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ANIMAL TRACTION AND RESOURCE PRODUCTIVITY: EVIDENCE FROM UPPER VOLTA

Presented at
Farming Systems Research Symposium
Kansas State University, Manhattan, Kansas

by:
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ANIMAL TRACTION AND RESOURCE PRODUCTIVITY: EVIDENCE FROM UPPER VOLTA

William K. Jaeger[1]

Animal traction, the use of draft animals in performing farm operations, has long been recognized as a technology appropriate for small farms in West Africa where nearly all farming operations are done manually with a short handled hoe. As a power source to supplement or replace human power this form of mechanization has proved elsewhere to benefit farmers through increases in labor productivity, allowing seasonal labor bottlenecks to be overcome, and by direct and indirect yield increasing agronomic benefits. But while these gains have been well documented in many parts of the world, efforts to promote the adoption of animal traction in West Africa have met with very limited and uneven success (Sargent, et al., 1981, review 125 related projects in francophone West Africa). Numerous projects, begun as early as the 1950's to encourage adoption of animal traction often resulted in the technique being abandoned in three to five years. Although recently large numbers of farmers in Senegal and Mali have begun to use animal traction, the belief that the technology is readily adaptable throughout the Sahel has not been born out by experience in Upper Volta and elsewhere. Animal traction has become a focal point among research and extension efforts to introduce new technologies appropriate to small farms, but there exists a lack of consensus--and even some mystery--about the hypothesized, and attainable, benefits.

POTENTIAL BENEFITS

The benefits most often cited include: (1) deeper preplant plowing that increases yields through better plant development resulting from the loosening of the soil, better water infiltration and retention, as well as the incorporation of organic materials in the soil; (2) increased labor productivity for plowing, planting, weeding and harvesting operations which reduce labor bottlenecks allowing increases in

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[1] Formerly agricultural economist with Purdue University's Farming Systems Unit in Upper Volta. Doctoral candidate, the Food Research Institute, Stanford University.

cultivated acreage; (3) being able to perform these operations faster may increase yields when done on a more timely basis; and (4) the availability of manure from the draft animals can improve soil fertility.

Experimental Evidence

Individually, these effects have been substantiated by research evidence. Deep plowing has been shown to result in yield increases of up to 50% on research station plots. Yield increases due to early planting and more timely weedings are also well documented. During on-station trials in Mali comparing the labor requirements between manual and animal-powered operations, the Institut de Recherches d'Agronomie, IRAT (cited in Sargent, 1981) found a reduction in total labor requirements of 43% with animal traction. Sargent (1981) points out that these labor savings occur primarily for weeding and ridging while labor requirements for land preparation and planting are not significantly reduced. Moreover, since most cereal fields are planted directly without any land preparation, the introduction of animal traction plowing in many cases will increase labor use by adding a field operation that was not previously done. In contrast to these findings, Delgado (1979, 1981) incorporates in his analysis a decrease in seedbed preparation time and increases in weeding and harvest labor requirements, assumptions drawn from experiment station information.

Skeptical analysts suggest that the yield effects do not hold up in practice (Sargent, et al., 1981), and that increases in acreage under cultivation with animal power are limited where relaxing one constraint has little effect before another constraint becomes binding. Labor requirements for maintenance of draft animals can conflict with labor needs during critical periods (Delgado, 1979; Vail, 1973). In contrast to these abundant hypotheses and experimental results there is a shortage of empirical evidence.

Empirical Findings

The ongoing debate over the benefits of animal traction in Upper Volta and elsewhere has led to several recent attempts to supply empirical evidence that these benefits have been attained by farmers. Two studies have used cross-section comparisons to detect the expected benefits from farm survey data. The recent Michigan State University project in Eastern Upper Volta used stratified sampling for their farm production survey across farms using manual, donkey and oxen traction. Results from their data did not show statistically significant differences in acreage cultivated per worker or in yield except for the small compound maize plots where yield increases are often attributed to the application of additional manure by farmers possessing draft animals. Similarly their regression analysis did not show the use of animal traction to be significantly related to yields (Barrett, et al., 1982).

Using survey data from ICRISAT's village studies in central Upper Volta, McIntire (1981) employed decomposition analysis to break down the effects of using animal traction into yield, acreage and cropping pattern effects. He found, however, no acreage increase with animal traction except when differences in family size were ignored, the differences attributable to yield effects were found to be negative. Differences between the two groups, such as cropping pattern and input use such as fertilizer, were negligible.

These somewhat discouraging results have done little to dissuade projects in research and extension from emphasizing the high potential of animal traction for the area. Many of those reporting the results just presented remain optimistic, preferring to offer alternate explanations for the failure of the data to show significant benefits. The conclusion drawn by some observers is not the benefits do not exist, but rather that they have yet to be adequately documented.

THE FARMING SYSTEM UNIT'S STUDY[2]

In response to this need for better designed surveys and analysis to assess observable benefits from animal traction, Purdue's Farming Systems Unit (FSU) in Upper Volta carried out a program to measure the effects of animal traction on resource use and productivity on-farm.[3]

The best method to obtain empirical results about the effects of using animal traction on-farm would be a combination of cross-sectional and time-series (before and after) observations across samples of small farms. The impracticality of such a long-term data gathering effort leaves the alternative of gathering the "before" data on a recall basis. Although this technique brings up the issue of bias from subjective responses, it should be pointed out that it is precisely the subjective view of the decision-makers involved that is pertinent to the decision to adopt and continue to use animal traction.

With this in mind, the Farming Systems Unit chose an approach that combined a season-long farm production survey with a set of subjective farmer interviews.

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[2] The Farming System Unit is part of the Semi-Arid Food Grains Research and Development Program (SAFGRAD), OAU/CSTR. Funding for this research was provided through Joint Project 31, contract AFR-C-1472 between Purdue University and the United States Agency for International Development (USAID).

[3] FSU benefitted greatly from the experience, advice and findings of the studies cited earlier, in designing and carrying out their research program.

Site Selection

In 1982 FSU worked in three study villages. Two of these villages, Nedogo and Diapangou, had sufficient numbers of households using animal traction to permit this type of cross-sectional comparison. The villages were chosen to be representative of a larger region of Upper Volta. Within the villages samples of sixty households were chosen randomly, but stratified purposively between animal traction equipped farms and manual farms.

Nedogo, a village on the densely populated Mossi plateau (thirty to fifty inhabitants per square kilometer) thirty kilometers north of Ouagadougou, is one of the two sites with a sample of twenty-four manual farms and thirty-six donkey traction farms (five of which also have single ox traction). The second village, Diapangou, is in the sparsely populated eastern region twenty kilometers west of Fada N'Gourma (five to fifteen inhabitants per square kilometer). The sample there of fifty-nine households consists of eleven manual farms, twenty-one donkey traction and twenty-seven oxen traction (seven of the latter also use donkey traction). Both villages are in the rainfed millet-sorghum zones of Upper Volta with average annual rainfall being near 700mm for Nedogo and 800mm in Diapangou. Secondary crops include peanuts, cowpeas, bambara nuts, rice and maize. In Diapangou soybeans are also grown.

Agriculture in these villages is typical of much of Upper Volta: over 90% of farm production is consumed by the farm family with little or no marketed surplus in most years (although some farmers in Diapangou market significant surpluses). Soil fertility and yields are low. Fallow is rare in Nedogo, while in Diapangou shifting cultivation is practiced. In both villages manure and crop residues are used to maintain fertility.

The two villages are not representative of the regions in one respect--as many as half the farm families use or have used animal traction. Although this divergence limits the extent to which the results can be extrapolated to estimate animal traction use of these regions, it should not affect the internal consistency of the "with and without" comparisons being made. The reasons for the higher rates of use appear to be the result of exposure to extension and credit programs rather than any agronomic anomalies.

Production Survey Methodology

Each farm family was interviewed twice a week by Voltaic numerators about the labor and nonlabor inputs in all fields (except a small subsample of minor crops). All fields were measured and harvests were weighed. Threshing coefficients and dry weights were computed by drying and threshing a sample from all major fields.

Farmer Interviews

In addition to the farm production survey, in-depth farmer interviews were conducted within the farm samples. These pertained to two general areas of inquiry: first, they elicited farmers' perceptions about changes in resource use and productivity since they began using animal traction (e.g., do they farm more land now than before using animal traction?). Second, they recorded farmers' perceptions about the potential and actual benefits of animal traction (e.g., their estimate of yield increases for sorghum due to plowing before planting).

INTERVIEW RESULTS

The results of these interviews are compared with the farm production results, but also were used extensively in formulating the principal hypotheses regarding animal traction in Upper Volta. A list of the principal hypotheses appears below:

1. Yield increases associated with animal traction are due mainly to preplant plowing; these effects are larger with oxen plowing than the shallower donkey plowing.

2. Potential acreage increases with animal traction are due mainly to increased productivity of labor during weeding operations.

3. Problems associated with peak labor bottlenecks can be exacerbated when preplant plowing results in delayed planting and first weeding. Preplant plowing alone may actually result in a decrease in area cultivated for two reasons: first, plowing with the onset of early rains, instead of planting directly, can delay planting and reduce the period during which planting is possible. Second, if weeds have not yet germinated when plowing occurs, it may accelerate weed growth and limit even further the planting period by moving up the time when planting activities must give way to weeding. In addition, delaying planting increases the risk of low yields due to late season drought stress.

4. Animal traction allows child labor to be used more productively, thereby reducing the constraint on adult family labor during critical periods.

5. The critical timing required for animal traction activities associated with short season, rainfed agriculture restricts the potential for the development of rental markets and thereby limits profitability for smallholders.

6. There are economies of scale associated with animal traction.

7. Complementarities exist between animal traction and other soil fertility and moisture conservation technologies such as nitrogen fertilizers and tied-ridging.

8. Actual production increases can diverge from potential increases due to income effects associated with increased labor productivity: Farmers may choose to work less, while at the same time maintaining, or increasing their production.

9. Increased factor productivity with animal traction results in a larger share of resources being allocated to cash crop activities.

10. The opportunity cost of investing in draft animals for many smallholders is the sacrifice of benefits derived from investing in more "liquid" livestock assets such as goats and sheep which are widely used as a form of crop insurance and a store of wealth.

11. Maintenance of draft animals does not present a major problem except for very small households where adequate child labor is unavailable.

12. By plowing part of their fields farmers can reduce labor bottlenecks at weeding time since the plowed part will usually require weeding at a later time, so that the operation can be staggered between the plowed and nonplowed parts. But this occurs only if early rains have caused weeds to sprout prior to plowing.

In general, farmers perceived substantial benefits from the use of animal traction. However, responses about increased area cultivated over time were inconclusive: although nearly all households reported cultivating more land than they had before adopting animal traction, nearly all households increased the number of active workers as well, and hand tillage households gave similar responses. There was, however, a notable increase in marketed surplus according to farmers. All animal traction households in Diapangou and 75% of those in Nedogo reported that they sell more of the production from the principal family millet field than they did before using animal traction. Harvests from personal fields are more often marketed now as well; the increase is mainly in millet, followed by peanuts, and in Diapangou, by soybeans.

In both villages first weeding appears to be the primary labor bottleneck, followed by planting in Nedogo, and preplant plowing in Diapangou. Animal traction appears to have shifted these constraints on household labor. Farmers were asked to indicate the activity for which the lack of labor restricted their ability to increase production both before and after adopting animal traction. The results are presented in Table 1. In Nedogo, preplant plowing is not normally done. Even with animal traction, line tracing or superficial scarification with the Houe Manga are the only land preparation activities (The Houe Manga is a multipurpose tool bar using tines and sweeps for scarification and interrow cultivation). The use of the Houe Manga appears to have lessened the constraint on first weeding substantially: two-thirds of those using animal traction said that labor is no longer a constraint. In Diapangou, animal traction appears to facilitate preplant plowing and to reduce the constraint of early weeding. Planting was more frequently cited, presumably a result of increased preplant plowing that delays

TABLE 1

ACTIVITY PERCEIVED TO BE MOST CONSTRAINING BY FARMERS

	Preplant Plowing	Planting	First Weeding	Second Weeding	Labor Not Constraining
DIAPANGOU					
Before Using Animal Traction (n = 48)	43%	11%	66%	19%	0%
With Animal Traction (n = 48)	6%	38%	49%	21%	9%
Hand Tillage Households (n = 11)	36%	36%	55%	0%	0%
NEDOGO					
Before Using Animal Traction (n = 36)	---[a]	36%	81%	0%	3%
With Animal Traction (n = 36)	---	14%	25%	0%	67%
Hand Tillage Households (n = 24)	---	30%	70%	0%	0%

Note: Totals exceed 100% due to multiple responses. Planting and first weeding were often cited jointly.

[a] Preplant plowing is not practiced here. Donkey drawn adjustable tool bars are sometimes used to "scarify" the field before planting.

planting and constricts the period during which it can be done. Mechanized planting and harvesting are rare in Upper Volta.

Table 2 summarizes farmers' perceptions about factor productivities with animal traction. Yield increases due to preplant plowing are thought to be greatest for maize and peanuts, followed by sorghum and millet. With donkey traction, farmers expect to perform weeding operations twice as fast as by hand tillage; and with oxen traction, it is believed to cut weeding time to about a third. Oxen reportedly can plow twice as much land per day as donkeys, but it appears that the shallower donkey plowing can be continued longer after a rain under dryer soil conditions. (In Nedogo, the same shallow scarification is done with both donkeys and single ox traction.)

FARM PRODUCTION SURVEY RESULTS

The cross-sectional production data from FSU's 1982 farm surveys is examined in five separate, but related, ways for evidence of the benefits of animal traction. First, acreage cultivated by crop is compared (both total area and as a share of total cropped area). Second, yields are compared between groups. Third, total production by crop is compared, which will incorporate net effects of both yield and acreage differences. Fourth, total production is valued at harvest period market prices to compare the direct effects of animal traction on farm income. Finally, labor use in the subsamples is compared for evidence of changes in the use of household labor.

Acreage Effects

Tables 3 and 4 compare arithmetic means of area cultivated by crop. Minor crops occupying less than one percent of land area are excluded. Fields that were intercropped are classified according to the dominant crop.

In Nedogo where the Houe Manga is used primarily in weeding operations, donkey traction households cultivate an average of 1.23 hectares per worker compared to 0.94 hectares per worker for hand tillage households. This increase of 32% is significant at the 0.01 level and is the result of increases in area planted to millet, white sorghum, maize, and groundnuts. The cropping patterns of the two groups are nearly identical except for a small shift from red sorghum to white sorghum by animal traction households.

In Diapangou where more preplant plowing is done and only 60% of the animal traction farmers have weeding equipment, there is no increase in area cultivated per worker. Increases in cropped area per household occur for millet/sorghum, maize and peanuts, but these are attributable to the larger number of workers in animal traction households. Millet's share of the total cropped area is less among animal traction farmers with an increase in the shares of white sorghum, peanuts, rice and

TABLE 2

ANIMAL TRACTION AND RESOURCE PRODUCTIVITY

FARMERS' SUBJECTIVE RESPONSES

	NEDOGO (n=36)	DIAPANGOU (n=48)
Yield Increases Expected With Preplant Plowing:		
Millet	20% - 50%	20% - 50%
Sorghum	10% - 60%	30% - 60%
Maize	50% - 150%	20% - 50%
Peanuts	20% - 100%	50% - 100%
A Field Requiring Ten Days to Weed by Hand, Requires How Many Days With:		
Donkey Traction?	5 Days	4 - 6 Days
Oxen Traction?	3 Days (single ox)	2 - 4 Days
A Field Requiring Five Days to Plow With Oxen, Requires How Many Days With a Donkey?	7 - 8 Days (compared to a single ox)	8 - 12 Days
Maximum Hours Per Day the Animals Can Plow:		
Donkey?	4 - 6 Hours (Scarification)	3 - 4 Hours
Oxen?	7 - 8 Hours (Scarification)	4 - 5 Hours
Number of Days After a Good Rain That Preplant Plowing Is Possible With:		
Donkey Traction?	3 - 5 Days (Scarification)	4 Days
Oxen Traction?	4 - 6 Days (Scarification)	3 Days
Hours Per Day Animals Can Weed:		
Donkey?	5 - 7 Hours	4 Hours
Oxen?	6 - 8 Hours	5 Hours

TABLE 3

LAND USE AND CROPPING PATTERNS, NEDOGO

	Hand Tillage (n = 24)		Donkey Traction (n = 36)		
	Area (Ha)	Percent of Total	Area (Ha)	Percent of Total	Increase Over Hand Tillage (Ha)
Millet	2.74	62.0	5.20	63.0	2.46***
White Sorghum	0.68	15.4	1.51	18.5	0.83***
Red Sorghum	0.56	12.7	0.71	8.6	0.15
Maize	0.09	2.0	0.20	2.4	0.11***
Groundnut	0.24	5.4	0.45	5.5	0.21***
Bambara Nuts	0.08	1.8	0.10	1.2	0.03
Rice	0.02	0.5	0.01	0.1	0.01
Total	4.41	100.0	8.18	100.0	3.77***
Active Workers Per Household	4.71		6.64		
Mean Area Cultivated Per Worker	0.94		1.23		0.3** (Increase of 32%)

Significance levels: * = 0.1; ** = 0.05; *** = 0.01.

TABLE 4

LAND USE AND CROPPING PATTERNS, DIAPANGOU

	Hand Tillage (n = 11)		Donkey Traction (n = 21)			Oxen Traction (n = 27)		
	Area (Ha)	Percent of Total	Area (Ha)	Percent of Total	Increase Over Hand Tillage (Ha)	Area (Ha)	Percent of Total	Increase Over Hand Tillage (Ha)
Millet/ Sorghum	4.48	89.1	5.59	75.0	1.10	6.27	81.2	1.79
White Sorghum	0.14	2.8	0.87	11.7	0.73*	0.25	3.2	0.11
Maize	0.14	2.8	0.17	2.3	0.03	0.28	3.6	0.14**
Groundnut	0.18	3.5	0.45	6.0	0.27	0.58	7.5	0.40*
Bambara Nut	0.03	0.6	0.04	0.5	0.01	0.06	0.8	0.03
Rice	0.01	0.2	0.13	1.8	0.12	0.07	0.9	0.06
Soybean	0.05	1.0	0.20	2.7	0.15	0.22	2.9	0.17
Total	5.03	100.0	7.45	100.0	2.42	7.73	100.0	2.70
Active Workers Per Household	4.36		6.38			7.63		
Mean Area Cultivated Per Worker	1.15		1.17		0.02	1.01		-0.14

Significance levels: * = 0.1; ** = 0.05; *** = 0.01.

soybeans, an indication that land is shifted away from subsistance production towards cash crops.

Yield Effects

Tables 5 and 6 compare yields for the two villages.[4] The results from Nedogo show a significant decrease in white sorghum yields and a similar (but not statistically significant) increase in red sorghum yields.

The yield effects in Diapangou are more pronounced. Statistically significant yield increases are obtained for white sorghum, millet-sorghum, maize and peanuts. A large decrease in soybean yields was observed among donkey traction households. (The comparison is questionable, however, since the manual farm sample contains only six observations for a total area of 0.55 Ha. Similarly, for white sorghum and peanuts, the number of manual households is small.)

Total Crop Production

Differences in weight harvested between farm classes should be close to the product of the acreage and yield effects presented above. The actual differences presented in Tables 7 and 8 will diverge from these products for two reasons. One, intercrops will be represented here separately when they were harvested and weighed apart; and two, the product of mean yield and mean acreage will differ from the mean of the products of yield and acreage if yield and acreage are correlated.[5] The measure used here is the most straightforward one; summing harvested weight by crop and by household.

In spite of differences between the two villages in yield and acreage effects, the overall effects on production per worker are surprisingly similar: both show significant increases in millet, or millet

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[4] Mean yields were weighted within households by field area, but grouped means are arithmetic between households. Minor intercrops and border crops were ignored. Harvests were summed when cereals were intercropped.

[5]

$$1/n \left(\sum_{i=1}^{n} a_i b_i \right) \neq 1/n \left(\sum_{i=1}^{n} a_i \right) \left(\sum_{i=1}^{n} b_i \right)$$

where: corr (ab) $\neq$ 0

a_i = yield (Kg/Ha) from field i

b_i = area (Ha) of field i

TABLE 5

YIELDS BY TILLAGE TECHNOLOGY, NEDOGO

(Kilograms Per Hectare)

	Hand Tillage	Donkey Traction		
	Mean Yield	Mean Yield	Increase Over Hand Tillage	Percent Increase
Millet	350 (n=24)	336 (n=36)	-14	-4.0%
White Sorghum	515 (n=19)	343 (n=30)	-172**	-33.4%
Red Sorghum	421 (n=20)	578 (n=32)	157	37.3%
Maize	1140 (n=24)	971 (n=35)	-169	-14.8%
Peanuts	502 (n=24)	435 (n=36)	-67	-13.4%

Significance levels: * = 0.1; ** = 0.05; *** = 0.01.

TABLE 6

YIELDS BY TILLAGE TECHNOLOGY, DIAPANGOU

(Kilograms Per Hectare)

	Hand Tillage	Donkey Traction			Oxen Traction		
	Mean Yield	Mean Yield	Increase Over Hand Tillage	Percent Increase	Mean Yield	Increase Over Hand Tillage	Percent Increase
Millet/Sorghum (Sole-cropped Millet Included)	329 (n=11)	403 (n=21)	74*	22%	391 (n=26)	62*	19%
White Sorghum	171 (n=5)	428 (n=13)	256	150%	368 (n=9)	197*	115%
Maize	1429 (n=11)	1636 (n=21)	208	15%	1879 (n=26)	451**	32%
Peanuts	256 (n=6)	519 (n=19)	263***	102%	548 (n=20)	292**	114%
Soybeans	762 (n=6)	297 (n=18)	-465***	-61%	764 (n=19)	2	0.3%

Significance levels: * = 0.1; ** = 0.05; *** = 0.01.

TABLE 7

PRODUCTION PER WORKER, NEDOGO

	Hand Tillage (n = 24)	Donkey Traction (n = 36)		
	Kg/Worker	Kg/Worker	Increases Over Hand Tillage	Percent Increase
Millet	190.8	262.6	71.9***	38%
White Sorghum	83.2	71.6	-11.6	-14%
Red Sorghum	57.6	49.5	-8.1	-14%
Maize	15.4	24.1	8.7**	56%
Groundnut	17.0	23.6	6.6*	39%
Bambara Nut	8.5	2.2	-6.3	-74%
Cowpea	7.5	7.7	0.2	3%

Significance levels: * = 0.1; ** = 0.05; *** = 0.01.

TABLE 8

PRODUCTION PER WORKER, DIAPANGOU

	Hand Tillage (n = 11)	Donkey Traction (n = 21)			Oxen Traction (n = 27)		
	Kg/ Worker	Kg/ Worker	Increase Over Hand Tillage	Percent Increase	Kg/ Worker	Increase Over Hand Tillage	Percent Increase
Millet/Sorghum	294.3	454.7	160.4**	54.0%	416.2	121.9*	41.0%
Maize	42.2	46.5	4.3	10.2%	74.1	31.9**	75.6%
Groundnut	6.7	27.0	20.3***	303.0%	27.5	20.8**	310.0%
Bambara Nut	6.8	5.6	-1.15	-16.9%	3.35	-3.4	-50.0%
Cowpea	44.6	51.5	6.9	15.5%	44.7	0.1	0.2%
Soybean	6.5	7.2	0.7	10.7%	7.21	0.71	10.9%

Significance levels: * = 0.1; ** = 0.05; *** = 0.01.

-sorghum, maize and peanuts. In both villages, there is evidence of a decrease in bambara nut production (although not statistically significant) and no change in cowpeas harvested per worker. In Nedogo, although millet production per worker increased 38%, red and white sorghum production declined (not statistically significant) resulting in a net increase of 16% for millet and sorghums.

Labor Use

Increases in total production per worker are not sufficient to conclude that animal traction has a direct effect on labor or land productivity. Changes in labor use patterns or other input use associated with one of the two subsamples being compared could lead to false conclusions. Income and/or substitution effects of changes in labor's productivity may result in increases or decreases in the hours worked per household member. If one were to find that more hours were spent weeding per person in the animal traction sample, it would become more difficult to argue that an increase in acreage cultivated was due to increased labor productivity rather than simply increased labor (reduced leisure).

The comparisons in Table 9, however, show that in no case was labor input per household member increased significantly in the animal traction sample, but that in several cases the labor inputs were reduced. Combining this evidence with the increases in farm production per worker already shown lends support to the hypothesis that animal traction increases labor productivity. In addition, this implies that the income effect of increased labor productivity dominates the substitution effect in the labor-leisure choice. Table 9 does not, however, support the hypothesis that animal traction allows labor requirements to be shifted from adult labor to child labor.

Farm Income

In order to combine the yield and acreage effects associated with animal traction, we have valued all crop production at harvest period prices in the respective villages (using three month averages beginning at early harvest) and compared value of farm production per worker between farm classes. The differences shown in Table 10 are significant in all classes of animal traction farms. Somewhat surprisingly the largest increase is in donkey traction in Diapangou, although this figure is not significantly different from the increases associated with oxen traction.

Assuming then that the increases associated with animal traction are attributable to animal traction, we multiply the differences per worker by the mean number of workers per household to estimate the production benefits of animal traction by farm class. Here oxen traction in Diapangou comes out slightly ahead of donkey traction; the results suggest an increase of 67,500 francs CFA in farm income with a

TABLE 9

MEAN HOURS SPENT ON MAJOR OPERATIONS

PER ACTIVE FAMILY MEMBER

NEDOGO

	Men		Women		Children[a]	
	Manual (n=24)	Animal Traction (n=36)	Manual (n=24)	Animal Traction (n=36)	Manual (n=12)	Animal Traction (n=29)
Preplant Plowing	17.3	13.1*	20.6	11.1***	6.9	9.8
Planting	55.8	49.3	76.4	76.3	37.1	40.4
First Weeding	225.0	196.9	217.2	200.9	82.5	124.4
Second Weeding	132.2	130.1	120.4	113.1	44.2	79.1*

DIAPANGOU

	Men		Women		Children[a]	
	Manual (n=11)	Animal Traction (n=48)	Manual (n=11)	Animal Traction (n=45)	Manual (n=8)	Animal Traction (n=40)
Preplant Plowing	74.5	70.7	37.0	31.5	37.5	57.5
Planting	93.8	45.9***	77.2	92.0	45.1	40.2
First Weeding	239.1	202.4	144.4	143.5	166.5	101.9*
Second Weeding	316.2	203.2**	185.6	120.8**	189.9	95.0***

Significance levels: * = 0.1; ** = 0.05; *** = 0.01.

[a] Children are active workers 15 years old and under.

TABLE 10

VALUE OF PRODUCTION PER WORKER

(IN CFA FRANCS)[a]

	Hand Tillage	Donkey Traction	Oxen Traction	Donkey and Oxen Traction
NEDOGO	(n=24)	(n=31)		(n=5)
(A) Revenue Per Worker	24,422	26,418*	---	31,862*
(B) Increase Over Hand Tillage	---	4,473*	---	7,439*
(C) Percent Increase	---	18.3%	---	30.4%
(D) Workers/ Household	4.71	6.45	---	7.8
(E) Increased Revenue Per Worker x No. of Workers (D x B =E)	---	28,850	---	58,024
DIAPANGOU	(n=11)	(n=21)	(n=20)	(n=7)
(A) Revenue Per Worker	22,191	32,670	31,196	29,556
(B) Increase Over Hand Tillage	---	10,479***	9,004**	7,358*
(C) Percent Increase	---	47%	40%	33%
(D) Workers/ Household	4.36	6.38	7.5	8
(E) Increased Revenue Per Worker x No. of Workers (D x B = E)	---	66,856	67,530	58,864

[a] One dollar equals approximately 380 CFA francs.

Significance levels: * = 0.1; ** = 0.05; *** = 0.01.

pair of oxen, and 66,900 francs CFA in farm income with a single donkey. Since farm classes were grouped independent of the number of years of experience with animal traction, this will tend to bias downwards our estimates of the potential benefits after several years experience with animal traction.

Although grouped comparisons of this kind offer strong evidence in support of animal traction, they are only a crude means by which to measure the productivities of these labor inputs to production. A more direct and insightful approach would capture the relationship between inputs and output using regression analysis. Since neither land nor capital play significant economic roles in the production function, the appropriate specification is simply income regressed on the five types of labor inputs (land has no market value, is abundant in most of the country, and would be impossible to value given qualitative differences. Capital is largely absent except for animal traction which will be included implicitly as a labor input). The resulting coefficients will represent the marginal and average value products of those inputs since they are linear and pass through the origin.

The cogent results in Table 11 leave little doubt that there are substantial productivity differences between manual and animal traction inputs. In both villages donkey traction is roughly six times more productive than manual adult labor, oxen traction in Diapangou is about seven times as productive. Taking into consideration the number of people driving these traction teams suggests that two adult workers are about three times as productive when working with traction animals than when working by hand.

Validation of these results can be achieved by two obvious tests. First, economic theory predicts that these coefficients, which represent marginal value product, will equal the observed wage and rental rates. Actual observed payments for labor hire and animal traction rental match these with surprising accuracy. Mean wage rates of 36 and 45 CFA francs per hour were observed in Nedogo and Diapangou respectively, and animal traction rentals were near 300 CFA francs per hour. Second, these estimates correspond quite closely to the relative productivities implicit in the farmer interview responses.

The contrasting coefficients for child labor in the two villages are somewhat puzzling. However, by grouping fifteen year olds with seven year olds it is not surprising that inconsistancies arise in estimating their productivity.

The existence of a "learning curve" associated with animal traction is most clearly demonstrated in Nedogo by a log linear regression of years of experience on area cultivated. The regression is presented in Table 12 and the estimated learning curve is illustrated in Figure 1. The strong findings suggest that with four years experience a donkey traction household expands the area cultivated by more than two hectares. Not only does this provide very strong support for the dynamic relationship between experience and productivity with animal traction,

TABLE 11

REGRESSIONS ON FARM INCOME

DEPENDENT VARIABLE: VALUE OF FARM PRODUCTION[a]

(IN CFA FRANCS)

NEDOGO

Variable	Coefficient	t - Value
Intercept	origin[b]	
Hand tillage		
Man hours[c]	40.3	3.0***
Woman hours	43.1	3.9***
Child hours[d]	48.1	2.8***
Donkey team hours	271.1	5.9***
Single ox hours	143.2	2.2**

$R^2 = 0.93$
$F = 151$
$n = 60$

DIAPANGOU

Variable	Coefficient	t - Value
Intercept	origin[b]	
Hand tillage		
Man hours[c]	58.1	4.0***
Woman hours	50.4	4.7***
Child hours[d]	-14.0	-0.7
Donkey team hours	398.7	3.8***
Oxen team hours	428.6	4.5***

$R^2 = 0.90$
$F = 95$
$n = 59$

[a] All crop production is valued at harvest period prices.

[b] The estimated regression line was forced to include the origin, since logically zero inputs must result in zero output.

[c] Hand tilling hours exclude the hours spent "driving" the animal traction teams. Donkey teams typically require two people, oxen teams are most often observed with three. These labor times are included where appropriate, however, such as Table 12.

[d] Children are active workers 15 years old and under.

Significance levels: * = 0.1; ** = 0.05; *** = 0.01.

TABLE 12

REGRESSION ON CROPPED AREA, NEDOGO

DEPENDENT VARIABLE: TOTAL AREA CULTIVATED BY HOUSEHOLD

Variable	Coefficient	t - Value
Intercept	origin	
Male Workers	0.57	2.4**
Female Workers	1.14	5.4***
Child Workers	0.51	1.9*
Ln (1 + years of experience with animal traction)	1.35	4.9***

$R^2 = 0.93$

$F = 182$

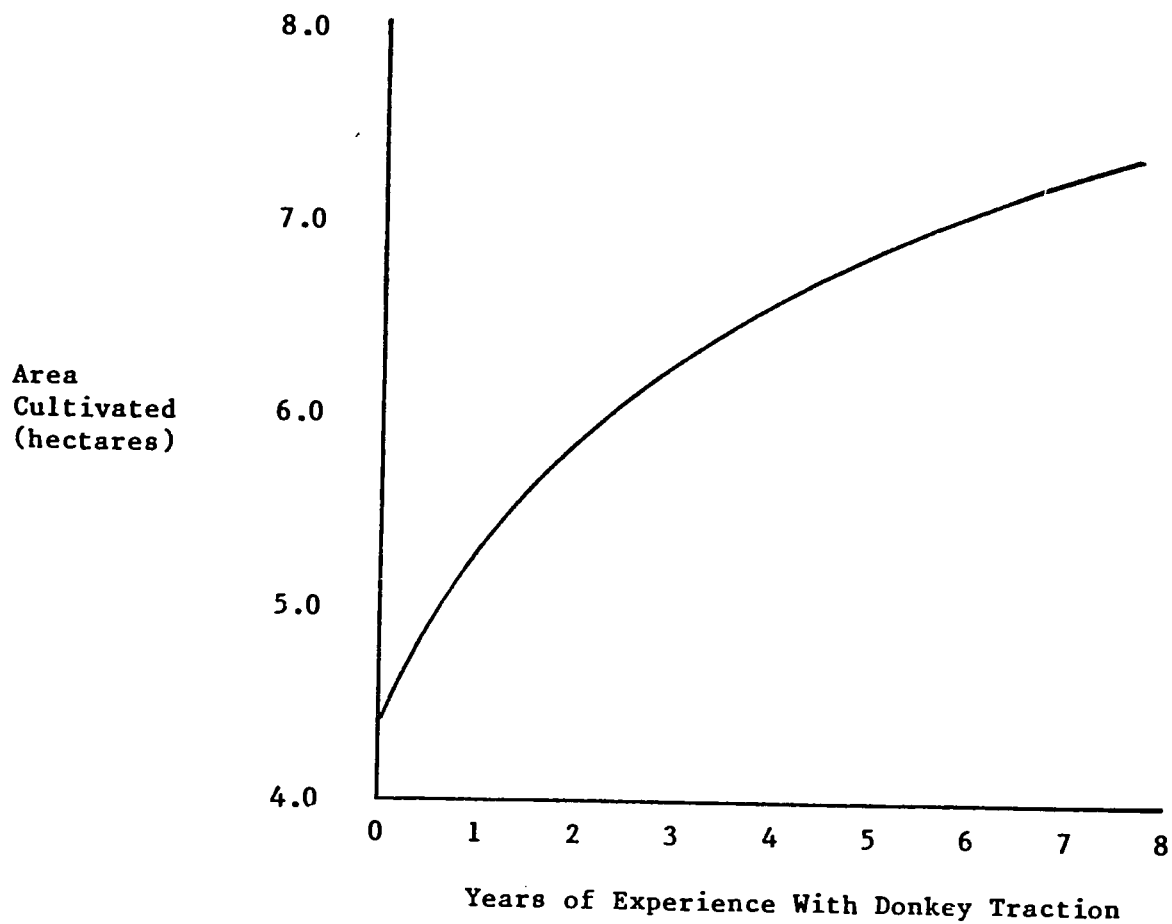
$n = 60$

Significance levels: * = 0.1; ** = 0.05; *** = 0.01.

FIGURE 1

ILLUSTRATION OF LEARNING CURVE

WITH ANIMAL TRACTION, NEDOGO



Source: Regression equation, Table 12.

but it casts serious doubt on the assertion that land is a strictly binding constraint on this part of the Mossi plateau. Farmers appear to be able to add land to their farms as animal traction and experience increase the productivity of their limited family labor force.

RETURNS TO INVESTMENT IN ANIMAL TRACTION

As an investment activity, adoption of animal traction must be evaluated over time and compared to the opportunity cost of that investment. The results from the previous sections, including evidence of a learning curve are incorporated into the partial budgets presented in Tables 13, 14 and 15. These projections assume no increase in production the first year, but a linear "learning curve" in the four following years so that in year five the adopter obtains the mean increase in production income found in Table 10. Animal prices and all variable costs are means derived from information collected in the two villages. The expected cost, or risk of financial loss, when an animal dies is calculated directly from complete histories of animal traction use by all households in the sample. Equipment prices are current prices from APICOMA, one of the two major farm equipment suppliers in the country. Values used are chosen to give conservative results of the profitability of animal traction. For example, most donkeys sold maintained their value or appreciated slightly. Nevertheless, we assume here a 40% depreciation over four years. On average, oxen appreciated 15,000 francs CFA per year; we use here 12,500 francs CFA. These budgets indicate an internal rate of return of 9.8% for donkey traction in Nedogo and 31.2% in Diapangou. For oxen traction in Diapangou, the value is 20.7%.

CONCLUSIONS

As with all empirical data inferences should not be made beyond the range of observation. But the several sources of bias notwithstanding, these results contrast sharply with studies which have previously been unable to document significant benefits to animal traction. The analysis presented here leads one to conclude that (1) weeding with donkey and oxen traction increases labor productivity roughly by a factor of three and can allow significant acreage increases where land is not constraining, (2) plowing before planting can result in substantial yield increases when early rains permit plowing prior to planting, (3) oxen have an absolute advantage in both plowing and weeding operations, and (4) donkeys have a comparative advantage in the weeding operations which require less power and more control.

With animal traction smallholders tend to increase the share of resources used in the production of market-oriented crops. Farmers indicated that their marketed surplus grew with the adoption of animal traction. In both villages the production increases were in millet, sorghum, peanuts and maize. These increases do not appear, however, to

TABLE 13

PARTIAL BUDGET FOR DONKEY TRACTION, NEDOGO

	Years							
	1	2	3	4	5	6	7	8
Revenues								
Incremental Value of Crop Production	0	7,000	14,000	21,000	28,000	28,000	28,000	28,000
Animal Sales	--	--	--	--	15,000	--	--	15,000
Equipment Sales	--	--	--	--	--	--	--	2,000
Variable Costs								
Equipment Purchase	29,000	--	--	--	--	--	--	--
Animal Purchase	25,000	--	--	--	25,000	--	--	--
Equipment Repair	--	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Feed Grain, Salt	4,310	4,310	4,310	4,310	4,310	4,310	4,310	4,310
Expected Loss Due to Animals Death (5% per year)	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250
Expected Net Benefits	-60,050	-560	6,440	13,440	10,440	20,440	20,440	37,440

Internal Rate of Return = 9.84%

TABLE 14

PARTIAL BUDGET FOR DONKEY TRACTION, DIAPANGOU

	Years							
	1	2	3	4	5	6	7	8
Revenues								
Incremental Value of Crop Production	0	16,500	33,000	49,500	66,000	66,000	66,000	66,000
Animal Sales	--	--	--	--	15,000	--	--	15,000
Equipment Sales	--	--	--	--	--	--	--	2,000
Variable Costs								
Equipment Purchase	39,060	--	--	--	--	--	--	--
Animal Purchase	25,000	--	--	--	25,000	--	--	--
Equipment Repair	--	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Feed Grain, Salt	4,310	4,310	4,310	4,310	4,310	4,310	4,310	4,310
Expected Loss Due to Animals Death (5% per year)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Expected Net Benefits	-70,370	8,190	24,690	41,190	47,690	57,690	57,690	74,690

Internal Rate of Return = 31.2%

TABLE 15

PARTIAL BUDGET FOR OXEN TRACTION, DIAPANGOU

	Years							
	1	2	3	4	5	6	7	8
Revenues								
Incremental Value of Crop Production	0	16,750	33,500	50,250	67,000	67,000	67,000	67,000
Animal Sales	--	--	--	--	200,000	--	--	175,000
Equipment Sales	--	--	--	--	--	--	--	4,000
Variable Costs								
Equipment Purchase	48,710	--	--	--	--	--	--	--
Animal Purchase	100,000	--	--	--	100,000	--	--	--
Equipment Repair	--	3,000	3,000	3,000	3,000	3,000	3,000	3,000
Animal Feed, Salt	8,275	8,275	8,275	8,275	8,275	8,275	8,275	8,275
Expected Loss Due to Animals Death (5% per year)	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
Expected Net Benefits	-162,985	-525	16,225	32,975	149,725	49,725	49,725	228,725

Internal Rate of Return = 20.7%

be a result of increased labor inputs. To the contrary, the evidence suggests some reduction in labor inputs.

A better understanding of the slow adoption rates will require additional analysis beyond the scope of this paper, but a few observations can be made at this point:

1. Plowing with animal traction will encounter resistance where rainy seasons are short and risks of losses to delayed planting are high.

2. Acceptance of weeding with animal traction depends on the quality and proximity of available land.

3. Although the internal rates of return calculated above appear to be satisfactory, there is no adequate way of evaluating the opportunity cost, or scarcity value, for a farmer's alternative uses of capital in the absense of developed capital markets.

4. Recognizing the riskiness of agricultural production under the conditions described and the unacceptability of large losses to farmers near the subsistance level, the evidence presented suggest that adoption of animal traction would meet less resistance when weeders precede plows and donkeys precede oxen.

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