Evolution of farming systems and the adoption and profitability of animal traction

A case study from the savanna highlands of North West Cameroon

by

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Abstract

The study examined the effects of agricultural intensification on the adoption and profitability of animal traction under four farming systems at various levels of evolution. It was found that while intensification could increase the pace of mechanisation, adoption depended more on the agronomic requirements of particular crops, and the need to expand cropped areas to take advantage of market availability. Profitability depended critically on the level of evolution in the farming system and the availability and use of complementary, fertility-enhancing inputs.

Introduction

Efforts to tractorise farming in sub-Saharan Africa to improve the performance of agriculture have generally failed (Pingali, Bigot and Binswanger, 1987). Following these failures, there is renewed interest in animal traction as an appropriate technology (Starkey, 1988), and a convergence of views that it is more suitable to the region (Langha, 1995). However, it is still far from evident under what conditions animal traction can be used to optimise farm output. Moreover, despite substantial resources devoted to promoting its use over seventy years, the whole region has less than six million of the 400 million draft animals in the world, and only some 15% of farmers use animal traction (Starkey, 1988).

Early studies examined factors limiting the supply of appropriate technologies and concluded that adoption was blocked by equipment inappropriately designed for African conditions, inadequate extension and an absence of support services (Kline et al, 1970; Le Moigne, 1978). Later field studies shifted the debate to farm-level profitability and the demand for animal traction. Delgado and McIntire (1982), for example, concluded that ox cultivation in isolation from other components of improved technologies, is not sufficiently profitable to compensate for the high opportunity costs of farm resources tied up in the technology. Crawford and Lassiter (1985) criticised this work for overestimating labour costs for animal maintenance and underestimating supply-side constraints. More recently, Jaeger and Matlon (1990) concluded that high levels of utilisation are crucial for profitable adoption; levels of use depended on agroclimatic conditions and learning (experience). Panin and Ellis-Jones (1994) emphasised the linkage between profitability and adoption and suggested that profitability depends signifcantly on macro-economic aggregates (exchange rates, taxation, import duties etc), and that a longer-term vision needs to be taken in any promotion efforts.

A major weakness of many studies is the failure to include the dynamics of rural change in the analysis. As a result, the intermediate stages of the adoption process are often set aside, resulting in an incomplete and often hazy understanding of the adoption process. Therefore, a number of theories and some empirical studies have focused on the evolution of farming systems as a measure of rural change. First developed by Boserup (1965; 1987) and later on expanded and refined by Ruthenberg (1971), Pingali, Bigot and Binswanger (1987), Strubenhoff and Jahnke (1989) and others, the theory links farm mechanisation to increased agricultural intensification (more frequent cropping of land) which itself results from rising labour to land ratios (pressure on limited land). When labour to land ratios increase, aggregate population food needs rise while the quantity of land available for cropping falls. The increased labour available is applied to intensify farming. When population pressure leads to an increase in the frequency with which land is cultivated, there follows a diminution of the tree cover and the advent of grassy vegetation with roots that are too strong to be cleared by fire or removed by the hand hoe. These conditions necessitate the introduction of mechanical power, usually animal-drawn plows, which are usually the first stage in farm mechanisation. On the other hand, increased population leads to urbanisation and specialisation, thereby facilitating infrastructure improvements and providing farm households with crop markets and a source of improved farm inputs. These conditions combine to favour an improvement in welfare.

The chain of linkages running from population pressure, agricultural intensification, technical change in agriculture, economic growth and societal well-being is very long and complicated, and is difficult to test empirically in a comprehensive way. Turner, Hyden and Kates (1993) limited their investigations to the linkages between intensification, growth and material well-being. Langha (1995) traced the household-level linkages between demographic and socio-economic characteristics of households, population pressure, agricultural intensification, farm incomes and material well-being. This paper is limited to the relationships between intensification of agriculture and the adoption and profitability of animal traction in the savanna highlands of North West Cameroon.

Measuring agricultural intensification in North West Cameroon

Boserup (1965) identified five stages in the evolution of land use from hunting and gathering through fallowing to stationary cultivation systems. Ruthenberg (1971) developed a numerical measure of farming intensity (R) that takes into consideration the number of crop cycles per year, the number of years of fallow and the number of years of cultivation. Later on, Pingali, Bigot and Binswanger (1987) related the five stages of evolution to the R-value, identifying the types of technology at each stage.

North West Cameroon is located between latitudes 5.2° and 7.0° N in the northern part of a volcanic mountain range that extends north-eastward from the coast for 800 km on the Cameroon side of the Nigerian border. The land area is approximately 18,000 km^2, characterised by an extrememly varied relief composed of mountains, escarpments, valleys, plains and plateaux. A basic pattern of altitude zones runs along a southwest to northwest axis, with a central mountainous spine running from Western Province to Nkambe in the north of North West Province. The central axis is flanked by high altitude plains, with lower-lying plains and river valleys forming a third zone.

Farming systems are, in general terms, at an advanced stage of evolution towards intensive stationary cultivation. The diminution of tree cover, the advent of grassy vegetation and declining soil fertility mean that peasant farmers require high levels of skill and effort for survival. The advent of grasssy vegetation has attracted cattle-rearing Fulanis to settle in the region, thereby creating some crop-livestock interactions which could favour agricultural intensification. The number of fallows is falling rapidly towards the annual cropping stage, and crop rotation on family holdings is a feature on many farms. With farming intensities (R-value) averaging 60 to 100, and population density exceeding 70 inhabitants per sq km, this region falls squarely within the short fallow stage of evolution when animal power begins to be used side-by-side with the hand hoe.

However, this general picture is somewhat misleading, as the varying relief, climate, soil types and infrastructure characteristics result in a number of subsystems at various stages of evolution. These subsystems are characterised by different levels of input use and farming intensities, farm output and and returns to the factors of production, and agricultural commercialisation. The two case-study villages were selected to reflect this variation.

The first locality, Wum, represents a zone of low intensity of animal power use and farmers using the technology were geographically very widely dispersed. On the contrary, animal power use in Bamessing village was very intense, although it was introduced in 1988, barely four years before the study. Both areas, located at about 1000 m above sea level, have similar temperatures, rainfall, vegetation and soil types.

In each of the two villages, two subsystems were identified. In Wum, there were marked differences between Fulani farmers in the hilly countryside

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and the sedentary population in the low-lying ares, with the Fulanis cropping more intensively and using higher levels of animal power. In Bamessing, the same farmers practised different systems on rice and non-rice fields, with the rice fields receiving multiple cropping and high levels of animal power and labour while non-rice fields were less advanced. Hence, four subsystems can be classified, in order of evolution of the farming systems, beginning with non-Fulani farmers in Wum through non-rice farms in Bamessing through Fulani farms in Wum to rice fields in Bamessing.

All ox farmers in each community were interviewed between February and October 1992. There was a total of 59 farmers in both communities, 23 from Wum and 36 from Bamessing. Twelve of these farmers failed to respond regularly, thereby reducing the effective number of respondents to 47.

Some of the important data on farming intensities in each village are shown in Table 1. In Wum, the mean total input was 94 traction days per farm (or 62 traction days per ha). Animal power in Wum was used entirely for land preparation (mainly tilling and, to a very limited extent, ridging to form contour bunds), and for no other operation. Compared with the entire sample (105 traction days per farm) and with Bamessing, the intensity of animal power use in Wum was very low. The seven Fulani farmers owning oxen and equipment, however, had a mean total animal power input that was more than double the mean animal power input for the entire sample, and far above mean use in Bamessing. Mean use on non-Fulani farms was less than half that on Fulani farms. Even when cropped areas were considered and utilisation was calcualted on a per ha basis, Fulani farmers continued to display a more intensive use of this technology.

As Fulani farms were on average much larger than other farms in the region, whether in Wum or in Bamessing, it is tempting to conclude that animal power was used mainly to expand cropped areas. Per ha utilisation levels on Fulani farms were much lower than those in Bamessing, indicating that cropped area expansion probably accounted for much of the increased level of use on Fulani farms. However, per ha utilisation levels on Fulani farms were still more than double those on non-Fulani farms in Wum. Therefore, the level of animal power use on these farms is likely to have been determined by a mixture of agricultural intensification and crop area expansion.

The structure of animal power use on non-rice fields in Bamessing was very similar to that in Wum: all the animal power on these fields went for land preparation. While the mean level of use on all of these fields combined was just a little over half of that on rice fields alone, the intensity of use on the latter was about four times the intensity on the non-rice fields. Animal power use

Table 1: Farming intensities and other characteristics of farms in Wum and Bamessing

	Wum			*Bamessing*			*Entire sample*
	Fulani	*non-Fulani*	*Mean*	*Rice*	*Other*	*Total*	
Size of holding (ha)	8.3±1.4	3.8±2.1	6.8±4.9	0.6±0.5	4.9±3.5	5.4±3.7	6.0±4.3
Cropped area (ha)	1.9±1.3	1.3±0.7	1.4±0.9	0.6±0.5	1.2±0.7	1.8±0.9	1.7±0.9
Farming intensity	96±27	84±38	88±29	167±18	78±35	103±24	94±22
Traction days per ha	116	57	65	128±11	33±30	89±65	62
Traction days per farm	219	75	94	75±61	41±42	124±95	106
Labour days per ha	220±219	125±93	208±113	288±122	110±78	167±101	175±117
Labour days per farm	417±311	166±122	301±276	167±80	137±93	304±105	301±234

Note: Where samples are large enough figures are given ± standard deviation on rice fields in Bamessing was far more intensive that anywhere else. Most of it (48%) was used to transport people and farm produce from the distant fields in the valleys to storage structures in the village and the roadside market at Ntenka. Tilling and puddling the swamps took up a further 43%, and the rest went for weeding (9%).

While rice fields were cultivated more intensively than any other fields, the structure of animal power use on rice fields would seem to suggest that utilisation levels were determined more by transportation needs (to reduce the burden and time required to move persons, farm inputs and produce to and from the distant valleys) and the agronomic requirements of rice cultivation (need to till and puddle swamps). It does not seem that animal power is required either to displace or to supplement labour at peak periods: incremental labour requirements are met by hiring more labour.

These results were tested further by constructing a *primary mechanisation function*, a multiple regression model. The dependent variable in this model was total traction days. Independent variables included:

- farming intensity, capturing the level of evolution of the farming systems
- household resource base, captured by housing standards and household possession (scored following the methods used in the region in MIDENO, 1984), farm income levels and the availability of off-farm sources of income
- commercialisation of agriculture, captured by the level of crop sales the previous year and the value of purchased inputs used on the farm
- farm labour input and years of experience.

The results demonstrated that, contrary to the common logic of farming systems evolution theory, the relationship between agricultural intensification and primary mechanisation is not at all straightforward. While intensification is likely to increase the pace of mechanisation, the latter will not necessarily result from the former. On rice fields in Bamessing, for example, primary mechanisation appeared to be driven along by the agronomic requirements of rice cultivation. On non-rice fields, it was determined by the desire to expand the area under crops in order to increase marketed output. The role of agricultural intensification in these cases was marginal. In Wum, the experience of users was the important factor, perhaps driven along by the need to expand cropped areas.

Agricultural intensification was not found to be a precondition for primary mechanisation; intensification alone would not result in mechanisation. Increasing intensification will only accelerate the pace of mechanisation, provided that the agronomic conditions require mechanisation, that there are crop markets, and that labour is available to meet the increasing requirements of crop area expansion or increased cropping frequencies. Hence, mechanisation will succeed only if there are gainful interactions between mechanised farms and the rest of the economy.

Evolution of farming systems and the profitability of animal traction

Yield response to animal power (not reported here), confirmed the findings of previous studies elsewhere: improved tillage does not necessarily increase yields. Cropping patterns and farm output were more varied in Bamessing than in Wum as Tables 2 and 3 show.

With very low levels of inputs and near total absence of diversification, output in Wum was correspondingly low, although Fulani farmers had a farm output almost twice that obtained by non-Fulani farmers. Cropping patterns and farm output in Bamessing were more varied and more interesting. Intercrop densities (not reported here) were much higher in Bamessing, while maize densities were lower than those in Wum. On non-rice fields, the pattern was very similar to that in Wum.

While a greater variety of crops was produced on the rice fields in the valleys, total crop value from these fields was less than half of the crop value from the other fields. Indeed, the crop value from rice fields represented barely 31% of total crop value, while the rice crop iteself constituted a mere 20% of the value of all crops. Yet more than 60% of all animal power and nearly 55% of all farm labour in Bamessing were used on rice fields alone. None of the rice produced was kept for home consumption, while less than half of the maize produced on the non-rice fields was sold.

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Table 2: Crop production and crop value on Fulani and non-Fulani farms in Wum

Crop	*Fulani (n=7)*	*non-Fulani (n=11)*	*Mean (n=18)*
Maize			
Quantity (kg)	2700 ± 2759	1609 ± 1300	2141 ± 2003
Value (000 FCFA)	257 ± 262	153 ± 124	203 ± 190
Groundnuts			
Quantity (kg)	-	52 ± 137	52
Value (000 FCFA)	-	6.2 ± 16	-
Total crop value (000 FCFA)	257 ± 262	159 ± 143	219 ± 195

Notes:
1) Figures ± Standard deviation
2) US$=FCFA500 approximately

Therefore it seems that increased labour and animal power were used on the rice fields because of the *cash income* to be derived from cropping them. In other words, *crop marketing* appears to have been the driving force of (both) intensification and mechanisation on the rice fields, and that primary mechanisation is not necessarily a consequence of agricultural intensification.

To investigate the profitability of animal traction and its impact on the efficiency of resource use, a production fucntion was estimated, and marginal value products (MVPs) of all inputs calculated. The results are shown in Table 4.

Table 3: Crop production and crop values on rice and non-rice fields in Bamessing

Crop	*Rice field*	*Other fields*	*Total*
Maize			
Quantity (kg)	673 ± 438	5054 ± 2345	5727 ± 3458
Value (000 FCFA)	64 ± 42	480 ± 223	544 ± 329
Beans			
Quantity (kg)	59 ± 129	84 ± 95	143 ± 107
Value (000 FCFA)	7 ± 14	9 ± 11	16 ± 12
Potatoes			
Quantity (kg)	200 ± 189	-	200 ± 189
Value (000 FCFA)	6 ± 6	-	6 ± 6
Rice			
Quantity (kg)	2786 ± 2100	-	2786 ± 2100
Value (000 FCFA)	139 ± 105	-	139 ± 105
Total crop value (000 FCFA)	216 ± 167	489 ± 233	705 ± 451

Notes:
1) Figures ± standard deviation
2) US$ 1 = FCFA500, approximately

From the MVP values it seems that farm income response to primary mechanisation depended largely on the level of evolution of the farming system. In systems such as that in Wum at the start of evolution, farm incomes depended on the area under crops and the level of use of purchased inputs rather than on animal power. Crop area expansion and the use of fertilisers and good quality seed would be the more appropriate policy options to raise farm incomes. Expansion of cropped area need not necessarily be done using animal power. While a lot of animal power was used to expand cropped area on non-rice fields in Bamessing, the study results were not conclusive as to whether it would be profitable to use animal power for crop area expansion in Wum.

In systems with high cropping intensities, such as the rice fields in Bamessing, farm income response to animal power input depended critically on the use of complementary factors of production, principally land augmenting, fertility-enhancing inputs such as fertilisers. In these systems, some cropped area expansion would be profitable, but as this is virtually impossible, increased intensity of use of purchased land-augmenting inputs (ie increased use per unit of land) was the key to raising farm production in conjunction with animal power.

In other, less highly-evolved but progrssive systems such as that on non-rice fields in Bamessing, marginal returns to animal power were approaching zero. Analysis of the production function indicated that increasing the level of use of animal power per ha would lead to heavy losses in farm incomes. The key to increasing farm incomes in such a system using animal power lay in expanding the area under crops. As in the other subsystems, the absence of land augmenting, fertility-enhancing inputs appeared to be the most limiting factor.

The interpretation of the ratio MVP:MFC is not at all straightforward. A ratio of 1.0 is accepted in previous studies as evidence of allocative efficiency (Shapiro, 1976). If this criterion is accepted then it is tempting to conclude that, with the exception of purchased input use (per ha) in Wum and non-rice fields in Bamessing, there is considerable inefficiency in the use of animal

Table 4: Marginal value products (MVP) and ratios of MVP to marginal factor costs (MVP:MFC) for animal power, human power and agricultural inputs

	Wum		*Bamessing (rice)*		*Bamessing (non rice)*		*Sample*	
Factors	***MVP***	***MVP:MFC***	***MVP***	***MVP:MFC***	***MVP***	***MVP:MFC***	***MVP***	***MVP:MFC***
Animal power								
per farm	-	-	-107	-0.06	14	0.008	-326	-0.19
per ha	856	0.51	624	0.37	-640	-0.38	1571	0.94
Labour								
per farm	-	-	775	3.16	402	1.64	531	2.16
per ha	-525	-2.14	-467	-1.91	-	-	-	-
Inputs								
per farm	116	0.12	-122	-0.12	355	0.36	-281	-0.28
per ha	1052	1.05	1077	1.08	3500	3.50	6879	6.88

Notes:
1) - indicates variable was not significant in the primary mechanisation function
2) There was no factor market for land, and its value was therefore excluded.
3) MVPS are in FCFA; US$ 1 = FCFA 500, approximately.
4) Cropped area was a significant variable in the model, but is omitted from MVP estimates because of the absence of a factor market for land in the region.

power and the other factors of production in North West Cameroon. In the absence of comparable data on farming without animal power, it is impossible to say whether this is better or worse than the predominant hand-hoe-based system. However, it is noteworthy that the ratio MVP:MFC for the entire sample of animal power users is very close to one when considered on a per ha basis. What can be said for sure, therefore, is that at current levels of use per farm there are considerable inefficiencies, but that the situation can be improved by increasing the intensity of use, subject to respecting the location-specific differences in farming systems.

Shapiro (1976) provided a formula for calculating the relative change in marginal value product (D) that is required in order to equate MVP to MFC thereby optimising output. The required change is the absolute value of D in the equation:

$$D \quad \frac{MVP \quad MFC}{MVP}$$

The D values (in percentage terms) for the ratios in Table 4 are presented in Table 5, with the exception of land for which there is no factor market.

The D-value for animal power is highest for non-rice farms in Bamessing (input use per ha), and lowest for rice fields in Bamessing (input use per farm). The interpretation of D=168 is that to be efficient, farmers should have been obtaining about double the marginal value product of animal power at the current intensity of use on rice fields. With a production elasticity of 0.21 (ie a 1% increase in animal power input would result in an income change of only 0.21%), and with MVP increasing less than proportionally to MFC, it would seem that the appropriate adjustment would be to reduce the intensity of animal-power use. Considerable inefficiencies also existed in the intensity of use in Wum and Bamessing.

In the case of labour, there were large inefficiencies in Wum, Bamessing (rice and non-rice) and for the entire sample. Purchased input use was far more efficient in Bamessing rice fields that on all other farms, whether considered per ha or per farm. In Wum, MVP could be increased up to seven-fold at current levels of input use per farm. On non-rice fields in Bamessing, MVP could be increased two-fold. In general terms therefore, the levels of efficiency could be said to be lowest in the more advanced farming system in Bamessing and highest in the more remote areas in Wum.

Conclusions

The adoption of animal power does not depend solely or even mainly on the level of farming intensity. Farmers will adopt the technology in order to expand cropped areas to increase aggregate output so as to take advantage of market

Table 5: Percentage change in the marginal value products required to equate them with the marginal factor costs

	Wum	*Bamessing (rice)*	*Bamessing (non rice)*	*Entire sample*
Animal power				
per farm	-	6	118	19
per ha	59	168	38	6
Labour				
per farm	-	216	39	54
per ha	214	119	-	-
Inputs				
per farm	762	12	65	28
per ha	5	7	250	588

Notes:
1) - indicates that the variable was not significant in the regression model

availability, or to meet the agronomic requirements of cultivating a specific crop such as swamp rice, provided there is a ready market for the crop.

Animal traction is a profitable technology if used under conditions of double- or multiple-cropping, accompanied by application of soil fertility-enhancing inputs such as fertilisers. Therefore, to improve profitability and increase the chances of adoption and sustainability, promotion efforts should be accompanied by measures to reduce fallow periods and introduce stationary cultivation. Development of rural infrastructure to link farmers to markets for crops and inputs is an essential accompanying measure.

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