ. The Data

This study draws upon the data gathered from three rural regions of the central (Mossi) plateau of the Bourkina fasso as part of Purdue University's regional project.[1] A three - stage selection procedure was followed to choose the regions within the country's rural development organizations (ORDs), the villages within the region, and finally the households within the villages. In total, there were seven villages and 105 households(menages) which were selected through random sampling procedures. The regions and villages were purposely selected on the basis of rainfall, soil type, crop patterns, and potential for incorporation yield-increasing technology. Of the seven villages and 105 households in the initial sample, only five villages and sixty households were retained for intensive day-to-day socio-economic investigations and agronomic trials in farmers' fields.

The household data were gathered with the help of pre - tested and structured questionnaires and through personal interviews conducted by local field investigators and graduate supervisors. The investigating personnel stayed in the villages for the entire survey period of the agricultural year 1980. Each household in the sample was visited once a week for the purpose of intensive interviews. Such personal visits and interviews were carried out continuously during the entire agricultural production year, which helped to capture the important seasonal characteristics of agricultural and other economic activities that are performed by rural households.

Spreading the economic surveys across the slack, the peak and the semi-peak(or slack) periods were considered particularly useful for the study of labor time usage of household members. The major components of the questionnaires consisted of production systems that covered the land-use patterns, use of farm inputs, timing of operations, and cropping patterns and yields ; labor time allocation of each member of the household to different activities ; and the family's demographic and socio-economic features.

Ⅲ. The Model

Schultz argues that there are tendencies, in small subsistence level farming,

[1] Farming Systems Research under the Semi-Arid Food Grain Research and Development(SAFGRAD) Project, Purdue University, was led by Dr. Ram Das Singh. He was a team leader of Purdue's Farming Systems Research Unit in Bourkina Fasso during 1979—1981. For details, see Singh *et el*.

to keep a stagnant level of skills and to change little in "the state of preference and motives for holding and acquiring sources of income." He points out that these tendencies lead to a particular economic equilibrium at low levels of resource productivity. In this sense, setting up a function that becomes the object of the maximization of total profit or net income is not necessarily a relevant approach to modeling subsistence level farming behavior. The problems of finding the best representation of an objective function for subsistence level farming production have been discussed by Lunning, Ruthenberg, and Welsch. However, they do not seem to be successful in suggesting the best function which would be appropriate within the setting of small subsistence level farms.

Even though a wide range of production functional forms is available, selection of an appropriate form may not be accomplished easily without some guidance from several sources. As Hayami and Ruttan suggested, nice properties of the Cobb-Douglas production funtional form have attracted many empirical studies to use it. However, using a Cobb-Douglas form may also cause some practical problems such as multicollinearity and heteroscedasticity. There exist questions about orthogonality between log transformed values of input variables and between those of input variables and error terms. Since there is a certain range of production scale through the sample households, it is more likely that the variance of dependent variables depends upon the magnitude of crop production.

As indicated by Intrilligator, problems of multicollinearity and heteroscedasticity stemming from use of the Cobb-Douglas form can be avoided when we estimate an intensive production function in log form.[2] However, to estimate an intensive production function, one must make the assumption of constant returns to scale, and hence we cannot test decreasing or increasing returns to scale. To overcome some of the problems associated with aggregate production functions, this study estimates separately the production functions for each of the four major crops : millet, sorghum, peanuts and corn (maize). Based on economic theory and literature, an estimable model is formulated as follows :

$$(1) \qquad Q_{ij}=A_i N_{ij}^{a1} K_{ij}^{a2} A T_{ij}^{b3} exp^{u_{ij}}$$

where subscripts i and j represent i^{th} crop and j^{th} household ; Q, total crop yield(Kg) per hectare of the crop ; N, total labor hours (man-hour during the production period) per hectare ; K, total stock value (in CFA, 1 U. S. dollar=225–250 CFA) of equipments per hectare; and u, disturbance term assumed to be independently and identically distributed (iid) Gaussian.

[2] For example, in a capital-labor onput case the equation is : $In(Y/L)=a+b\ In(K/L)+u$, Where Y is an output, K is a capital, L is a labor input and u is an error term.

The study uses pooled data for estimating the production function. It may be pertinent to raise a question about structural differences within the context of a given production functional form (e.g., intensive type of Cobb-Douglas form) between AT and non-AT subsamples. Estimated structural differences in the production function indicate different processes or levels of production technology.

Since, in general, four major crops are raised by households, it is more likely that there may be non-zero correlations between the disturbance terms across those four major crop production equations. And if it is true, the ordinary least squares (OLS) estimators are no longer the most efficient ones (Johnston, pp 238-240). To produce more efficient estimates of our production model, the study uses the "seemingly unrelated regression(SUR)" method.

In a Cobb - Douglas production functional form, it is assumed that both the elasticity of scale and the elasticity of substitution are fixed regardless of the level of the factors of production. This is mainly due to the fact that most econometric studies about production functions focus on finding an approximate form that shows a relevant production process with the given finite data. Estimating production function within this context requires simplifying restrictive assumptions such as homotheticity and constant elasticities of scale and substitution (Griliches and Ringstad, p. 7). However, in a more realistic case, the elasticities of scale and of substitution are not fixed because they depend upon the level of each of the input factors. One of the production functions that permits relaxation of these restrictive assumptions is the translog production function[3] which is actually a generalized Cobb-Douglas form (Griliches and Ringstad; Christensen, Jorgenson and Lau). The algebraic form of the translog production function is expressed in equation (2) with the same definitions of the variables as given for equation (1)

$$(2) \quad \begin{aligned} Ln\ Q_{ij} = {} & A_i + B_1\ Ln\ N_{ij} + B_2\ Ln\ K_{ij} + B_3\ Ln\ AT_{ij} \\ & + C_1(Ln\ N_{ij})(Ln\ K_{ij}) + C_2(Ln\ N_{ij})(Ln\ AT_{ij}) \\ & + C_3(Ln\ K_{ij})\ (Ln\ AT_{ij}) + D_1(Ln\ N_i)^2 \\ & + D_2(Ln\ K_{ij})^2 + D_3(Ln\ AT_{ij})^2 + u_{ij} \end{aligned}$$

Estimation of translog production function requires more reduction of degrees of freedom than estimation of Cobb-Douglas form does simply due to the fact that interaction terms and quadratic terms in the input variables are involved in translog form. Due to a small number of observations in our sample, we were only able to estimate a translog production function for the case of millet production.

[3] "Transolg" is an abbreviation of "transcendental logarighmic."

Ⅳ. Results

The results of the test of constant returns to scale for four major crops utilizing estimated coefficients of total yield production and net income using the Cobb-Douglas production function are presented in Table 1. The *F*-values of total yield production and net income functions suggest that sums of parameter estimates of millet, corn and peanuts are considered unitary at the conventional significance level (5 percent level). The sums of estimated coefficients of the production function and the net income function for sorghum are significantly different form unitary at 5 percent level. However, when the level of the test for constant returns to scals is 10 percent, the hypothesis cannot be rejected. This implies that the focus of estimation should be the intensive form of the Cobb-Douglas production function.

Table 2 presents the regression coefficients estimated using the weighted ordinary least squares (WLS) regression method (Wannacott and Wannacott, pp. 431-432) for per hectare yield functions for millet, sorghum, corn and peanuts. The results of the WLS regression with a common intercept for all the four major crop production functions are also introduced in Table 2. The intensive form of the Cobb-Douglas production function seems to fit well in the case of corn and peanut production. All the estimated coefficients are positive and statistically significant. In the case of millet production, the labor input is the only variable that truns out to be significant. In the case of sorghum production, the labor input turns out to be significant when a common intercept is used otherwise it appears insignificant. The capital input is significant in both regressions. The results of the WLS regression may imply that labor oriented production behavior is used for millet production. Considering the effect of AT on crop productivity, the elasticities of the AT variable range from 0.1 to 0.2, except for millet. This means that given the intensive form of the Cobb-Douglas production function, the introduction of animal traction does increase the per hectare yield (productivity) except in the case of millet production.

Since the Cobb-Douglas production function has unitary elasticity of substitution (Henderson and Quandt, p. 62), the curvature of the isoquants for a particular input combination is constant. Since the production functions considered here involve three inputs, more sophisticated interpretations are needed. However, due to the diffculty of the interpretation, this type of analysis has not been performed(McFadden, pp. 73-83). This simplification makes it difficult to analyze the differences between technology improvements and simple substitution effects due to an AT program. However, it is obvious that AT is an important input factor that causes an increase in crop productivity.

Within the constraints of resources such as land and labor in our sample, competition among the four major crops, particularly between millet and sorghum, is expected to lead to intercorrelations across those production

TABLE 1. **Estimated Returns to Scale of Four Major Crop Productions, Bourkina Fasso, 1980**

	Sum of Parameter Estimates	F–Value [1]	PB [2]
Total Yield Production:			
Corn	1.026	0.0301	0.8632
Peanuts	1.105	0.2951	0.5899
Millet	0.890	1.1770	0.2836
Sorghum	0.616	3.3521	0.0746
Net Income Function:			
Corn	1.022	0.0147	0.9043
Peanuts	1.131	0.4733	0.4953
Millet	0.891	1.3570	0.2921
Sorghum	0.613	3.3089	0.0764

[1] *F*–Value is for the test of constant returns to scale with the null hypothesis that the sum of parameter estimates is unitary.
[2] PB value is a probability of accepting the null hypothesis.

TABLE 2. **Estimated Regression Coefficient Using Weighted Regression Method[1], Bourkina Fasso, 1980**

	Corn	Peanuts	Millet	Sorghum
Labor	0.589(5.35)*	0.253(1.50)****	0.274(2.05)**	−0.016(−.14)***
Capital	0.098(2.57)*	0.148(1.84)***	0.014(0.47)	0.300(3.24)*
Animal	0.141(1.96)****	0.216(2.20)**	0.028(0.41)	0.086(1.04)
Intercept	2.021(2.64)*	4.237	4.254	6.334
	N=186	F=11.858*	R^2=0.511	
Labor	0.313(3.91)*	0.244(3.22)*	0.268(3.87)*	0.301(4.43)*
Capital	0.067(1.73)***	0.149(1.83)***	0.041(0.45)	0.242(2.57)*
Animal	0.107(1.45)****	0.215(2.21)**	0.027(0.40)	0.105(1.23)
Intercept		4.294(10.07)[2]		
	N=186	F=12.419*	R^2=0.463	

[1] Dependent variable=Total yield per hectare (logged).
[2] *F*–value for testing equal intercept for four major crop regressions is 1.7033 with degrees of freedom 3 (for numerator) and 170 (for denominator).
[3] Figures in parentheses are *t*–values.
* Significant at 1%
** Significant at 5%
*** Significant at 10%
**** Significant at 15%

equations. Table 3 represents variance-covariance matrices of residual errors from OLS regression analyses for the four major crop production functions. As evident from the results, millet and sorghum are clearly competitors within the setting of subsistence level farming in Bourkina Fasso. It also appears that the other crop productions, namely corn and peanuts, are not strongly related with any other crop production.

Table 4 compares the results from OLS and SUR by crop. The OLSI and SURI used a sample data set of 32 households which cultivated all four

TABLE 3. **Correlation Matrices of the Residual Errors Across Models, Bourkina Fasso, 1980**

	Corn	Millet	Sorghum	Peanuts
Corn	1.00	0.05	0.07	−0.04
Millet		1.00	−0.45	0.07
Sorghum			1.00	0.03
Peanuts				1.00

TABLE 4. **Estimated Regression Coefficients Resulting from OLS and SUR[1], Bourkina Fasso, 1980**

	OLS	OLSI	OLSII	SURI	SURII
			Millet		
Labor	0.274(2.79)*	0.266(1.81)**	0.304(2.88)*	0.243(1.85)***	0.310(3.04)*
Capital	0.014(0.64)	−0.036(−0.21)	0.015(0.66)	0.042(0.27)	0.003(0.15)
Animal	0.028(0.56)	0.021(0.29)	−0.001(−0.02)	−0.009(−0.14)	−0.033(−0.61)
Intercept	4.254(6.83)*	4.375(5.45)*	4.095(6.15)*	4.451(6.21)*	4.113(6.39)*
N	51	32	45	32	45
F	2.876**	1.68	2.95**		
R^2	0.155	0.153	0.178	0.279	0.184
			Sorghum		
Labor	−0.016(−0.12)	−0.114(−0.78)	−0.016(−0.12)	−0.103(−0.12)	−0.058(−0.46)
Capital	0.299(2.79)*	0.348(2.56)**	0.299(2.79)*	0.334(2.80)*	0.301(2.91)*
Animal	0.086(6.90)	0.132(1.17)	0.086(0.90)	0.183(1.84)***	0.099(1.07)
Intercept	6.334(7.61)*	7.058(7.53)*	6.334(7.61)*	6.965(8.36)*	6.600(8.20)*
N	45	32	45	32	45
F	2.730***	2.36**	2.730***		
R^2	0.167	0.202	0.167	0.279	0.184
			Corn		
Labor	0.589(4.67)*	0.645(4.69)*		0.627(4.67)*	
Capital	0.098(2.25)**	0.002(0.4)		0.011(0.18)	
Animal	0.141(1.72)***	0.106(1.13)		0.107(1.16)	
Intercept	2.021(2.30)**	2.749(2.40)**		2.778(2.48)**	
N	44	32		32	
F	12.03*	7.38*			
R^2	0.474	0.442		0.279	
			Peanuts		
Labor	0.253(1.59)****	0.124(1.50)		0.112(0.55)	
Capital	0.148(1.96)***	0.099(0.79)		0.109(0.88)	
Animal	0.216(2.34)**	0.176(1.61)****		0.169(1.55)****	
Intercept	4.237(4.31)*	5.249(4.31)*		5.307(4.38)*	
N	46	32		32	
F	4.284*	1.27			
R^2	0.234	0.120		0.279	

[1] Seemingly unrelated regression. Dependent variable=Total yield per hectare(logged).
[2] Figures in parentheses are t−values.
* Significant at 1%
** Significant at 5%
*** Significant at 10%
**** Significant at 15%

major crops, and OLSII and SURII took a 45 household subsample characterized by the fact that they planted millet and sorghum together. Since OLSI and SURI used a reduced number of households from the original sample of households, the results may not be consistent with those of the OLS with a full complement of households or the results from OLSII and SURII with 45 households. The facts that the pairwise correlation coefficients for corn or peanuts with all other crops are fairly low and that there exists a significantly negative correlation between millet and sorghum suggest the results from OLS with full households for corn and peanut production and those from OLSII and SURII for millet and sorghum production should be used for an appropriate analysis in the study. The estimated coefficients do not seem to have changed drastically by the SUR method. However, statistics for these estimates improve to some extent. It seems that the SUR method does not make any significant difference in interpreting the results from the OLS analysis with the full households. Improvement in the efficiency of the estimates is the primary goal of using SUR.

The results from the OLS and SUR estimations may suggest two possible conclusions. First, the intensive form of the Cobb-Douglas function fits well for both corn and peanut production data. Furthermore, if the intensive form is considered appropriate for millet and sorghum production the following points emerge. The labor input is the only input variable which contributed to an increase in productivity in the millet production case. Hence, animal traction may not seem to have a significant influence on productivity. In contrast, in the sorghum production case, it is the capital input which appears the most influential, while animal traction has some moderate impact on productivity per hectare. The second implication is that specification of the intensive form of the Cobb-Douglas function is not correct in the case of millet and sorghum production.

Table 5 compares the results from the Cobb-Douglas and translog production functional forms with subsamples of AT households and non-AT households in the millet production case. A translog production function with the full (pooled) sample of households has also been estimated. A multicollineatity problem is inevitable in estimating the translog form because of the presence of quadratic terms in each input variable.[4] This problem inhibits the use of R-square and t-ratios for judging the statistical precision of the model.[5] Table 6 presents the estimated coefficients from two restricted translog forms for millet production. The results from the reduced form I and reduced form II are much better than those from the translog form based upon the AT subsample. The multicollinearity problem is resolved to some extent and the statistics for testing the goodness of fit of the model and the significance of individual coefficient estimates have been considerably improved.

The results from estimating the translog production function indicate a couple of important points that need to be addressed with respect to millet production. First, it is quite likely that the production process(or behavior)

TABLE 5. **Comparison of the Estimated Coefficients between Cobb-Douglas and Translog Production Functions for Millet, Bourkina Fasso, 1980**[1]

	Cobb–Douglas		Translog		
	Non-AT	AT	Non-AT	AT	Pooled
Labor(L)	0.333(2.52)*	0.144(0.96)	–5.074(–3.44)**	4.811(1.29)	–3.809(–2.81)**
Capital(K)	0.031(0.96)	–0.013(–0.44)	–0.285–0.81	–1.975(–1.87)***	–398(–1.28)
Animal Traction(A)		0.129(1.17)		0.411(0.27)	0.635(1.12)
L×L			0.429(3.57)**	–0.429(–3.32)	0.329(2.96)**
K×K			0.041(0.74)	–0.000(–0.02)	0.018(1.65)***
A×A				–0.277(–1.84)**	0.038(0.65)
L×K			0.008(0.49)	0.298(1.54)****	0.044(0.82)
L×A				0.143(0.57)	–0.106(–1.26)
K×A				0.046(1.20)	–0.020(–1.41)
N	30	21	30	21	51
F	3.577*	0.928	5.35**	1.46	3.07 **
R^2	0.21	0.14	0.53	0.54	0.40
Factor–Test[2]					
L			8.52**	1.17	6.23**
K			1.25	2.08****	1.75****
A				1.48	0.92

[1] Dependent variable =Total yield per hectare (logged).
[2] Joint test on all the parameters involving the factor. The test tests the hypothesis that the parameters for all combined are all zero.
[3] Figures in parentheses are t–values.
* Significant at 1% level.
** Significant at 5% level.
*** Significant at 10% level.
**** Significant at 15% level.

[4] The three highest condition indices of multicollinearity are 157.1, 218.6 and 751.0, which indicate that there are severe multicollinearity problems. Some of coefficients of the correlation of estimates give an idea where the multicollinearity problem comes from. They are presented in the following form of the correlation coefficient matrix.

	Capital (K)	Animal Tracion (A)	L∗K	L∗A	K∗A
L	– 0.67	–0.17	0.69	0.21	0.10
K		0.18	–0.99	–0.23	–0.20
A			–0.22	–0.92	0.21
L∗K				0.17	0.10
L∗A					0.13

The study found that even though the estimate of the interactive term of labor and capital is highly correlated with the estimate of capital, dropping one of them would neither improve the model in terms of the multicolinearity problem(the highest condition index changed from 715 to 667) nor in terms of R–square measure(R–square drops from 0.53 to 0.25) and F–value (F–Value drops from 2.095 to 0.760).

[5] For an understanding of the entire main consequences of multicollinearity, see Johnston, P. 160.

TABLE 6. **Estimated Coefficients from Some Restricted Forms of Translog Millet Production Functions, at Households[1], Bourkina Fasso, 1980**

	Original Equation	Reduced Form I[2]	Reduced Form II[3]
Labor(L)	4.811(1.29)[4]	4.697(1.79)*	4.759(3.37)*
Capital(K)	−1.975(−1.87)*	−1.939(−2.95)**	−1.952(9.04)***
Animal Traction(A)	0.411(0.27)	1.199(2.13)**	
L×L	−0.429(−1.32)	−0.394(−1.88)*	−0.435(4.28)*
K×K	−0.000(−0.02)		
A×A	−0.277(−1.84)*	−0.257(−1.88)*	−0.269(3.90)*
L×K	0.298(1.54)****	0.291(2.81)**	0.295(8.22)**
L×A	0.143(0.57)		0.205(4.96)**
K×A	0.046(1.20)	0.046(1.29)	0.044(4.28)*
N	21	21	21
F	1.46	2.10****	2.19*
R^2	0.54	0.53	0.54

[1] Dependent variable = Total yield per hectare(logged).
[2] Reduced Form I is the case when the square term of capital (K × K) and interactive term of labor and animal traction(L × A) are dropped.
[3] Reduced Form II is the case when animal traction (A) and the square term of capital (K × K) are dropped.
[4] Figures in parentheses are t - value.
* Significant at 10% level.
** Significant at 5% level.
*** Significant at 1% level.
**** Significant at 15% level.

between the AT households and non-AT households is different. This suggests the possibility of different levels of technology use between the two subsamples. Hence, if AT has a positive effect on the productivity, then it may be inferred that AT shifts the level of technology, thus making AT an innovative technology. Second, those two subsamples not only have different shapes for the production function but also possess different input factor orientations. The results of estimating the translog production form for both AT and non-AT farmers indicate that the production process of the non-AT households (which are using only labor and capital inputs) seems to be heavily dependent upon labor inputs and the production process of the AT households relies on all three input factors ; labor, capital and animal traction. This may indicate some form of an advanced technology for producing millet in such a way that capital and labor are efficiently utilized with the introduction of an AT program.

V. Conclusion

Within the setting of the subsistence level farming in Bourkina Fasso, the hypotheses were tested with respect to followings : (1) the introduction of an animal traction program has a positive effect on the productivity per unit land area, and (2) an AT program, known as a labor-saving technology, is also an innovative technology.

The major findings can be summed up as follows.

1. In the case of corn and peanuts, labor, capital and animal traction variables are statistically significant and positive. However, in the case of millet production, the labor variable is only significant, while in the case of sorghum production, the capital variable is most significant.

2. Animal traction contributes to improved per hectrare yield(productivity) except in the case of millet.

3. The results show some substitutability between millet and sorghum, and this is reasonable in the setting of substence level farms in Bourkina Fasso.

4. The translog production function estimates for millet suggest a couple of improvement implications : a) there exist different levels of technology use between AT and non-AT households and b) there exist not only different shapes of production functions but also different input factor orientations between the AT and non-AT households.

5. Within the context of the translog production function in the case of millet production, the results indicate that the production process of non-AT households seems to be heavily dependent upon labor input and that of AT households on labor, capital and animal power input.

That whether animal traction is an innovative technology or it is a simple substitute for labor is not directly verified in this study. However, several findings from this study provide support in these regards. It is likely that some results from the study may indicate the existence of different patterns of production. In the case of corn and peanuts, an AT program may appear to substitute for labor. In this rather simple labor-saving technology setting, an AT program does not shift the technology level. In the case of sorghum and millet, particularly the latter, the introduction of an AT program may alter the pattern of production.

The study found that the translog production function fits more appropriately than the Cobb-Douglas form in the millet case. And, the result of estimating the translog form suggests different levels of technology exist for the AT and non - AT households. The study draws an inference that in the case of millet production an AT program may be considered an innovative technology leading to an increase in labor productivity as well as in land productivity. The introduction of an AT program in the case of millet production will imply some form of an advanced technology in such a way that capital and labor inputs are more efficiently utilized.

The study had several primary and important assumptions. One of them was the homogeneity of the AT program across the households using animal traction. This was due to the lack of information about the experience of the AT program of each household. It has been pointed out by some researchers, although without any supporting evidence, that the essential requirement for a successful AT program is experiencing the program for more than ten years with the appropriate conditions and supprots (Jaeger). The second assumption was the homogeneity of land quality and the constant returns to scale of the productions of four major crops. Since land quality is the dominant factor in the cropping patterns in our sample data, breaking down into four major crops may relax this constraint to some extent, but not completely.

The total production function of the Cobb-Douglas form verifies the constant returns to scale of the four crop production. However, in our sample region, land area is not a binding production constraint yet (Spencer and Byerlee, p.876). Due to the above mentioned simplified assumptions, our results, to some extent, have distorted some of the real facts about the subject. Nevertheless, it provides some extremely relevant results about the effects of an AT program.

It is generally observed that a mixed cropping pattern is universal in the subsistence level farms in Bourkina Fasso and elsewhere in the sub-Saharan region (Singh *et al.,* p. 18). It was, therefore, difficult to separate input use by the individual crops grown in associations. For instance, labor hour input in the case of millet production was not used, solely to produce millet. In a setting such as this the results may be underestimated. Further, in view of the differences in soil quality the production functions for the major crops should be considered as field production functions of four major crop fields, which are closely related with land quality. It is highly desirable that more precise decomposed data will be collected from sample households for further study in the future.

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