AN ECONOMIC ANALYSIS OF SMALL FARM MECHANIZATION IN WESTERN PROVINCE, KENYA.

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Willis A. Oluoch-Kosura

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B F Stanton
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Willis A. Oluoch-Kosura, Ph.D.
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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.

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BIOGRAPHICAL SKETCH

Oluoch-Kosura was born in Gem Location, in Siaya District, Kenya in 1952. He obtained his early education at Nyamninia and Luanda A.C. Primary Schools, Mwihila Secondary School and Friends' School Kamusinga, before joining the University of Nairobi in 1973. He obtained his BSc. in Agriculture in 1976, and received the Gandhi Award for being the best Final Year Agriculture student in his class. In 1977, he obtained an Australian Government Scholarship to undertake a Masters degree in Agricultural Development Economics at the Australian National University, which he completed in August 1978. Upon returning to Kenya, he was employed by the University of Nairobi in the Department of Agricultural Economics as an Assistant Lecturer. In May 1979, he got an award from the Netherlands government to undertake a six-week workshop organized jointly by F.A.O. and the Netherlands, on Agricultural Industrialization in Developing Countries in the Hague. In September 1979, he was granted study leave to pursue a PhD degree in Agricultural Economics at Cornell University, completing it in May 1983. He is married and has been blessed with one daughter.

To My Parents, Flora and John Osura and My wife, Hellen.

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My greatest intellectual debt is owed to all who taught me and particularly to members of my Special Committee. The chairman of the Committee Professor Robinson was always ready to quickly read each chapter and make suggestions which greatly improved the final product. Even when he was away on sabbatic leave, he continued to be of great assistance. The timely completion of the dissertation could have been impossible without the able guidance of Professor Stanton, who was a minor member of the Committee, but on Professor Robinson's absence acted as the chairman. His experience in technical writing is reflected in this dissertation. I was very fortunate to have Professor Sisler as a proxy member of my Committee. He clearly demonstrated his interest in the subject, despite his heavy schedule, and through his great insight improved the organization of the thesis. Professor Thorbecke was very instrumental in exposing to me the current literature on the subject.

On a rather special note, I must thank my parents, Flora and John Osura. Through their hard work and great foresight about the value of education, they gave me encouragement to continue pursuing studies in spite of the short-term monetary gains I was foregoing. This dissertation is dedicated to them, together with my wife Hellen, who, in addition to speedily and skilfully typing the indecipherable drafts into the computer, always understood the stress I was undergoing sometimes and provided good humour and cooperation.

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The Kenyans and other friends at Cornell who provided moral suport deserve thanks. What is said or unsaid in the dissertation clearly remains my responsibility.

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Chapter I

INTRODUCTION

Smallholder farm labour is a major resource in Kenyan agriculture. The importance of Agriculture to the country is evident for by 1979, the sector contributed about 34% of the gross domestic product (Kenya, 1981). About 80% of the population currently estimated to be 16 million, lives in rural areas and actually derives its livelihood from agriculture and directly related activities (Kenya 1979). Although Kenya has a dual agricultural sector, the large scale and the small scale sectors, the latter sector comprises about 80% of the output from farming in Kenya.[1] In areas where land is available, improving the productivity of farm labour is probably the best way of raising the income of a large section of the population[2]. This is because intensive cropping largely depends on non-conventional inputs, like fertilizer whose timely deliveries cannot be assumed due to poor infrastructure. Maize is the chief staple food and increases in production are necessary to feed and support a population

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[1] The small-scale sector here includes farms in arable areas of less than 20 acres.

[2] Given the identity: $Y/L = A/L \times Y/A$, where Y is output, L is labour used and A is cropped area, output per unit of labour (labour productivity) can be improved by achieving high output per unit area (intensification) or having a low man to cropped land ratio (extensive farming).

which is now growing at the rate of 3-4% per annum (Kenya, 1981a).

One way of increasing labour productivity (output/labour) may be to mechanize some farm operations which now restrict the amount of land that can be cultivated. Partial mechanization is particularly appealing, because it may help to reduce drudgery in farm work, thereby making farming more attractive for those working on the land. However, the effectiveness of farm mechanization (as in any agrucultural technology) depends on the physical and socio - economic environment. The objective of this study is to examine the economics of small farm mechanization in Western Province of Kenya[3].

1.1 THE PROBLEM

Most farmers in Western Province depend on rainfall for crop production. The nature of the rainfall distribution requires that farmers get their fields ready for planting at the onset of the seasonal rains. Otherwise yields drop considerably, as has been shown by agronomists (e.g Allan, 1971). Just before the rains start, however, soil conditions are such that land preparation hand is very difficult by Most smallholders depend on hand tools, mainly the hoe, for land preparation. Muchiri (1981) reports that of the 3.1 million

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[3] Kenya is administratively divided into provinces. Each province is divided into districts which in turn are divided into divisions then locations, sub locations and finally villages.

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. Human power output is limited by the stress of high temperatures, and often by an inadequate or imbalanced diet. Therefore only a limited acreage of land can be readied for planting after the onset of the rains. In areas where the man/land ratio is still relatively low, dependence on hand tools for crop production acts as a constraint to increased output of maize. While a labour shortage may occur at land preparation/planting time, underemployment is likely for other times of the year. Extension agents advise farmers, especially those planting improved varieties of maize, to "plant early, weed early and apply fertilizer," if the yield potential is to be realized. What is often overlooked is the power input to bring the available land under cultivation on time in these areas.

Most farms which depend on the hoe seldom realize output beyond a subsistence level. In fact, with continual increase in family size, the family food available is sometimes inadequate and if adequate leaves little surplus for selling so that the farmers can buy other necessities that they cannot produce themselves. There is the additional problem of great drudgery involved in many farm tasks especially land preparation. All these considerations cause the quality of life in the rural areas to be relatively poor. Partly because of the conditions in the rural areas and a preference for urban employment, the younger generation have a tendency to migrate to towns, expecting a better life there. This exacerbates the problem of adequately feeding the unemployed in towns. Moreover, the marginal product of the young migrants may be lower than if they stayed in the "improved" rural area.

The government has recognized the problems outlined above. 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 also has made available some tractor hiring services for farms at different locations. For the Western Province, the tractor hiring station is located in Busia District. No smallholder in the province owns a tractor. However, some farmers own oxen, which they use in their fields and sometimes rent out to other farmers. Despite the existence of these forms of traction, the problem of generally low acreages planted to crops still persists, despite the fact that this is an arable area with excess land. Therefore a set of questions arise, which include:

1. Whether the cost of using tractor or oxen is too high for some farms to use them profitably;
2. Whether the available tractors and oxen facilities are insufficient to cover all farms; and
3. Whether the facilities (especially the tractors) are mismanaged so that farmers are reluctant to depend on

them for timeliness and only a special group benefits from the facilities.

The basic problem then is to find out 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.

1.2 THE OBJECTIVES OF THE STUDY

The broad objective of this study is 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.

1.3 JUSTIFICATION OF THE STUDY

The small farm sector forms a major proportion of the population. In the rainfed farming system of the low density population areas in Western Province, the power constraint that farmers face is real[4]. In some situations this power constraint may be reduced through the applications of a higher level of mechanization. As an input, mechanization should serve to remove or reduce the constraint on the physical or economic performance of farm units. It should not create new or increased problems for farmers. Smallholders currently use different techniques for land preparation, but largely similar techniques for subsequent crop operations. A detailed analysis of the economic prospects for partial mechanization would be helpful to extension agents and policy makers charged with formulating a good mechanization strategy for small farms.

The Kenyan Ministry of Agriculture recognizes the possibility of mechanization of smallholder farms relying on annual crops. The Ministry operates a tractor hiring service (THS). But there are both technical and socio-economic

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4 The population density for Western Province as a whole is 223 persons per sq.km. (Kenya, 1981). This varies greatly within districts and divisions. For instance, the density is 163 in Bungoma, 183 in Busia and 294 in Kakamega. Within Kakamega district, Vihiga Division has density of 750 persons per square km, while in Lurambi division, where the Kakamega sample was taken, the density is only 166. Because 1 sq.km has about 250 acres, this implies that each individual in Lurambi on average could have over 1.5 acres. Considering that in Kenya as a whole, 48% of the population under the age of 15, each adult could have more than 2 acres to farm.

problem in instituting such a scheme. For instance, even those who have access to a credit facility do not use the tractor service! For those relying on oxen the question arises about the opportunity cost of keeping oxen instead of cultivating the land with crops.

To determine the most appropriate farm mechanization strategy is one of the controversial aspects of decisions on agricultural technology (FAO, 1975). The controversy is not whether mechanization is desirable but over what level of mechanization is appropriate for various conditions. The answer to the controversy is related to the situation and the specific nature of development and can only be found by carefully analysing "all" the variables in each situation.

Work has been done on these issues in only a few areas of Kenya. Various authors have suggested that research be carried out in specific areas to determine the effects of mechanization. Heyer et al (1976) specifically called for research in the area of small farm mechanization because its effects are not clear in various situations. Clayton (1972, p. 314) reports:

> Painstaking empirical observation is the only way of arriving at a firm assessment of the employment impact of mechanization in a particular situation.

Binswanger (1978) in his study of the Southeast Asian situation emphasized that the economic profitability of tractorization or use of oxen is an empirical question and not a theoretical one. Each case must be analysed in its own right. In a seminar on small farm mechanization, Hemmi and Atsumi (1981) report that participants agreed that mechanization is a means to an end and not an end in itself; one has to be clear about what the end really is. If the objective is to reduce rural poverty and promote equality in income distribution, as is the case in Kenya, then the strategies which do not adversely affect the objectives should be found by empirical analysis. Between 1973 and 1981, for instance the cost of diesel fuel per litre rose from Kshs. 0.84 to Kshs 5.18, an increase of over 500 percent. Even if inflation is taken into account, this is a sizeable increase. The high cost of energy calls for an appropriate strategy for farm inputs if losses are to be reduced or avoided and appropriate incentives introduced. In addition, the theme of the current Kenya Development Plan (Kenya 1979) is "Alleviation of Poverty", with a focus on rural areas. Designing means of improving the quality of life in rural areas will be an important element in achieving the objective of the plan. Given the objectives of this study, our understanding of what part small farm mechanization can play in solving the farmers' dilemma will be a central issue.

1.4 THE HYPOTHESES

The hypotheses posed are directly related to the objectives of the study. These include:

1. Oxen-use for land preparation is associated with greater demand for labour and land.
2. In the three districts of Western province, higher levels of mechanization are associated with increased output of maize per acre.
3. Labour productivity is lower on farms that rely only on hand tools.
4. Use of fertilizer and a high-yielding variety of maize without the means for timely planting by farmers is not profitable.

1.5 MECHANIZATION TERMINOLOGY USED IN THIS STUDY

Various terms used in this study need to be defined.

(i) 'Farm mechanization' refers to the use of all types of tools, implements, machines and equipment for agricultural land development, farm production, crop harvesting and processing within the farm. On small farms in this area, mechanical aids in maize production differ only during land preparation. 'Mechanization' will therefore essentially refer to the method of land preparation.

(ii) The term 'level of mechanization' refers to the three principal sources of power corresponding to the technologies: hand tool, animal draught and mechanical power. Animal draught technology refers to the use of oxen/bulls. Mechanical power technology takes many forms, but for this study refers to the use of any type of tractor for field preparation and/or transport. This level is sometimes refered to as tractorization.

(iii) 'Appropriate mechanization' refers to a level of mechanization which is best suited for use in a specific farming system. Appropriateness is determined by technical requirements, economics, and cultural and social characteristics of the population. Relatively broad generalizations are not useful in this regard. Other terms which have dual meanings are avoided here. For instance, 'selective mechanization' (FAO 1975) sometimes refers to a type of mechanization which does not decrease the demand for labour per unit of land. Sometimes it is used to describe the choice of size or design of tools or implements for specific agricultural situations. Also, the term 'intermediate technology' (Schumacher, 1975) is sometimes used to describe a form of mechanization somewhere between hand tools and large tractors without specifying the type of technology used. Sometimes the term is used to mean animal draught technology, while other times it means a scaled-down tractor of the 20-30 horse power variety or a single axle tractor. We confine the language used in this study to the term 'appropriate level of mechanization' in the area.

(iv) The term 'farm implements' refers to devices pulled behind, pushed, or otherwise used with a human, animal or mechanical power to carry out agricultural operations. These include ploughs, hoes, transport sledges and carts.

1.6 THE FRAMEWORK OF THE STUDY

The problem, specific objectives, justification for the study and hypotheses have been outlined in the preceding pages. The next chapter considers the methodological issues on the subject of farm mechanization. It specifically focuses on the controversies, together with analytical procedures used in the studies. Chapter 3 describes the national outlook and the study area. Data sources and sample characteristics for the study area are described in Chapter 4. The resource base, farming system, and evolving levels ofmechanization are identified, using records from the 1977 and 1981 surveys. The limitations of the data are discussed. The fifth chapter considers the theoretical bases for analysing the data. The relevant variables and the analytical procedures used in this study are discussed. The empirical results of the study and their evaluation are presented in chapter 6. Conclusions drawn from the study and inferences for policy are summarized in the final chapter.

Chapter II

METHODOLOGICAL ISSUES

The role of farm mechanization within the organization of a farm should be viewed according to its influence on farm output, which is used either to feed the family or to sell 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 labour profiles in Chapter 4 show peak and off-peak seasons for agricultural activities. 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. The aim of this chapter is to review these issues, and how they relate to this study.

2.1 THE HISTORICAL PERSPECTIVE OF TECHNOLOGICAL DEVELOPMENT

The modes of technology used on farms in various countries have not been uniform. Using country studies, authors such as Hayami and Ruttan (1971) and Johnston and Kilby (1975) have found a positive relationship between output per unit of land cultivated and advances in biological technology, and also between output per worker and advances in mechanical technology. The historical differences in area technical adoption have given rise to the cross-sectional differences in productivity and factor use, and the development of the induced technological innovation hypothesis by Hayami and Ruttan (1971). In the induced innovation model, the initial factor endowment of an economy determines the path of technological development. Thus, technology is developed to facilitate the substitution of relatively abundant and hence cheap factors for relatively scarce and hence expensive factors of production. Thus land-scarce countries should emphasize biological technologies, such as the development of high-yielding (fertilizer responsive) crop varieties designed to substitute fertilizer for land availability. This type of response is demonstrated by Japan and Taiwan. It is referred to as 'land-saving' (labour using) technology. If labour is scarce, as was characterized by the United States during its growth period, mechanical technology should be designed to save on labour; hence 'labour-saving'. This type of technology facilitates the substitution of power and machinery for labour, thus enabling a given number of workers to extend their efforts over a larger land area.

This view of country-wide technological development assumes that a country is homogenous factorwise and so pursues a unimodal strategy. All farmers are assumed to be either small scale or large-scale within that country. In Kenya, for historical reasons, the country has a bimodal structure in its agricultural sector. Deliberate government policy will largely determine what kind of technology is available. In fact, countries such as Kenya sometimes get aid from the developed countries (DC's) in the form of mechanical equipment to be employed in their agricultural sector. As such, advances in technology in the DCs in response to their own resource endowment may result in a bias in the technical materials and information that become available to LDCs. This may also be facilitated by an overvalued exchange rate.

It is apparent that more intensive use of traditional inputs generates little surplus to improve the well-being of rural people or to be transferred to the rest of the economy. This argument is developed more fully in Schultz (1964), where the traditional farmer is viewed as "poor but efficient." According to this argument, simple reallocation of resources within farms in the absence of technical change has little chance of providing the necessary surplus to enhance rural development. Several studies have tested and not rejected Schultz's hypothesis, e.g. Hopper (1965), and Yotopoulos

(1967). If this view is correct, then even for the present study area reliance on the traditional methods of cultivation may be a hindrance to development there. For instance, if essentially the same resources and technology are known to the farmer for generations, simply increasing the amount of effort on their part cannot significantly increase output. The crucial question is, what should take priority in a given rainfed agricultural environment? Should it be an extensive or intensive method of cultivating land for an important staple crop, given the infrastructure? Are there ways to improve the timeliness of the planting operations at modest cost, in order to raise yields? Another relevant question in the case of development aid would be to evaluate the pace of technological change that can be absorbed by the receiving environment, whether extensive or intensive methods of production are being pursued. This brings in the question of using a given technology most profitably.

2.2 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.

2.2.1 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. Donaldson and McInerny (1978), 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. 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.

2.2.2 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. This can be seen in table 2.1, which compares the average work performance of the 3 sources of power in preparing one acre of land for maize[1]. The figures were derived from field research conducted by the Ministry of Agriculture on typical well-managed farms in regions similar ecologically to this study (Ministry of Agriculture, 1980).

The figures may be regarded as near optimal rates of work by various power sources, because the operators were conscious that they were being observed. However, they give a rough idea of the relative work performance by power sources. For instance, a 4-oxen team could 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

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[1] Weeding, which is the most labour intensive operation is done manually and requires about 136 hours per acre.

[2] There is now evidence that a 2-oxen team can perform the

TABLE 2.1

The Average Work Rate Per Acre for Manual, Oxen and Tractor in Land Preparation for Maize

Power Source	Operating hrs/acre
Manual (one adult)	96
Oxen*	10
Tractor**	1

* Two pairs of oxen with 1-furrow mouldboard plough and 3 guides.

** 45 hp tractor with 3-furrow mouldboard plough.

Source: Ministry of Agriculture 1980. pp. 104, 135-136

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 classified factors affecting maize yield as physical inputs (seed, nitrogen and phosphorus fertilizer) and husbandry factors (date of planting, quality of weeding and spacing). He conducted a series of 2^6 factorial trials in maize growing areas at a high (good) and low (poor) levels of management.

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operation at the same rate as a 4-oxen team if they are well trained and healthy. (Alexander, 1975).

The physical inputs alone produced a 66% increase in yield over the original average of all practices taken at a low level of husbandry. The good husbandry practices produced a 148% increase. When all practices were performed at a high level, yield rose by 307%.

The most important of the agronomic finds was the importance of early planting. It is recognized 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 (Allan 1968). 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 when the rains are tailing off[3]. 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. This will be further described in Chapter 4. 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

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[3] From the agronomic report, it seems as if the soil became colder with more rain, inhibiting good germination. If the soil was waterlogged, there would be poor aeration.

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 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. density of available oxen ploughs or tractors the average time of planting.

Because of the low for a whole community may be very late[4]. 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

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[4] 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.

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.

2.3 MECHANIZATION AND LABOR USE

The relationship between mechanization and employment of labour in rural areas has also received attention by various researchers. Some studies indicate that adoption of higher levels of mechanization is undesirable in the rural areas of less-developed countries 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 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 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[5]. Bailey's study in Botswana (Bailey, 1982) shows that if nutritional levels are inadequate prior to or during the planting period, labour productivity is low, even after putting aside the drudgery factor.

There is also a possibility that, with promotion of higher levels of mechanization, increased rural employment may be possible through the generation of off-farm employment. This increase in employment results from the necessity to have rural artisans to repair the farm equipment. Kline (1969) has shown that such a possibility exists. If this should be demonstrated in the study area, then the argument that generation of off-farm employment in rural areas is important for rural development should reinforce the promotion of a higher level of mechanization for land preparation.

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[5] 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.

2.4 MECHANIZATION AND CROPPING INTENSITY

Higher cropping intensity results from being able to have more than one crop in a growing season. Cropping intensity should be determined by the period the crop takes to mature and the turnaround time between one crop and the next. In irrigated systems, increased cropping intensity should be theoretically possible through reduced turnaround time after mechanizing (Jayasurya et al, 1982). In practice, the turnaround times don't differ markedly among the farm categories. In rainfed systems such as are found in the study area, the maize crop takes 4 to 6 months to mature, and there has been no development of a quicker maturing variety for the area to permit harvesting more than one crop per year[6]. For this reason, higher levels of mechanization cannot be expected to enable higher cropping intensity.

2.5 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

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6 The Katumani maize, a composite variety, is drought-escaping and takes about 3 months to mature. It is specifically confined to the semi-arid region of Eastern province. Due to high altitude, the temperatures of the study region are relatively low, and the maize takes longer to mature.

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[7]. Those 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

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[7] 1 Ksh. is approximately equal to 10 U.S. cents.

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. Narayana (1977) also reported that in Chitor District, India, ownership of a tractor depended critically on the types of crops grown in the region. For certain crops in certain clusters in Narayana's study, cultivation with own tractor was not as profitable as cultivation with bullocks.

Because ownership of tractors on small farms is economically impossible (based on a purchase price of currently available tractors of between Kshs. 30,000 to 100,000), small farmers must rely on using tractor-hire services, these may be government operated or privately owned by large-scale farmers. In 1981, hiring a government tractor to break new land cost about Kshs. 134 per acre. The cost was Kshs. 120 per acre for ploughing land which had not been left fallow. For private tractor hiring, the cost was at least Kshs. 200 per acre. Analyses comparing the profitability of tractorization in small farms therefore only consider tractor hiring on such farms. Gemmill and Eicher (1973) report that most government tractor hiring schemes in Africa have not been successful because of high operating costs on fields which are small, scattered and irregular in shape. In the case of private tractors, evidence exists that in Kenya only about 40 percent of the tractors are operational at any one time (Otieno et al 1975). Kolawole (1972) revealed that the government tractor scheme in Western Nigeria did not benefit participating farmers because of frequent breakdowns and a shortage of experienced operators resulting in delayed planting. Such is the case with the small farmers in the study region with the result that at present very few farmers are interested in tractor hire. This will be evident from the survey records.

This study will use 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. Eicher and Baker (1982), for instance, report a study by Winch (1976) in Ghana where government taxes and subsidies greatly distorted the relative profitability of the different rice production systems. The systems which relied on tractor mechanization were found to be the most profitable to farmers but least profitable to society when economic costs were taken into account. 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.

Chapter III

THE NATIONAL OUTLOOK AND THE AREA OF STUDY

The agricultural sector is the most important sector in Kenya, contributing about 34% of gross domestic product and providing the source of livelihood for over 80% of the population. It is dichotomous in almost every respect. There are large and small-scale farms, high and low potential agricultural areas, cash and food crops, capital and non-capital intensive farms, and a wide variety of farmers with different managerial skills. Such diversity implies that any measure aimed at improving production efficiency be carefully considered in relation to a particular location and its available resources. The aim of this chapter is to describe the prevailing circumstances in the study area and in the country regarding various farm inputs, land potential, available mechanization alternatives and the capacity to develop and distribute new or improved agricultural technology.

3.1 THE PRICE TRENDS OF SOME FARM INPUTS

The adoption and continous use of any farm input depends on the prices farmers have to pay for that input in relation to individual product prices, because these price ratios determine net returns. In the case of maize production, if farmers adopt the use of hybrid seed, it is desirable that they continue to purchase new seed to plant (together with other complimentary inputs) if the yields are not to decline. The various input prices connected with maize production are given in table 3.1 for the years 1972, 1975 and 1980/81. The percentage changes between 1975 and 1980/81 are also given.

From the table, it is clear that seed, gasoline and wages had very high percentage increases between 1975 and 80. The relative decline in prices for fertilizer was partly due to the subsidies the government made available for fertilizer in the years between 1975 and 80. These prices do not reflect the actual availability of the inputs in the smallholder areas, because they refer to prices at the main retail centres. If the distributional difficulties and availability of inputs are taken into account, then it can be said that the indicated prices are of limited relevance to the small farmer.

With regards to hybrid maize, Gerhart (1975) reports that over 75% of the smallholders in Western Province had adopted hybrid maize by 1974. Even in the 1980s, it is not unusual to find that small farmers actually store the harvested seed for planting as they did in the past, because they are not sure that they will get new seed when they need it. Sometimes when the seed is available farmers complain that they cannot afford the price. For instance, to plant one hectare of maize, about 25 kg. of seed is recommended. This costs about Kshs. 138.

TABLE 3.1

Prices of Selected Agricultural Inputs in Kenya (Kshs./Unit)

Input	1972	Year 1975	1980/81	%Increase 1975-80/81
Maize seed(10kg)	20	22	55	150
Fertilizer: Phosphate(ton)	570	3125	1733	-45
CAN* (ton)	580	2120	2178	3
Compound 25:5:5(ton)	760	3100	2779	-10
Tractor (45 hphp)	30,000	78,000	100,000	28
Gasoline(litre)	1.05	2.40	5.30	120
Wages/month	75	150	350	133
Hoe	19.70	28	40	43
Ox Plough	n.a	250	400	60

* CAN refers to Calcium Ammonium Nitrate.
Source: Kenya National Farmers Union;
Ministry of Agriculture: Yields costs - prices 1980/81
Ministry of Economic Planning: Economic Survey 1976.

Another way of looking at this seed cost is that it is equivalent to buying about one 90 kg. bag of maize. Considering the yields the farmers expect to get, it is not surprising that many smallholders do not purchase hybrid seed.

Although by 1980/81 use of fertilizer was being subsidized, very few smallholders were using fertilizer for maize production. The subsidy actually benefits the large-scale farmers the most, because there is no guarantee that the fertilizer will be available to the smallholder. The large-scale farmers, some of whom have their own transportation facilities, can always get fertilizer at the various retail shops. Those smallholders who raise livestock sometimes use manure in the maize fields, if they can commit family labour to carry the bulky input to the fields which may not be near to the homestead. Use of fertilizer by smallholders is therefore confined to the relatively rich farmers. If they can not get fertilizer but have livestock, they can hire labour to carry manure to the fields. To date, no smallholders use herbicides for weeding maize.

The prices of farm equipment as given in table 3.1 suggest that the hoe is the cheapest equipment a smallholder can buy. However, even hoes have risen in cost by 43% since 1975. The meaning of this cost increase is that most smallholders do not replace the hoe very often, but use it until it is virtually ineffective. The ox-plough is the next cheapest piece of equipment a smallholder can afford. However, to use it, s/he has also to have the oxen or animals to pull it. The animals of necessity need grazing land. Therefore only a few farmers can afford the ox-plough. Hiring a tractor for ploughing has been made very difficult for smallholders due to the rise in cost of tractors and gasoline. If the farmers who can afford to hire it adopt its use and see no net benefit, tractor use may in effect be confined only to large-scale farms. Given these facts about available equipment, it is useful to examine the relative importance of the various levels of mechanization to land preparation in Kenya.

3.2 THE RELATIVE CONTRIBUTION OF VARIOUS LEVELS OF MECHANIZATION

The relative significance of the various levels of mechanization to land preparation can be appreciated by observing the acreage each covers. Table 3.2 gives these contributions for small farm areas in Kenya in 1976. It is clear that in smallholder areas, most of the land preparation is done using human labour and the hoe.

The number of tractors in good operating condition owned by the Tractor Hiring Scheme (THS) of the Ministry of Agriculture in the country was 198 in 1981. Their distribution according to province is shown in table 3.3.

The horsepower (hp) of the tractors cover a wide range; 4% were 45hp or less, 92% were in the 75-80hp range and the remaining 4% were 110hp. each. It is therefore evident that the majority of the tractors are not small. Also it is clear

TABLE 3.2

The Relative Contribution to Land Preparation of the Various Levels of Mechanization Kenyan Smallholder Farms, 1976.

Level of Mechanization	Acreage	Total Percent
Tractors	105,000	3.4
Ox-Plough	375,000	12.2
Hand Prepared	2,594,250	84.4
Total	3,079,250	100.0

Source: Adopted from Muchiri (1981).

that the total number is not large enough to provide service for most smallholders[1]. Power tillers or small tractors have been tested by the Agricultural Mechanization and Testing Unit (AMTU) and found unsuitable for ploughing in most areas. They break down easily in hard soils, and therefore have not been recommended for small farms.

In the case of Western Province, the study area, the THS station is located in Busia District at Matayos. Of the 24 tractors for the province, only 12 were actually serviceable

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[1] Taking the 1980 prices, the total cost of purchasing the 198 tractors would be about Kshs. 24 million. (Ministry of Agriculture, 1980). If the maintenance cost of 130% of new price during the working life of 10,000 metre-hour for each tractor is taken into account, the total cost of providing the service is staggering. (Metre-hours refers to the units of the tractor effective life.)

TABLE 3.3

THS Tractors Numbers per Province, Kenya, 1981

Province	No.	% of Total
Coast	21	10.6
Eastern	39	19.7
Central	35	17.7
Rift Valley	60	30.3
Nyanza	19	9.6
Western	24	12.1
Total	198	100.0

Source: Yobera - In Charge Tractor Hiring Service
The Ministry of Agriculture.
(Private Communication).

at the time of the author's visit to the station. The cultivation period for rainfed agriculture is the same for all farmers in the region. This places a severe constraint on the number of farms which can utilize the government tractor service for land preparation.

For one tractor to be operated profitably on small farms, the Ministry of Agriculture recommends that at least 200 acres within a 5 mile area be available for tractor ploughing. This requires groups of small farmers to organize themselves and apply for the services. The organizational difficulties of small farmers, and the fact that the availability of a tractor cannot be assured instantly or even within a few days has made this service very unpopular. In addition, the minimum acreage considered for release of a tractor to a farm is 3 acres. This would take a 45 h.p. tractor about 3 hours to plough. Since some farmers allocate less than 3 acreas for annual crops, these farmers cannot get the service. Thus it becomes extremely difficult to find enough qualified applicants within 5 mile radius who are ready to organize themselves to meet the 200 acre requirement. Private contractors, on the other hand will plough even if the acreage to be ploughed is less than 3 acres, provided the land is properly cleared. However, the higher charge per acre between the THS and the private contractors restricts demand for private services.

For Western Province,the THS charges are fixed, and are given in Table 3.4

These THS rates are in most cases almost a half of what the private contractors charge farmers. However, the prices given in table 3.4 are not the prices perceived by farmers who are willing to use the tractors. This is because small farmers must rely on private contractors for their small land areas[2]. This is because arranging for the service with a private

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[2] It turned out that the size of the farm in the study region was not the factor determining the ability to hire a tractor. Some relatively small farms were hiring a tractor to prepare some portion of land for maize cultivation. The money for hiring apparently was obtained through remittences from urban areas. These issues are discussed in detail in the following chapter.

TABLE 3.4

Tractor Charges in Western Province THS, Ministry of Agriculture, 1981

Task	Kshs./acre
1st Ploughing (Old Land)*	120
1st Ploughing (New Land)	134
2nd Ploughing	90
Harrowing	75

* Old land refers to land which has not been under fallow in the previous growing season. New land refers to land which is being broken after some period of fallow.

Source: Manager, THS Matayos (Private Communication).

contractor. is relatively easy and therefore reliable. It is to be stressed again that in the study region, where a higher level of mechanization is used, it is usually confined to ploughing. Inter-row cultivators are rare and seeders or fertilizer applicators are even more uncommon.

Records in the Ministry of Agriculture reveal that ox-cultivation is in use, especially in Western Kenya and Eastern Province. In Western Province, the present study area, about 34% of the farmers own oxen ploughs in Bungoma, 25% own them in Kakamega, and 10% own them in Busia District. The oxen depend upon natural grass in uncultivated areas for grazing.[3] They have developed a resistance to local diseases. These would be dangerous for exotic breeds, since veterinary care is minimal in some areas. Training of oxen is mostly done traditionally and is based on intimidating the animals by shouts and whipping when guiding them in ploughing. However, there are serious attempts at Bukura Institute of Agriculture in Kakamega District to develop an improved method of handling the animals.

3.3 THE AVAILABILITY OF ARABLE LAND

The extension of the land area to be cropped depends on its availability. The classification of the land area in the country is based on its potential for crop production. This classification is given in table 3.5. The potential depends largely on the amount of rainfall received per year.

On the agricultural land the intensity of use varies, but in most areas is not at maximum levels. Table 3.6 shows the intensity of land-use by province in 1976. There was no evidence that there has been major changes in land-use intensity through 1981.

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[3] The use of the traditional oxen or bulls for ploughing is the current practice. However, some studies, such as those done by the International Livestock Centre for Africa, indicate that cross-breeds can perform better at ploughing because they provide greater power. Some even suggest the use of cows, which farmers openly frown upon as a very strange suggestion.

TABLE 3.5

Land Areas and Related Rainfall

Land Area	Annual Rainfall	Sq.Km.	% of Total
High Potential	>=857.5mm	67,850	11.89
Medium Potential	735-857.5mm	31,570	5.54
Low Potential	<=612.5mm	422,370	74.07
All Other Land*	na	48,430	8.49

* All other land refers to mountainous areas, and areas covered by lakes and rivers.

Source: Ministry of Agriculture: Dryland Farming Research and Development Project Ken 74/017, 1977.

At the national level only about 38% of arable land is under crop, while for Western Province, about 59% is under crop. Although some of the arable land may be used for livestock production, there is sufficient land to allow for additional extensive cultivation of maize, should this be desirable. A limited expansion of maize acreage is necessary to allow for an appropriate crop rotation, and also to provide enough maize to support the food needs of the family.

Table 3.6

Intensity of Land Use by Province - 1976

	Central	Coast	Eastern	Nyanza	Rift Valley	Western	Total
				('000 hectares)			
1. Total agricultural land	772.7	1,819.8	1,153.5	1,125.2	3,115.9	663.6	8,650.7
2. Land under forest	167.2	122.6	189.2	19.1	615.0	42.8	1,155.9
3. Land available for agriculture (1-2)	605.5	1,697.2	964.3	1,106.1	2,500.9	620.8	7,494.8
4. Land cropped	563.6	254.9	658.6	501.2	533.5	364.5	2,876.3
5. Intensity of land use (4)÷(3)x100	93.1	15.0	68.3	45.3	21.3	53.7	38.4

Source: Kenya (1981a).

3.4 THE CAPACITY FOR MANUFACTURING FARM MACHINERY

The manufacturing sector in Kenya relies heavily on imported intermediate inputs. About 50% of the import bill is accounted for by capital and intermediate goods (Kenya, 1979). In comparison, about 33% of the bill is accounted for by oil imports. In the class of capital and intermediate goods, machinery and capital equipment account for approximately 20%. Tractors are largely imported in fully assembled units. In 1980, for instance, 5752 tractors were imported at a cost of Kshs. 166 million (Kenya 1981). Most of the tractors are meant for large-scale farming, although some are imported for land clearing, government land development programs and public works programs. It is clear that importation of tractors is a big drain on scarce foreign exchange. If one adds the cost of importation of spare parts to service them and oil to run them, then encouraging increased use of tractors by smallholder farmers for staple crop production becomes questionable. Sustaining a government tractor hiring service which is dependent on the availability of imports at a time when foreign exchange is very scarce for the country may be very costly. The opportunity cost associated with alternative uses of that capital must be closely examined.

Local manufacturing or fabrication of agricultural hand tools and oxen ploughs is possible within the country[4]. The

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[4] Local fabrication should facilitate the availability of

value of imported agricultural handtools was only about Kshs. 12 million as compared to the 166 million for tractors in 1980. (Kenya, 1981). The import bill for small farm implements could decline even further if local fabrication is encouraged. Although most of the fabrication of animal drawn implements and hoes is still based in Nairobi, a few local producers of these items are emerging in some rural areas, especially where the rural development centres established by the Kenya Industrial Estates are operating (Kenya 1979). Certainly capacity exists in the rural areas to manufacture simple implements. In fact, in many villages there are craftsmen who undertake repairs and do some fabrication to order by farmers. But in these cases both capital and the design information required for success are lacking.

3.5 THE AREA OF STUDY

Western Province, Kenya was the area selected for study. The province is divided into Bungoma, Busia and Kakamega Districts. Figure 3.1 shows the province and its relative position in Kenya in an inset. The locations of the sample farms are also indicated.

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implements at prices farmers can afford. In addition, the foreign exchange saved could be diverted to other, more urgent priorities, such as importing more fertilizer (which has obvious yield-increasing effect if applied appropriately). Moreover, the employment generated for the local artisans and blacksmiths would be good for the economy.

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.[5]

As indicated in section 3.2, use of animal traction for land preparation is not new in Western Province. Raising livestock is possible because there are no tsetse flies in the area to transmit trypanosomiasis. The basic level of technology in land preparation is the use of the hoe, which has been in existence for a long time.

The study area is located in medium-to high-potential agricultural zones (Zone II and Zone III) in Figure 3.2. The zones, classified according to the annual rainfall, receive more than 735mm per annum. (see Table 3.5). All the smallholders in the province grow maize as a staple food crop. Those who do not have any other source of cash income sell a portion of the maize output from the farm to enable them to buy other necessities.

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[5] 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.

FIGURE 3.1. THE AREA OF STUDY AND ITS RELATIVE LOCATION IN KENYA

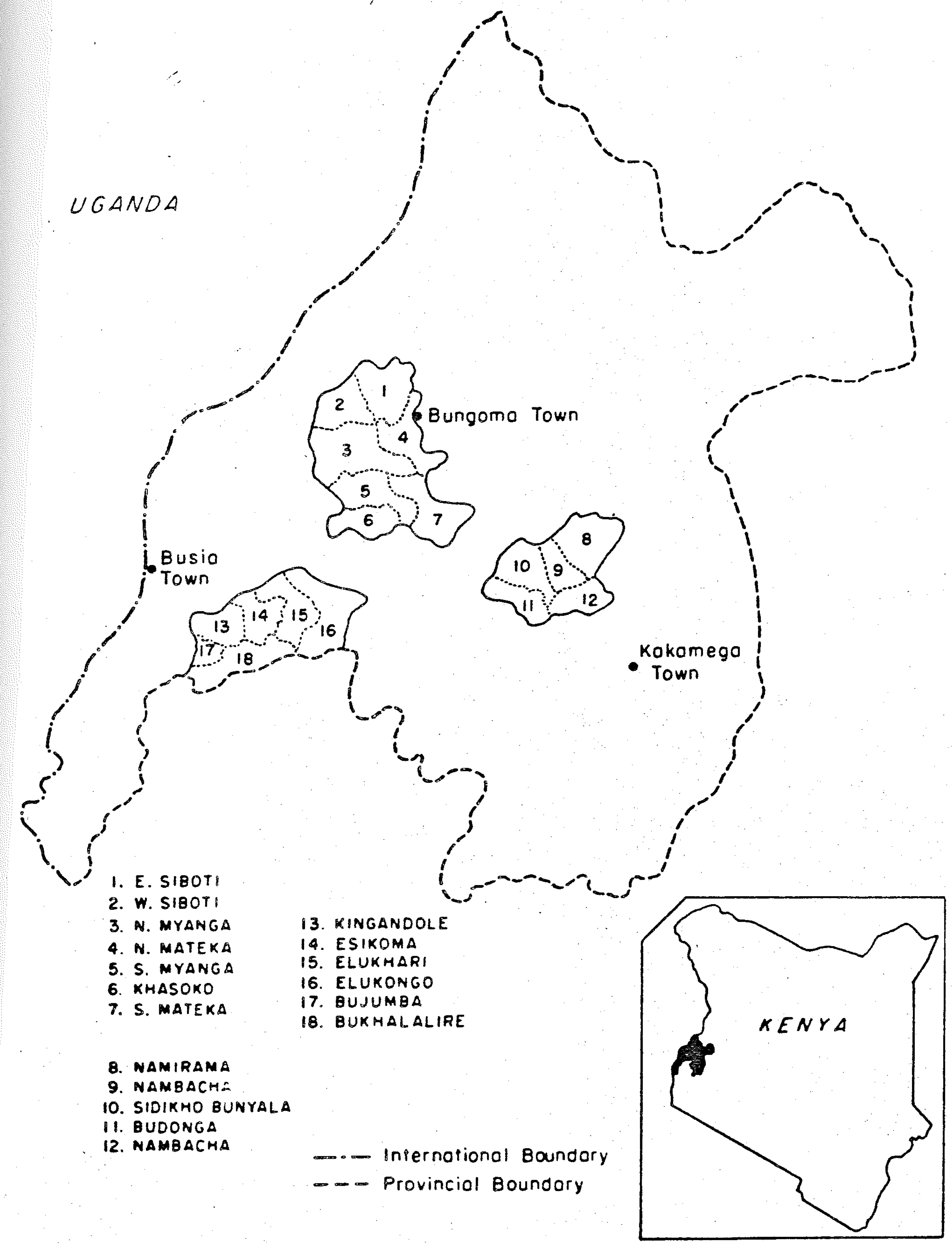
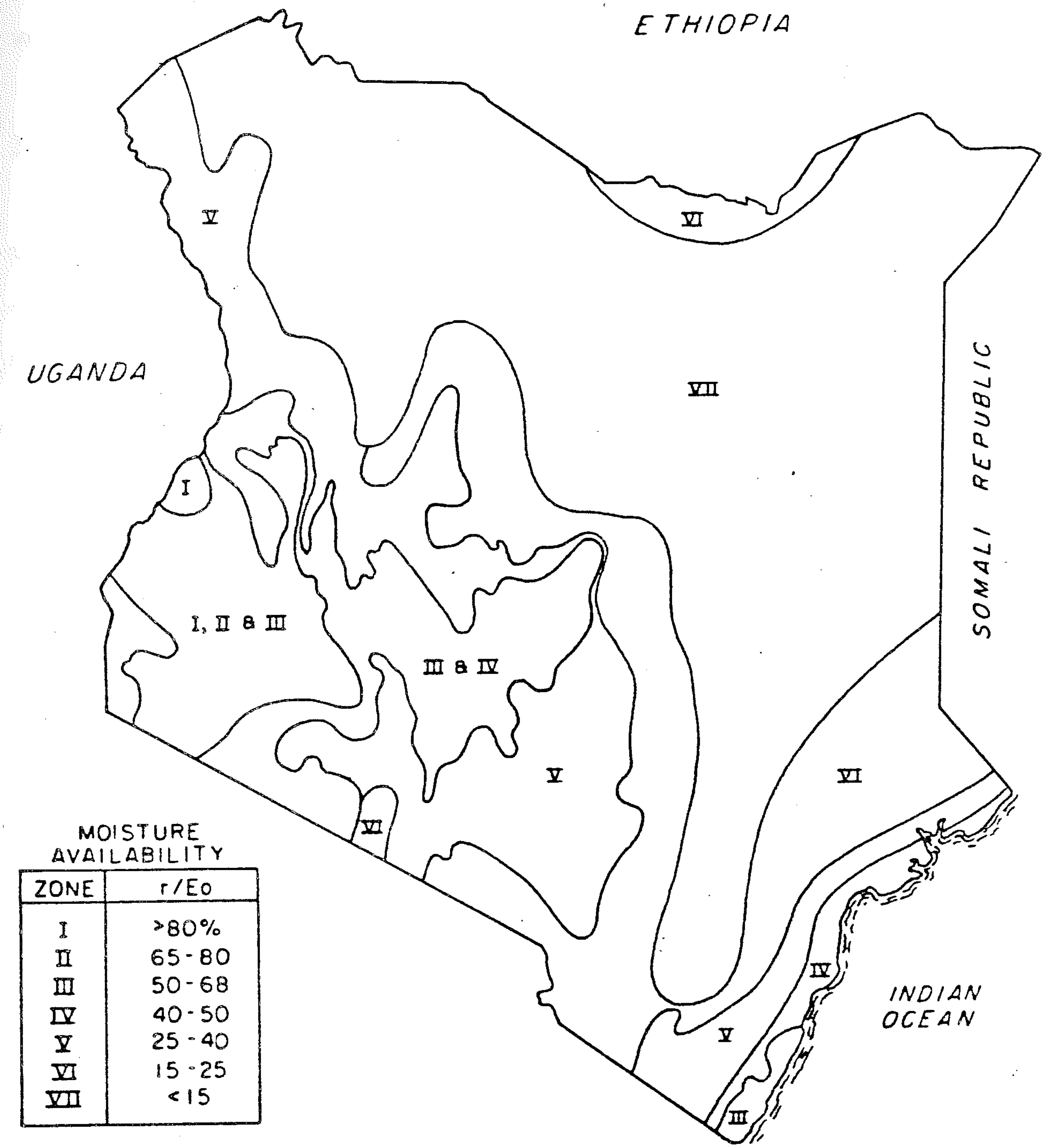


FIGURE 3.2. THE MAJOR AGRO-ECOLOGICAL ZONES IN KENYA



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

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

3.5.1 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.

3.5.1.1 The Rainfall Distribution

Figures 3.3, 3.4 and 3.5 show the mean monthly rainfall for the three sample areas of Bungoma, Busia and Kakamega respectively. These 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.

It is useful to relate the rainfall regime to the maize plant in its various stages of development from the time of planting. No experiment known to the writer has been done regarding the relationship between plant growth and development and the rainfall regime for the study region. However, Turner (1966) in a study to investigate the causes of low yield in late-planted maize at the Ilonga Research station in Tanzania, which has a very similar bimodal rainfall pattern. His results may give us insight into the relationship. Turner used five eight-day interval planting

Figure 3.3: The Average Monthly Rainfall (Bungoma Station)
5-Year Average - 1977 to 81

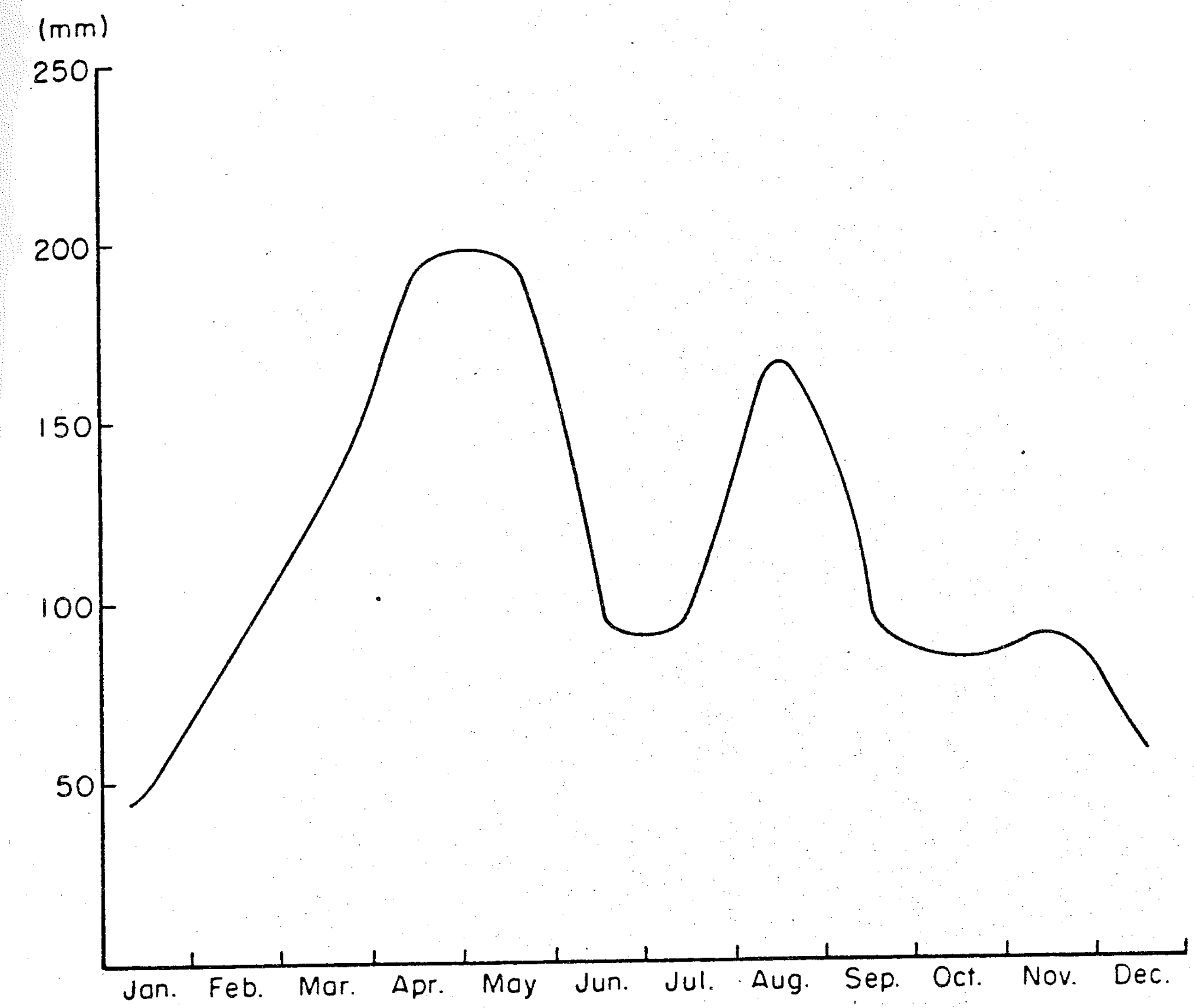


Figure 3.4: The Average Monthly Rainfall (Nambale Station - Busia) 9-Year Average - 1972 to 80

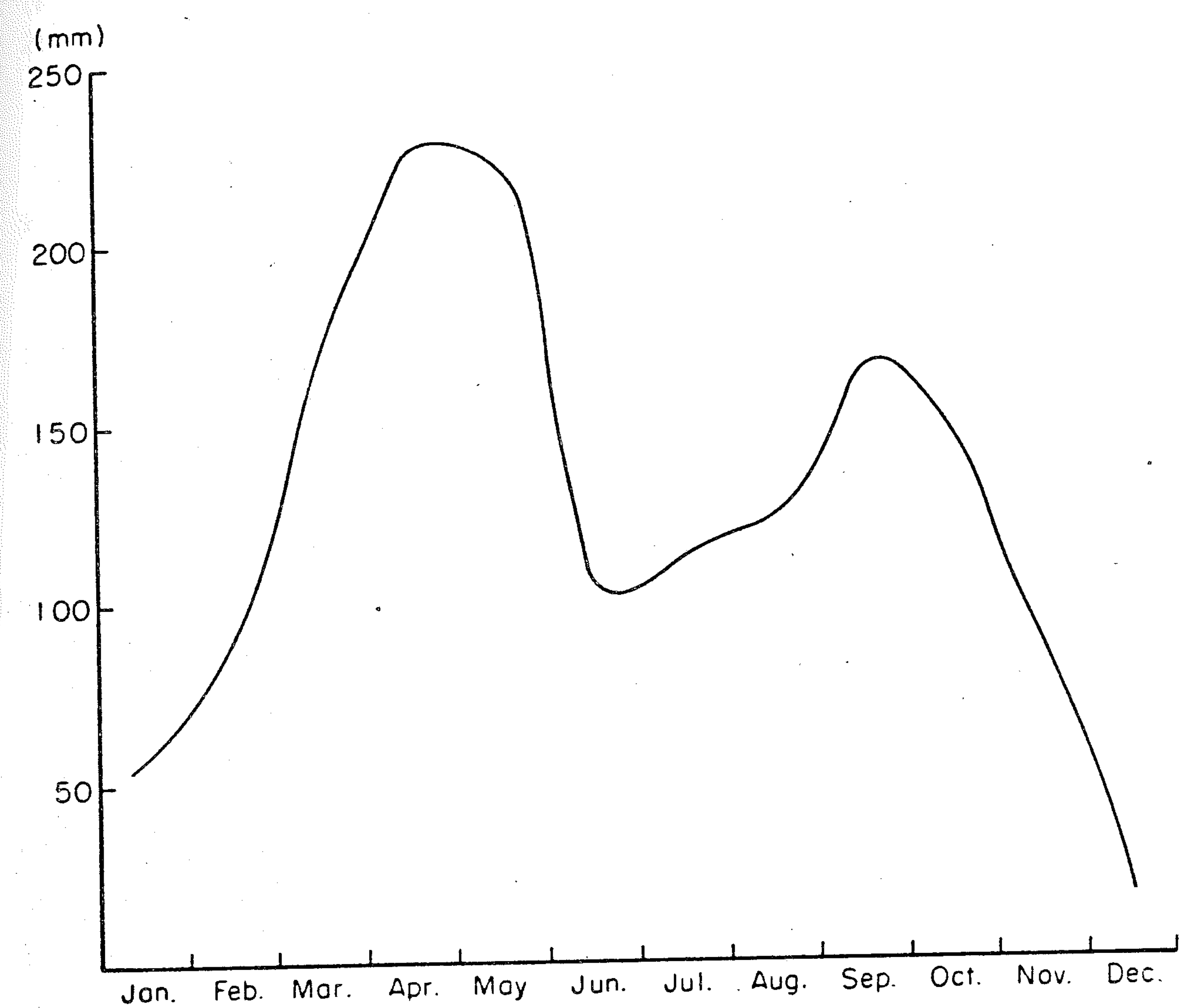
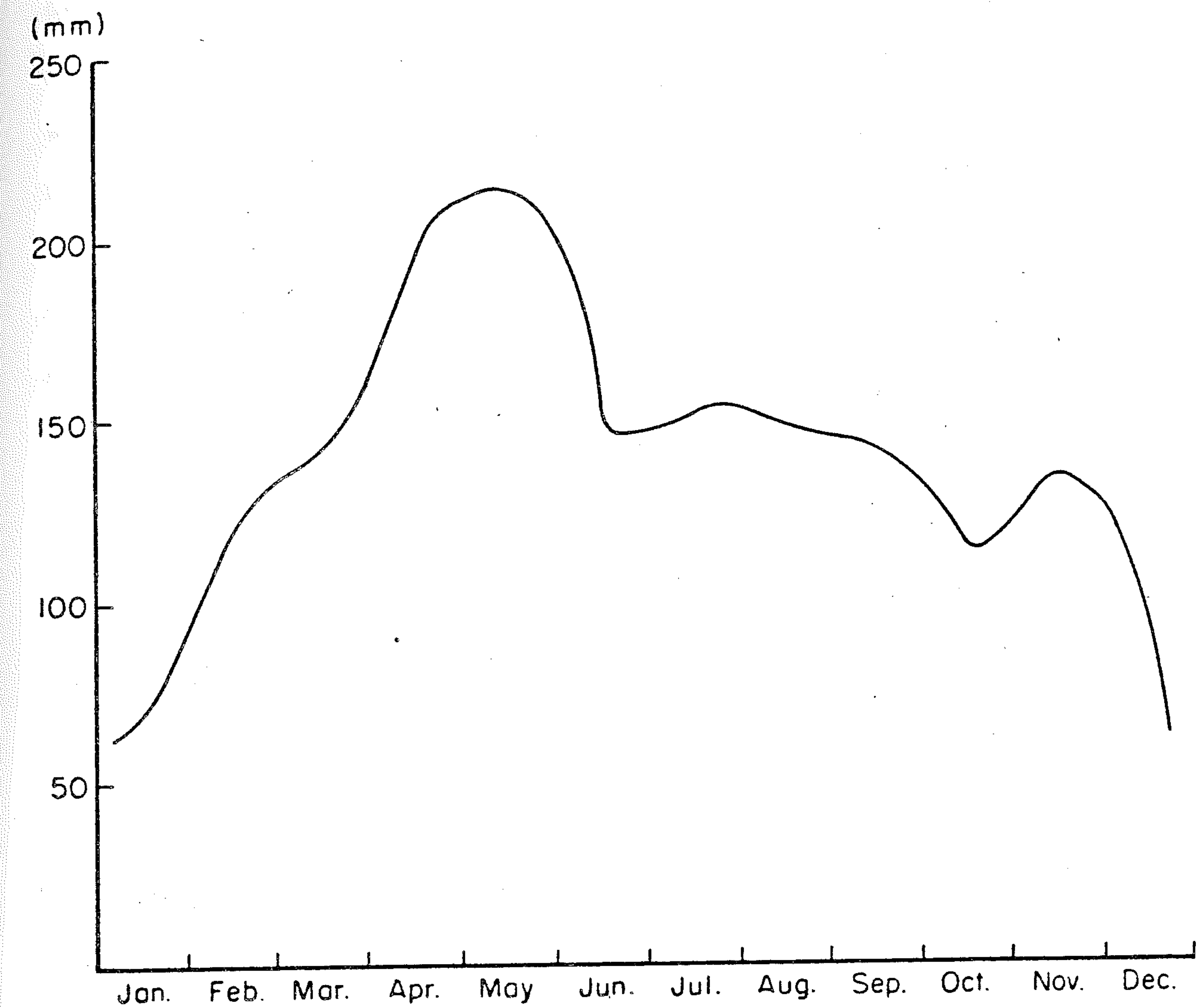


Figure 3.5: The Average Monthly Rainfall (Lurambi Division - Kakamega) 5-Year Average - 1977 to 81



dates with two levels each for spacing and fertilizer.His results showed that while the flowering dates varied slightly, all treatments had 50% of silk emerging at about 60 days from sowing. All plantings had the vegetative stages of development occupying approximately 60 days. Thereafter, cob and grain formation were important in all cases; the plants were ready for harvest at about 120 days from planting. Differences in the amount of rainfall available to each treatment were greatest during the later stages of development. Vegetative growth until flowering time showed no great variations. The lower yields of late plantings were due to a greater proportion of barren cobs, fewer grains per harvestable cob, smaller grain sizes and higher density of plant population. The experiment showed that an adequate supply of moisture during the later stages of development (grain formation and ripening) are crucial in obtaining higher yields.

Referring to the rainfall patterns shown in the study region (Figures 3.3-3.5) it seems that 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.

3.5.1.2 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 brown to Catosolic soils and some stretches of Vertisols and gleyed soils (Gleysols) 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.

3.5.2 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 the 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 the these locations assert that the prices of the inputs are higher than they can afford. Here then is a case where farmers differ in their capacity to obtain farm inputs. As will be evident in the next chapter, the farmers' characteristics and management skills are also associated with the emerging farming systems.

Chapter IV

DATA SOURCES AND SOME SAMPLE CHARACTERISTICS

This chapter describes the data base for the study and some important features of the sample. There were three sources of data. Use was made of the Integrated Agricultural Development Program (IADP) primary data set. This was supplemented with information from a sample of non-IADP farmers. The third source was secondary data obtained from government records in Kenya.

4.1 THE IADP SAMPLE

The Integrated Agricultural Development Program, which was initiated in Kenya in 1977 to promote the development of smallholder agriculture, has a monitoring and evaluation unit collecting production data from small farms. The small farms covered by the IADP are in 14 districts, including 3 districts from Western Province to be considered in this study. The aim of the data collection by the IADP unit is to monitor the progress of the program for small farms in the 14 arable districts.

In each district, a random sample of 40 farmers was selected. The sampling frame included all farmers who belonged to a cooperative through which any credit could be channeled. This is because the IADP program has in its package a credit component which allows loans to farmers who may not necessarily have land titles as collateral. In that case, the cooperative acts as a link between the government agency and the farmers. Data collection has been going on since 1977. The frequency of data collection depends on the type of information needed. General information about the holder, the household and the holding is gathered once a year, while information relating to crop inputs and any resulting output is gathered once a month[1]. This minimizes the recall period to which farmers are subjected. There is one enumerator for each cluster in a district.

Of the 40 original farmers selected in 1977, not all are still in the survey. In fact, even for the initial year not all records for each farmer were available by 1981. Consequently, the sample size was reduced to 30 farmers from Bungoma, 32 from Busia and 19 from Kakamega. All these farmers had records for both 1977 and 1981, and are referred to as "regular" farmers. The intervening years of 1978, 1979 and 1980 had rather irregular participation from the original farmers. Moreover, 1977 and 1981 were essentially normal years because there was no drought, as there was in the 1979/80 growing season. Using the observations for these two years was therefore believed to be the most appropriate

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[1] A structured questionnaire is used for interviewing the farmers by the enumerators, who were trained by the Ministry of Agriculture.

action. This gave a total of 81 paired observations for the regular farmers in 1977 and 1981.

4.2 CATEGORIZATION OF THE FARMERS

There were 4 categories of farmers. Farmers depending on the hoe for land preparation were designated as the hoe group (HND). Those who used owned oxen for ploughing were the oxen owners group (OXN). The other two groups hired oxen (OXH) and private or government tractor (TRCT) respectively.

Table 4.1 gives the number of regular farms according to the level of mechanization, year and location. Figure 3.1 provides the approximate location of the sample farms in the study area. For both periods, 33 regular farmers belonged to the hoe group, 60 to the oxen-owners group, 64 to the oxen-hiring group and only 5 to the tractor-hiring group. It is therefore clear that small farmers hiring tractors were very few. No regular farmer hired a tractor in 1977. Some farmers belonged to one group in 1977 but to a different group in 1981. For instance, a few farmers hired oxen for ploughing in 1977, but in 1981 either used the hoe or had acquired own oxen.

Table 4.1

The Number of Farmers Participating in the Survey

According to the Level of Mechanization

Mechanization	1977			1981			Total
	Bungoma	Busia	Kakamega	Bungoma	Busia	Kakamega	
HND	-	10	2	3	18	-	33
OXN	10	5	10	13	9	13	60
OXH	20	17	7	14	1	5	64
TRCT	-	-	-	-	4	1	5
Total	30	32	19	30	32	19	162

* Mechanization level:
HND - Used the hoe for land preparation.
OXN - Used own oxen for ploughing.
OXH - Hired oxen for ploughing.
TRCT - Hired a tractor for ploughing.

4.3 THE ADDITIONAL NON-IADP SAMPLE

An additional sample of 40 non-IADP participants were interviewed for the 1981 long rainy season. The sample frame was similar to that used by the monitoring and evaluation unit, but all the farmers who had been selected in 1977 were excluded before the additional farmers were selected. The purpose of having the additional sample was twofold. One reason was to contrast the original IADP sample which had existed since 1977 with the new sample. The second reason was to augment the sample size, since the number of regular farmers was not considered large enough to provide a basis for analysis or generalization.

With the help of the local agricultural officers, the four groups of farmers designated for the regular farmers were delineated from the sample frame. In each of the 3 regions under study, only one farmer had used a hired tractor in the sample frame considered in 1981. All of them were therefore included in the additional sample, although the Kakamega tractor-hiring farmer was unwilling to provide his production records.

The number of additional farmers in each of the four categories is shown by location in table 4.2. The tractors used in Bungoma and Busia cluster were hired from a private owner despite the proximity of the THS station in Busia. Those in the HND and OXH group each consisted of 11 farmers while the OXN group and the TRCT group comprised 16 and 2 farmers respectively.

TABLE 4.2

Additional Non-IADP Farmers According to the Level of Mechanization

Mechanization	Bungoma	Busia	Kakamega	Total
HND	2	5	4	11
OXN	6	4	6	16
OXH	8	2	1	11
TRCT	1	1	-	2
TOTAL	17	12	11	40

4.4 THE AUGMENTED SAMPLE

The regular farmers, together with the additional farmers, comprise the augmented sample. Table 4.3 shows the categorization of farms according to level of mechanization for the regular farmers in 1977 and the augmented sample in 1981. The sample size was 81 and 121 for 1977 and 1981 respectively. This gave a total of 202 observations for the 2 periods.

The three enumerators of the monitoring and evaluation unit assisted the author in interviewing the farmers of the

Table 4.3

The Augmented Sample According to

Level of Mechanization and Cluster

Mechanization	1977			1981			Total	% of Total*
	Bungoma	Busia	Kakamega	Bungoma	Busia	Kakamega		
HND	-	10	2	5	23	4	44	22
OXN	10	5	10	19	13	19	76	38
OXH	20	17	7	22	3	6	75	37
TRCT	-	-	-	1	5	1	7	3
Total	30	32	19	47	44	30	202	100

* Refers to the % of total number of observations.

augmented sample in 1981, using the structured questionnaire given in Appendix A. The information obtained in 1981, together with the 1977 survey records held by the Ministry of Agriculture, were compiled. The data set formed the basis for summarising the characteristics of the sample farms and for further analysis.

4.5 CHANGES IN THE LEVEL OF MECHANIZATION AMONG THE SAMPLE FARMS.

The grouping of the farmers was based on the method of land preparation, because that was the distinctive feature in the level of mechanization. For regular farmers, the changes which occured in the level of mechanization between 1977 and 1981 can be discerned from Table 4.4. The proportion of farmers hiring oxen declined from 54% to 25% between the periods. Some of those hiring oxen in 1977 reverted to use of the hoe, while others acquired oxen. Thus, the proportion using the hoe for land preparation rose from 15% to 26%, while those owning oxen rose from 31% to 43%. There was no tractor usage among the sample farms in 1977, but the proportion using a hired tractor was 6% in 1981.

These changes reflect the evolving pattern of the methods of land preparation. Although a priori, it was thought that the proportion relying on the hoe for land preparation would be very high, as reflected in the national average (Table 3.2), it turned out that it was relatively low, being between 15% and 26%. Farmers justifiably expressed their desire to

TABLE 4.4

The Changes in the Level of Mechanization Between 1977 and 1981 for Regular IADP Farms

Year	1977		1981	
Mechanization	No	% of total	No	% of total
HND	12	15	21	26
OXN	25	31	35	43
OXH	44	54	20	25
TRCT	--	--	5	6
TOTAL	81	100	81	100

reduce the drudgery involved in hoeing if they could. Those who failed to hire oxen for ploughing either reverted to hoe use, despite the drudgery, or acquired oxen and ploughing equipment. Failure to hire oxen was due either to the difficulty of raising enough cash to pay for it, or simply because the oxen owners were busy in other fields. It was apparent that during the ploughing period more people sought the oxen-hiring service than were oxen available, with the consequence that the charge per acre tended to be relatively high. Failure to use own oxen in some cases was due to lack of both the oxen and the equipment; in some cases it was due only to lack of the equipment.

The charge per acre for using a private tractor was about Kshs. 200, or almost 2.5 times that for hiring oxen for ploughing in 1981. For a government tractor, the charge was about 1.7 times that for hiring oxen, although the availability of the tractor for a single small farmer was not assured. Some farmers were not even aware of the existing government tractor-hiring services. Some complained that they couldn't rely on the tractor service, since the station was far away. Practically, of course, it is difficult to centralize a tractor service and at the same time make it accessible to most small farmers. Usage of a tractor seemed to depend either on the ability to raise the money for the private service or to be influential enough to get the government tractor service to come to the farm.

There were cases where bulls/oxen were on the farm but the farmer had no plough[2]. One possibility of assisting the majority of small farmers to raise the acreage planted to a crop is to increase the density of available oxen ploughs in a region. Such a strategy can be easily facilitated if the animals for traction are already available within the farms. This would have three consequences. The charge per acre for renting oxen-plough would be relatively lower than before,

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[2] The bulls/oxen needed training before they could be utilized for ploughing. However, most farmers already owning oxen responded that they trained their animals traditionally using the shout and whip method. Interviews with the local agricultural officers familiar with these locations revealed that not more than 50% of the farmers own oxen plough in any one location, while over 80% own cattle.

hence an additional number of small farmers could afford to hire. Second, most of the ploughing on the small farms would be done soon after the onset of the long rains. Third, those able to acquire the oxen and the ploughing equipment if assisted initially, would get additional income from renting the oxen to their neighbours. The characteristics of the farms are crucial when considering the possibilities of expanded use of one method over another.

4.6 THE CHARACTERISTICS OF THE SAMPLE FARMS

Such important features as the size of farm, the average times that planting and weeding take place, maize acreage, and the proportion of fallow for different groups of farms were considered in studying these farms. In addition the family size and the available farm labour were important in determining if any changes were likely to bring displacement of labour. The other agronomic practices, such as fertilizer used, weeding frequency and intercropping, were also considered.

4.6.1 The Size of Holding

Four categories for size of holding were established so that the size distribution within each sample could be examined. These categories were: 1. very small farms, between 0 to 5 acres; 2. small farms, between 5 to 10 acres; 3. medium farms, between 10 to 20 acres; and 4. large farms, over 20 acres. Table 4.5 shows the four size categories and the proportion of each group in each category between the periods.

For the hoe group, one half of the farmers had less the 10 acres of land in 1977, while in 1981 the proportion in this size range increased to 76 percent. This increase in the proportion of those with relatively smaller acreages was due to the shift of those who hired oxen in 1977 to hoe use. About 34% of the farmers in the hoe group were within the medium size category of 10-20 acres, while 17% had more than 20 acres in 1977. In contrast, in 1981 only one fourth of the farmers in the hoe group had more than 10 acres of land.

There was no oxen owner in both periods with less than 5 acres of land. Over 75% of the farmers had more than 10 acres of land. This reflected the need to have more acres of holding for grazing the animals[3]. Half of the farmers in the oxen-hiring group also had less than 10 acres of land in both periods. To the extent that some oxen owners in the sample also had between 10-20 acres, it seemed possible that some of the farms in the category hiring oxen could manage to own oxen and utilize their land for grazing the animals. Some initial assistance would have to be provided for farmers who are willing but not able to acquire the oxen or the equipment. The issue is discussed more fully in Chapter 6.

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[3] It was sometimes the case that cattle from different farms were grazed together, not necessarily on the owner's land.

Table 4.5

The Size Categories and the Proportion of

Regular Farms by Level of Mechanization

Size of Holding	1977				1981			
	HND	OXN	OXH	TRCT	HND	OXN	OXH	TRCT
	------------percent------------				------------percent------------			
0 - 5 acres	8	-	5	-	33	-	30	-
5 - 10 acres	42	24	45	-	43	14	20	80
10 - 20 acres	33	48	36	-	14	52	30	20
> 20 acres	17	28	14	-	10	34	20	-
Total	100	100	100	-	100	100	100	100
Total observations (No.)	12	25	44	-	21	35	20	5

Those who used tractors did not necessarily have the biggest acreage. Four of the farmers using the tractor for ploughing had 5 to 10 acres, while one had about 18 acres. It seemed that tractor-hiring mainly depended on the urgency to plough and the availability of the cash to hire the service. Farmers seemed to be using off-farm income, mainly remittances from an urban area, to hire tractor work. There was reluctance on the part of all the respondents to reveal either the amount or the regularity of such remittances. In fact, in some cases where the cash remittances were not regular, farmers who hired oxen or tractor to plough failed to raise the cash to hire labour to perform the subsequent operations adequately.

4.6.2 The Time of Planting Maize

To examine the relationship between the level of mechanization and planting, farmers were sorted on the basis of average date of planting. Four categories were considered for date of planting. Early planting was considered to have taken place between week 1 and 4 or in January, just before the rains begin. Planting in this period is referred to as dry-planting by agronomists. Planting on time was considered to occur between weeks 5 and 7; this is the period within February when the long rains are normally expected to begin (see Figures 3.2 to 3.5). Late planting occurred between weeks 8 and 10; very late planting took place from week 11 onward (Table 4.6). Since staggered planting was common amongst the small farmers, the average time that planting was completed on the maize plot was determined.

TABLE 4.6

The Proportion of Maize Planting at Various Times According to the Level of Mechanization

	Mechanization			
WEEK *	HND	OXN	OXH	TRCT
	Percent			
1-4	--	1	--	--
5-7	75	55	35	71
8-10	9	24	20	--
>11	16	20	45	29
Total	100	100	100	100

* Weeks numbered from January.

The practice of dry planting was uncommon, irrespective of the level of mechanization applied in all areas of the study. Only one oxen farmer in Kakamega planted early, and then only once, in 1977. Most farmers in the hoe group planted on time. Only 25% in the group planted in the period designated as late to very late. This timely planting by the group may be due to the fact that the area readied for planting was generally low, so that planting could be completed within a short time, especially if the seed was broadcast instead of planting in rows[4]. The experience of the farmers revealed that early planting was taken very seriously. Thus, although time staggering in planting was common, very late planting was generally avoided.

Over 50% of the oxen owners planted on time, but 44% in the group planted late to very late. It is apparent that most of those who planted late among the oxen owners preferred to rent out their oxen first to prepare their neighbours' land for cash, rather than preparing their own plot on time. The proportion planting late in this group can be reduced if the number of farms owning oxen and ploughing equipment can be increased. Similarly, the high proportion of those planting late to very late among those hiring oxen (65%) could be reduced. Two of those using the tractor planted very late. The reason given for this late planting was that the land preparation by the tractor was done late. Usage of a tractor therefore doesn't guarantee timely planting.

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[4] In Kakamega, where maize acreages were generally larger than their counterparts in the other clusters, almost 80% in the hoe group planted late to very late.

4.6.3 Timeliness and Frequency of First Weeding

The weeds start competing with the crop for water and nutrients soon after its establishment. It is necessary to have a relatively weed-free maize plot if yields are to be improved. Maize germinates after about 7 days. Assuming that optimal maize development pattern in a rainfed environment is fixed, we would expect that those who plant early but weed late incur a considerable yield loss. Similarly, those who plant late and weed late suffer an even greater yield loss. Taking weeding within March (weeks 8-10) to have been timely for those who planted relatively early (by early March), about 30% among the hoe group weeded on time, and 34% and 28% weeded on time among the oxen owners and those hiring oxen respectively (Table 4.7). It appears that the weeding pattern for each of the groups had no difference. A relatively large proportion in each of the groups weeded late.

Despite the late first weedings, some farmers still adhered to the advice to weed twice. This is considered beneficial, especially if the first weeding is done on time. Whether those weeding twice had greater labour productivity will be examined in Chapter 6.

4.6.4 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,

TABLE 4.7

The Proportion of Farmer Using Various Mechanization Types Completing Weeding in the Given Periods

Time (week)	Mechanization			
	HND	OXN	OXH	TRCT
	Percent			
8-10	29	34	28	43
11-14	52	50	35	43
>14	19	16	37	14
Total	100	100	100	100

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.

4.6.5 The Labour Profiles

The average labour used per operation by calendar month was calculated for each group of farms[5]. Family labour and hired labour were considered separately for purposes of drawing the labour profiles.

4.6.5.1 The Hoe Group

The labour profile for the hoe group is presented in Figure 4.1. 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

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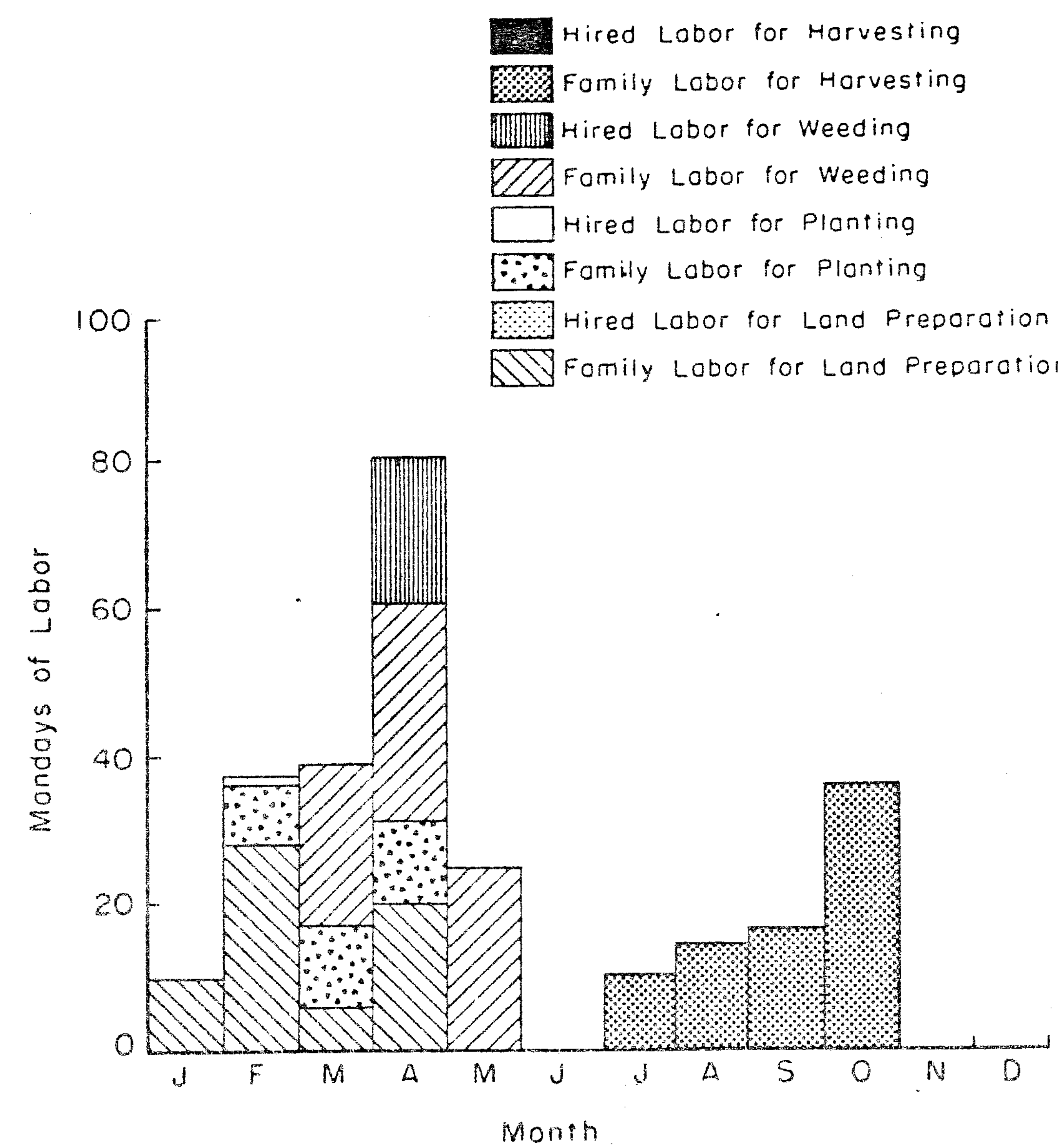
[5] The calendar months were used only for convenience. Normally the operations are not neatly divided by calendar months.

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.

4.6.5.2 The Oxen Owners Group

The profile for the oxen owners differed from that of the hoe group in various respects. Figure 4.2 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

Figure 4.1: The Maize Production Labour Profile for the Hoe Group



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.

4.6.5.3 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 4.3). 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.

4.6.5.4 The Group Hiring Tractor

The labour profile for this group is presented in Figure 4.4. Although the profile was based on a sample of only seven

Figure 4.2: The Maize Production Labour Profile for the Oxen Owners Group

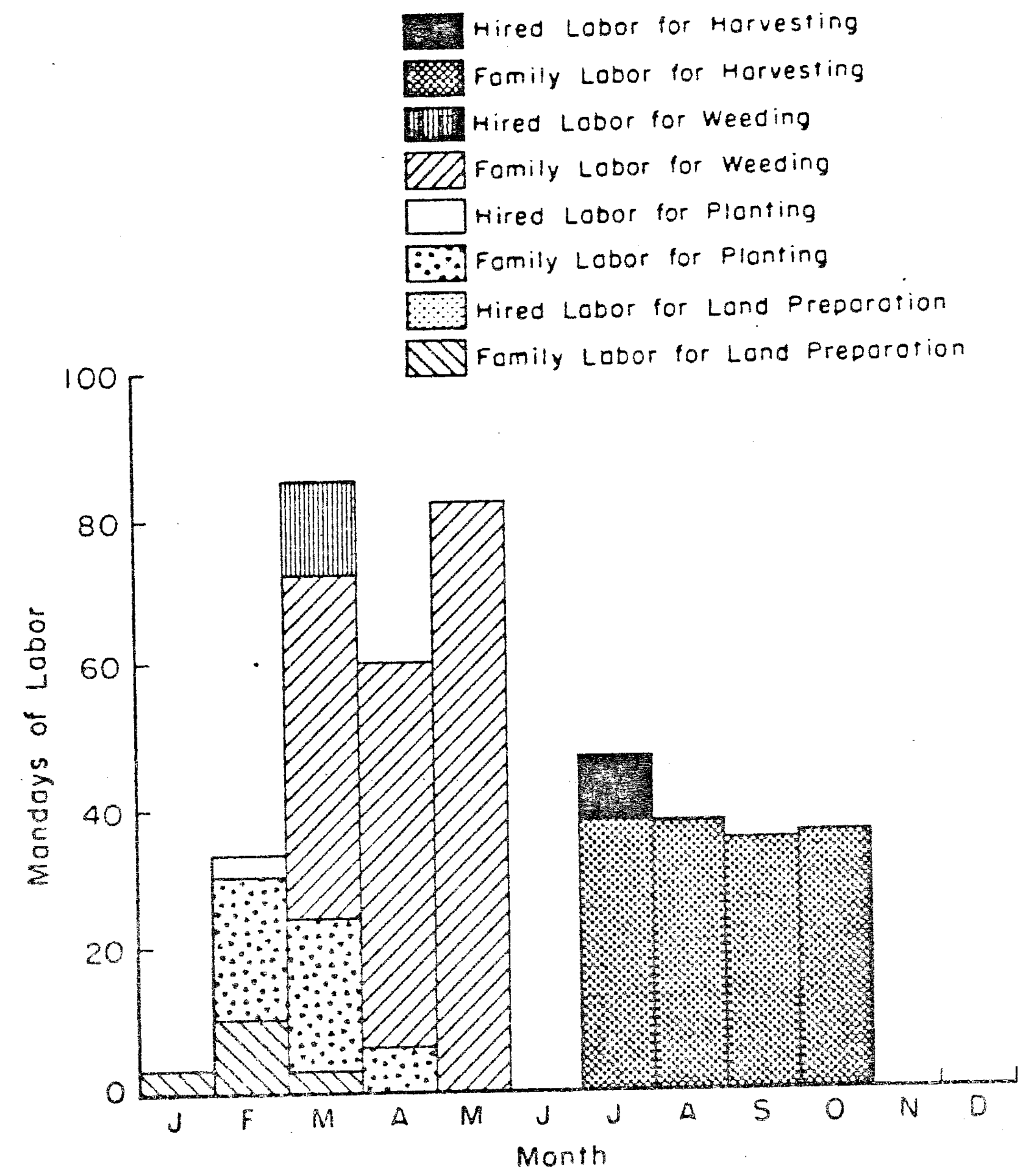
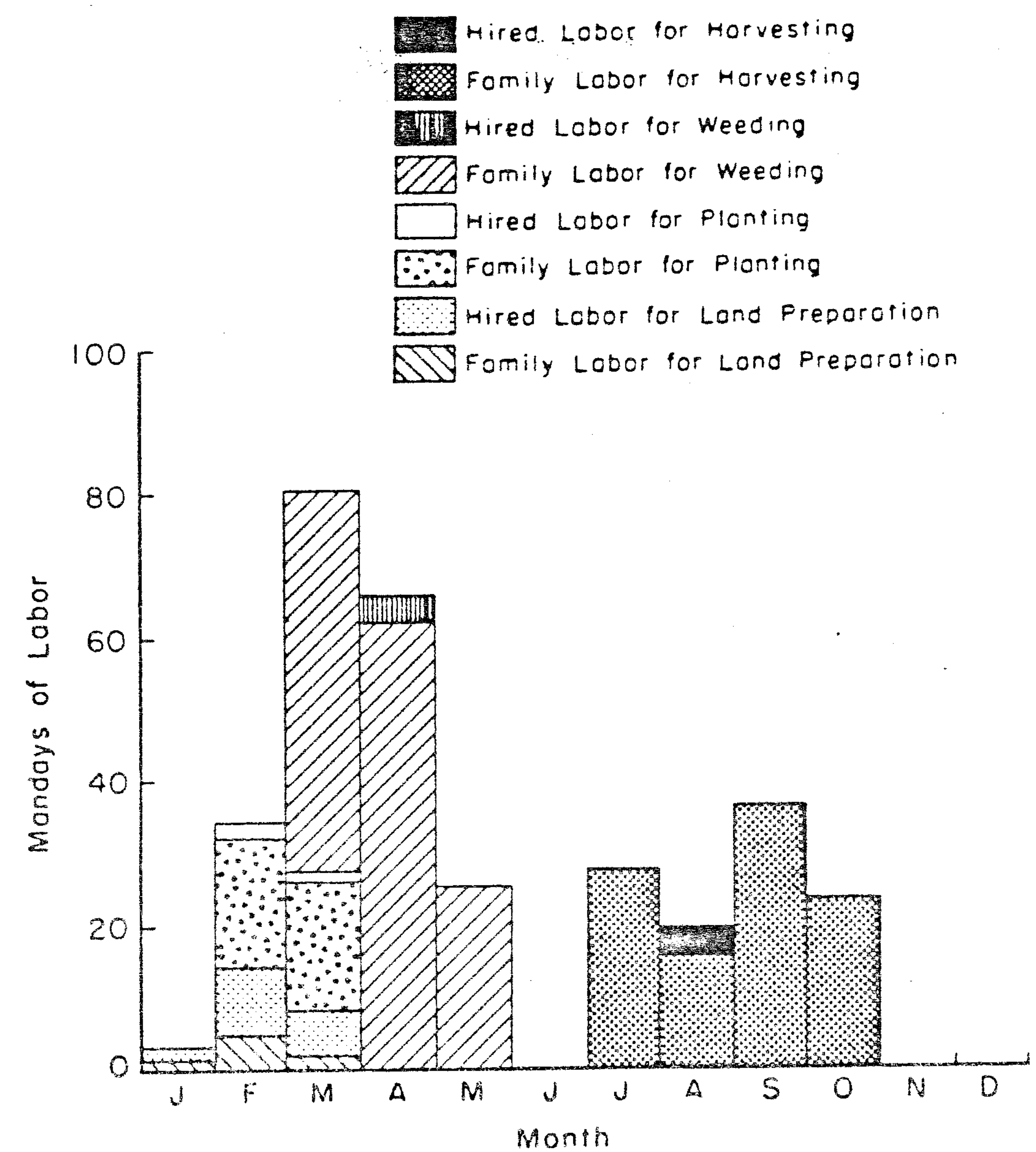
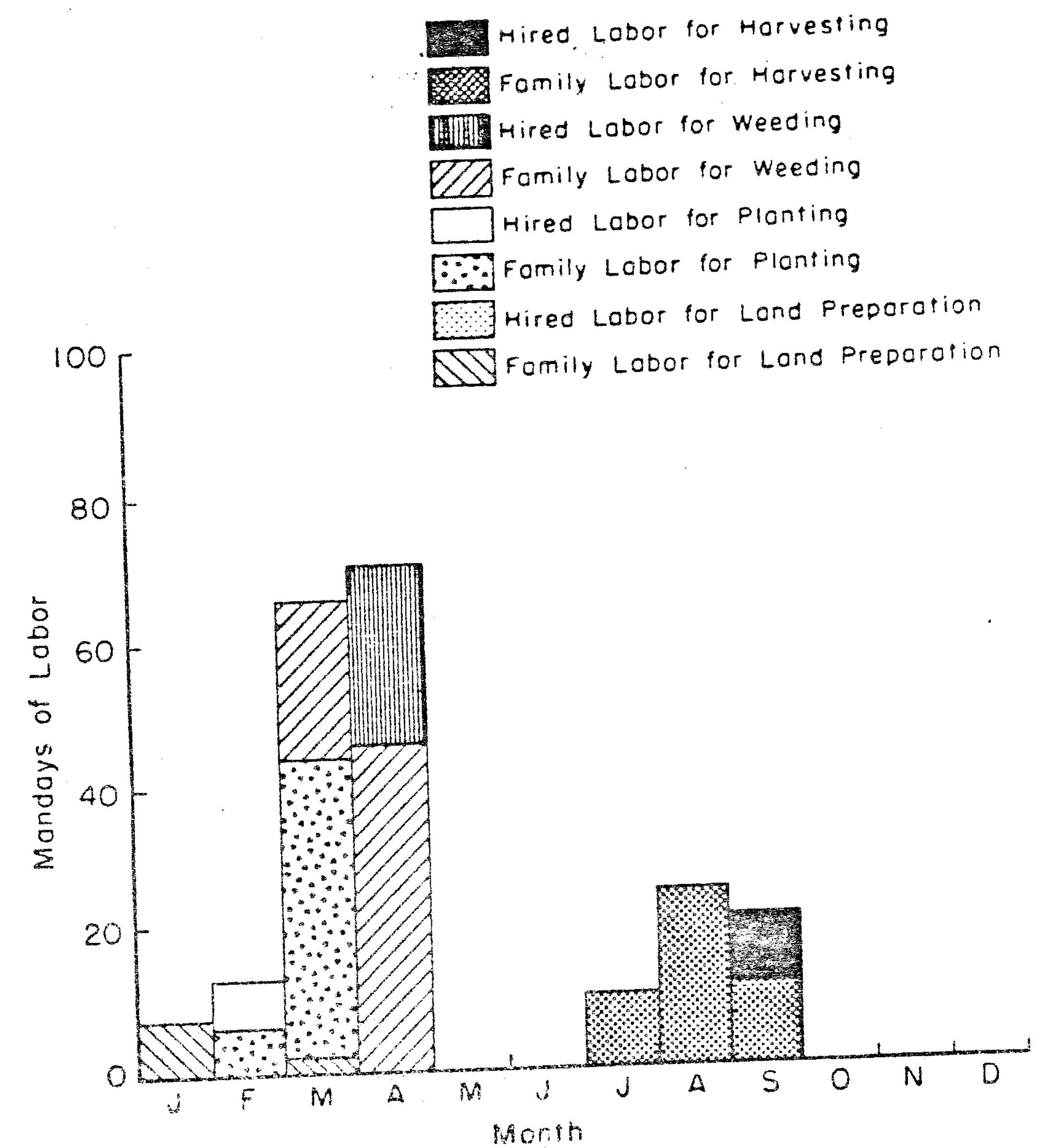


Figure 4.3: The Maize Production Labour Profile for those Hiring Oxen



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 4.4: The Maize Production Labour Profile for the Tractor Hiring Groups



4.7 DESCRIPTIVE STATISTICS FOR SAMPLE FARMS

The mean values for some of the variables, classified by degree of mechanization, were calculated for all the farms. Table 4.8 shows these values. The sample of farms hiring a tractor was very small, and this made meaningful generalization very difficult. However, to the extent that the small farm population in the study area includes only a few farms occasionally hiring a tractor, the averages in the sample may be considered as representative as anything available.

The average family size was smallest for the tractor farms (about 6 people) and largest for those owning oxen (about 12 people). Members of the family above 14 years were considered able to contribute fully towards the production of maize. The proportion of those over 14 years to the family size did not differ very much between groups. It varied from 41% for the group owning oxen to 49% for the hoe group, with the proportions for the other groups falling in between[6].

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[6] It is remarkable that although a considerable proportion of household members consisted of children below 14 years of age, the children, especially those above 7 years, can perform various tasks, including looking after cattle or scaring birds from the crop fields. These are very important contributions. However, the greater proportion of children on a farm may cause a dependency burden for the adults, who contribute significantly to food output.

TABLE 4.8

Descriptive Statistics (Mean Values) of Selected Variables in Each Group of Farms

Variables (Units)	Level of Mechanization HND	OXN	OXH	TRCT
Family size (No)	7.7	11.8	9.4	5.9
Size of holding (acres)	9.4	25.0	13.5	8.3
Proportion of fallow (%)	45.0	42.0	44.0	46
Area of maize (acres)	1.6	4.2	2.7	3.1
Maize yield (kg)	400	600	560	546
Planting date(week*)	7.9	7.0	9.2	7.4
Adults on farm (No)	3.4	4.7	4.0	2.4
Prop. of adults**(%)	49.0	41.0	48.0	43.0
Farm size/adult(ratio)	3.1	5.3	3.5	3.7
Maize acreage/ adult (ratio)	.54	1.1	0.8	1.3
Fertilizer/acre (kg)	18.0	23.0	40.0	10.0
Seed rate(kg)	9.9	8.4	8.8	9.2

* Date of planting: week, numbered from January (5-7 February, 8-11 March)

** Number of adults/family size.

The number of adults on the farm was found to cluster between two to five. The average size of holding was largest for farms owning oxen (about 25 acres) and smallest for the farms hiring tractor (about 8 acres). The average acreage by type indicate that it was not necessarily the largest farms which hired a tractor. Tractor-hiring or oxen-hiring was based on the need to have the ploughing done faster if one had the money to hire the services, irrespective of the size of holding.

Fallow land, defined as the land with no crop on it at the time of the survey, existed in each of the farms. The proportion of fallow was between 42% and 46% in the sample farms. Most farmers indicated that they needed the fallow for grazing of livestock. Others who did not have livestock indicated that they could not manage to put all of their land under crop. Part of the reason for fallow seemed to be the necessity to rest the land for soil conservation purposes.

Maize occupied an average of 1.6 acres for the hoe group farms, 4.2 acres on the oxen-owning farms, 2.7 acres on the oxen-hiring farms, and 3.1 acres on the tractor-hiring farms. These maize acreages appear to be rather low. The low maize acreages may have been due to the small farmers' interest in producing for subsistence, and since previously movement of maize across districts was restricted, cash sales seemed unlikely. It is estimated that one adult-equivalent equals about 120 kg. of maize per year for consumption (Kenya 1982).

In a farm with 4 adults, one acre of maize may therefore be sufficient for subsistence if a yield of about 500 kg. can be achieved. The restriction of cash maize markets resulted in almost no incentive to produce surplus of this crop.

The average maize yield (output of maize/acre) varied from about 400 to 600 kg. Such a maize yield would sustain about 4 adult-equivalents adequately for a year if a farmer cultivated only one acre of maize. However, if a farmer producing only maize were compelled to sell a proportion of that output, he is at risk of experiencing famine for some part of the year[7]. The Ministry of Agriculture expects a yield potential of about 1800 kg. per acre if all the proper agronomic practices are followed in the study region. Since only about one third of the expected yield is achieved on the sample farms, either these farmers are not applying the recommended agronomic practices, or the experimental yields suggested are outside the reach of practicing farmers.

The average planting date was about the first week of March for all the groups except that hiring oxen, which planted in the third week of March. Recognizing that the optimal date recommended for planting is mid-February, just when the long rains are expected to begin, most farmers must have planted late. Referring to the above labour profiles, it was observed

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7. Indeed, most small farmers have been shown to consume only 50% of own produce and sell the remainder (Kenya 1977 p. 63). If the farm output is small, this may result in inadequate diets for the household unless off-farm income supplements the farm income.

that some farmers planted as late as April.

The amount of land per adult (farm size/adults) was 5.3 for the oxen-owning farms. This contrasted with the remaining groups, where this ratio was between 3 to 3.7. It appeared that each adult had sufficient land to work on, and that land was not a constraint. On the other hand, the ratio of maize acreage/adult was relatively low for the hoe group, being only 0.54. This ratio was 1.1 for oxen-owning farms, 0.8 for oxen-hiring farms, and 1.3 for tractor-hiring farms. It was apparent that the maize acreage for the hoe group could have been increased to more favorable proportions by the adults on the farm. This could be done by readying more land for subsequent operations.

The average fertilizer used per acre was generally low across all groups of farms. Only the group hiring oxen applied a significant amount of fertilizer per acre (40 kg). The rest of the group applied between 10 kg. and 25 kg. of fertilizer. Because the fertilizer was normally bought in 50 kg. bags, it appears that farmers who used fertilzer bought only one or two bags and then spread that quantity over the entire maize plot. Some farmers with livestock used animal manure instead of fertilizer. However, ownership of livestock did not insure manure application to the maize plot.

The amount of seed planted per acre of maize averaged from 8.4 kg. for the oxen owners group to 9.9 kg. for the hoe group. Recalling that the recommended seed rate by the

Ministry of Agriculture is 25 kg. per hectare (10 kg. per acre), the farmers were close to the recommended practice. However, the seed was not necessarily the purchased hybrid variety, and most frequently was own stored seed from the previous harvest.

4.8 OTHER ASPECTS OF THE FARMING SYSTEM

This section describes the existing farming situation with regard to crops and agronomic practices. The kinds of crops grown, whether they were grown in pure stands or intercropped, and the integration of crops and livestock are considered.

4.8.1 The Other Food Crops

In addition to maize, the common food crops were sorghum, beans, finger millet, cassava and potatoes. Beans were mainly intercropped with maize. The farms studied from Busia district had the greatest diversity in cropping patterns, with such crops as bananas and rice also grown by about 30 per cent of these farmers. The wide variety of food crops in the Busia sample meant that the labour devoted directly to maize was reduced. In contrast, the cluster from Kakamega had little diversity in food production. Apart from beans and sorghum, no other food crop was grown by the respondents.

4.8.2 Cash Crops

Cash crops such as sunflower, cotton, tobacco, groundnuts and sugarcane were grown in the area. The implication of growing cash crops was that land and labour had to be allocated between cash crops and food crops. Categorizing farmers according to whether they had cash crops or not on their farms revealed that the proportion of regular farms having cash crops differed markedly between 1977 and 1981. In Bungoma, about 83% of the farmers grew cash crops on their holding in 1977. This increased to about 93% in 1981. In contrast, there was a decrease in the proportion of farmers growing cash crops between 1977 and 1981 in Busia. About 56% had cash crops in 1977, but only 28% grew them in 1981. This significant decline may be attributed to the lack of enthusiasm which developed for growing cotton in Busia. Paradoxically, the tractor-hiring service was stationed in Busia mainly to help raise the cotton production from small farms, and yet by 1981 not more than 10% grew cotton! Part of the reason for the decline in cash crop production in Busia might be connected with greater diversification in food crops[8]. For Kakamega, only 15% of the sample had cash crops in 1977, but the proportion rose to 26% in 1981. The increase in Kakamega was due to the promotion of sugarcane growing by smallholders after the Mumias Sugar Factory was established.

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[8] Following the coffee boom of 1976 to 1978 and the subsequent famine of 1979/80, farmers in Busia (which borders Uganda) must have learnt that having cash may be no good if there is no food to buy.

Those who did not have cash crops as such sold a proportion of maize output to obtain cash.

4.8.3 <u>Intercropping Practices</u>

The practice of intercropping is prevalent. The issue as to whether intercropping is better than monocropping for small farms has received some attention among researchers (e.g. Norman 1974). Some extension agents condemn the practice of intercropping but farmers ignore them. In our sample, over 80% were intercropping maize with beans. When sole maize was grown, it was largely because beans were not grown that season.

Theoretically, the effect of one crop on the physical yield of another in a mixture depends on whether their relationship is competitive or complementary. It is known that beans, being legumes, fix nitrogen which is beneficial to maize. The maize plant population is lower with intercropping, but it has been found that the total returns to labour per acre is higher with intercropping than with monocropping (Norman 1974). It is therefore not unusual that the practice of intercropping is predominant among the small farms. However, as far as mechanization is concerned, the practice inhibits use of oxen or tractors for weeding, since the bean seed is broadcast between the row-planted maize crop. In any case, to the extent that some farms still broadcast the maize seed when planting, higher levels of mechanization would continue to be confined to land preparation and transport, even if the oxen were trained for weeding maize.

4.8.4 Integration with Cattle

About 70% of the farmers in the Bungoma and Kakamega samples owned cattle, while about 35% had cattle in Busia. The animals were either the traditional Zebu cattle or crossbreeds resulting from artificial insemination. Where there were cattle but no oxen or bulls, the herd comprised cows which provided a small amount of milk for the family. Their manure was not always used on the fields, largely because of the bulkiness and the heavy work involved in applying it to the distant crop fields. Crops grown close to the homestead, however, had better soil due to the organic manure from the animals grazing near the home[9].

The respondents who had cattle had fallow land available for grazing, and there was very little supplementation with grains. However, in most cases, the land area left fallow was larger than necessary to maintain the cattle[10].

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9 Azevado and Stout (1974) report that animal manure generally cannot increase short-term crop yields as much as equivalent amounts of chemical fertilizer. Depending on the nature of the field, availabilities of manure nitrogen are only 30 to 40 percent in the first year, but significant improvement in soil properties is assured. Experiments on maize have shown that animal manure was only 20% as effective as ammonium sulphate in increasing yields.

10 1 acre of grassland is sufficient to maintain a cow or ox in this region (Muasya and Schmidt 1980). For those using a 4-oxen team, the area necessary for oxen maintenance would be 4 acres. However, since there is evidence that 2 well-trained oxen could equally perform the task, if a

The fact that these farmers are already familiar with cattle raising provides a better opportunity for success in promoting ox-plough, should this be economically viable for those presently relying on the hoe. As Lassiter (1982) reports for Upper Volta, the farmers who had no prior experience with cattle had a long expermental period before they could make good use of the animal traction package the government was trying to promote.

Almost all the farmers who owned oxen used them for some kind of transport such as carrying building material or farm produce. Ox-carts were made locally. Building materials were transported on a kind of sledge which required considerable effort on the part of the animals. There was certainly room for improving this transport method. It was surprising that the manure was not being transported to the fields by the oxen. Those who did not use oxen for transport used human labour. None hired a tractor for any other purpose apart from land preparation.

4.8.5 Usage of Purchased Inputs

In the initial years of IADP, considerable effort was made to provide credit to the farmers to purchase fertilizer. That effort was not sustained either due to problems in repayment from farmers who received the credit first, or due to

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2-oxen team is encouraged, the area for oxen maintenance could be reduced, or there could be spare animals for traction.

procurement problems. The fertilizer price has also been rising. Thus, usage of fertilizer showed a considerable decline between 1977 and 1981. For instance, in Bungoma 93 percent of the respondents said they used fertilizer in 1977, while only 27% did so in 1981. The proportion reporting use of manure rose from 3 percent in 1977 to almost 60 percent in 1981. The Busia and the Kakamega samples showed a trend similar to that of Bungoma.

None of the farms in the sample purchased any crop protection chemical (such as insecticides) to be used in the field or in storage. No herbicides for weeding were purchased, which implies that the minimum tillage technique may have limited application, because the practice depends on eradicating weeds and grass in fields by use of selected herbicides.

4.9 THE IMPLICATION OF POWER SOURCE LABOUR REQUIREMENT AND FARMING SYSTEM

In this chapter, the survey data was used to examine the pattern of labour use for growing maize in the long rainy season. The existing farming system was also discussed. The power source in land preparation determined the acreage which could be readied in time for subsequent operations. Farmers seemed to have an idea beforehand about how much acreage they wanted to allocate for maize, based on the resources they commanded and what yield they expected. The labour profiles showed a remarkable similarity to the rainfall pattern. They indicated that where higher levels of mechanization were used in land preparation for maize production, subsequent operations called for a greater labour input. The farmer would feel committed to complete all the operations based on the available resources. Thus, evidence existed that a higher level of mechanization was associated with greater subsequent demand for labour in this area, because a larger acreage was planted. The overall labour used per acre of maize did not differ very much between the groups. Thus labour displacement effects of higher mechanization seemed to be non-existent when a higher level of mechanization was used only for land preparation.

Farmers had the desire to reduce the drudgery in farm work. Between 1977 and 1981 the proportion in the sample owning oxen increased from 25 to 43%. Although some of those hiring oxen reverted to hoe use, the willingness to reduce drudgery was demonstrated. Because of the familiarity with cattle, promotion of oxen ownership would not be a problem for most farmers. A significant proportion of land in each group was left fallow. Moreover, each adult in the hoe group on the average managed only 0.54 of an acre of maize, as opposed to about 1 acre managed by those owning oxen. Tractor hiring was clearly limited among the small farmers in the region, despite a government hiring station located in the province. Based on the farming system in the region, the potential for further promoting use of oxen ploughing is high.

Chapter V

THE THEORETICAL BASES UNDERLYING THE ANALYSIS OF MECHANIZATION, PRODUCTIVITY AND PROFITABILITY

Increased agricultural productivity is a primary requirement for rural development. A higher level of selected mechanization may be one of the instruments which will help in achieving that goal. The previous chapter has considered the characteristics of the farms in the study area. Partial mechanization was found to be one characteristic of crop husbandry on some farms. The aim of this chapter is to consider the theoretical underpinnings of farm mechanization for a given environment. Specifically this chapter will:

1. identify the technical relationships that theoretically exist between maize yields and the specific factors of production.
2. provide a framework for evaluating the profitability of use of different levels of mechanization for specific production situations by farmers.

Use is made of production function analysis to identify the productivity of the various resources in producing maize. A production function is a technical relationship based on physical input - output relations indicating the yield attainable for alternative combinations of a set of defined inputs. Based on these technical relationships, a partial budget framework is used to evaluate the profitability of the different levels of mechanization. The results are represented and discussed in the following chapter.

5.1 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.

5.1.1 The Model Specification

The appropriate functional form for a given production system is both a logical and empirical problem. The biological basis of the form specified is an important consideration.

A general production function can be represented as:

$$Y = f(X_k) \qquad \text{(i)}$$

Where Y = the output of maize per acre (yield)

X_k = set of K inputs

Such a relationship, linking yield to K inputs in a purely physical fashion, is difficult to model. In the case of maize production, a complex system is involved. Yield is increased or decreased by the physical environment including the action of the farmer and his tools. Therefore we are forced to make some assumptions to enable estimation. In in practice, the function for estimation becomes:

$$Y_i = f(X_{ki}) + e_i \qquad \text{(ii)}$$

Where e_i is the disturbance term to reflect variability unaccounted for and the subscript i represents farm i.

The usual regression assumption about e_i is that individual disturbances are independent of each other, have zero mean and a constant variance. It encompasses measurement errors and also any relevant variables which should have been included in the analysis but are not observable.

The postulated key variables in maize production are discussed in section 5.2. After examination of the data by partial analyses such as scattergrams and correlation matrices, the functional forms which appeared to be most useful and biologically appropriate were the linear and the Cobb-Douglas forms. The physical input and output units were used to fit the function. The functions which required the use of wage rates, such as the profit function, were not included, because in the sample the wage rates did not vary among the farms studied.

The linear equation is easy to estimate and explain because some of least squares regression is built on linear model. A simple linear equation for a given production function can be represented as:

$$Y_i = a_o + \sum_{j=1}^{k} b_j X_{ij} + e_i \qquad \text{(iii)}$$

where a_o = the intercept term, b_j = the coefficent for factor X_j and is assumed the same for all farms using the factor.[1]

In the simple linear framework, the coefficient b_j represents the numerical effect a unit change of X_j would have on Y_i. The objection of indiscriminate use of the linear form arises from the interpretation of estimates of a_o and b_j. If a_o is found to be positive and significant, it might be interpreted that some level of output can be achieved without any inputs! On a farm, it is known that without some labour, seed or land input, there can be no output. However, in circumstances where the level of X_j is non-zero Moock (1973), cited by Rukandema (1978), has pointed out that a simple linear functional form may pose no problem. This is because it may be assumed that the response of Y to changes in X_j , ceteris paribus, takes the form OT as in figure 5.1

In that case, if the observation on X_j is between B and E, then a linear function shown by LN in the diagram can be considered as a close approximation of the true production function, despite some variations of b_j across farms. The

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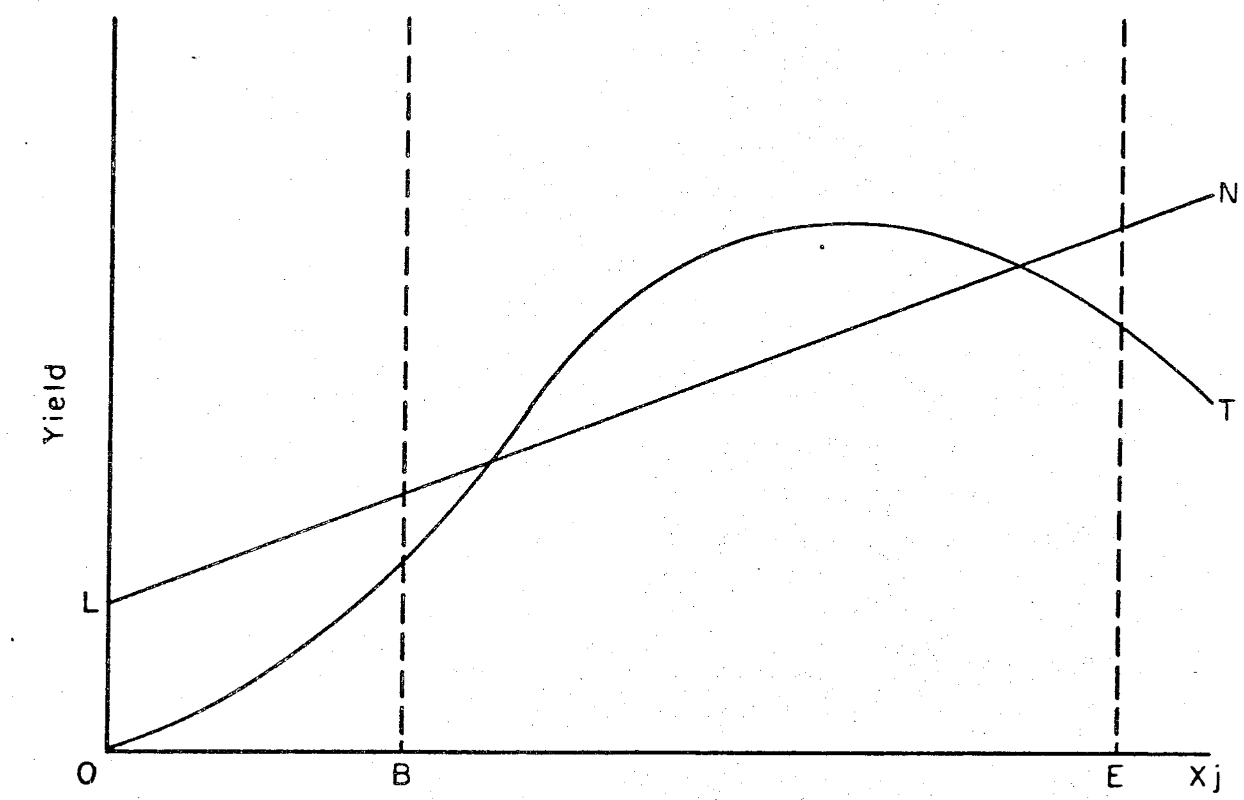
[1] The differences among farms is captured in the term e_i.

Figure 5.1: The Structure of the Changes in Output with Changes in Input X_j



interpretation of a_o is then not a problem because BE excludes zero level of input. Moreover, in cases where some key inputs (such as land or seed) are not specifically included in the function the coefficient a_o captures the inherent productivity or contribution to output from these basic inputs not specified among the variables in the regression equation.

The second problem regarding the coefficient b_j is that the marginal physical product of X_j is assumed to be constant, whatever the level of application with respect to itself and to other inputs. This may pose no problem if the inputs have no interaction with each other. When some interaction occurs between inputs or if the law of diminishing returns applies, marginal productivities also change. The ceteris paribus conditions are therefore crucial to the interpretation of b_j.

A functional form including exponential coefficients which describes the expected diminishing returns of technical relationships are exemplified by the production function typically called the Cobb-Douglas form. The Cobb-Douglas form can be represented mathematically as:

$$Y_i = aX_{j_i}^{b_j} e_i \qquad \text{(iv)}$$

This functional form has several desirable features.

(1) It can be easily transformed into the convenient linear form by taking the logarithm of the dependent and independent variables to become:

$$\ln Y_i = \ln a + b_j \ln X_{ji} + e_i \quad \text{(v)}$$[2]

(2) Unlike the linear form, the marginal product of a factor does not remain constant with increased level of input, i.e. marginal product of

$$X_j = dY/dX_j = b_j \; Y/X_j \qquad \text{(vi)}$$

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[2] The multiplicative nature of the error term in equation (iv) is justified mainly by convenience as indicated by Intriligator (1978). Thus, the error term is additive in (v) because in the original multiplicative form it is assumed to be raised to the natural logarithm.

Since Y/X_j declines as X_j increases, the marginal productivity of a factor declines with increased levels of the input. This is a logical and expected biological relationship.

(3) The coefficient b_j is also the elasticity of Y with respect to X_j. The elasticity of production is defined as the percentage change in Y that results from a one percent change in input X_j. Thus, it is:

$$(dY/Y)/(dX_j/X_i) = (dY/dX)/(X/Y) = (b_j\ Y/X_i)X_j/Y = b_j \quad \text{(vii)}$$

If b_j is between 0 and 1, then this implies that a one percent increase in input X_j always increases output by less than one percent, ceteris paribus.

(4) The economies of scale, which is indicated by the output change resulting from a simultaneous change of all the inputs by the same percentage can be obtained by merely summing the coefficients b_j. The key assumption in interpreting the subsequent results of the summation is that all the important inputs are properly specified and included in the equation, or are so correlated with the existing factors that they are incorporated in the regression coefficients. Thus,

$$\text{If } \sum_{j=1}^{k} b_j = 1$$

then constant returns to scale are implied; with a one percent increase in all the k inputs leading to an increase in output of one percent also.

If $\sum_{j=1}^{k} b_j < 1$, then we have decreasing returns to scale, where increasing all inputs by 1 percent results in a less than one percent increase in output. Increasing returns to scale occurs when $\sum_{j=1}^{k} b_j > 1$.

The elasticity of substitution, which measures the cumulative percentage rates of substitution between factors of production, is unity in the case of the Cobb-Douglas production function. A certain percentage change in the marginal productivity ratios of two factors, for instance (the marginal rate of technical substitution) induces an equiproportional change in their utilization ratios.

The constant elasticity of substitution of the Cobb-Douglas formulation is a restrictive property, as has been shown by Arrow et al. (1961). They found the parameter to be different from unity in 10 out of 24 industries in a study using cross section data from 19 different countries. However, Griliches (1967) in a study of production in the manufacturing sector found only one industry out of 17 in which use of the Cobb-Douglas production function was not justified on those grounds. The function in agricultural production studies provides a good fit to most data sets (e.g. Yotopoulos, (1967), Dillon and Hardaker (1980). Yotopoulos and Nugent (1976) report that a comparison of a Cobb-Douglas functional form and a constant elasticity of substitution (CES) form applied on Indian data showed that

> "the extra sophistication of the CES seemed both unnecessary and unwarranted by the quality of the available data" p. 69.

The Cobb-Douglas production function is also appealing and widely used because the estimated coefficients can easily be interpreted and are so widely accepted by analysts.

5.1.2 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.

5.2 THE VARIABLES CONSIDERED

5.2.1 The Dependent Variable

The maize output per acre (yield) in kilograms was considered the key dependent variable[3]. 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.

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[3] 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.

5.2.2 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 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.

(i) 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.[4] 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

$$O_i = a + b_1X_1 + b_2X_2 + e_i \quad \text{(viii)}$$

Normalizing with X_1 we get:

$$O_i/X_1 = a/X_1 + b_1 + b_1X_2/X_1 \quad \text{(ix)}$$

Therefore:

$$Y_i = a_o + b_1 + b_2\ X_2/X_1 = a_o^* + b_2X_2/X_1 \quad \text{(x)}$$

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

$$Y_i = a_o + b_1X_1 + b_2X_2/X_1 \quad \text{(xi)}$$

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

In the Cobb-Douglas functional form, if

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

$$O_i = AX_1^{b_1}X_2^{b_2} \qquad \text{(xii)}$$

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

$$Y_i = AX_1^{b_1-1}X_2^{b_2} \qquad \text{(xiii)}$$

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

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

$$Y_i = A(\frac{X_2}{X_1})^{b_2}X_1^{b_1-1+b_2} = Ax_2^{b_2}X_1^{b_1^*} \qquad \text{(xv)}$$

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.

(ii) 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, as noted in Chapter 4, 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[5]. Rao (1978) has also justified the exclusion of harvesting labour on the same grounds.

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 5.2 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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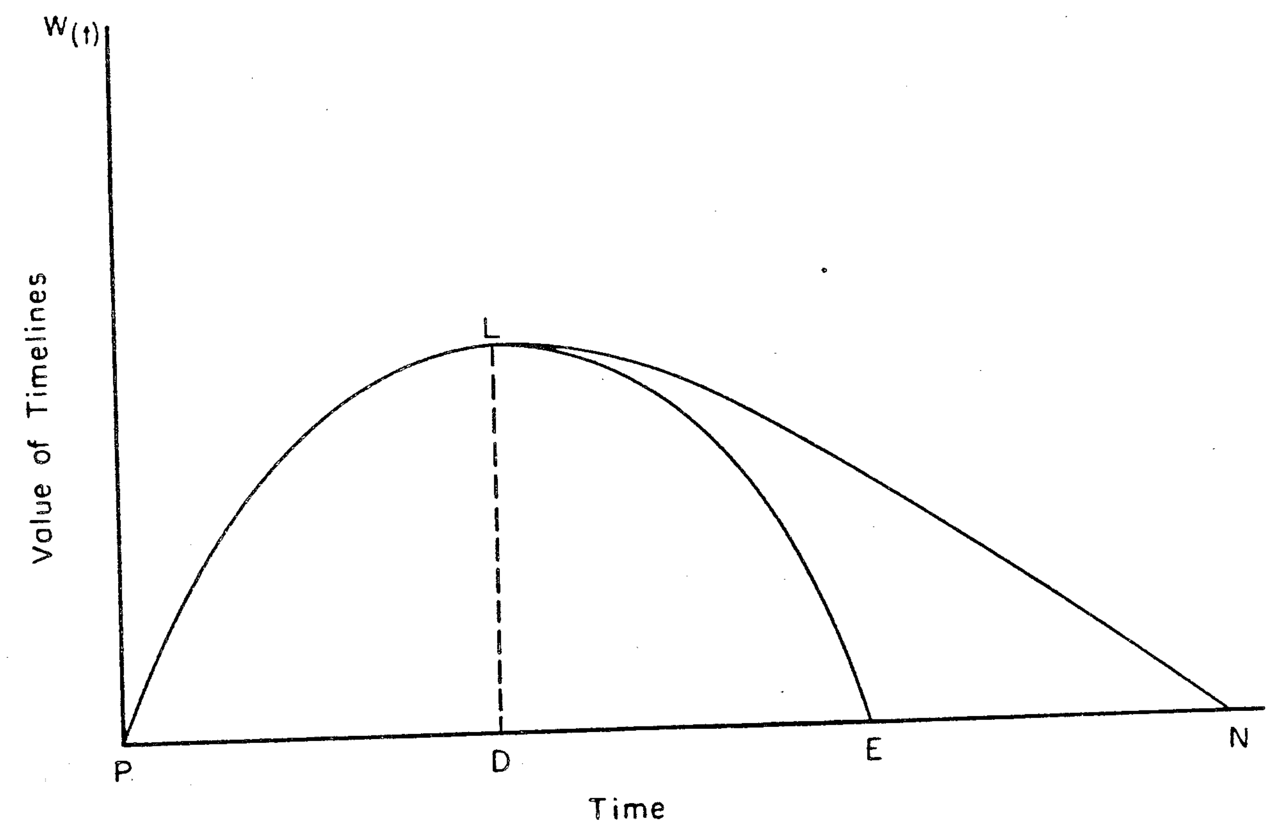
[5] Considering the relatively low average maize yields obtained by the sample farms (Chapter 4) and the importance of the crop, it was felt that whatever output was available for harvest, labour would be forthcoming to harvest it.

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

Figure 5.2: 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 3, 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[6]. 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[7]. The declining proportion of the weighting scheme, LN, shows this as time for weeding advances after about the middle of March[8].

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

[7] 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.

[8] The structure shown in figure 5.2 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.

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

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

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 5.2 shows that it can be given as:

$$w_t = q_o + q_1 t + q_2 t^2 \qquad \text{(xvii)}$$

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

$$q_1 E + q_2 E_2 = 0 \qquad \text{(xviii)}$$

$$q_2 E^2 = -q_1 E \qquad \text{(xix)}$$

$$q_2 = -q_1/E. \qquad \text{(xx)}$$

Substituting for q_2 in (xvii) gives

$$w_t = q_1 t - (q_1/E)t^2 \qquad \text{(xxi)}$$

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

Rearranging equation (xvi) gives:

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

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 5.2, 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 5.2 as a modification from DLN, the scheme developed above assumes that three weeks after planting is the optimal time of weeding. Thus,

$$w_t = q_o + q_1 t + q_2 t^2 \qquad \text{(xxiii)}$$

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

$$dw/dt = q_1 + 2q_2 t = 0 \qquad \text{(xxiv)}$$

$$2q_2 t = -q_1$$

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

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

at time N = 17 in our case,

w_t = 0 and therefore

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

substituting for q_1 from (xxv)

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

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

Then substituting for q_o and q_1 in (xxvii),

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

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

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

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

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

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

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.

(iii) Levels of Fertilizer per Acre (FTQA)

Fertilizer usage is considered a sure way to increase available plant nutrients, and thus increase yield if correctly applied (Allan 1971). Those who used chemical fertilizer applied a compound fertilizer bought from retail shops in 50 kg. bags. The quantity reported by the respondents was therefore considered accurate. However, since some farmers used animal manure, or neither manure nor chemical fertilizer, there was need to include 3 dummy variables, CHEM, MANU and NONE. Each dummy variable refers to use or non use of chemical fertilizer, animal manure and neither of the two respectively. There was no case where both chemical fertilizer and manure were applied. The aim of using a dummy variable in this case was to estimate the effect of using animal manure[9]. Greater use of animal manure is expected to improve the yields of maize due to the improvement of soil fertility and its water-holding capacity.

(iv) Proportion of Fallow Land (PFAL)

This variable was defined as (total land area - cropped land)/ total land area. The rationale for including it in the model was to test if the intensity of cropping had some effect on maize yield. Thus, whether or not heavy cropping on some farms and less use of land on others had significance for yield would be captured by this variable. The expectation is that, all other things being equal, more fallow should allow for greater rotation and hence soil conservation[10].

(v) Method of Land Preparation

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9 When the dummy variables were used, the quantity of chemical fertilizer used (for those who used it) was excluded and replaced by 1, otherwise we would have singularity of matrix problem in the estimation procedure.

10 However, in the case where farmers continued to plant on the same land rather than open fallow land due to the ardous nature of both clearing and hoeing work, a greater fallow would imply lower productivity of the land allocated to maize.

One objective of the study was to compare the productivities among farms using different levels of mechanization in land preparation for maize production. Three dummy variables were defined for this purpose, depending on whether a method was used or not used. The dummy variables were HND = 1 if hoe was primarily used, 0 otherwise; OXN = 1 if owned oxen were used, 0 otherwise; OXTR = 1 if either oxen or tractor was hired, 0 otherwise. The third dummy variable OXTR combined ox-hiring and tractor hiring because those hiring tractors were very few and an F test was performed which showed that there was no statistically significant, measurable difference in yield per acre between the group hiring oxen and the group hiring tractors[11].

(vi) Weeding More than Once (DMW)

Some farmers followed the practice of weeding twice, however late the operation was. A dummy variable was included to test for this effect. It was defined as DMW = 1, if only one weeding was done DMW = 0 if more than one weeding was done.

(vii) Days After onset of Rain to Complete Planting (DAFR)

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[11] The details and results of this test are given in sections 5.3 and 6.3 respectively.

This variable referred to the number of days after the onset of rain that planting maize was completed on each farm. It is meant to show the direct effect of timeliness in contrast to two labour variables. Planting very late after the onset of rain is expected to have a negative impact on yield.

(viii) Level of Education of the Farmer (EDM)

The management resource is important in any production process, Griliches, (1957). Defining and then measuring this variable is not easy. Some studies have made use of education as a proxy; e.g Yotopoulos (1967). In this study a dummy variable was used for education. If the decision maker had any formal education, s/he was given a value of 1, otherwise 0. This variable was introduced to indicate in some measure the effectiveness with which inputs were applied. A higher level of education would imply more effective use of inputs and therefore greater yield.

(ix) Regional Dummy Variables

The study had 3 clusters drawn from 3 districts of Western Province, Kenya. It was therefore necessary to test whether maize yield and the underlying production process differed among the districts. This regional dummy variable implicitly incorporated differences in soil and microclimatic differences among the clusters. Thus, the 3 regional variables were BUN = 1 if Bungoma, 0 otherwise. BUS = 1 if Busia, 0 otherwise; KAK = 1 if Kakamega, 0 otherwise[12].

(x) IADP or Non-IADP Farms

One reason why the additional non-IADP farmers were included in the survey in 1981 was to test if the yields obtained in the two groups of farms showed any statistically significant and measurable difference. Therefore a dummy variable IADP = 1 if the farmer was regular and IADP = 0 if the farmer participated in the survey only in 1981 was defined to test for this difference, if any.

(xi) Period of the Survey (YEAR)

To test whether there was a shift in the level of yield, ceteris paribus, between 1977 and 1981, the two periods were assigned dummy variables. If the records were for 1977 the value of 1 was assigned; if from 1981 the value of 0 would be given.

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12 The whole sample, however, comprises farmers of similar ethnic origin and it was expected that their background and culture would not be very different.

5.2.3 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_o). 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. The details of the estimation procedure is deferred to section 5.3.

5.2.4 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.

5.3 TECHNIQUE OF ESTIMATION

Ordinary least squares regression was used to estimate the parameters for each of the independent variables of the production function[13]. 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.

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[13] 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 covariance analysis combines the features of analysis of variance and regression. Assuming two data sets with N and M numbers of observation respectively and K regressors, we can use the analysis to test whether the same regression model fits each data set equally well. The linear regressions are used to illustrate this. Given the regressions models:

$$Y_i = b_o + \sum_{i=1}^{n} b_k X_{ik} + e_i \qquad (1)$$

$$Y_i = a_o + \sum_{j=1}^{m} a_k X_{jk} + e_j \qquad (2)$$

where equation (1) comprises all the N observation and equations (2) involves only M observations. The regression coefficients are allowed to differ in the two equations (i.e. b_k and a_k). However, to test whether the assumption of two different regression models is correct, we start with the null hypothesis that the regressions are identical. Running the two separate regressions enables us to get the unrestricted sum of squares ESS_{UR}.[14] This is obtained by summing the error sum of squares from the two regressions (Pindyck and Rubinfeld 1981). Thus $ESS_{UR} = ESS_1 + ESS_2$. The number of degress of freedom involved is (N-K)+(M-K) = N+M-2K. If the null hypothesis is true such that $a_k = b_k$, a single equation on the pooled (N+M) observations can be logically estimated:

$$Y_i = b_o + \sum_{i=1}^{m+n} b_k X_{ki} + e_i$$

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[14] It is called unrestricted because no restriction has been placed on the estimated parameter.

From this regression we get the restricted sum of squares ESS_R with K restrictions. The F test used is to find whether the difference between the two residual sums of squares is significant and is given as:

$$F = [(ESS_R - ESS_{UR})/K]/[ESS_{UR}/(N+M-2K)]$$

We reject the null hypothesis of no difference in the two regressions if the F statistic is larger than the table value with K and N+M-2K degrees of freedom and then treat each data set separately. In the case where the additional M observations are few, such as our sample farms using tractors, a similar test is done with the idea of finding if the additional (M) observations obey the same response relationship as the first, Chow (1960). The error sum of square (ESS_L) for the first L observations is computed. Secondly, the pooled (L+M) or N observation are used to compute the residual sum of squares ESS_N The test is given by:

$$F = [(ESS_N - ESS_L)/M]/[ESS_L/(N-K)]$$

and we reject the hypothesis of commonality of the additional observation with the first if the F statistic is larger than the table value with M and N-K degrees of freedom.

5.4 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.

5.4.1 The Technical and the Financial Information

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[15].

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[15] 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

Thus, a maize enterprise 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. 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.

5.4.2 The Partial Budget Analysis

This technique is suitable for evaluating the consequences of changes in farm organization that affect only part of rather than the whole farm business. Since our concern was to determine the effects of changes in farm mechanization, analyses were done for the following alternative changes in land preparation.

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markets varied from month to month, the average price was close to the controlled price.

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.

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 out. The assessment of the change on farm profit is of course contingent upon the accuracy of the technical and financial data used.

Chapter VI

THE EMPIRICAL RESULTS

The previous chapter discussed the analytical procedures used to consider the productivity and profitability of the three farm categories based on three methods used to plough the land and prepare the seedbed for maize production: (1) hoe (2) owned oxen (3) those hiring oxen or tractor. The aim of this chapter is to report and discuss the numerical results from this analysis.

6.1 THE CORRELATION OF THE VARIABLES CONSIDERED

The correlation coefficients, measuring the degree of the linear association among individual pairs of variables considered were calculated[1]. Although the correlation coefficients do not indicate the direction of causation, the logical relationships among some key variables can be validated. The coefficients also provide one way to monitor the potential problem of multicollinearity in ordinary least squares estimation. Pindyck and Rubinfeld (1981) state that the rule of thumb to detect severe multicollinearity involves examining whether the simple correlation coefficient between

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[1] These refer to Pearson correlation-coefficients, which are zero-order correlation in the sense that when two variables are consideted, the others are held constant.

two independent variables is higher than the correlation of each of the independent variables with the dependent variable. The coefficients together with their respective levels of statistical significance are given in Appendix B.

The variables whose correlations were significantly different from zero at the 5% level were discerned. For this sample, the correlations were generally low[2]. Positive and statistically significant correlation implies that the variables increase or decrease together in the same direction. The converse holds in the case of negatively correlated variables. Size of holding was positively correlated with maize acreage, the education of the farmer, ownership of oxen, and the application and use of commercial fertilizer. Negative correlation existed between size of holding and location of the farm in Busia, and also with hoe cultivation. Busia farmers and the hoe users tended to have smaller holdings. Use of a tractor or use of hired oxen had no statistically significant correlation with size of holding. The use of individual methods of tillage and cultivation were associated with their availability and the need to have the task done.

Days after the onset of rain had a significant, positive correlation with fertilizer used per acre. This indicates a tendency to apply fertilizer late to raise yield, even though

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2 The correlations, however, can not be regarded as spurious, because the prior expectations regarding the association between variables, considering the area of the study, were validated.

planting was done late. As the regression results showed, the magnitude of change in yield resulting from use of chemical fertilizer was low, and in some cases not statistically significant. Land preparation and planting labour (PLNTLAB), weeding labour (WIDLAB) and harvesting labour (HAVLAB) were all positively correlated with maize acreage (MZA). Thus, measures which would increase the maize acreage would consequently require greater use of labour in these operations. For instance, the amount of preparing and planting labour (PLNTLAB) was positively associated with use of the hoe (HND) for land preparation while WIDLAB and HAVLAB were both negatively associated with HND. This is a logical and expected result. Readying an acre for planting by hoe takes more mandays of labour compared with the use of oxen or tractor. Thus, maize acreage is more restricted on hoe farms than for other farms, and WIDLAB and HAVLAB are negatively related to hoe farms, but positively related to farms where oxen are owned (OXN).

6.2 THE PRODUCTION FUNCTION RESULTS

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

$$MYLD_i = a_o + b_1MZA + b_2LABPL + b_3LABW\ b_4DAFR + b_5FTQA\ b_6PRFAL + d_1HND + d_2OXN + d_3OXHTR + d_4DMW + d_5BUN + d_6BUS + d_7KAK + d_8EDM + d_9YEAR + d_{10}IADP + d_{11}CHEM + d_{12}MANU + d_{13}NONE + e_i.$$

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 6.1. 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.

TABLE 6.1

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

MYLD	MODEL	
Variable (j)	LINEAR b_j	LOG LINEAR b_j
Constant	577. (3.5)	6.97 (10.65)
MZA	95. (7.1)	.64 (5.35)
DAFR	-11. (1.0)	-.21 (1.18)
LABPL	-.39 (.99)	-.19 (3.42)
LABW	-89. (1.75)	-.16 (2.65)
FTQA	1.80 (2.81)	.058 (1.70)
PRFAL	1.45 (1.08)	.041 (.62)
HND	-123. (1.42)	-.16 (1.17)
OXN	135. (1.96)	.21 (1.90)
DMW	15. (.19)	.11 (.81)
BUN	-135. (1.67)	-.22 (1.62)
BUS	-247. (2.58)	-.41 (2.57)
EDM	-109. (1.41)	-.27 (2.12)
IADP	32. (.39)	-.069 (.46)
YEAR	- 71. (.92)	-.11 (.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.

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 (xv) of Chapter 5, 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 (LABW) consist of the unknown parameters of the weighting scheme of q_1 and q_2 respectively, as shown in Chapter 5. 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:

$b^* - 1 = .64$, 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[3].

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[3] 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

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.

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[4]. 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

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fertilizer farmers used in the region were above Kshs. 100 per 50 kg. bag.

[4] 1 bag of maize is equivalent to 90kg.

tractor[5]. 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 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.

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[5] 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).

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.

6.3 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. As explained in Chapter 5, 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 6.2.

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.

6.3.1 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 6.3. 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 6.2

Covariance Analysis Results for the Various Categories of Farms

Group		ESS_1*	(N)	ESS_2	(M)	ESS_{UR}	(N+M)	ESS_R	(K)	$F = \frac{(ESS_R - ESS_{UR})/K}{ESS_{UR}/N+M-2K}$
Hoe and Oxen Owned	(1) (2)	7.44	(44)	22.57	(76)	30.01	(120)	38.22	(12)	$\frac{.68}{.31} = 2.19$
Hoe and Oxen Hired	(1) (2)	7.44	(44)	31.42	(75)	38.86	(119)	49.45	(12)	$\frac{.88}{.41} = 2.15$
Hoe and Tractor Hired**	(1) (2)	7.44	(44)		(7)		(51)	8.06	(12)	$\frac{.09}{.19} = .47$
Oxen Owned and Oxen Hired	(1) (2)	22.57	(76)	31.42	(75)	53.99	(151)	63.26	(12)	$\frac{.77}{.42} = 1.83$
Oxen Owned and Tractor Hired	(1) (2)	22.57	(76)		(7)		(83)	23.36	(12)	$\frac{.11}{.32} = .34$
Oxen Hired and Tractor Hired	(1) (2)	31.42	(75)		(7)		(82)	31.84	(12)	$\frac{.06}{.45} = .43$

* Subscript refers to the group.

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

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.

TABLE 6.3

The Regression Results for the Hoe Group

MYLD VARIABLE (j)	LINEAR b_j	LOG LINEAR b_j
Constant	214. (1.0)	7.1 (4.32)
MZA	93. (2.64)	.64 (1.98)
DAFR	-.098 (.01)	-.36 (.70)
LABPL	-.15 (.63)	-.18 (1.96)
LABW	.22 (.32)	-.065 (.55)
FTQA	-.21 (.31)	-.035 (.53)
PRFAL	-2.45 (1.0)	-.18 (1.09)
DMW	78.3 (.76)	.42 (1.54)
BUN	-246. (1.53)	-.73 (1.47)
BUS	- 80. (.72)	-.31 (1.02)
EDM	73. (1.96)	.62 (2.09)
IADP	146.4 (.95)	.18 (.82)
YEAR	-299. (1.51)	-.46 (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

6.3.2 <u>The Regression Results for the Oxen Owners Group</u>

The regression results for those using owned oxen are presented in Table 6.4. 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 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

TABLE 6.4

The Regression Results for the Oxen Owners Group

MYLD VARIABLE (j)	MODEL LINEAR b_j	LOG LINEAR 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

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.

6.3.3 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 6.5).

TABLE 6.5

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

MYLD VARIABLE (j)	MODEL LINEAR b_j	LOG LINEAR b_j
Constant	200. (.77)	5.7 (4.8)
MZA	120. (4.56)	.81 (3.89)
DAFR	-23. (1.35)	-.42 (1.20)
LABPL	-.44 (.23)	-.016 (.15)
LABW	-1.16 (1.65)	-.33 (3.23)
FTQA	2.54 (3.12)	.13 (2.12)
PRFAL	2.6 (1.30)	.065 (.63)
DMW	- 81. (.63)	-.07 (.34)
BUN	-106. (.78)	-.23 (.95)
BUS	-228. (1.43)	-.48 (1.60)
EDM	-130. (1.19)	-.41 (2.11)
IADP	- 86. (.66)	-.33 (1.37)
YEAR	-106. (.72)	-.41 (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 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.

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.

6.4 THE MAIZE ENTERPRISE BUDGETS

A maize production budget for each of the different categories of farms was developed for average farm conditions in the region. These budgets were based primarily on the 1981 survey data.

6.4.1 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 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[6]. The maintenance cost was therefore part of the

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[6] This overstates the cost incurred by the oxen owner on his own maize production, because he could rent out the oxen

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[7]. While the

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using the same plough shares.

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.

6.4.2 The Maize Budget Results

The results of the maize enterprise budgets are presented in Table 6.6. 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.

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[7] 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.

TABLE 6.6

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 6.6

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.

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 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.

6.5 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 6.7. 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 a1.1 additional acres.

The results showing the effect of changing from using the hoe to owning oxen for ploughing are shown in Table 6.8. 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

TABLE 6.7

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 6.8

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.

grazing oxen is acceptable to farmers[8]. 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 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 6.9. 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

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

the tractor. The results are given in Table 6.10 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

TABLE 6.9

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 6.10

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*.

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 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.

6.6 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 6.2). 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.

Chapter VII

SUMMARY, CONCLUSIONS, AND SOME INFERENCES FOR POLICY

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. 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. This was one of the primary reasons for the study.

7.1 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. 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 primary hypotheses tested were that:

1. The use of oxen for ploughing is associated with greater aggregate demand for labour and land in producing maize, the staple crop.
2. Higher levels of mechanization are associated with increased yield of maize.
3. Labour productivity is lower on farms that rely on the hand tools for seedbed preparation.
4. Use of fertilizer and high yielding varieties of maize is not profitable unless good cultural practices, such as appropriate timeliness of planting and weeding, can be achieved.

The analysis of the survey data showed that the group which owned oxen and plough had on average the largest land holdings per farm. This group had an average of 25 acres of land. The group using the hoe had an average of 9 acres per farm; those using hired oxen had 13.5 acres, while the group hiring the tractor had about 8 acres per farm. Hiring a tractor was not associated with larger farm size. If one had the cash and needed the land preparation to be done in a short time, a tractor could be hired, if available. Hiring human labour for hoeing did not occur. It would cost more to hire human labour to ready an acre of land than to hire even an expensive tractor if the time of completion and its subsequent effect on yield was taken into account. A zero-order correlation analysis showed that the coefficient between oxen ownership and farm size (which was also highly correlated with maize acreage) was statistically significant and positive (Appendix B). Categorization of farms according to size group also showed that over 80% of the farmers owning oxen had more than 10 acres of land in 1981. Only one fourth of the farmers in the hoe group had more than 10 acres, while one-half in the group hiring oxen had more than 10 acres in the same year (Table 4.5). Farmers who owned oxen also had the largest acreage under maize, an average of 4.2 acres. The farms hiring oxen had 2.7 acres; those using the hoe had 1.6 acres, while those hiring a tractor had 3.1 acres of maize on average.

To establish a typical labour utilization for each of the different groups, a labour profile across the year was developed. It was found that the labour use pattern corresponded closely with the rainfall regime. Thus, the land preparation activity occurred in each of the months between

January and April. Planting was staggered between February and April, while weeding occurred between March and May. This made the months of April and May the peak periods for labour use on these farms, because the 3 operations overlapped. Harvesting took place between July and October, leaving June a period of little activity in maize production in the study area. The labour profiles indicated that the farmers who did not rely on the hoe for land preparation utilized relatively fewer mandays of labour for this activity. Subsequently they employed more labour to perform all the other necessary operations on the readied land for maize production. Specifically, although the family mandays per acre were not different in total among the non-tractor hiring-farms, the total mandays per farm in maize production after land preparation was significantly higher for the group of farms that used oxen. This group was able to prepare and plant a greater acreage (4.2 acres). On the other hand, the farmers using the hoe readied only a limited acreage (about 1.6 acres), and utilized in aggregate about 40% of the labour used in maize production by the oxen owners' group. On average, each adult relying on the hoe managed about 0.54 of an acre of maize, as opposed to 1.1 acres managed by an adult in the group owning oxen for ploughing. This is a major consideration in an area where land is not a limiting resource in maize or crop production.

There was no evidence of labour displacement on farms using higher levels of mechanization. It was found that, on a per-acre basis, the average labour employed for maize production was not very different among groups, raging from 47 to 49 family mandays (plus 20 to 30 hired mandays) for non-tractor hiring- farms. The tractor hiring-farmers, who used considerably less family mandays per acre (20), had to hire more labour than the other groups in the subsequent operations to complete the remaining tasks to weed and then harvest their crop. Thus, the need for more labour was basically due to the expansion of acreage brought about by a higher level of mechanization in land preparation during a time period when operations had to be completed rapidly.

The fact that the annual labour used per acre of maize was not very different between the groups may appear unusual. Some studies (eg. Berry and Cline, 1979) indicate that the overall labour per acre is normally higher on the relatively smaller farms. One reason for obtaining almost the same amount of labour per acre of maize in this study could be the tendency for some small farmers to take off- farm jobs in the village, irrespective of the level of mechanization in their farms. Another reason may be that only the labour used for maize production was considered, and the more acreage that was readied, the greater would be the labour requirement in subsequent operations.

7.2 REGRESSION ANALYSES

Production function analyses, where yield of maize in kg. per acre was the dependent variable, provided a way of testing the other 3 hypotheses. There were 6 independent variables and 13 dummy variables regressed against maize yields. The structure of the regression model was such that the coefficient for the maize acreage was a composite coefficient giving a measure of returns to scale in the log-linear model; the planting labour and weeding labour were weighted to take into account the time the operations were carried out; and the dummy variables were interpreted as slope shifters. In the situations where the dummy variables were considered both as slope shifters and sources of behaviorial differences between groups, a covariance analysis was performed.

In all the regressions, the maize acreage coefficient was found to be positive and statistically different from zero. This implied increasing returns to scale. This contrasted with studies which have shown evidence of decreasing or constant returns to scale in smallholder farms (e.g Berry and Cline, 1979; Yotopoulos and Nugent, 1976; Moock 1976). These studies assert that smaller farmers are more efficient than larger farmers. Gunning (1979), using the IRS data from Kenya, found evidence of decreasing returns to farm size.

Possible reasons for the difference found in this study compared to other previous work could be associated with the nature of the sample farms on which this study was based and the variables considered. In each of the group of farms in this study, there was evidence that the proportion of fallow land was over 40%. As a result, most of these farmers had substantial amounts of unused land at their disposal. One reason for increasing returns to scale within one's own farm is the result of commencement of cultivation of previously fallow and hence more fertile land.[1] Another possible explanation is that the relatively larger farmers within each group are located on more fertile or productive soil. The agronomic skills and managerial capacity of the larger farmers may also be greater. If these assumptions hold, then increasing maize acreage would logically result in greater yields, provided labour is available and cultural operations are performed on time.

Any increase in labour to perform operations which were already late was not useful. Because of the nature of the planting and the weeding labour variables, which are based on the maize agronomy for a rainfed agriculture, the marginal contribution of another unit of planting labour or weeding labour was very low or nil. Finding that existing labour productivities were very low was disturbing in view of the urgency to increase labour productivity. One way to increase labour productivity is to improve timeliness in planting by using animal power for ploughing where this alternative is

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[1] If the farm size were very small, expansion of acreage could result in a "bumping effect", where other farmers would be squeezed out, creating landlessness; this creates income distribution problems.

currently not available or used.

The regression results showed that there was a statistically significant difference between the yields on the 3 groups of farms. Those who owned oxen for ploughing achieved a yield of about 7.5 bags of maize; those who hired oxen or tractors achieved 6 bags of maize per acre and those using the hoe for land preparation achieved an average of about 4.5 bags of maize per acre. If one considers that the mandays of labour used per acre was not markedly different among the groups, then the labour productivity (output/labour), although low in each of the groups, was even lower for the group depending on the hoe for land preparation. The covariance analysis (Table 6.1) also showed that the 3 groups were statistically different in the manner that the variations in yield were explained among them.

The quantity of fertilizer used per acre was shown to have a positive and statistically significant coefficient in relation to yields. However, the magnitude of the coefficient was very low. In fact, the value of the marginal product of fertilizer was even lower than the price per unit. Use of animal manure showed no statistical effect on yield. Most farmers were planting their own seed, and therefore no measurable effect from the use of hybrid maize seed could be observed for the sample farms. Weeding was mostly done late; therefore, there was no improvement of yield resulting from more weedings.

7.2.1 Enterprise Budgets

Maize enterprise budgets for each of the 4 groups of farms revealed that the net cash income per acre was highest for oxen owners, netting about Kshs. 580 per acre, as compared to those hiring private tractor who had Kshs. 200 per acre. Those in the hoe group netted about Kshs. 332 per acre, and those hiring oxen Kshs. 376. Use of a government tractor was cheaper than hiring a private tractor by about Kshs. 70 per acre.

The changes in profitability from using alternative levels of mechanization for land preparation was analysed using partial budgeting. The technical coefficients obtained from the production functions were used, assuming no other changes, in calculating the financial returns. The results indicated that in addition to the reduction in drudgery involved from hoe use (and which is difficult to quantify), it was financially viable to use a higher level of mechanization especially in land preparation. On an annual basis, the highest profit per farm (about Kshs. 1250) was obtained by changing from hoe use to owning oxen and associated equipment. Of the total gain from the change, almost 70 percent could be attributable to the value of maize from the additional 2.6 acres of maize. The remaining 30 percent of the gain came from renting out the oxen for ploughing. Changing from hoe use to hiring oxen had a net gain of Kshs. 149 per farm. All the net gain was due to the value of maize obtained from additional 1.1 acres of maize. Changing from hiring oxen to own oxen for ploughing netted about Kshs. 990 per farm. Almost half of the total gain was due to the value of maize on the additional 1.5 acres of maize, 40 percent of the gain came from renting out the ploughing services and the remaining 10 percent of the gain was the cost saved from hiring oxen for ploughing.

Shifting from hired oxen to hiring private tractor or government tractor ha financiald a profit of Kshs. 73 and 99 respectively. Most of the gain (87%) was due to the increased acreage while the remaining proportion of the gain could be attributed to the cost saved from hiring the oxen.

Additional evidence of the viability and profitability of owning oxen was demonstrated by the adoption of oxen ownership between 1977 and 1981 on IADP farms. From 1977 to 1981 those hiring oxen for ploughing declined from 54% to 25%, while those owning oxen rose from 25 to 43 percent. It was expected that due to a large foreign exchange component in the costs of tractor use (both in tractor parts and fuel), the number of tractors available for hiring by small farmers would diminish. This is likely to raise the cost of private tractor hiring considerably. Consequently the profit connected with changing from hired oxen to hired tractor will similarly diminish with time.

7.3 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.

7.4 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.

7.4.1 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.

7.4.2 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.

7.4.3 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.

In Chapter 6, 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.

7.4.4 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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Appendix A

The Questionnaire

CONFIDENTIAL

SMALL - FARM MECHANIZATION QUESTIONNAIRE

1. District: ....

2. Farm Identification No.: ....

3. Date completed: ....

4. Name of operator (Farmer): ....

5. Approximate age: ....

6. Farm background: ....

   a) What is the size of this farm? ....acres.

   b) Is it registered? ....Yes/No

   c) Do you have other plots elsewhere? ....Yes/No

   d) If yes. Where? ....(miles away) and what size, ...

   e) You got this farm by................................inheritence

   ....buying

   ....hiring

   ....others (specify)

7. Family background:

   Individuals:

   a)

Living on the farm	age	sex (male/female)	Years of School
....	.....	....	....
....	.....	....	....

7. Family background: (cont.)

a) Living on the farm | age | sex (male/female) | Years of School

....

....

....

....

7. b) Living elsewhere (specify) | age | sex | Years of School

....

....

....

....

....

....

c) Of these living on the farm, how many are available for farm work? ....

d) For the members of the family living outside the farm, when did they leave the farm?

1. ....year
2. ....year
3. ....year
4. ....year
5. ....year

7. e) Why did they leave?

1. ....
2. ....
3. ....
4. ....
5. ....

8. Land usage:-

What crops did you grow on your farm in 1981?

a)

Crop	Seed qt used	acreage	output	harvested
....	....	....	....	....
....	....	....	....	....
....	....	....	....	....
....	....	....	....	....
....	....	....	....	....

b) How much land did you leave fallow? ....acres

c) Why ....

d) If owning oxen, approximately how much land do they require for grazing ....acres

9. Land preparation:-

a) For the past 5 years which of these have you used for land preparation?

....hand tools

....owned oxen

....hired oxen

9. a) cont.

....privately hired tractor

................................government tractor hiring service

b) If not using hand tools, when did you stop using them? ......year

c) Why? ....

d) If you use your own oxen:

i) Which year did you acquire the oxen? ....

ii) Which year did you acquire the equipment? ....

iii) How did you acquire the oxen? ....inheritance

....own cash

.....................................others (specify)

iv) How did you acquire the equipment?

....inheritance

....credit

....own cash

.....................................others (specify)

v) What was the cost of oxen? K.shs......................

vi) What was the cost of equipment? K.shs.................

Plough K.shs..

Yoke K.shs..

Other (specify) K.shs.................................

vii) How did you train the oxen? ....

....

viii) How long do you expect to use oxen? ....

....

9. d) ix) Do you plough for other farmers? Yes/No................

x) If yes, what do you charge? K.shs/acre.................

Labour exchange basis ....

xi) If no why? ....

xii) What is the maintenance cost for the equipment per year

K.shs? ....

xiii) What other use do you make of your oxen?

....transport

....nothing

.....................................other (specify)

xiv) If nothing, why? ....

xv) Who repairs your Ox equipment when need arises? ....

....

xvi) How many oxen are in the team? ....

xvii) How many guides do you use? ....

e) If you have ever hired oxen for land preparation since 1977 which years did you do this?

.......1977; ....1978; ....1979; 1980; 1981

i) Was all or part of the land cultivated?

....All

....Half

....Less than half

....More than half

ii) If not all land cultivated, why? ....

....

9. e) iii) How was the timing of the land preparation operation?

....early

....about on time

....late

iv) What was the cost of service per acre? K.shs...........

v) If you have used the hired oxen for less than 5 times since 1977, why was this? ....

....

vi) If you used the hired oxen in 1981 do you plan to continue to use the service for land preparation in the future? Yes/No..................................

vii) If yes, Why? ....

viii) If no, Why? ....

f) If you have ever hired tractor for land preparation since 1977 which years did you do this?

......1977; ......1978; ......1979; 1980; 1981

i) Was all or part of the land cultivated?

....All

....Half

....More than half

ii) If not all land cultivated, Why? ....

....

iii) How was the timing of the land preparation?

....early

....about on time

....late

9. f) vi) What was the cost of the service per acre? K.shs........

v) If you used the tractor hire for less than 5 times since 1977, why was this? ....

vi) If you used the tractor hire in 1981, do you plan to continue to use it? Yes/No. If yes, Why? ....
....

vii) ....

viii) If no, Why? ....
....

10. The effects of mechanization on land use:-

a) What changes in land use have you made since you started using tractors or oxen?

i) Area cultivated ....More
...................................Less
.........................About the same

ii) Number of Harrowing................................More
................................Less
.......................About the same

iii) Crop mixtures ....only maize
...................................more maize and beans
..............................more cash crops (specify)
....less fallow land
....same mixtures
....others (specify)

10. b) Have you made any changes in weeding practices?

i) Time of weeding ....earlier

.................................later

...................about the same time

ii) Number of weedings ....more

................................less

......................about the same

11. Effects on labour use:-

What changes have occurred in labour use since you started mechanizing farm operation?

	Before	Man days	After
Land preparation	....	....	....
Weeding	....	....	....
Harvesting	....	....	....

12. Effects on yields:-

What effect has mechanization had on yields?

Higher.....................by how much................bags of maize

Lower ....by how much................bags of maize

About the same...

13. For 1981

a) When did you start preparing the land for various crops?

Plot	Crop	Time (week)
....	....	....
....	....	....
....	....	....

13. b) How many times did you harrow?

....none

....once

....twice

....others (specify)

c) How many days of family labour were used for land preparation?

Crop	Number of Adult Family Labour	Days	Acres
....	....	.....	......
....	....	.....	......
....	....	.....	......
....	....	.....	......

d) If hired labour used, how many days of hired labour?

Crop	Plot	No. of hired labour	Indicate if Perm/Casual	Days	Cost K.shs.
....	....	....	....	....	....
....	....	....	....	....	....
....	....	....	....	....	....
....	....	....	....	....	....
....	....	....	....	....	....

e) When did you plant?

Crop	Plot	Days after rain	Acreage
....	......	....	....
....	......	....	....
....	......	....	....
....	......	....	....
....	......	....	....

13. f) Which seed type did you use and what quantity?

Crop	Seed Quantity	Type (traditional or HYV)
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....

g) How much labour did you use and for how long did you plant?

Crop	Plot	Man days of family labour	Man days hired labour	Days planting completed
......	....	....	....	....
......	....	....	....	....
......	....	....	....	....
......	....	....	....	....
......	....	....	....	....

h) When was the first weeding started and completed?

Crop	Started (week)	Completed (week)
......	....	....
......	....	....
......	....	....
......	....	....
......	....	....

i) How much labour did you use for first weeding?

Crop	Family Man days	Hired Man days	Mechanical Hand
....	....	....	....
....	....	....	....
....	....	....	....

13. j) If second weeding done, how much labour did you use?

Crop	Family Man days	Hired Man days (Cost K.shs)	Mechanical/Hand
......	....	....	....
......	....	....	....
......	....	....	....
......	....	....	....
......	....	....	....

k) How much fertilizer was used for various crops and at what cost?

Crop	Fertilizer (Kg)	Cost K.shs.
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....

l) How much pesticide did you use and at what cost?

Crop	Quantity of pesticide (specify)	Cost K.shs.
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....

m) When did you start harvesting?

Crop	Plot	Week of month
....	....	....
....	....	....
....	....	....

13. n) How much labour did you use for harvesting?

Crop	Plot	Family Man days	Hired Man days	Cost K.shs.
......	....	....	....	....
......	....	....	....	....
......	....	....	....	....
......	....	....	....	....
......	....	....	....	....

o) What was the quantity of crop harvested from the field?

Crop	Output	Qty (bags)
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....

p) Approximately how much was damaged in the field?

Crop	Output	Damaged	Cause of damage
......	....	....	....
......	....	....	....
......	....	....	....
......	....	....	....
......	....	....	....

14. How much maize are you able to store in your farm? ....bags

15. a) Do you have other business apart from farming? Yes/No............

b) If yes, how much time hrs/day do you spend on the business?

....hours

15. c) If no, why?

....No opportunities

....farm work is enough

....others (specify)

d) How many members of your family have off-farm income?

....No.

e) On average, how much remittance do you receive from them per month? ....K.shs.

16. General

a) Can you get more land to farm? ....Yes/No

i) If yes, where? ....how far.................miles

ii) If yes, How? ....at what cost............K.shs.

b) Can you get added labour you need if you can get more land?

....Yes/No

i) If yes, where? ....

ii) If yes, how much would you pay per day? ....K.shs.

c) What prevents you or limits you from increasing production?

....limited land

....limited labour

....limited power input

....capital (specify)

....others (specify)

d) If land, how much more land would you need and what would you pay per acre?

........................acres. Cost ....K.shs/acres

16. e) If labour, what operation creates the bottleneck?

Land preparation...

Planting...

Weeding..

Harvesting...

Combination (specify)..

f) If power, what prevents you from using a higher level of mechanization from your current level? ....

....

g) If capital is the constraint, have you tried applying for credit?

....Yes/No

i) If yes, Why didn't you get it? ....

ii) If no, why? ....

17. a) If you have used oxen for ploughing, what is:-

i) the greatest shortcoming...................................

ii) the greatest advantage....................................

b) If you have used government tractor service, what's their:-

i) greatest shortcoming.......................................

....

ii) greatest advantage..

....

c) If you have used private tractor service, what's their:-

i) greatest shortcoming.......................................

....

ii) greatest advantage..

....

Thank you.

APPENDIX B

The Correlation Coefficients of Some Key Variables
(The figures in ( ) indicate the level of statistical significance)

	MYLD	SIZ	MZA	PLNTLAB	WIDLAB	HAVLAB	HND	OXN	OXHTR	PRFAL	DAFR	DMW	EDM	IADP	FTQA	BUN	BUS	KAK
Maize yield (MYLD)	1																	
Farm size (SIZ)	.34 (.0001)	1																
Maize acreage (MZA)	.63 (.0001)	.42 (.0001)	1															
Planting labor (PLNTLAB)	.20 (.005)	.17 (.02)	.34 (.0001)	1														
Weeding labor (WIDLAB)	.23 (.0001)	.31 (.0001)	.37 (.0001)	.27 (.0001)	1													
Harvest labor (HAVLAB)	.43 (.0001)	.60 (.0001)	.49 (.0001)	.21 (.007)	.63 (.0001)	1												
Hoe group (HND)	-.32 (.0001)	-.18 (.01)	-.29 (.0001)	-.34 (.0001)	-.16 (.03)	0.21 (.009)	1											
Oxen owned group (OXN)	.35 (.0001)	.29 (.0001)	.35 (.0001)	-.15 (.04)	.21 (.003)	.23 (.003)	-.41 (.0001)	1										
Hiring group (OXHTR)	-.08 (.28)	-.14 (.05)	-.10 (.16)	-.13 (.06)	-.07 (.31)	-.06 (.48)	-.44 (.0001)	-.61 (.0001)	1									
Prop Fallow (PRFAL)	.04 (.58)	.04 (.53)	-.04 (.57)	-.13 (.06)	-.20 (.005)	-.07 (.40)	-.04 (.59)	-.05 (.47)	.02 (.80)	1								
Days after rain (DAFR)	-.08 (.27)	.05 (.48)	.10 (.16)	-.04 (.60)	-.15 (.03)	-.17 (.02)	-.15 (.04)	.16 (.02)	.28 (.0001)	.08 (.28)	1							
More weeding (DMW)	-.09 (.21)	-.07 (.32)	-.09 (.21)	-.06 (.41)	-.24 (.0006)	-.21 (.009)	.21 (.003)	-.07 (.32)	-.11 (.13)	.18 (.009)	-.18 (.01)	1						
Education (EDM)	.17 (.01)	.21 (.003)	.27 (.0001)	-.20 (.004)	.30 (.0001)	.25 (.002)	-.39 (.0001)	.22 (.001)	.10 (.13)	-.21 (.002)	.18 (.009)	-.50 (.0001)	1					
IADP farms (IADP	-.08 (.29)	.05	-.05 (.50)	-.09 (.22)	.02 (.75)	-.02 (.83)	-.07 (.33)	-.02 (.73)	.08 (.25)	.08 (.24)	.26 (.0002)	.05 (.45)	.11 (.12)	1				
Chemical fertilizer (FTQA)	.28 (.0001)	.14 (.04)	.26 (.0002)	-.15 (.03)	.05 (.50)	.17 (.04)	-.26 (.0002)	.10 (.16)	.12 ([illegible])	.01 (.84)	.39 (.0001)	-.30 (.0001)	.36 (.0001)	.25 (.0004)	1			
Bungoma farms (BUN)	-.03 (.64)	.12 (.09)	.004 (.95)	-.13 (.06)	.16 (.02)	.22 (.005)	-.29 (.0001)	.0006 (.99)	.25 (.0005)	.28 (.0001)	.15 (.04)	-.33 (.0001)	.40 (.0001)	-.04 (.52)	.09 (.20)	1		
Busia farms (BUS)	-.34 (.0001)	-.15 (.03)	-.38 (.0001)	-.11 (.13)	-.35 (.0001)	-.27 (.0006)	.41 (.0001)	-.22 (.001)	-.12 (.08)	.22 (.002)	-.10 (.14)	.48 (.0001)	-.55 (.0001)	.07 (.26)	-.27 (.0001)	-.60 (.0001)	1	
Kakamega farms (KAK)	.42 (.0001)	.04 (.59)	.43 (.0001)	.02 (.70)	.21 (.002)	.06 (.46)	-.13 (.06)	.25 (.0003)	-.14 (.04)	.08 (.28)	-.04 (.51)	.17 (.02)	.17 (.02)	-.04 (.59)	.20 (.004)	-.44 (.0001)	-.44 (.0001)	1