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ON-FARM ANIMAL TRACTION RESEARCH: EXPERIENCE IN ETHIOPIA WITH THE INTRODUCTION OF THE USE OF SINGLE OXEN FOR CROP CULTIVATION

Guido Gryseels

BACKGROUND

The International Livestock Centre for Africa (ILCA) is one of 13 international agricultural research centres supported by the Consultative Group on International Agricultural Research (CGIAR). ILCA has field programmes in the major ecological zones of sub-Saharan Africa, namely the arid and semi-arid, sub-humid and humid and highland zones. This article reports on some of the Farming Systems Research activities of ILCA's Highlands Programme.

To date, research in this programme has focused on the Ethiopian highlands. Ethiopia has the largest highland area of the continent, accounting for almost half of the total African highland zone. It is an ecologically diverse country with the agricultural sector contributing the major share of gross national product and almost all export earnings. Nearly 80% of the population is directly dependent upon agriculture and per capita income is estimated to be less than US $140 per annum, classifying it as one of the least developed countries in the world.

Of the total area of Ethiopia of 1.22 million km^2, half is highlands above 1500 m altitude. Some 70% of the total human population of about 32 million live in the highlands. Ethiopia has the largest livestock population in sub-Saharan Africa with some 26 million equines and 1 million camels. The majority of the cattle, sheep and equines are in highland areas. Agricultural conditions vary widely throughout the country, according to topography, climate, and soils. However, the highlands are generally temperate and comparatively favourable for both crop and livestock production. Ethiopia's rugged terrain is a major constraint to economic development because of related transport and communication problems. For example, it is often claimed that three-quarters of the population live more than one day's round trip walk from an all-weather road.

Since the mid-seventies, rural development has been organised in a socialist framework. However, collective farming accounts for less than

5% of the total area cultivated. The bulk of agricultural output is still produced by individual subsistence smallholders who have 'family rights' over the land they till.[1]

ILCA's field research in the Ethiopian highlands has concentrated on the central highlands where mixed smallholder farming is the dominant mode of production. Rainfall here averages between 600 and 1200 mm per annum, of which about 70% falls in the main rainy season between July and September. Farm sizes range from .5 to 5 hectares, and around 80% of all farm produce is used for subsistence consumption. About two thirds of cultivated land is sown to cereals. The majority of the remainder is sown to pulses. The fraction of fallow land in different parts of the highlands is quite variable. In some locales almost no land is fallowed while elsewhere fallow periods of up to 12 years after 3 years of crop are common. The main crops are teff, wheat, barley, maize, sorghum, horse beans, chick peas and field peas. Grain yields average between 500 and 1000 kg per hectare sown. Access to modern inputs such as chemical fertilizers or improved seeds is limited. Fewer than 10% of farmers regularly use either input. Most farmers own livestock, and a typical inventory is two oxen, a cow, a few sheep and a donkey. As most livestock manure is used as household fuel, only little is returned as fertilizer to the fields.

Cattle are kept mainly as a source of draught power and manure production. Milk, meat, and hides are relatively less important by-products. Livestock are privately owned, so are an important form of investment and financial security. Usually only oxen are used for cultivation. Productivity is low for all livestock, reflecting an underexploited genetic resource and generally inadequate nutrition, particularly during the extended dry season of up to seven months each year. For example, milk offtake from indigenous Zebu cows kept under traditional management rarely exceeds 400 kg for lactations of seven months. Calving intervals average two years. Sheep also are comparatively unproductive, as, along with cattle, they are subject to heavy endoparasite burdens and to extended periods of nutritional stress.

It is against this background of a traditional subsistence agriculture where productivity gains must be achieved to ensure survival in the coming years that ILCA established a research programme in the Ethiopian highlands.

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[1]In Ethiopia, land is not individual owned, but is allocated annually by Peasants' Association (PA) of which each farmer necessarily is a member. The size of individual allocations, comprising several plots, depends on family size, local population density and the policies of the local PA. Land distribution takes account of the different fertility levels of the soils within the land area of the PA. Each PA has on average 250 individual members and controls around 800 ha of land.

OVERVIEW OF THE RESEARCH PROGRAMME

The basic objectives of the research are to study ways and means of improving the overall productivity of mixed smallholder farms by increasing the technical and economic efficiency of livestock enterprises. Particular emphasis is given to enhancing the complementarity of the livestock and crop components. Results and experiences of the research in Ethiopia will in many cases have direct relevance to other highland smallholder situations in sub-Saharan Africa where the same immediate concerns to increase agricultural production apply.

The Programme has adopted the farming systems approach to research. This stresses on-farm technology testing and appraisal, backstopped by relevant station research on components where greater experimental control is advantageous. In addition to research undertaken at its headquarters in Addis Ababa, field work is undertaken in two study areas: at Debre Zeit located 50 km south of Addis Ababa at an altitude of 1800 m, and at Debre Berhan 120 km north east of Addis Ababa, at an altitude of 2800 m. The area around Debre Zeit is intensively cultivated, with virtually no arable land kept fallow. Teff (Eragostis teff) is the principal cereal grown. Debre Berhan represents the high altitude zones. Frosts, hail and a shorter growing season, in addition to low soil fertility levels, cause the area to be less productive than Debre Zeit. Most of the land cultivated there is sown with barley. Research stations have been established by ILCA at both Debre Zeit and Debre Berhan.

The station research focuses on key elements of the traditional farming systems: soil fertility, forage production, various aspects of draught animal utilization, and small scale dairy processing technologies. Innovative livestock enterprise combinations considered to be relevant future options for smallholders are also under test on station in research farms.

Baseline surveys were made in both study areas before beginning experimental work. These have been followed up by ongoing studies with a random sample of individual farmers ("outside" farmers) in the areas surrounding the ILCA sites to provide time series data on the dynamics of these agricultural systems and to serve as a control group against which the impact of innovations can be evaluated.

ILCA has regular field days for farmers of the surrounding areas, government officials and extension agents to demonstrate the research in process and to discuss the programme with the target population. When a suitable technology is available for testing at the farm level, volunteer test farmers are sought from among the farming community. Test farmers implement the improved technologies at their own expense and risk, and are responsible for their own management decisions. ILCA only offers technical advice. Certain inputs will be provided against cash payment or short term credits. Preferably these test farmers have previously been 'outside' farmers. In this way an evaluation of the

improved technologies is possible; firstly, by comparison with the prior performance of these test farmers using the traditional method of produotion; secondly, within any year through comparison of the test farmers with the control group farmers who did not adopt the improved technologies; and thirdly through a comparison of both farmer groups with the test results from the station researoh.

On-farm trials are being conducted on research associated with improved dairy husbandry at the smallholder level, animal traotion and the use of methane digesters.

The Programme has allocated substantial resources to studies on various animal traction-related topics. Work in progress includes the evaluation of different cultivation systems using oxen of local and crossbreeds, the technical and economic efficiencies of using crossbred cows for draught purposes as well as milk production, the use of oxen worked as singles rather than as pairs as they are traditionally used in the Ethiopian setting, and the working efficiency of oxen subject to nutritional stress. Different harnesses and yokes are also being developed.

This paper reports on the experiences with on-farm trials with the use of oxen worked as singles rather than as pairs.

BACKGROUND

The primary contribution of cattle to agricultural production in the Ethiopian highlands is as a source of draught power. ILCA surveys showed that animal power used for crop related work averaged more than 1000 hours per farm per annum. Most of this power was supplied by oxen, but other cattle were sometimes employed for threshing.

The land is tilled with the traditional cultivation tool known as the *maresha* drawn by a pair of oxen of indigenous breeds.[2] Depending on the soil type and the crop to be planted, the land is cultivated up to six times before planting.

Available data for the Debre Berhan area indicate that just over half the farmers had two or more oxen, around 30% one, and 20% had no oxen. Since oxen are traditionally paired for work, almost half the farmers were dependent on renting or borrowing one or two oxen for crop cultivation. In the Debre Zeit area relatively more farmers had two or more oxen, but around 25% of the smallholders had none or only one ox. These results from the two ILCA study areas are representative of the national situation as, according to one study (Ministry of Agriculture, 1980), around 29% of Ethiopian farmers have no ox, 34% one, 29% two and 8% three or more.

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[2]An ox in working condition weighs approximately 280-300 kg.

A farmer owning less than two oxen has various ways to overcome this problem of inadequate draught power. For households already owning one ox, the usual arrangement is a mekanaia agreement with a household in a similar position, whereby the pair of oxen is used on the partner's fields on alternative days. The drawback of this strategy is that often the ploughing season is so short that the draft capacity is insufficient to allow both farmers to plough at the optimal time. In many locations, especially when soils have a high clay fraction, cultivation can only begin after the beginning of the rains. Moreover, the changing of handlers of the pair of oxen and the pairing of different animals causes a substantial efficiency loss in the tractive power developed. It is also often difficult to find a partner near enough, making a workable arrangement difficult.

Another strategy widely used is for the farmer to use one ox of another farmer in return for one day's field labour. Around Debre Zeit, it has been observed that farmers with one ox rent another ox from farmers with surplus oxen, at an annual cost of 200 kg of grains or on average 15% of total farm production. If a farmer has no oxen, the common exchange system is to give two days of human labour for every day a pair of oxen is borrowed. Sometimes oxen will be retained on a cash basis usually US$1.50 per day for a pair, and US$2.50 per day if a handler is also included.

ILCA surveys have also revealed that the number of oxen owned strongly influences the area cultivated and the cropping pattern. The cropping pattern is most strongly influenced if the draught power inputs for land preparation vary substantially among crops which favours the selection of crops with lower power requirements by farmers with less than two oxen. For the study area around Debre Zeit for example, substantial differences were observed among ILCA's control group of outside farmers in the 1980 crop year. These are summarized in the table below:

Impact of Oxen Ownership on Area Cultivated and Cropping Pattern at Debre Zeit (1980)

Farmers grouped by oxen ownership	Average area cropped per farm (ha)	Average sown to cereals (%)	Average sown to pulses (8%)
Owning no oxen	1.2	54	46
Owning one ox	1.9	44	56
Owning two oxen	2.7	67	33
Owning three or more oxen	3.6	92	8

The table illustrates that there is approximately a linear relationship between oxen ownership and area cultivated. The change in cropping pattern reflects the need for more intensive land preparation for cereal crops than pulses, and therefore higher labour inputs and

draught power. Furthermore, the market value of cereal crops is about twice that of pulses. Together these factors meant that farmers with less draught power at their disposal sowed less land in total and also had lower incomes than their counterparts with an adequate supply of draught power.

Around Debre Berhan, the situation was somewhat different. The dominant crops in that area all require similar labour inputs for land preparation. The impact of oxen ownership on the amount of land cultivated was smaller than around Debre Zeit, and the cropping pattern remained similar for farmers with different supplies of draught power.

In both study areas, there was no apparent effect on crop yields. This suggests that the problem of timely cultivation is largely overcome when a smaller area is cultivated and farmers choose to safeguard yields on smaller areas rather than risk lower yields over a larger area which can arise if seedbeds are poorly prepared.

Thus the availability of draught power proves to be a major factor affecting income distribution in the Ethiopian highlands.

DESIGN AND TESTING OF THE SINGLE OX TECHNOLOGY

Underlying the problem of inadequate draught power was the tacit assumption by farmers that two oxen are invariably needed for cultivation. ILCA has some prior experience in the use of crossbred oxen as singles but these are much heavier than local oxen (average liveweight of 500 kg versus 280 kg for local oxen). Elsewhere in the world other animals such as buffaloes and horses have worked as singles, but their liveweights are also much greater than of the local Zebu ox used in Ethiopia. Despite this low liveweight, ILCA decided to experiment with the use of a single local ox for crop cultivation.

ILCA developed a suitable yoke and harness, as well as a modified version of the local wooden plough maresha, for use by a single ox of local breed. The traditional neck yoke designed for an ox-pair (Figure 1) was replaced with a simple, 'inverted V' - type yoke (Figure 3) and a swingletree joined by two traces made of nylon ropes. A simple metal skid was attached under the shortened beam to overcome the tendency of the modified maresha to penetrate the ground at an oblique rather than acute angle (Figure 2).

During the on-station trials no particular technical difficulties were encountered and the work output of the singles was considered to be adequate to warrant initiation of on-farm trials in the next crop season. Preliminary trials showed that adequately fed single oxen could cultivate some 60-70% of the area ploughed by a pair in a day. Cultivation was slightly shallower than with the traditional maresha, but the desired depth could be achieved by making extra passes.

In each of its study areas, ILCA then organized field days for farmers of the Peasants Associations surrounding the ILCA stations to demonstrate the new technology. In addition to around 80 farmers, local government officials and extension workers attended. After the demonstration by ILCA staff, farmers were invited to try ploughing with the single ox themselves. Many did so, and although the general consensus was that this modification of the traditional system could have its benefits, farmers were hesitant about the ability of local oxen to work singly for extended periods.

Farmers were invited to use the technology on their own farms. They were to do this at their own risk and expense but ILCA was to give technical advice and assist in the training of the animal to work singly. For those who did not want to modify the implement themselves, ILCA offered to sell the necessary implements at US$5 each, to be paid immediately after the next harvest. At the end of the field day at Debre Berhan seven farmers volunteered to test the single maresha. At the Debre Zeit field day 15 farmers volunteered.

Around Debre Zeit, because soils are heavy and rainfall is essentially monomodal, cultivation for the main cereal crops has to be done within a very limited time period. Around Debre Berhan, the rainfall is more uniformly distributed (weakly bimodal) over the year and soils are lighter than at Debre Zeit, so ploughing can be done almost year round in that area. Around Debre Zeit, average farm size is around 2 ha and around Debre Berhan 3.5 ha. In the latter area however, only 50% of this is cultivated each year.

Shortage of draught power is therefore much more pressing and crucial problem than around Debre Zeit than Debre Berhan. The different initial farmer reaction to the technology in the two areas undoubtedly reflected these considerations.

ILCA held training sessions where these test farmers were assisted in retraining their ox previously used in pairs to work as singles. Most oxen adapted without difficulty, while others needed up to two days retraining. In April 1983, these farmers started their land cultivation. ILCA closely monitored their performance and initiated a data collection system.

Test farmers are visited twice weekly and data collected include land holdings, cropping pattern, inputs and outputs by plots, cultivation details, and feeding levels for the work oxen. Additionally farm assets, personal data and livestock inventories are recorded.

More farmers became interested as the season progressed and wanted to join the research programme. By July 1983, ILCA was monitoring the performance of 20 single ox farmers in each of the study areas. Many more farmers volunteered, but in order to have complete data records and to allow for a proper evaluation, ILCA was obliged to limit its

involvement to technical advice on how to make and operate the implement. By early October 1983, over 140 farmers had approached ILCA for assistance in ploughing with a single ox, and many of these had been experimenting on their own.

Initially, all farmers who volunteered to plough with a single animal were accepted, irrespective of the numbers of oxen they owned. Problems arose as farmers with more than one ox could rotate their animals in the work. This will make the evaluation of the impact of the technology more difficult.

Few technical problems have arisen since the start of the farm trials. The original metal skid was not strong enough for the often stony fields and it had to be replaced by a thicker metal. Also, farmers at Debre Zeit initially worked their single animals only two to three hours per day, for fear of exhausting them. Farmers, however, observed ILCA's nutrition trials whereby oxen are working singly for four to five hours per day.[3] As a result farmers gradually increased the hours they worked their animal to four to five hours per day.

Nutrition was seen as a problem by the test farmers. The animals worked as singles required extra feed when worked and therefore many farmers supplemented the normal ration with feed concentrates (wheat bran) which are available locally. In some cases, when the farmer was unable to afford these concentrates, ILCA supplied short term credits to be repaid immediately after harvest.

Concurrently with ILCA's research programme, the Ethiopian government introduced a drive towards cooperative production in the Debre Zeit area. Farmers had to work one or two days per week on the land owned by this cooperative. However, these farmers are followers of the Christian Orthodox Church which prohibits field work for around 160 days each year. The number of days available for cultivating their own fields was therefore even further reduced.

This unexpected reduction in the labour available for the preparation of their plots, combined with their natural caution about the new technology, resulted in all the test farmers using a mix of single and traditionally paired oxen. Thus the farmers were experimenting on the impact of single ox cultivation on area cultivated and crop performance.

Around Debre Berhan where farmers can cultivate almost year round, timeliness is not such a constraint. As a result, farmers have easier

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[3]In this particular trial nutritionally stressed oxen are worked as singles on farmers fields under the supervision of researchers. Their performance is being compared to the work output of well nourished oxen. The stressed animals are fed 75% of the level of the well nourished oxen.

access to find additional oxen for cultivation. However, soil fertility is a major problem in the area, and also many fields have a high stone cover. Farmers encountered difficulties in using oxen singly on plots where the stone cover was above 50%, so they resorted to the use of pairs on these fields. The first cultivation on land being cropped after an extended fallow phase of 10 to 15 years also proved very difficult for oxen worked as singles, and farmers with these plots opted to do the first cultivation with the conventional pair of oxen. No other difficulties were encountered in using the single ox. To date, seven farmers in the area have even sold their excess oxen to buy a crossbred cow. Such crossbred cows have average milk yields of 2000 liters per year under farmers conditions compared with 400 liters of a local cow.

It is too early yet to quantify the impact of this technology on agricultural productivity at the farm level. This year's crops will be harvested around November-December 1983 and only after then will an evaluation over a full crop cycle of the impact of the technology be possible. ILCA will continue to monitor the problems in and the impact of adopting the new technology on the test farmers. It will also study the rate of adoption of the technology among other farmers.

OUTLOOK

There are some 6 million draught oxen in Ethiopia, the highest population of work animals in sub-Saharan Africa. The feed resources to keep these animals fit enough for work are diminishing yearly. As the human population rises, progressively more land is being sown to food crops, reducing the proportion left for grazing.

Widespread use of the single ox could dramatically reduce the number of oxen and their attendant breeding and replacement stock needed to support food crop production, thereby increasing the feed resources available for each working animal. Not only would grazing pressures be reduced, lowering the risk of environmental degradation, but the nutritional status of the remaining oxen would improve. In addition, more timely cultivation of larger areas of land would lead to increased food crop production and allow more balanced cereal/pulse rotations to be practiced.

The single ox technology has two other major advantages which make the prospects for its uptake most encouraging. Firstly, it does not put subsistence crop yields at risk, and secondly, it requires minimum investment - the new yoke and harness can be made cheaply from local materials, while the modifications to the *maresha* can be carried out by the village blacksmith.

If uptake is successful and occurs on a large enough scale, the single ox technology will have far-reaching implications for the smallholder farmers of Ethiopia, who are among the world's poorest people.

SUMMARY

In its Highlands Programme, ILCA has acquired considerable experience with the FSR approach focussing on the livestock enterprise. Various on-farm trials have been initiated and this paper reports on the initial experiences of using a single ox instead of the conventional pair for crop cultivation. The FSR approach has been very effective in quantifying the impact of draught power availability on farm level productivity and led directly to the selection and design of the single ox technology. On-farm trials have identified adoption problems not anticipated from the results of station research. In addition, farmers have experimented themselves by using a mix of the old and new technology on their land.

The relatively smooth transfer from the experiments conducted on the research station to more extensive trials in the traditional production system bodes well for the wider uptake of this new technology.

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Figure I. Traditional Maresha.

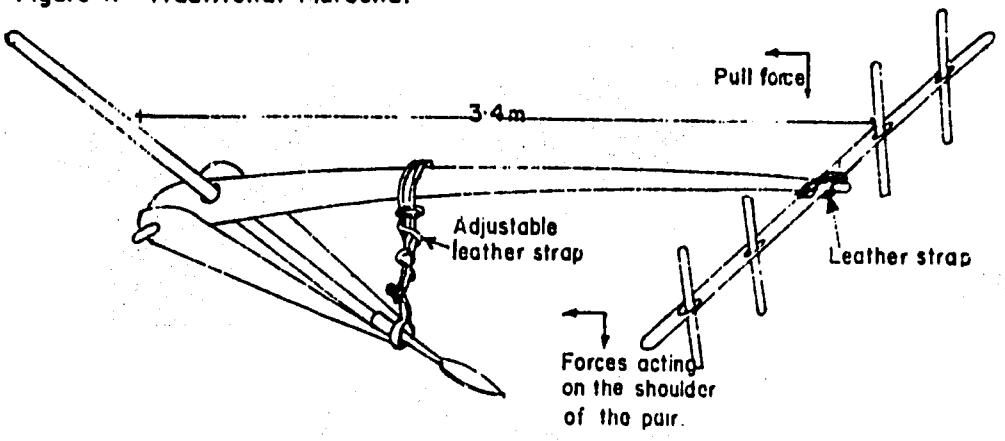

Figure 2. Modified Maresha for Single Animal use.

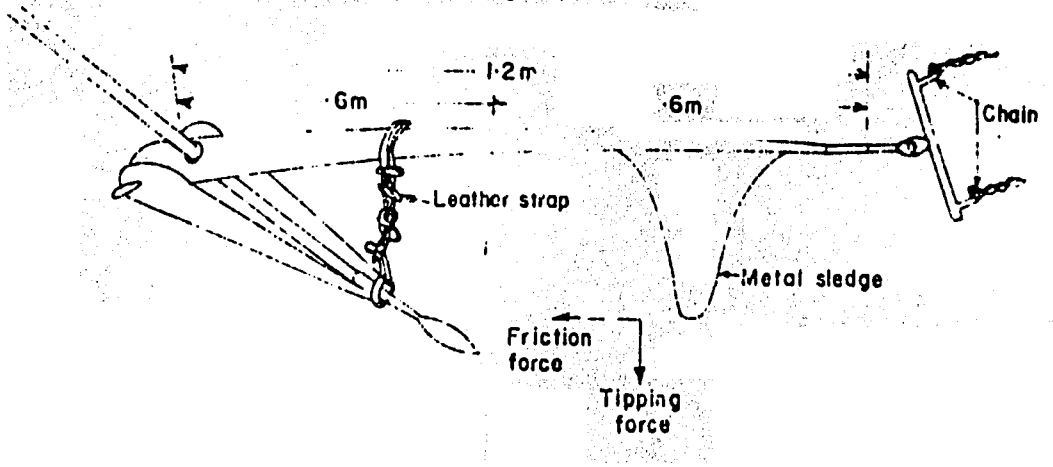

Figure 3. Single basic yoke design.