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The introduction of animal traction into inland valley regions. 1. Manual labour and animal traction in the cultivation of rice and maize: a comparison

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SUMMARY

Rice, a cash crop, was grown in the alluvial valley bottom (fadama) of an inland valley region of central Nigeria. The main staple crop, maize, was grown on the adjacent upland areas. Both oxen and manual labour were used for initial cultivation (ploughing and harrowing for rice and ridging for maize). Times spent were 94·3 and 315·2 h/ha respectively for rice and 28·2 and 65·5 h/ha for maize. Plots cultivated by animal traction (AT) produced more weeds and required more time for weeding than manually cultivated ones. Thus although animal traction saved time at the most critical time of year, it did not save time overall. Total time values were 1045 and 1064 h/ha for rice using animal traction and manual cultivation respectively. Corresponding values for maize were 654 and 484 h/ha. Type of cultivation had no significant effect ($P > 0·05$) on yields of crops (4·50 and 4·55 t/ha, AT/manual, for rice and 1·60 and 1·83 t/ha for maize). Not weeding the plots reduced rice yields to 2·78 and 2·83 t/ha for ox and manual cultivation respectively and to virtually zero for maize.

INTRODUCTION

The development of Nigeria's agriculture largely depends on the productivity of numerous small-scale farmers. It is this sector of the population that produces the bulk of the staple food consumed in the country (Akinyosoye 1992; Phillip & Ogunbile 1993). Manual labour is predominantly used to cultivate the cropped area. The resulting bottle-necks at peak labour periods (land preparation, weeding and harvesting) limit not only the area under cultivation but also the yield per capita (Jansen 1993; Oguejiofo 1993). In the sub-humid middle belt of Nigeria, animal traction was a completely unknown phenomenon until recently. However, with a reduction in the threat from adverse environmental factors such as trypanosomiasis, the International Livestock Research Institute (ILRI) has started work on the introduction of animal traction into these regions. An important feature of agriculture in the sub-humid zone is the presence of seasonally inundated low-lying valleys, or fadamas. The valley bottom is formed by the accumulation of fine soil particles. It is flat, clayey and inclined to be waterlogged. In contrast, the surrounding soil, known as the uplands, from which the fine particles are washed, is coarse and gritty although still fairly fertile.

The valley bottoms are used almost exclusively for rice production (the principal cash crop) in the wet season and by peripatetic Fulani herdsman as a source of winter grazing for their cattle. The uplands are used principally for the production of food crops such as maize and sorghum. Many village communities depend on upland and fadama land for their subsistence. But with finite amounts of cultivable land available and a growing population, the utilization of both upland and fadama land will have to be intensified (ILCA 1991; Jansen & Lawrence 1991). Inland valleys have a large potential for agricultural production, which in many cases is not fully realised. The main purpose of ILRI's research in the fadamas and the surrounding upland regions was to find ways in which draught oxen can be used to improve timeliness of cultivation, to alleviate the drudgery of manual labour and to assess the agronomic and

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economic consequences of increased draught animal use (ILCA 1987, 1991).

This paper describes the results of two experiments, carried out in 1991, which were set up to enable a comparison of the inputs and yields associated with the main cash and subsistence crop, rice and maize respectively, when using manual and ox-drawn implements.

MATERIALS AND METHODS

Four fadama and four upland plots (30 × 30 m), located on land rented from local farmers, were used in the experiments. Crops were raised as far as possible under the same conditions as those of local farmers except where experimental procedures dictated otherwise. For this reason, all field hands were hired in the village and the experimental plots were not fenced off from those adjoining them. At harvest, all grain not required for scientific purposes was divided amongst the people who worked regularly on the experimental plots. The people concerned were informed of this at the beginning of the season. This provided them with the same motivation to look after the growing crops, especially in matters such as scaring away birds, as the other farmers in the valley.

Ox and manual cultivation of the fadama fields consisted of ploughing once and harrowing once. Ox and manual cultivation of the upland fields consisted of ridging once. Ox ploughing was carried out using an Emcot plough. Harrowing was done using a disc harrow. Ox ridging of upland fields was performed with an Emcot ridger (all implements by John Holt Company, Zaria, Nigeria). Manual cultivation was carried out using hand hoes.

Measurements taken during ox cultivation were: Total time (h), Elapsed working time (EWT; h), Work done (J) and Distance travelled (m), for ploughing, harrowing and ridging. Measurements of EWT, work done and distance travelled were made using an ergometer (Lawrence & Pearson 1985). Distance averaged draught force (DADF) was calculated by dividing the work done by the distance walked. Ox cultivation was carried out by two men and a pair of oxen.

Measurements taken during manual cultivation were: Total man hours available (h) and EWT (h). To measure the EWT during manual cultivation, all operations were done by a group of four workers. A fifth person kept a record of the number of people in the group working at the start of each minute. Individual workers could thus work at their own speed and rest when they needed to. The total man hours worked by the group during any working session was later calculated from the records kept. Following cultivation, one half of each fadama and upland plot was allocated to either the 'weeding' (W) or the 'no weeding' (NW) treatment, resulting in a split-plot design for both experiments.

Fadamas were sown at the rate of 10 kg per 30 × 30 m plot (110 kg/ha), using 48 h pre-germinated local KUF II rice variety. The seed was broadcast as evenly as possible. For the upland experiment maize seeds (TZB) were sown on ridges 25 cm apart, three at a time. After germination, maize seedlings were thinned to one per hole and transplanted to any place within the subplot where seeds had failed to germinate.

Fifty kg of NPK fertilizer (27:13:13) per 30 × 30 m plot (550 kg/ha) was applied at planting for both rice and maize. Ten kg of urea per 30 × 30 m plot (110 kg/ha) was applied to the maize 8 and 12 weeks after planting and to the rice 10 weeks after planting.

All weeding in the rice was done manually. Two weedings were carried out, respectively 4 and 8 weeks after sowing, on half the plots. It had been intended to perform the first weeding in the ox-cultivated maize plots using the Emcot ridger with the blades folded back. This method, however, proved to be unsatisfactory and both weedings, 4 and 8 weeks after planting, were carried out manually on half the plots. Measurements taken during sowing, fertilizing and weeding were as follows: Total man hours available (h), EWT (h) and Total dry weight (kg) of weeds from each subplot at both weedings, i.e. a total of 32 samples. Wet weight yields were measured as soon as possible after the weeds had been pulled out and the roots cleaned. Subsamples of 1·0 kg were dried until their weight was constant to determine the dry matter content.

During the rice harvest, each subplot was divided into four 3 × 3 m plots leaving 3 m borders around each harvested area. During the maize harvest, a 2·5 m strip was left around each 15 × 15 m subplot and the remainder was divided into four 10 × 2·5 m strips running parallel with the ridges. Plots were completely stripped of vegetation which was divided into grain (rice) or cobs (maize), crop residues and weeds. Total wet weights of the individual categories were recorded. Samples of 1·0 kg were taken to determine the dry matter content of each of the categories. Harvesting of both crops was carried out over 2 days. No human time inputs were recorded during the harvesting because the harvesting method (i.e. selective cutting of weeds) was very different from the methods normally used by farmers.

Experimental results for each crop were analysed separately using an analysis of variance on GENSTAT 5 (Lawes Agricultural Trust 1993).

RESULTS

Cultivation

Fadama

Total human time inputs and EWT during the manual

Table *Mean values for human time inputs (h/ha) on the experimental plots during wet season fadama rice cultivation in Kufana village, central Nigeria, 1991 (n = 4, 6 D.F.)*

	Total time			EWT		
Operation	Ox	Manual	S.E.	Ox	Manual	
Ploughing	64·2	247·5	25·3	49·9	184·5	18·9
Harrowing	30·1	67·7	9·0	21·1	51·1	7·2
Planting/fertilizing	36·8	36·8	0·0	36·8	36·8	0·0
First weeding	647·0	486·2	154·7	541·4	453·8	140·9
Second weeding	266·4	226·0	31·9	229·5	210·4	7·6
Total time weeding	913·4	712·2	136·5	770·9	664·2	119·1
Total time	1044·5	1064·2	132·0	878·7	936·6	111·5

EWT, elapsed working time.

Table 2. *Mean values for human time inputs (h/ha) on the experimental plots during wet season upland maize cultivation in Kufana village, central Nigeria, 1991 (n = 4, 6 D.F.)*

	Total time			EWT		
Operation		Manual		Ox	Manual	
Ridging	28·2	65·5	5·8	19·9	52·5	4·7
Planting	140·2	76·1	21·5	123·4	64·3	16·0
Fertilizing	47·5	37·2	7·1	47·5	37·2	7·1
First weeding	272·6	174·8	78·6	222·2	153·4	63·4
Second weeding	164·8	130·4	22·3	157·8	118·5	23·2
Total time weeding	437·4	305·2	96·0	380·0	271·9	80·8
Total time	653·3	484·0	107·7	570·8	425·9	82·9

EWT, elapsed working time

ploughing of the fadama were significantly higher ($P < 0·001$) than the total human time inputs and EWT during ox ploughing (Table 1). EWT, or time spent working during the total human time inputs, was 74·8 and 78·2% for manual and ox ploughing respectively. Total human time inputs and EWT during the manual harrowing were also significantly higher ($P < 0·01$) than the total human time inputs and EWT during the harrowing of the fadama with oxen (Table 1). EWT averaged 75·4 and 70·1% of the total human time inputs during manual and ox cultivation respectively.

Upland

Results from the upland cultivation showed similar tendencies to those from the fadama. Total human time inputs and EWT during manual ridging were significantly higher ($P < 0·001$) than for ox ridging (Table 2). Of the total human time inputs 80·1 and 70·9% was spent working on the hand and ox-cultivated plots respectively.

Oxen

Table 3 shows the mean ox inputs for both wet season rice and maize cultivation. Work done, distance walked, total time and EWT for the ploughing of fadama fields was significantly different ($P < 0·001$) from that needed for the harrowing of fadama plots or the ridging of upland fields. Power output and working speed were significantly higher ($P < 0·05$) during upland cultivation. No significant differences were found in the DADF for the three operations, although DADF was consistently higher during upland cultivation.

Planting and fertilizing

Fadama

Total human time inputs and EWT for sowing and fertilizing (twice) were identical on the hand and ox-cultivated plots (Table 1).

Upland

Total human time inputs for the planting of maize on the hand-cultivated plots was significantly lower ($P < 0·05$) than the total human time inputs for sowing maize on the ox-cultivated plots (Table 2). Of the total time spent in the field, 84·7 and 89·0% was spent

Table 3. *Mean values for ox inputs during wet season rice and maize cultivation in Kufana village, central Nigeria, 1991 (n = 4, 6 D.F.)*

	Rice cultivation – fadama		Maize cultivation – upland	
	Ploughing	Harrowing	Ridging	S.E.
Work done (MJ/ha)	39·3	14·6	19·4	2·5
Distance walked (km/ha)	40·5	17·5	19·3	1·6
Total time (h/team/ha)	32·1	15·0	14·1	1·3
EWT (h/team/ha)	24·9	10·6	10·0	1·0
Power (W)	442·0	389·0	547·0	52·7
DADF (N)	970·0	840·0	1016·0	88·1
Speed (m/s)	0·46	0·46	0·54	0·03

EWT, elapsed working time; DADF, distance averaged draught force.

Table 4. *Mean values for grain or cobs and straw dry matter yields (t/ha) on the experimental plots during wet season fadama rice and upland maize cultivation in Kufana village, central Nigeria, 1991 (n = 4)*

	Rice cultivation – fadama		Maize cultivation – upland	
Treatment	Grain	Straw	Cobs	Straw
Ox				
No weeding	2·78	6·43	0·05	0·4
Weeding	4·50	7·95	1·60	2·2
Manual				
No weeding	2·83	5·92	0·20	1·17
Weeding	4·55	8·13	1·83	3·40
S.E. (6 D.F.)	0·59	1·60	0·19	0·37

working on the hand and ox-cultivated plots respectively. EWT on the hand-cultivated plots was significantly lower ($P < 0·01$) than the EWT on the ox-cultivated plots (Table 2). Total human time inputs and EWT for fertilizing (thrice) did not significantly differ on the hand and ox-cultivated plots (Table 2).

Weeding

Fadama

Although the total human time taken and EWT during the weeding of rice plots which had been cultivated by hand was consistently lower than the total human time taken and EWT for the weeding on the ox-cultivated plots, no significant differences were found (Table 1). Of the total time spent in the field weeding, 92·7 and 85·0% was spent working on the hand and ox-cultivated plots respectively (Table 1).

Upland

Total human time inputs and EWT during the weeding of the maize plots followed a similar trend to the results obtained for the rice, and no significant differences were found between the hand and ox-cultivated plots (Table 2). Of the total time spent in the field weeding, 88·7 and 87·9% was spent working on the hand and ox-cultivated plots respectively (Table 2).

Yields

Fadama

Yield of grain was significantly higher ($P < 0·001$) on the weeded plots, but type of cultivation did not significantly influence yields. Total straw production was not influenced by cultivation or weeding treatments (Table 4). The total dry weight of the weeds collected during weedings was not influenced by the type of cultivation. The same observation was made for weeds collected from the non-weeded plots at harvest (Table 5).

Upland

Yields of cobs and straw were significantly higher ($P < 0·001$) on weeded plots. Whereas no significant differences were found between the yield of cobs on hand or ox-cultivated plots for both the weeded and non-weeded treatments, straw yield was significantly higher ($P < 0·05$) on hand-cultivated plots (Table 4).

Table 5. *Mean values for weed dry matter yields (t/ha) on the experimental plots during wet season fadama rice and upland maize cultivation in Kufana village, central Nigeria, 1991 (n = 4, 6 D.F.)*

	Rice cultivation – fadama			Maize cultivation – upland		
	Ox	Manual		Ox	Manual	
First weeding	0·68	0·44	0·18	4·67	1·87	1·44
Second weeding	0·46	0·47	0·12	2·23	1·34	0·53
Harvest weeds	0·29	0·34	0·16	0·87	0·27	0·21
Total weeds	1·43	1·25	0·24	7·77	3·48	1·93
Harvest weeds – NW plots	3·50	2·64	1·24	4·49	4·90	1·28

NW, non-weeded.

Total dry weight of the weeds collected from ox-cultivated plots was consistently higher, but only weeds collected at harvest were found to be significantly heavier ($P < 0·05$) than those collected from the hand-cultivated plots (Table 5). Weeds collected from the non-weeded plots at harvest were not influenced by the type of cultivation.

DISCUSSION

Yields of rice grain averaged *c.* 4·5 t/ha dry weight for both ox and manual cultivation. This is about twice the yield obtained by local farmers, the difference probably being due to the use of fertilizer on the experimental plots. Although yields were much lower, Adesina (1992) also found little difference in lowland rice yields in south-west Mali when using hand or ox tillage. The current set of results emphasises that although using draught animals for cultivation results in rather more weed infestation than manual cultivation, this does not cause a depression in yields. This factor, coupled with the time and labour saved during cultivation, makes ox cultivation of fadama rice land an attractive option for farmers.

Yields of maize, however, were consistently lower using ox cultivation (1·6 *v.* 1·9 t/ha for manual), although differences were not statistically significant. Whereas the poor and variable quality of the soil on the experimental plots may have influenced the results, the ox-drawn ridger does not cover weeds as well as the hand hoe and ways of further improving ox cultivation techniques for maize grown under these conditions will have to be investigated before animal traction can be recommended with confidence to farmers for maize cultivation. Adesina (1992), Akinyosoye (1992) and Olukosi & Ogunbile (1994) all reported higher maize yields when using ox cultivation. Unless depth and quality of cultivation are major constraints, there are no good reasons, if all other inputs are identical, why a change from manual to ox tillage should have a direct yield effect. Closer scrutiny of these data, however, reveals that hand-cultivated plots required more weeding (Olukosi & Ogunbile 1994), depth of cultivation was a limiting factor (Adesina 1992) and other extra inputs such as fertilizers and herbicides were employed on ox-cultivated land (Akinyosoye 1992).

In both the rice and maize trials, values for the work input, speed of travel and draught force of oxen in both fadama and upland cultivation were much the same as those obtained in the previous year (unpublished data). This indicates that these values are likely to be representative of the soil types of the region. Total and elapsed working times for cultivation using oxen were also similar, but corresponding figures for manual cultivation were lower than in the previous year. This was certainly due more to the greatly improved management by the ILRI field staff than to any radical changes in soil or working conditions but, even so, oxen cultivation still required 50–75% fewer man hours per hectare than hand labour, which underlines the potential of oxen for promoting timely cultivation and planting.

The sowing of the maize on the hand-ridged plots was approximately twice as fast as sowing maize on the ox-cultivated plots. This was mainly due to the fact that the ox-drawn ridger does not cover weeds as well as the hand hoe, which makes it more difficult to find suitable places for sowing. Future research should focus on devising ox-drawn implements and cultivation techniques which suit these soils better.

Weed infestation was heavier and weeding took longer on ox-cultivated plots in both rice and maize. This had no significant influence on the yields, although maize yields were consistently higher on the manually cultivated plots. Weeding was by far the most time consuming operation, but results from the non-weeded plots demonstrated how essential this operation is; lack of weeding depressed rice yield by nearly half and maize growth almost totally. One of the objectives of future trials should be to look at ways of reducing this time by using herbicides and the control of water levels while the rice is growing. Because of the extra time required for weeding, the use of oxen cannot be said to result in any absolute saving of time, but they do enable substantial savings

at the most critical period of the year, so that the crops can be planted on time.

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