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ECONOMICS OF ANIMAL WORK VERSUS MECHANIZATION FOR EGYPTIAN AGRICULTURE

BY
Soliman, Ibrahim
Professor of Agricultural Economics
Department of Agricultural Economics, Faculty of Agriculture
Zagazig University, Zagazig, Egypt

ABSTRACT

The present study depended upon several successive farm management field surveys over the period 1981-1987. The analysis focused upon the socio-economic issues associated with the interrelationships between the different working power usage for agriculture in Egypt, particularly mechanization and animal work. The major objective was to find out the approach towards appropriate technology. The major findings showed that the share of mechanization in the gross HP applied for agriculture has recently reached about 90% while animal work share has diminished to less than 5%, but human labor intensity has not changed significantly over the last decade. The least cost combination of the three inputs for the four major crops in Egypt showed that human labor should be decreased, significantly, for mechanization to reach a maximum profitability of the agricultural sector. However, such expected shrinkage in human labor will cause extra unemployment above the current increasing rate. Under free market price policy the expected unemployment due to the introduction of agricultural mechanization up to the optimum economic level will be, (only from the four major crops cotton, maize, wheat and rice) about 175,000 man year associated with additional required HP from mechineries of about 128 million HP a year, that require abundant funds to be invested. Animal work has shown insignificant effect on crop yield of cotton, wheat and maize but it still has the highest economic efficiency for rice production, i.e. higher than mechanization, because there are some operations have not been mechanized. The impact of animal work on milk production depends upon the type of farming operation. Hard jobs as land preparation and threshing are harmful to milk yield, while operating the "Sakia" for irrigation is not effective because of the nature of the operation and the management of the "Sakia" work by the farmers. Therefore, land preparation and threshing of grains have reached almost 100% mechanized, while the "Sakia" work is still exists and will not vanish soon. Transportation by draft animals is still the major work by animals in Egypt, (although its share decreased from 16% in seventies to less than 4% in eighties) this is because of two reasons. First, the economic distance contours between 1 to 6 km around the wholesale markets are, entirely served by carts with draft

animals because they are of the least costs. Secondly, within most of the villages the roads have not reached yet the form suitable for trucks, however, those animals are consuming a bulky quantities of the limited feed resources in Egypt, particularly grains that are needed for human resources.

INTRODUCTION

The animal work is an exogenous output of animals. It is a source of operating power in agriculture. The classification of animal work pattern could be done by two ways. First, by type of animal: (a) Draft Animals: Donkeys, Camels, Mules and Horses and (b) Productive Animals: Cattle and Buffalo Secondly, by type of operation: (a) Transportation and (b) On-farm operation: Land preparation (plowing and leveling), Irrigation (rotation of water-wheel "Sakia" and Threshing. Because transportation is entirely done by draft animals and on-farm operations are almost done by buffalo and cattle, the study followed the classification by operation.

From the development point of view, there are two approaches: (a) The biological approach and (b) The Physical approach. The former approach includes seeds variety, fertilizers and pesticides and the later includes working power sources (Human Labor, Machinery Work and Animal Work. On the other hand, animal work and human labor as a package is considered as a traditional technology versus agricultural mechanization as a modern technology.

As input-output relationships, animal work as an output it is a joint product of the livestock sector that is competing for feeds with meat and milk production. As an agricultural input animal work is a source of working power. It is a substitute for other working power sources, mainly machinery work.

The planner, either on the micro level (farm level) or on the macro level (national economy) faces multi-objectives decision making. Therefore there should be adequate criteria for assessment and well identification of the constraints and both direct and indirect impacts, to make this complexity of the decision is oriented towards appropriate technology for developing countris. Th major constraints that are controlling such a decision are the availability of feeds, the availability and quality of the infrastructure, availability of energy supply (fuel), size of the market, magnitude of government intervention in the price mechanism (subsidies or taxation policies) and availability of funds to establish manufacturing and maintenance for required machineries or to import them. The indirect impacts are the rate of unemployment due to expansion in machinery work or the magnitude of pollution or the negative effects on meat

and milk production. The criteria for assessment under the current free market economy is the economic efficiency of the three working powers.

DATA BASE AND ANALYTICAL PROCEDURES

This paper deals with the investigation of the animal work within other working power for agriculture towards appropriate technology considering the socio-economic criteria and impacts. Because the published time series data are not satisfactory to cover the target issues in this study, thee analysis depended upon field sample surveys. Five sample surveys were used here to cover the objectives. The first four were conducted by the author successively for the agricultural years, 1977, 1982, 1983 and 1987 and were sponsored by the Ford Foundation, USAID and Zagazig University (Zagazig, Egypt), respectively. The theme of these surveys was farm management and input-output relations of the farming activity with emphasis on livestock enterprises. The fifth one concerning the transportation of vegetables by draft animals versus trucks was conducted by Ali Farrag in 1983 under the supervision of the Department of agricultural economics, Zagazig University in Egypt. The First survey included 175 farms from 10 villages representing both lower and upper Egypt and various farm size classes. The second survey included 9 villages from lower Egypt and the sample size was 250 farms representing different farm size classes. The third one composed of 150 farms in 10 villages from upper Egypt, middle Egypt, and the Delta, where the latter was divided into North, East and Mid-Delta. Therefore, 2 villages from each of the five regions were selected randomly. The fourth one considered the input-output relations of the four major crops in Egypt (Cotton, Maize, Rice and Wheat) on farms of various farm size classes. The sample size was 140 farms from four villages representing two regions. A region with Agricultural Mechanization Station and another one far from such facilities. The fourth one concerning the performance and economics of the transportation means for vegetables at two marketing levels (from production sites to wholesale market and from wholesale market to retail distribution sites). It is mainly concerned with the comparison between Carts with draft animals versus trucks.

The analytical procedures ranged from descriptive statistics to estimation of multiple regession models for crop production functions and derived economic criteria.

WORKING POWER AND TECHNICAL CHANGE IN AGRICULTURE

Major criteria of technological change in agriculture can be detected through investigating the relative share of the working power sources, i.e. animal work, machinery work and human labor. Dramatic changes has occurred concerning

such inputs over the last decade. The share of each type of work was estimated as horse-power (HP), based on the following index : One hour of animal work=1 HP, one hour of human labor=1/6 HP and one hour of machinery work varies according to the type of machine (tractor, irrigation pump ... etc.). The range is between 60 HP to 10 HP.

Table 1, presents the density of the three types of operating power for crop production per feddan (4,200 m^2). There was a significant towards agricultural mechanization from seventies to eighties. The share of machinery power increased from about 74% in seventies to about 90% in eighties. However the bulk of this change was in terms of tractors. Whereas, human labor share stayed almost constant as absolute figure, i.e. from 144 HP/Feddan in seventies to about 142 HP/Feddan in eighties, its relative share decreased from 6.6% to 5.3%. The effective impact of mechanization expansion was on animal work. Its share decreased from about 20% (429 HP/Fed.) in seventies to less than 5% (13 HP/Fed.) in eighties.

STRUCTURAL FACTORS AFFECTING ANIMAL POWER USE ON FARM

Farm size, type of operation and type of animals are the three major structural variables that affect the density of animal work on farm. Table 2, presents the animal work hours per feddan per year by farm size class, type of animal and type of work. Donkeys are the main animal for transportation for the distances between fields and farm house utilities. On farm operations are almost served by cattle and buffalo. Among on-farm operations, rotation of the water wheel (Sakia) is the bulky work served by cattle and buffalo. The larger the farm size the less is the density of using cattle and buffalo for farming work due to assessability to use custom services. Two questions are raised here: Why does the farmer try to vanish the use of cattle and buffalo for threshing service and land preparation work while using them for rotating the "Sakia"? and Why is the transportation by donkeys still significant?. In the following successive sections the analysis will provide evidences.

ECONOMICS OF ANIMAL WORK VERSUS TRUCKS FOR TRANSPORTATION OF AGRICULTURAL PRODUCTS

From the sample survey conducted by Ali Farrag (1983), the performance of the transportation pattern of vegetables and the economic price per ton per kilometer were analyzed for the various transportation means. Between the production sites and the wholesale market the service area of draft animals pulling carts is limited between the distance's contours of 3-5 Km, this transportation means serves only 0.06% of the economic area of transportation around the

market. However draft animals pulling carts are dominant transportation means within this area without any competition from trucks. Other transportation means are dominant within the distance's contours beyond 5 Km, as shown from the figure No. 1. Between the wholesale market and the retail sites, the man pulling carts is dominant for the area between 0.6-1.5 Km contour lines around the market. They occupy 1% of the total served area. Draft animals pulling carts are two types. The first is with two wheels has an economic area of service between 0.6-6.5 Km and serving about 9.3% of the economic area of the market. The second is with four wheels which are serving 12.5% of the economic area around the market. Its service area is located between 2.2-7.5 Km. After the contour line of 7.5 Km. The Half-Trucks (1-1.5 tons loading capacity) becomes active up to 20 Km from the market which is the boarder of the retail sites, Fig. 2.• It was concluded that draft animals pulling carts transported 82% of the vegetables and fruits between the wholesale market and the retail sites and within the economic area of service of the carts it is not recommended to eliminate them by administrative law, because it would have being not feasible. The consumer would bare much increase in the prices and the costs of transportation would have being doubled.

In addition, the transportation problem within villages due to narrow twisting roads and small fragmented farm holdings with dispersed plots enforce small farmers to use more work animal power for transportation, rather than machinery power, particularly with multicrops pattern per season and little marketable output.

Estimation of the animal feeds used for feeding mules, donkeys and horses that pull carts for transportation around the market area showed that they consume about 26% of the barely produced in Egypt, 20% of the broad beans produced, 2.1% of the straw produced beside about 47,000 tons of imported yellow corn and the output of 32,000 feddans of berseem. Even though the number of animals pulling carts around the market area is only less tha 7% of the total number of draft animals in Egypt.

IMPACTS OF ANIMAL WORK ON DAIRY ANIMALS PRODUCTION

Dairy cattle and buffalo-cows working on farm are providing two levels of farm work hard jobs which are land preparation operations and threshing and relatively mild one which is rotation of the "Sakia". The impact of these various kinds of work on milk production was estimated through estimation of the milk response function on farm from cross section data of a farm management survey. The results were surprising. Therefore it was repeated two years later from another sample survey which confirmed the output

hours a day. He pointed out that the same hard jobs may lower the milk yield level 1 to 2 kilograms a day if the animal is worked 2 to 4 hours.

IMPACTS OF AGRICULTURAL MECHANIZATION PROGRAM ON ANIMAL WORK DENSITY

The successive two five-years development plans (1982-1987) and (1987-1992) focused upon expansion in mechanization through establishment of 150 stations which provide custom services for the farming operations in the villages in addition to extension services, concerning machinery use.

Table 5, presents the estimates of the working power density as hours per feddan in 1987 on farms of two different regions in the Nile-Delta. The first region consists of two villages which are far from the newly established agricultural mechanization stations. The other region consists of another two villages which agricultural mechanization stations. The farms of the sample (140 farms) were selected among those who were cultivating the four major field crops (Cotton, Maize, Rice and Wheat).

The difference between the density of animal work hours per feddan by crop in the two regions was tested for statistical inference by applying the proper t-test. The results showed that there were statistically significant difference between each comparable averages. It is an evidence that the availability of custom service for all farms in a region decreases the level of the traditional technology package, i.e. animal work density for rice, maize and wheat.

EFFECT OF WORKING POWER SOURCES ON CROP PRODUCTIVITY

In the present study the most important objective is to assess the efficiency of the animal work versus machinery work. Therefore, the most critical functional relationship to be captured is the input-output responses of animal work and machinery work for major field crops which quantity the crop response of each input used. The specified crop-response function depended upon a sample survey in 1987, as shown in the data base section of the study. The function included an aggregate variable other than working power hours from human, animal and machinery. Such fourth variable identifies the biological technology level (capital inputs) in monetary term. The levels of the variables were introduced to the function on per farm base as an economic unit. Machinery power was estimated as equivalent tractor hours. The best fitted functional form was the double logarithmic form (cobb-douglas function) shown in table (6). This form captured most of the variability in the crop

of the first research. Both were conducted by the author of the present paper. Tables 3 and 4, show the estimated response functions of both surveve.

From tables 3 and 4, the most critical functional relationships to be captured here is the product-product interaction between animal work and milk yield which can measure the loss in milk production due to animal work. The specified functions included variables other than animal work hours for identification purposes. Animal work was separated into irrigation work and other work (pulling plow and thresher). As cross section data set, the regression coefficient of any variable was considered statistically significant if its value was greater than the corresponding standard error at a confidence coefficient 85% and above.

It is concluded that the effect of animal work on milk production depends upon the type of farm operation served by the animal livestock power used for plow or threshing work operations is the only type of work that has a significant negative impact on milk yield. Using animal power to operate the "Sakia" for irrigation has neutral or slightly positive impact on milk yield, physiologically, "Sakia" operation is a type of moderate animal work (usually the Sakia is under the shade of a big tree) that may consider as a physical exersice activating the milk yield. In commercial farms the managers povide time allowance for dairy cows to get some walking exercise, either for a short distance to the range area of within the farm yard. Each irrigation period is usually two hours a time. The farmer intends to use one animal for only one hour. If he has only one dairy cow he borrows his neighbor's cow for the other hour and they exchange cooperatively this service. These results provide evidence why the traditional plough and thresher have almost vanished within Egyptian agriculture while the Sakia-animal technological package has not being not vanishing rapidly, at the same rate as the plow and thresher operations.

To evaluate the impact of liberating of one head of dairy cows from plowing and threshing work, the following estimates were derived from the estimated response function: The saved quantity of milk (4% fat corrected milk) per day is 3.7 Kg, from cattle and 5.1 Kg, from buffalo wiith a weighted average of 4.4 Kg, per dairy-cow and 45.76 Kg, per feddan. On the national level about 274,560 tons per year could be saved.

El-Tambadawy's farm survey (1979) showed that there is no loss in milk yield if the animal is worked less than 4 hours per day. However, if the animal is worked more (up to 7 hours per day) the eyening milking is less productve and generates a loss between 1 and 2 kilograms of milk. He showed that hard work operations (ploughing) decrease daily milk yield between 2-3 kilograms if the animal is used for 7

production per farm, because the adjusted coefficient of determination ranged between ,77 to ,86. The signs of the estimates followed both the economic and technical logic. The most empirical results deducted from the estimated functions were presented in this section as well as the following two sections of the study. While both human labor and machinery work had significant positive effect on the farm production of all concerned crops, animal work had insignificant effect on the production of cotton, maize and wheat. The only crop-response with significant positive impact of animal work on production per farm was the rice response. This crop-response showed the following estimates for the elasticity of production : an increase in machinery work on farm by 10% will increase proportionally the production of cotton, maize, wheat and rice by 1%, 1%, 3.6% and 1.9%, respectively. a compatible increase in animal work input, i.e. by 10% will proportionally increase the production of rice by almost 1% and will not affect the production of other crops.

ECONOMIC EFFICIENCY OF VARIOUS WORKING POWER IN AGRICULTURE

The economic efficiency of the three working power sources was estimated from the following model which, in turn, was derived from the crop-response functions in table 6.

(1) Marginal physical product of input i $(MPP)_i = b_i\ (Y/X_i)$
(2) Value of marginal physical product of input i $(VMPP)_i = P_y(MPP)_i = P_y b_i\ (Y/X_i)$
(3) Economic Efficiency Criteria (EE) = Marginal return/L.E. of costs of input i $= (VMMP)_i/P_i = (P_y/P_i)b_i(Y/X_i)$

where :

b_i = estimated coefficient of input i, Y = average yield of the crop
X = average level of input i, Py = the farm-gate price of the crop
and P_i = the price (cost/unit) of the input i.

The prices of both inputs and outputs are free market prices. Application of this model for the four crops resulted in the values in Table 7. These values are the average marginal return in Egyptian pounds which are created from the additional Egyptian pound spent on a certain work input for the corresponding crop. Obviously, this ratio should be greater than one to consider that any further expansion in a certain input is feasible, other wise the level of this input should be diminished.

Therefore, from table 7, agricultural mecahnization is the work input of the highest economic efficiency for cotton followed by wheat. It surpassed the efficiency of the othr two work inputs. Economically it is recommended to expand its level at the expanses of human labor and animal work for

the production of these two crops. The economic efficiency of the three work inputs is less than one for Maize, and in fact it is zero for animal work, therefore, the increase in the production of this crop should be through the biological technology package, associated with a decrease in the level of the three working power sources. Consequently, there would be an economic response in production of maize. After that it will be possible to show a feasible decision about expension in the working power.

Rice is the only major crop that showed an economic efficiency of animal work higher than human labor and mechanization. However, the three inputs have economic efficiencis above one, i.e. a decision to increase the level of their intensity will be feasible. This is because up to 1987 (the year of the survey), there are several operations that have not being mechanized yet.

IMPACTS OF MECHANIZATION ON UNEMPLOYMENT RATE

The optimum allocation of working powers in agriculture will have some negative impacts of socio-economic nature. One of these negative impacts is the expected shrinkage in human labor intensity which will cause additional increase in the current increasing ratee of unemployment. Such expected unemployed labor that will be released under the maximization profit decision of the producer, will create additional demand for investment to create jobs for those unemployment people as extra social costs.

The study tried to quantify such expected rate of unemployment, depending on the extimated crop-response functions of the four major crops in Table 6. Therefore derived "Isoquant curves function" was estimated and the "Isocline functions" under the free market price ratio of machinery rent rate of human labor wage rate were also derived. Figures 3-6, illustrate the isoquant curves at the average level of production of each crop. Each curve represents all possible combinations of human labor and machinery work (in equivalent tractor hours). The intersection between the isocline curve and the isoquant curve for each crop represents the least cost combination of mechanization and human labor that maximizes the profit of each crop at such average yield level.

To generalize the results on national level, the expected change in both inputs were adjusted to be Man-Year equivalent of human labor and HP for mechanization, on base of 6 hours work per man per day and 50 HP per equivalent tractor hour. The adjusted changes in both inputs were weighted by the production period of each crop and the total area occupied by each crop. The total area under cotton

rice, maize and wheat were 1,081,009 feddans, 984839 feddans, 1914433 feddans and 1,859,200 feddans, respectively.

The aggregate human labor to be saved will be about 175,000 man-year and the additional mechanization inputs required will be about 128 millions of HP. As shown above if we considered other crops (the cropped area in Egypt in now being about 14 million feddans), abundant volumes of unemployment and funds to finance importation and/or manufacturing the machineries are required.

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Table 1: Role of animal work in working power sources for agriculture.

Type of working power	Weighted Average Hp per feddan in seventies		in eighties	
	HP	%	HP	%
Human Labor	144	6.6	142	5.3
Animal Work For:				
On farm operations	77	3.6	28	1.1
Transportation	352	10.3	98	3.7
Total	429	19.9	12.6	4.8
Machinery work of:				
Tractors	400	18.5	890	33.5
Other Machines	1190	55.0	1500	56.4
Total	1590	73.5	2390	89.9
Gross Working Power	2163	100	2658	100

Table 2: Animal work pattern by farm operation.

Farm size	Transportation		Farming operations			Total
	Camels	Donkeys	Land preparat	Irrigation	Threshing	
Less one feddan	0.0	122	22.05	136.2	0.8	158.65
1-3 feddans	13.4	74	1.25	92.6	0.0	252.50
3-5 feddans	5.6	50	0.05	54.4	0.0	54.40
5-10 feddans	3.9	28	1.70	67.2	0.0	68.35
10 + feddans	0.4	42	0.30	52.8	0.0	53.10

Table 3: Impacts of agricultural mechanization model on animal work level.

Comparative item	Rice		Maize		Wheat	
	Far	Near	Far	Near	Far	Near
Crop area/far(Feddans)	1.85	2.67	1.65	2.06	1.5	2.30
Yield/Feddan (Tons)	2.44	2.33	1.58	1.76	1.29	1.24
Animal work(hr.fed.)	21	8	8	4	8	4

Far = Farms in villages far from agricultural stations
Near= Farms in villages near to agricultural stations

Table 4: Estimated milk response function of cattle and buffalo under traditional system (1981, Field survey)

Explanatroy variable	Estimated coefficient	Significance level
Constant	-343.06	.05
Lactating buffalo(heads)	1491.58	.01
Lactating cattle (heads)	1099.19	.01
% of milk for suckling	-4.63	.15
Berseem fed (1)	-0.54	nss
Green maize (1)	15.22	nss
Berseem hay (2)	1.01	.01
Straws (2)	0.05	nss
Concentrate mix (w)(3)	-.98	.05
Concentrate mix (s)(3)	0.16	nss
Other concentrates (4)	0.07	nss
Plow work/head (5)	-3.19	.15
Irrigaion work/head(5)	0.49	nss
Farm size (6)	-33.28	.15
Family size	-7.59	nss
Family adult females	19.52	nss

R^2 = 0.799 ; Number of valid observations = 107

(1) Kirate-cut kirate = 175 m^2 and yields about 4 cuts/season (2) in kilograms, (3) W= in winter season and S= in summer season and the unit is kilograms, (4) in kilograms, (5) in days and (6) in feddans. ness = not statistically significant at less than or equal, P= .15.

Table 5: Estimated milk response function for buffalo-cow under traditional farming system (1982 sample survey)

Explanatory variable	Estimated coefficient	Level of significance
Constant	1297.88	
Dry period in days	-1.04	.01
Irrigation work/head/year	-0.32	nss
Other work/head/year	-2.17	.07
Feeds/head/season,(TDN)	0.23	.01
Farm size (1-3 feddans)(1)	-280.71	.01
Farm size (3-5 feddans)(1)	-309.22	.01
Farm size above 5 feddands(1)	-356.27	.01
2nd Lactation (1)	47.32	.01
3rd Lactation (1)	91.90	nss
4th Lactation (1)	98.95	.07
Region effect (1)	608.43	.01

R^2 = .545, N= 240 , F= 20.81 & (1) A dummy variable (0,1 variable)

Table 6: Estimated crop response function size.

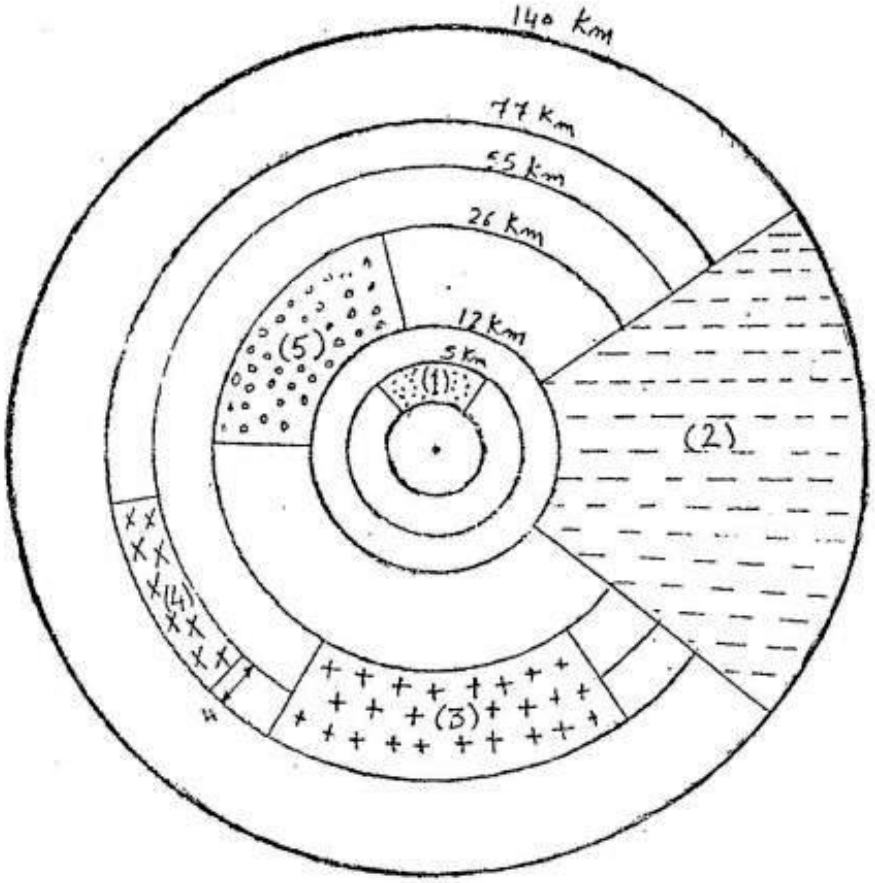
Crop	Sample size	Estimated cro response function	R^{-2}
Cotton	120	$LnY = -2.51 + .51^{*}LnX_1 + .37^{*}LnX_2 + .1^{*}LnX_3 + .02LnX_4$	.86
Maize	131	$LnY = -2.27 + .74^{*}LnX_1 + .21^{*}LnX_1 + .1^{*}LnX_2 + .02LnX_4$	.81
Wheat	125	$LnY = -1.45 + .13^{*}LnX_1 + .43^{*}LnX_2 + .36^{*}LnX_3 + .07^{*}LnX_4$	.85
Rice	125	$Lny = -3.09 + .25^{*}LnX_1 + .4^{*}LnX_2 + .19^{*}LnX_3 + .09^{*}LnX_4$	.77

Where: Ln=natural log., Y_i = the estimated production in tons per farm of crop i, X_1 = the aggregate capital imputs in monetary term for crop i, X_2 =human labor hours for crop i, X_3= machinery hours fro crop i (estimated as equivalent tractor hours) ad X_4 = animal work hours for crop i.
* = The estimate is statisticlly significant at probability level .05.

Table 7: Estimated economic efficiency coefficient for working power sources for various crops production.

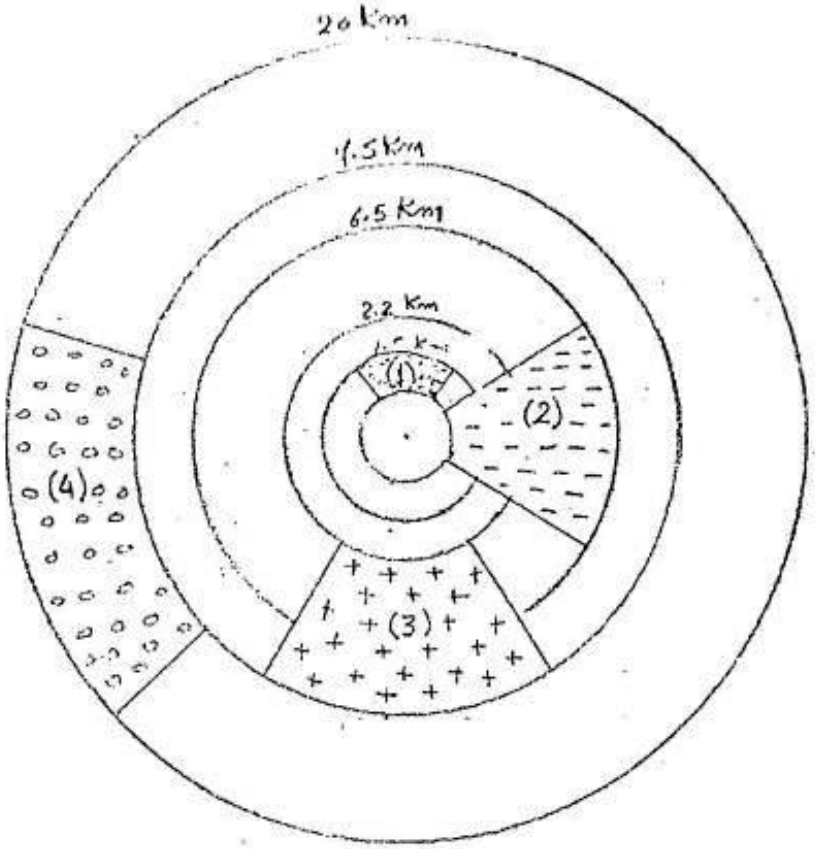
Crop	Magrinal return/Additional Unit of money of Input costs Human labor	Machinery work	Animal work
Cotton	4.20	7.50	0.0*
Maize	0.50	0.81	0.0
Wheat	2.07	4.14	0.0
Rice	3.20	2.31	6.9

* ='not statistically significant.
Source: Estimated from the response functions in table 6 and using equation 3 in the text.



(1) Carts with four wheels and two draft animals
(2) Half-Trucks (1-1.5 tons)
(3) Trucks (2-3 tons)
(4) Trucks (3-5 tons)
(5) Tractors with trailler

Fig. (1) : Contours of Maximum Transportation Service from Production Sites to Market.



(1) Man-Pull Cars with Two Wheels
(2) Carts with 2-wheels & 1-draft animal
(3) Carts with 4-wheels & 2-draft animals
(4) Half-Truck (1-1.5 tons).

Fig. (2) : Contours of Maximum Transportation Service From The Market to The Retail Distribution Sites.

Least Cost Combinations of Human Labor and Mechanization per feddan at average Crop Yield and Under Free Market Prices of Inputs.