AN ECONOMIC ANALYSIS OF ALTERNATIVE METHODS OF LAND PREPARATION IN WESTERN PROVINCE, KENYA

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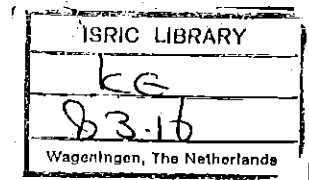Cornell University, Ithaca, New York

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METHODS OF LAND PREPARATION

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By

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ABSTRACT

This study evaluated alternative methods of land preparation for maize production on small farms in Western Province, Kenya. Human, oxen and tractors were the three sources of power. The crop production is dependent on rainfall, and timeliness of operations is critical. To ensure optimum yields, farmers in this area need to ready the available acreage for maize planting soon after the rains begin. An effective method of land preparation to improve labour productivity is desirable.

Data were obtained from the Integrated Agricultural Development Program (IADP) records for 1977 and 1981 for Western Province, together with an additional sample of 40 farmers selected in 1981 from the same province. Based on the level of mechanization in land preparation, farms were categorized into those using: 1. the hoe, 2. owned oxen, 3. hired oxen, and 4. hired government or private tractor.

Typical labour utilization profiles indicated that those not using the hoe for land preparation used fewer mandays of labour for that task but subsequently employed more labour to perform all the other necessary operations on the readied land. The proportion using owned oxen for ploughing increased from 25% in 1977 to 43% in 1981. Drudgery involved in hoeing was a factor facilitating the adoption of oxen-ploughing.

Production function and covariance analyses showed that those owning oxen achieved higher yields of maize than those hiring oxen or tractors. Those using hoes had the lowest yield as well as the lowest labour productivity. Net cash income per acre was highest for oxen owners (Kshs. 580), but lowest for those hiring private tractor (Kshs. 200). Using owned oxen was more profitable than either hoeing or hiring oxen or tractor for ploughing.

The main conclusion of the study is that oxen ploughing provides a viable way to increase the crop acreage and improve timeliness, yields and incomes in the specific region considered. Labour productivity is increased and the total labour requirement for maize production is maintained. Farmers who are willing but unable to invest in improved animal draught equipment should receive government assistance. Public support for tractor hiring service should be deemphasized, and diverted to alternative programs.

CONTENTS

INTRODUCTION

The purpose of this study was to examine the economics of mechanization on small farms in the Western province of Kenya. One of the most important problems confronting farmers who depend on rainfall for their agriculture is that of ensuring that the land available for maize production is readied for planting as soon as the rains begin. For the farmers who rely on human power and the hoe for land preparation, the problem is particularly acute. Not all the available land for maize can be readied on time because of the overlap of other maize production activities which need to be performed by available labour at the same time as land preparation. The use of oxen for ploughing on ones' own farm and to rent out to other farmers is one alternative method of land preparation. Hiring a tractor for this function on small farms is yet another. Muchiri (1981) reports that of the 3.1 million cultivated acres in Kenya, about 84% is cultivated using hand tools, about 12% is ox-cultivated and only 3.5% is cultivated by tractor equipment. In a given physical and socio-economic environment, finding a viable method of land preparation which reduces the problem of timeliness which farmers face is necessary.

The problem of low labour productivity has been recognized by the government. The development plan of 1979-83 states:

> Low labour productivity, a major bottleneck in smallholder development, will be dealt with by appropriate mechanization to fully mobilize the ample labour capacities in rural areas. p. 258.

The government has made available some tractor hiring services for farms at different locations including Western Province. The problem of generally low acreages planted to crops still persists in some arable areas with excess land within the Province. The queston then arises as to whether or not the existing tractor hiring service or use of oxen provides an economically viable solution to easing the constraint associated with land preparation faced by farmers in Western Province of Kenya.

THE OBJECTIVES OF THE STUDY

The broad objective of this study was to examine what potential exists for increasing the output of maize in Western Kenya through levels of farm mechanization that are economically viable. It is recognized that mechanization is only one element of the many inputs used in production of maize. The manner in which these inputs interact to achieve a certain level of output is important. A single input can seldom stand alone to increase output. The specific objectives therefore are to:

1. Examine the impact of mechanizing land preparation on yield of maize.

2. Identify the relationships that exist between mechanization and other factors of production.

3. Compare the relative factor productivity among farms employing different forms of mechanization.

4. Evaluate the profitability of employing different technologies for producing maize.

THE AREA OF STUDY

Western Province, Kenya was the area selected for study. The province is divided into Bungoma, Busia and Kakamega Districts. Figure 1 shows the province and its relative position in Kenya in an inset. The locations of the sample farms are also indicated.

The choice of the area was based on the fact that none of the forms of mechanization for land preparation is unfamiliar to the farmers. There are about 24 government tractors in the province, all centrally located in Busia District. Privately owned tractors are found on the neighbouring large scale farms and in settlement schemes.[1]

The study area is located in medium-to high-potential agricultural zones (Zone II and Zone III) in Figure 2. The zones, classified according to the annual rainfall, receive more than 735mm per annum. All the smallholders in the province grow maize as a staple food crop. Those who do not

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[1] The large scale farms are found predominantly in the neighbouring Rift Valley Province. Settlement Schemes are found on the former larger-scale farms owned by white settlers, which were acquired by Government and given to small farmers under the Settlement Fund Trustees.

have any other source of cash income sell a portion of the
maize output from the farm to enable them to buy other
necessities.

The Physical Characteristics

The amount, reliability and duration of rainfall, the soil
type, and temperature conditions strongly influence the
scheduling of farm operations. The topography also determine
what level of mechanization can technically be applied.

The Rainfall Distribution

Figure 3 shows the mean monthly rainfall for the three
sample areas of Bungoma, Busia and Kakamega respectively. The
averages and records were obtained from the weather stations
in the respective regions. The Bungoma and Lurambi stations
are within the sample area while Nambale station in Busia was
the closest station to the Busia sample farms. There was
evidence of a bimodal rainfall distribution in each of the
areas, hence the common reference to the long and the short
rainy seasons.

The recommendation of agronomists for farmers to plant in
February is based on the expected development stages of the
maize plant and its subsequent moisture requirements. The
maize planted at the beginning of February begins tasseling in
April. In all the study areas, the normal peak rainfall
occurs between April and May. Thereafter the amount of
rainfall tapers off, with the month of June being the one with
the least rainfall during the long rainy season. If a farmer
plants in late March, as was common in the study region, the
plant starts off with ample soil moisture due to high
rainfall. However, the crucial period of grain formation
(after 60 days) occurs in June; the maize thus suffers
moisture stress, with the consequence that yields are likely
to be reduced. In fact, if evapotranspiration during the
relatively dry period is considered, then very little soil
moisture remains. This moisture in some cases has to be
shared with weeds, due to inadequate weeding.

The Soil Type and Topography

A detailed soil survey has not been conducted for the area
under study. However, the area is situated in the uplands and
highlands region described in general terms by Odenyo and
D'Costa (1979). It has shallow to moderately deep reddish

Figure 1:   The Area of Study and Its Relative Location in Kenya
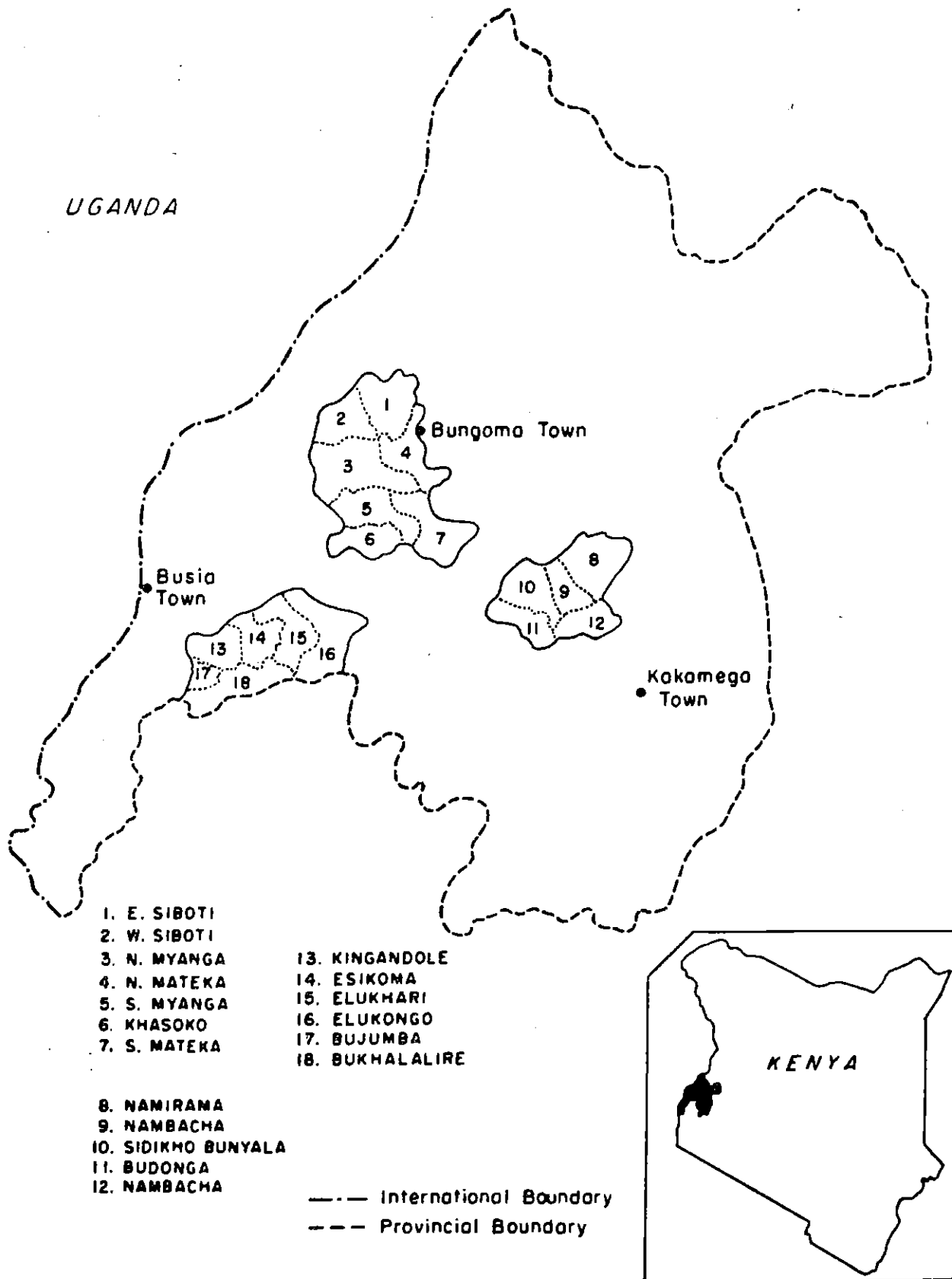
Figure 2:   The Major Agro-Ecological Zones in Kenya

ZONE	r/Eo
I	>80%
II	65-80
III	50-68
IV	40-50
V	25-40
VI	15-25
VII	<15

MOISTURE AVAILABILITY
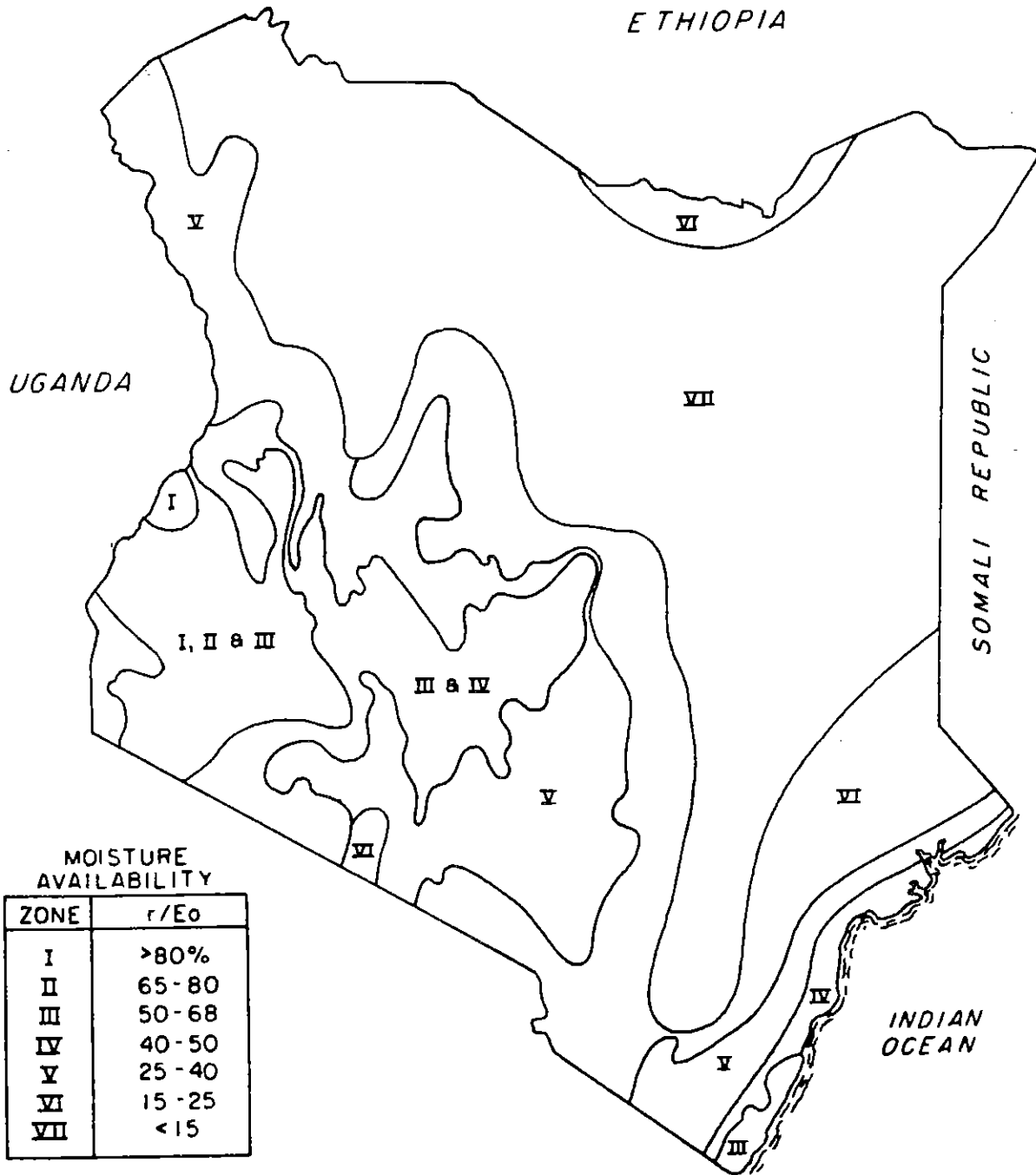
SOURCE: ADAPTED FROM KENYA SOIL SURVEY DRAWING NO. 81037.

Figure 3:   The Average Monthly Rainfall of the Three Areas

(mm)

.... Lurambi Division-Kakamega (1977-81)

———— Nambale Station-Busia (1972-80)

———— Bungoma Station (1977-81)
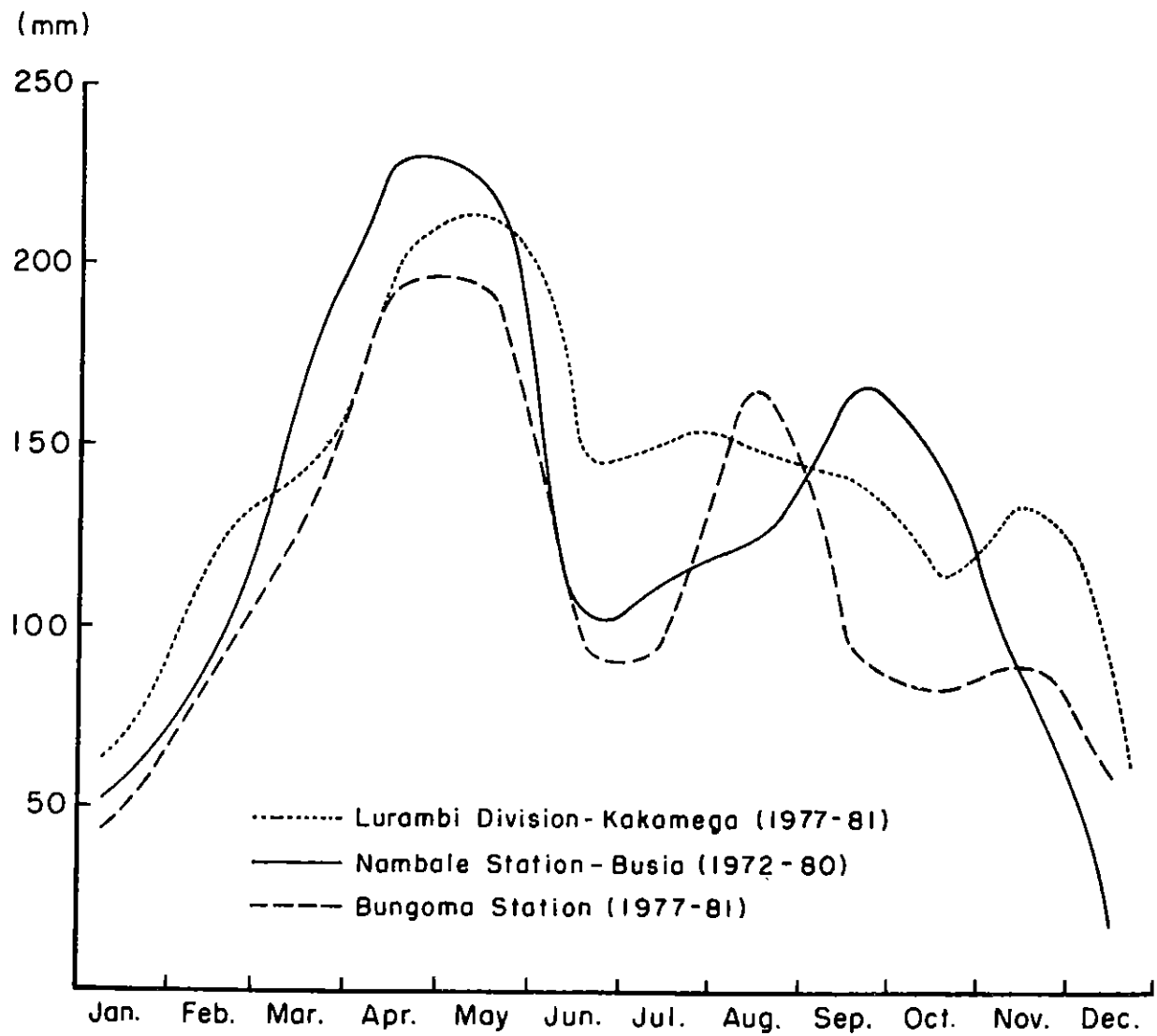
brown to <u>Catosolic</u> soils and some stretches of <u>Vertisols</u> and gleyed soils (<u>Gleysols</u>) in low lying areas. The soils are generally shallow on steep slopes, deeper on gentle slopes and of varying depths in valleys. In relatively higher rainfall areas, especially where the soils have not been cultivated for long periods, there is a thick to very thick organic surface horizon. In dry periods these soils have a hard, impenetrable structure. The implication of these soil characteristics is that ploughing should be done at varying depths to take advantage of the natural fertility of the soil. They are easy to work only when moist.

In a few places in the area, there are hills and rocks which may limit the use of animal or mechanical power in whole plots. However, such places usually form only a part of the holding.

The Infrastructure in the Study Area

The rural areas of Kenya have a poor transportation and market infrastructure. Except for the tea zones, which are served by numerous feeder roads to enable tea collection, these regions have inadequate road networks. This means that farmers have to find their own way of getting to the major market centres to obtain the inputs which may be recommended by extension agents. It is also in the market centres where supplies for rural artisans can be found. In some remote market centres, deliveries of farm inputs from their source are often late. This has made some farmers lose faith in "modern" inputs, because their availability is not assured when they are needed. Since good maintenance of whatever equipment farmers have depends on the availability of spare parts, lack of them in local centres creates high costs in terms of time lost until repairs can be made.

In Western Province, the various District Headquarters are also the main centres where inputs may be readily available. The source of these inputs are mainly the Kenya Farmers Association (KFA), with depots located in Bungoma, Webuye, Busia and Kakamega towns. Shopkeepers in the rural markets sometimes bring the farm inputs from the KFA depots closer to the small farmers. While some farmers complain that the inputs brought into the local retail shops don't satisfy their demand, other farmers from these locations assert that the prices of the inputs are higher than they can afford. The farmers differ in their capacity to obtain farm inputs.

SOME CONTROVERSIES IN FARM MECHANIZATION

The determination of the effect of farm mechanization on output is crucial because the output is used to feed the family or is sold as surplus production. Output can of course be achieved by employing various levels of mechanization, some being more labour-intensive than others. In Kenya, as in other less developed countries, the existence of surplus family labour (including distant relatives) on farms for some part of the year is not unusual. The existence of surplus labour is a strong point in the argument over the rationale for employing higher levels of mechanization in agricultural production. It is believed that such an emphasis would cause even greater "underemployment." In addition, there are disagreements among researchers on how mechanization affects crop yields. This stems partly from the methodologies used in the studies, and partly due to the differences between the various study areas with regard to technical and socioeconomic factors. A review of these issues, and how they relate to this study is provided in this section.

MECHANIZATION AND YIELD

Changes in the mechanization level may increase crop yields, if they are used by the farmers to remove or reduce a key constraint on increased field performance. There are both direct and indirect effects of mechanization on yield. They are discussed below.

The Direct Effects

Studies to show the direct effect of mechanization on yield have not shown consistent results. Some studies indicate that use of higher levels of mechanization increase yield due to the subsequent higher-quality land preparation and timeliness in operation (e.g. Rao 1972, Inukai, 1970). Other studies show no significant difference in yield, e.g. Binswanger (1978) Mutebwa (1979), Sargent et al (1981). One of the problems in measuring the effect of higher levels of mechanization has been the confounding effects of the substitution of different factors of production in various

farm categories. This problem is highlighted in Binswanger (1978), in his review of the studies focusing on Asia, where the subject of agricultural mechanization has been widely studied.

It is known that the power source is a production element that may be associated with particular farm types. A common practice in cross-section studies has been to categorize farms according to the source of power used in land preparation, and then compare the resulting yields, e.g. McInerny and Donaldson (1975), Pudsaini (1979). However, the fact is that in addition to power source differences, the farms also differ in fundamental aspects of production. This causes difficulty in interpreting results. All other factors are not held constant. For instance, it may be argued that those who can afford to hire a tractor can also buy fertilizer or seed. Hence, increased yield may not necessarily be attributed to the power source. However, this objection neglects the fact that the hardware of technology may be very different from the application of the technology. The fact that a farmer can hire a tractor or oxen to prepare his land may not necessarily mean that he can follow the proper agronomic practices. It is not uncommon to find farmers with off-farm income who purchase farm inputs (e.g. fertilizer) which may not be properly applied due to lack of proper management or supervision.

To isolate the direct effect of mechanization on yield, there is need to remove the confounding factors. One possible approach is the use of covariance analysis. Kahlon (1976) and Gopinath (1978) have attempted this methodology for Indian farms and found no significant direct effect of tractor use on yield. Jayasurya et al (1982) in a review of theoretical considerations for the effects of mechanization on rice yields in Asia report 10 studies showing no significant effect on yield after adjusting for fertilizer use between farms. This study will also use the covariance analysis technique to find out if use of a particular power source has any significant effect on maize yield for the sample of farms studied.

Another useful method to avoid attributing the effects of other confounding factors on yield to power source is to find a situation where particular farmers have just adopted a different level of mechanization. In that case, a comparison can be made of yields "before" and "after" the adoption. In this study, the sample included two years, 1977 and 1981, with some farmers using the hoe in 1977 and a different level of mechanization in 1981. However, the number of farmers falling into this category were so few that no meaningful generalization could be applied regarding yield changes. Moreover, confounding factors such as a higher level of experience in using other kinds of technology apart from mechanization between 1977 and 1981 still persisted for that category. Holding other factors constant over this span of years became a practical difficulty.

The Indirect Effects

The indirect effects of mechanization on yield have been less disputed. The indirect effects include the ability of those with higher levels of mechanization to achieve greater timeliness in land preparation. Mechanization is therefore seen (if appropriately applied) as facilitating a more effective use of high yielding inputs. The fact that use of manual methods for land preparation is slower than other methods, that farmers must wait to use these methods until the rains soften the ground is not at issue. Both manual methods and use of oxen plough usually depend on the onset of rains to start land preparation in hard soils. This is because the oxen may lack sufficient draught power to plough the hard soils. It is in this context that authors such as Mettrick (1978) and Gemmill (1972) found no significant improvement in timeliness between hand labour and oxen power. However, once the rains start, oxen ploughing allows faster preparation of a given acreage. Use of a tractor, if available, could also improve timeliness, whatever the condition of the soil. Small farmers in this study region have to depend on hiring a tractor if one is used at all. The queuing and organizational problems associated with hiring tractors are well known, and the timeliness of the tractor power is not assured, as Kolawole has shown for Nigerian farms (Kolawole 1972). But as in the case of oxen ploughing, once a tractor is in the field the task can be performed quicker than if hand labour were used. One adult takes about 96 hours to complete hoeing an acre (Ministry of Agriculture 1980). A 45 - hp tractor with 3-furrow mouldbourd plough takes 1 hour, while two pairs of oxen with 1-furrow mouldboard plough and 3 guides takes 10 hours to perform the same task. A 4-oxen team could therefore plough 1 acre in 2-3 days, while similar work would be completed in 20 days if an adult used a hoe for the land preparation[2]. The faster rate of land preparation has some added cost. Determining the profitability of using each type of power is one objective of this study.

The timeliness advantage of mechanization (when available) has been demonstrated in agronomic studies close to the present study region in Kitale by Allan (1968). Allan pointed out that poor root aeration in the early stages of growth is harmful to the maize plant. Maize needs a small amount of moisture in its early stages of growth and then considerable moisture in the later stages when it is tasselling and filling out the cobs. Planting well after the rains have started means that the plant starts off in very wet, cold, poorly aerated soil, and then may suffer later from water shortages

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[2] There is now evidence that a 2-oxen team can perform the operation at the same rate as a 4-oxen team if they are well trained and healthy. (Alexander, 1975).

when the rains are tailing off. One problem of implementing early planting methods is that the ground is hard before the onset of rains. Smallholders also fear that the rains might be late and dry-planted seed will be wasted. Dry planting is very unpopular, as was evident in this area from the number of farmers dry-planting. Moock (1976) also found that planting before the rains had the lowest acceptance of any "new" cultural practices. The loss due to late planting may be enormous. Allan, for instance, found a loss in yield of an average of about 7.6 bags for a 20 day delay after the start of the rains. If we consider that his agronomic trials were carefully controlled, it is conceivable that the loss in average farms may even be greater.

There is a risk aversion element involved here. Farmers tend to forego the higher yields which result from early planting in favour of a greater certainty that the rains have actually started and will continue. Evidence of this risk aversion is implied by the strategy the farmers in the area tend to follow in their operations even after the rains have started. Those who depend on the hoe do not prepare all the land prior to planting of the crop. They prepare a small plot of land which they then plant. Farmers continue with a prepare/plant strategy due to uncertain rainfall. Clayton (1968) and Rukandema (1978) give further evidence demonstrating that with the prepare/plant strategy, the farmer then faces the problem of whether to start weeding the first planted crop, or to continue to prepare/plant. Early and continous weeding results in a higher yield per acre but it will also limit the total acreage planted and delay the average sowing date of the planted area. On the other hand, planting as large an area as possible will result in an earlier average sowing date, but may lead to a low average yield due to inadequate weeding. The average yields should depend on technical coefficients, whether intensive or extensive cultivation is in use. In the subsistence situation, trying to maximize food output per farm to ensure self sufficiency is top priority. Whenever average returns to labour on expanded crop acreage (if available) are higher than those on limited acreage, the farmer may opt to have a relatively large cropped acreage, producing low crop yields. Such a tendency is common where the infrastructural support system is inadequate.

The extensive method of cultivation is facilitated by the use of higher levels of mechanization. This is largely due to the fact that once oxen power or tractor power is available on a farm, land preparation is performed more nearly optimally. However, sometimes the standard of operation in oxen-ploughed land is very low, and additional hand labour is required to ready the land for sowing (Kline 1969). If this is the case, then the difference between ox-ploughed and hand-ploughed land in terms of achieving timeliness in planting is reduced

substantially. The same applies to tractor use with inexperienced drivers. Because of the low density of available oxen ploughs or tractors the average time of planting for a whole community may be very late[3]. Mettrick (1978), for instance, estimated that the use of oxen for cultivation leads to an average increase in groundnut acreage of 20-25 percent. Where this level of mechanization was only for land preparation, ox-using cultivators who used no fertilizer and weeded by hand achieved lower yields than hand-cultivators who also used no fertilizer. However, the total yields on ox-using farms were higher due to their operation of larger total acreages. Thus, there was an opportunity for area expansion and larger family income through cash sales of output; consequently oxen cultivators were better off than hand cultivators, owing primarily to area expansions.

MECHANIZATION AND LABOUR USE

The adoption of higher levels of mechanization has been considered undesirable in the rural areas of less-developed countries by some studies because of the labour displacing effect of mechanization, e.g. Binswanger (1978), Jayasurya et al (1982) Sargent et al (1978). Other studies, such as Fisk (1961), Barker et al (1972), and Doraswamy (1979) suggest that if labour use is considered by farm operation, there may be low labour use in some operations which are mechanized, but the overall labour use on the farm will be higher due to increased acreage and the need to employ additional workers in operations not being mechanized. This is the result of the seasonality of agricultural operations. The labour bottleneck during land preparation is broken, and consequently the farmer has more time to weed and harvest the resulting larger crop, hence an increase in the demand for labour.

The view that a higher level of mechanization is not desirable until the problem of absorbing surplus rural labour into other employment has been solved may be an oversimplification. The existence of underemployment in the smallholding areas is not itself a sufficient reason for rejecting mechanization. Higher levels of employment are desired and pursued as an objective because normally they are associated with higher levels of income and welfare. But if higher employment levels imply low marginal productivities of

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[3] One team of 4 oxen could be used to prepare an average of about 15 acres of maize during a long rainy season in the present study area. If one acre takes 2-3 days to complete, then readying 15 acres requires over one month, with the consequence that other fields must be prepared late.

those actually employed, pursuit of such an employment
objective can be retrogressive. On the other hand, the
difficulty in the area of this study is that labour mobility
between the regions is extremely low due to institutional
factors. As such, even at the peak of an operation, such as
land preparation, labour available for hire may be very
limited within the area. Thus even for those who can afford
to hire, dependence on own family labour is common, because
everybody is busy on their own fields. Labour from presumed
"surplus" areas may not be forthcoming. Heyer et al (1976)
also report such a tendency. This may result in high but
seasonal utilization of family labour at least for operations
which are not mechanized.

An associated argument for improving the form of
mechanization for those employed in agriculture is that
drudgery and heavy physical labour is often reduced by
adopting higher levels of mechanization. The drudgery effect
is very difficult to measure in quantitative terms, but can be
appreciated if one participates in performing an operation
such as digging with a hoe. Studies based on the
landlord-tenant system in Asia (Binswanger, 1978) reject the
drudgery argument for promoting mechanization. This is
because the tenants have few other alternatives apart from
actually performing manual jobs. Binswanger (1978) pointed
out:

> "...in an environment of stagnant or declining
> wages, loss of employment may relieve landless
> labourers of drudgery but it clearly increases
> rather than reduces their suffering...... As long
> as population and slow growth of manufacturing and
> tertiary sector employment continue to press on
> rural wages, reducing drudgery is not a social
> benefit. It simply redistributes benefits from the
> poorest groups to already richer strata of rural
> society." p. 75.

In the study area, however, the farming system is such that
landless tenants do not exist. In that case, increasing the
amount of land under cultivation may bring real social
benefit. Only land preparation would be done by a higher
level of mechanization, and the larger area farmed will allow
more employment in all other tasks associated with the crop.

In fact, the extended family system is still very much in
evidence in the area. The farmer is obliged through the
kinship system to provide food to feed the farm population,
whether the individual members of the household work or not.
What matters to them is not the lack of field employment, but
the lack of production from which to feed themselves.
However, although the individual may opt out of work, the
importance of status ensures that everybody actively seeks
work; otherwise their reputation suffers.

Cleave (1974) points out that removal of drudgery may itself be important in improving labour productivity. This is because the nutrition of some of those supposed to be working in the field is such that their physical condition cannot enable them to do arduous work for a lengthy period[4].

MECHANIZATION AND ITS COST

Any potential benefits of mechanization such as a larger acreage cultivated and/or the higher yields through timeliness, can be offset by high cost of equipment and its operation. The fact that higher crop yields are attainable by one form of mechanization over another is not sufficient reason to recommend a particular level of mechanization for farms. The difference should be of such magnitude as to compensate for the extra cost which may be associated with the technology. The profitability of the technology should determine the choice of the power used for cultivation.

Studies which have been undertaken to compare the profitability of various forms of mechanization have largely used cost-benefit analysis to arrive at their conclusions. Such studies include those of Green (1972), Gemmill (1971) Adelheim and Schmidt (1975) and Kolawole (1972). Green's work was based on case studies in Ethiopia. In one of the case studies reported in Gemmill and Eicher (1973), budgets were drawn up showing the costs and benefits of changing from the current bullock technology on an 8 hectare farm to either improved bullock power or tractor hire. On the basis of financial analysis, Green concluded that the returns from a small project with improved bullock power were modest; however, because it provided greater employment, this project was preferable to tractor hire. This reinforced the idea that based on economic analysis, use of bullocks would be the choice. Gemmill's study was based on a study of 132 farmers in Malawi, half of whom used hand methods and the other half bullock power for land preparation. Simple budgets showed that the private profitability of bullock power was very low in an area of dense population with limited opportunity to increase crop acreage. But the farmers who used bullocks had social gains from the reduction in drudgery.

The cost of hiring oxen for ploughing varies in the Western province; it ranges between Kshs. 60 and 100 per acre[5]. Those

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[4] The same applies to draught animals, but, as indicated the rate of work is faster than hand labour once there is sufficient grass after the rain, assuming there is no supplemental feeding.

[5] 1 Ksh. is approximately equal to 10 U.S. cents.

who own oxen can therefore receive additional income from renting out these services. If the time taken to ready an acre for planting maize is taken to be about 20 days by hand labour, and the cost of hiring a manday of labour averages Kshs. 5, then if a farmer were to choose between hiring labour and hiring oxen to prepare his land, he would opt for oxen. This is because oxen-ploughing is faster, and yet the total cost for hiring the service is almost the same. Use of hand labour for land preparation is therefore confined mainly to family labour.

In the case of oxen and tractor hiring, Adelheim and Schmidt (1975), in their budget analysis for model farms in various agricultural regions in Kenya, concluded that in high potential areas with small farm sizes and correspondingly high population density, "the economic advantages of using oxen as compared to tractors are generally low, and they must be expected to decrease in the long run with an increase in the level of intensity of farming." On the other hand, Adelheim and Schmidt stated that in areas with larger farms but of relatively low agronomic potential, ox cultivation would still have an economic advantage. This observation is connected with the opportunity cost of land which is set aside for grazing. Where high-value crops can be grown, it may be profitable to devote most of the land to crop production rather than setting a portion aside for grazing. In that case, use of tractor service could be encouraged. However, it should not be forgotten that a high-value crop can be devalued if the marketing system is inefficient This has been partly the case with cotton in Western province.

This study used partial budget analysis to evaluate the profitability of the alternative forms of mechanization in the study area. The cost-benefit analysis technique is a powerful tool if all the costs and all the benefits can be identified. The difficulty with it is that some of the costs and benefits are not easily quantified. For the financial analysis, if input costs and output prices can be found, then evaluating the financial viability of practices or enterprises is straight forward. However, for social profitability some non-pecuniary costs and benefits may be involved, and these must be appreciated. Such non-pecuniary elements include drudgery reduction and the possibility of reducing available employment. Distortion of prices is also common in areas where tractors tend to be promoted by governments resulting in private profitability but losses to society. In Kenya, agricultural tractors and farm equipment are imported duty-free. Moreover, the charge per acre of using a government tractor was fixed at Kshs. 134 in 1981 compared to the privately hired tractor which cost an average of Kshs. 200 per acre. The government tractor hiring charge was clearly artificially low; yet their availability for farmers was far from adequate, judging from the number of tractors that were unserviceable at the tractor hiring station and the number of farmers using them.

METHODOLOGY AND STUDY PROCEDURES

The basic data for this study came from the IADP sample farm records for 1977 and 1981, together with an additional non-IADP sample of farm records in 1981. The IADP records were gathered by the monitoring and evaluation unit of the Ministry of Agriculture using a panel survey of 40 farms in each of the three arable districts in Western Province. These data were expected to provide an opportunity to examine the changes in the adoption of various levels of mechanization after 1977, and the consequent productivity and profitability of the farms employing various sources of power. Moreover, since IADP included a credit component, initial financial assistance to farmers who were willing to invest in a viable, higher level of mechanization could be facilitated. Because some farmers in the panel survey had dropped out by 1981, only those whose records were available in both 1977 and 1981 were considered for this study. Over the two periods, there were a total of 162 farm records. An additional 40 non-IADP participants were selected in 1981 to augment the sample. The data set had a final total of 202 observations from 3 clusters in Western Province, each cluster representing an administrative district.

The sample farms were categorized according to the power source used in land preparation. This division was made because land preparation is the operation where substantial differences in methods were observed. Additionally, a difference in time of planting affects yields in this area. The physical characteristics in each cluster, such as the rainfall regime were examined. There was no marked disparity between locations. Each area had a bimodal rainfall distribution, the long rains beginning around mid-February and peaking between April and May before tapering off in June-July (figure 3). The four categories of farms established were: (1) the hoe users (2) those using own oxen (3) those hiring oxen (4) those hiring a tractor.

THE ANALYSIS OF LABOUR USE IN MAIZE PRODUCTION

The labour used in farm work is first and foremost determined by the available number of adults in the household who are able and willing to work. This is the family labour, which may include even distant relatives. In rural households, complete unemployment is non-existent for those willing to work. However, productivity may be low, thus resulting in chronic underemployment. In cases where the available family labour is insufficient to meet the labor requirements, hired labour is used if possible.

For an important food crop such as maize, the allocation of labour for its production takes priority over any other competing activity on the farm. This is especially true if maize movement across regions is restricted. For instance, farmers in the region have shown reluctance to plant cotton early despite possibilities of increasing cotton yields, because the planting time coincides with that of maize. This was shown by Kennedy (1963). Farmers were unwilling to risk a loss in yield of the food crop, maize, by diverting their labour to planting the cash crop. Furthermore, there was no guarantee farmers would get the cash in time or food if cotton were given priority.

The operations in maize production include land clearing and tillage, planting, weeding and harvesting. All the operations require timeliness if losses in yield are to be avoided or reduced. Since they are sequential, the initial operations are critical, limiting the area that can be harvested.

In the sample farms, the number of individuals over 14 years who were actually working on the farms varied between 2 and 5. The concept of "manday" was used to define a labour unit. In this study, one manday is equivalent to an adult working for 5 hours in the field. Thus, women and men were considered to be participating equally in the field. There was no reason to give them a weighting of half as other authors have done (e.g. Norman 1973). As is pointed out by Rukandema, (1978), Norman's weighting scheme for labour use may be justified because of the Muslim tradition regarding the participation by women in farm work. In Western Province, only ploughing with oxen is exclusively the work of men and boys above 10 years. Children below 14 years and adults beyond the age of 60 who worked on maize could achieve only 1/2 manday of work per day.

The 5-hour duration for a manday was justified because of the climatic condition in this area. After about 12 noon, it becomes too hot to perform arduous work in the field. Haswell (1973) and Cleave (1974) have both pointed out that the 8-hour day some studies use for defining a manday cannot be justified under tropical conditions.

For 1981 the average amount of family labour used per acre in the sample farms was 47 mandays for the hoe group, 45 for oxen group, 48 for those hiring oxen and only 20 for the tractor-hiring group. The amount of hired labour per acre was about 52 mandays for the tractor-hiring farms, while the hired labour varied between 20 to 30 mandays per acre for the other 3 groups of farms. The amount of family labour and hired labour combined, when considered on a per acre basis, did not vary much among the groups of farms. This may be because only land preparation had different levels of mechanization. Thus, while there was lower utilization of labour in the mechanized operation, more labour per farm was required in subsequent operations due to increased acreage readied.

Using the 1981 augmented sample data, labour profiles for maize production were derived for each group of farms. The mandays for each operation referred to the average labour used per farm.

THE PRODUCTION FUNCTION ANALYSIS

To estimate a production function, the specification of the true structure of a production process in an economic sense is essential (Griliches, 1957). Adequate consideration should be given to the relevant variables, the algebraic form of the function, the economic and physical logic implied by the function and the technique to be used in estimation. The economic implication of the functional form chosen are important insofar as various functional forms have specific properties, some of which may appear illogical in a production framework.

The Choice of a Functional Form

The choice of a good functional form must be based on some general criteria. As outlined by Hu (1974), first it is desirable to choose a simple rather than a complicated form if the two can explain the problem equally well. Secondly, economic theory and biology should guide the choice as much as possible, lest we come up with measurement without a logical foundation. A model with good predictive power is useful. The functional form should fit the data well. The fit of the data can be evaluated by using statistical measures such as R^2, the adjusted R^2 (adjusting for degrees of freedom), and the F statistic for the model. The higher the R^2, the greater the proportion of the dependent variable being explained by the explanatory variables. The regression coefficients should be statistically significant (measurably different from zero). The insignificant coefficients help in monitoring variables

which may be incorrectly defined or measured, or those which have coefficients which are unstable with slight changes in the data. This can help to detect severe multicollinearity among the variables and attendant problems of interpretation.

A careful examination of the residuals helps to determine whether or not the functional form used is appropriate. In ordinary least squares estimation, if the basic assumptions with respect to the error term hold, the residuals when plotted against an independent variable or the dependent variable should be random and homoscedastic. This study makes estimates for both the linear and Cobb-Douglas functional forms. These choices were made after the above considerations were taken into account.

The Variables Considered

The Dependent Variable

The maize output per acre (yield) in kilograms was considered the key dependent variable[6]. This refers to the output from each farm normalized by the number of acres which were devoted to maize production. Since one of the objectives of the study was to compare productivities of various categories of farms, this partial productivity measure was the logical variable to be explained.

The Independent Variables

Inclusion of all the relevant variables in maize production in the study area is crucial if we are to get reliable and meaningful estimates. Omission of relevant input variables will tend to bias one or more of the coefficients of the included variables (Griliches 1957). The direction of bias depends on the correlation between the omitted and included variables. The included variable will be overestimated if the omitted variables have positive correlation with the included ones, while the converse will hold in the case of negative correlation between the omitted and the included variables. At the same time, inclusion of highly correlated independent variables introduces the problem of severe multicollinearity. In that case, the regression coefficients will have high

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[6] The kilogram unit was appropriate because the maize sale in local markets was in terms of tins which contain 2kg. of maize, "christened" after the 1979 famine as "Gorogoro," hence very familiar. 90 kg. of maize make 1 bag. The 1977 records of maize output were also in kg.

standard errors and therefore show little or no statistical significance. It is also difficult to determine the separate effects of the highly correlated variables. Combining such variables is one way of alleviating the problem. The way inputs are measured and the form in which the variables are to be included in the production function is clearly important (Heady and Dillon, 1961, Yotopoulos, 1967). The explanatory variables considered important in determining maize yield in the study area and a description of how they are defined and measured in the production function analysis follows.

Maize Acreage (MZA)

The area planted to maize was measured in acres. Apart from this variable being used to normalize maize output and other production factors to a per acre basis, it was also included as an explanatory variable. The rationale for doing this was twofold. One was to have maize acreage show its own contribution to the yield. The other was to reduce multicollinearity among the independent variables.[7] If maize acreage were excluded as an independent variable, it could be shown that its effect is captured in the intercept term, while the other coefficients remain unaffected. Thus, suppose maize output (O_i) is a linear function of two inputs, maize acreage (X_1) and purchased inputs, X_2 such that

$$O_i = a + b_1X_1 + b_2X_2 + e_i \quad (i)$$

Normalizing with X_1 we get:

$$O_i/X_1 = a/X_1 + b_1 + b_1X_2/X_1 \quad (ii)$$

Therefore:

$$Y_i = a_0 + b_1 + b_2 X_2/X_1 = a_0^* + b_2X_2/X_1 \quad (iii)$$

a_0^* then incorporates the effects of changes in maize acreage on yield. Including maize acreage after normalizing gives us:

$$Y_i = a_0 + b_1X_1 + b_2X_2/X_1 \quad (iv)$$

The b_1 coefficient now shows the effect of the changes in maize acreage on yield.

In the Cobb-Douglas functional form, if

$$O_i = AX_1^{b_1}X_2^{b_2} \quad (v)$$

Normalizing with X_1 and not including it as an independent variable gives:

$$Y_i = AX_1^{b_1-1}X_2^{b_2} \quad (vi)$$

Thus, the elasticity of Y_i with respect to maize acreage is reduced by one; there is no effect on b_2. However, including maize acreage after normalizing each input in this case should

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[7] This was because the other inputs were thought to be highly correlated with maize acreage.

give us a measure of returns to scale as the coefficient of X_1. An additional algebraic step is involved to illustrate this

$$Y_i = AX_2^{b_2} X_1^{b_1-1+b_2-b_2} \qquad \text{(vii)}$$

$$Y_i = A(X_2/X_1)^{b_2} X_1^{b_1-1+b_2} = AX_2^{b_2} X_1^{b_1^*} \qquad \text{(viii)}$$

As such, b_1^* should be regarded as a composite of the coefficients of all the independent variables normalized by maize acreage, less 1. It measures the proportional change in yield resulting from a unit proportional change in acreage, ceteris paribus.

The Effective Labour Inputs (LABPL and LABW)

Whatever acreage is planted to maize, labour must be applied to achieve some output. Labour may come from family members or be hired from outside the farm. Because of the limited hiring activity among sampled observations, hired and family labour were combined as one variable. However, it was considered necessary to estimate the effects on yield from labour according to key categories of operations performed. This was because the expected marginal contribution to yield will differ for each major category of activity. To capture the unknown but true marginal productivity, the labour used should be related to the time the operations were performed, because it is assumed that its impact on resulting yield depends on timeliness relative to weather.

Land preparation and planting labour were combined to become one variable (PLNTLAB) because, in most cases they were highly related or even concurrently performed. Weeding labour (WIDLAB) was considered as a separate variable, while harvesting labour was excluded from the production function because it was reasoned that it did not directly contribute to the available output of maize to be harvested from the fields[8].

Following Rukandema (1978), a theoretical weighting scheme was designed to depict the declining yield of maize if the operation, was not timely, based on the times recommended by agronomists in the neighbouring research station. Figure 6 shows the structure of the theoretical weighting scheme adopted. It represents a quadratic function of time with PLE being the structure for preparing and planting labour. The

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[8] Considering the relatively low average maize yields obtained by the sample farms and the importance of the crop, it was felt that whatever output was available for harvest, labour would be forthcoming to harvest it.

weighting structure for weeding labour (DLN) is superimposed
on that for land preparation and planting labour, (PLE).

Figure 6:   The Structure for the Weighting Scheme for Land
             Preparation/Planting and Weeding Labour
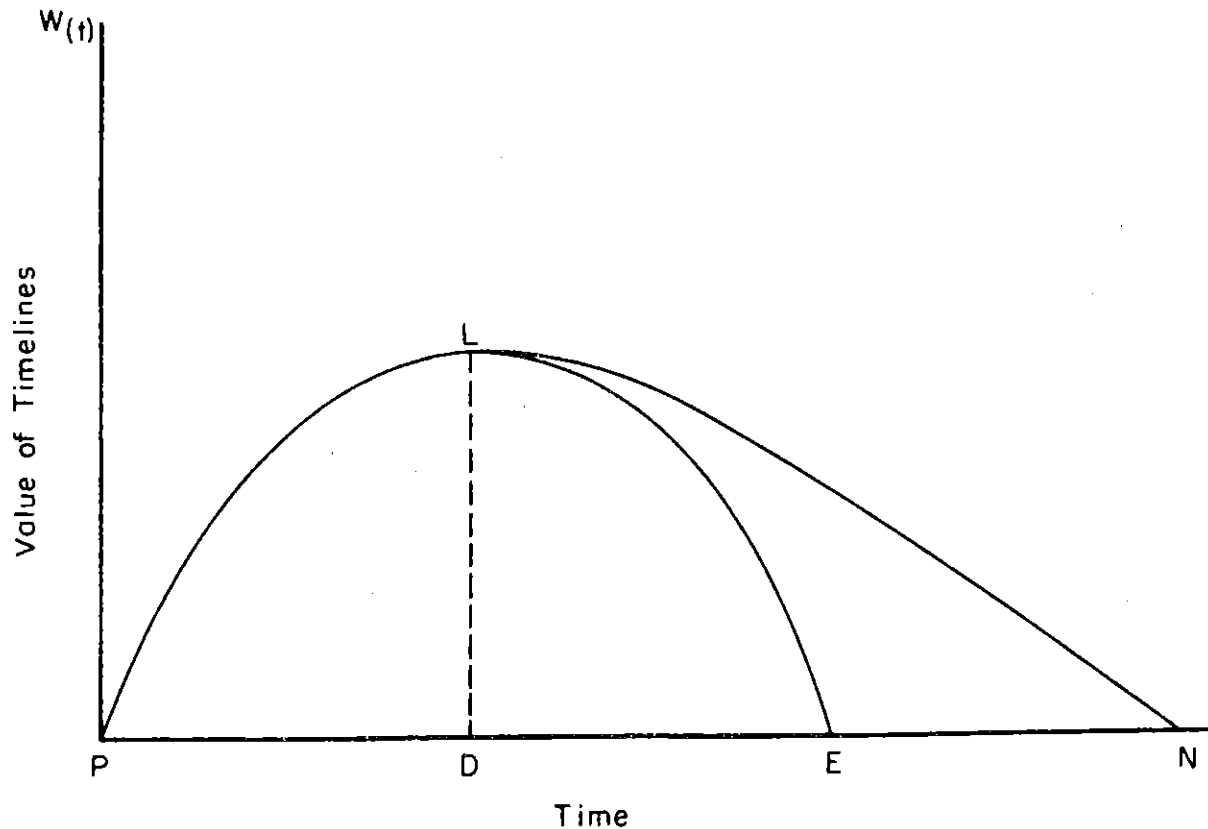
In the figure, the horizontal axis represents the time span
for the operation while the vertical axis shows the relative
importance (theoretical weight) of labour used in the
operation. The interval PE is approximately between
mid-January and the end of March, while DN represents roughly
the second week of March to the beginning of May.

The rationale for adopting a quadratic weighting structure
was connected with the rainfall pattern in the area, together
with the effects of the competition between weeds and the
maize plant for water and nutrients. In Chapter 1, we found
that maize planted well after mid February starts off with
ample soil moisture, but experiences water stress at the
critical time of flowering and ear formation. It was apparent

that the longer the delay after the optimum time of planting, the more intense would be the stress[9]. The consequence would be a reduction in the marginal contribution which might be obtained with further applications of labour. The weighting scheme for planting labour was designed to approximate this effect. The rationale was similar for weeds, where germination occurs about the same time as for the crop. It may be argued that after 3 weeks from planting date, non removal of weeds will continue to be increasingly more harmful to the maize crop because of the intense competition for the available moisture and nutrients[10]. The declining proportion of the weighting scheme, LN, shows this as time for weeding advances after about the middle of March[11].

Because of the quadratic relationship assumed between the value of timeliness (weight) and the time the operation was performed on maize production, the algebra to establish the weights could easily be manipulated. To demonstrate this, suppose yield (Y_i) is a linear function of only land preparation and planting labour (X_2). Then

$$Y_i = a + b_2 \{w_t X_{2t}/X_1\} \qquad (ix)$$

Where t = the average time (week of operation) ranging from 1 to E

w = the weight for the labour used in the week.
X_1 = the maize acreage.

To obtain w_t, reference to figure 6 shows that it can be given as:

$$w_t = q_0 + q_1 t + q_2 t^2 \qquad (x)$$

where q_i = the structural parameters of the scheme. Assuming $w_p = 0$ and $w_E = 0$; then $q_0 = 0$ and

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[9] The quadratic relationship assumption hinges on the occurrence of the optimum.

[10] In case fertilizer is used the weeds, which also benefit from the fertilizer but are often more vegetatively aggressive than the crop, might even overwhelm the crop, reducing yield considerably.

[11] The structure shown in figure 6 may shift depending on the onset of rains and the amount of rain over the period. This would imply shifts from year to year. However, on average, these shifts could be reflected on a stable structure.

$$q_1E + q_2E_2 = 0 \qquad (xi)$$

$$q_2E^2 = -q_1E \qquad (xii)$$

$$q_2 = -q_1/E. \qquad (xiii)$$

Substituting for q_2 in (x) gives

$$W_t = q_1t - (q_1/E)t^2 \qquad (xiv)$$

$$= q_1(t-t^2/E).$$

Rearranging equation (xvi) gives:

$$Y_i = a + b_2q_1 \{[(t-t^2/E)]X_{2t}/X_1\} \qquad (xv)$$

The adjustment of the labour used per acre by the time that the specific operation was performed is realistic because we are dealing with a rainfed environment. The marginal contribution of labour depends on the time operations are performed in relation to the time that operation is regarded ineffective with respect to maize yield in the region (E). The variable was referred to as LABPL.

Similarly weeding labour (WIDLAB.) was also weighted to take into account the time period it was performed. Referring to figure 6, D represents 3 weeks after planting, when weeds start competing with the new maize seedlings. Any delay in their removal has an increasingly negative effect on maize yield. N represents the time when further weeding has no effect. In this study it occurs at the beginning of May (about 17 weeks after P). In fact, weeding beyond time N may technically be worse than no weeding at all, because it is conceivable that the roots of the maize plant may be harmed. It was for this reason that a dummy variable for double weeding, which implies weeding beyond time N, was incorporated in the production function to test for such an effect. Given the weighting structure for weeding labour in figure 6 as a modification from DLN, the scheme developed above assumes that three weeks after planting is the optimal time of weeding. Thus,

$$W_t = q_0 + q_1t + q_2t^2 \qquad (xvi)$$

where t is redefined to mean weeding time at time D = P+3 where P is planting time.

$$dw/dt = q_1 + 2q_2t = 0 \qquad (xvii)$$

$$2q_2t = -q_1$$

$$t = -q_1/2q_2 = (P+3)$$

$$q_1 = -2q_2 (P+3) \qquad \text{(xviii)}$$

at time N = 17 in our case,

$$w_t = 0 \text{ and therefore}$$

$$q_o + q_1 t + q_2 t^2 = 0$$

substituting for q_1 from (xviii)

$$q_o - 2q_2(P+3)N + q_2 N^2 = 0 \qquad \text{(xix)}$$

$$q_o = 2q_2(P+3)N - q_2 N^2$$

Then substituting for q_o and q_1 in (xvi),

$$w_t = 2q_2(P+3)N - q_2 N^2 - 2q_2(P+3)t + q_2 t^2 \quad \text{(xx)}$$

$$= q_2(2PN + 6N - N^2 - 2Pt - 6t + t^2)$$

and since N is fixed for all farms at 17, we have

$$w_t = q_2(34P - 187 - 2Pt - 6t + t^2) \qquad \text{(xxi)}$$

Designating the labour weeding weight as

$$w_t = q_2(G),$$

where G is the bracketed term in (xxviii), yield as a function of weeding labour (X_3) becomes

$$Y_i = q_2(GX_3)/X_1), \qquad \text{(xxii)}$$

and the marginal contribution of weeding labour incorporates the interaction of planting and weeding time in relation to the time weeding becomes ineffective in the study area. The effective weeding labour was referred to as LABW.

Other Included Variables

In addition to the above variables, the othe varables included to explain the variation in maize yields were:
a) the levels of fertilizer per acre (FTQA)
b) the proportion of fallow land (PFAL)
c) the days after the onset of rain that to complete planting (DAFR)
d) the 0-1 or dummy variables representing:
  - the methods of land preparation;
  - the frequency of weeding;
  - the level of education of the farmer;
  - the location of the sample;
  - the participation in IADP;
  - and the period of the survey.

Some Excluded Variables

Variables such as intercropping, seeding rate, age and sex of the farm manager showed very little variation. They were therefore excluded from the production function analyses.

TECHNIQUE OF ESTIMATION

Ordinary least squares regression was used to estimate the parameters for each of the independent variables of the production function[12]. The regressions were run for various categories of farms before pooling, and productivities were compared among them. The aim of running separate regressions first was to examine the yield obtained within each group, using the given explanatory variables. This provided a basis for covariance analysis. The key groups of farms considered were the hoe farmers, those using owned oxen, and those depending on hiring oxen or tractors for land preparation, the combination of which was made after no statistical difference between them was detected.

PROFITABILITY OF VARIOUS LEVELS OF MECHANIZATION

The fact that one level of mechanization may be associated with higher yields than another level is not sufficient reason by itself to ensure profitability or loss for farms using the technique. What is desirable is for the difference in yields to be of such magnitude as to offset any additional cost involved. It is for this reason that one objective of the study was to determine the profitability of alternative methods of land preparation. Based on the technical relationships obtained from the production functions, partial budget analyses for the various farm categories were developed.

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[12] Implicit in the use of this procedure is the assumption that independent variables are fixed and uncorrelated, the error term (e_i) have zero mean and constant variance for all observations. The (e_i) are also uncorrelated and are normally distributed.

The Budget Analyses

For each category of farm, the average identifiable quantity of inputs which went into maize production was obtained from the survey data. Such inputs included the acreage planted, family labour, hired labour, oxen or tractor use and fertilizer applied. The variable cost and physical quantities the farmers used for these inputs was available. Because maize is a staple crop and only a proportion of the total output was sold for cash by each farmer, the government controlled price in 1981 was used to value the total maize outputs to obtain the gross income for the enterprise[13].

The Maize Enterprise Budgets

A maize production budget was developed for each category of farms and net cash income per acre obtained assuming the current organization of the farm to be fixed.

The Costs Considered

Some costs could be identified as directly allocable to maize production, and therefore comprised the variable costs in production. However, some of the costs which could not be assigned directly to maize production were regarded as fixed costs. Some of these costs were similar for each category of farm. For instance, hoe ownership was not confined only to the group designated as HND in this study. The hoes were necessary in each of the other farm categories to perform other farm operations. Generally, the number of the hoes per farm were approximately equal to the number of adults working on the farm.

The fixed costs of such items as hoes and ploughs were difficult to evaluate. A hoe which is regularly in use may be effective for only 5 years. However, there were cases of hoes approaching 10 years of age but still in use. As noted in Chapter 3, farmers find it difficult to purchase new hoes currently at Kshs. 40; only 10 years ago, the same hoes were bought at half this price. Taking the effective life of a hoe in regular use to be about 5 years, and considering the

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[13] The maize was sold both to the National Cereals and Produce Board, which accepts only deliveries in 90 kg. bags, and also in local markets, where 2 kg. tins of maize were the units of measurement. Although the price in the local markets varied from month to month, the average price was close to the controlled price.

initial cost of the hoe to be Kshs. 40, annual values could be obtained. Since each category incurred this cost, its inclusion was not crucial in determining the relative profitability of mechanization.

For oxen ploughs, most owners replaced the plough shares, costing about Kshs. 60, at the start of every growing season to ensure effective ploughing. However, the plough units ranged in age from 2 to 30 years. The Ministry of Agriculture figures indicate that the plough should have a useful life of 10 years. The fixed cost per year is quite low, considering the effective life of equipment on some farms. But the average life indicated by the Ministry of Agriculture was adopted to arrive at the annual fixed cost.

The annual cost of ploughs for oxen ownership was the purchase price of the plough plus attachments, or what was in effect the annual repair and maintenance cost of the equipment[14]. The maintenance cost was therefore part of the variable cost for oxen owners.

Other variable costs were easily derived from expenditures on specific items for maize production. The oxen depend on natural grazing; feed supplementation was non-existent. Therefore no additional feed cost was incurred. Herding the animals was done by family labour, especially children above 10 years. As long as the animals were healthy, they appreciated in value annually from the age when they started ploughing (normally 3 years). After their useful work-life of about 5 years, they could be sold for slaughter. Moreover, they could also be sold to other farmers during their useful work-life if the original owner had excess bulls/oxen. The main cost of owning oxen was therefore the opportunity cost of the grazing land, which for this area was relatively low, considering the available fallow land. Any new owner of oxen would incur the opportunity cost of the funds they invested in the animals instead of placing the money in a bank. The cost of one 3-year old bull/ox was taken to assumed to be about Kshs. 600.

Land was owned, and almost all farmers had title to the land. Those who hired labour paid Kshs. 5 per manday. Purchasing hybrid seed was limited, while value of own seed from the farm, if used, was assumed to be equal to what would be paid for ordinary maize, or about Ksh. 1. per kg. Hiring oxen cost an average of Kshs. 80 per acre[15]. While the

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[14] This overstates the cost incurred by the oxen owner on his own maize production, because he could rent out the oxen using the same plough shares.

[15] At that charge, if a farmer had 3 acres to be ploughed, hiring oxen for two consecutive years could be approximately equivalent to the cost of a new ox plough.

government tractor hire service cost Kshs. 134 per acre, the
private tractors charged Kshs. 200 per acre. This difference
and timeliness were considered the primary factor
differentiating those using private service from those using
the government service.

The Partial Budget Analyses

This technique is suitable for evaluating the consequences
of changes in farm organization that affect only part of
rather than the whole farm business. Incorporating a change
in the organization of the farm, such as changing from using a
hoe to oxen for land preparation, had to consider the current
limit on capacity of other farm resources, such as labour and
land for maize production. If the aim was to own oxen for
ploughing, for instance, labour should be available for
working on the extra acreage readied and also the existing
fallow should be enough to graze the oxen[16]. The estimated
increase in output for each method of land preparation
obtained from the production function analysis formed the
basis for calculating the additional income resulting from
each change in the partial budget.

Since our concern was to determine the effects of changes
in farm mechanization, analyses were done for the following
alternative changes in land preparation.

1. from using the hoe to use of hired oxen.

2. from using the hoe to use of own oxen

3. from oxen hiring to owning oxen

4. from hired oxen to use of hired private tractor.

In each case, the format of the budget reflected the losses
and gains involved in effecting the change. The losses
included the revenue lost due to the change as well as the
extra costs due to the change. The gains included extra
revenue resulting from the change and the costs saved due to
the change. If total pecuniary gains outweighted total
pecuniary losses, then it would be financially possible to
carry out the change; otherwise not. In each case, the
non-pecuniary implications of the change were pointed oug.
The assessment of the change on farm profit is of course
contingent upon the accuracy of the technical and financial
data used.

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[16] Sometimes farmers have livestock on the farm which could
be trained for ploughing. In this case, lack of implement
and training are the barriers to oxen use.

THE EMPIRICAL RESULTS

LABOUR UTILIZATION IN MAIZE PRODUCTION

The average labour used per operation by calendar month was calculated for each group of farms[17]. Family labour and hired labour were considered separately for purposes of drawing the labour profiles.

The Hoe Group Labour Profile

The labour profile for the hoe group is presented in Figure 7. Land preparation took place between January and April for this group, with highest labour requirement occurring in February. During that time, about 30 mandays per farm were used. However, within February, planting also had to start, and about 2 mandays of labour was hired for this operation. Land preparation, planting and weeding occurred concurrently in March. The peak period for labour was in April when weeding, which requires a lot of labour, was intense. In April, a total of about 80 mandays of labour were used, with about 20 mandays of labour being hired for weeding. Harvesting took place between July and October, with the highest mandays of labour for harvesting (36) being in October.

The profiles have some resemblence to the rainfall pattern discussed earlier (Figure 3.3). The peak of labour activity in April closely corresponds to the rainfall peak for the areas. For the hoe group, not more than 40 mandays of labour were used in any one month for maize production, except for April, when about 80 mandays were used. There were slight variations between locations. The hoe group of the Bungoma and the Busia samples tended to complete land preparation earlier than the Kakamega sample. This might have been due to the generally larger maize acreage cultivated by this group in Kakamega. Also, the hiring activity in Busia cluster was generally not common.

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[17] The calendar months were used only for convenience. Normally the operations are not neatly divided by calendar months.

Figure 7: The Maize Production Labour Profile for the Hoe Group

The Labour Profile for the Oxen Owners Group

The profile for the oxen owners differed from that of the hoe group in various respects. Figure 8 shows the profile for this group. Land preparation for the group ended by March. In contrast to the hoe group, which had about 28 mandays of land preparation in February, only about 10 mandays of labour were utilized for land preparation by the oxen group. The month of March was the peak activity period, with about 85 mandays of labour being used for maize production. During this month, all operations were being performed, with about 20 mandays of labour being hired. The weeding activity was very labour-intensive for three successive months, from March through May. For each of those three months, over 40 mandays of labour had to be used in maize production for this group. Harvesting was again spaced between July and October, but with peak harvesting labour in July, where about 45 mandays were used. This signifies that generally planting was relatively early for this group, although it went on until April. It also appears that the labour utilization over the year is more even than for the hoe group after land preparation is completed. The even labour distribution over the year is a feature also found in smallholder tea farms, (Oluoch, 1978). It prevents idleness of available labour for some parts of the year.

The Labour Profile for The Group Hiring Oxen

This group had also relatively few mandays of labour between January and February. However, a greater amount of labour in March and April was expended compared to the hoe group (see Figure 9). Land preparation was also spread out between January and March. Weeding, the most labour-intensive activity, occurred between March and May. Over 40 mandays were spent weeding per month in March and April, and about 25 mandays in May. The month of June was free of any activity for maize production as was also true for the other groups. Harvesting occurred between July and October; September was the peak month for harvesting activity. About 5 mandays of labour was hired for harvesting maize during August.

The Labour Profile for the Group Hiring Tractor

The labour profile for this group is presented in Figure 10. Although the profile was based on a sample of only seven farms, it showed that the two months of March and April, when land preparation, planting and weeding all had to be concurrently performed, were the busiest months. This is consistent with the other groups. Land preparation occurred in January and March, while harvesting took place between July and September. Hired labour was necessary for planting in February, weeding in April and harvesting in September. About 70 mandays of labour for maize production was the peak requirement for labour in the month of April. The two months of May and June had no maize production activity for this group.

Figure 8:   The Maize Production Labour Profile for the Oxen
            Owners Group

Figure 9: The Maize Production Labour Profile for those
           Hiring Oxen

Figure 10:   The Maize Production Labour Profile for the Tractor Hiring Groups

THE PRODUCTION FUNCTION RESULTS

The basic regression model in linear form included 6 independent variables and 13 dummy or 0-1 variables:

$$MYLD_i = a_o + b_1 MZA + b_2 LABPL + b_3 LABW \ b_4 DAFR + b_5 FTQA \\ b_6 PRFAL + d_1 HND + d_2 OXN + d_3 OXHTR + d_4 DMW + d_5 BUN \\ + d_6 BUS + d_7 KAK + d_8 EDM + d_9 YEAR + d_{10} IADP + \\ d_{11} CHEM + d_{12} MANU + d_{13} NONE + e_i.$$

Where $MYLD_i$

	= Kg. of maize per acre (yield).
MZA	= Maize acreage
LABPL	= Effective land preparation and planting labour per acre
LABW	= Effecting weeding labour per acre
DAFR	= Days after onset of rain to complete planting
FTQA	= Kg. of Fertilizer applied per acre
PRFAL	= Proportion of fallow land
HND	= Hoe group dummy
OXN	= Owned oxen dummy
OXTR	= Ox or tractor hired dummy
DMW	= More weeding dummy
BUN	= Bungoma sample
BUS	= Busia sample
KAK	= Kakamega sample
EDM	= Education dummy
YEAR	= Year dummy
IADP	= IADP dummy
CHEM	= Chemical fertilizer dummy
MANU	= Animal manure dummy
NONE	= No fertilizer dummy

a_o = the constant term, whose interpretation varies according to the dummy variable considered,

b_j = the slope coefficient of respective variable (j)

d_j = the magnitude of the shift of the slope by a respective dummy variable (j) relative to the constant term (a_o)

The corresponding Cobb-Douglas form of the equation becomes linear in the logarithm but with the slope coefficients (b_j) interpreted as elasticities of the maize yield with respect to the independent variable. The regression results for analyses when all the observations were considered simultaneously are presented in Table 1. The results in the table include the quantity of chemical fertilizer used per acre. The regressions where this variable was excluded, and replaced

with 3 dummy variables to indicate either fertilizer usage or non-usage, were essentially similar, except that the coefficient for the animal manure dummy variable (MANU) was not significantly different from zero.

The linear model explained 49 percent of the variation in yield while the log linear model explained 50 percent of the yield variation in the sample farms. These measures are determined from the R^2. The corresponding measures for the adjusted R^2 were 45% and 47% respectively. The F statistic of about 13 also shows statistical significance of the overall models at the 1% level. The values for the adjusted R^2 were not very different from the unadjusted ones. Each additional variable claims a degree of freedom. Adding a variable which doesn't contribute much towards explaining the variation in the dependent variable reduces the adjusted R^2.

Because only 50% of the variation in yield could be explained by the model, there were other unknown variables which were not accounted for in the model. This necessitates caution in interpretation of the results.

Some of the likely reasons for the unexplained variation in yield of maize included: (1) errors of measurement and (2) omission of some variables which could not be measured. The errors of measurement might be related to misreporting by the respondents, or to enumerator bias. Although the respondents were assured of the confidentiality of the information at the time of the interview, in some cases the assurance might have been doubted. Similarly, although the enumerators were carefully supervised, they might still have introduced bias into the records. The variables such as management skill and microclimate for individual farms are essential in explaining yield, but their measurement is problematic. The proxy for management in the study was the education dummy variable, and that for microclimate was the regional dummy. These proxy variables are not likely to reflect the true variability of the real variables on maize yield.

The interpretation of the regression coefficients must also consider the structure of the regression model in relation to the variables included. Maize acreage (MZA) was used both to normalize the other variables to a per-acre basis and as a separate variable in its own right. As is shown in equation (viii) of Chapter 3, the coefficient for (MZA), b_1^* is a composite of the other independent variables normalized by the maize acreage less 1, and gives a measure of returns to scale. Thus if the coefficient is positive, then in the Cobb-Douglas form, this may be an indication of increasing returns to scale.

The coefficients for the effective land preparation and planting labour per acre (LABPL) and weeding labour per acre

TABLE 1

Maize Production Function Regression Results for All the
Sample Farms, Western Province, Kenya, 1977 and 1981

MYLD	MODEL	
	LINEAR	LOG LINEAR
Variable (j)	b_j	b_j
Constant	577.	6.97
	(3.5)	(10.65)
MZA	95.	.64
	(7.1)	(5.35)
DAFR	-11.	-.21
	(1.0)	(1.18)
LABPL	-.39	-.19
	(.99)	(3.42)
LABW	-89.	-.16
	(1.75)	(2.65)
FTQA	1.80	.058
	(2.81)	(1.70)
PRFAL	1.45	.041
	(1.08)	(.62)
HND	-123.	-.16
	(1.42)	(1.17)
OXN	135.	.21
	(1.96)	(1.90)
DMW	15.	.11
	(.19)	(.81)
BUN	-135.	-.22
	(1.67)	(1.62)
BUS	-247.	-.41
	(2.58)	(2.57)
EDM	-109.	-.27
	(1.41)	(2.12)
IADP	32.	-.069
	(.39)	(.46)
YEAR	- 71.	-.11
	(.92)	(.93)
R^2	.49	.50
$\bar{R}^2$	.45	.47
F	13.0	13.8
Number observations	202	202
$F_{14,187}$**	2.17	2.17

*   Figures in bracket are the t ratios.
** Table value of the F distribution at 1%
    significance level.

(LABW) consist of the unknown parameters of the weighting scheme of q_1 and q_2 respectively, as shown in Chapter 3. Thus, the coefficient for

$$LABPL = b_2 q_1$$
$$LABW = b_3 q_2$$

The composite coefficient of (MZA) should also embody these unknown parameters, such that the effect on yield of a given percentage change of the farm inputs should depend on time of application. The coefficients for days to complete planting after rain (DAFR) and the impact of fallow land on nutrient availability (PRFAL) are interpreted as the respective marginal contributions to maize yield from a unit change of the variable in the linear model. In the log-linear model, these coefficients represent the proportional changes in yield that result from a given percentage change in the variable. The variables which are included as dummy variables in the regression analysis are interpreted as the slope shifters relative to the underlying constant term.

The maize acreage regression coefficient in both models was positive and significantly different from zero at the 1% level. In the linear model, an additional one acre of maize could raise yield by about 1 bag of maize. In the Cobb-Douglas model, the positive sign of the acreage coefficient indicated increasing returns to scale, since a one percent increase in all the inputs simultaneously would lead to a 1.6 percent increase in yield. This is obtained from the result:

$$b_* - 1 = .64, \text{ the coefficient on maize acreage hence,}$$
$$b_* = 1.64.$$

This could also mean that small farms have more limited sets of resources with which to work the available land. The increasing returns to scale result for the farmers studied here differs from the decreasing returns to scale parameter reported by Gunning (1979), who made use of Kenya's unpublished Integrated Rural Survey (IRS) of 1974/75. Moock (1976) reported a constant returns to scale for the smallholders he studied in Vihiga Division of Kenya. For smallholders in Ikolomani and Lurambi Divisions in Kakamega District, Rukandema (1978) found increasing returns to scale. The main reason for the diverse results appears to be the nature of the sample and the variables considered. Gunning (1979) was using highly aggregated (IRS) data and had output as the dependent variable to be explained by farm size. In the IRS data set, it is common for respondents to lay claim to a piece of land and yet derive their income from an urban employment. This is an institutional phenomenon. In that case, output coming from such a farm will either be very low

or nil. Therefore, the farm size parameter (which means returns to land) for such aggregated data will tend to be low. This study had yield as the dependent variable and the actual maize acreage allocated to maize as one of the independent variables. The proportion of fallow was also included as an independent variable. It would appear that the farmers in this study on the average increased maize yields when they had the resources to expand the maize acreage. There was no acute land shortage.

One reason for increased maize yield with expansion could be due to the opening up of fallow land, and therefore more fertile soil. Because maize acreage expansion is possible only with larger farm holdings (hence the positive correlation), one reason for increasing yields with the scale of the operation could be associated with the possibility of using crop rotation and therefore moving maize from field to field. However, the regression coefficient on the proportion of fallow (PRFAL) was not statistically significant, while having a positive sign. This may be because the (PRFAL) did not have sufficient variation to show the underlying true effect of the available land on yield. Since maize yield and size of holding were positively correlated, the indirect association regarding crop rotation can be inferred. The influence of earlier use of fertilizer may also be contributory to yield increases with increased scale of operation, because of the possible residual effects from fertilizer. Other reasons could include the fact that relatively large farmers may have inherently more productive soils on their farms. Moreover, the skill and managerial capacity of the relatively larger farms could be greater than that for smaller farms.

Studies which are centered in areas of very small farms and landlord-tenant systems of farming tend to indicate constant or decreasing returns to scale (Moock, 1976; Yotopoulos and Nugent, 1976; Berry and Cline, 1979). With a very small farm, the farmer is careful to use all his resources very intensively. All the resources will be highly divisible and there may be no scale economies. In a landlord-tenant system of farming, the land area cropped tends to be large, but often with poor management. Therefore, one would expect to get decreasing returns to scale in such a system.

The coefficient for weighted labour for land preparation and planting per acre (LABPL) was negative and significant at 1% level only in the Cobb-Douglas model. The results indicate that a ten percent increase in the quantity of labour used for land preparation reduced yield by about 2 percent. Although this magnitude is small, it can be inferred that intensive use of labour when the operation was late anyway was not useful. With the linear model, the regression coefficient for this variable was not significant.

Similarly, with the weighted weeding labour coefficient (LABW) the log-linear regression coefficient was negative and statistically significant at the 1% level. A 10 percent increase in the weeding labour per acre resulted in about 2% decline in yield. In the linear model, this coefficient was only statistically significant at the 10% level. This implies that if the amount of weeds present require more labour for weeding, the crop would likely to be damaged somewhat even if weeding occurs.

The fertilizer quantity per acre (FTQA) showed a positive and statistically significant relationship with yield at 1% level in the linear model. However, the magnitude of the coefficient was very small, one additional kilogram of fertilizer used per acre increasing yield by only about 2 kg. In fact, in the log-linear model the coefficient was statistically significant only at the 10% level. The fertilizer contribution to yield was not as high as expected. If it is considered that the value of 2 kg. of maize was about Kshs. 2, and the retail price of 50kg. bag of compound fertilizer (18x46x0) at Kakamega was about Kshs. 206 in the 1980/81 growing season, then it is evident that using the average application of fertilizer did not pay for its cost[18]. The value of the marginal product of fertilizer at Kshs. 2 is half the average price of 1kg. of fertilizer of about Kshs. 4. Acland (1971) expresses doubt about the usefulness of recommending fertilizer to farmers as a matter of priority in a very apt statement:

"A farmer who does not sow at the optimum time, who does not achieve an adequate plant population and who controls his weeds inefficiently is wasting money by applying fertilizer." p. 130.

The days after the onset of rain that planting was completed (DAFR) was expected to capture the effects of timeliness on maize yield per se. However, the regression coefficients in both models were negative, while not statistically significant. This might have been due to the fact that most of the farmers planted late.

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[18] The price of the various compound fertilizers varied. However, those with higher nitrogen or phosphorus content, such as 11-52-0 fertilizer, had higher prices than the 18x46x0 fertilizer. In general, all prices for the compound fertilizer farmers used in the region were above Kshs. 100 per 50 kg. bag.

The Implication of the Dummy Variables in Estimation and Interpretation

The variables which were included as dummy variables in the regression analyses are interpreted as the slope shifters relative to the constant term (a_0). As an example, the method of land preparation had 3 dummy variables: HND = 1 if hoe was used and 0 otherwise; OXN = 1 if oxen was used, 0 otherwise; OXHTR if oxen or tractor was hired, 0 otherwise.

To be able to do a least-squares regression analysis, one of the dummy variables must be excluded. Including all the dummy variables would result in perfect collinearity in the model. If, for instance OXHTR were excluded, the regression constant term would embody the expected yield associated with hiring oxen or tractor for land preparation. The other two dummy variables would be considered additive to the constant term. The coefficient for OXN, if statistically significant, represents the difference in yield associated with a change from OXHTR to OXN, ceteris paribus. If, the coefficient is not statistically significant, this suggests that there was no measurable difference statistically between the two groups. Similarly, the coefficient of HND represents the difference in expected yield between using OXHTR and HND.

The same procedure in estimation and interpretation was applied to the other dummy variables. Because changes in slope could occur between groups, apart from merely shifts in slopes, it was desirable to perform an analysis of covariance. This was meant to test whether the yield response to the independent variables differed between groups.

Referring to the results in Table 6.1, the constant term and the OXN dummy variable are both positive and significantly different at the 5% level. Those who hire oxen or tractor, assuming the other factors are constant, achieved an expected yield of about 577 kg., or 6 bags of maize per acre[19]. Those using own oxen achieved about 1.5 bags higher than those hiring oxen. The coefficient for hoe usage was negative but not statistically significant from zero at the 5% level. At the 20% level of significance the hoe users were obtaining about 1.5 bags of maize less than those hiring oxen or tractor[20]. The regional difference in yield was demonstrated by the significant coefficient for Busia at the 5% level. In the linear model, the Busia samples had yields of about 2.5

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[19] 1 bag of maize is equivalent to 90kg.

[20] Further analysis of the 3 groups separately indicated that the yield response to increased acreage of maize was higher in the farms depending on hiring service than in the other groups (see section 6.3.3).

bags below those of Kakamega. The Bungoma coefficient is
statistically significant only at the 10% level, and shows
that the group had yields averaging 1.5 bags below the
Kakamega group, ceteris paribus.

Some of the other dummy variables were not statistically
significant. These variables included the weeding dummy
(DMW), IADP participation (IADP), and year of survey (YEAR).
Whether one weeded once or twice could not be shown to have a
definite and measurable effect on yield among the sample farms
in this study. This result contrasts with the recommendations
given by the extension agents to small farmers. At the
research station, keeping the maize field clean by frequent
removal of weeds has been shown to significantly improve
yields -- but this seems to be the case if the weed removal is
started early to begin with. As the maize plant gets older,
disturbing the established roots of the plant by frequent
weeding may be harmful to the crop. This is apparently
because water and nutrient uptake by the roots is temporarily
impaired at crucial times, such as during flowering or ear
formation.

Yields for IADP participants were not significantlly
different from those for non-IADP participants. This result
at least partly explains the reason for the lack of enthusiasm
expressed by the participants for that on-going project. They
claimed that since they started participating in the project,
they had not witnessed the sustained benefit they anticipated
in 1977. This might also explain the significant number of
voluntary dropouts from participating in the project since its
inception.

There was no statistically significant difference between
the yields obtained in 1977 and those obtained in 1981. This
is a startling result. One would expect that with time, there
would be significant improvements in yield when new
technologies are developed and adopted. However, this just
reinforces the idea that technology as applied at the
experiment station with controls is different from the actual
farm situation and the application of such technology. If the
farmers are unable to apply the known technology, due either
to lack of effective or timely distribution of the relevant
input, to prohibitive costs, or to lack of appropriate
technology for local conditions, then we should not be
surprised to see lack of improvement in yield over the years.

The impact of formal education did not have a statistically
significant coefficient in the linear model, but there was a
significant coefficient with negative sign at the 5% level in
the linear-in-logs model. This implies that formal education
did not by itself help to bring about improvements in yield on
the small farms. Those who had some formal education may have
obtained education which was unrelated to agricultural

production. Moreover, formal education has often been associated with non-agricultural activities, e.g. Hopcraft (1974). This may mean that those with formal education sought off-farm jobs, and in the process neglected maize production, or alternatively, those who could least effectively compete for off-farm jobs were those who remained on these farms.

If the attitude toward agricultural work should change, one would expect that formal education should at least help the farmers to read extension pamphlets and apply the recommendations, in the event that their earlier education did not emphasize agronomic practices.

The Covariance Analysis Results

Dummy variables for methods of land cultivation shift the slopes of the other coefficients (b_j) without changing their values. It is conceivable, however, that there may both be a shift and a change in the slopes. One way to test if there are significant differences in the behaviorial relationships between sets of observation is to perform covariance analyses. The restricted error sum of squares (ESS_R) and the unrestricted error sum of squares (ESS_{UR}) are obtained, and the F-test determines if the relationships are similar. Of course the OXN and the HND variables must be omitted when doing the regression runs. Using the log-linear model, the F statistics were calculated as shown in Table 2.
The analysis shows that at the 5% level of significance, the three groups are statistically different from each other in the way the included independent variables explain variations in maize yield. These groups are those (1) using the hoe, (2) those owning oxen and (3) those hiring oxen for land preparation. Those hiring a tractor for land preparation showed no statistically signficant difference in yield obtained from either the hoe group, the oxen owners or those hiring oxen. They were then grouped with those hiring oxen for further analysis to show the effects of these variables on maize yields when the three groups were considered separately. This combined group could be designated as those depending on hiring service for land preparation.

The Regression Results for the Hoe Group

The key feature of the separate regression for the hoe group was that maize acreage and the education dummy were positive and significant in both models. The results are presented in Table 3. The explanatory power of the linear model was lower than when all observations were pooled. This may be the consequence of lack of variation within the hoe group with respect to some of the included variables, hence the non-significant coefficients. However, the MZA

TABLE 2

Covariance Analysis Results for the Various Categories of Farms

Group		ESS_1*	(N)	ESS_2	(M)	ESS_{UR}	(N+M)	ESS_R	(K)	F**
Hoe and Oxen Owned	(1) (2)	7.44	(44)	22.57	(76)	30.01	(120)	38.22	(12)	2.19
Hoe and Oxen Hired	(1) (2)	7.44	(44)	31.42	(75)	38.86	(119)	49.95	(12)	2.15
Hoe and Tractor Hired***	(1) (2)	7.44	(44)		(7)		(51)	8.06	(12)	.47
Oxen Owned and Oxen Hired	(1) (2)	22.57	(76)	31.42	(75)	53.99	(151)	63.26	(12)	1.83
Oxen Owned and Tractor Hired	(1) (2)	22.57	(76)		(7)		(83)	23.36	(12)	.34
Oxen Hired and Tractor Hired	(1) (2)	31.42	(75)		(7)		(82)	31.84	(12)	.43

* Subscript refers to the group.

** $F = \dfrac{(ESS_R - ESS_{UR})/K}{ESS_{UR}/N+M-2K}$.

*** In the case where hired tractor is involved, F is given by $F = \dfrac{ESS_R - ESS_1/M}{ESS_1/N+M-K}$.

coefficient was similar for this group to that in the pooled sample. An increase of 1 acre of maize results in an increase in yield of about 1 bag of maize. Those who had some formal education achieved about 2 bags per acre more than those without any formal education. This result contrasted with the pooled sample, where the coefficient was negative. The reason why this was the only group where the education dummy variable was positive was not very clear. It may well be that those who had attained some formal education and had to use the hoe were keen to apply other good husbandry practices, which they read from extension leaflets.

In the log-linear models, the LABPL coefficient was negative and significant at 5% level. A 10 percent increase in the labour used for land preparation and planting decreased yield by about 2 percent at the geometric mean. This shows that for those depending on the hoe, using more labour than the average for land preparation and planting may not help in raising yields if the time they perform the operation is considered in most cases. Similarly the weighted weeding labour (LABW) which had a statistically insignificant coefficient shows that intensified use of labour by itself was not effective in increasing yield if the operation was late. There were no significant regional differences within the group using the hoe for land preparation.

The Regression Results for the Oxen Owners Group

The regression results for those using owned oxen are presented in Table 4. The linear and the log-linear models explain 47 and 46 percent respectively of the variations in yield (indicated by the adjusted R^2) and are also significant.

An increase of 1 acre of maize results in an increase in yield of just about 1 bag of maize. The other statistically significant coefficients which are important are those for days after rain of completing planting (DAFR), LABPL, and the Busia dummy variable. Oxen owners had the choice of immediately using the oxen upon the onset of rain on their own plots, or to plough for other farmers and then prepare their own land later. In effect, there was considerable variation of the time planting was completed on their own farm. Any day that planting was delayed after rain decreased yield by about 69 kg. (or .8 of a bag) among oxen owners. Loss of yield through late planting is likely to be reduced if the number of oxen ploughs per 100 acres in the region is increased. Thus, should ownership of oxen ploughs be promoted, the density of oxen owners in any region will be higher, resulting in more timely planting after the onset of the rains. The loss of yield of the magnitude reported here is greater than the .4 of a bag of maize loss per day reported by Allan (1971) in his

TABLE 3

The Regression Results for the Hoe Group

MYLD		MODEL	
	LINEAR		LOG LINEAR
VARIABLE (j)	b_j		b_j
Constant	214.		7.1
	(1.0)		(4.32)
MZA	93.		.64
	(2.64)		(1.98)
DAFR	-.098		-.36
	(.01)		(.70)
LABPL	-.15		-.18
	(.63)		(1.96)
LABW	.22		-.065
	(.32)		(.55)
FTQA	-.21		-.035
	(.31)		(.53)
PRFAL	-2.45		-.18
	(1.0)		(1.09)
DMW	78.3		.42
	(.76)		(1.54)
BUN	-246.		-.73
	(1.53)		(1.47)
BUS	- 80.		-.31
	(.72)		(1.02)
EDM	73.		.62
	(1.96)		(2.09)
IADP	146.4		.18
	(.95)		(.82)
YEAR	-299.		-.46
	(1.51)		(1.03)
R^2	.46		.62
$\bar{R}^2$	.25		.48
F	2.24		4.27
Number of observations	44		44
$F_{12,31}$	2.09		2.09

TABLE 4

The Regression Results for the Oxen Owners Group

MYLD	MODEL	
	LINEAR	LOG LINEAR
VARIABLE (j)	b_j	b_j
Constant	1346.	8.1
	(4.16)	(8.55)
MZA	70.	.41
	(3.67)	(2.28)
DAFR	- 69.	-.75
	(3.55)	(3.27)
LABPL	-4.1	-.30
	(1.77)	(3.09)
LABW	.036	-.01
	(.04)	(.07)
FTQA	3.8	.096
	(1.56)	(1.83)
PRFAL	3.4	.16
	(1.32)	(1.37)
DMW	80.	.12
	(.49)	(.54)
BUN	-219.	-.32
	(1.60)	(1.88)
BUS	-434.	-.59
	(1.95)	(1.90)
EDM	-126.	-.26
	(.67)	(1.0)
IADP	-215.	-.29
	(1.46)	(1.55)
YEAR	212.	-.022
	(.75)	(.12)
R^2	.55	.54
$\bar{R}^2$	.47	.46
F	6.53	6.34
Number of observations	76	76
$F_{12,63}$	1.91	1.91

maize agronomy study for Kenya. The reason for this difference may be that the population covered by this study is made up of farmers who generally achieved low yield levels compared to the controlled field experiments studied and reported by Allan.

The farmers from Busia who used owned oxen received almost half the yield of those from Kakamega. Observing maize fields in Kakamega and Busia, it is noted that the crop husbandry practices in Busia were poorer, based on the stand of maize. However, the yield difference between Kakamega and Busia identified by the regression result is remarkably larger than one would expect! There was no significant difference in yield between Kakamega and Bungoma.

Land preparation and planting labour had a negative and significant coefficient in the log-linear model. A 10 percent increase in labour applied would reduce yield by about 3 percent among the oxen owners at the geometric mean. The penalty in terms of yield loss from using labour late on oxen-owned farms was greater because timely management of the relatively large plot was so difficult thereafter as to reduce significantly the resulting yields.

The Regression Results for those Using Hiring Services.

The same models for the other groups were used for those depending on hiring oxen or tractor for ploughing. The linear model explained only 37 percent of the variation in yield, while the log-linear model explained 39% of the variation, as indicated by the adjusted R^2 (Table 5).

The maize acreage coefficient was again statistically significant. In the linear model, one additional acre of maize increased yield by about 1.5 bags of maize. This response differed from the hoe and-owned oxen group, which realized an increase of about 1 bag for every additional acre of maize. Those who decided to hire intensified their efforts on the readied land. The size of the operation was predetermined, based on the available resources, with the result that yields improved as size increased. This was supported by the MZA coefficient in the log-linear model. A 10 percent increase in all the variable inputs led to a 18 percent increase in the yield of maize measured at the mean. The negative but statistically significant coefficient for weighted weeding labour (LABW) implied again that intensifying labour use on late weeding reduced yield. No significant regional differences existed in the group depending on hiring services for ploughing.

TABLE 5

The Regression Results for Those Using Hiring Service (Oxen or
Tractor)

MYLD	MODEL	
	LINEAR	LOG LINEAR
VARIABLE (j)	b_j	b_j
Constant	200.	5.7
	(.77)	(4.8)
MZA	120.	.81
	(4.56)	(3.89)
DAFR	-23.	-.42
	(1.35)	(1.20)
LABPL	-.44	-.016
	(.23)	(.15)
LABW	-1.16	-.33
	(1.65)	(3.23)
FTQA	2.54	.13
	(3.12)	(2.12)
PRFAL	2.6	.065
	(1.30)	(.63)
DMW	- 81.	-.07
	(.63)	(.34)
BUN	-106.	-.23
	(.78)	(.95)
BUS	-228.	-.48
	(1.43)	(1.60)
EDM	-130.	-.41
	(1.19)	(2.11)
IADP	- 86.	-.33
	(.66)	(1.37)
YEAR	-106.	-.41
	(.72)	(1.26)
R^2	.46	.48
$\bar{R}^2$	.37	.39
F	4.9	5.3
Number of observations	82	82
$F_{12,69}$	1.89	1.89

The fact that the yield response to increased maize acreage was higher among the farms depending on hiring service may be an indication that the farmers in the group were merely able to command greater productive resources, even though applying them late, as indicated by the marginal contribution to weeding labour. For instance, the coefficient for chemical fertilizer per acre (FTQA) was positive and significant at the 1% level. In the linear model, one kg. of fertilizer increased yield by about 3 kg. In the log-linear model, a 10 percent increase in fertilizer use raised yield by about 1 percent. If the value of 3 kg. of maize is considered to be about Kshs. 3 and the price of a kg. of fertilizer to be about Kshs. 4, then these farmers on the average were not getting a marginal return for the use of fertilizer applied.

The Maize Enterprise Budget Results

The results of the maize enterprise budgets are presented in Table 6. Although the mean area operated by each category of farm varied from 1.6 acres for hoe users to 4.2 acres for the oxen owners, the family labour employed per acre was practically the same in all the categories except for the tractor-hiring farmers. They used less family labour but more hired labour per acre.

The total operating expenses were highest for tractor-hiring farms and least for hoe farms. The hoe farmers had only about one-third the cash operating cost of those using oxen ploughs, and about 10 percent of the operating cost of those hiring private tractors. Among the hoe farmers, most of their expenditure was in hiring labour. Oxen owners' greatest expenditure was for fertilizer, while the other groups spent more money in hiring oxen or tractor ploughing than on any other item.

The net cash income per acre was highest for oxen owners, who earned about Kshs. 580 per acre. The net cash income per acre was lowest for those using private tractor service. They netted about Kshs. 200 per acre. The farmers using government tractors obtained Kshs. 70 per acre more than those using private tractors. The hoe group and oxen hiring farmers had a net cash income per acre of Kshs. 332 and 376 respectively, and constituted the middle income positions in this category.

The return to labour, land and management per family manday was almost the same for the farmer using a government tractor and those using owned oxen. This value was Kshs. 13 and 12.4 respectively. The return for the hoe group was Kshs. 6.7 per manday, while for the group hiring oxen and private tractor it was Kshs. 7.5 and 9.8 respectively. If the opportunity cost

TABLE 6

The Maize Enterprise Budgets in 1981

ITEM	HND	OXN	OXH	TRCT
1. Number of farms(No)	32	51	31	7
2. Adults on farm(No)	4	5	5	3
3. Area of maize(acres)	1.6	4.2	2.7	3.1
4. Proportion of fallow (%)	46	39	40	46
OUTPUT:				
5. Maize yield (bags)	4.5	7.5	6.0	6.0
6. Gross output(bags) (3x5)	7.2	31.5	16.2	18.6
7. Value of output (Kshs.)	684	2993.	1539.	1767.
COST:				
8. Family labour per acre (md)	47	45	48	20
9. Total hired labour cost (Kshs.)	105	135	115	260
10. Used fertilizer cost (Kshs.)	20	256	124	121
11. Seed cost (Kshs.)	28	86.0	69	130
12. Hiring cost (Kshs.)	--	--	216	620*
13. Maintenance cost (Kshs.)	--	73	--	--
14. Total variable cost (Kshs.) (9 through 13)	153	550	524	1131

TABLE 6

Cont.d

ITEM	HND	OXN	OXH	TRCT
Fixed Costs:**				
15. Hoes (Kshs.)	32	40	40	24
16. Plough (Kshs.)	--	60	--	--
17. Total fixed cost (Kshs.) (15+16)	32	100	40	24
18. Total cost (14+17)	185	650	564	1155
RETURNS:				
19. Net cash income (7-14)	531	2443	1015	636
20. Net cash income/ acre (19/3)	332	582	376	205
21. Return to labour, land and management (19-17)	500	2343	975	612
22. Return per acre (21/3)	313	558	361	197
23. Return per family, man-day per acre (22/8)	6.7	12.4	7.5	9.8***

* This figure is Kshs. 415 for Government tractor hiring farms

** Ownership of hoes is common in all groups. The oxen depend on natural grazing and no additional feed cost is incurred. The initial cost of oxen plough was taken to be Kshs. 600 which is higher than if it was bought 5 years earlier.

*** The figure is 13 for the farmer using government tractor.

of labour is considered to be the labour hiring charge of
Kshs. 5 per manday, then the return per manday to contribute a
return to land and management alone could be considered as
Kshs. 1.7 for the hoe group and about Kshs. 7 for the oxen
owners. The hiring of a private tractor resulted in Kshs. 5
per manday as a net return to land and management. These
results indicate that oxen ownership should yield a higher
level of return for the farmers than any other method of land
preparation if the government tractor charge is similar to
that of the private tractors, and if timeliness of the various
methods follows the pattern shown in this study.

The Partial Budgeting Results

The net change from using the hoe for land preparation to
hiring oxen for the same operations is given in Table 7. The
extra gains are due primarily to the increment in the acreage
that is cultivated. The extra costs were calculated from
those incurred by the group hiring oxen, as shown in Table
6.6. It was more profitable to cultivate using the
oxen-hiring services than to rely on the hoe, because the
labour available was not able to prepare the seedbed for an
equivalent increased acreage. The profit realized from the
use of this added land and resources was Kshs. 149 for 1.1
additional acres.

The results showing the effect of changing from using the
hoe to owning oxen for ploughing are shown in Table 8.
An extra 2.6 acres could be readied for own maize production.
In addition, the four purchased oxen could do additional
contract work on 10 acres per annum off one's own farm, which
will generate a substantial increase in income for the owners.
This is equivalent to ploughing for at least 3 neighbours.
From Table 6.6 it was observed that the proportion of fallow
did not vary between the groups, and was between 39% and 46%.
Oxen must depend on natural pasture, and therefore the
question of the opportunity cost for the grazing land arises.
The fallow area plays a part in crop rotation, and hence soil
conservation. Farmers know that some part of their land must
have grass cover. Therefore, making use of the grass for
grazing oxen is acceptable to farmers[21]. It was therefore
assumed that the opportunity cost of grazing land already
available was zero for purposes of the calculation.

The annual cost of providing oxen and associated equipment
was considered. This may well be an overestimate of the
actual cost, because some farmers already own livestock, but

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[21] The land could be used for grazing milk cows, but to date,
cows are not used for draught purposes in the area.

TABLE 7

Change From Hoe Use to Hiring Oxen on An Additional 1.1 Acres
of Maize (Annual Basis)

LOSSES	Kshs.	GAINS	Kshs.
Revenue lost due to change	Nil	Extra revenue due to change	
		1. Value of maize produced on the additional 1.1 acres (6x1.1x95)	627
Extra cost		Cost saved	Nil
1. Hiring cost to plough 1.1 acres of additional maize (80x1.1)	88		
2. Additional hired labour (115/2.7x1.1)+ (48x1.1x5)	311		
3. Additional fertilizer (124/2.7)x1.1	51		
4. Seed cost (69/2.7)x1.1	28		
Total financial losses	478	Total financial gains	627

Financial profit = Kshs. 627 - 478 = Kshs. 149.

Other considerations:
1. Human drudgery in hoeing reduced.
2. Risk may be involved if oxen to hire
    not available in time.
3. If the farmer not able to hire labour, family
    labour to work extra hours.
4. Proportion of fallow land reduced.
5. A stable market is assumed after regional
    increase of farm maize output.

TABLE 8

Change from Hoe to Use of Own Oxen on An Additional 2.6 Acres
of Maize (Annual Basis)

LOSSES	Kshs.	GAINS	Kshs.
Revenue lost due to the change		Extra revenue due to the change	
1. Interest at 12% p.a. on Kshs. 600 used for purchasing own equipment	72	1. Value of maize produced on 2.6 extra acres (2.6x7.5x95)	1853
2. Interest at 12% p.a. on Kshs. 2400 used to purchase own 4 oxen	288	2. Contract work on 10 acres	800
Extra costs due to the change		Costs saved due to the change	Nil
1. Plough depreciation	60		
2. Maintenance cost	73		
3. Harness equipment	20		
4. Hiring labour (135/4.2)x2.6+ (45x2.6x5)	671		
5. Fertilizer 256/4.2 x 2.8	158		
6. Seed cost 86/4.2 x 2.6	53		
Total financial losses	1395	Total financial gains	2653

Financial profit = Kshs. 2653 - 1395 = Kshs. 1258

Other considerations:
1. Reduced human drudgery in hoeing.
2. Improved timeliness of land preparation.
3. Proportion of fallow land may be considerably reduced.
4. Farm transport eased by animal traction, while
   appreciation of oxen not considered in gain.
5. There may be need to assist the farmer with a loan of
   Kshs. 3000 to invest on oxen and the equipment.
6. A stable market is assumed.

merely lack the equipment for ploughing. Apart from getting
rid of ticks on oxen in cattle dips, the veterinary costs are
minimal. Because the animals come mainly from traditional
Zebu cattle, losses from disease should be very low. The
interest rate of 12% p.a. which the commercial banks pay for
fixed deposits was used as the opportunity cost of investing
in oxen for ploughing. The net cash profit per farm from this
kind of investment was Kshs. 1257. This is appealing. The
result is not inconsistent with that of Mutebwa (1979) in a
study of Eastern Province of Kenya.

The change from oxen-hire to owned oxen can be expected to
be more profitable. The financial gains come from contract
work and the additional acreage planted on one's own farm.
The results are presented in Table 9. In addition, there is
an important reduction in risk, because one's own ploughing
can be done immediately after the rains come.

Between hired oxen and hired private tractor, the financial
benefit is greater in this budget analysis when the tractor is
hired. This is mainly due to the acreage increasing effect of
the tractor. The results are given in Table 10 The financial
gain is more than the financial loss by Kshs. 73. Because the
cost of hiring a government tractor was lower than for a
private one, the financial profit was Kshs. 99 per farm using
a government tractor.

These partial budgets should serve as indications of the
likely result of using alternative methods of cultivation,
holding all other factors constant and assuming additional
land for cultivation is available. This analysis shows that
oxen ownership is the most beneficial method of land
preparation. This is due to the possibility of both
increasing one's own maize acreage and renting the ploughing
service to neighbours. Use of either private hire service or
government tractor service yielded a higher marginal return
than hiring oxen. This was mainly because of the expected
area increase due to the tractor service. If one considers
that ensuring the availability of a tractor on time is more
problematic, then the profitable thing for a farmer with no
oxen to do is to hire oxen. Recall that hiring oxen to plough
was more profitable than depending on the hoe to prepare the
land. In fact, if the number of those owning oxen increased,
then the cost of hiring oxen might also be lower (and less
profitable to oxen owners). With more oxen and equipment in
an area, more farmers will be able to prepare their land for
planting soon after the rains begin. The increase in the
density of oxen owners in this region could be accomplished
more efficiently by making available credit or government
backed loans to enable farmers who already have oxen to
purchase ploughing equipment. If the cost of sustaining the
government tractor hiring service is reduced or avoided, these
funds can be used to help farmers obtain oxen and ploughs to

TABLE 9

Change from Oxen Hired to Owned Oxen on An Additional 1.5
Acres of Maize (Annual Basis)

LOSSES	Kshs.	GAINS	Kshs.
Revenue lost due to the change		Extra Revenue due to the change	
1. Interest at12% p.a on Kshs. 600 used for purchase of plough unit.	72	1. Value of maize produced on the additional 1.5 acres (7.5x 1.5x95)	1069
2. Interest at 12% p.a on Kshs. 2400 to purchase four own oxen	288	2. Contract work on additional 10 acres	800
Extra cost due to the change		Cost saved due to the change	
1. Hiring labour (135/4.2 x 1.5)+ (45 x 1.5 x 5)	386	1. Cost of hiring for ploughing 1.5 acres = (1.5 x 80)	120
2. Fertilizer (256/4.2)x1.5	91		
3. Seed cost	31		
4. Maintenance cost	73		
5. Plough depreciation (600/10)	60		
Total financial losses	1001	Total financial gains	1989

Financial profit = Kshs. 1989 - 1001 = Kshs. 988 per farm.

Other considerations:
1. Improved timeliness in ploughing own farm possible
2. The animal can be used for transporting farm products.
3. The proportion of fallow reduced.
4. The farmer may need a loan of Kshs. 3000 to purchase equipment plus the oxen. In that case these costs would be under the "extra cost due to the change."
5. Land not considered to be a constraint.
6. Appreciation of oxen not considered in gain.

TABLE 10

Change from Hired Oxen to Hired Private Tractor on An
Additional .4 Acres of Maize (Annual Basis)

LOSSES	Kshs.	GAINS	Kshs.
Revenue lost due to change	Nil	Extra revenue due to change	
		Value of maize produced on the extra .4 acres (.4x6x95)	228
Extra cost		Costs saved	
1. Hiring labour (260/3.1)x.4+20x.4x5	74	Hiring oxen for extra .4 acre (.4x80)	32
2. Hiring tractor .4 x 200	80		
3. Fertilizer 121/3.1 x .4	16		
4. Seed cost 130/3.1 x .4	17		
Total financial losses	187	Total financial gain	260

Financial profit = Kshs. 260 - 187 = Kshs. 73 per farm.

Other considerations:
1. The use of tractor could be faster if available.
2. Reduced drudgery for ploughing.
3. Use of government tractor is even more profitable
   since it gives financial profit of Kshs. 99 per farm,
   ceteris paribus.

ready their land for planting on time. Organization of the tractor hiring service could then be left in the hands of private concerns, if it proves profitable for them.

EVALUATION OF THE RESULTS.

The results of the study indicate that ownership of oxen and ploughing equipment is associated with higher aggregate labour and land utilization for the maize crop, along with greater yields of maize, and therefore is an economically viable alternative in this region. These results were based on the grouping of farms according to the power source in land preparation. The power source limited the area which could be readied for planting and other maize operations.

The covariance analysis attempted to remove the confounding factors which could be associated with one particular group, such as use of fertilizer. The result was that the groups achieved statistically different yields from each other (Table 2). Since the dummy variable for oxen ownership showed a statistically significant coefficient, the oxen owners actually achieved more maize per acre than other groups.

The viability of adopting oxen ploughing on farms which now rely on the hoe for land preparation in the region was evaluated based on partial budgeting using the aggregate technical coefficients, ceteris paribus. This technique was used largely because the concern is on food crop production, which has been given emphasis by the government. The maize price increase between 1980 to 1983 from Kshs. 90 to 158 demonstrates this. A complete budget would incorporate all the enterprises on the farm, but since maize production has the priority for the available small-farm resources, confining the analysis to partial budgeting was justified. The proportion of fallow was incorporated in the production function analysis to take into account the role of the other crops in the farm, together with the implications of further increase of maize acreage on yield.

Because of the wide ranges of variations within the group considered in aspects such as land size, it would be useful to undertake case studies within each of the groups and validate the aggregate results. This could take the form of a detailed input-output analysis for the model farms from each category of farms.

The results from this study were based on a static framework. It is recognized that mechanization is a dynamic input. It is influenced by input-output prices, the rate of rural population growth, and other technological changes. Some of these changes could be influenced by the government. For instance, it is assumed in this study that the increased output will find a ready market if it is not consumed on the farm. Therefore, a stable market for maize is crucial to the validity of these results.

CONCLUSIONS AND SOME INFERENCES FOR POLICY

THE CONCLUSIONS

The conclusions derived from this study are:

1. Owning oxen for land preparation provides a way to increase maize acreage on farms where considerable land is still lying fallow. The increase in maize acreage is also associated with a higher net farm income per acre.

2. The labour used on farms owning oxen for ploughing and therefore capable of increased crop acreage is allowed to do more productive work on a timely basis rather than being displaced.

3. Using own oxen for ploughing is associated with higher yields when compared with the other methods considered. At the same time labour productivity on hoe farms is found to be the lowest of all the groups.

4. For farmers with relatively small holdings (less than 10 acres), dependence on ox-hiring is more profitable than relying on the hoe, if oxen-hiring were readily available. The size of these farms could accomodate area expansion for maize, but not grazing their own oxen as well.

5. Because of the limited number of tractors available for hiring, their use by small farmers is very restricted. In the case of the government tractors, the logistics for obtaining this service by a small farmer are very complicated, and use is therefore confined to a few influential individuals.

6. Application of fertilizer in fields which were generally planted and weeded late is found not to be profitable.

These conclusions provide the basis on which the policy implications from this study are drawn. However, a note of

caution is necessary when drawing general policy inferences
from such a study. First, the study area was located in a
region where land shortage was not acute by 1981. Secondly,
the sample size was rather small, especially for the group
using hired tractors. The proportion of the farmers using the
hoe to prepare land in the sample was only about 22%. This
can be compared with the national proportion of land prepared
by hand of 85 percent. This clearly shows that the small
farmers in the study region may not be representative of all
small farmers in Kenya. Therefore, the results found may not
be appropriate to generalize for all small farmers in the
country. This reinforces the call from other researchers that
studies to determine the profitability of various levels of
mechanization be location-specific, and that they carefully
consider the other resources which are being combined in
production.

POLICY IMPLICATIONS

Within the study region, policy formulation useful to
extension agents may be explored based on the inferences and
information obtained in this study.

The promotion of ox-cultivation in the study area has
promise for increasing maize output per farm, due mainly to
increased maize acreage and risk reduction because of improved
timing during planting. This calls for an effort to assist
farmers who are willing to invest in oxen and associated
equipment but are handicapped initially because of limited
cash. Such assistance can be very modest if farmers already
own oxen/bulls but lack the cash to purchase the plough.
There were cases where farmers hired oxen annually for
ploughing and yet, if the hiring cost for three consecutive
years were considered, that would be enough to purchase and
pay for a plough unit. If most farmers in a region depend on
hiring the relatively few available oxen and ploughs in the
region, the result will be a continuing general tendency to
plant late. Therefore, increasing the available ploughing
equipment in a region will help farmers to ready their fields
sooner after the rains begin.

The Necessity for Credit

Assistance for small farmers will necessarily be in the
form of credit. IADP has a credit component. It has had
problems in terms of coordinating services, identifying
profitable innovations, and ensuring credit repayments. Part
of the difficulties associated with loan repayment from
farmers is connected with the low returns forthcoming from the

financed investments. This study, for instance, has shown that using fertilizer on maize which is planted and weeded late is not profitable unless the crop is planted earlier with a different set of cultural practices. It is not uncommon for farmers to get credit to buy fertilizer and then get no yield increase. They consequently blame the fertilizer instead of recognizing that their other cropping practices must be changed to take advantage of the fertilizer.

The priority for assistance should shift in favour of ensuring timeliness of crop operations. The most effective change would be to assist those who already own oxen/bulls to purchase ploughing equipment if they are willing and interested.

It has been demonstrated that this is a profitable investment. Repayment problems will therefore be reduced, because a number of the farmers are already paying to hire oxen ploughing service annually.

Extension officers can play a role by eliciting the views of small farmers who are actually in need of and are willing to invest in the oxen and associated equipment. Farmers' participation from the beginning is crucial. The program should not allow participation by the relatively wealthy farmers, who are able to finance equipment purchases without special assistance. Emphasis should be placed on the need and the willingness of farmers to invest in the plough/oxen. It may also be necessary to have the equipment widely distributed, because renting out of oxen for ploughing is confined mainly to neighbouring farms. To ensure that credit is not diverted to other uses, it should be given in kind (i.e. the equipment itself).

The loan should be categorized according to whether only the equipment is financed or whether both the equipment and the oxen are needed. Collateral provided should be the equipment itself, plus the farmers' commitment to work hard towards achieving the expected output and timeliness in planting, as determined by the extension agent; otherwise the equipment should be withdrawn.

The Capital Requirement

The number of smallholdings in Western Province is approximately 255,000 (Kenya, 1981). A survey by the author revealed that the province had about 25,220 oxen ploughs in 1981. Thus, about 10% of the holdings had own oxen ploughs. It is recognized that some farms are too small to own oxen. Thus, farmers with less than 10 acres of land should be encouraged to hire the oxen unless there is a communal grazing arrangement. Changing from hoe use to hiring oxen for

ploughing was found to be profitable for the smallest farmers.
In order to have a significant improvement in the availability
of oxen-ploughing service and hence timely land preparation
in the region, it is proposed the proportion owning oxen
ploughs be initially increased by at least 1% of total
holdings (or 2,550 holdings) by public investment. The
distribution of the additional equipment should ensure that
access to oxen hire is unlikely to be a problem to
non-oxen-owning farms. The funds so invested should be
recovered from the farmers receiving loans at a rate of
interest slightly above the inflation rate. A negative
effective rate of interest should be avoided. In this way, a
revolving fund can be developed to enable the expansion of the
program to farmers willing to invest in ploughing equipment.
If successful, the scheme could expand to assist small
farmers in the purchase of suitable equipment for other crop
operations, such as planting and weeding.

Given the cost of a plough unit at about Kshs. 600, the 1%
increase in ploughs would imply government capital of about
Kshs. 2 million. Because over 50% of the farmers own cattle
already, which could be used for draught purposes, the funds
to purchase oxen could be limited to another Kshs. 2 million.
The cost of a 3-year old bull/ox averaged about Kshs. 600. A
team of four oxen is usually employed, but two healthy
well-trained animals can perform this task in the region.
Some money must be appropriated for the distribution and the
administrative organization of such a scheme. This should not
require more than Kshs. 1 million annually. This last
component of initial cost should include training of the
animals for ploughing, educating participants in the skills to
achieve improved results and to keep good farm records. The
initial capital and administrative costs therefore total about
Kshs. 6 million. The small scale farm mechanization project
of IADP had allocation of about Kshs. 40 million over 4 years
for the whole country (Kenya 1976). The proposed program for
improved land preparation is within the capacity of IADP for
Western Province, Kenya.

There is existing capacity and skill for local fabrication
of the oxen equipment in the centers already making the
equipment to order. There is very little foreign exchange
requirement for oxen ploughs or the fabrication equipment.
Because of the increased requirement for such equipment given
the public investment, the centers where the fabrication is
done will of necessity require more labour. The off-farm
income thus obtained will be useful in improving the standard
of living in the region, as well as increase on-farm
investment.

The Expected Repayment Schedule and the Need for a Stable Market

It may be necessary, or at least it should be an option, to allow participating farmers at least one crop season as a grace period before scheduling his/her repayment of the loan for equipment and/or oxen. This will build their confidence in the scheme. The farmers will have time to get acquanted with the new equipment and the animals.

The repayment schedule should reflect the nature of the farmers' cash flow. It is often forgotten that this is crucially determined by how and when the inputs and services are to be paid for and also when the farmer actually sells his crop. It would be a big mistake to have a fixed repayment schedule if the time for delivering of inputs and sale of output are not fixed. One alternative would be to accept repayment in maize equivalents with a specified price per kilogram established at the time of the loan. In this case, the loan agency should have a provision for marketing the maize received from the farmers in this way.

It was found that on an annual basis, changing from using a hoe to owning oxen and associated equipment for ploughing netted about Kshs. 1200 of profit when there was additional fallow land available to plant maize. Changing from hiring to owning oxen netted about Kshs. 990. Changing from hoe use to hiring oxen added about Kshs. 150 in profit. With the increased density of ploughs, there will be variations in these profits, because prices will change. However, the technical relationships are bound to change towards higher yields because of the improved timeliness in land preparation on a regional basis, given the expected rainfall pattern. It is therefore expected that farmers will be willing to pay back their loans to the credit agency if the anticipated increase in output finds a ready and stable market. If one-third to one-half of the increase in yields is to be paid back annually, those who owe the credit agency for only the equipment valued at Kshs. 600 could repay the loan easily within 3 crop seasons, well before the effective life of the plough expires. Those owing the agency the maximum of Kshs. 3000 could pay back the loan within 5 crop seasons, ceteris paribus. The fact that bulls/oxen may appreciate in value up to about the age of 8 should make repayment and replacement feasible.

The marketing arrangements must be streamlined to avoid crop losses within farms due to lack of good storage facilities. To the extent that the price of maize currently is very favourable (the price of a 90 kg. of maize rose by about 66 percent between 1981 to 1983, from Kshs. 95 to 158), the farmers have the incentive to produce the crop. A proper marketing arrangement is crucial to getting a good loan

recovery rate. If it is disorganized, the consequence will be a substantial loss in public investment. Some minimum price for maize might well be established to provide incentives and increase stability in the local economies. The restriction of maize movement within Kenya should be relaxed in this regard.

Other Areas of Assistance

Part of the program effort should go towards improving the performance of the oxen and equipment so that a higher standard of work and timeliness on small farms can be achieved. For the animals, supplementary feed and proper training may be required. For the equipment, there is need to consolidate efforts among researchers to improve the harness and the tillage efficiency of the implement. Training local artisans in the fabrication of new equipment is necessary. Use of animal traction for operations such as weeding should also be studied in the light of existing farming systems in the region. To date, the oxen have not been trained for weeding. Implements suitable for these operations are not available in this region. In Eastern Province, farmers use oxen for ploughing and weeding but use mouldboard plough for both operations (Mutebwa, 1979). If implements suitable for planting and weeding, together with trained animals, are available, it should be possible to expand the utilization of the oxen team over a longer period for cropping operations. The labour bottlenecks likely to occur after readying a larger area for planting may be reduced.

Sustaining tractor hiring services for small farmers was found to be very costly. In Western Province, 12 out of 24 tractors had broken down in 1981. The operation and maintenance costs of the serviceable tractors were generally rising. There was a significant requirement of foreign exchange to keep the tractors operational. Because of the critical lack of foreign exchange in that period, more of those particular tractors would soon be out of order.

It would be advisable to use the capital invested in the tractor hiring service in alternative ways. One way could be to use the resources to improve the timing of delivery of inputs such as seed and fertilizer. Another would be to subsidize the cost of hybrid seed. Farmers who adopt the usage of adapted hybrid seed in their locations will not have to store own seed for next planting, with the inevitable reduction in yield. An example of a relatively successful subsidy scheme could be drawn from the Artificial Insemination (A.I.) service (ILO, 1972). The cost to the farmer per service was reduced from Kshs. 10 to Ksh. 1 in 1971 in an effort to upgrade the traditional milk cattle. Most farmers adopted the use of A.I., and farmers continued to use it at

least in the '70s. This is not to suggest that there should
be a big subsidy on fertilizer or hybrid maize purchase. What
is urgent is to cover some of the fixed costs involved in
distributing these inputs. The farmers who ready their fields
on time can then benefit from the timely deliveries of these
inputs. Farmers with sufficient land, who are willing to
invest in own oxen for ploughing, could also be assisted, if
the credit available from IADP is not sufficient to cover
their needs. Private tractor owners (who generally have very
large farms) would then compete with oxen owners for the
customers willing to hire ploughing services.

A consistent practice of small farmers in the study area
was that of staggering planting to avoid the risk of losing
all the crop should the rains fail. This led inevitably to
some late plantings and lower average yields. Thus,
increasing the capacity for more rapid land preparation by
itself will enable only modest gains in yields. Some farmers
may still not plant all the readied field immediately after
the rains start. There is need to investigate the potential
of either supplemental irrigation or an insurance scheme for
these small farmers. If the improved land preparation and
cropping practices prove viable, that would lower the risk the
farmers have to bear in the event of total crop failure due to
lack of rain at critical periods. The initial capital for
starting such schemes may come from the resources currently
being used to sustain the tractor hiring service. If the
farmers feel such insurance services are beneficial to them,
such schemes could be self-financing, because the farmers
would be prepared to contribute part of the cost to sustain
these operations.

A recurring theme in this study was the urgency to improve
labour productivity and hence real incomes in smallholder
farms. The results of the study indicated that for
smallholder areas with considerable portions of unused arable
land, that resource could be brought into more effective use.
Employment of draught animals for ploughing instead of either
ploughing by publicly supported tractor hiring service or
hoeing would be more profitable. An initial credit scheme to
encourage use of oxen equipment in Western Province was
proposed. Greater availability of oxen ploughing service will
improve the timeliness of planting and yields. This should
also facilitate improvement in rural labour productivity, and
enable farmers to raise their incomes and standard of living.
Moreover, some of the proposed strategies will help the region
move towards achieving self-sufficiency for an important
staple crop, while providing more economic activity in the
rural areas.

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