"AGRICULTURAL MECHANIZATION IN SEMI-ARID AREAS: FINDINGS FROM LOW-LAND MACHAKOS DISTRICT"

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This thesis is my original work and has not been presented for a degree in any other University

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Abstract

This study examines the role of mechanization in agricultural production under semi-arid conditions, drawing on findings from low land Machakos District. The complementarity between hydrological, biological, chemical and mechanical inputs is emphasised; to underline the desirability of a package approach in introducing innovations needed in expanding agricultural production; to provide a framework within which mechanical innovations must be viewed.

On the basis of the relative factor scarcities both from the national and individual farmers' point of view as well as the size distribution of the individual operating units and the availability of financial resources at the farm level, a theoretical range of the form of farm machinery that would be consistent with efficient resource allocation as well as being feasible and both technically and economically efficient has been constructed. The characteristic of such machines should include labour augmenting properties, in view of the relative abundance of labour, be able to fit in small operating units in view of the small sizes of the typical farms, be accessible to farmers with limited financial resources and involve minimal risk of financial losses in such areas as under study where crop failures are frequent. In concrete terms, an intermediate mechanical technology roughly covering animal drought and or small motorized implements would seem desirable.

It has been found that the predominant use of animal drought in these areas is consistent with the postulated relevant technology. The contribution of mechanization to agricultural production can be viewed through the extent of cultivated areas. It has been suggested that the expansion of cultivated areas would increase potential outputs. While the technology in use is relevant, there are marginal improvements that could increase its effectiveness. Such factors as the use of more appropriate implements e.g. the ard or tine instead of the heavy all steel mouldboard plough and greater attention to selection training and breeding of task animals would greatly improve the effectiveness of the animal based technology.

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I am however fully responsible for the shortcomings of the study.

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CHAPTER ONE

Introduction.

The agricultural sector is very important in countries like Kenya; in terms of the proportion of the country's population it supports, its contribution to national product and exports. Indeed agriculture's foreign exchange earnings have been the basis of the country's industrial development which has relied on imported inputs.

The objectives of more income generating potential, more favourable income distribution and employment that has recently dominated official policy can only be obtained through increasing production and productivity in the agricultural sector. since the capacity of the urban industrial sector to absorb an increasing potential labour force is seriously limited by its size and the availability of capital and foreign exchange.

It is in this context that the importance of promoting agricultural development should be viewed. The sector, particularly the peasant agriculture subsector in which a large proportion of the population depend, has not received as much attention as it ought to have, in the past. The recent policy change towards paying greater attention to rural development is encouraging.

A shift in emphasis in favour of agriculture without at the same time inducing technological change towards labour intensive and capital and foreign exchange saving end of the technological spectrum will be infeasible because this will also come against capital and foreign exchange constraints that limit the pace of industrial growth.

An intermediate technology, lying between the extremes of hand techniques on the one hand and tractors and allied implements on the other, based on animal draught power and or simple motorised implements that can be manufactured locally are often more appropriate under conditions of scarce capital, relatively abundant labour resources, and small farm units.

This study is based on findings from a field survey in the semi-arid lower Machakos district. The existing situation, the demographic characteristics and the structures of the production systems have been studied.

It has emerged that the land:population ratio is adversely low, the land can hardly support the populations in the study areas, and that this situation is getting worse both from natural population growth and immigration. This underlines the importance of seeking solutions to the low productivity of the land, to reduce the threat of famine, they are regular recipients of famine relief, and increase income opportunities in these areas.

The factors inhibiting the expansion of crop production in the study areas are; the limited water supply, the cost of clearing bushes, the competition of the livestock activities for land resources, the limitations of the energy sources and implements used, and the limited adoption of the available bio-chemical inputs (improved seeds and chemical fertilizers) as well as the resistance to adopt certain drought resistant crops arising from dietery preferences.

The use of animal draught power is widely adopted. Everybody used this source of power in ploughing and weeding, the only crop operations in which this source of power is used at all. This falls within the range of suggested appropriate technology. It is, however, suggested that there are possible improvements in mechanization that would make significant contribution in the expansion of crop production.

The absence of animal feed during droughts is a major factor which limits the available draught power when this is needed, just before the rains. Little attention is paid to selection of suitable animals and their training. Better feeding of draught animals, especially during drought, would increase their energy and more careful selection and training of task animals would increase their efficiency.

The mouldboard plough, the only animal drawn tillage implement available, used is unsuitable in these areas, it encourages unnecessarily deep ploughing and turns the soil thereby promoting evaporation of the limited available moisture. It is remarkable that it is so widely adopted. This indicates the peoples appreciation of the superiority of animal draught power in comparison with the hand methods. The crucial determinant here has been the source of power. If more suitable implements such as the ard and the tine ploughs, which disturb the soil minimally allowing more efficient utilization of the available power while increasing infiltration of rain water and do not encourage evaporation, became available they would have a great chance of acceptance. Such tools would encourage expansion of crop production through enabling expansion of cultivated areas due to their smaller demand on power and the yield effect of the moisture conserved.

Moisture availability is the most serious factor limiting crop production in these areas. This study, while falling short of suggesting means of increasing water supply - an area that may pay dividends, emphasises moisture conservation as an important means of increasing crop production. The importance of this factor is highly appreciated in the study areas as evidenced by the widespread adoption of bench terracing which reduces runoff and encourages infiltration. As already noted more can be done by making more suitable implements, than those in use, available.

There is some qualitative evidence supporting the proposition that crop and livestock activities compete for the limited cleared land. No detailed analysis of the alternative forms of land utilization could be done due to the inaccessibility of data on the costs and values in the various activities. The existance of large areas under bushes, more so in one area Kalawa than in the other, suggest that there is room for expanding both activities. The factors that have led to the retention of these bushes have not been determined, the understanding of this phenomenon would be of great importance in understanding the structures of these economies. Three possible explanations might be usefully examined. Either the costs of clearing bushes are too high, i.e. labour availability is a limiting factor throughout the year or the returns from the activities on cleared land are too low to justify expanding this facilities or cleared land is not expanded because the crop activity cannot be expanded with the existing power sources. It is plausible that if the chances of crop success is increased, through moisture conservation and adoption of yield increasing seed-fertilizer combinations and or drought resistant seeds, and more power becomes available, reducing labour bottlenecks if these are limiting as well as enabling expansion of crop activities, these improvements would make expansion of cleared land more attractive and feasible.

Katumani maize seeds are also widely adopted. This drought evading seed innovation reduces but does not eliminate chances of crop failure. The development and promotion of yield increasing and drought resistant varieties would assist the suggested transformation process. The use of fertilizers is negligible. This is one area in which research may be of assistance in determining the yield effects of various chemical fertilizers and whether or not the promotion of their adoption is justifiable in view of the rapid rises in the prices of these products.

The complementarity between these bio-chemical, mechanical and hydrological inputs make a package approach to the problem desirable. Better moisture conservation which has the effect of reducing the chances of crop failure would encourage adoption of more intensive cultivation practices involving purchased high yielding seed varieties and chemical inputs as well as making expansion of cultivated areas more worthwhile.

It has been found that the techniques used in carrying out the major farming operations (breaking new land, ploughing and weeding) do not change according to variations in access to resources. The ownership of draught animals was used as a measure of access to draught power and the association between this and the techniques used in carrying out the major operations examined.

The explanation provided for this result is that the technology used, as defined by the manner in which there operations are performed and the resources used, is the cost minimising alternative of the available alternatives. The techniques in use involved both hand method and use of animal draught power. There were two tractors, one in each sample area, available for hire, but these were largely used in transportation. While one tractor is hardly enough to serve people in a location of over 20 thousand people or 300 square kilometers, the tractors services were not demanded at rates of about Sh. 60 per acre, which is comperable to rates elsewhere in the country. It is conceivable that more tractors would have been available if the demand for tractors were high.* Thus although the mould board ox-drawn plough is inappropriate, as already noted, this was still the prefered alternative of those available.

It was not possible to give a quantitative demonstration on a cost comparison basis due to data limitations. However, a behavorial model to test the contention that the resource base (labour, land and capital) and competitive livestock activities determine the scale at which the crop activity (measured in terms of cultivated area) is carried out has been constructed and subjected to emperical test.

While the result of this study are not definitive, they do offer some indication that the stocks of draught animals and availability of land explain the scale of operations. The effect of family labour availability on the scale of operation has not been clearly established.

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* Tractors used in Tranzoia district come from as far as Central Province and Tanzania. District Agricultural reports.

CHAPTER TWO

The Background to the Study.

Kenya is, and will for a long time remain, predominantly an agricultural country. Agriculture accounts for 60 percent of the Gross National Product and supports 90 percent of the population (according to the 1969 census). The industrial and service sectors only account for 40 percent of the Gross National Product and support 10 percent of the population.

Thus while the agricultural sector contributes a larger proportion of the national product and supports a larger percentage of the people, in absolute terms, the per capita product and consumption is much lower in this sector than in the non-agricultural sectors. This condition has arisen from and reflects the relatively lower level of capital investment in the agricultural sector and the resultant low labour productivity in agriculture.

One of the most serious problems is unemployment and skewed income distribution both in the urban and the rural areas of the country. While the population growth rate is high at 3.5 percent per year, unemployment will continue to grow rapidly due to the limited ability of the urban-industrial sectors to generate job opportunities for the increasing numbers of the active portion of the population.

The constraint on the expansion of the industrial sector largely derives from the scarcity of capital and/foreign exchange on which this relatively capital intensive sector is heavily dependent.

The choice of development strategy must take these factors into consideration. In particular the existing conditions recomend selection of strategies that promote growth as well as creating employment for the increasing numbers of job seekers.

Due to the limited scope for employment in the industrial sector, the focus of attention must be redirected in creating improved income earning opportunities in the agricultural sector, especially in the peasant agriculture sub-sector where most people reside.

W.H. Nicholls notes that the experiences of the New World, Western Europe and Eastern Europe indicate that the existance of agricultural surplus is a precondition for development (1). Supporting the same argument B.F. Johnston has said that the phenomenally rapid development of Japan was the result of rapid increases in agricultural output both from expansion of cultivated areas and yield increasing technologies which both enabled a decline in the agricultural labourforce and generated surpluses for investment in the manufacturing sector (2).

A programme that leads to increasing labour productivity in the rural areas, thereby reducing the urban-rural income differential would assist in arresting the rural-urban labour migration and the open urban unemployment to which this contributes. It would at the same time lead to a more equitable income distribution due to its effect on a larger proportion of the population. The surpluses that can be expected from any significant growth in agricultural output would also contribute to industrial development.

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(1) W.H.Nicholls "The Place of Agriculture in Economic Development" In "Agriculture in Economic Development" C.Eicher and L.Witt ed. McGRaw Hill Inc. 1964.

(2) B.F. Johnston "Agricultural Productivity and Economic Development in Japan" Journal of political economy, Vol.59 1951 pp 505-508.

However, such a programme must recognize that capital and foreign exchange are limited and therefore increasing capital labour ratios in agriculture, as a means of increasing labour productivity, without altering the structures of production will be infeasible. Labour intensive technologies which will absorb more labour per unit of capital, thereby creating employment and improving income distribution while saving scarce capital resources are strongly indicated.

Technological inputs which can be incorporated in an agricultural development strategy include yield increasing or land substituting technologies; such as water development and conservation, high yielding seed varieties adopted to particular environmental conditions and chemical inputs eg. fertilizers, to the extent that they lead to increases in returns, and those permitting expansion of cultivated areas; such as labour augmenting mechanical technologies.

The various inputs in agricultural production are complementary. C.H.Gotsch found, in his study of mechanization in Pakistan (3), that there is a close relationship between the regional distributions of tractors and tube wells which enable multiple cropping which in turn demand larger energy resources to ensure timelyness of operations. The yield effects of improved water availability and control, improved seed varieties and chemical inputs are also likely to require improvements in mechanical inputs eg. in harvesting and processing to cope with higher outputs. Because of these complementarities between the various inputs and the coincidence of the diverse problems that need to be overcome a package approach is recomended.

This could be carried out in conjunction with rural industrialization programmes built around agricultural inputs and consumer goods to the extent that these can be produced economically, i.e. where economies of scale are unimportant.

This paper concentrates on the role of mechanization in the package of complementary inputs to raise agricultural production. A useful

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(3) Carl H. Gotsch "Tractor Mechanization and Rural Development in Pakistant" International Labour Review. Vol.107 No.2 Feb. 1973.

definiton is provided by Duff:"Agricultural mechanization is the application of mechanical technology to tasks, operations or systems of agriculture for the purpose of increasing output, reducing costs or improving resource distribution and utilization" (4). The purpose of mechanization is to make man a more efficient director of power and enable him to intensify his production system. His capacity to work depends on the power available to him. Bottlenecks develop because soil preparation, planting, weeding and harvesting require much time but must be accomplished within limited time periods due to the existance of exogenously determined factors such as the time distribution of rainfall. One factor which limits the expansion of agricultural production in peasant agriculture is the scarcity of power and suitable mechanical implements. Indeed the role of power is so central to an agricultural system that a change from one source to another is likely to alter the whole farm structure due to its effect on total labour requirements and the

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(4) Bart Duff "Output, Employment and Mechanizatiolity in Phillipine Agriculture" Cyclo. F.A.O. Rome Nov. 1975

distribution of labour peaks and slack periods. Infact it is now widely believed that appropriate mechanization strategy, in situations where there are seasonal and open unemployment, should be forcused on breaking labour bottlenecks thereby enabling expansion of cultivated areas which would reduce seasonal unemployment and even lead to reduction of open unemployment.

Growth in output, employment and improvement of income distribution are the important ingradients of economic development. The phenomenon of "...positive unemployment growth associated with positive output growth ..." (5) arising from indiscriminate adoption of capital intensive technologies in the third world is undesirable. This is indicative of resource misallocation in an economy. There is general agreement on the inappropriateness of capital intensive mechanical technologies in countries with abundant labour and scarce foreign exchange

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(5) Raj Krisha "Unemployment in INdia" Presidential address delivered at the 32nd Annual Conference of the Indian Society of Agricultural Economists in 1972. Indian Journal of Agricultural Economics 1973, 28 (1) Bombay, India.

and capital resources (6).

The form of a mechanical technology that would be suitable in a particular situation is determined by the relative factor scarcity in an economy, where labour is relatively abundant and capital and foreign exchange scarce the technology should be labour intensive; the size distribution of operating units, where farm units tend to be small and irregular large machines such as the tractor with built in economies of scale are costly alternatives; the financial resources of the people who will use the technology, subsistance farmers with purchasing power constraints cannot afford costly machines. The list is only indicative of the issues that will have to be considered in making technological choices.

The choice of capital intensive technologies in the large scale farms sector has been encouraged by such government policies as tariff and tax

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(6) C.H.Gotsch and R. Krisha op.cit. as well as K.C.Abercrombie "Agricultural Mechanization and Employment in Latin America" International Labour Review Vol. 106 No.1, July 1972.

concessions, cheap credit (low or even negative interest rates in view of inflation), minimum wage legislations and social security payments. These have been reinforced by overvalued exchange rates. The effect of these has been over valuation of labour and undervaluation of capital. The result of the choice of capital intensive techniques has led to a divergence between private and social profitability.

The existance of factors which have distorted relative factor prices make the usefulness of excercises which concentrate on comparing costs of alternative mechanical technologies doubtful unless the distortions can be quantified and excluded from the comparisons.

Government tractor hire services have been introduced and private tractor hire operators have emerged in several areas. One would like to compare the costs of these, to the individual farmer, with alternative machinery. However, these costs are unrealistic due to the factors that have underpriced capital. A more defensible excercise would be to work out the extent of the subsidy element and determine what would be paid by the users if the subsidies were removed. Moreover several other factors make tractor use in the peasant sector costly.

The cost of running tractors in these areas are high. Operators must travel long distances to get spare parts which are often scarce partly due to the large number of makes and models relative to the domestic stock of tractors. Fuel points are widely distributed leading to waste in travelling to fill up. Mechanics are scarce and workshops distant with the result that the tractors are not sufficiently maintained. The farm units are small and scattered with the result that a tractor spends a large number of the running hours travelling between one job and the next.

The availability of tractors for hire might be enough for a farmer for whom purchasing is either infeasible due to his limited financial resources or uneconomic due to the small size of his farm. He will however have to meet costs to the operator arising from the sources above. Besides he has to wait his turn after he has ordered for the services of the tractor. An important consideration in efficient organization of a farming business is the control by an individual farmer over his power source and implements to ensure timeliness of his operations and avoid delays which are characteristic of hired services. These arguments recommend an intermediate technology involving implements and power sources within the means of the average farmer and which fit in the framework of small operating units.

Because they are simple a country like Kenya, with modest industrial development, can build the capacity to manufacture them and therefore save on scarce capital and foreign exchange resources that would be expended on imported machinery. Their operation utilizes higher labour input per unit capital with the consequence that employment is created by their use. Their small sizes enable them to fit well in the existing small farms. And because they are cheap they are accessible to a larger number of the peasant farmers. The machines are required to expand production through breaking labour bottlenecks and making expansion of cultivated areas possible.

There is a current emphasis on development of the rural areas by the government (7) as a means of of achieving the national goals of increasing the incomes of the 'largest number' of the people (8). The practical execution of this policy requires intimate understanding of the resource availability at the farm level and the manner in which it is allocated, the direction in which improvements may be made on the basis of the problems at this level and the limitations of the available resources.

This study hopes to make a contribution toward the understanding of the structures of the agricultural production systems in the peasant areas. The study concentrates on the role of mechanization in agriculture within the framework of the complementarity between all the relevant factors in agricultural production, which cannot be overemphasised, with a view to understanding the current situation, identifying some of the factors limiting production and offering some suggestions for improvements.

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(7) See the 1969-74 and 1974-78 Development Plans. Nairobi Government Printer.

(8) For a policy statement on the objectives of development see "African Socialism" Kenya National Assembly sessional paper no. 10 of 1956 Nairobi Government Printer 1965.

The areas chosen for illustration are of interest both because of their particular problems and because they give an indication of the nature and form of the technology that will have a chance of success, more generally, in peasant areas. Being semi-arid, precipitation is very low and bimodal . crop yields are low in these areas. The low yields demand that a farm family should cultivate large areas even to meet the subsistance requirements of grains and legumes that constitute their staple diets. However, due to the low yields the people in these areas have limited financial resources and are unable to purchase such large machines as the tractor which would enable them to expand areas under cultivation. Moreover, living so close to the margin of survival, they are acutely sensitive to risks and may not risk losing the limited financial resources at their disposal in hiring. They use oxen-drawn implements which have low maintanance and running costs, and the animals, besides providing motive power, constitute a form of storage of their capital, readily negotiable in the event of pressing need for funds. Besides animal keeping is a long established practice which makes animal draught power fit into the local culture.

The conditions that have been described with respect to these areas have general relevance in other peasant farming areas. Differences are largely in the degree to which a particular factor e.g. climatic factors limit production. It has been suggested that the seasonality of labour requirements even in Vihiga, "with an extremely high population density", but with the existance of peaks in labour demand for certain operations is so serious a problem that as much as 30 per cent of the land on individual holdings remain uncultivated (9). Mechanization can be focused on breaking these labour demand peaks to enable expansion of cultivated areas and reduce the cyclical loops in the labour demand. The degree of poverty in such an area, even though is lower than in the semi-arid areas, can thus be reduced by application of mechanization.

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(9) "Employment, incomes and equality: a strategy for increasing productive employment in Kenya." Report of an inter-agency team financed by UNDP and organized by the international labour office. The reported uncultivated proportion of individual land holdings seems to be on the high side and should be treated with caution. It, however, serves for illustrative purposes."

In the semi-arid areas under study, improvement in agricultural mechanization based on animal power will have minimal distrubance of the existing social and economic structures, because cattle are are an important part of their culture. The focus of attention should be on implements that would increase soil moisture by increasing infiltration of the limited rain water and promote its conservation by reducing errosion and evaporation, besides enabling expansion of cultivation through efficient utilization of available power. There is an enormous backlog of implements that have been developed in other areas with the desired characteristics. All that is needed is research and development directed at identified problem areas to produce models suitable for the climatic and soil conditions in these areas. The maintainance and repair and even the local production of these implements can constitute the nucleus of rural workshop and manufacturing programmes.

CHAPTER THREE

The Study Areas.

Two areas, refered to in the study as Kalawa and Makaveti, were chosen for this study. Kalawa and Makaveti are market centres in the study areas, Kibauni and Kalama respectively.

Kalama is an administrative location in the Western Division of Machakos District. The distance from Machacos town to Makaveti, the approximate centre of this sample area is about fifteen miles in the general South Eastern direction. The area is located in a valley between the hills adjacent to Machakos town to the West and Mbooni hills on the Eastern side. Kibauni is also an administrative location but in the Eastern Division of Machakos District. It lies to the South-Eastern side of Yatta plateau, about ten miles to the south of Machakos-Kitui boarder.

Both areas are characterized by low rolling hills, a little steeper in Kalawa. The natural vegetation in Makaveti consists of scattered tree grass-land while in Kalawa one observes desert grass bush. Both areas are, however, semi arid receiving low and unreliable rainfall in the range 500 to 800 millimeters per year, divided between two seasons October to January and March to June. They are, therefore, suitable only for the most extensive forms of land utilization. Kalawa soil is predominantly light sand with patches of gravel in some places while in Makaveti the soil is redish loam with sand mixtures in some areas. The low and unreliable rainfall imposes the most serious constraint on crop production.

The peoples awareness of the importance of conserving the limited moisture for crop production in these areas is evident. They have adopted the practice of constructing bench terraces along the contours of the sloping land on which their farms are located. This controlls soil errosion and at the same time increases infiltration of rain water a factor which enables more efficient utilization of the limited moisture available for the growth of crops. The practice is more wide-spread in Makaveti where it has a longer history judging by the 'steps' form which the fields have taken than in Kalawa where one observes a large number of farmers in the process of constructing these benches.

Makaveti seems to have been settled earlier than Kalawa, with a higher density of home steads and evidence of older homesteads as well as a greater degree of fragmentation of land holdings, Homes are generally fewer and more widely scattered in Kalawa and the holdings usually in one piece.

The population pressure is higher in the western part of Machakos district, even in such marginal areas as Makaveti (table 3-1), than in the east. The population figures show higher population density in Makaveti than in Kalawa for census years. The population growth rates are of particular interest. Over the period from 1948 to 1969, for which census figures are available, it is evident that the population is increasing at an increasing rate in Kalawa while the growth rate in Makaveti is declining. There is some evidence of an eastward migration from the western side where the population density is higher. It was usual that people in Makaveti had relatives who had moved to Kalawa and the surrounding areas. This is probably one explanation for the changing rates of population growth. While it is probably to be expected that the population growth rate should be higher where the density is lower, there is cause to worry about the noted trend. The people are moving from wetter to dryer areas which cannot support the increasing numbers at the existing levels of subsistance.

It is evident that the population land balance has reached a stage, in the western end of this semi-arid area, that the land cannot support larger numbers of people under the present structure of the economies. The same will happen in the eastern end where the biologically determined growth is supplemented by immigration. Given that the eastern end is dryer, the living standards are expected to decline with the increase in population.

This situation calls for urgent measures that would increase land productivity and enable it to carry the increasing number of people, since although the population growth rates noted in these areas are lower than the national average estimated at 3.5 percent the environment in these areas is so hostile that a marginal increase is likely to have more serious consequences on the people's welfare than elsewhere in the country.

TABLE 3-1

Population Statistics.

		Kalawa	Makaveti
Population:			
	1948	12,819	13,807
	1962	14,603	19,207
	1969	16,717	21,183
Population Densities:(Per sqKm)			
	1948	32	78
	1962	37	109
	1969	43	120
Population growth rates: Percentages (Per annum)			
	1948-1962	.94	2.39
	1948-1969	1.27	2.06
	1962-1969	1.95	1.41
Area (sq.Km.)		392	176

Source: 1950, 1962. 1969 Population Census Reports. Kenya Government Printer.

The crops grown in Kalawa and Makaveti include; maize, cow peas, beans, pigeon peas, green grams, sorghum, millet, cotton, potatoes and cassava. It is evident that maize, beans, cow peas and pigeon peas are the major crops in both areas, judging from the number of people who plant them table 3-2. This cropping pattern reflects the peoples dietary preferences. While cow peas and pigeon peas are drought resistant and do well with low rainfall beans and maize require more rain. It is negretable that the people do not like such other drought resistant crops as sorghum, millet, green grams, potatoes and cassava which would provide subsistance needs in bad years and relieve them from famine. A drought evading synthetic maize seed variety, Katumani, that has been developed at the Katumani Research station is widely adopted because it is more reliable than the traditional varieties. This indicates that the people accept proven innovations readily (Table 3-4).

The crops are generally planted in mixtures with as many as 5 different crops found on one plot.

TABLE 3-2

The number of people planting the crops by region and season.

	Kalawa		Makaveti	
	short rains	Long rains	short rains	long rain
Maize	13	13	15	15
Cow Peas	13	13	0	3
Beans	12	11	13	13
Pigeon Peas	9	*	14	*
Green Grams	4	1	0	0
Sorghum	3	1	2	0
Millet	1	1	3	0
Cotton	3	*	4	*
Potatoes	0	0	1	4
Cassava	0	0	1	0

These figures are out of 13 and 15 farmers in Kalawa and Makaveti respectively.

* Pigeon peas take two seasons to mature, plated at the beginning of the short rains season, November, they are harvested at the end of the long rains season in June.

Cotton planted in the short rains are generally harvested twice, first at the end of this season and again at the end of the long rains season.

The common mixtures are: maize, covering a large proportion of the plots, planted in rows interplanted with beans and cow peas and a section under pigeon peas interplanted with beans and cow peas. During the short rains season, some maize is also interplanted among the pigeon peas but this is rarely done in the following season since the pigeon peas will have grown to sizeable bushes inhibiting the growth of maize if planted. The practice of mixed cropping has several advantages. Kline and others give a concise summary of some of the advantages (1) of particular interest are: "assurance against loss since it is unlikely that disease, draught or insects will wipe out all crops and cost reduction.." more efficient use of available power since the ground needs to be prepared only once for several crops...." and such other operations as weeding benefit all the crops.

The period from September to March has been classified as the short rains season and that from March to June as the long rains season. This is in keeping with the way the seasons are generally classified in the country. A large number of respondents, particularly in Kalawa objected to this classification arguing that they had more and

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C.K. Cline et al "Agricultural Mechanization in Equatorial Africa" 1969.

comperatively more reliable rains in the period refered to as the short rains. This classification has been retained but it is now apparent that there is no solid basis for it in the study areas. The usual connotations of these terms are not implied.

Simultaneous ploughing and planting take place as soon as the rains set in. These take place in August and September continuing into October in Makaveti, where it would seem the rains come earlier. The short rains planting take place in November and December in Kalawa (Table 3-3 a and b).

TABLE 3-3 a.

Makaveti: The Number of farmers reporting various operations by Months (out of 15 farmers).

	J	F	M	A	M	J	J	A	S	O	N	D
Ploughing & Planting		5	12	4				5	11	7	2	
Weeding	10			9	14	1					14	13
Harvesting	9	14	6									

TABLE 3-3 b.

Kalawa: The number of farmers reporting various operations by month (out of 13 farmers).

	J	F	M	A	M	J	J	A	S	O	N	D
Ploughing & Planting	-		6	12	3					3	13	4
Weeding	11			4	11						3	12
Harvesting	7	13	10									

(1) The figures in these tables are not mutually exclusive ie an individual farmer may appear in several months for a particular operation in a given season. Of interest are the modes which indicate the peaks of the various operations.

(2) Figures for the long rain harvests were not collected due to time limitations and are, therefore, not included in the tables.

The weeding for short rains crops spread over November December and January, with second weeding in the later part of the period, in both areas and harvesting starts in January, with cow peas and beans, through February and March, when maize is ready.

The long rains season activities again begin earlier in Makaveti where planting starts in March.Weeding covers the months of April, May and June. Unfortunately the farm record books, from which this information has been compiled, were not kept after June. However, the long rains harvests would be during June, July and August-on the basis of how long it look from planting to harvesting in the short rains season. Pigeon peas which take two seasons to mature are harvested during June.

The farming operations, therefore, cover most of the year except for a short period during late July, August and early September. This slack period enables the farmers to perform land developmental activities. Bush clearing, building bench terraces and breaking new land were reported to take place in July, August and September. Expansion of cleared land is only marginal which is puzling particularly in Kalawa with wide tracts of uncleared bushes.

Although data on the levels and distribution of labour requirements are not available, two factors emerge from these tables which enable qualitative inference on labour demand, the spread of various operations over several months and the overlaps of some operations.

Under conditions of scarce rains such as is the case in these areas, the timing of operations, particularly planting, is very crucial for satisfactory results. It is therefore surprising that planting is spread out over so many months, from 3 to 4 months. There is evidence of concern about planting at the right time. A large number of respondents reported planting just before the time the rains were expected. This would enable the crops to get the full benefit of the rains when they came. During the study period the rains did not come when they were expected. The result was widespread germination failure leading to the need for re-planting with all the accompanying losses; the first seeds were lost and the next ones planted too late as they had had to wait and see if the first ones would germinate. This is one factor which contributed to the wide spread of planting dates.

Even without the problems which lead to re-planting the planting period would still be wide due to the capacity limitations of labour and animal draft used in this operation. The evidence of appreciation of these limitations is provided by the practice of ploughing and planting at the same time. The preparation of a good seed-bed and weed control through ploughing and harrowing before planting is thereby compromised. It is conceivable that with more power resources and appropriate implements at their disposal, farmers would pay greater attention to land preparation before planting.

Another evidence of concern about planting at the right time is provided by a farmer who relied on a neighbour's oxen team for land preparation. Since the neighbour was still attending to his farm when the rains were expected, the farmer planted on unploughed land a practice which increased labour demand on hand ploughing between the seedlings.

The pressure on resources arising from requirements of the various operations and the need to perform them at optimal times is made even more serious by the overlapping of some of the operations. Weeding starts before all the gardens are planted and continue on the late planted areas when harvesting has to start. Before harvesting is over, the clearing operation has to begin in preperation for the next season, evident in the period from short rains to the long rains season.

The weeding operation has some other factor which increases the pressure on resources. It was noticed that farmers suspend weeding during draught because this promotes evaporation of the limited moisture leeding to withering of crops. This is a sensible practice under these conditions but it limits the period during which this operation takes place and increases the pressure on resources used. Weed pulling during such periods may reduce the pressures but this has heavy demands on labour and may not be practical for large farms.

The farmers adoption of biochemical innovations has been studied to give some insight into the intensity of their practices. A larger proportion has adopted the exclusive use of Katumani maize seeds in Makaveti than in Kalawa. Kalawa has a larger proportion of those still using local maize exclusively. The two areas are comperable with respect to those who use both local and Katumani seeds (Table 3-4). The use of fertilizer is still uncommon. Only two people in each area report applying fertilizer at all. The main difference between the regions, with respect to use of chemical inputs, arises in the use of insecticides. Insecticides are more widely used in Makaveti than Kalawa. The higher incidence of use of insecticides in Makaveti probably indicates that the white-ants problem, against which the insecticides are reportedly applied, is serious in this area. While chemical fertilizers are not widely used the use of animal manure is more widespread.

Livestock keeping is an important part of the economic activities in these areas. A large number of live animals are sold in Kalawa to traders from other regions. A consideration of this aspect of the farmers activities is important both because it competes with crop activities for labour and land resources and the motive power for crop activities is provided by oxen.

Livestock herding occupies one full man-day throughout the year even during those times when labour requirements in crop activities are at their peaks. The need to herd animals arises from the absence of fences around grazing areas while the animals must be kept from wandering into cropped areas and other peoples land. The value of pasture is so highly appreciated that, unlike elsewhere in the country e.g. Nyanza (personal observation), there are no common pastures in these areas. The

TABLE 3 - 4

The biochemical innovations : a frequency distribution of adopters.

Makaveti	Katumani Seeds.	Katumani and Local Seeds.	Local Seeds
Manure, Fertilizers and Insecticides	1	0	o
Manure and Fertilizers	0	0	0
Manure and Insecticides	4	1	0
Fertilizers and Insecticides	0	0	1
Manure only	3	2	0
Fertilizer only	0	0	0
Insecticides only	2	0	0
None.	0	0	0
Kalawa			
Manure, Fertilizers and Insecticides	1	0	0
Manure and Fertilizers	0	0	1
Manure and Insecticides	1	0	0
Fertilizer and Insecticides	0	0	0
Manure only	2	3	2
Fertilizer only	0	0	0
Insecticides only	0	0	0
None	0	1	2.

costs of pasture land, which consist of clearing bush for cattle and sheep grazing and the opportunity costs in terms of crops foregone, are internal to the individual farmers. All farmers allocate some part of their land for grazing. Grazing land can only be obtained from other people by formal arrangement and for payment. It was found that the two farmers, in the sample, without livestoct allocated grazing land for hired oxen, being payment for custom work, and for renting to those with livestock. During the dry periods, those with larger herds have a tendency to move some of their animals elsewhere. This practice is more common in the eastern region, Kalawa, where Kitui, Yatta and Makueni, pastoral areas further east, were mentioned as some of the destinations of such livestock movements.. In Makaveti it is usual to rent pasture, during dry periods for cash payments.

Maize stalks are administered to animals. However, due to the absense of storage facilities they are not available when they are needed most, during the draughts. The only evidence of draught-relief animal feeds was provided by the practice, by a few individuals, of growing napier grass and supplementing these with bench terrace grasses for cattle. Only one farmer reported purchasing hay. Watering presents no problem since there are several dams set in the gulleys which collect rain water and last through the year. While all the dams in Makaveti were constructed by the colonial government a large number of dams in Kalawa have been constructed by individuals.

It is therefore the case that animals are usually in very poor conditions during draughts, due to lack of feed, and the milk supply, which is modest during the best of times, virtually disappears. Of particular interest is the state of draught animals. Like all the other animals, draught animals are in very poor condition during draughts a factor which seriously limits their capacity to cope with demands on them when the seasons begin. The motive power available to the farmer can be greatly increased if measures to overcome this draught feeding problem are found.

Other factors which determine the quantity of power available to the farmer are selection and training of draught animals. Table 3-5 gives the qualities sought in draught animals as perceived by the farmers interviewed. The list of characteristics of suitable animals is long but contains quite a large

TABLE 3 - 5

Qualities sought in draught animals:

Frequency of responses.

	Makaveti	Kalawa
Wild	0	3
Mild	0	1
Big	5	8
Young	2	0
Middle aged	4	0
Old	1	0
Horizontally Short	2	0
Horizontally Long	5	0
Long limbs	2	0
Big Horns	1	0
Big Hips	2	0
Long Neck	1	0
Short limbs	1	0
Big Head	1	0
Short Horns	1	0
Strong bodied	1	0

number of contradictions. These contradictions and the low frequencies make it difficult to make inferences from this information. In particular it would seem the farmers may not have considered this factor before and that not much is done in the way of selecting particular animals for tasks. Middle aged, big and horitontally long are apparently the major qualities sought in draught animals, judging by their slightly higher frequencies.

On the presumption that the ability to give proper training to draught animals is unlikely to be widespread, concentration of the task of training ox-teams and their operators on particular people or institutions capable of giving good training can be used as an indication of appreciation of the importance of this factor. The survey revealed that the owner and his family members perform this task and it is considered easy and therefore does not need long experience. It therefore appears that not much attention is paid to training ox teams. Table 3-6 presents the periods required to train an ox team. While the range is too wide to allow clear inference about the length of time it required to train an ox team, it would appear, ignoring the extreme cases, that training generally takes 1 month or less.

The effect of poor training of task animals and their operators is observable in rough work, overlapping furrows, and crop destruction during weeding, admittedly partly due to the inappropriateness of the implement used for this operation (the mouldboard plough.)

TABLE 3 - 6

The period required to train draught animals: frequency of responses.

	Minimum Period	Maximum Period
1 Week	8	2
2 Weeks	5	6
3 Weeks	2	3
1 Month	2	4
2 Months	1	3
6 Months	1	0
1 Year	0	3
2 Years	0	1

Chapter Four

The Methodology of the Study

Having discussed the background to the study and the study areas a comment on the methodology used is required.

Sampling:

The sample used in this study had been drawn by another researcher, John Lynam [1], who had been working at Kalawa and Makaveti at the time of the field survey. He had drawn random samples of 18 respondents in each area of which I interviewed 12 and 15 in Kalawa and Makaveti respectively. I was not able to use the whole of his sample due to the limited time available for the interviews and problems associated with finding farmers home, not to mention the absence of public transport between the villages. Members of a homestead were treated as constituting one economic unit, a family. We observed that such units were fully integrated in performing agricultural tasks. The only exceptions arose in cases involving two or more wives. Each wife tended to have a separate homestead. However, since heads of families were chosen as respondents in the survey, the poligamous families had all the elements treated as one unit.

The use of Lynam's sample was convenient because it relieved me of the task of sampling, which would have taken a disproportionate

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[1] John Lynam is a Ph.D. candidate of Stanford Food Research Institute.

part of the limited time available for this study, and because it enabled me to draw from information he collected by means of keeping farm record books over a longer period than I could have hoped to do in the circumstances.

Data Collection:

The basic data used in this study was collected by means of a questionaire which I administered, Appendix 1. The interviews covered the period between the end of April and early June 1975, interrupted by trips back to Nairobi to collect survey students who carried out cultivated area measurements for us during the week-ends. I conducted the interviews myself through interpreters. This was to speed up the data collection exercise and bypass difficulties associated with instructing enumerators on the administration of a questionaire, particularly a long and complicated one as this one was, since competent field assistants could not be found. This approach also enabled me to get some useful information, that was not provided for in the questionaire, informally.

Despite these precautions, this phase of the study presented a lot of difficulties. Information on acreages; of holdings, under crops and of each crop and crop combinations and areas allocated to grazing were not obtainable from the interviews. This led to the decision to get the assistance of Survey Engineering Students. Due to the high costs involved in taking them to the study areas, we could not get all the various categories of areas we were interested in measured. We therefore only had cultivated areas measured. Uncultivated areas have been calculated on the basis of the respondents estimation of the proportions of their land holdings which have been cultivated. The most serious set of problems arose from the difficulties in getting flows of resource use and outputs from the crop activities. Information on family and hired labour utilization in terms of numbers of days and people involved in each operation for each technique could not be obtained from the respondents recall. Nor could information on other inputs, such as utilization of drought animals, and output flows and their disposal be obtained. We had hoped to get these from the farm record books, but infrequent farm visits by the enumerators and some difficulties in understanding what they were required to do, which we regrettably learnt about too late in the exercise, made the material unuseable (For a discussion of the divergence between what we had hoped to get from farm record books and what was forthcoming see Appendix 2).

Analytical Techniques:

In farm management studies, of this sort, it is usual to have some objective function whose value is to be maximized subject to managerial limitations and resource supply constraints. The usual objective is income. My original intention was to derive an optimal farm organization solution for the areas under study. The approach most suited in a situation involving several different farming activities would be a linear programming model. The data requirement for this is: input requirement for each crop activity, the competitiveness and complimentarities between various crop and between crop and livestock activities, the yields of various crops and outputs of livestock products and the values or prices of the various products. Also required would be the resource supplies during various times in the production cycle. The output and value figures would go into the construction of the objective function while the resource availability and requirements for each activity would constitute the constraints in the model. The contribution to the maximization of the objective function made by mechanization would be revealed by comparing optimal solutions under alternative regimes of power sources. Variation in the mechanical technology is therefore crucial to the understanding of the role of mechanization.

It was necessary to consider the various crop activities because one expects changes in the source of power to have such a fundamental impact on the farm organization to the extent that a completely different pattern of cropping would be optimal. A simple comparison of costs under different mechanical regimes, which does not take these likely changes into consideration, would be of limited value.

As it turned out, there was no variation in the mechanical technology and the figures on input and output flows were not obtainable. As a result neither a linear programming approach nor a gross margin analysis or a cost comparison between the various technicques could be carried out. Given the available data, Appendix 3, which only cover the stocks of various crop operations and livestock activities, the analysis that is possible has been modified considerably.

The analysis of the current situation takes a largely qualitative form. Inferences about the state of the mechanical technology are drawn on the basis of relationships between the various factors used. The qualitative results are presented in tables.

A behavorial model has been constructed and subjected to empirical test. It has been found that the cropping pattern is similar between the farmers and the two regions under study. It is therefore assumed, abstracting from differences arising from marginal differences in soil characteristics and climate, that the expected returns from crop activities are proportional to the cultivated areas. The peoples objective, in these areas where the threat of femine is very great, is to maximize outputs of the crops they grow subject to the limitations of the resources they own. There are limited opportunities for non-farm employments and leasure is a luxury they cannot afford. Given the ecological parameters which affect crop yields interfarmer differences in the scale of their operation, measured in terms of the sizes of cultivated acreages, and hence the expected returns are determined by variations in access to resources.

The expected relationships are embodied in the model $A = f(D,L,H,G,C)$. Where A is cultivated area, D the stock of drought animals, L the stock of family labour, H the size of holding, G the number of goats and C is the number of cattle. And it is expected that $\frac{\partial A}{\partial D}, \frac{\partial A}{\partial L}, \frac{\partial A}{\partial H} > 0$ i.e. cultivated area is directly related to the stocks of animal drought power, labour and the size of holding. Whereas $\frac{\partial A}{\partial G}, \frac{\partial A}{\partial C} < 0$, the livestock activities, keeping of cattle and goats are, competitive with crop activities for labour and land resources. The cultivated area is therefore expected to bear a negative relationship with the number of animals kept.

If these hypotheses are empirically upheld this would support the notion that the resource base and the extent to which competitive activities are undertaken condition the scale at which crop activities are undertaken. The findings will therefore shed some light on the economic pressures and factors limiting crop production in these areas.

Chapter 5

Results and Analyses

The average family size is approximately 9 people of whom the adults number 4 with 5 children. Family sizes are larger in Kalawa, 11 people of whom 6 are children, than in Makaveti, 8 people of whom 4 are children (Table 5-1). It is not clear why family sizes are larger in Kalawa.

Table 5-1

The Family Sizes

Categories	Total Numbers			Average Per Family		
	Kalawa	Makaveti	Kal.& Mak.	Kalawa	Makaveti	Kal.& Mak.
Male Adults	27	17	44	2.07	1.13	1.57
Female Adults	31	31	62	2.38	2.06	2.21
Children Under 15	80	49	129	6.15	3.26	4.61
Adults	58	48	106	4.46	3.20	3.78
Whole Family	138	97	235	10.61	7.46	8.39

The sizes of holdings are fairly large; a little more than 25 hectares in Kalawa and 11 hectares in Makaveti, on average, (table 5-2). The sizes range between 1 to 64 hectares in Makaveti

Table 5-2

Land Resource and Utilization

Hectares

	Kalawa	Makaveti	Kalawa & Makaveti
Number of farmers	13	15	28
Number of Adults	58	48	106
Whole Family	138	97	235
Total Holding	327.19	170.29	497.48
Average Holding (per farmer)	25.16	11.35	17.76
Average Holding (per adult)	5.64	3.55	4.69
Average Holding (per family member)	2.37	1.75	2.12
Cultivated Area	69.92	55.82	125.73
Average Cultivated area(per farmer)	5.22	3.72	4.49
Average Cultivated area(per adult)	1.20	1.16	1.18
Average Cultivated area (per family member)	.50	.57	.53
Cultivated Area / Total Holding.	.21	.32	.25

and 4 to 46 hectares in Kalawa, but the concentrations, modes, are around the means which are slight overestimates due to the existence of a few cases of uncharacteristically large areas. These figures, however, provide some rough insights into the land resource availability situation.

The cultivated areas are on average - approximately 25 per-cent of total holding size; a little lower in Kalawa, 21 per cent, than in Makaveti, 32 per-cent. This leaves about 75 per cent of the land holdings for livestock grazing and bush fallows. Since it is unreasonable to suggest that the two activities are three times as important as crop activities, it would seem that there is a wide scope for expension of cultivated areas, even allowing for unsuitable marginal land; provided improved mechanical, bio-chemical and hydrological technologies become available.

The land resources available per family (table 5-2) reveal that the two regions are comparable with respect to cultivated areas. While the sizes of holding per family member or adult are larger in Kalawa, the cultivated areas are approximately 1 hectare per adult or ½ hectare per family member in both areas. This shows that there is more uncultivated land per head in Kalawa than in Makaveti. Part of the explanation for this inter-regional difference in land utilization might be in the difference between the areas with respect to the livestock activities, livestock is more important in Kalawa than in Makaveti.

Two major considerations make the livestock activity relevant in this study. The livestock activity is important in its self, generating income to the farmer from sales of the livestock and livestock products besides home use of these as well as providing a form of storage of wealth. The allocation of resources between livestock and crop activities is therefore of interest. Livestock activities utilize land resources, grazing facilities, and labour, in herding and general care, as well as financial resources, e.g. in veterinary care. On the other hand, the livestock activity is complementary to crop activities, e.g. in the provision of manure and, of greater interest in this study, in the contribution of motive power in ploughing and weeding in these areas.

The importance of livestock in these areas is underlined by the sizes of stocks kept (table 5-3). Out of 13 people in Kalawa; 11 have cattle and draught animals, 8 have goats, 6 have sheep and 4 have donkeys. The corresponding figures for Makaveti (column 2) are out of 15 farmers. It is clearly evident those who do not keep animals at all are very few, and that livestock keeping is an important part of the local culture.

Table 5-3

Stocks of Livestock

Type	No. of Farmers With			No. of Animals			Average per farmer		
	Kalawa	Makaveti	Kal&Mak.	Kalawa	Makaveti	Kal&Mak	Kal.	Mak.	Kal&Mak.
Cattle	11	14	25	223	122	345	17.15	8.13	12.32
Drought animals	11	11	22	34	27	61	2.61	1.8	2.17
Goats	8	8	16	253	51	304	19.46	3.4	10.85
Sheep	6	6	12	60	36	96	4.61	2.4	3.42
Donkeys	4	0	4	7	0	7	0.53	0.	.25

The average figures show that the livestock activity is more important in Kalawa than in Makaveti. There are more cattle, goats and sheep per family in Kalawa than in Makaveti. This means that either land is more abundant in Kalawa or that livestock activities are relatively more profitable than crops in this area than in Makaveti.

The differences between the two regions in the sizes of herds and partly explained by the proportions of livestock herds to the sizes of uncultivated areas (Table 5-4). The number of animals per unit of uncultivated area are roughly comparable between the two regions. This relationship between livestock herds and uncultivated areas indicates conscious allocation of land resources between crop and livestock activities. The larger uncultivated areas in Kalawa are needed for grazing the larger herds kept in this area.

Table 5-4

Stocks of Livestock per uncultivated area (hectares)

Type	Kalawa	Makaveti	Kalawa & Makaveti
Cattle	.86	1.06	.92
Drought Animals	.13	.23	.16
Goats	.98	.44	.81
Sheep	.23	.31	.25
Donkeys	.02	0	.01

Although the cultivated areas per family member are comparable between the regions the rainfall is lower and less reliable in Kalawa than in Makaveti. The per family member cultivated areas should, therefore, be higher in Kalawa to meet subsistance requirements of crops. The relationship between livestock and uncultivated areas seems to indicate that livestock activities are considered more reliable in generating income than crops. This should change if technologies that increase crop yields and reliability are made available. The picture of land utilization is however incomplete. A cursory observation of the areas reveals that Kalawa is characterized by larger proportions of uncleared bush than Makaveti, where the population pressure on the land is relatively more intense. The uncleared bushes provide the basic feeds for the larger number of goats in Kalawa. It is therefore important to distinguish uncultivated cleared areas suitable for grazing cattle and sheep and bushes which among other uses, e.g. charcoal burning, provide grazing facilities for goats. These two different states of uncultivated land were, however, not separated in the data. The utilization of uncleared land is not, therefore, clearly revealed.

The hand implement stock figures Table 5-5 reflect the characteristics of economic systems that have evolved over a long period with hand methods. Although animal drought is widely used, the use of hand methods in crop operations is still very extensive. The range of hand implements is impressive, covering a wide range of operations from bush clearing (Axe, 'Panga' and'Matox'*) through primary tillage and weeding (jembe and panga) as well as developmental activities such as bench-terrace construction. The jembe is the principle implement in primary tillage as well as in weeding where the panga is also used.

All these hand implement, with the exception of some few jembes, which are locally made from scrap motor-vehicle leaf springs, are products of large scale industries. There is little evidence of locally produced hand implements. This is one area where rural industrialization could contribute to the creation of employment.

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* The Matox is a heavy duty hand implement with an axe and jembe bits on either sides for removing tree stumps.

Table 5-5

The Stock of hand implement

Type	No. of Farmers With			Total No. of Implement			Average per Farmer		
	Kalawa	Makaveti	Both	Kalawa	Makaveti	Both	Kalawa	Mak.	Both
Jembes	13	13	26	97	69	166	7.46	5.30	6.38
Pangas	13	13	26	45	68	113	3.46	5.23	4.35
Shovels	12	12	24	29	38	67	2.23	2.92	5.15
Fork Jembes	0	9	9	0	17	17	0	1.30	.65
Axes	6	9	15	7	28	35	.54	2.15	1.35
Metox	5	3	8	6	9	15	.46	.69	.57
Wheel Barrow	8	7	15	9	8	17	.69	.61	.65
Maize-Grinder	3	3	6	3	3	6	.23	.23	.23

The average figures show that the jembe, panga, shovel and axe, are the more common implements. The people in these areas stock more hand implements than their counterparts in Mbere, an area of comparable environmental characteristics, as revealed by Dr. Hunts study in this area, where households owned only 1.5 jembes, 2.5 pangas and only one in four had an axe [11].

[11] Diana Hunt, IDS Working papers Nos.166, and 180 1974.

Table 5-6

Hand Implements per unit of labour

Type	Kalawa		Makaveti	
	Per Adult	Per Family	Per Adult	Per Family
Jembe	1.67	.70	1.44	.71
Pangas	.77	.33	1.42	.70
Shovel	.50	.21	.79	.39
Fork Jembe	0	0	.35	.17
Axes	.12	.05	.58	.29
Matox	.10	.04	.19	.09

The number of hand implements conforms to the labour force figures revealed by the hand implements per family labour, Table 5-6. There is, therefore, no evidence of over-investment in these tools.

Both of the regions are basically animal and hand powered systems. The widespread use of animal draft power in the two major operations (ploughing and weeding) separates them from purely hand or engine powered systems. The use of engine power is particularly insignificant (table 5-9) but as elsewhere, where animals are used, hands are used extensively in conjuction with animal drought power in the same or successive operations.

Diana Hunt, IDS Working Papers Nos.166 and 180 1974.

There are 1.18 ploughs to every farm family, on average, (Table 5-7). Acess to the plough is higher in Kalawa than in Makaveti. This ranking is reversed in the case of ox-carts; while there is an ox-cart to every four families in the whole sample, there is only 1 to twelve people in Kalawa. There is only one ox-draw earth scoop in the whole sample. This is probably because the uses to which this implement is put are too unimportant to warrant its cost.

Table 5-7*

Ox Drawn Implement

Type	No. of farmers with			Total No. of Implements			Average per Farmer		
	Kalawa	Makaveti	Both	Kal.	Mak.	Both	Kal.	Mak.	Both
Plough	12	10	22	20	13	33	1.54	.87	1.18
Ox-cart	1	6	7	1	6	7	.08	.40	.25
Earth Scoop	0	1	1	0	1	1	0	.06	.0[illegible]

* The number of farmers figures are out of 13 and 15 farm households in Kalawa and Makaveti respectively.

The high average figures for the plough indicate a high level of access to this implement and indicates that oxen-cultivation is widely adopted in the study areas. This provides the definition of the level of mechanization in these areas.

The range of hand and animal-drawn implements leave certain gaps. There are no tools for such operations as harrowing or specifically designed for planting. Suitable tools for later stage operations such as harvesting, threshing and cleaning are conspicuous by their absence. The maize-grinder, the only domestic final processing machine found in the areas, is very scarce, there is only one to about four families. The scarcity of transport equipment is reflected by the stocks of wheelbarrows, owned by only 60 per cent of the people, and ox-carts of which there is only one to four people. The filling of these gaps would reduce drudgery in agricultural activities and release labour for expansion of the agricultural production.

The mould-board, a heavy all steel tool designed for deep ploughing and turning the soil is an inappropriate implement in the semi-arid areas. Johnston and Muchiri have noted that the "---objectives of tillage in semi-arid areas are to improve soil structure reduce bulk density, control weeds, reduce run off, increase infiltration and reduce moisture loss by evaporation--" my emphases. The tine or ard ploughs, which disturb the soil minimally, do not turn the soil and leave trash on the surface to reduce surface run off and evaporation, are more appropriate implements under such conditions. The introduction of implements that fit better with the environmental conditions would enable increases in yields resulting from better conservation of the limited available moisture.

Such implements could be based on a multipurpose tool-bar with provisions for various attachments than can be acquired successively as funds become available. The popular use of ox-carts indicates that a multi-purpose tool-bar convertable to an ox-cart could enhance its acceptance.

The combination of 2 drought animals per plough is the standard practice, defining the technical relationship between these forms of capital (Table 5-8). 13, out of 23,cases have two drought animals per plough.Where the ratio is 3, two cases, one respondent reported keeping a spare one for relief and other uses 6 animals (of which two donkeys which also carry back loads) on two ploughs. Besides being the owner of the largest number of drought animals, he is the only one in the Kalawa sample with an ox-cart that is used very regularly.

The effective ratio in both cases is therefore two. The two cases of 4 animals to the plough are the only exceptions. The ratio of 0 shows that drought animals have been used in the past but the plough owner had no drought animals at the time of the survey. Such apparently idle capital are contributed in joint enterprises with owners of drought animals who do not own ploughs. This is confirmed by a case of a farmer with two drought animals who is a member of such a joint arrangement. The practice is, however, rare, ownership of both ploughs and drought animals is the general practice.

Table 5-8

The relation between the stocks of drought animals and ploughs (a frequency distribution of cases).

No. of Ploughs	No. of Drought Animals					No. of drought animals plough					No. of farmers
	0	2	3	4	6	0	1	2	3	4	
0	5	1	0	0	0	1	0	0	0	0	6
1	1	9	1	2	0	1	0	9	1	2	13
2	0	4	0	4	1	0	4	4	1	0	9
> 2	-	-	-	-	-	-	-	-	-	-	-
Total						2	4	13	2	2	28

The relationship between the stocks of ploughs and drought animals show that there are no excess-capacities in either form of capital. The stocks kept conform with the technical relationship defining the manner in which they are combined in

Performing agricultural operations.

A consideration of the method used in carrying out various operations confirm the widespread use of drought animals and the dominance of 2 animal teams - (Table 5-9).

Table 5-9

The Methods used in performing various farming operations. A frequency distribution.*

	Hand Methods	2-Oxen	4-Oxen	Tractor
Breaking New Land	1	12	14	4
	(1,0)**	(10,2)	(3,11)	(1,3)
Ploughing	1	27	2	0
	(1,0)	(13,14)	(0,2)	(0,0)
1st Weeding	4	24	0	0
	(1,3)	(12,12)	(0,0)	(0,0)
2nd Weeding	18	10	0	0
	(11,7)	(2,8)	(0,0)	(0,0)

* Frequency distributions are not exclusive. An individual respondent may appear in more than one cell. The figures are, however, considered reflective of the dominant practices.

** The figures in brackets allocate the figures above then between Kalawa, the first figure, and Makaveti the second.

The figures reveal interesting contrasts between the two areas. Considering the modes, the mechnaical technology for both areas jointly might be described by: The use of 4 oxen in breaking new land, 2 in ploughing and the first weeding and hand methods in the second weeding. This is, however, a weighted sum of two different patterns i.e. Kalawa is more accurately described by the use of 2 oxen in the first 3 operations and hand methods in the second weeding, while in Makaveti the dominant pattern is 4 oxen in breaking new land.

The most significant difference between the two regions is in breaking new land, 4 oxen in Makaveti and 2 in Kalawa. This difference may be explained by the difference in soil types. The Makaveti soil is the more difficult, heavy redish loan while in Kalawa the dominant soil-type is the lighter, light-coloured sandy soil. The difference with respect to the second weeding is marginal and probably superficial. For operations which take place every season, on old land, these patterns are therefore comparable.

The analysis of the relationship between the methods used and ownership of drought animals (Table 5-10) indicates that the techniques adopted are invariant with the ownership of these resources. The pattern of the techniques used by those without and those with 2 or more drought animals is the same.

Table 5-10

A cross tabulation, frequency distribution, of the relationship between ownership of drought animals and methods used.

No. of Drought Animals	Operations	Hand-Methods	2-Oxen	4-Oxen	Tractor
0	Breaking New Land	1	2	3	1
	Ploughing	1	6	0	0
	Weeding	5	5	0	0
2 or 3	Breaking New Land	0	8	6	2
	Ploughing	0	14	1	0
	Weeding	9	14	0	0
4 or more	Breaking New Land	0	2	5	1
	Ploughing	0	6	1	0
	Weeding	6	7	0	0

True the number of people with no drought animals, in the sample, are few, but such people are few in these areas as was learnt from informal communications.

It is, therefore, the case that the methods used in carrying-out the various major crop operations are roughly uniform within each of the areas and between them and invariant with the ownership of resources used.

The inference to be drawn is that the technology is static. The term is used in a historical sense with no pretence at predicting what the future state is going or likely to be or how long the state will continue to remain. A new farm tool or machine is an innovation. It must be technically and economically feasible to be adopted by the farmers. However, farmers in traditional subsistence economies, and to an even greater extent those in the more hostile environments e.g. arid regions, are understandably warry of assuming new risks because they are close to the margin of survival. A necessary condition for acceptance of new technologies is that they should have demonstrable significant impacts on production.

The nature of economies under study presents a system which has evolved and settled in equilibrium with nature, though at a level of poverty and constant threat of femine. Of such peasant systems M.P. Collins notes that agriculture is conditioned by natural factors (not economic forces which modify natural advantages of particular areas e.g. location with respect to markets in urban centres) [12]. It is remarkable that such expensive implements as the ox-cart and mould-board plough and ox-carts that were unknown in these areas three decades

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[12] M.P. Collinson "Farm Management in Peasant Agriculture: A handbook for rural development planning in Africa". Praeger special studies in International Economics and Development. New York, Praeger, 1972.

ago are so widely adopted. The mouldboard plough is admittedly inappropriate in these areas with limited moisture that should be conserved. It must have been adopted because of its demonstrably superior capacity in comparison with the hand methods that dominated before it. In the absence of more appropriate implements with comparable capacity, e.g. ox drawn, it is a significant component of the optimal technology available.

Diffusion in these areas is generally a slow process. For it to take place there must be an initiator from off the farm either the government or a private firm which makes the machine available. In a rare instance of agreement T.W. Schultz and J.W. Mellor [13] note that an important general characteristic of inputs of technological change is that most of them must be socially provided or require social decision in allocating resources to them. Initial adoption will be by those who are more responsive to change either because they are more educated, informed, or innovative. In these earlier stages of adoption variations will be observed with the proportion of those still attached to the more familiar traditional practices declining over-time under the pressures of more attractive returns. The whole region gradually moves towards and eventually settles in a static equilibrium characterized by widespread adoption of the machine. Under conditions of rapidly changing technology,

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[13] T.W. Schultz "Transforming Traditional Agriculture" Yale, 1964
J.W. Mellor "Towards a theory of Agricultural Development" in Agriculture Development and Economic Growth H.M. Southworth & B.F. Johnston ed. Cornell University, 1967.

one of A.T. Moshers "essentials for agricultural development" [14] the equilibrium points are transitory and largely academic. It is in this sense that the term 'static' is used here. Stability in the sense that there is a strong resistance to change even if there were new attractive possibilities is not implied. The area simply awaits the arrival of the next disturbance with attractive technical and economic attributes to be set in motion to towards a new superior equilibrium.

The dominance of animal drought in these areas can be explained in technical and economic terms. Although the various technologies are generally found together in practice, and in the study areas both hand techniques and animal drought power are used, it is convenient for clarity of exposition to treat the various states of technology (hand, animal and engine powered systems) as alternatives. In peasant agriculture the opportunity cost of family labour is generally considered low because there are few alternative opportunities for employment. This is particularly true of Kenya with limited non-farm employment opportunities. The major cost of family labour is the leisure foregone which is probably a luxury not worth considering in situations where one resides at the margin of survival. In terms of costs of

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[14] A.T. Mosher "Getting Agriculture Moving: Essentials for Development and Modernization," Praeger.

getting particular tasks done, therefore, hand methods are likely to cost less than either animal or engine powered alternatives. Hand methods are however limited in their capacities and tedious. The choice of animal drought power in the major operations is logical because it reduces the drudgery of hand methods and has a higher capacity. The dominant factor conditioning this choice is therefore technical because it expands the production possibility frontier.

Why then, one could ask, do they not adopt the more technically superior engine powered machines? The engine powered machines are definitely techncially superior their adoption is however unlikely to be economic.

The costs involved in animal powered systems include, as well as those in engine power, the initial costs of acquiring the capital items less their disposal values (discounted if preferred) and the maintenance costs. The initial costs of the ploughs are low and their life very long (A large number of the ox-ploughs in use were acquired as early as the late 1930s and mid 1940s at as low prices as Sh.90). Their maintenance costs are also low, replacements of the shear every two seasons, the wheel after two to three years, cases of breakages were few but cheaply corrected by welding in local machine shops. The drought animals involve initial financial costs if bought but are often born on the farms. Their maintenance costs include herding labour, which is invariable with the sizes of herds and could be ignored in these areas where the livestock activity is an important part of the culture, grazing facilities are worth considering in view of the scarcity of grass in these areas and marginal costs of introducing an additional animal might be important but are diminished in as much as the drought animals are eventually disposed of on the markets for beef at comparable prices with the other cattle. One could perhaps break down the cost items much more but the advantage of such an exercise might be very limited.

The costs of using a tractor are likely to be much higher than the animal drought power alternative. Two possibilities exist; either the individual farmer purchases a tractor or he hires one. The cost of buying a tractor is too high for the average farmer and the machine too large for the size of his farm. Running costs which include fuel and maintenance are also high. Refueling points and maintenance workshops are often distant and competent mechanics very few. In the hiring alternative, the size of the farmer's farm might not be a limiting factor but the costs incurred in travelling between the farms will be passed on to the farmer. Because the rainfall is low and unreliable in these areas and few people grow cash crops or harvest enough of the traditional food crops to realize marketable surpluses, financial resources are limited and probability of loses of money spent on hiring very high. Animal drought is therefore preferable for the additional reason that loss of financial resources is avoided. It was generally the case that a farmer without drought animals of his own either contributed his own labour in working with the team on his and the owners farms in exchange for the custom work or provided grazing facilities in exchange and only rarely made monetary payments.

The individual control over ones source of drought power is also an important factor. A problem with reliance on hired teams is that the operations are not performed at the right time since the owner attends to his farm before hiringout. In Kalawa there is one farmer with no drought animals of his own (he is really a case of extreme poverty, he does not own any livestock, and ranks below the rest by any measure of wealth except land) who relied on his neighbour for custom work in exchange for grazing facilities. He planted his farm before ploughing when the rains came in March because the neighbour was still too occupied on his own farm to perform custom work. Lateness is a problem [illegible] that is generally mentioned even in the high potential areas where tractors are widely hired. Since the costs involved in animal drought systems are within the means of most farmers, this alternative form of mechanization also facilitates individual control over the source of power and implements.

From the national point of view an animal powered system does not impose as heavy a demand on the foreign exchange resources as the tractor does and shields the economy from such external sources of destablizing inflationary pressures as rises in oil prices. It fits well with the cultures of the people who traditionally keep cattle and does not displace labour. It would therefore seem that the trend observed in the study areas deserve support on social grounds.

Having noted that the methods used in carrying out the various operations is invariant with the ownership of resources, what then is the significance or effect of variations in access to resources? A major proposition of the study, empirically tested, is that the variations in access to resources are discernible in variations in the scales of operation.

The scale of operation is ideally defined to include both the extensiveness of the farm business (acreage worked) and its intensiveness (e.g. cropping patterns; multiple cropping, mixed cropping and crop densities and use of such inputs as fertilizers). The factors affecting the intensiveness of the farm business have not been studied in details in this study. However, due to the comparability of crop activities, in terms of crops grown and patterns of crop mixtures, within each study area and between the areas this factor is considered unimportant in the cross section analysis. The implication of comparable cropping patterns is that the input requirements for unit acreage for all the sequences of operations carriedout over the whole agricultural cycle will be comparable. This presumption has not been tested due to lack of data on input flows into the various activities. However, assumption of comparable management levels, a reasonable assumption in situation where the technology is fairly uniform, enables inference of comparable intensity in the crop activities.

The variable used as a proxy for the scale of operation, size of farm business, is therefore just the cultivated area. The scale, so defined, at which a farmer operates reflects whatever bottlenecks that exist anywhere along the production cycles, imposing a constraint on expansion. The untested presumption is that even if weeding labour, for example, is the source of an effective bottleneck, the farmer adjusts to this by only ploughing and planting as much as he can weed with the resources of labour available to him. Weeding labour constraint is therefore indirectly reflected in the cultivated area even though the exact magnitude of its influence might not be isolated.

Linear models, with the following variables, have been run to test this proposition.

A = Cultivated area

D = The number of drought animals owned.

L = The number of people in the family (excluding infants under 10 years) one proxy for labour availability.

L' = The number of adults above, 15 years of age, an alternative measure of labour availability.

H ≡ The size of holding

G ≡ The number of goats, competing with crops for land resources.

C ≡ The number of cattle, competing with crops for land resources.

C' ≡ The number of cattle, competing with crops for land resources (C' excludes drought animals).

The equations used to analyse the relationship between the scales of crop activities, resource availability and competitive activities are:

$$\text{I} \quad A = \beta_o + \beta_1 D + \beta_2 L$$

$$\text{II} \quad A = \beta_o + \beta_1 D + \beta_3 H$$

$$\text{III} \quad A = \beta_o + \beta_1 D + \beta_2 L + \beta_3 H + \beta_4 G + \beta_5 C$$

$$\text{IV} \quad A = \beta_o + \beta_1 D + \beta_2 L' + \beta_3 H + \beta_4 G + \beta_5 C'$$

$$\text{V} \quad A = \beta_o + \beta_1 D + \beta_2 L' + \beta_3 H + \beta_4 C'$$

$$\text{VI} \quad A = \beta_o + \beta_1 D + \beta_2 L' + \beta_3 H + \beta_4 G.$$

These are behavorial functions, models of farmers decision making in choosing how much to cultivate. Linear relationship between the dependent and the independent variables have been assumed. Logged versions of a Cobb-Douglas production function form were attempted but the loss of degrees of freedom arising from the existence of zero values in some of the variables was too great to allow any meaningful inferences from the results.

The results were:

I $$A = 2.0 + 0.48D + 0.16L \qquad R^2 = .582$$

Significance levels .025 .1 ?

II $$A = 1.95 + .31D - .03L + .14H \qquad R^2 = .763$$

Significance lelevs .005 . 2 .4 .005

III $$A = 2.25 + .4D + .06L + .15H + .01G - .03C \qquad R^2 = .775$$

Significance levels .025 .2 .4 .005 .4 .2

IV $$A = 2.28 + .36D - .14L' + .14H + .0G - .02C' \qquad R^2 = .776$$

.025 .2 . 4 .005 .45 .25

V $$A = 2.18 + .36D - .12L' + .14H - .02C' \qquad R^2 = .776$$

Significance levels .01 .4 .4 .005 .25

VI $$A = 2.08 + .34D - .13L' + .14H - .0G \qquad R^2 = .766$$

Significance levels .025 .2 .4 .005 .45

The relationship between cultivated area and the principal sources of power, drought animals and family labour is examined in equation I. It shows that the stocks of drought animals (D) and family labour (L) determined the cultivated area. The coefficients are significant at 10 per cent but the predictive power of the model is low, these two only explain about ~~50~~ 60% per cent of the variations in cultivated area. Including the size of holding (H), equation II, improves the predictive power of the model. This equation shows that the size of holding and stock of drought animals are significant determinants of cultivated area. Two curious things happen with the introduction of the holding size. The labour coefficient takes the unexpected negative sign even though it is not significantly different from zero and the significance of the drought animals coefficient declines. The labour coefficients take the unexpected (negative sign in equations (II, IV, V and VI) but at 40 per cent significance level these coefficients are not significantly different from zero.

The high significance of the sizes of holding in the explanation of cultivated areas is surprising because it indicated that this variable imposes limits to expansion of cultivated areas a result at variance with the finding from average calculations that about 75 per cent of the land is uncultivated. It may be that the result has been influenced by cases, especially in Makaveti where the holdings are generally smaller, in which case the land is limited and larger proportions are cultivated. Filtering the data to allow comparison of the two regions on this question was not done because the samples were too small. That Kalawa has more potential for expansion of cultivated areas than Makaveti is evident from a comparison of the proportions of cultivated areas. (Table 5-2). However, even in Makaveti there is a wide scope for expansion of cultivated area.

The curious results of introducing the size of holding in the model may be partly the result of the nature of the variables used. Both the holding sizes and cultivated areas are continuous variables while the stocks of drought animals and family labour are discrete variables. The use of flows of drought animal and labour services is more appropriate but these were, as already noted, unobtainable. Given these limitations the results as in equation I are probably more revealing of the influence of these factors on cultivated areas. It must however, be admitted that the labour measures used, the number of people or adults in a family, may not reflect the level of labour availability. Since actual observations were not made some such dependents as those who are too young or too old to make reasonable contribution to agricultural production may have been included.

Cattle are competitive with crops for resources. This is the implication of the negative coefficients in III, IV and V. However, the level of significance of these coefficients is low at 20 - 25 per cent. The influence of goats is a lot weaker. The coefficients of the number of goats are not significantly different from zero. In fact the results give zero coefficients in equations IV and VI. Goats might not be directly competitive with crops for land resources since they depend on uncleared bush for feed. The missing link in the relationship between goats and cultivated land would be such factors as the cost of clearing bushes for both crop activities and cattle grazing.

These results show that the variations in access to resources, while not reflected in variations in techniques used, are discernible in variations in the scale of operations. This is more conclusively demonstrated in the cases of drought animals and land resources availability than in the case of labour. The average figures indicate that there are large tracts of uncultivated areas. The limit to the expansion of cultivated areas implied by the significance of holding sizes, in the equations, may not be very important taking the regions as a whole. Some redistribution could be considered as a means of increasing efficient utilization of land resources.

Cattle are competitive for land resources. The complementarity between cattle and crops e.g. the provision of manure that may recommend the extension of the farm business along the intensive margins favouring joint crop and livestock activities has not been examined. Goats are understandably not directly related with cultivated areas due to the type of feed they depend on. which is obtained in uncleared bushes not readily useable for crop activities.

Chapter Six

Summary, Conclusions and Policy Implications

It has been argued that in countries such as Kenya where the agricultural sector is very important; in terms of the proportions of the country's population it supports, its contribution to national product and foreign exchange earnings, not to mention its importance as a source of food supplies and industrial inputs; development strategies aimed at increasing income generating opportunities, employment and more equitable income distribution should give great attention to this sector. It was noted (Chapter two) that while the agricultural sector's contribution to national product was large at 40 per cent, the per capita product and consumption is lower than the national average. The lower labour productivity in this sector, relative to the non-agricultural sectors, reflects its relative neglect in the past.

It has also been argued that in view of the scarcities of capital and foreign exchange and the relative abundance of labour in the country generally and in the peasant agricultural areas particularly, strategies based on labour intensive technologies are consistent with optimal resource allocation. The objectives of employment and more equitable income distribution is also accommodated in such strategies. This is the background to this study.

The urgency of the need to seek technological solutions to the problems of agricultural development is underlined by the conditions which obtain in the areas studied. The areas are in the semi-arid region with bi-modalrain distribution adding up to less than 800 millimeters in an average year. They are regular receipients of famine relief supplies of grains. The population land balance is adverse under the existing state of the technology in these areas as can be discerned from the population migration from the more densely populated but more favoured areas to the more marginal less populated areas. The conditions are getting worse with the increasing population pressure. Technological solutions to this population land imbalance are clearly urgently needed.

Inputs in the development of technological change must be socially provided since private producers will undersupply due to their inability to capture all the benefits of the outcomes and due to the fact that they require larger capital outlays in research and development than the farmers can provide. New technologies must be technically and economically attractive to the farmers to be adopted. Since the farmers living at the margin of survival are understandably wary of assuming new risks associated with adoption of new technologies these must have demonstrable significant impacts on production be accepted.

As has been noted, mechanical, chemical, biological and hydrological inputs are so complementary in agricultural production that a package approach in the designing of strategies for expansion of output is strongly recommended. On the biological front, the major problems arise from adaptation of crops to the environment. It was observed that there is some divergence between the peoples dietary preferences and the crops which are better adapted to the environment in which they live. Such crops as maize and beans, which are not drought resistant, feature highly in their dietary preferences and are widely grown (Table 3-2) while such relatively more drought resistant crops as green grams, sorghum, millet and cassava are not as popular. The only relatively drought resistant crops which are also popular are cow peas ans pigeon peas.

Two policy suggestions can be made to handle the problems associated with this divergence between tastes and environmental adaptation of crops. Nutrition programmes promoting the consumption of the relatively more drought resistant crops based on factual information on their nutritive contents, and supported by technological developments in processing the crops to make them more attractive could be used to influence tastes and hence cropping patterns towards better conformity with the environment. Alternatively or in conjuction with these, research development of drought resistant strains of such crops as maize and beans which feature so highly in the people's dietary preferences could be carried out. The development of the drought evading "Katumani" a synthetic maize variety, is a welcome development whose success is reflected in its widespread adoption. However, drought resistance would be more attractive than just drought evasion for comparable expected yields.

The low yield problem may also be partly the result of low levels of plant nutrients, particularly in the longer settled areas where land has been exhausted by repeated use without replenishment. Soil studies should be carried out to determine the levels of availability of these nutrients. It has been observed that the use of chemical fertilizer in these areas is insignificant. This is probably made up for by the more widespread application of manure. Whether or not application of more chemical fertilizers should be encouraged and the prices at which they would be profitable to the farmers should be determined. Although it is doubtful in view of the high and rising fertiliser prices and the peoples understandable evasion of practices in which losses of financial resources might be involved, it may be that the low level of use of these inputs result from bottlenecks in the marketting channels.

Water supply is the most serious factor limiting crop production in these areas. The rainfall is extremely low and bi-modalwith very low reliability (Chapter Three). It has been noted that the people have voluntarily adopted the practice of constructing bench terraces along the contours in their fields which increase infiltration of the limited rain and avoid such operations as weeding during droughts, to limit evaporation, in acknowledgement of and to cope with the water problem. Such land developmental activities as bench terrace construction should get governmental encouragement. This examination falls short of examining possibilities of increasing supplies of water. This is however an area where investigations could lead to greater improvements. It has been suggested that one means of promoting more efficient use of available water would be the development of more appropriate mechanical implements adapted to the particular conditions in the dry areas. Implements which leave trash on the soil after primary tillage, to serve as mulching material, by not turning the soil for example would promote moisture conservation.

The focus of this study relates to the role of mechanization in the production process. The availability of power and suitable implements is a major factor which limits expansion of cultivated areas in peasant agriculture. From the national resource allocation point of view as well as the conditions of the peasant farmers with respect to their access to resources it has been argued that labour intensive alternatives are sensible. Intermediate technologies based on animal draft or simple motorized implements are deemed consistent with the appropriate technology so defined. The choice of animal drought power and its widespread use in the study areas conforms with this suggestion.

A sketch of resource availability and use provides a useful framework for viewing the mechanization question. It has been observed that the land plots available to the families in these areas are fairly large (Table 5-2) based on the average figures - 25 and 11 hectares in Kalawa and Makaveti respectively - but that the proportions that are cultivated are very low. This leaves approximately 75 per cent of the land uncultivated on average, for both areas. The larger uncultivated areas in Kalawa are partly explained by the existence of larger herds in this area. In fact the livestock per unit uncultivated areas figures (Table 5-4) are roughly comparable between the areas,slightly higher in Makaveti. Livestock is evidently a relatively more important activity in the more marginal area, Kalawa, than in Makaveti. This indicates conscious and expected allocation of land resources between the two activities in conformity with environmental characteristics. There is therefore some indication of competition between crop and livestock activities. In the behavorial model constructed and tested in Chapter 5, competition between cattle and crops is revealed in the regression coefficients, albeit at low levels of significance. The competition of goats with crops is however not indicated.

Land resource utilization has not been exhaustively analysed. There are some uncleared areas; larger in Kalawa than in Makaveti, where the population pressure is higher. This indicates that there is room on the margins to expand both crop and livestock activities. While goats rely on these uncleared areas for feed and their population is higher in Kalawa with larger uncleared areas it would seem that such areas more than meet the requirements for keeping goats. It has been suggested that the binding constraint might be technological, the limitations of the sources of power as well as the factors which affect yields - e.g. the chemical hydrological and biological inputs referred to above. And that if technological solutions to the low yields, which would make expansion of cultivated areas attractive, are found and more power became available, such expansions would take place. One may even expect redistribution of resources from livestock to crop activities.

From the regression results the size of holding, land availability, has a surprisingly high significance in the determination of cultivated areas, a result at varience with the inference from the averages that large areas are left uncultivated because it implies that land is a binding constraint on crop activities. The explanation offered is that smaller sizes of holdings in Makaveti where relatively larger proportions are cultivated may have exerted undue influence on the regression results, a proposition which remains untested due to the fact that the sample was too small to allow filtering. More generally, the average figures do not reveal the variations among the individuals with respect to access to land.

The availability of drought power, measured in terms of the number of drought animals available to the farmer, show some remarkably consistent association with cultivated areas. This indicates that the availability of power is a determinant of the scale of operation.

Recommendations for improvement of the mechanical technology have been made within the existing framework based on animal draft. It has been suggested that the development of more appropriate lighter animal drawn implements would lead to more efficient utilization of the available power and moisture, a suggestion which favours such alternative tools as the line amd ploughs above the mouldboard ploughs now in use. It has also been found that little attention is paid to the selection and training of drought animals and that the scarcity of feed during droughts seriously affected the power rating of the oxen (Chapter Three). Research should be directed at the development of suitable implements tailored to the requirements of particular regions - e.g., those that promote more efficient utilization of power and the limited moisture in the semi-arid areas. Expansion of the veterinary services to include advice and assistance with the selection of task animals would be useful. The creation of institutions for training the animals and their operators is also recommended. Fodder crops which can grow in these areas utilizing such land as the bench terraces as well as the more marginal places, should be identified and encouraged. Such by products as maize stalks become available and are administered to the livestock at times when grass is relatively abundant. The development of techniques for processing such products and storage facilities so that they can be held over till the times of great need is one way in which the solutions to the drought feed problem may be approached to increase power availability.

Appendix I

The Questionaire

The table included in this appendix presents the questionnaire administered for this study.

It is probably not too surprising that there were many problems with questions which required exact measurements of quantities or areas and those requiring recall among people who do not have standard units of measurement of quantities and where the land has not been surveyed and who do not keep records of their activities either.

Question 1 a asked for numbers of pieces of land held and their acrages and other characteristics. While all the other questions were well answered this was not true of the acrages which were the more important but not known. Total holding sizes were therefore calculated on the basis of cultivated areas which were measured and estimates of proportions under cultivation. Crops and crop mixtures' treatment came out well except for the acrage problem. Timing of the operations was good and cross-checked with information from record books. Lateness, a measure of resource constraint however could not be determined, . Implements used and owned questions 2 and 3 were easily obtainable so was hiring of these question 4 which revealed very little evidence of hiring. Family, community and hired labour utilization was given on incidence basis, since it was difficult to give numbers and days involved, questions 5 and 6, except in the case of permanent hired labour whose contribution to particular activities and operations could not be determined either. The question stocks of livestock and their care, question 7 and 8 was generally well answered. The desirable properties in draught animals, question 9, did not give analysable results. Sources of draught animals and who trains them, question 10, came out well. The length of the training period and the value attached to trained animals did not give useful results. Stocks of animal drawn implements question 11 and their initial costs and maintanance question 13 gave useful information. The work rates question 12 were not obtainable however.

1 (a) How many pieces of land do you possess and where are they located?
How much can be cultivated, and how much is cultivated etc.?

Pieces	Location/ syblocation	Topography & Acrage	Cultivatable	Owner Cultivated	Other use: (specify)	Rented-(1) Fallow (2) Grazed (3)	Soil colour & Type etc e.g. Rocky
1st Here							
2nd							
3rd							
4th							

Topography: Flat, Undularing, Steep slope, River Valley, Terraced etc.

1 (b) Please tell me the acrage of the crops for the last short rains (SR) and the current long rains (LR) specifying whether they were pure strands (P) or mixtures (M)

Broadcast (B) or row planted (R)

Crops	Acrage	Treatments: Insecticides (I) Manure (Ma) Fertlizer (F)	Seeds: Local (L) Improved (Im) Hybrid (H)	Harvest: (where applicable Lbs. etc.	Sales: Quantity Revenue & or Price	Domestic use
SR:						
LR:						

1 (c) What is the best time (In terms of 1^{st} 2^{nd} etc Week of J, F^{nd} etc, month for the following operations and when did you carry them out?

Operation	Short Rains		Long Rains		Explain why If late
	Best time Week/Month	When done Week/Month	Best time Week/Month	When done Week/Month	
Breaking new land					
1^{st} Ploughing					
2^{nd} Ploughing					
Weeding:					
1^{st}					
2^{nd}					
Harvesting					

1.d. Of the activities ploughing, weeding and harvesting which is it most serious to delay in? (Which next etc.)

2 (a) What Implements (farm tools) do you use for the following different operations Give the answer in order of preference, 1, 2, etc; specifying whether own (O), Hired (H), or Jointly owned (J).

Operations	Tractor	6-Ox	4-Ox	2-Ox	Hoe	Jembe	Panga	Ox-cart	Other (specify)
Breaking New land									
1st Ploughing									
2nd Ploughing									
3rd Ploughing									
Planting									
Weeding									
Harvesting									
Threshing									
Transporting Produce									
2 (b) Do you use ox-teams or tractors for any other thing?(Specify)	○ Ox-team (Give Size)								

Tractor

3. Which of the following farm equipment do you own; Individually (O); jointly with others (J)

Equipment	Number	Make	Date purchased	Price	(O)	(J) (specify number of people)			
						With Relatives	Cooperative society	Business partners	Other (specify)
Tractor									
Landmaster									
Ox-Plough									
Wheel barrow									
Ox-cart									
Tractor Plough									
Tractor Harrow									
Tractor Cart									
Maize Planter									
Other seeder (specify)									
Maize Grinder;									
Jembe									
Panga									
Spade									
Other (specify)									

4 (a) Do you hire farm equipment for some operations, or did you hire during the last year and the early part of this year? If so, please give me the following information.

Frequency: Yearly (1), Often (2), Occasionally (3), Never (4). Who from: Neighbour (1), Friend (2) Other (specify)

Equipment	Operations	who from	frequency	Acrage last year ect.	Cost last year etc.	Quality of work: Late (1), Poor work (2) Other (specify)	Other quantity other than Acrage
Tractor							
Ox-team							
Land Master							
Ox-cart							
Tractor trailer							
Other (specify)							

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4 (b) Give me further information about contracting?

(i) When do you pay? When booking (1), Before work starts (2), When work starts (3), After work (4), At harvest (5)

(ii) What is the source of money you pay? Saving(1), Loan from neighbour(2), Government loan(3) Earnings from other occupation (specify) (4), Sale of crops (5) Other (specify)

(iii) Other problems with hiring not mentioned

5. I would like to know how many of your family members do farm work? I would also like to know whether any, who live here, do some other work.

No	Ploughing with Oxen (OP) Hand Ploughing (HP)	Planting (OP,HP)	Weeding (OP,HP)	Harvesting	Transporting Produce (OP,HP)	Threshing	Business (B)Other (specify)	Any Othe Farm work
Male adults								
Female Adults								
Male Children (Under 15yrs)								
Female Children								

(a) Do you use community labour of any sort? If so, what do you use it for Mark with ✓	Breaking New land	Weeding	Harvesting	Thresting	Building	Other (specify)

6. (b) How many permanent employees do you have? Specify whether make (M), Female (F), or Child (C) and the monthly cash & Kind wages.

Cash: Shs per month	
Food	
House	
Clothes	
Other (specify)	

6. (c) Is it easy to get permanent labour If not, Why?

Can you usually get good permanent labour If not, Why?

What other problems are there with labour

6. (b) Do you use casual labour on your farm? (1), By day (2), Piece work (3), Both (4), If yes, give me the following information (Note M-Males, F-Females, C-Children) for last year date

Operation	Crop	Number hired M/F/C	Days hired M/F/C	Rate paid per worker M/F/C or total spent	Week of Month of Month	Rates per M/F/C Other than Cash
Ploughing						
Planting						
Weeding						
Harvesting						
Threshing						
Transporting produce						
Other (specify)						

----------						

6. (e) In which months do you use most casual labour? (1), (2), (3), (4), (5), (6), (7), (8), (9), (10), (11), (12),

____

Is it easy to get casual labour during those months?

____

If not, Why?

____

What other problems do you find with hired labour?

____

7. I would like to know the different types of cattle you own (enter), (L) for local (G) for grade (C) for cross breeds.

	Cows	Heifers	Mature Bulls	Young Bulls	Oxen Mature	Oxen Young
Total on this farm						
Total owned by farmer						
How many are used for ploughing and other tasks?						
What rodder crops do you give to which animals? In which months?						
What supplementary feeds do you give to which animals? In which months						
Do you spray (1), or dip (2), your cattle? (Give detail of ownership of facility and its distance from farm).						

8. Where do your cattle usually graze?

Owners Land		Common Pasture	Hired Pasture	Elsewhere (specify)
On this farm	on another farm			

9. What qualities do you look for in task oxen

(1)
(2)
(3)

10. (a) Of the oxen you use how many were?

Born on the farm	Borrowed	Bought	Other (specify)

10. (b) When you want to buy them, are the oxen easy to find.

10 (c) Who trains your oxen?

Owner	Wife	Child	Employee	Other (specify)

10 (d) How many weeks does it take to train them? Minimum ....Maximum..........

(e) Would you pay extra if the ox was trained rather than untrained?

(e) How much extra would you pay Sh.................

11 What items of ox equipment do you have on the farm? (Give numbers)

Ploughs	Yokes	Chains	Harrows	Carts	Cultivators	Other (specify)

12 Give me information on how long it takes; how many people are involved; their sex; and how much it costs per acre to carry out the following operations, by the different methods (Answer for the ones you know only) per acre.

Operations	Hand Labour man-days/ cost	2-ox team days Hire cost.	4 ox-team/ days Hire cost	6 Ox-team days Hire cost	Tractor hours Hire cost	Remarks
Breaking New land						
1st Ploughing						
2nd Ploughing						
Weeding						

13 (a) Of all the ox equipment you have, give me the following information.

Item/Make/Type	Year Bought	Supplier	Cost when Bought	Condition (Working order)

13 (b) What are the minor repairs that cannot be done on the farm that your ox-equipment needs from time to time? Who does them and at what cost?

Repair	Done by whom	Cost	Done in Past year?	Cost

Appendix II

Farm Record Books: Their usefulness and short-comings.

The field assistants were provided with farm record books in which they were asked to keep records of farm family activities for each crop and crop mixtures for each season and each farmer.

They were asked to record the cropping patterns (i.e. sizes of planted to each crop and crop - mixtures). For each of such plots they were required to keep records of the dates on which each of the various operations (e.g. ploughing, planting, weeding and harvesting) were performed. They would also indicate the methods used (whether tractor, ox-ploughs, hand methods or any combination fo these) as well as whether these had been hired or were owned by the farmer himself. To complete the activities picture they were also asked to record all non-crop activities, eg. resources committed to livestock and household activities.

The date on which the various operations were performed would be useful in constructing the agricultural callendar which would reveal the time constraints on each of the various operations. The methods used in each operation as well as the resources used would provide data for calculating resource requirements on a per unit acrage basis by various techniques. The results could be used to analyse the relationship between resource availability on individual farms and requirements to determine the implications of resource availability on the scales of the operations under the various alternative methods. This would provide a faramework for ranking the alternative methods in terms of their technical efficiencies (work rates). The extent to which hiring is neccessary under the alternative methods, in view of the stock of the familys' resources, could also be determined from this excercise.

The assistants were also required to record the expenses of the farm families on both farm inputs and non-farm expense items. From the farm expense items (eg. purchased seeds, hired labour and hired ox-teams e.t.c.) the costs of various activities (including imputed costs of own resources used) would be calculated. These would be substracted from the estimated gross values of outputs to obtain estimates of net returns from the farming activities.

Output figures were to be recorded at harvest and their values would be estimated on the basis of the average prices observed in the local market places in the areas under study. The net incomes from crop activities so calculated as well as records of incomes from other sources (eg. livestock and livestock product sales and off-farm employments) would provide a measure of incomes from which domestic consumption requirements and other non-farming expenditures could be substracted to obtain what is potentially available for purchased inputs and farm machinery, indeed for any expansion or intensification of the farming business to the extent that land availability and the existing technology allow.

Whether or not extension or intensification of the farming business are desirable of course depends not only on the technical advantages of the technologies that would be used but more significantly on their economic advantages or profitability. Thus even though an improved seed fertilizer combinations ensured superior yields to the traditional seeds, they would only be desirable if they ensured higher net returns. It is in a similar sense that animal draft may be preferred to tractorization under particular situations. These could be determined by comparing returns under different mechanization regimes and with different biochemical inputs, under the conditions which obtain in the study areas.

As it turned out there has been a great divergence between what we hoped to extract from the farm record books and what was forthcoming. While records of various operations in each crop or crop combinations were kept and the time periods over which the various operations are performed is determinate the same is not true of resource utilization. The methods used were recorded but the quantities and in some cases the exact length of time taken was not recorded. In one area, for example, our emunerator only recorded the labour contributions of the respondents and hired labour, excluding the contributions of the other members of the family rendering labour input figures inaccessible. Even worse infrequent visits led to inaccurate records of levels of resource utilization. Records on the extent of hiring, particularly the hiring of labour were similarly incomplete as were records of other purchased inputs the expenses on these as well as sales volumes and values. The calculations of income domestic use of outputs, costs and returns have therefore become impossible. Neither could the extent of use of the alternative techniques be separated to provide a framework for comparing their technical attributes eg. technique, not to mention comparative costs of getting a particular job done. These errors were regrettably discovered too late in the exercise to allow correction. The scope and structure of the study has therefore been seriously altered.

The record books have however been of assistance in providing cross - checks on the information obtained from the questionaire. They have for example provided more accurate dating of the various activities on the basis of which a rough agricultural callendar has been constructed.

Appendix III

On data used in the study

Appendices I and II have implicitly given explanations of the sources and nature of the data used in this study. There are are however some specific properties of the labour and land variables that deserve separate treatment.

Family labour availability has been infered from stock figures obtained from the questionaire. Due to the difficulties in getting information on the flows of labour utilization, the participation ratio has been difficult to get at. An attempt was made to determine this from the stock figures, by distinguishing between adults above 15 years and children below 15 years. There were evidently some below 15 years whose participation was comparable with those of active adults but who could not in the end be separated from infants and some of the adults were two old to make regular contributions in farming activities. While the two would tend to cancel out, the impurity involved should be born in mind.

The manner in which the land resource and utilization statistics were put together also need explanation. As already noted, appendix I, the acrages of holdings and areas under cultivation were inaccessible from the interviews. The respondents however gave rough gueses of these acreas as well as the proportions of their holdings under cultivation. It was possible to work out proportions under cultivation from these rough estimates of areas and a comparison of cultivated proportions were roughly comparable. It was then decided that while estimates of acrages were suspect, the proportions could be used. Cultivated areas were therefore measured physically, with the assistance of survey engineering students at Nairobi University, and due to the high cost of this excercise holding sizes were not measured but estimated on the basis of cultivated areas and the proportions of total holdings of these.

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