Animal Traction: An Underused Low External Input Technology among Farming Communities in Kaduna State, Nigeria

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Summary

In spite of the slow rate of adoption of animal traction (AT) technology in West Africa, the potential benefit of the technology, in terms of increase in hectares cultivated and the reduction in drudgery has been a subject of discussion by researchers. This paper uses a linear programming and binary choice probit model to analyze the benefits and constraints to AT technologies taking into consideration socio-economic and institutional factors and perception variables. One hundred and twenty households from Maigana and Yakawada villages in Kaduna State were enumerated by a simple random sampling technique using both structured and unstructured interview procedures. The result revealed considerable under-exploitation of AT technology in the study location. The partial use of AT technology for tillage operation only increased gross margin by 32% and labor bottlenecks experienced in the peak of the season can be reduced by 43%. However, the increase in gross margin is over 78% when the full AT technology package is used. The general trend in the models showed that by adopting the complete package of the technology, the full potential could be exploited. The size of family labor force substantially influenced the adoption behavior of the household while the selected perception variables were quite useful in explaining household's perception of the technology. Conversely, the use of tractors showed a highly significant but negative relationship with the adoption of AT technology. Households' managerial know how, financial constraint and the family labor capacity limits the benefits derived from the technology. These results suggest that farm mechanization using complete AT package is a viable panacea for agricultural intensification and increased productivity among the smallholders in the northern guinea savanna ecology of Nigeria. The paper concludes with pragmatic steps of how the identified constraints can be eliminated to sustain holistic adoption of AT technology and exploit its full potential benefits.

Résumé

Traction animale: une faible technologie du matériel agricole sous - exploitée par les communautés rurales dans l'état de Kaduna au Nigeria

En dépit du faible taux d'adoption de la technologie de la Traction Animale (TA) en Afrique de l'Ouest, l'avantage potentiel de cette technologie en terme d'augmentation des superficies cultivées et de réduction de la pénibilité du travail demeure un sujet de discussion au niveau des chercheurs. Cet article utilise une programmation linéaire et un modèle `Probit` de choix binaire pour analyser les avantages et les contraintes liés à la TA en tenant compte des facteurs socio-économiques et institutionnels ainsi que des variables de perception. Cent vingt ménages des villages de Maigana et Yakawada dans l'état de Kaduna au Nigeria ont été sélectionnés par une technique d'échantillonnage aléatoire et simple en utilisant des procédures d'interviews structurées et non structurées. Le résultat a révélé une sous-exploitation considérable de la TA dans les sites de l'étude. L'utilisation partielle de la TA pour le labour seulement, a augmenté la marge brute de 32%, et le goulot d'étranglement du travail observé pendant la période de pointe peut être réduite de 43%. Cependant, l'augmentation de la marge brute est supérieure à 78% quand l'ensemble du paquet technologique de la TA est utilisé. La tendance générale dans les modèles a montré qu'en adoptant l'ensemble du paquet technologique, tout son potentiel pourrait être exploité. La taille de la main-d'oeuvre familiale influence de façon substantielle le comportement du ménage à adopter la TA, alors que les variables de perception sélectionnées étaient utiles pour comprendre la perception de la technologie par le ménage. Inversement, l'utilisation des tracteurs a montré une forte corrélation négative avec l'adoption de la TA. Le savoir - faire en gestion des ménages, la contrainte financière et la capacité de main-d'oeuvre familiale limitent les avantages obtenus de la technologie. Ces résultats suggèrent que la mécanisation agricole utilisant l'ensemble du paquet technologique de la TA est une panacée viable pour l'intensification agricole et l'augmentation de la productivité par les petits paysans de la zone écologiques de la Savane de Guinéenne au Nord du Nigeria. Cet article conclut en mettant l'accent sur des étapes pragmatiques concernant la manière dont les contraintes identifiées peuvent être éliminées afin d'assurer la durabilité d'une adoption holistique de la TA et d'exploiter tous ses avantages potentiels.

Introduction

Animal traction (AT) has played and still plays an important role in meeting the power requirements of many parts of developing world, because it is an appropriate, affordable and sustainable technology requiring few external inputs and hence relatively low capital investment. AT was first introduced in the 1920s in the northern parts of Nigeria (1). Since then, its use has become wide spread in various parts of the tsetse free zones of Nigeria (8). In addition to the governments' efforts during the colonial period, some private agencies provided impetus for adoption of the technology by establishing farm training and work bull training centers. However the vigor with which draft animal power technology was promoted declined significantly in the 1970s when campaigns for increased food production favored capital-intensive tractor mechanization - approach. This approach failed to achieve the desired increased food production partly because the socio-economic profile of small-scale farmers were neglected in the scheme and because the tractors, implement, and spare parts had to be imported with scarce foreign exchange. The failure of the approach coupled with

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down turn of the Nigeria economy and a compelling need to meet rising demand for food production led to strident calls for cheaper labor saving and locally sustainable technology for agricultural mechanization.

AT technology appeared to have provided the answer in this regard, especially for small-scale farmers. According to Phillip *et al.* (9), the use of AT for agricultural practices is potentially useful and an appropriate means of improving the efficiency of traditional farming system in many developing countries. Advocates of animal-based mechanization projects generally believed that the introduction of AT in African smallholder systems would bring considerable advances in agricultural production. AT would increase crop yields through better and timely cultivation and planting. It would reduce labor requirement per unit area and allow an increase in the area under cultivation. It would also help to resolve bottlenecks in weeding, and reduce the drudgery of manual labor (3). However, most of the available literature on AT utilization indicates that farmers have not taken full advantage of using work animal for the various possible operations on the farm (2, 7, 9, 11). Despite the potentials of AT to alleviate seasonal labor shortages, which, together with capital shortages, are widely considered as the primary production constraint in sub-Saharan African farming systems, less than 10% of the total cultivated area is cropped using animals (10). This situation prevails despite considerable efforts by the World Bank sponsored Agricultural projects (ADPs) aimed at promoting increased use of AT, mainly through the provision of loans to qualified farmers. It is in the face of these and other constraints that it become necessary to look for viable alternative means of enhancing agricultural production through increased use of AT. The main objective of this paper is to identify the economic potential of AT technology among smallholders and examine the significance of institutional, socio-economic and household perception variables as influenced by the decision to adopt AT technology

Materials and methods

Study area

This study was carried out in Kaduna State of Nigeria. Kaduna State lies in the North central position of Nigeria between latitudes 9°10' and 11°30' north and longitude 6°52' and 9°10' East of Greenwich meridian, which falls mostly within the northern guinea savannah zone of the sub humid climate of Nigeria. Soils in this zone have a sandy loam to clay loam texture. The topsoil has a pH of 5 to 7 and an organic carbon content ranging between 0.5 and 1.5%. The soil properties as described by Norman *et al.* (6) are leached ferruginous tropical soil, with reddish fine loam clay to sandy loam. Two seasons can be distinguished – the rainy season from May to September / October and a long dry season from October to May. Temperature during the rainy period is between 27.0 - 34.0 °C (maximum) and 18.0 - 21.0 °C (minimum). The zone's long growing period of 180 - 270 days accommodates the predominant crops like sorghum, millet, maize, groundnut cowpea, rice as well as cocoyam, cassava and yam.

The Kaduna State Agricultural Development Project (KADP) divided the state into three zones for administrative convenience; namely, Samaru zone, Birnin Gwari zone, Maigana zone. This study was specifically conducted in Yakawada and Maigana, both in Miagana zone.

Sampling procedure and data collection

A stratified random sampling procedure was employed to select 120 farm households in Yakawada and Maigana. Sixty households were randomly selected from each village, stratified according to their use of AT technology. Households were stratified into three groups: manual / hand hoe tillage; partial AT users and full AT users. The partial AT users were those who use the technology for tillage purposes only while the full AT users were those who use the technology for tillage operations and other operations such as weeding, transportation and harvesting. Three forms of questionnaires were used in soliciting data from the respondents. An inventory form was used to record family size and composition, material inventory, animal inventory and plot inventory. The second form was used to collect farm input and output records. This form was used to elicit information on labor use, animal power use, material input and output for the 1999 agricultural season. Finally the last form was used to collect information on potential benefit of AT, credit needs, farm management practices, implement use, animal handling skills cultural and social issues concerning draft animal adoption.

The household head was the unit of response. This was to ensure that the various components of the farming systems in the area were effectively covered. Where necessary, some key members of the household were also interviewed.

Analytical techniques

The data collected were analyzed using probit and linear programming models. Multivariate binary choice probit approach was estimated to analyze the adoption decision regarding AT technology. Factors hypothesized as influencing adoption of AT technology were categorized into three; socio-economic and institutional and perception variables.

Six socio-economic variables: age, family labor capacity, educational level of household head, use of fertilizer, use of tractor, and farm size were hypothesized to influence adoption of AT. Institutional variables considered were the distance to the nearest point of sale of AT implements, extension contact and membership of cooperative society. Two perception variables were included in the model: perception of credit need and benefits of AT. Household's perception of the benefits of AT was measured by three different components: reducing drudgery, increase farm size and improve income. Binary probit model is a type of regression where the dependent variable is converted into a dichotomous binary variable coded 1 for households using AT and 0 for households using manual cultivation.

The probit model has the following functional form (5):

$$P_i = \text{Prob}\ (Y_i = 1) = \text{Prob}\ (\Sigma\beta_j X_{ij} + \in_i > 0) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ 1$$

$$P_i = \text{Prob}\ (Y_i = 1) = \text{Prob}\ (\in_i > -\Sigma\beta_j X_{ij}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ 2$$

The second equation implies that the i^{th} household will use AT technology if:

$$\in_i > -\Sigma\beta_j X_{ij.}$$

Thus, the probability that a household will adopt AT technology is a function of the vector of explanatory variables X_{ij} and an unobserved error term $\in_i$.

P_i = probability that the household will use AT technology

β_j = Coefficients of the explanatory variables X_i

$\in_i$ = error term which is normally distributed with zero mean and variance one.

Linear programming model formulation

A single period linear programming model of a representative farm was used. Three basic models were used to capture diversity in the potential benefit from partial animal traction technology with the plough only and the complete animal traction package, which consist of plough, weeder and cart and hand hoe tillage operations. The use of linear programming makes it possible to make comparative analysis of the different modes of production. Also the efficiency of the individual factors of production and the allocative efficiency of factors of production can be captured and analyzed simultaneously. The objective is the maximization of gross margin using the two technologies.

Given the objective of maximization of gross margin, the mixed integer programming techniques were developed for the study as follows:

Max. Gross margin $Z = \sum_{j=1}^{n} C_j X_j$ (j = 1, 2, 3,............n)

Subject to: $b_1 \geq \sum_{j=1}^{m} a_{ij} X_j$ (i = 1, 2, 3, ...m)

And: $X_j \geq 0$

Where:

Z = objective function (Gross Return);

X_j= the quantity of the activities where there are n activities to be considered,

C_j= net prices per unit of activity with n activities. It measures the marginal contribution of each decision variable,

a_{ij}= resource requirement per unit of activity. It represents how much of a resource is required for each activity unit,

b_j= available productive resources in limited supply (constraints),

n = number of activities,

m = number of resources.

Activities in the models

The activities in the models are categorized into five major groups; production activities, selling activities, consumption activities, labor hiring activities and capital borrowing activities. Crop production activities included in the models were maize, sorghum, rice, millet, cowpea, sorghum / cowpea. The choice of these crops is based on their dominance in the cropping system of the study area. It was also assumed that crops produced are immediately transferred into selling activities after deducting the minimum requirement for home consumption. A minimum food requirement was stipulated in the models for certain staple food common in the study area; sorghum, millet and maize. Labor hiring activities were included in the model to ensure that shortage of family labor does not serious constraint the households to produce. A restriction was placed on the level of labor to be hired based on family cash availability and the estimated supply of labor in the area. Capital borrowing activities were included in the models to enable the households increase the amount of capital available for production. The loan obtained to finance the AT packages was scheduled to be repaid over a period of time, while capital borrowed for operating expenses was repaid in full at the end of the season. It is assumed that these loans should be self- liquidating in the same year.

Constraints in the models

Two types of constraints were considered based on the resource situation in the household. These are the resource and subjective constraint. The resource constraints include; land, family labor, draught power supply and capital. The subjective restriction includes the production of minimum amount of food required to sustain the family. Output allocation constraint was included to ensure that all that is produced is either consumed or transferred into selling activity.

Results and discussion

Factor influencing AT utilization

According to the log likelihood test, the probit model used to examine factors affecting the adoption of animal traction in the study area was significant at the one percent level. The variables included in the model accounted for 85% of the variations in the level of adoption of AT technology. Based on the t-values of the individual coefficients, most of the explanatory variables included in the model were significantly related with the adoption of animal traction (Table 1). The likelihood of adopting AT technology was higher for older farmers than for younger ones. The possible explanation to this could be that older farmers have greater access to institutional assistance, and could be in control of more wealth than the younger ones. This finding is consistent with those of other researchers (4, 8) whose studied were specifically on AT farm-households. The model also showed that with increasing family labor force, the probability of adopting animal traction increases. The implication of this is that larger family labor force is an important precondition to the acquisition and adoption of AT technology. This is due to the conflict in the allocation of labor between crop production and tending the animals for traction purposes. Also, the estimated coefficient of educational level of the household heads was positive but not significant. The insignificance of this factor shows that lack of formal education may not be a constraint in AT technology adoption. As expected, the use of other improved farm practices (fertilizer) showed a positive and significant ($p< 0.10$) relationship to the adoption of AT. This is quite important in view of the general assumption that the use of related technologies clearly promotes the adoption of others. The implication of this is that the promotion of AT will receive a boost if other supplementary inputs, such as fertilizers herbicides and improved seed are equally promoted. The probability of adopting AT technology was observed to be positively related to farm size, though the

Table 1
Socio-economic, institutional and perception variables influencing AT utilization

Variable	Coefficient	Standard error	t – values
Family labor	0.0667*	0.0422	1.5813
Educational level	0.0281	0.0380	0.7401
Age	0.0113	0.0092	1.2198
Tractor use	-1.1435***	0.3451	3.3108
Farm size	0.2701	0.3407	0.8788
Fertilizer use	0.4518*	0.2702	1.6006
Extension contact	0.2521***	0.0775	3.2536
Cooperative Membership	0.1290	0.3127	0.4153
Distance to the nearest point of sale	0.0768	0.0164	1.0878
Perception of AT benefit	0.8122***	0.2969	2.7256
Perception of credit need	1.1314***	0.3303	3.4258
Constant	-3.7458**	1.0208	-3.6695

*** $p< 0.01$ ** $p< 0.05$ * $p< 0.10$

Likelihood ratio= 78.95

Percentage of right prediction= 0.85.

relationship was not significant. This could be attributed to scale advantage derived from using AT. Larger farms tend to make use of AT more efficiently and therefore derive higher benefit from its use.

In relation to complementary factors, the model estimated a negative relationship between adoption of animal traction technology and use of tractors. The likelihood of adopting animal traction was higher for large farms than for smaller farms, the relationship was highly significant at $p< 0.01$. Extension contact and the membership of cooperative society were found to positively influence adoption of AT technology. However, only the coefficient of extension contact was significant at $p <0.01$.

The perception of credit availability proved to be a highly significant ($p< 0.01$) factor to farmers' adoption of animal traction. Most of the farmers were of the opinion that with increased availability of credit, the level of adoption of animal traction technology is bound to increase. The need for credit is as a result of the initial investment in the animals and draught implements. Also farmers' perception of the benefit of animal traction to reduce drudgery, increase farm size and improve farmer's income was positive and significant ($p< 0.01$) to the adoption of the technology. It means that farmers' perceived advantage of AT to reduce drudgery, increase farm size and improve farmers' income as a very important factor influencing adoption of the technology.

Farmers' perception variables and extension contact were the most important factors influencing adoption behavior of household with regards to AT utilization. Thus, structural transformation that would encourage intensification in the use of AT technology for increased farm productivity will need to take into consideration the attitude of farm household with respect to the expected economic advantage of the technology over traditional alternatives. Also the role of extension in the different stages of adoption and diffusion is equally important in ensuring adoption of AT technology.

Optimal farm plan of the basic models for the three modes of cultivation

The three basic models representing the optimum situation of the average households that used manual / hoe cultivation, partial AT technology (plough) and full AT package (plough, weeder and the ox-drawn cart) are presented in table 2. While the total land area available in the fadama was completely used up in the manual cultivation models, there was a surplus of 0.27 hectares of upland field. The reverse was the case in the partial and complete AT models. The underutilization of the fadama land in the AT models could be attributed to inability to use AT to work the fields as a result of flooding and due to clayey nature of fadama soils. The striking point of the enterprises choice in the optimum plans of the three modes of cultivation is that it does not deviate much from the dominant existing cropping pattern in the study area. The feasible enterprise combinations in the models were mainly cereal-based as indicated in table 2. The available land in the manual cultivation models was fragmented into six plots while the AT models had fewer number of plots for ease of draught operation. The cropping pattern of the three models is similar in many ways. Sorghum/cowpea enterprise, millet and maize were dominant in all the farm models. Sorghum/cowpea enterprise and millet occurred without exception in all the three models. This seems to underline the importance of subsistence of these crops to the farmers. Rice occupies a place in all the three models but assumes less importance as the tillage methods changes from hand tillage to complete AT.

The pattern of labour use in the three models tends to validate the models representation of the farming system. Labour restriction was divided into three periods; January - April, May - August and September - December. In terms of resource use, the complete AT model allows for surplus labor in all the seasons. No labor bottleneck was experienced throughout the year for this model. Although less labor was used, the return to family labor was higher with the full AT than all the other methods. Return to labor was ₦34.65, ₦67.7 and ₦157.7 per man-hour for manual cultivation, partial AT and complete AT models respectively. Although all these figures were higher than the average wage rate of ₦20.00 per hour, which shows that labor is being efficiently utilized.

Table 2
Optimal Farm Plan of the Basic Models for the Three Modes of Cultivation

ITEM	Unit	Activity level		
		Hand hoe	Partial AT	Complete AT
Rice	Ha	0.40	0.38	0.26
So – Cp	Ha	1.04	1.97	0.77
Millet	Ha	0.98	1.09	0.71
Groundnut	Ha	0.46	-	
Maize	Ha	0.28	-	1.43
Sorghum	Ha	0.03	-	
So – GN	Ha	-	-	0.15
Jan – April	Man – hrs	115.0	138.7	95.0
May – August	Man – hrs	1200.0	640.50	480.9
Sept – Dec.	Man – hrs	780.8	745.0	316.5
Hired labor	Man – hrs	42.68	26.24	-
AT usage	Man – hrs	-	78	120
Rice selling	Naira	1010.8	957.74	958.74
Sorghum selling	Naira	189.67	659.18	659.18
Groundnut selling	Naira	526.27	-	58.7
Millet selling	Naira	192.38	-	-
Cowpea selling	Naira	518.7	986.52	-
So consumption	Kg	950	1450	1000.0
Millet consumption	Kg	500	550	550.0
Maize consumption	Kg	550	-	2771.63
CP consumption	Kg	-	50	50.0
Total GM	Naira	78,840.87	103,163.76	140,531.11
Land use efficiency	N / Ha	24,715.0	29,989.46	42,328.65
Labor use efficiency	N / man - hr	34.65	67.7	157.7

Gross margin was highest with the full AT technology and lowest for the hand hoe technique. The models show that gross margin can almost double with the use of the full AT compared to the hand hoe method. The partial AT models also show increases in gross margin but the farm potential is not fully exploited due to the transference of certain constraints in resource use. When the partial AT method was used, greater weeding efforts and higher costs of harvesting increased the total cost of production and reduce the gross margin. The results show that AT will be most beneficial to farmers if used fully.

Although the cost of one hectare of land is not known in the study area, the return to a unit of land used was highest for full AT, the partial AT and manual tillage in that order. Comparing the shadow price of land to its marginal value product of land estimated in the model, it shows that land is used more efficiently, particularly in the complete AT package compared to other modes of cultivation. These findings points to the fact that resources, particularly land and labor were more efficiently utilized as the households adopt the full package of AT technology.

Conclusion

The result revealed considerable under-exploitation of AT technology in the study location as only about 30 percent of the farmers using the technology actually derived substantial benefits from it. The partial use of AT technology for tillage operation only increased gross margin by 32 percent and labor bottlenecks experienced in the peak of the season can be reduced by 43 percent. However, the increase in gross margin is over 78 percent when the full AT technology package is used. The general trend in the models showed that by adopting the complete package of the technology, the full potential could be exploited. Our study also suggests that family labor capacity and fertilizer use had highly significant effect on adoption of AT technology. Perceptions variables, which were represented by farmers' subjective evaluation of the benefits of AT and credit need for investment in AT technology are the two most important ingredients affecting the adoption decision regarding AT technology. Structural transformation that would encourage intensification in the use of AT technology for increased farm productivity will need to take into consideration the attitude of farm household with respect to the expected economic advantage of the technology over traditional alternatives. The findings also indicate that, the role of extension in the different stages of adoption and diffusion is equally important in ensuring adoption of AT technology.

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