Economic Analysis of Cow Traction Farm Technology in the Ethiopian Highlands[1]

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Abstract

Using a linear programming model based on data from smallholdings in the Ethiopian highlands, this paper evaluates the farm level economic efficiency of cow traction and the traditional oxen-pair. Cow traction farm technology has the potential for increasing the net income of farmers at the existing levels of farmers' resources.

Introduction.

Unlike many countries in sub-Saharan Africa (SSA), the use of oxen for tillage in crop production has a long history in the Ethiopian highlands, dating back thousands of years (Starkey, 1988). Nevertheless, as in most SSA countries, Ethiopian farmers use oxen mainly for tillage. The period for tillage is normally very short, thus the animals are idle for most of the year and their maintenance cost is very high relative to their overall productive use. Traditionally, the oxen are paired. The use of cows for both draught and milk production has been proposed as a means to reduce overhead cost of keeping animals for traction.

Use of crossbred cows for traction has some obvious potential benefits: the output of milk and progeny in addition to draught power. The milk output would be an important source of protein to the farmers and also of daily cash income. The widespread use of crossbred cows may contribute to reducing pressure on grazing and towards efficient utilisation of feed resources. Both overgrazing and insufficient feed resources constitute a major problem to crop-livestock farming systems in most SSA countries.

The adoption of crossbred cows can stimulate farmers to sell much of the oxen stock kept for traction purposes.

Since 1980, cow traction technology has been introduced into farming systems of the Ethiopian highlands (Gryseels and Anderson 1983). The cows used are crossbred. However, available evidence indicates that adoption has been very slow (Goe 1987), owing partly to the high initial investment cost.

This study draws on the experience of smallholders from villages surrounding Debre Zeit where, since 1980, cow traction technology has been introduced. A linear programming analysis of two traction technologies - traditional paired oxen teams and crossbred cows - is presented in terms of their effects on cropping patterns, income, labour use,and sales of crop and livestock products.

Linear Programming Model.

The linear programming model is constructed to represent the resource endowments and production activities of smallholders from Ethiopian highlands site-Debre Zeit. Data for the model are based on a 1985/86 ILCA farm level survey of farmers using the two different animal traction technologies in the Debre Zeit area, namely, traditional paired oxen teams and crossbred cows. This data was supplemented with information from secondary sources where necessary, to construct a comparative analysis which attributes differences in results to differences among traction technologies per se rather than to differences among sample farmers in resource endowments, farm organisation, and level of technology.

Each of the two traction technologies was analysed under 2 traction animal replacement scenarios referred to as Models I and II. Model I assumed that replacements would be purchased and no breeding animals or followers are kept on the farm. Model II assumed that replacements for the

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traction animals as well as for the females for producing them are produced on the same farm.

Constraints

The basic constraints include land, availablilities of seasonal labour and traction animal time, as well as household subsistence requirements for cereals, pulses, milk, and dung for fuel. Labour and animal traction time, likewise the requirements for these were divided into 4 periods (Table 1) to cover the distinct different farming operations over a one year period.

The land constraint was initially set at 2.55 ha of cropland of which no more than 80% could be planted to cereals. An additional 0.5 ha of lowland pasture is available from which 4,300kg of 90% DM roughage is taken as hay and grazing per year. In addition, feed from communal grazing is assumed available in the amount equivalent to 5000 kg of 90% roughage.

Minimum household subsistence requirements were specified as 1000 kg of cereals of which a minimum of 500 kg teff and 150 kg of wheat was required. Minimum total pulses required for household consumption was 250 kg of which a minimum of 75 kg each must come from horse-beans and rough peas. The model did not provide for purchase of cereals or pulses to meet house- hold subsistence requirements. A minimum of 215 kg of milk is required for household use and 2000 kg of cattle dung for fuel. The model provided the option of purchasing these re- quirements.

A minimum reserve of feed, 6000 kg, over and above annual requirements for animals was specified for each farm traction technology. These quantities represent normal reserves kept during normal crop years.

Activities.

Basic cropping activities were the same in models I and II for the two traction alternatives. These included teff, wheat, barley, oats for hay, horse beans, and rough peas. Yields were not affected by type of traction but labour and animal traction time varied.

Sale of draught animal time is optional for traditional paired oxen during the critical period (May to August). However, this option is not available for cow traction as extra work may jeopardise milk production and reproduction.

A calving interval of 14 months was assumed for crossbred cows used for traction, and that cows may not be used for traction for a total of two months before and following parturition. These assumptions imply that each cow will be unavailable for draught for two months during the critical cultivation period once in 8 years. To always avoid conflict of calving with work would require a continuous 24 month calving interval. Alternatively oxen could be hired to fill in whenever such a conflict arose. Thus, in the cow traction model it was assumed that, on average, 85.5 hours of draught animal time would be hired per year.

Feed from crop residues (straw), hay, pasture, and communal range was aggregated into a roughage supply, which on average represented feed of approximately 2 Mcal of ME per kg DM which was in aggregate more or less sufficient in protein to support traditional productivities of draught animals, reproduction and lactation. Oat hay could be optionally used to augment this supply at 1.1kg of DM equivalent roughage for each of oat hay DM. Crossbred cows required minimum quantities of both concentrated and oat hay as indicated by the farm survey, in addition to other roughage.

The feed requirements were estimated on the basis of requirements for maintenance, liveweight gain, draught, lactation and pregnancy. Details of the estimation procedures are provided by Panin (1989).

A herd replacement model was used to determine the number of cows and followers required to replace draught animals. Given the estimated weaning rates and attribution rates it was found that one cow is more than sufficient for supplying the expected replacement of itself and one

Table 1. Seasonal labour and animal traction time constraints

Period	season	labour (man-hrs)	animal traction time (hrs) *
1	May -August	958	342
2	Sept. - Oct.	588	**
3	Nov -Dec.	605	216
4	Jan - Apr.	1361	486

* per pair of draught animals.

** traction time is not limiting in period 2 draught animal. A small surplus of both females and males would accrue over time. The replacement model derived an expected distribution of followers by age.

Replacements for the local breeds were assumed to enter the breeding inventory or draught inventory at 4 years of age. Two cows could be expected to provide annually 1.38 males and female of which 0.25 of each sex would be needed to replace breeding and draught animals. This permits an expected annual sale of 4 year olds of 0.13 males and 0.13 females. In total there are 1.9 females and 1.9 females and 1.9 male followers ranging in age from 1 year to 4 years of age.

For crossbred cow traction no replacement males are necessary and the two cows produce their own replacements. Males are assumed to be sold at 2 years of age and females may enter the breeding herd at 3 years of age. The earlier calving results from the higher plane of nutrition provided for crossbred animals. This replacement scenario provides for sale of 0.5 two- year old males annually.

Net annual weaning rates were assumed the same as for local breeds even though the calving internal was shorter by 4 months. However, the crossbred animals were assumed to mature for use as replacement breeding stock one year earlier than local breeds under traditional management. This gives a considerable advantage to the crossbreds in terms of the number of followers required for replacement of breeding stock and the potential for offtake of followers for sale. An expected annual inventory of 0.44 three-year old females results, of which 0.25 are needed for replacements. This permits an expected sale of 0.19 three-year old female crossbred heifers per year. In total there are 1.08 male followers ranging in age from 1 to 2 years, and 1.52 female followers ranging in age from 1 to 3 years.

Of course fractional animals cannot exist. However, such inventories can be said to represent the expected value or mean of a large number of farmers. The expected value approach may be expected to approximate a representative integer inventory set and adequately serve the purpose for comparative analysis among alternative traction technologies.

Results and Discussion

Results are presented in 3 sections: Model I, Model II and sensitivity analysis of Models I and II.

Model I: Replacement Animals Purchased from Outside

Optimal solutions for the two technologies under Model I are presented in Table 2.

The principal results are as follows:

a) Maximum net farm income, exclusive of the value of farm produced goods consumed by households, was 67% higher for cow traction technology than oxen pair.

b) Except for the inclusion of oat hay in the cow traction farm model only, crops produced were the same for both technologies: teff, wheat, horse beans and rough peas. The minimum acreage of each crop required for subsistence was planted.

c) Under the traditional oxen pair technology, total draught animal time in period I was utilised; even so, all crop land was cultivated. Both teff and wheat was planted in excess of minimum household requirements. After meeting all the minimum requirements for cereals and pulses, instead of planting all land to the highest value crop per ha, teff, the pair oxen time was strategically allocated between teff and wheat. This enabled maximisation of the value of scarce draught animal time in period I and the utilisation of all the land area available to cereals.

d) These results are consistent with previous highlands studies which have shown that teff is both the most profitable and labour intensive crop but its production is limited by the inadequacy of draught animal time (Gryseels et al. 1983).

e) Similar to the traditional oxen pair, all crop land was cultivated under the cow traction technology. In the latter farming system, it is necessary to increase the amount and quality of feed by purchasing concentrates and feeding oat hay. Draught animal time is not limited in any period. The remaining land is planted to teff which produces the highest net revenue per ha.

f) Under the oxen pair technology income was earned from sale of teff, wheat, horse beans and fodder. Cow traction households, on the other hand, had a considerable quantity of milk and dung for fuel for sale in addition to sales of teff, horse beans and fodder. Income from these sales was partially affected by purchases of concentrates, and draught animal time to fill in for periods when calving interfered with the availability of cows for traction use.

Table 2. Optimal solutions obtained by sub-model I, Farm size 2.55 ha.

Item	Optimal farm plans	
	Traditional	Crossbred cows
Net farm income (birr)	620.15	1034.44
Total cultivated area (ha)	2.55	2.55
Area cropped in (ha):		
teff	1.14	1.15
wheat	0.90	0.54
rough peas	0.14	0.14
horse beans	0.37	0.37
oat hay		0.35
No. of draught animals		
to be replaced (head)	0.25	0.25
Sheep	4	4
Feed transferred (kg dm)	309.00	4870.00
Sales:		
cull ox (head)	0.13	
cull cow (head)		0.13
sheep (head)	1.20	1.20
roughage (km dm)	5993.95	4996.94
manure (kg)	0.00	2513.30
milk (kg)	0.00	3405.00
draft oxen time (hrs)	0.0	+
grain (kg)		
teff	425.04	427.54
wheat	324.84	0.0
horse beans	158.81	158.81
Purchases:		
milk (kg)	215.0	0.0
manure (kg)	0.0	
draught oxen time	+	85.5
Total annual labour use		
(man - equivalent hours)	1765.49	2409.7

+ not specified for the respective farm technology.

g) The impact of cow traction technology on total annual labour use was substantial, providing an increase of 37% over the traditional oxen pair technology.

Model II: Replacement Animals and Breeders Produced on Farm

Results obtained through Model II for traditional oxen pair and cow traction technologies are presented in Table 3. Comparison of the results from both Models I and II reveals the following key points:

a) Net farm income obtained through Model II relative to Model I increases for both traction systems. It is 38 and 133%, respectively, for traditional oxen pair and cow traction technologies. The increases in income for the traditionalist are generated from the introduction of sales of milk, manure, cull cows and surplus followers; but for the cow traction, they are attributable to the sales of increased manure and followers. Income from cow traction technology still remains higher than traditional oxen pair.

b) Except for introduction of oat hay in the farm plan for the traditional farm technology, there were no changes in crop production oxen pair technology.

Table 3. Optimal solutions obtained by Model II, Replacement Animals and Breeders Produced on Farm.

Item	Optimal farm plans	
	Traditional	Crossbred cows
Net farm income (birr)	854.18	1714.83
Total cultivated area (ha)	2.55	2.55
Area cropped in (ha):		
teff	1.10	1.15
wheat	0.72	0.54
rough peas	0.14	0.14
horse beans	0.37	0.37
oat hay	0.22	0.35
Feed transferred (kg dm)	11470.62	728.00
Sales:		
cull ox (head)	0.13	0.0
cull cow (head)	0.13	0.08
surplus followers (head)	0.26	0.0
surplus male followers (head)	0.0	0.5
surplus female followers (head)	0.0	0.19
sheep (head)	1.20	1.20
roughage (km dm)	0.0	2038.94
manure (kg)	3862.95	4110.66
draught oxen time (h)	0.0	+
milk (kg)	535.0	3405.00
grain (kg)		
teff	392.33	427.54
wheat	161.19	0.0
horse beans	158.81	158.81
Purchases:		
draught oxen time	+	85.5
Total annual labour use (man - equivalent hours)	1840.9	2409.79

+ not specified for the respective farm technology.

c) There is a reduction of sales of roughage under the two systems, but this is more drastic for the traditional farms than those using cow traction. Whilst cow traction farmers still had excess forage to sell the traditionalist had none. This suggests that cow traction tech- nology has the potential to reduce grazing pressure on available pasture land.

Effects of Variations in Size of Crop Land on Optimum Solutions

Changes in the solutions resulting from a one ha increase or decrease in total cultivable crop area are shown in Table 4.

Changes in Model 1

An increase in crop land by 1 ha results in net farm income increases of 5 and 74%, respectively, for traditional oxen pair and cow traction technologies. Changes in cropping pattern and in total amount of extra land that could be cultivated account for the variations in the relative increase in income among the farming systems.

The traditional oxen pair systems are only able to cultivate an additional 0.5 ha. after realigning crop areas, decreasing area of teff and wheat and increasing the area planted to horsebeans.

Changes in the cow traction farming system from the one ha increase in crop land include a 0.9

Table 4. Impacts of variations in farm size on optimum solutions (in Birr) obtained through Models I and II*.

	Model I Farm size (ha)			Model II Farm size (ha)		
Technology	2.55	1.55	3.55	2.55	1.55	3.55
Traditional	620	-6	650	854	**	950
Cow traction	1034	**	1799	1715	**	2479

** not feasible

ha increase in teff and a 0.2 ha increase in horse beans. Draught animal time was still not limiting. However, the surplus traction time in period I was reduced from 107 to 4 hours. Substantial further increase in cultivatable area are possible under crossbred cow traction by reducing the area planted to wheat and horse beans.

A decrease of one ha in the crop land results in infeasibility for the crossbred cows due to lack of feed. In the case of traditional oxen pair technology, net farm income is decreased by 101%. The reduction of land by one ha resulted in a decrease of areas planted to teff, wheat, and horse beans, all of which the traditionalist previously produced in surplus of subsistence needs.

Changes in Model II

Under the traditional oxen pair, a one ha increase in crop land results in an additional 0.47 ha under cultivation leaving 0.53 ha unused. Areas planted to teff, wheat and oat hay were reduced and the area planted to horse beans was increased. Net revenue increased by 96 Birr or 11%.

Under cow traction, the additional ha was fully utilised with teff increasing by 0.8 ha and horsebeans by 0.2 ha. This resulted in an increase in income of 45%.

When land area was reduced by one ha from 2.55 to 1.55 ha, both traditional oxen pair and crossbred cow traction technologies became infeasible owing to insufficient feed supplies.

Conclusions

The paper has shown that economic efficiency is higher in the cow traction farming systems than the traditional oxen pair. Cow traction farm technology appears to have the potential for increasing the net income of farmers at the existing levels of farmers' resources. This highlights the need for strengthening the existing extension services to exploit the potential in its wide scale adoption. Another possibility may be to grant investment loans to farmers interested in the use of the technology, since its relatively high initial investment cost can discourage potential adopters.

Résumé

S'appuyant sur un modèle de programmation linéaire élaboré à partir de données recueillies auprès de petites exploitations agricoles des hauts plateaux éthiopiens, cette étude procède à l'évaluation de l'efficacité économique au niveau de l'exploitation de l'utilisation de femelles en culture attelée comparativement à l'utilisation de la paire de boeufs traditionnelle. Il apparaît que la technologie fondée sur l'utilisation de vaches de trait offre une possibilité intéressante d'augmentation du revenu net des paysans compte tenu du niveau des ressources dont ils disposent actuellement.

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