UNIVERSITY COLLEGE OF RHODESIA AND NYASALAND

THE LABOUR ECONOMY OF THE RESERVES

R. W. M. JOHNSON

OCCASIONAL PAPER No. 4
DEPARTMENT OF ECONOMICS
SALISBURY
1964

THE LABOUR ECONOMY OF THE RESERVE

by

R. W. M. JOHNSON,
M.Agr.Sc.(N.Z.), B.Litt.(Oxon.)

Occasional Paper No. 4 of the Department of Economics,
University College of Rhodesia and Nyasaland.

Printed by Unitas Press Ltd., 17 Park Street, Salisbury.

Contents

Acknowledgments

The Department of Economics is especially grateful to The Rockefeller Foundation for making a grant available for this work. The field diaries were recorded by Messrs. A. Matewa, M. Sibanda, A. Mutiti, J. Gora, P. Mavunga and P. Mtisi. Messrs. G. Chavanduka, M. Lukhero and C. Bganya helped in the preliminary survey and in collecting land utilisation data. Messrs. P. Hamilton and T. Curtin also helped considerably in supervising the field work. The punch cards were prepared by A. Matewa and the tabulations by D. Masarirambi.

I am grateful to Professor J. C. Mitchell for reading a preliminary version of the manuscript.

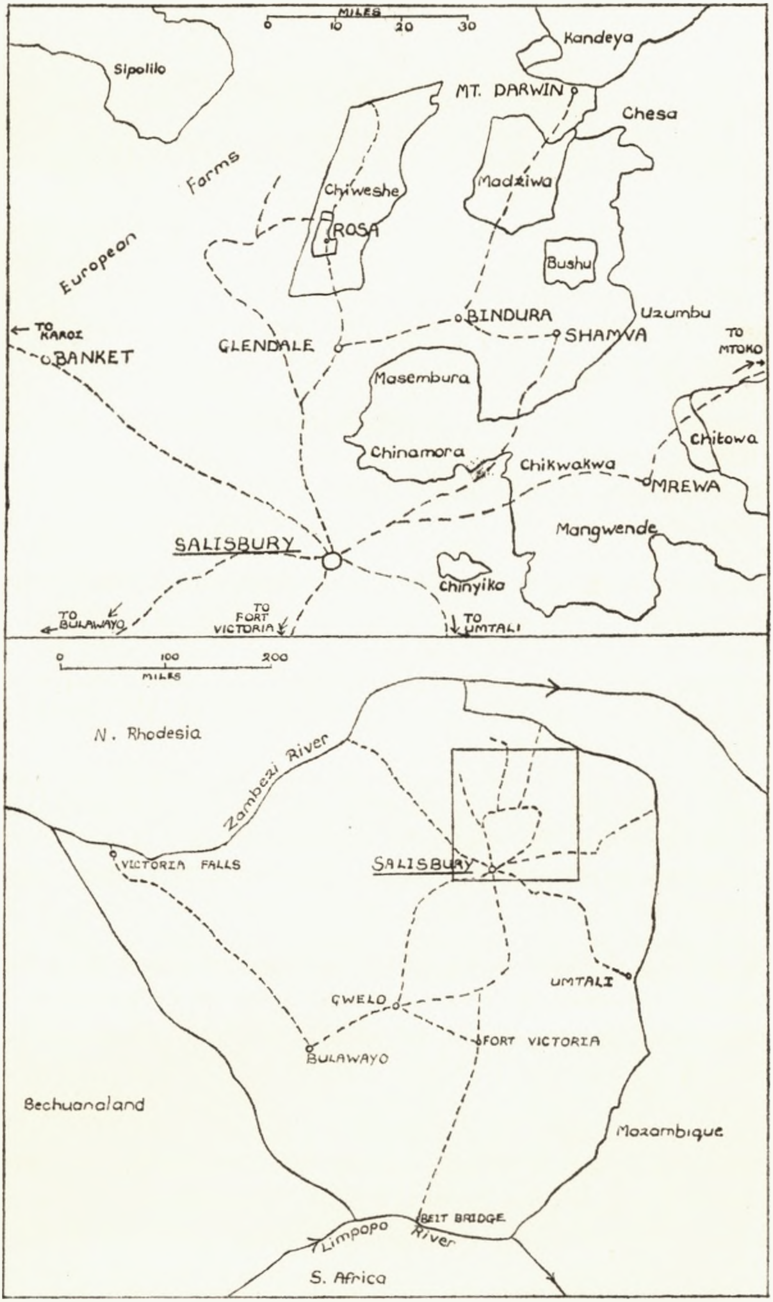
THE LABOUR ECONOMY OF THE RESERVE

INTRODUCTION

This paper presents the results of a detailed examination of agricultural work patterns in a fairly typical area in the African Reserves of Southern Rhodesia. Some 120 family holdings were observed over the growing season of 1960-61 and records kept of all work associated with agriculture. Owing to the pressure of other work, the full analysis of these records has taken some time to complete. The actual data collected is now summarised in these pages and an attempt has been made to formulate some preliminary hypotheses particularly about the seasonal distribution of work inputs. The results of the survey and the formulation of the above hypothese are set out in some detail so that other workers in the field can arrive at their own conclusions.

After a general introduction to the organisation of African Reserves in Southern Rhodesia, and Chiweshe Reserve in particular, I first look at the supply and organisation of labour; family size; numbers of children and effects of migration. Secondly, I look at the patterns of work among the main crops. The remainder of the analysis is divided into two parts, both based on linear programming techniques of analysis. The first part is an analysis of subsistence agriculture as a whole; choice of crop, labour constraints and importance of food crops. The second part is an exercise in individual programming where improved farming plans are constructed for application in real situations. The study concludes with a preliminary discussion of the policy decisions which emerge from the results.

R. W. M. J.



Map—Upper: African Tribal Trust Land in Northern Mashonaland.
Lower: Southern Rhodesia, showing research area.

I

THE RESERVE BACKGROUND

The Reserves of Southern Rhodesia were set aside for exclusive African occupation between 1890, when the first Europeans settled in the territory, and 1923, when the existing reserves were ratified by the constitution of the new self-governing colony. Further lands allocated for exclusive African use in more recent years have been termed Special Native Areas, and these two types of land now total some 40 million acres out of a total area of 96.6 million acres. These Reserves and Special Native Areas are distributed widely throughout Southern Rhodesia, and hence exhibit a variety of environmental conditions which affect agriculture markedly. The Reserve in which this data was collected is representative of the higher rainfall reserves on the main plateau of the territory, and hence is really typical of only about 2 million acres* out of the above 40 million acres. It is thought, however, that the cropping patterns found in this reserve are prevalent over a much wider area than 2 million acres, and may be typical for up to 10 million acres of all the reserves and special areas. Such an area would probably include over half the total number of African cultivators in the territory, as these reserves are the more densely populated ones.

The main axis of the watershed between the Zambesi and Limpopo Rivers runs in an east-west direction at a general altitude of 4,000-5,000 feet. The plateau of Southern Rhodesia extends from fairly sharp escarpments in the north to the more gradual slopes toward the Limpopo Valley in the south. Some two-thirds of the total area of the territory is thus higher than 3,000 feet and a quarter is above 4,000 feet. The incidence of rainfall is closely related to altitude. The tropical convergence zone moves over Southern Rhodesia normally toward the end of November and initiates a wet season of 3-4 months. Rainfall is heaviest in the hills on the eastern border of the territory (40 inches plus), moderate along the main east-west watershed (24-32 inches), and distinctly low in the valley basins (less than 24 inches). As already indicated, the pattern of agriculture to be described here is that found in the reserves in the plateau above 4,000 feet and with an annual rainfall expectancy of over 32 inches.

The soils of Southern Rhodesia are in the main derived from the pre-Cambrian Basement Complex. The granites and sediments of

* The area of the Reserves in Natural Region II of the Agro-Ecological survey of Southern Rhodesia. There are a further 5½ million acres in Natural Region III.

this underlying geological formation give rise to the typical light sand soils or granite sands. These are interspersed, however, with red loams and clay loams where dolorite intrusions have been exposed in the basement complex. The reserves, for a variety of historical reasons, are almost all located on the sand soils of the territory, and hence exhibit to a striking extent many of the land pressure problems found on similar soils in other parts of Africa. The catena, in particular, is often a very long and relatively flat one, and hence is typically interrupted by a drainage problem in its mid-reaches, with depressive effects on crops in wet years.

The main crops grown in the higher rainfall areas are maize, groundnuts and *Eleusine* millet. Small plots of sweet potatoes, roundnuts (*Bambarra* sp.) and vegetables are usually found in the vicinity of homesteads. Maize is the dominant crop, being not only the basic food crop, but also the source of cash income in good years. Nuts and millet do not occupy large areas of land and are not sold in the cash economy in large amounts. Both of those crops require large inputs of labour relative to maize. Arable holdings average about 8-12 acres, with certain exceptions which will be noted later.

Nearly all the families in these reserves own cattle. The average holding of cattle is around 5-6 head, though there is a wide variation about the average. As in other cattle-owning African societies, the role of cattle in village life is a complex one. As far as agriculture is concerned, they provide the main motive power for ploughing and also farmyard manure for the fields. In the growing season, they are herded in areas away from the main arable fields, but once the harvest is complete at about the beginning of June, they are free to roam anywhere. Families combine together in their herding arrangements, especially when the younger children are at school.

As already mentioned the reserves proper had been fully demarcated by 1923 when the Colony of Southern Rhodesia obtained its constitution. The total area concerned was 21 million acres. The remaining 19 million acres in special native areas, which were to be occupied under conditions similar to the reserves, were sanctioned by the amendments to the Land Apportionment Act between 1950 and 1962. These lands had previously been held in reserve for European or African freehold settlement and at the date of transfer had not been allocated for this purpose. The existing inhabitants of such areas thus became the *bona fide* occupants of such land. As those areas were transferred, they also became subject to all the legislation affecting the reserves proper.

The most important agricultural legislation affecting both areas is that concerned with soil erosion and over-grazing by cattle. Prior to the second war, these two problems were dealt with by the Chief Agriculturist in the Department of Native Affairs. The existing pattern of scattered homesteads and arable lands was modified under a series of Government regulations that provided for consolidation of arable land. By this process grazing could be confined to specified areas which were subject to some degree of control while the arable lands could be protected from erosion by the systematic use of contour ridging. Homesteads were removed from the arable land and concentrated in lines along the sides of the blocks. The whole process was known as Centralisation. Actual destocking of cattle dates from 1943 when Government Notice No. 271 laid down the policy to be followed. According to a survey in 1945 some 42 of the 92 reserves in Southern Rhodesia were thought to be overstocked with cattle.*

By the end of 1951 some 8.2 million acres in the reserves had been consolidated.** In that year, all previous regulations were incorporated in the Native Land Husbandry Act. This Act carried the system of consolidation one step further and provided for the legal registration of all individual plots of land in the arable blocks. Before registration, the whole reserve was subjected to a complete re-survey of its potential land use, and arable blocks were to be re-sited if necessary. Once chosen, a proper system of graded conservation ridges, roadways and waterways was provided for the arable blocks. Allocation to individuals then followed through the local headmen or chiefs.

The Act also provided for the registration of grazing rights, which had of course to be based on the right to graze a particular number of cattle and not on the use of any particular piece of land for that grazing.

This Act was implemented with vigour by the Government, especially in the period from 1956 to 1961. By the end of 1962, some 28.5 million acres in the reserves and special native areas had been surveyed, and 15.8 million acres actually allocated in the form of communal grazing or arable plots. Some 291,000 farm rights were registered covering a total arable area of 2,017,543 acres. One reason for the lag between survey and allocation was the difficulty in dealing with heavily populated reserves. In these cases the Act had made provision for a smaller arable area to be made available to each claimant than the full economic holding, usually considered

* Annual Report of Director of Native Agriculture, 1946.
** Annual Report of Director of Native Agriculture, 1952, p.105.

to be eight acres. Smaller holdings would clearly be uneconomic and as such would only serve to perpetuate the existing shortage of land, until a major movement of population out of the reserves took place or Government intervened with resettlement plans. This background information is particularly important to the present study, as the reserve used for data collection was initially surveyed for Land Husbandry Act purposes in 1957 but never proceeded with owing to the pressure of population on arable land found in the survey.

The actual choice of a reserve for research purposes was governed by distance from Salisbury more than any other factor. It was not desirable to be too close to Salisbury because of the presence of a distinct vegetable belt round the town, but the project could not be carried out a long way away because of the need to supervise field work from the University in Salisbury. Thus of the several reserves to the north of Salisbury within 100 miles of the town, Chiweshe Reserve, some 45 miles to the N.N.W., was chosen.

As can be seen from the sketch map, this reserve is a long piece of land running from north to south for some 30 miles and only 12-13 miles in width. The total area is 211,180 acres. It is entirely surrounded by land alienated to European farmers. The southern third of the reserve consists of gently undulating country interspersed with scattered granite outcrops. The outcrops are more frequent in the central part, with somewhat less arable land, and in the north outcrops and hills predominate with small areas of undulating land suitable for cultivation.

The population is given as 33,300 in the assessment report prepared under the Land Husbandry Act in 1957, which gives a population density of 101 per square mile. The 1962 Census of Africans, however, gives the *de facto* total as 25,740 in April/May of that year, reducing the density per square mile to 82. The higher figure was probably calculated from the total number of taxpayers registered and must be regarded as an attempt at measuring the *de jure* population of the area. In point of fact, the *de jure* population of a given area within a country would be very difficult to calculate in a migrant economy such as this, without intensive research into the whereabouts of all the migrants concerned, and making some judgement on the strength of the connection with the rural area.

In the sample area of Chiweshe Reserve chosen for this study, the total population was defined as all those people who maintained contact with the reserve by physical visits to their relatives resident there in the year of survey. Of this total some 75 per cent of men and 83 per cent of women were actually resident for most of the time in April/May, 1961. The remainder of the normal population were away for more than 15 days in these months. For both men and women the highest numbers are present in the reserve in the month of December, the main planting month, and the highest numbers are absent in August, the middle of the dry season. On average, through the year, 29 per cent of all men could be considered as absent by the above criteria and 18 per cent of all women.

Although this definition of residence tends to be an artificial one, the pattern of migration is readily apparent. Taking the average number of those resident in April/May as 79 per cent, the population with some base in the reserve can be calculated as 32,175 if the ratio is applied to the Census count of 25,470. This total still omits registered taxpayers who did not pay a visit to the reserve in 1960-61, or who did not maintain a household in the reserve in this period. This is a reasonable reconciliation, however, with the assessment report figure, hence both estimates of the population can be accepted on their definitions. In effect, some 29,000 people are resident in this reserve in December at the height of the planting season, and about 22,500 people are there in August, when agricultural activity is at its lowest.

This pattern of migration out of the reserve is determined by the agricultural cycle but the underlying cause of such movements of population is economic. Owing to the general level of agricultural techniques in use and the related population pressure on land, discussed below, the reserves of Southern Rhodesia just do not offer comparable economic opportunities to that offered in the wage economy. Moreover, because men can leave their families behind in the reserve reasonably well provided for, it is actually worthwhile to supplement subsistence income in the reserve by working for wages. There were only 3 or 4 families in the sample of 120 who did not have one male number of the household at home for December planting of crops in 1960, but after this date more and more men depart for work outside, some to return for harvest in April and May, but many to stay away for another 11 months, with occasional short visits.

The general effect on agriculture is that the women and older men are left to carry on most of the agricultural tasks, with some help from younger children. This is clearly one of the basic reasons why agricultural productivity in their reserves is very low and why new techniques are very difficult to introduce. Where the head of the household in the prime of life does devote the majority of his time to agricultural tasks during the growing season, the results are fairly spectacular. Improved agricultural management plans for those persons are the subject of Chapter V of this report.

The extent of population pressure in Chiweshe Reserve emerges from the land utilisation data collected in 1957. The assessment report states that some 59,512 acres of cultivated ground were found in the reserve, which shared among 5,480 landholders resulted in an average of 10.9 acres per holder. The report also states, however, that the area of land *suitable* for cultivation is only 35,000 acres, or 6.4 acres per holder. Thus the standard holding of 8 acres envisaged in the Land Husbandry Act could not be allocated to every claimant to land if cultivation were to be restricted to the suitable land only. The assessment committee's report therefore concludes that the possibility of moving some of the people should "be sympathetically considered at an early date" and that, "without some adjustment of the population, the proper implementation of the Act and the stabilisation of the area is impossible". The position to the present day therefore remains the same as it was in 1957 when the assessment report was prepared. As will be seen later, there is a wide variation in the land holdings of different families in the sample area, and also considerable "idle" land, either lying fallow because it is exhausted or because it was allocated by the headmen prior to 1957 and the absentee wants his claim maintained in the event of further government action.

The position with regard to the cattle population in Chiweshe Reserve is not so critical. The following numbers of different types of livestock were enumerated in 1957:—

Calves	2,322
Cattle	18,410
Donkeys	644
Sheep	114
Goats	1,101

Following the government's procedure for weighing small stock at 1/5th of a unit and donkeys at 1/4th of a unit, the total number of animal units is given as 19,278. Over 4,368 stock owners, this is 4.4 units per owner. The assessment report gives the assessed carrying capacity of the reserve as a whole as 18,200 units, so this optimum level is only exceeded by some 6 per cent.

The actual sample of families for the project was enumerated in an area of some 10 square miles to the west of the township of Rosa (see sketch map). This township has a medical clinic and a ward, several African shops, most of whom are trader-agents for the Grain Marketing Board, and the homes of several Agricultural Department supervisors and demonstrators. It is some 55 miles from Salisbury. It is important to note that except for government employees in the clinic and the Agricultural Department and one or two traders, there are no residents in the townships. The residents are the rural people themselves who live in their village units near the blocks of land on which they cultivate.

Starting at a point some two miles to the southeast of Rosa and working north, every family found in each village was included until some 120 family groups had been identified. This finishing point was some three miles to the north-west of Rosa, about halfway along the fifth village. The general intention at the outset was to examine fully the range of experience found in the sample area rather than to be absolutely satisfied that the villages were representative of the reserve as a whole. Six research assistants, familiar with the local language, were employed, and each assistant had around 20 families to regularly visit.

A comparison of the people found in this manner and the reserve as a whole was as follows:—

Characteristic	Total No.	Sample Area	Percentage
Cultivators	5,460	147	2.7
Area (acres)	211,180	6,512	3.1
Cattle (head)	17,531	592	3.4
Arable (acres)	59,512	1,566	2.7
Stockholders	4,368	121	2.8
Families	6,600	118	1.8

(Total data from 1957 Assessment Report)

Except for the number of families, the sample area gives a consistent proportion of the total universe for each characteristic. The definition of families must be very different in the two surveys. It is not clear from the Assessment Report how the family is defined; it can only be noted that the number is even higher than the number of cultivators who registered. The more detailed enumeration shows that cultivating families are very much less than the total number of cultivators.

The 118 families were recorded for a whole year from November, 1960 to September, 1961. Each research assistant was provided with a bicycle and it was his job to keep up to date with a daily diary of the agricultural activities of his families. At the same time, the land utilisation pattern in the five villages was checked and paced and maps drawn of the extent of every holding. As in the territory as a whole, parts of Chiweshe Reserve have red loam soils derived from dolerite, though the majority of the reserve has sand soils through to sandy loams, derived from granite. Such a soil change occurred just north of the township of Rosa and ran in an east-west direction. Thus the fourth and fifth village enumerated were found on this slightly more fertile red loam, while the first three were on the sand soils. The number of families on the red soil was 45 and those on the sand soils were 75.

II

THE SUPPLY OF LABOUR

In this chapter, the land holdings and cattle numbers belonging to each family are first examined, followed by an analysis of the size of family in relation to migration, size of holding and agricultural work performed. The chapter concludes with tables showing the breakdown of agricultural work according to seasons, the different crops, farm operations, and the different persons who do the work.

The family unit is taken throughout this study as being composed of those people concerned with a single cultivation unit. That is, the people within the family share the daily agricultural tasks and are generally subject to the supervision of the head of the family be it husband, grass widow or real widow. This grouping thus includes polygamous wives but would not include married sons starting out on their own. In polygamous families separate fields, houses and granaries are usually allocated to each wife, while the husband occupies a separate house of his own. Each wife cooks for her own offspring, and, in her turn, for the husband. If these cooking units are referred to as separate households, then in any given area there are likely to be more households than cultivation units. Since the husband allocates spending money to each wife in the polygamous case, the households are the operational units for a survey of income and expenditure. There were thus 135 of these households found in the five villages, made up of 103 men with one wife or widows, 13 men with 2 wives and 2 men with 3 wives. In this survey these expenditure units have been amalgamated to fit in with the concept of the cultivation unit. As will be seen shortly, both the work power and command over land of a family cultivation unit are greatly enhanced by having more than one wife or a large family of working age.

In Chapter I the position with regard to land claims was briefly set out. In this reserve, government legislation and action had brought about a situation where all possible claims to arable land had been registered with the District Commissioner. Some four years later, when the present survey was carried out, by a person not easily differentiated from a government servant, the same claims to land were apparent. Thus in the arable area of the five villages concerned there were 22 claims to uncultivated pieces of land of varying size by absentees, and seven more absentee claims being used in the meantime by relations, which added to the 118 being actively used, gave a total of 147 land holders in Land Husbandry Act terms. By this process, the people make sure that all land is allocated to someone in order to preserve their rights of use. In turn, this means that the reserve gives the appearance of being over-populated without necessarily being so.

One word of caution may be in place here in interpreting the above statement. The correct position with regard to land-holding was that in this particular year (1960-61) 118 family groups were actually in residence and using land in an area where 147 claims had previously been made. The position changes from year to year as an unspecified number of the absentees do come and make use of their land. On average the 118 families may well be quite typical in a run of years, with some of those present in 1960-61 absent in other years, and others back to replace them.

Absentees also have the right to run cattle in the reserve. Numbers, however, are controlled by the District Commissioners through the issue of dip books under the dipping regulations. Thus as long as absentees hold dip books, their rights to graze cattle are protected. On the decease of a husband, the widow continues to hold the dip book unless she makes it over to her sons. Since cattle have a customary value in bridewealth as well as important agricultural functions, the right to graze cattle (i.e., the possession of dip books) is highly sought after. The loss of a book through death would be unthinkable and cattle are subtly moved if this possibility is likely. The District Commissioner has to be sparing in the issue of books, in his turn, by his need to keep total cattle numbers to reasonable levels.

In this enumeration of 118 cultivating family groups, 26 had no grazing rights at all (22 per cent). There are two main reasons for this. Ten of these people were "strangers" who had settled in the area in recent years. They would have brought no cattle with them and in any case would have found it difficult to obtain permission to dip them. The majority of the remainder are younger sons of the older families in the area. There was evidence that some of them had inherited cattle in the normal course of marriage settlements and the like but had no formal right to graze them. The cattle would therefore be shown in an elder brother's book or that of the father or widowed mother.

Of the remaining 92 families, 71 were in possession of one grazing right, 15 had two rights, 4 had three rights, and 2 actually had four rights, giving a total of 121 rights or books held among 92 family groups. The breakdown of the extra 29 dip books according to their original owners shows the particular reason why this aggregation of books has taken place.

Books belonging to absent sons	13
Books belonging to absent brothers	8
Books belonging to other male relatives	2
Books belonging to female relatives	6
	29

Turning now to the family unit itself, the impact of migration on the family must be examined before looking at it as a working unit. As indicated in Chapter I, December was the time of year when migration out of the reserve is at a minimum, and August was the period of greatest absence (see diagram 1(a)).

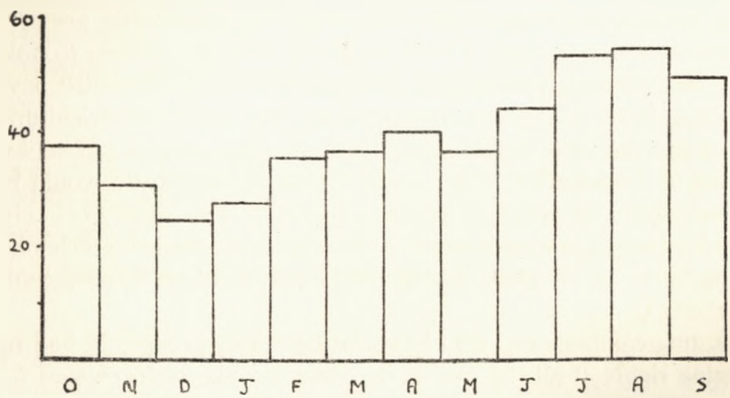


Diagram 1(a)—Heads of families absent per month. Total sample of 118.

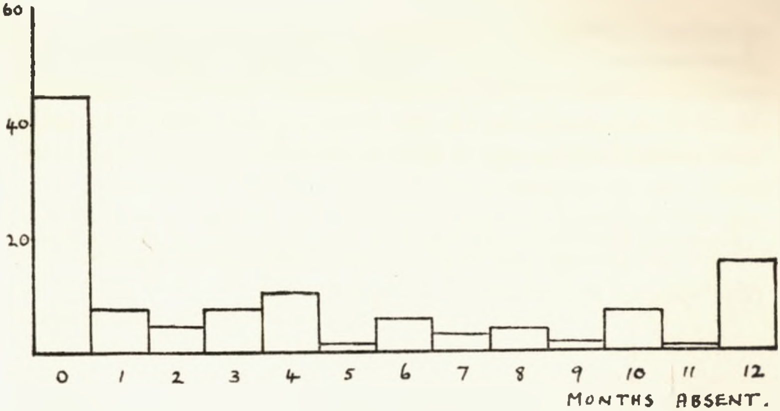


Diagram 1(b)—Numbers of family heads absent by length of absence.

From the point of view of agriculture it was suggested that the presence or absence of the male head of the family was most crucial for organising better farm methods. Out of the total of 118 families enumerated, some 45 or 38 per cent. of the heads did not leave the reserve at all in the course of the year from October 1960 to September 1961 (see diagram 1b.). The measure of presence or absence being 15 days as before. This 45 includes most of the elderly people and the several widows who are family heads in their own right. There is then a fairly even distribution of months absent right up to 10 months away. Eleven months does not seem important and could be counted as 12 months absence to all intents and purposes. There were thus 17 male family heads who were away throughout the year, but who either maintained their families in the reserve or at least started out to do so in late 1960.

In the crucial planting and weeding months of December and January, some 8-11 other family heads were also absent to give the total numbers absent of 25 and 28 respectively. From the month of December through to the month of August a further 30 family heads are away from the reserve for the majority of the months, though a greater number than this are away at some time in the course of the year. This number must be the balance left over after the 45 stay-at-homes which is 73.

In the possibility that the 15 day measure partly obscures shorter visits to the reserve, and also to test the appropriateness of 15 days as a measure of absence, Table II. 1 has been prepared. This table sets out for the months of December and January the actual number of days spent in the reserve of the family heads absent in those months. In the month of December there are two distinct groups. There are 8 or 9 persons who did not come at all, and there are 15 persons who came for a short stay, possibly the Christmas holiday. There is only one person in the 25 who could possibly be said to have stayed long enough to help in the fields.

TABLE II. 1

Frequency Distribution of Length of Visit to Reserve of Family Heads Absent more than 15 Days in December–January 1960–61

Days Spent in Reserve	December 1960	January 1961
0	8	16
1	1	1
2	—	1
3	1	1
4	6	3
5	2	—
6	4	—
7	—	1
8	2	—
9	—	1
10	—	1
11	—	2
12	—	1
13	—	—
14	1	—
15	—	—
16	—	—
	25	28

In January, the number who did not come at all has increased to 16-18, with 3 who came for a long weekend. The remaining 6 stayed for periods of a week or more and may have contributed something to agricultural output.

Of the 8 who did not come at all in December, one spent most of January in the reserve and one more made a very short visit. This leaves six hard cases, as it were, who did not come at all in these months. Of these 6, three abandoned their agricultural efforts and their wives joined them. These agricultural records were thus lost to the survey except where the fields were absorbed by relatives. Of the 16 absent for all of January, 10 had made visits to the reserve in December, though only 3 of these were for any length of time. Further details of migration of the heads will be published elsewhere; it is only necessary at this stage to establish the main pattern.

There remains, however, the movements of the families of these absentees. Some indication of this is given by the months spent in the reserve by the wife of the absentee. Table II. 2 sets out the frequency distribution of the months spent in the reserve (months of 15 days and over) for the wives of the 25 and 28 family heads absent more than 15 days in December and January respectively. After the 3 families who moved away in the middle of the growing season, there is a distinct group of 5 who apparently only stayed for the growing season and then left, another group of 7-8 who stayed 7-9 months in the reserve, and 8-11 who hardly left the reserve at all. Again, the full analysis of this data will be published elsewhere.

TABLE II. 2

Frequency Distribution of Months Spent in Reserve by Wives or Nearest Dependant of Absentees in December or January.

Months spent in Reserve	Dec. Absentees	Jan. Absentees
1	2	2
2	—	1
3	2	2
4	1	1
5	4	4
6	—	—
7	2	2
8	4	3
9	1	1
10	1	1
11	—	1
12	8	10
	25	28

The potential working force in this reserve can now be defined as all those persons over 6 years of age present in the reserve for more than 15 days in the months of December and January. At this stage, children over 6 years are given equal weighting with adults in the estimation of the available labour force in agriculture. Many tasks can be performed with about equal efficiency by either men, women or children, and without strong evidence that this is not the case, weights have not been introduced at this point.* Although the labour demands at harvest time in April and May are just as great as in December and January, it is self-evident that what has not been planted and weeded cannot be harvested. Furthermore, labour resources can also be found to help in the harvest, which can be spread over a longer period than the earlier operations.

The frequency distribution of the potential labour force can be seen in Table II. 3 where it is related to the number of acres cul-

* It is hoped to explore this problem more fully at a later date. For the rest of the analysis all persons over 6 years of age are regarded as contributing equally to output.

tivated by each family. The mean work family in December and January is $5\frac{1}{2}$ persons as compared with 7 persons if young children are included. The frequency distribution of the work family and the total family, and that of cultivated acres can be seen in Diagram 2.

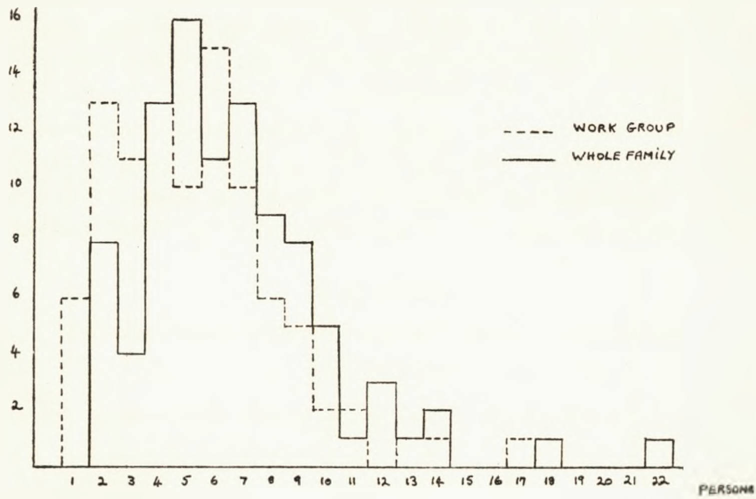


Diagram 2(a)—Frequency distribution of family sizes, Chiweshe Reserve, 1960-61 (January).

Diagram 2(b)—Frequency distribution of holdings as measured by cultivated area, 1960-61.

It will be noted that the number of families left in the analysis is now 97. Of the 118 families, three did not finish the agricultural season and hence did not provide any further information on themselves. Two further family groups consisted of young married sons whose agricultural operations could not be distinguished from that of their parents; these were thus combined into one in each case. Finally, there were 16 other families where the crop or labour record was incomplete. These had to be rejected at this stage.

Returning to Table II. 3, the broad association between the working family and acres cultivated can readily be seen. The average size of holding cultivated by each family size is shown down the right hand side and the average family size for each holding size along the foot of the table. Owng to differing family circumstances, there is likely to be a wide range of size of holding for given family sizes. It is apparent, however, that there are no large families on small holdings, though some small families cultivate larger holdings.

TABLE II. 3

Relationship of Family Working Groups to Acres Cultivated.

Size of Working Group	Cultivated Acres 2–3.9	4–5.9	6–7.9	8–9.9	10–14.9	15–	Total	Mean Acres
0–1.9	2	3	1	—	—	—	6	4.9
2–3.9	5	6	9	1	3	—	24	6.3
4–5.9	—	6	4	5	8	—	23	8.9
6–7.9	2	5	5	5	6	2	25	9.0
8–9.9	—	—	1	3	4	3	11	11.6
10–	—	—	—	1	3	4	8	17.8
Total	9	20	20	15	24	9	97	9.1
Mean Family	3.0	3.9	4.1	6.1	6.4	10.9	5.5	—

This two-way relationship between family size and holding size can thus be interpreted in terms of working capacity, that is, how many acres per person can be physically cultivated; or alternatively as a nutritional problem, how many acres does it take to support and feed one person? For the moment, the two variables should be regarded as mutually dependent and further judgement delayed until the work contribution of each family has been analysed more fully.

For the purposes of the analysis which follows in the next three chapters it is important to establish at this stage the physical input of work that can be expected from each working group. Table II. 4 shows the average number of hours each group size spent on agricultural work in selected 10-day periods in the 1960-61 season. The 10-day period is used as a base here as a convenient way of dividing the season into suitable work periods. Its full usefulness will be apparent in Chapter IV. The actual periods chosen are the seven busiest in the growing season. Again, the seasonal distribution of labour is discussed in the next few pages; it is important at this stage to establish the general framework on which an analysis can proceed. These time periods were obtained by dividing each month into 3 ten-day periods, and simply designating them in order, e.g., Nov. 1, Nov. 2 and Nov. 3.

With one or two exceptions, the amount of work increases with the size of the working group in each time period. It is also apparent, however, that only in the two businest periods, that is, Jan. 1, and May 1, do the large families fully extend themselves. In each of the other periods the work input does not increase with the availability of workers in the family group. It is thus clear that larger families have a lighter individual work load than small families, and also that they have, for the same reason, greater resevoirs of work power when seasonal peaks require it.

TABLE II. 4

Ten-day Work Input by Group Sizes and Selected Time Periods

(Hours per Family)

Size of Working Group	Time Periods — Nov. 3	Dec. 2	Jan. 1	Jan. 2	Apr. 2	Apr. 3	May 1
0–19	43.2	28.5	53.5	30.5	42.2	19.0	46.3
2–3.9	58.3	55.4	60.8	40.0	42.6	32.5	59.3
4–5.9	64.1	61.5	87.9	60.1	78.9	67.8	104.0
6–7.9	80.2	66.5	100.5	66.3	78.8	59.3	103.0
8–9.9	87.7	81.6	118.6	74.6	75.3	68.1	111.2
10–	93.7	108.9	192.0	113.0	51.4	96.8	189.9
Mean	70.6	65.4	94.3	60.8	64.9	56.3	97.0

Turning now to the seasonal distribution of work, Diagram 3 shows the distribution of the work spent in the three main crops, maize, groundnuts and millet by 10-day time periods. This seasonal pattern shows three distinct peaks associated with the demands of different types of work. Planting in late November, weeding in early January, and harvest in early May. There is a marked falling off of agricultural work between weeding operations in January and February and the start of the groundnut harvest late in March. Whereas maize seems to have first priority at planting time, followed by groundnuts and millet about equally; the harvest sequence starts with groundnuts, turns to millet and finishes up with the maize.

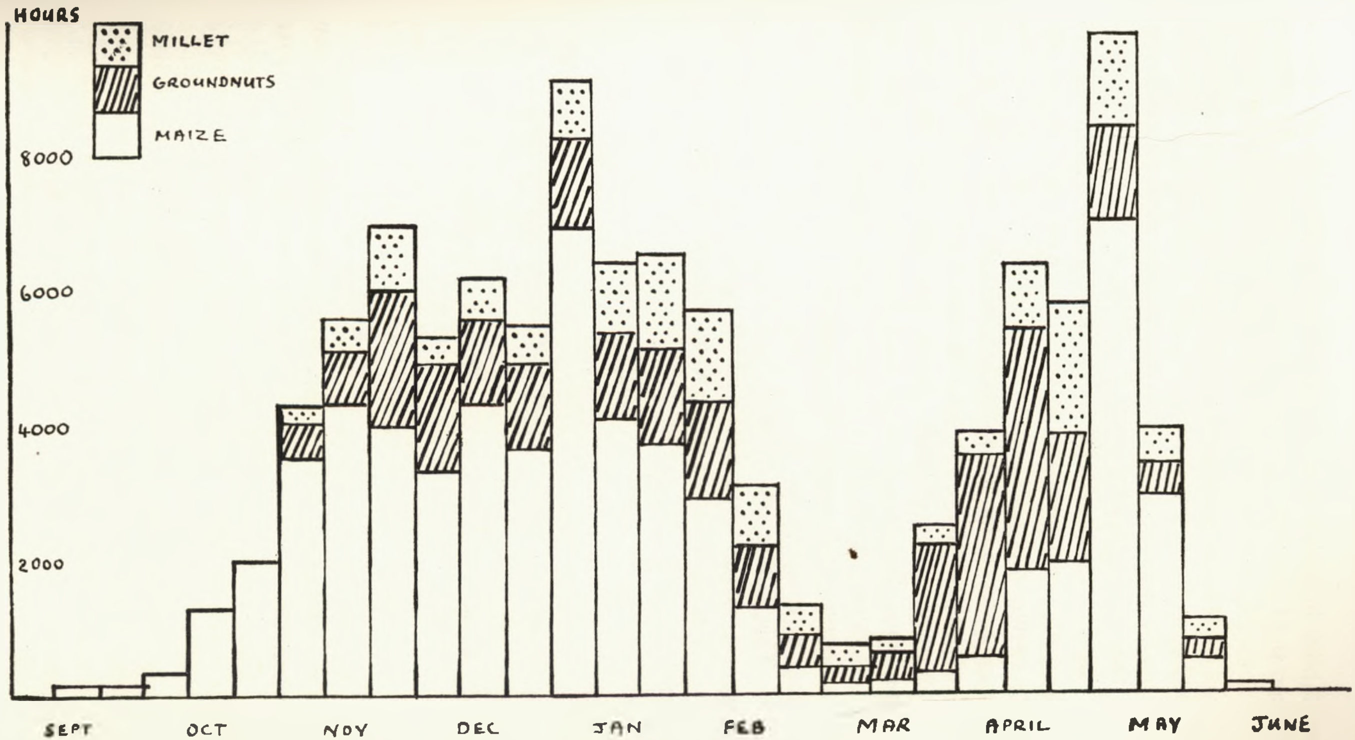


Diagram 3—Seasonal distribution of labour input on three main crops, all farms, 1960-61.

The labour intensity of each crop over the whole season can be seen from the following comparison:

Crop	Per Cent Area	Per Cent Output	Per Cent Labour
Maize	75.5	58.8	58.4
Groundnuts	13.2	17.4	14.4
Millet	11.3	17.4	14.4

Thus the work put into maize approximates more to its value than to the area it occupies. Groundnuts are highly labour demanding and do not seem to give a share of output commensurate with the work required.

Table II. 5 shows the break-down of the total work input by the kind of operation and by the sex and age of individuals. Weeding takes the greatest time on maize and millet; harvest is the greatest for groundnuts. The allocation of work between men, women and children is fairly constant for the three crops, though within the different operations it is clear that manuring for maize is a man's job; whereas weeding and harvest are the work of women and children. This falling off of the share of work done by men at weeding and harvest time may well be related to the progressive immigration of men out to work which takes place from the new year onwards rather than any traditional sharing of agricultural tasks.

TABLE II. 5

Patterns of Work by Crop, Operation, Sex and Age
(Per Cent)

	Manuring	Ploughing	Weeding	Harvest	Total
MAIZE	(7.6)	(20.7)	(43.3)	(24.3)	(100.0)
Men	50.6	34.9	26.3	26.0	29.8
Women	30.7	38.3	47.5	44.4	43.6
Children	18.7	26.8	26.2	29.6	26.6
Total:	100.0	100.0	100.0	100.0	100.0
GROUNDNUTS		(19.6)	(34.3)	(46.1)	(100.0)
Men		29.6	24.2	20.2	23.4
Women		43.9	53.1	53.9	51.7
Children		26.5	22.7	25.9	24.9
Total:		100.0	100.0	100.0	100.0
MILLET		(15.6	(49.3)	(55.2)	(100.0)
Men		33.9	27.9	25.8	28.1
Women		33.4	47.1	46.3	44.7
Children		32.7	24.9	38.0	27.2
Total:		100.0	100.0	100.0	100.0

III

CROP LABOUR REQUIREMENTS

In this chapter, factors affecting the labour requirements of each of the three crops are examined. For convenience of working in budget and improvement programmes, the labour requirement of a crop is expressed in hours per acre. The analysis is not concerned with the average "acre" of each crop but with the averages of groups of holdings. For this reason, the following results appear to be inconsistent as the various means worked out are not interchangeable. The reader familiar with cost of production surveys in Great Britain and elsewhere will recognise that the mean of a series of ratios is not the same as the mean ratio worked out from the original data. Budgets for actual farmers must, of course, be worked out for the average farm and not for the average acre of a given crop.

Table III. 1, brings together the main characteristics of the three crops grown in the reserve. Accurate records were obtained for 101 separate maize plots, 85 groundnut plots and 51 millet plots. There are thus a few plots of maize which were recorded properly and and suitable for inclusion here, but which were omitted from the analysis in Chapter II because some other attribute of the particular holding was deficient. The general aim of the analysis in this chapter is to study the variation in each crop separately, hence the need to obtain full representation of all the conditions under which the crop was grown was deemed more important than securing exact comparability with the 97 complete sets of family data in Chapter II.

TABLE III. 1

General Characteristics of Three Crops grown in Reserve
(Mean of Ratios)

Characteristics	Maize	Groundnuts	Millet
Number of holdings	101	85	51
Average acreage	7.38	1.17	1.13
Average yield/acre	444 lbs.	300	264
Average hours/acre	88	281	183
Average hours/100 lbs.	25	116	93
S.D. Hours/acre	53.8	161.3	109.5
C.V. Hours/acre	61.2	57.3	59.9
S.D. Hours/100 lbs.	16.3	99.2	52.5
C.V. Hours/100 lbs.	63 8	85.8	56.2
Value per 100 lbs.	9s. 6d.	35s 0d.	30s. 0d.
Average return/hour	4.5d.	3.6d.	3.9d.

S.D. Standard deviation.
C.V. Coefficient of Variation.

D

As already seen in Chapter II, maize occupies over three-quarters of the area of land, followed by equal areas of groundnuts and millet of about 1 acre each. The average yield per acre is uniformly low for all three crops. The labour expended on each crop, however, is more in proportion to the values than the areas the crops occupy, as can be seen from the average return per hour of work. Finally, the variation in the labour requirement of each crop is shown. In line with previous surveys of labour requirements of crops in African peasant agriculture,* there is a very wide dispersion about the means. It is the purpose of this chapter to look for factors which explain this wide variation. The less variation in a given characteristic used for farm planning purposes, the more accurate the advice that can be given.

The next Table, III. 2, shows the dispersion in the labour requirements of each crop broken down by type of operation. A definite pattern emerges from these figures. With the exception of the harvest data, expressed in terms of output, all the individual farming operations show *greater* dispersion about the mean than the total for each crop. It is clear from this that some of the variation in the individual operations for each crop must therefore be compensatory. The harvest requirement of labour for 100 lb. of output seems reasonably consistent around 5 hours per 100 lb. for maize, 44 hours per 100 lb. for groundnuts and 25 hours per 100 lb. for millet. It may be possible to reduce this variability later, but at this stage the harvest component of crop labour looks to be the only stable element it is possible to isolate from Table III. 2.

The next possibility to consider is whether peasant cultivators vary the amount of other work in accordance with the size of harvest. At the same time, there may also be a possibility that the supply of labour in the family cultivation unit may be operating as a limiting factor. If this were the case, it would be expected that small families would tend to spread their efforts over the available acreage they have to cultivate, while large working families could devote more attention to their crops. Clearly there comes a point where the large family might have the same amount of land per person as the small family, in which case it would be anticipated that the intensity of labour effort would be about the same. Since these two factors of yield and size of holding might be operating at the same time, it is next necessary to analyse the work requirements given in Tables III. 1 and III. 2 by both factors simultaneously.

* See for instance "The Economics of a Savannah Village" by M. R. Haswell, HMSO, 1953; and "Nigerian Cocoa Farmers" by Galletti, Baldwin and Dina, Oxford, 1956.

TABLE III. 2

Dispersion of Crop Labour Requirements by Farm Operation.

Crop	Operation				
Maize	Manuring	Ploughing	Weeding	Harvest	Total
Hours/acre	6.4	17.9	42.5	20.8	87.6
S.D.	4.4	12.9	30.0	16.2	53.8
C.V.	68.7	72.1	70.5	77.8	61.2
Hours/100 lbs.	2.0	5.2	12.7	5.4	25.3
S.D.	2.5	4.0	9.5	3.1	16.3
C.V.	127.2	76.9	74.6	58.4	63.8
Groundnuts					
Hours/acre		52.9	98.9	129.5	281.3
S.D.		41.5	90.7	103.6	161.3
C.V.		78.4	91.7	80.0	57.3
Hours/100 lbs.		25.1	46.5	44.0	115.6
S.D.		38.0	60.6	18.6	99.2
C.V.		151.2	130.3	42.2	85.8
Millet					
Hours/acre		32.6	94.6	55.5	182.7
S.D.		27.6	76.8	40.6	109.5
C.V.		84.8	81.2	73.1	59.9
Hours/100 lbs.		22.2	46.1	25.1	93.4
S.D.		31.1	34.9	10.5	52.5
C.V.		139.9	75.8	41.7	56.2

To do this, cross-classification tables are constructed which make the best use of the available number of observations for each crop. This technique has been used before for European farm holdings though not for African peasant holdings as far as is known.* Table III. 3 shows the distribution of the individual plots recorded for each crop by yield groups and by size groups. Size is measured here in acres. The results of this analysis of each crop are now discussed in turn.

Maize:

Table III. 4 shows the mean ratios for the 101 maize plots cross-classified by the yield and size groups given in Table III. 3. The class intervals for this and following tables are not printed each time. The upper two parts of the table are included to check whether the average yield and average acreage of each class vary independently of each other. Reading downwards in part (a), each acreage class has a reasonably constant average size as yield per acre increases. There is certainly no trend in this average acreage with rising yield within the table itself. But because of the weighting caused by the unequal distribution of plots across the high yield group, the average column on the right tends to show a downward

* See "The Economics of Yield and Size on European Farms" by R. W. M. Johnson. Rhodesian Agricultural Journal, Vol. 58, No. 5, 1961.

TABLE III. 3

Distribution of Farms by Yield and Size Groups.

(No. of Farms)

(a) MAIZE

Yield per Acre	Acreage in Crop 0–2.9 acres	3.0–6.9 acres	7.0 acres and over	TOTAL
0–199 lbs.	1	7	8	16
200–399 „	1	18	25	44
400–599 „	2	7	9	18
600–999 „	0	8	6	14
1,000 and over	5	3	1	9
TOTAL:	9	43	49	101

(b) GROUNDNUTS

Yield per Acre	Acreage in Crop 0–0.9 acres	1.0–1.9 acres	2.0 acres and over	TOTAL
0–199 lbs.	9	15	8	32
200–399 „	23	12	1	36
400–599 „	6	2	1	9
600 and over	6	2	0	8
TOTAL:	44	31	10	85

(c) MILLET

Yield per Acre	Acreage in Crop 0–0.9 acres	1.0–1.9 acres	2.0 acres and over	TOTAL
0– 99 lbs.	4	6	2	12
100–199 „	8	6	2	16
200–499 „	10	3	2	15
TOTAL:	28	17	6	51

trend. Reading across part (b) of the table, the pattern of yield per acre for different sized plots can be read off. Again, within yield groups the results are consistent but the averages along the bottom are decidedly weighted by the distribution of observations.

Taken together, parts (a) and (b) of Table III. 4 demonstrate a phenomenon which had been reported in African agriculture before.* Over the whole sample, there appears to be an inverse

* See "An Economic Survey of Commercial African Farming among the Sala of the Mumba District of Northern Rhodesia". Government Printer, Lusaka, 1954; "Nigerian Cocoa Farmers", Galletti, Baldwin & Dina, Oxford, 1956; and "The Economy of Central Africa" by W. H. Barber, Oxford, 1961.

TABLE III. 4

Yield and Size Differences in Labour Requirements for Maize.

(Groupings from Table III. 3(a)

(a) Maize Acreage—Acres.

2.90	4.41	9.56	6.89
2.46	4.70	11.21	8.35
1.97	5.15	10.63	7.54
—	4.88	9.11	6.69
2.42	5.35	10.02	4.24
2.38	4.80	10.55	7.38

(b) Yield per Acre—lbs.

103	135	167	149
294	282	273	277
508	488	481	487
—	776	726	754
1,230	1,191	1,170	1,211
840	447	367	444

(c) Hours per Acre—Hours.

56	72	59	64
112	87	56	70
139	99	69	89
—	116	84	103
259	114	68	189
193	94	62	88

(d) Hours per 100 lbs.—Hours.

54.0	55.7	36.4	46.0
38.2	32.8	21.2	26.3
27.1	21.3	14.2	18.4
—	15.6	11.6	13.9
21.1	9.6	6.1	15.6
28.0	29.8	20.9	25.3

relation between yield per acre and size of plot. As part (a) of Table III. 3 shows, the distribution of individual plots tends either to the lower left hand corner with high yields on small plots or the top right hand corner with low yields on larger plots, thus giving the trend in yield per acre shown along the bottom of Table III. 4(b). When yield is held constant (across b) this trend does not emerge, of course. Probable reasons for this phenomenon will emerge as the present chapter progresses.

Parts (c) and (d) of Table III. 4, show the mean labour hours per acres for each class and the mean labour hours per 100 lb. of shelled maize. There is a marked rise in the input of work as yield per acre increases. These trends, combined with the yield patterns in (b) give the efficiency relationships set out in (d). Within yield groups (reading across) the amount of labour per unit of output declines, and within size groups (reading down) there is also a decline in the amount of labour required per unit of output. These trends are reproduced in the summary columns on each side of (d).

Since the input of hours per acre is systematically related to both size in acres and yield per acre in this sample of maize plots, it is now possible to estimate how much of the variance in hours per acre is explained by the other two factors. Table III. 5 summarises

TABLE III. 5

Regression Results for Maize Plots.

Explanatory Variable	Regression Coefficient	Correlation Coefficient	Standard Error (of Estimate)	Percentage S.E. (of Estimate)
Variation about mean	—	—	53.8	61.2
"Acres"	—0.06	0.51	44.8	51.1
"Yield"	0.11	0.64	40.0	45.7
"Acres	—0.04)	0.71)	37.0)	42.2)
x Yield"	0.08)	)	)	)

the regression calculations. By calculating the standard error of estimate of the remaining variation about the regression line after it has been fitted, and converting this to a percentage of the original mean of the dependent variable, a measure is obtained which can be compared for each explanatory situation. "Yield" is a better explanatory variable in this sense than "acres". In fact, in the multiple regression, "acres" only reduces the percentage variance of hours per acre from 45.7 to 42.2, after "yield" has been used.

A second reason why total hours per acre is highly variable between farms is that the requirements for different farm operations may vary systematically in different acreage or yield classes. The next two sets of tables therefore set out the operational man-hour requirements for the whole sample, classified by acreage groups in Table III. 6, and by yield groups in Table III. 7. It would be ideal to take each row and column of Table III. 4(c) separately to analyse these effects, but this would take some eight large tables. Since hours per acre falls systematically within each yield group and rises systematically within each acres group, the main effects of the different operations can be discerned by taking the summary row and column.

In Table III. 6 six acreage classes are now distinguished instead of the three in Table III. 4. The operations used in maize growing

TABLE III. 6

Maize—Hours per Acre, Yields, Hours per 100 lbs. and Total Hours by Operations and Acreage Groups

(a) **Hours per Acre.**

Acreage Group	Manuring	Ploughing	Weeding	Harvest	Total
0– 2.9 acres	8.4	36.2	99.8	49.0	193.4
3.0– 4.9 „	4.9	21.1	49.2	23.3	98.4
5.0– 6.9 „	9.3	20.3	42.3	17.5	98.1
7.0– 8.9 „	7.9	12.9	30.9	17.2	68.2
9.0–12.4 „	4.6	13.0	30.0	16.4	64.0
12.5 upwards	5.3	8.4	21.6	11.0	46.4
Mean:	6.4	17.9	42.5	20.8	87.6

(b) **Average Acreage, Yield per Acre and Output.**

Acreage Group	No. of Farms	Ave. Acreage (acres)	Ave. Yield (lbs.)	Ave. Production (lbs.)
0– 2.9 acres	9	2.4	840	1,986
3.0– 4.9 „	24	3.9	432	1,809
5.0– 6.9 „	19	5.9	466	2,762
7.0– 8.9 „	19	8.0	343	2,711
9.0–12.4 „	21	10.3	401	4,119
12.5 upwards	9	16.5	344	5,386
Total:	101	7.4	444	2,973

(c) **Hours per 100 lbs. of Output.**

Acreage Group	Manuring	Ploughing	Weeding	Harvest	Total
0– 2.9 acres	0.8	5.2	15.3	6.8	28.0
3.0– 4.9 „	1.3	7.0	17.1	6.4	31.8
5.0– 6.9 „	3.2	6.0	13.5	4.7	27.3
7.0– 8.9 „	3.2	4.5	11.6	5.9	25.3
9.0–12.4 „	1.3	4.3	9.3	4.7	19.6
12.5 upwards	1.7	2.7	7.1	3.5	15.1
Mean:	2.0	5.2	12.7	5.4	25.3

(d) **Total Input of Hours.**

Acreage Group	Manuring	Ploughing	Weeding	Harvest	Total
0– 2.9 acres	20 (44)	86	236	117	459
3.0– 4.9 „	19 (42)	84	195	93	931
5.0– 6.9 „	54 (68)	119	247	102	521
7.0– 8.9 „	63 (68)	103	246	137	544
9.0–12.4 „	47 (76)	134	309	169	660
12.5 upwards	87 (98)	139	356	181	766
Mean:	47 (63)	132	314	154	646

Parenthesis—percentage applying manure.

can be divided into the time spent in putting farmyard manure on the land, ploughing and planting, weeding and harvesting respectively. Harvest includes carrying to house but not threshing. The results show that there is a falling off of the input of work per acre in *all* the categories of farm operation, with the decrease least in the manuring operation, and evenly spread over the remaining three. The especially high labour requirement of holdings under three acres is related to the several high yield per acre plots contained therein; the rest of the acreage classes show a fairly uniform level of yield per acre. This is reflected in part (b) of Table III. 6.

The work requirements per unit of yield for different plot sizes is shown in part (c) to Table III. 6. There is little or no gain in efficiency for the manuring operation as would be expected from the data for hours per acre in part (a). On all three other operations there is an increase in the efficiency of production with greater size of plot of approximately 50 per cent. No significant differences between these operations are apparent in explaining the fall in labour requirements per unit of output.

The general result of the first three parts of Table III. 6 thus point to an increase in the efficiency of production of maize as size of plot increases without specifically indicating any particular operation as being responsible. The uniformity of the results in part (c), in fact, suggests that there is a common outside factor at work, such as the availability of labour. If the work force is limited, then the obvious response would be to spread what is available as evenly as possible over the available area of land. The limit is further restricted, of course, by the seasonality and timeliness factor in agricultural production. As already mentioned, such a relationship need not be exactly compensatory, as families grow up, move away from the home, and possibly return again to settle.

This total input of hours of work in each plot size group is thus shown as part (d) of Table III. 6. The figures in parenthesis after the manuring hours refer to the percentage of plots in each group which apply some manure to their maize lands. Small holdings are thus seen to spend rather less time on the manuring operation on average, although a part of this difference is explained by the lower percentage of cultivators in these groups who apply manure. In all other operations, the increase in total work output is approximately 60 per cent from the lowest acreage group to the highest, while the size of plot has increased by four times. It is quite clear that the total supply of labour is the dominant factor.

The discussion of yield per acre groups is confined to the same groups as set out in Table III.3 and the breakdown by operational categories is given in Table III.7. On hours per acre, the manuring, ploughing and weeding labour requirements increase with higher yield is of the order of 2.5 times, and on harvest work it is nearly 4 times. In terms of hours per unit of output, however, the manuring, ploughing and weeding operations show a fairly uniform increase of efficiency with higher yield. Harvest work, on the other hand, increases proportionately with yield, hence the hourly input per 100 lb. of output is fairly constant for all yield groups except the very lowest.

TABLE III. 7

Maize—Hours per Acre, Hours per 100 lbs., Total Hours by Yield per Acre Groups.

(a) **Hours per Acre.**

Yield Group	Manuring	Ploughing	Weeding	Harvest	Total
0–199 lbs.	4.1	13.2	34.3	12.9	64.4
200–399 „	6.4	16.0	33.6	13.9	69.9
400–599 „	5.8	16.4	47.2	19.8	89.2
600–999 „	7.1	19.5	43.0	33.1	102.7
1,000 lbs. upwards	11.3	36.1	90.5	51.4	189.4
Mean:	6.4	17.9	42.5	20.8	87.6

(b) **Hours per 100 lbs.**

Yield Group	Manuring	Ploughing	Weeding	Harvest	Total
0–199 lbs.	3.2	9.2	24.5	9.1	46.0
200–399 „	2.4	5.8	12.9	5.2	26.3
400–599 „	1.3	3.6	9.4	4.1	18.4
600–999 „	0.8	2.6	6.0	4.5	13.9
1,000 lbs. upwards	0.9	2.9	7.5	4.3	15.6
Mean:	2.0	5.2	12.7	5.4	25.3

(c) **Total Hours.**

Yield Group	Manuring	Ploughing	Weeding	Harvest	Total
0–199 lbs.	28	91	236	89	444
200–399 „	53	134	281	116	584
400–599 „	44	124	356	149	673
600–999 „	47	130	288	221	686
1,000 lbs upwards	48	153	384	218	803
Mean:	47	132	314	154	646

(d) **Distribution of Manure, Fertilizer Use and Soil Type by Yield Groups.**

Yield Group	Percentage Using Manure	Percentage Using Fertilizer	Average Expenditure on Fertilizer	Ratio Sand Soil to Red Loam
0–199 lbs.	44	6	0.6 sh.	88 : 12
200–399 „	70	23	9.6 „	82 : 18
400–599 „	66	39	17.9 „	56 : 44
600–999 „	57	64	60.0 „	29 : 71
1,000 lbs. upwards	66	66	74.0 „	0 : 100
Mean:	63	33	22.4 „	63 : 37

Part (c) of Table III. 7 shows the total input of work by yield groups and operations. The narrow range of work put in, except for harvest, is readily apparent. The low yield group is clearly a special case, and must include the old, the infirm, the widows or the absent. Some explanation of the yield pattern itself is evident in the farm practices summarised in part (d) of the Table. Except in the lowest group, the incidence of manuring does not appear to be a significant factor. The use of fertilizer, however, certainly is. Moreover, the amount spent on fertilizers also increases rapidly. These factors indicate that yields are greatly dependent on the will to use improved practices as well as having sufficient labour resources to cope with higher outputs. Part of the increase in yields in this particular categorisation, however, is explained by the change in the soil type in the two areas studied. This tends to be fixed as far as the individual is concerned and is rather outside the factors which skill and initiative can correct.

Groundnuts:

Table III. 8 sets out the distribution of acreages, yields, hours per acre and hours per 100 lb. of crop for the categories defined in Table III. 3. Mean acreages are reasonably constant down yield groups except in the size group over two acres. These may be discounted, however, as the number of farms in this column is too small for reliable data. Mean yields across acreage groups are also satisfactory except where the above proviso also applies. The summary row and column, however, are distorted by the distribution of farms within the table and must be interpreted accordingly. The input of hours of work per acre falls as acreage increases but increases markedly as yield per acre increases. Both of these trends are also significant in terms of productive efficiency; more efficient output as measured by hours per 100 lb. of grain can be obtained by larger plots or higher yields per acre, or both. It is significant, however, that the distribution of farms within Table III. 3 does not support this latter supposition. The tendency is for farms to be *either* high yielders on small plots or low yielders on larger plots.

Table III. 9 sets out the breakdown of the work input on groundnuts according to the operations previously outlined and by size groups. There is no manure on groundnuts. The class intervals have been expanded to five to identify the trends in efficiency more closely. The numbers within each class interval and the yield per acre and total production data for the new intervals are given at the top of the table. The interpretation of this table is made more difficult by the systematic fall in yield per acre as size of plot increases.

TABLE III. 8

Groundnuts—Yield and Size Interactions.

(a) **Acres.**

Yield per Acre	0–0.9 Acres	1.0–1.9 Acres	2.0+ Acres	Mean
0–199 lbs.	0.63	1.41	3.37	1.68
200–399 „	0.64	1.31	2.00	0.90
400–599 „	0.47	1.20	2.65	0.88
600 lbs. upwards	0.53	1.27	—	0.72
Mean:	0.60	1.35	3.16	1.17

(b) **Yield in Lbs.**

Yield per Acre	0–0.9 Acres	1.0–1.9 Acres	2.0+ Acres	Mean
0–199 lbs.	132	149	118	136
200–399 „	279	289	346	284
400–599 „	511	493	500	506
600 lbs. upwards	793	780	—	790
Mean:	350	266	179	300

(c) **Hours per Acre.**

Yield per Acre	0–0.9 Acres	1.0–1.9 Acres	2.0+ Acres	Mean
0–199 lbs.	256	185	117	188
200–399 „	337	221	345	299
400–599 „	401	254	196	346
600 lbs. upwards	516	465	—	504
Mean:	354	221	148	281

(d) **Hours per 100 lbs.**

Yield per Acre	0–0.9 Acres	1.0–1.9 Acres	2.0+ Acres	Mean
0–199 lbs.	239	129	98	152
200–399 „	122	79	97	107
400–599 „	79	50	39	68
600 lbs. upwards	60	62	—	60
Mean:	132	100	93	116

In effect the fall in total hours per acre is made up of two elements —the influence of size and the influence of yield per acre. From Table III. 10 it is apparent that the number of hours required to produce an extra 100 lb. of grain is 50. But from Table III. 9(b) it is clear that the fall in hours per acre is rather greater than this amount, in terms of the fall in yield as acreage increases. It is possible to conclude that both influences are at work, the exact share of each being a matter of more refined statistical calculation.

From Table III. 9(c) it can be seen that the fall in harvest hours is

TABLE III. 9

Groundnuts—Breakdown by Acreage Groups.

(a) **Production Data.**

Acres Group	No.	Average Acreage	Average Yield	Average Production
0–0.49 acres	13	0.30	374 lbs.	110 lbs.
0.5–0.99 „	30	0.73	347 „	247 „
1.0–1.49 „	21	1.20	280 „	333 „
1.5–1.99 „	11	1.67	229 „	367 „
2.0 acres up	10	3.16	179 „	517 „
Total:	85	1.18	299 „	295 „

(b) **Hours per Acre.**

Acres Group	Ploughing	Weeding	Harvest	Total
0–0.49 acres	113.5	164.8	182.1	460.5
0.5–0.99 „	47.4	118.2	147.4	312.9
1.0–1.49 „	47.0	73.4	125.0	245.3
1.5–1.99 „	31.0	63.6	78.4	173.0
2.0 acres up	28.0	47.3	62.8	148.1
Mean:	53.0	98.9	129.3	281.4

(c) **Hours per 100 lbs.**

Acres Group	Ploughing	Weeding	Harvest	Total
0–0.49 acres	54.8	98.8	45.5	191.1
0.5–0.99 „	17.5	45.7	42.3	105.6
1.0–1.49 „	24.0	32.2	47.1	103.2
1.5–1.99 „	18.7	41.7	37.7	98.1
2.0 acres up	18.9	27.7	46.0	92.6
Mean:	25.1	46.5	44.0	115.6

(d) **Total Hours.**

Acres Group	Ploughing	Weeding	Harvest	Total
0–0.49 acres	32.7	57.1	48.6	138.3
0.5–0.99 „	34.5	83.5	104.7	222.7
1.0–1.49 „	56.6	98.6	146.2	292.3
1.5–1.99 „	51.6	107.4	125.3	284.3
2.0 acres up	70.1	122.5	202.1	394.7
Mean:	46.1	88.7	120.5	255.2

strictly proportioned to yield per acre, but that ploughing and weeding per acre fall rather more quickly than yield to give a gain in productive efficiency in terms of hours per 100 lb. of nuts. The range of total input of hours is rather wider in the case of groundnuts than in that of maize (Table III. 6(d)). There is evidently not such a fixed quota of time to be allocated to this crop as there is with maize. The general effect of this is that greater total hours are worked on larger acreages but at a declining rate on a per acre basis, which is more than compensated for in terms of yield. There are thus considerable advantages in growing more than 1 acre of groundnuts.

TABLE III. 10

Groundnuts—Breakdown by Yield Groups.

(a) **Production Data.**

Yield Group	No.	Average Acreage	Average Yield	Average Production
0–199 lbs.	32	1.71	136	226
200–399 „	36	0.90	284	257
400–599 „	9	0.88	506	443
700 lbs. up	8	0.72	790	574
Total:	85	1.18	299	295

(b) **Hours per Acre.**

Yield Group	Ploughing	Weeding	Harvest	Total
9–199 lbs.	45.8	72.9	69.0	187.8
200–399 „	54.8	123.5	120.4	298.8
400–599 „	46.6	95.2	204.1	346.0
700 lbs. up	80.2	95.7	325.4	503.7
Mean:	53.0	98.9	129.3	281.4

(c) **Hours per 100 lbs.**

Yield Group	Ploughing	Weeding	Harvest	Total
0–199 lbs.	40.0	64.3	48.2	152.4
200–399 „	19.5	42.1	42.5	106.9
400–599 „	9.1	20.0	39.2	68.3
700 lbs. up	9.2	12.2	39.2	60.5
Mean:	25.1	46.5	43.9	115.6

(d) **Total Hours.**

Yield Group	Ploughing	Weeding	Harvest	Total
0–199 lbs.	57.7	92.4	103.3	253.5
200–399 „	43.9	94.3	107.1	245.2
400–599 „	32.8	66.1	157.1	256.1
700 lbs. up	37.3	70.9	207.9	316.0
Mean:	46.1	88.7	120.5	255.2

The breakdown of the work input data by the yield groups defined in Table III. 3 is presented in Table III. 10. The total input of work in terms of hours per acre and total hours is relatively constant for ploughing and weeding over all yield classes. This in turn leads to a marked rise in the efficiency of production in terms of the number of hours required to produce 100 lb. of nuts. The harvest component of the work load in groundnuts is the biggest of the three operations referred to and can be seen in Table III. 10, to increase in proportion to the yield of nuts per acre. There is thus a large increase in the total hours devoted to groundnuts at harvest time, when it may be presumed that there is no question of a bottle-neck in labour use in the reserve economy.

The reasons for the differences in yield per acre are not easily explained. There is no marked trend from the sand soil to the red loam as yields rise. Indeed there is little to be observed in this survey which would help explain these differences except the tendency already referred to in Table III. 3 and Table III. 8 that these high yielding farms tend to be very small plots less than one acre in size, and are thus more intensively cropped.

Millet:

The number of plots suitable for this analysis was 51. The interaction between the two main variables is set out in Table III. 11. The distribution of plots within cells and the inconsistency between internal rows and columns with the summary rows and columns is very similar to that for groundnuts. There is a decrease in the input of hours per acre as the size of the plot cultivated increases, which is thus partly explained by spreading of a fixed work load over a larger area and partly by the associated fall in intensity of production. There is an increase in the number of hours per acre as yield

TABLE III. 11

Millet—Yield and Size Interactions.

(a) **Acres.**

Yield per Acre	0–0.9 Acres	1.0–1.9 Acres	2.0+ Acres	Mean
0– 99 lbs.	0.59	1.45	2.50	1.34
100–199 „	0.71	1.46	2.70	1.24
200–499 „	0.66	1.58	2.39	1.07
500 lbs. up	0.52	1.30	—	0.72
Mean:	0.64	1.46	2.53	1.13

(b) **Yield per Acre** (lbs.)

Yield per Acre	0–0.9 Acres	1.0–1.9 Acres	2.0+ Acres	Mean
0– 99 lbs.	63	77	75	72
100–199 „	138	148	146	143
200–499 „	332	266	237	306
500 lbs. up	710	730	—	715
Mean:	319	213	153	264

(c) **Hours per Acre.**

Yield per Acre	0–0.9 Acres	1.0–1.9 Acres	2.0+ Acres	Mean
0– 99 lbs.	99	77	111	90
100–199 „	183	117	80	145
200–499 „	258	179	132	226
500 lbs. up	315	320	—	316
Mean:	226	138	108	183

(d) **Hours per 100 lbs.**

Yield per Acre	0–0.9 Acres	1.0–1.9 Acres	2.0+ Acres	Mean
0– 99 lbs.	138	119	147	128
100–199 „	138	78	58	106
200–499 „	80	79	57	77
500 lbs. up	43	46	—	44
Mean:	97	89	87	93

TABLE III. 12

Millet—Breakdown by Acreage Groups.

(a) **Hours per Acre.**

Acreage Group	Ploughing	Weeding	Harvest	Total
0–0.9	46	113	67	226
1.0–1.9	17	76	45	138
2.0 upwards	15	63	30	108
Mean:	33	95	55	183

(b) **Hours per 100 lbs.**

Acreage Group	Ploughing	Weeding	Harvest	Total
0–0.9	27	45	25	97
1.0–1.9	18	45	25	89
2.0 upwards	11	51	24	87
Mean:	22	46	25	93

(c) **Total Hours.**

Acreage Group	Ploughing	Weeding	Harvest	Total
0–0.9	26	74	42	141
1.0–1.9	24	110	66	200
2.0 upwards	35	154	74	263
Mean:	27	95	53	175

TABLE III. 13

Millet—Breakdown by Yield Groups.

(a) **Hours per Acre.**

Yield Groups	Ploughing	Weeding	Harvest	Total
0– 99 lbs.	24	44	21	90
100–199 „	28	77	41	145
200–499 „	36	122	67	226
500 lbs. upwards	46	154	115	316
Mean:	33	95	55	183

(b) **Hours per 100 lbs.**

Yield Groups	Ploughing	Weeding	Harvest	Total
0– 99 lbs.	45	56	24	128
100–199 „	21	56	29	106
200–499 „	13	42	22	77
500 lbs. upwards	7	21	17	44
Mean:	22	46	25	93

(c) **Total Hours.**

Yield Groups	Ploughing	Weeding	Harvest	Total
0– 99 lbs.	22	65	30	117
100–199 „	24	85	47	156
200–499 „	33	122	58	213
500 lbs. upwards	28	111	92	230
Mean:	27	95	53	175

increases, which again is partly explained by an associated falling off in size of plot. On the face of it, there is no difference in economy of production in the different sized plots with this data, but there are considerable gains in terms of higher yields of grain per acre.

The breakdown to operational level of the acreage groups is set out in Table III. 12. Only on the ploughing operation does the input of time fall faster than yield to give rising efficiency of production. In weeding and in harvest the input of time per acre is roughly proportional to yield which thus gives approximately the same level of efficiency in each size group. The range in total hours of input per group is not great, being greatest over the weeding operation, least in ploughing. It is likely that the people do economise in land preparation of millet because it has to compete with maize and groundnuts at planting time. Poor land preparation, however, means greater weeding and attention later which may explain why the economy in ploughing evident here is not repeated in the weeding.

Table III. 13 gives the analysis of yield effects by operational categories. There is a marked increase in the input of time in all operations, especially in weeding attention. Harvest time does not increase as rapidly as might be expected, and suggests some economies in harvesting heavier crops over light crops. Perhaps there is a psychological factor at work here making people work better when the crops are good! The compensatory relationship between planting and weeding is again apparent here, hence the economy in ploughing hours per 100 lb. should not be taken too literally. As before, the total number of hours devoted to ploughing tends to remain constant, with the weeding and harvest requirements expanding with yield per acre. There is obviously a very close relationship between the amount of work put into this crop and the resulting yield level. It may finally be observed that millet does better on a red loam type of soil quite distinct from groundnuts which do not show differences between the two soil groups.

IV

THE ECONOMICS OF SUBSISTENCE

The next two chapters of this report describe two rather different applications of the data so far presented. The first is to look at the "average" holding and how its performance may be improved. If the average holding is taken as typical of peasant agriculture in the area concerned, then it is possible to isolate broad policy issues about the general improvement of farming in the Reserve. On the other hand, the data for the average holding does not allow very meaningful statements to be made about the improvement of individual holdings. Thus the second application of the data, presented in Chapter V, concerns farm management advice suitable for advisory work among individual farms. Although the techniques used in both cases are very similar, the use and interpretation of the results in each chapter remain quite distinct from each other.

The various problems associated with the analysis of the average farm are best discussed in terms of a simple budget. This is shown on next page. The average acreages, yields per acre, and hours per acre for each crop are taken from Tables III. 4, III. 8 and III.11 respectively. The prices used for each crop are discussed below. The total value of output and the total number of hours worked are simply obtained from the basic yields, acreages, work requirements and prices given.

Crop	Acres (ac.)	Yield (lbs.)	Production (lbs.)	Value (sh.)	Labour (hrs.)
Maize	7.38	444	3,276	311	716
Groundnuts	1.17	300	351	123	329
Millet	1.13	264	298	89	207
	9.68		3,925	523	1,252

Maize occupies some 76 per cent. of the land cultivated, but is worth 59 per cent. of the value of total output, and utilises 59 per cent. of the labour input. Groundnuts occupy only 13 per cent. of the area cultivated, but contribute 24 per cent. of the value of output with 27 per cent. of the labour input. Millet occupies 11 per cent. of the land; is 17 per cent. of value of output and 14 per cent. of total labour input. The large area of maize per holding reflects the typical subsistence pattern where food crops have first priority. This large acreage is partly a reflection of the low yields that may be expected, but is also in itself a cause of low yields because the villagers' efforts are spread over the available land. It was clear from Table III. 4(b) that small plots can be made to give higher yields when land as a resource is scarce. In the circumstances of Chiweshe Reserve, where there were very small surplusses for sale of any of the three main crops, both groundnuts and millet can also be regarded as food crops. The relative proportions of the three crops grown are thus more likely to be related to the proportions that the crops enter into the local diet rather than by price-value considerations. Roughly speaking, the above budget provides 3,925 lb. of grain for consumption for a family of 7 persons, or about 560 lb. per person per year, or 1.5 lb. of grain per day. Such a level is roughly sufficient in terms of calories and no more. Such variety as there is, is provided by the various side dishes that groundnuts and green vegetables and herbs can make, plus the millet and maize beers which are widely consumed.

In the case where output is totally consumed by the village family, there is little scope for economic considerations linked with the price system to operate. But where the pure subsistence family starts moving towards a crop surplus for the market, then the sale values of the various crops gradually assume greater and greater importance in determining the composition of output. It is therefore important to examine the new composition of output that will be required and to suggest ways of achieving it. The appropriate set of prices to use in this examination are, of course, the selling prices of the crops.

At any given time there are two sets of prices operating in an African Reserve. There is the implicit price that is assumed when one villager exchanges crops with the next villager, sometimes for money and sometimes for some form of livestock. These exchanges are going on all the time. Secondly, there is the price at which local stores are will to take produce. In Southern Rhodesia all such stores are trader-agents of the statutory Grain Marketing Board which has complete control over all marketing of the main grains. The Board has its town or main depot price set by Government, but thereafter deducts for African grain prices a margin for the trader-agent, a levy for African development and a transport equalisation levy to give a standard trader-agent price for Africans for the whole of the territory. In the 1961 harvest year these net prices in Rosa Township, Chiweshe Reserve, were as follows:

Maize	19s. per 200 lb.
Groundnuts	70s. per 189 lb.
Millet	26s. per 200 lb.

During the course of the buying season—roughly from June to November—"local" transactions between villagers tended to follow the prices below:

Maize	20s.
Groundnuts	75s.
Millet	60s.

During the following growing season from December through to March, maize prices rose to around 30s. per bag; no transactions of groundnuts were recorded but millet prices went as high as 72s. per bag.

With the exception of millet, it is clear that the trader-agents' price operates for a considerable part of the year. It is therefore possible for villagers to make up any short-fall in their output in this period. In the case of maize, some people do tend to hold surplus output for sale in the scarce months as the price rise is considerable. This change in the price surely reflects the lack of provision that other people make for the scarce months; it must be argued that such people have the choice either of obtaining their supplies at normal prices during the harvest period itself, or they are waiting for something to turn up before they have to pay higher prices. In general, however, the valuation of output surplus to subsistence must be at harvest prices, which in this case are also the official prices. For maize 19s. per 200 lb. bag or 1.14d. per lb. is adopted, and for groundnuts 70s. per 189 lb. bag, or 4.20d. per lb. shelled.

In the case of millet, the local price is far in excess of the official price at all times of the year. The official price had been as high as 45s. in the 1956 season, but large deliveries at this price ,far in excess of requirements, had brought the price down to its 1961 level. In spite of all this, the "local" price for a bucket (about 33 lb.) of threshed millet suitable for brewing remained at 10s.–12s. in the reserves and 17s.–18s. in the towns.

This is equivalent to a price of 60s.–72s. per bag in the reserves and around 100s. in the towns! In Chiweshe Reserve, in the period from October 1960 to September 1961, only about 10 buckets of millet were recorded as changing hands and all of these were at a price in the region of 12s. It is therefore necessary to assume that this price would be maintained if a great deal more millet came on to the market, and to value all surplus millet at 60s. per bag or 3.60d. per lb.

As already stated, the first budget in this chapter represents some kind of choice among villagers as to the output of each crop they want to produce. It was suggested that the guilding principle in this choice was the need to obtain a balanced dietetic pattern from the available resources. It is now pertinent to ask what choice should be made if the weightings between crops are determined by market values and not dietetic preferences.

The problem of choice in this context involves changes in the entire cropping pattern of the village. Not only must they sow different acreages of each crop, but the demands on their own labour will also change. To simplify the problem at this stage, it is easier to calculate the new acreage to be devoted to each crop if

1. the same area of land is available,
2. the same labour supply is available,
3. yields per acre remain unaltered,

   and

4. labour requirements per acre remain unaltered.

The supply of land is straightforward. In this area of Chiweshe Reserve it is possible to assume that the average family has 9–10 acres already in cultivation. The question then becomes—is it possible to use the same land in a different combination of crops so that the value of output is increased over its former subsistence level?

The labour requirements of each crop are as follows:

Maize	....	88 hours per acre.
Groundnuts	....	281 hours per acre.
Millet	....	183 hours per acre.

The availability of labour to meet these requirements, however, is highly restricted by the seasonal pattern of growth of each crop. It is not really that maize needs 88 hours of work throughout the season, but that it needs 18 hours at planting time, 42 hours at weeding time and so on. In the case of weeding it is even narrower than this. If 7–10 hours per acre per week are not spent on weeding operations during the early part of January then the crop could be choked by weeds. At planting, groundnuts require 20 hours of work per week, and at weeding up to 14 hours per week. Millet requires a maximum of 13 hours at planting time and up to 17 hours per acre per week for weeding.

All of these figures are estimates of the *minimum labour requirements* of an acre of each crop. The argument is, quite briefly, that if attention is not devoted to the crops at the times stated, then yields will fall still further.

The minimum crop labour requirements are set out in Table IV. 1. For ease of calculation, the calendar month has been divided into three 10 day periods rather than weeks. These are indicated, as before, as Jan. 1, Jan. 2, Jan. 3, Feb. 1, etc. The actual 10 day requirements for each crop have been estimated from the seasonal labour data shown in Diagram 3. At the foot of the Table are shown the total labour inputs, yield per acre, the value of output at market prices and the value of output per hour. This latter figure is not to be taken as an absolute guide to the most efficient crop as the value of output at peak labour demand periods is more important. When land is short, again, output per acre may be more important than output per labour unit.

Looking back at Diagram 3, it will be clear that the maximum labour demands for the existing budget will be in the periods Jan. 1 and May 1. Using the actual per acre requirements given in Table IV. 1 for these two periods it is possible to calculate the potential labour input for the average family throughout the season.

The higher total of 110 hours of labour per period therefore sets the upper limit to the amount of labour that is available for any new crop pattern that is suggested. The limit on land will be 9.68

TABLE IV. 1

Seasonal Labour Requirements of Three Main Crops.
(Hours per Acre)

Period	Maize	Groundnuts	Millet
Dry Season	6	—	—
Nov. 1	4	5	4
Nov. 2	6	8	[illegible]
Nov. 3	6	20	13
Dec. 1	5	17	6
Dec. 2	6	13	8
Dec. 3	5	12	9
Jan. 1	11	14	11
Jan. 2	7	13	13
Jan. 3	6	14	17
Feb. 1	3	14	17
Feb. 2	2	10	11
Feb. 3	—	5	6
Mar. 1	—	3	4
Mar. 2	—	5	2
Mar. 3	—	21	1
Apr. 1	—	30	3
Apr. 2	3	36	9
Apr. 3	3	19	20
May 1	10	14	14
May 2	5	5	5
May 3	—	3	3
Total Hours per acre	88	281	183
Yield per acre	444 lb.	300	264
Value of output	42 sh.	105	79
Value per hour	0.48 sh.	0.37	0.43

Crop	Jan. 1 Requirements	May 1 Requirements
Maize	81.2 hours	73.8 hours
Groundnuts	16.4 „	16.4 „
Millet	12.4 „	15.8 „
	110.0 hours	106.0 hours

acres. The procedure at this point is to use the data in Table IV. 1 in a linear programme subject to the above limits. This mathematical technique determines the acreage of each of the three crops that will give the highest value of output. Some details of the hand working of a programme are set out as an appendix to this chapter.

In budget form, the imposition of market prices to the average subsistence holding gives the following results.

Crop	Acres	Yield	Production	Value	Labour
Maize	5.45	444 lbs.	2,425 lbs.	230 sh.	480 hours
Groundnuts	2.15	300 lbs.	645 lbs.	225 sh.	604 hours
Millet	1.83	264 lbs.	483 lbs.	145 sh.	334 hours
	9.43		3,553 lbs.	600 sh.	1,418 hours

It is clear that not all of the 9.68 acres are required, although only 0.25 of an acre will be idle. The supply of labour is thus the limiting resource and hence the programme will seek a solution which maximises output per unit of labour. This is done by increasing the acreage of both groundnuts and millet at the expense of maize. The result of this change is an actual lowering of physical output (3,553 instead of 3,425 lb.) but a 14.5 per cent. increase in value of output (600s. instead of 523s.)*. This new output in turn requires an increase in labour input of about 13 per cent., i.e., from 1,252 hours to 1,418 hours. Since the total input of hours in any one time period has been held fixed at 110 hours, the new budget has brought about a better spread of labour over the season and a considerable increase in the the value of output.

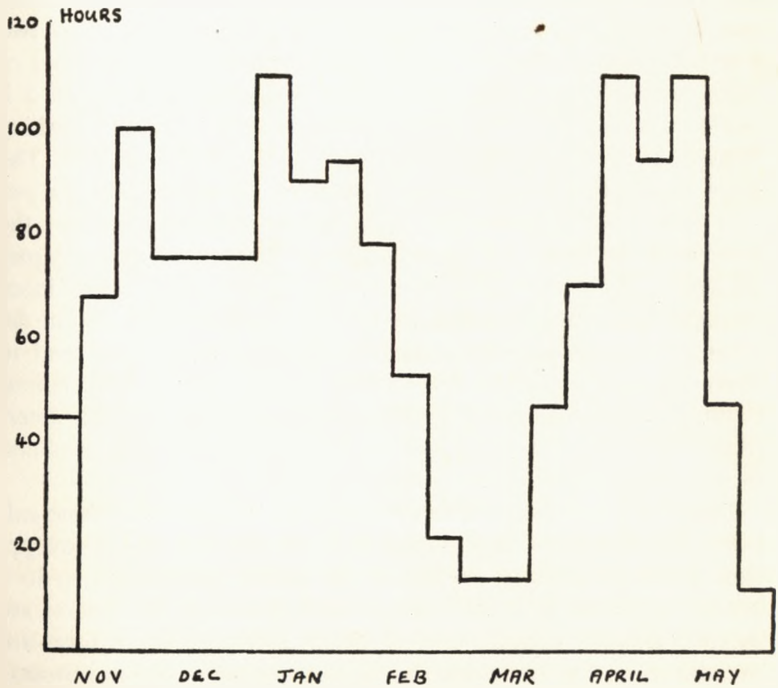


Diagram 4—Seasonal distribution of labour input for 9.43 acres and 110 hours solution, harvest restricted.

The distribution of the total labour input over the growing season for this budget is shown in Diagram 4. It is a fundamental property of the method used that the number of periods in which labour use

* In effect, this is some measure of the social cost of subsistence. It is the difference in output, valued at local market prices, between subsistence needs and market needs.

reaches its maximum are equal to the number of crops that are included in the final solution. If land is limiting, then only two of the time periods would be fully utilised. The importance of Diagram 3 at this stage is to note that one of the fully utilised periods falls at weeding time in January and two of these periods during the harvest in April and May. This raises the whole question, discussed in detail below, as to whether timeliness of operation at harvest is of the same crucial importance as that at planting and weeding.

It is next of some interest to examine the crop patterns determined when land is the limiting factor. Thus, if labour is held at 110 hours per time period and the area of land held at any area less than 9.43 acres, then a part of the least profitable crop will have to be given up. The analysis may be formalised to some extent by looking at the crop patterns at all acreages from 5 to 15 acres (see Diagram 1 for the actual distribution of farms within these two figures), when the family can provide 100, 150 and 200 hours of work respectively in each time period. Referring to Table II. 5 it can be seen that such work limits generally approximate to working families of 5, 9 and about 12 persons, at the busiest periods. The main assumption which underlies such an analysis is that the per acre crop labour requirements at higher and lower acreages are the same as at the mean. An inspection of the relevant tables in Chapter III shows in fact that small acreages have a far higher labour input per acre, while large acreages have one much lower than that at the mean. It is also apparent, however, that the three crops tend to move together in this respect, so that as long as the relative labour requirements remain unchanged, the programming will still determine which crops are most worthwhile under the different land and labour assumptions.

Diagram 5 has been drawn to summarise the results of these calculations. When the labour input is restricted to 100 hours per time period, it pays to devote all the land to groundnuts up to 3 acres in cultivation; it then pays to include millet until 5 acres are in cultivation; and maize can be added until just over 8 acres are in cultivation. The transition lines across the page slope downwards at first as part of the area of the previous crop must be given up to make room for the new crop at peak labour demand periods (see appendix for details of this). When the third crop has been included these lines level off, of course, as the ratios between the crops are fixed by the *linear* programme.

When the labour input is increased to 150 hours per time period, the point of entry of millet and maize is much later. Millet becomes

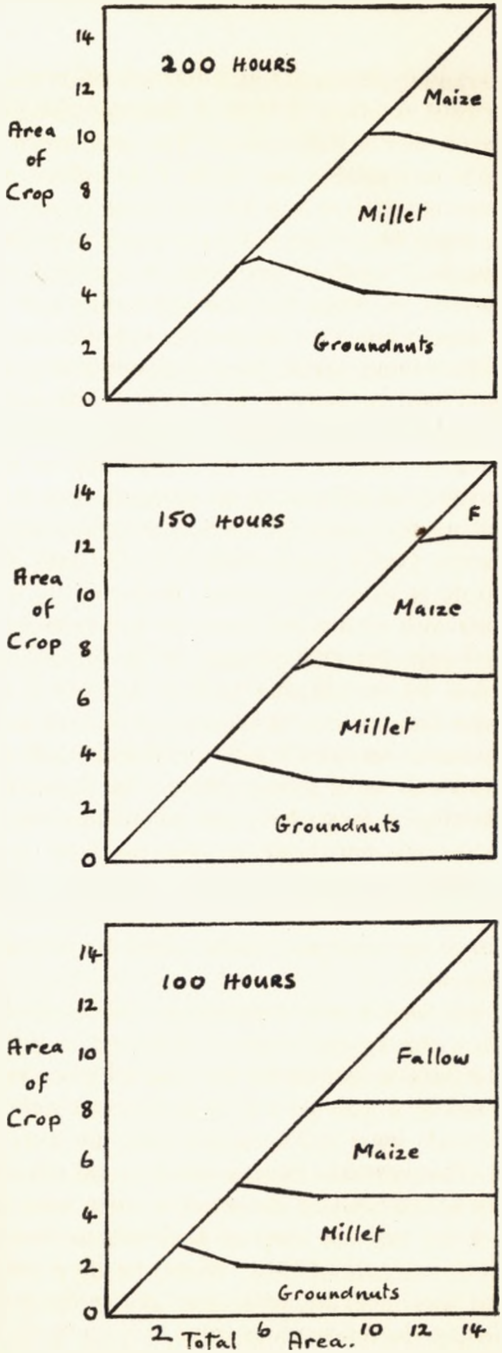


Diagram 5—Land utilisation patterns for different areas and labour inputs, harvest restricted.

worthwhile at 4 acres and maize at 7 acres. Land is left fallow only when 12 acres are in cultivation. Allowing for extra large families, or 200 hours of labour input in 10 days, millet becomes worthwhile at 5 acres and maize at 10 acres. All of the 15 acres would be under cultivation with such a labour supply.

In general, the order of priority among the three crops remains the same as in the original programmed budget. The various solutions indicate that in terms of the market values of the crops it pays to specialise in the crop which gives the best return up to the period where the labour supply in one period halts further expansion. Once this point is reached, it pays to substitute the next crop at the margin of time until its labour supply is limited and so on. The whole impression given in these results thus runs entirely counter to the subsistence pattern of production, and must indeed be regarded as a set of possibilities which *might* prevail if peasant cultivators were *not* subsistence minded. Furthermore, the solutions imply that no other structural changes take place in the transition from the subsistence to the cash economy. It must be quite clear that not only would the input-output ratios for each crop change considerably but the very price structure itself would change if all cultivators depended on the markets for their food supplies.*

The next assumption which might be challenged at this stage concerns the timeliness of labour operations at harvest time. As already suggested, the lack of harvest labour in each 10 day time period for each crop restricts the acreages devoted to the crops in the solutions already presented. It is clear that planting and weeding operations in peasant agriculture, or in plantation agriculture for that matter, are highly specific in time. Late planting lowers yields in Central Africa just as much as neglect of weeding. Do these considerations apply to the harvesting period? There is wide evidence that harvest is a joyful period in peasant societies and that the work involved is undertaken willingly. Mutual help is common where absentees or sickness prevents a family from completing their harvest. All this would suggest that the mere allocation of existing time at harvest (for that is what has been used) should not be allowed to dominate planned budgets for farmers. After all, planting and weeding are more critical. The one argument against abandoning time restrictions in April and May relates to the possibility of loss from ants and theft and the need to let the cattle into the arable fields. Ant damage is quite serious from May onwards, hence some

* I have dealt with this problem in the national income context elsewhere. See my "Notes on the Valuation of Subsistence Income" Occasional Paper No. 1 of the Department of Economics, University College of Rhodesia and Nyasaland.

urgency is desirable. Late rains can also make groundnuts sprout in the ground if delays occur.

All these reasons indicate that some caution is needed before proceeding to programmes based on planting and weeding labour restrictions only. Furthermore, if labour requirements differ too greatly between harvest and earlier operations, then a programme based on planting and weeding requirements alone may well involve a cropping pattern that is almost impossible to harvest. What is probably needed to overcome this problem is an independent investigation of how far the peasant family can really be extended over and above the hours they already put in at harvest time. Some guide to this may emerge from present studies of master farmers in Purchase Areas, where much greater outputs are already handled by simple methods similar to those used in the Reserve.

Proceeding as before, the results of removing harvest restrictions on labour are presented in budget form first.

Crop	Acres	Yield	Production	Value	Labour
Maize	3.94	444 lbs.	1,755 lbs.	165.5 sh.	347 hours
Groundnuts	2.19	300 lbs.	657 lbs.	230.5 sh.	615 hours
Millet	3.28	264 lbs.	865 lbs.	259.5 sh.	600 hours
	9.41		3,277 lbs.	655.5 sh.	1,562 hours

It can be seen that millet has increased considerably at the expense of maize and that groundnuts have scarcely changed. Apparently groundnuts are just as much restricted by labour problems early in the season as at harvest. Millet, on the other hand, was previously held back by fairly high harvest requirements which are not equalled by planting or weeding requirements. With the substitution of a higher valued crop (millet) for a lower valued crop (maize), physical output falls still further from previous levels but value of output has risen by some 10 per cent. The labour input has also increased, this time by a little over 10 per cent. Essentially, this gain in value of output has been achieved by a redistribtion of labour inputs and not by any increase in output per labour unit.

Diagram 6 shows the seasonal distribution of labour for the above budget. The three periods fully utilised up to 110 hours are Nov. 3, Jan. 1 and Jan. 3. Harvest requirements have increased by some 10 per cent. over this level, i.e.

April 2	....	120.2 hours
April 3	....	119.0 hours
May 1	....	116.0 hours

This extra demand for labour at harvest is not too excessive, hence the new budget probably demonstrates a realistic land

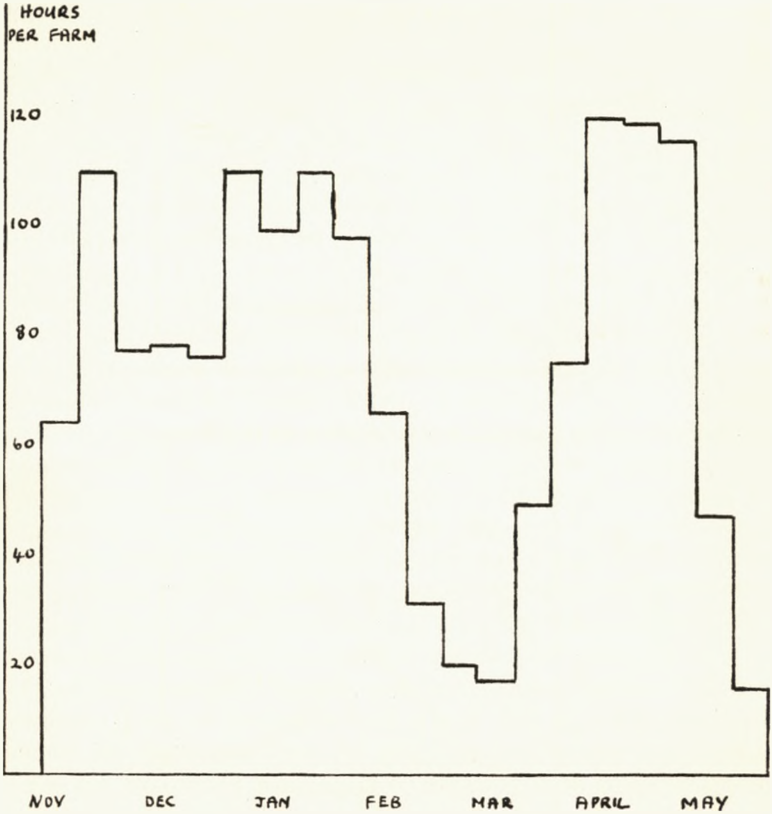


Diagram 6—Seasonal distribution of labour input for 9.41 acres and 110 hours, harvest unrestricted.

utilisation pattern under market demand conditions. Comparing this with average subsistence performance, the social cost of subsistence in value of income foregone rises to about 25 per cent. of output.

Since this result seems fairly reasonable it is worthwhile to go on to calculate the patterns of land utilisation when the total area cultivated is restricted successively to 5, 6, ... 15 acres and the labour input per period to 100, 150 and 200 hours respectively. Diagram 7 has been drawn to present these results in concise form. It is immediately apparent that the introduction of millet after groundnuts is delayed far later than in Diagram 4, although the ultimate areas of groundnuts work out about the same. In effect, however, there is a great deal of substitution at the margin possible between these two crops as shown by the slope of the transition

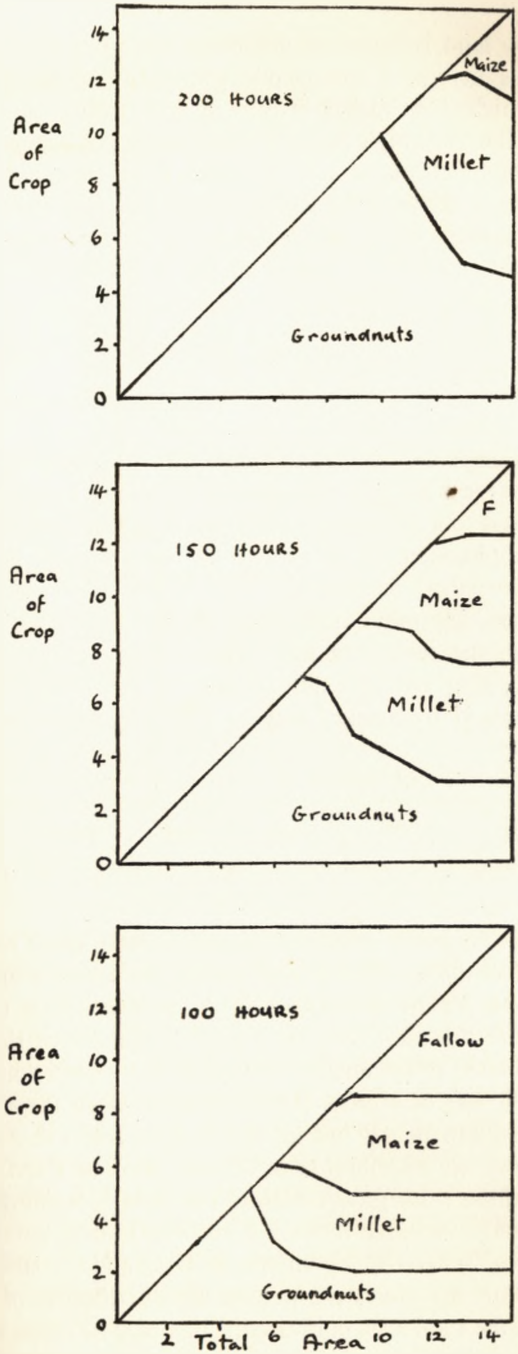


Diagram 7—Land utilisation patterns for different areas and labour inputs, harvest unrestricted.

lines. Fallow land is squeezed out when there is a plentiful supply of labour as before. There is one peculiarity of these solutions, however, which does rather invalidate any further conclusions to be drawn. The very high harvest requirements of groundnuts have been completely left out of account. Thus if the labour requirements at planting and harvest for the maximum area of groundnuts indicated in each chart are calculated, it can be seen that the peasant families could not hope to collect all the crop without considerable outside help.

Labour Restriction	Acres	Planting Hours	Harvest Hours
100 hours	5	100	180
150 hours	7.5	150	270
200 hours	10	200	360

Thus, although the 110 hour budget did not place excessive demands on harvest labour, the peculiar solutions indicated in Diagram 7 do lead to a disproportionate use of labour between seasons. No great emphasis need be placed on these results, however, as they are theoretical patterns of land distribution assuming that market values determine cultivator's actions.

In general, the results of this chapter show a wide divergence between cropping patterns determined by subsistence needs and those determined by market values. The crop areas indicated by market values show an order of priority, as well, when the total area available for cultivation is restricted. This order runs from groundnuts, to millet and then to maize. The area of land devoted to each of these crops in order is also increased when the size of family increases. The size of family being measured by the number of hours of labour available in 10 day periods.

Since some output is marketed in the Reserve, there remains the possibility that the choice of crop among the families enumerated is at least partly market determined. A suitable device to test this to see whether the total area cultivated or the size of the working family are related to systematic changes in the proportions of crops grown. By the use of a cross-classification between these two measures, the test can be set out in one table. Table IV. 2 does this. Part (a) shows the distribution of actual farms in three total area classes and three work group classes. The data is taken direct from Table II. 4 and condensed to form a new 3 x 3 table. Part (b) shows the total area cultivated by each subclass, and in summary for each class. Part (c) shows the percentage distribution of the three crops within the total area cultivated. The order of crops is maize—groundnuts—millet.

TABLE IV. 2

PERCENTAGE LAND UTILISATION IN DIFFERENT TOTAL AREA AND WORK GROUP CLASSES.

(a) **Distribution of families.**

Size of Work Group (persons)	Cultivated Area 0–5.9	6–9.9	10+	Total
(a) 1, 2, 3	16	11	3	30
(b) 4, 5, 6	8	16	14	38
(c) 7+	5	8	16	29
Total	29	35	33	97

(b) **Total Area Cultivated (acres).**

(a)	4.4	7.3	11.1	6.1
(b)	4.9	8.0	13.8	9.5
(c)	4.3	8.1	15.7	11.7
Total	4.5	7.9	14.4	9.1

(c) **Percentage Distribution of Crops.**

(a)	86: 9: 5	78:15: 7	79:13: 8	82:12: 6
(b)	65:24:11	72:17:11	80: 9:11	76:14:10
(c)	70:14:16	80:11: 9	79:13: 8	78:13: 9
Total	78:14: 8	76:15: 9	80:12: 8	78:13 :9

(Order of crops—maize, groundnuts, millet).

In conformity with all the other conclusions of this chapter, it is quite clear that the cultivators do not respond to market values as the proportions of the three crops grown stay remarkably constant over all farm sizes and family sizes. It is possible that the smallest families on the smallest holdings do grow proportionately more maize than any other group. The explanation of this is that these families do not grow less groundnuts and millet but rather that many of them do not grow these crops at all.

The two assumptions made at the beginning of this chapter which have not been examined so far relate to constant yields per acre and constant labour requirements per acre. Since these involve the basis input-output ratios that are assumed in Table IV. 1, a complete re-examination of the basic data in Chapter III must be made before further results relaxing these assumptions can be presented. Chapter V, therefore, goes on to examine new yield and labour requirements in the Reserve situation and then to present the results of programming these requirements.

V

IMPROVED FARMING IN THE RESERVE

It is the purpose of this Chapter to budget farm cropping plans in the reserve situation incorporating fairly high levels of technical expertise. In general this means selecting high levels of yield per acre for each crop and estimating the new pattern of seasonal labour requirements that will be required. For maize, holdings in the overall analysis yielding more than 1,000 lb. of grain to the acre were selected as the basis of the probable labour requirements; for groundnuts and millet the minimum levels were 400 lb. and 200 lb. respectively. A further restriction on budget plans based on linear programmes which can be varied at this stage is that of fixed input-output relations for each crop. This can be done by setting up different plans for the one crop thus incorporating different input-output possibilities.* In this Chapter, only maize is treated in this way though other crops can be varied if the data exists. More crop plans mean more calculations, of course, and simple methods of solving the programme may become too laborious.

The maize crop can conveniently be divided into three different plans, based on different levels of use of farmyard manure and artificial fertilisers, beside the minimum plan already used in Chapter IV. In all that follows, it is implied that the old minimum plans for maize, groundnuts and millet are "available" for selection in the final crop programme, even though the programme rejects them as having inferior levels of land and labour productivity. In this sense, therefore, the selection in this Chapter is based on eight different crop plans. The three new plans for maize can be summarised as (1) maize+manure+fertiliser (low dressing), (2) maize +fertiliser (medium dressing), and (3) maize+fertiliser (heavy dressing). Plans for each of these are now discussed in turn.

The first maize plan is based on general practice in the reserve where a portion of the maize crop is grown on manured land. In some cases fertiliser is added to this manure, in others it is spread on non-manured land. The supply of manure does not seem very high and is probably capable of great improvement. The manure plan is based on existing supplies, however, and it is recommended that higher dressings, if available, be placed on the same area rather than spreading the manure thinly over more infertile acres. Fertiliser supplementation is assumed for this plan at just over 100 lb. of Urea per acre.

* I use the word "plan" here instead of the technical phrases "real activities" or "non-basic activities".

In a separate investigation of all plots of maize grown with manure, not reported in detail in this paper, it was found that 16 holdings out of 68 achieved yields per acre over 1,000 lb. of grain. These 16 plots showed a marked variation in labour input per acre, however, according to the size of each plot. These details were as follows.

Size of Plot	No.	Average Size	Yield	Hours per Acre	Manure
Under 1 acre	4	0.62 acres	2150 lbs.	450 hrs.	3½ tons
1–1.9	10	1.36	1448	210	4
over 2	2	3.07	1035	92	6

There is thus a distinct pattern within this high yield group of plots according to the total acreage planted. Now since the purpose of this analysis is to find recommended plans for improved farmers, small plots less than one acre in size can be passed over as unrealistic. The larger plots, over two acres, must be passed over as well on the grounds of a probable shortage of cattle manure. This leaves the 10 holdings between one and two acres. The average seasonal distribution of their labour inputs therefore forms the basis of the maize+manure plan. The choice of these 10 plots places a new restriction on the final programme chosen as their labour requirements can only represent cultivation plans for an area of maize between one and two acres.

If the programming selects acreages above or below these limits then the plan must be adjusted for the new labour patterns that are entailed. The average expenditure on fertilisers of the 10 farms was 63s., or 47s. per acre treated. It is assumed that fertiliser is the only variable cost in the new plan, hence the value of net output (or gross margin) per acre of this maize works out as follows:—

1448 lbs. at 1.14d. per lb.	=	137.5 sh. per acre
104 lbs. of "P" or 117 lbs. Urea*	=	47.0 sh. per acre
Net Return	=	90.5 sh. per acre

The second maize plan has no manure but has a higher dressing of fertilisers to compensate. The yields and labour requirements are taken from Table III. 3 for all farms yielding over 1,000 lb. per acre. Again three different labour requirements are evident depending on the size of plot involved. The comparison is as follows:

Size of Plot	No.	Average Size	Yield	Hours/Acre
0–2.9 acres	5	2.42	1,230	259
3.0–6.9	3	5.35	1,190	114
over 7.0	1	10.02	1,170	68
	9	4.24	1,211	189

* Price of "P" compound taken as 45/- per 100 lb.
Price of Urea taken as 40/- per 100 lb.

This plan should provide the opportunity to the cultivator of growing quite a large area of maize if he wishes, hence the three farms in the range 3-6.9 acres represent the kind of pattern desired. The three farms spent an average of 100s. each on fertiliser in 1960-61, equivalent to an expenditure of 18s. per acre grown. Since there appears to be favourable soil conditions for all three farms, this level of expenditure must be regarded as inadequate for general recommendation. The absence of manure would necessitate the use of some "P" compound (N8–P24–K0) at planting, with a higher dressing of urea at knee height. 50 lb. of "P" and 95-100 lb. of urea would thus cost 60s. per acre. The net return per acre for this plan therefore works out as follows:

1190 lbs. at 1.14d. per lb. =	113/– per acre
fertiliser =	60/– per acre
net return =	53/– per acre

The third maize plan is based on high yields and high fertiliser use. Since a yield per acre of over 10 bags, or 2,000 lb., is sought, the data collected in Chiweshe Reserve is no longer useful. Instead, the plan must be built up from experimental data on fertiliser yields for the same soils and other local conditions.* This experiment was run during the same season as the above data was collected, and was based on a replicated trial of four manure levels and four fertiliser (urea) levels. The whole plot was treated with "P" compound at planting at the rate of 240 lb. per acre. The manure treatments were 0, 5, 10 and 15 tons, and the fertiliser treatments were 0, 85, 170 and 255 lb. of urea per acre. The treatment means in bags per acre were as follows:

	M_0	M_1	M_2	M_3	Average
N_0	0.2	2.5	1.3	2.3	1.6
N_1	7.5	7.4	10 0	8.0	8.3
N_2	10.2	15.7	13.2	16.4	13.9
N_3	10.5	14.1	15.7	19.0	14.8
Average	7.1	9.9	10.1	11.5	9.6

The high level of "P" compound used for the trial is not necessary at a field scale and 160 lb. per acre would be suitable provided a heavy dressing of nitrogen followed. Since 10 bags per acre were reached in the trial with 85 lb. of urea in the presence of manure, or with 170 lb. of urea in the absence of manure, the appropriate

* This experiment has been reported in the Rhodesia Agricultural Journal, Vol. 59, 1962, p.222. "Fertilizer Responses on Maize under Reserve Conditions".

level of urea to achieve the main objective would be about 120 lb. per acre. This may be putting the nitrogen level a little too low in the light of the above results, but any further increase reduces the value of net output to rather low levels.

The labour requirements of this plan will be similar to plan (2) except that seven hours more work will be required in Jan. 2 for fertiliser application and that harvest requirements will be proportionately greater. The same labour requirement per 100 lb. of grain as in plan (2) has been taken and spread proportionately over the same time periods. The calculation of net value of output is as follows:

2040 lbs. of 1.14d. per lb.	=	194/- per acre
fertiliser	=	120/- per acre
net return	=	74/- per acre

The labour requirements for the main operations under the four different maize plans are summarised in the cell below. All figures are hours per acre. The seasonal patterns of labour requirements of the new plans are set out in Table V. 1, along with those of groundnuts and millet.

Operation	Old Plan	Plan (1)	Plan (2)	Plan (3)
Manuring	6	48	—	—
Planting	18	48	28	28
Weeding	43	57	48	55
Harvest	21	56	38	71
Total	88	210	114	154

The new plan for groundnuts is based on five plots yielding over 400 lb. per acre and greater in size than one acre. These are shown in the bottom right-hand side of Table III. 8 a-c. The average acreage grown was 1.52 acres and the average yield was 609 lb. per acre. The average seasonal labour distribution for these five plots is set out in Table V. 1. There are no variable costs involved. It is assumed that it is skilful management that achieved this level of performance and not just luck. A comparison of the old and new plans for groundnuts appears next.

Characteristic	Old Plan	New Plan
Acreage	1.17 ac.	1.52
Yield	300 lbs.	609
Planting	50 hrs.	36
Weeding	98 ,,	100
Harvest	127 ,,	190
Total Labour	281 ,,	326

TABLE V. 1

Seasonal Labour Requirements for New Crop Plans.
(Hours per acre)

Period	Maize (1)	Maize (2)	Maize (3)	Groundnuts	Millet
Sept. 1	—	—	—	—	—
Sept. 2	6	—	—	—	—
Sept. 3	4	—	—	—	—
Oct. 1	3	—	—	—	—
Oct. 2	3	—	—	—	—
Oct. 3	12	—	—	—	—
Nov. 1	45	12	12	6	—
Nov. 2	15	11	11	4	8
Nov. 3	8	2	2	18	15
Dec. 1	3	3	3	8	4
Dec. 2	12	5	5	6	—
Dec. 3	12	7	7	13	8
Jan. 1	9	13	13	19	16
Jan. 2	6	6	13	4	15
Jan. 3	9	7	7	21	16
Feb. 1	3	3	3	17	18
Feb. 2	1	7	7	10	16
Feb. 3	3	—	—	6	7
Mar. 1	—	—	—	4	7
Mar. 2	—	—	—	2	6
Mar. 3	—	—	—	34	1
Apr. 1	—	—	—	48	1
Apr. 2	2	9	17	53	6
Apr. 3	7	13	24	9	39
May 1	36	11	20	12	10
May 2	9	5	10	6	7
May 3	2	—	—	26	6
RN/HR.	0.43 sh.	0.46 sh.	0.48 sh.	0.66 sh.	0.5 7
TOTAL	210	114	154	326	206
YIELD/ACRE	1448 lbs.	1190 lbs.	2040 lbs.	609 lbs.	391 lbs.
GROSS RETURN	137.5 sh.	113.0 sh.	194.0 sh.	215.0 sh.	117.3 sh.
NET RETURN	90.0 sh.	53.0 sh.	74.0 sh.	215.0 sh.	117.3 sh.
RETURN/HR.	0.43 sh.	0.45 sh.	0.48 sh.	0.66 sh.	0.57 sh.

There has thus been a considerable shift in the input-output ratios assumed. For a 16 per cent. increase in total labour input a 103 per cent. increase in output is expected. It should be quite clear that the new plan is based on the performance of good cultivators who can be confidently expected to apply their skills to all the crops they wish to cultivate.

The new plan for millet is based on seven plots, all over one acre, and yielding over 200 lb. per acre. The relation of these seven to the total can be seen in Table III. 11 a-c. The average acreage grown of the seven was 1.73 acres with a yield of 391 lb. per acre. The seasonal distribution of labour required is shown in Table V. 1. There are no variable costs involved. A comparison of the old and new plan for millet follows.

Characteristic	Old Plan	New Plan
Acreage	1.13 ac.	1.73
Yield	264 lbs.	391
Planting	30 hrs.	27
Weeding	99 „	111
Harvest	54 „	68
Total Labour	183 „	206

In this case, the increase in labour input is 13 per cent., and the increase in output is 48 per cent. This again assumes quite a shift in the management capabilities of the cultivator. It is such a raising of the level of output per cent. of labour which precludes the old plan from entering the new cropping pattern.

Before going on to discuss the results that emerge when these new plans are combined, it is useful to look at the actual combinations of yields found in the field survey. By combining all of these high yields plans in one budget it is assumed that good cultivators can do as well in all three crops as the best 10 per cent. of cultivators in each crop.

This practical consideration at this stage is introduced merely to caution the reader that yield patterns in the reserve are very uncertain and also differ widely between cultivators. It may well be that cultivators do tend to be specialists in certain crops, and high achievement in all crops is too difficult to achieve.

The patterns of yields are set out in Table V. 2 in the form of 3 x 3 tables taking each pair of crops in turn. Between maize and groundnuts there is a good correlation right across the table, low with low, high with high. There are a few high yield growers of groundnuts, however, that did not achieve high yields with maize. Between maize and millet, the correlation is not so good. High yield maize producers seem to have rather variable results with their millet. High yield millet growers seem to be high yield maize growers, on the other hand. Between groundnuts and millet there is again a reasonably good correlation; high yield groundnut growers having fair results with millet though the high yield millet growers do well with groundnuts too. In summing up, the millet crop seems to be the best guide to high yields per acre, with maize the next best and groundnuts the least. This whole view of the potentialities

TABLE V. 2

Yield Interactions Among Crops, Chiweshe, 1960–61.

(a) **Maize x Groundnuts**

Maize Classes	Groundnut Classes (lbs.)			
	0–199	200–399	400–	Total
0–299 lbs.	16	11	5	32
300–599 „	11	13	4	28
600– „	2	8	7	17
Total	29	32	16	77

(b) **Maize x Millet**

Maize Classes	Millet Classes (lbs.)			
	0–149	150–399	400–	Total
0–299 lbs.	7	8	1	16
300–599 „	8	5	4	17
600– „	4	5	4	13
Total	19	18	9	46

(c) **Groundnuts x Millet**

Groundnut Classes	Millet Classes (lbs.)			
	0–149	150–399	400–	Total
0–199 lbs.	8	8	0	16
200–399 „	8	7	4	19
400– „	3	3	4	10
Total	19	18	8	45

of each crop may run somewhat in conflict with the division of labour within the family group. It was clear from the discussion in Chapter II and Table II. 6, however, that this specialisation was not as widespread as expected, hence the above analysis of association between crops should not sufler too much from this. Further investigation is required into this point.

It is clear, then, that even in this subsistence-orientated economy, there are good cultivators and bad cultivators. The reasons for this are samewhat beyond the scope of this report. This conclusion does suggest, however, that new budgets can be formulated on the basis of high performance in all the crops grown in the subsistence economy. It is assumed that the market economy will become more and more important to such cultivators and that they will have considerable surpluses for sale.

Given those two basic suppositions ,it is now possible to go ahead and look at the resulting budgets.

Following the method of presentation used in Chapter IV, the total budget for the combination of plans selected shows most easily what is recommended. As before, it is assumed that 10 acres of cultivated land is available and that the work group can provide 100 hours of labour in each time period. Because of the respective net returns per acre, the programme selects the crops in the same order as previously, preferring maize plan (1) over the other two maize plans. The new budget then works out as follows:—

Plan	Acres	Yield	Output	Gross Revenue	Net Revenue	Variable Costs	Labour
Maize	1.72	1,448	2,490	236	155	81	361
Groundnuts	1.62	609	985	348	348	—	526
Millet	1.88	391	733	221	221	—	387
	5.22		4,208	805	724	81	1,274
(Old Budget)	(8.19)		(2,883)	(560)	(560)	(—)	(1,327)

The figures in parenthesis show the corresponding totals for the old budget, if based on 10 acres and 100 hours, given in Chapter IV. The main result is clear. There is a considerable saving of land with much more intensive agricultural methods—some 36 per cent.—alongside a 45 per cent. increase in physical output and a 30 per cent. increase in net revenue. The total input of labour is lower by 5 per cent.

If the available supply of labour is increased to 150 hours per time period, all three crop acreages increase by 50 per cent. as well. This results from the fact that 4.78 acres of land is lying fallow, and a 50 per cent. expansion would only require a further 2.61 acres. Thus with a limit of 150 hours of work there is still 2.15 acres of fallow land. Output, revenues and total labour required all increase by 50 per cent. as well.

There is not scope for a doubling of output if 200 hours of labour is available. As before, the least profitable crop is diminished first. Thus in the 200 hour solution, fallow land disappears, the acreages of groundnuts and millet double, and the acreage of maize increases by some 70 per cent. The overall effect is that net revenue is increased by 95 per cent. by this adjustment.

In all three crop plans, the acreage is restricted by labour demands at harvest. None of the time allocations at planting and weeding are fully utilised. It should be possible, therefore, to increase output to a considerable extent by relaxing the harvest restrictions, although a complete relaxation may lead to impossible results as it did in Chapter IV.

Starting with 10 acres and 100 hours of labour per period, and programming labour requirements at planting and weeding only, the following acreages for each plan are indicated with their corresponding net returns.

Land	Area	Net Return
Fallow	3.60 ac.	—
Maize (1)	1.39 ac.	125 sh.
Maize (3)	1.27 ac.	94 sh.
Groundnuts	3.75 ac.	806 sh.
	10.01 ac.	1,025 sh.

Since the previous solution gave a net return of 724s. this is an increase of 41 per cent.! Millet has fallen out of the budget because it is now competitive for the same labour as groundnuts. It will be remembered, however, that maize plans (2) and (3) should operate at levels over three acres to obtain the correct labour requirements, and that groundnuts should fall within one and two acres for the same reason. The discrepancy for groundnuts is the worse, as 3.75 acres would require 200 hours of harvest labour alone in April 2, when the whole budget is meant to be working at a little over 100 hours.

The difficulty can be overcome by holding groundnuts constant at two acres, the maximum permissible, and re-programming the other plans to take up the labour and land made available. The new pattern of land utilisation and corresponding net returns are as follows:—

Land	Acres	Net Return
Fallow	3.21	—
Groundnuts	2.00	430 sh.
Maize (1)	1.78	160 sh.
Maize (2)	0.67	50 sh.
Millet	2.34	274 sh.
	10.00	914 sh.

The sacrifice of some of the most profitable crop thus lowers net return to 914s., some 12 per cent. Millet has come back into the solution as it takes up the labour formerly used for groundnuts. The fallow land is decreased slightly by the expansion of maize (1) and millet. The acreage for maize (3) is unsatisfactory as such a small plot would require more labour than has in fact been provided in the plan.

Millet itself has now exceeded the acreage limits laid down in the initial plans, hence one more run of the programme can be made holding it at its maximum permissible acreage, i.e., two acres. The 2.34 acres of millet indicated above would require 92 hours of harvest time in April 3.

The new utilisation plan and net returns are as follows:—

Land	Acres	Net Returns
Fallow	3.21	—
Groundnuts	2.00	430 sh.
Millet	2.00	234 sh.
Maize (1)	1.66	149 sh.
Maize (3)	1.13	84 sh.
	10.00	897 sh.

The adjustment of net returns is fairly small with this change, though still in a downward direction. Fortunately the acreage for maize (3) has come up somewhat, though possibly not quite enough to satisfy the conditions laid down in its initial plan. If the total labour supply is increased to 150 hours per time period, and groundnuts and millet held at their pre-determined levels, the increase in labour must be directed towards either the maize (1) or the maize (3) plan. Since maize (1) has a serious bottleneck in early November, the available labour actually goes to maize (3). The final budget then becomes:—

Land	Acres	Net Returns
Fallow	—	—
Groundnuts	2.00	430 sh.
Millet	2.00	234 sh.
Maize (1)	1.79	161 sh.
Maize (3)	4.21	312 sh.
	10.00	1,137 sh.

It is this budget which probably represents the best recommendations that can be made to advanced farmers in the reserve. The total outlay on fertiliser would be 583s., thus gross returns would be 1,720s. The quantities of fertiliser would be 714 lb. of urea and 672 lb. of "P" compound. Diagram 8 shows the seasonal pattern of labour required for such a budget.

The manuring and planting of maize (1) causes a peak of 140 hours early in November, and the weeding of maize causes another peak early January. The 150 hour limit is exceeded for a whole month from April 10th through to May 10th. The greatest demand comes at the end of April, when the millet and maize demands coincide. At this time, an excess of 60 hours work must be found, or the harvest delayed. This represents an excess demand of some 40 per cent. over that normally available. Using Table II. 5 as a rough standard, there needs to be a working group of some ten (or

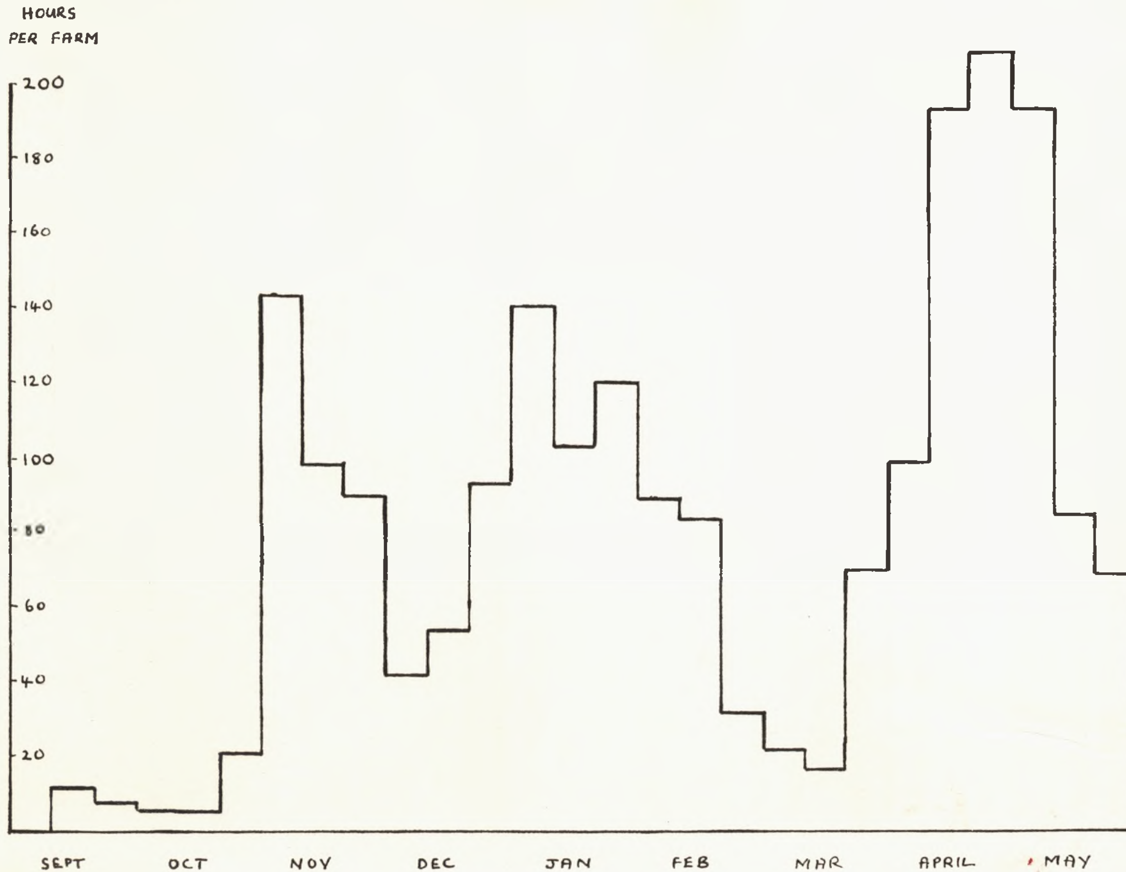


Diagram 8—Seasonal distribution of labour input for final budget based on new plans.

more) persons at certain periods, and particularly for the harvest.

In terms of the Native Land Husbandry Act standards where eight acres is the total area of cultivated land envisaged, the above programme only needs modification in the maize (3) plan. In effect, two acres can be deducted from maize (3) without altering the remaining plans. The remaining acreage for maize (3) would then be 2.21 acres, just a little bit below the three acre level thought desirable when the plan was drawn up. The net return to the cultivator would then be 989s.; the cost of fertiliser 340s. ;and the gross return would be 1,330s. The peak demand for labour in January would be reduced to 115 hours, and the peak at the end of April would be reduced to 162 hours. These changes in turn, would allow a family of eight to cope with such an agricultural programme.

There is one further interesting application of the technique which merits discussion. For many years, the African extension programme of Government in Southern Rhodesia has included a standard rotation of crops. This was in the following sequence:—

1st year	maize with cattle manure
2nd year	maize or sorghum, no manure
3rd year	groundnuts, beans or other legume
4th year	finger millet

Now the first year of the sequence approximates to the maize (1) plan above; the second year to the maize (2) plan, not hitherto considered in the programming; the third year could be an intensive crop of groundnuts and the fourth year a fairly good crop of millet. If the labour requirements of the plans drawn up in this Chapter can be accepted as an approximation to what Government has in mind, then it is possible to go ahead and test the rotation to see if in fact there would be labour available to keep to it. If there is labour available for the basic rotation, then additional crops can be selected for the cultivator that maximise his returns.

The normal plan for the cultivator is for him to plant one acre to each part of the rotation and to keep moving the fields round once each year. The labour requirements and net returns for this can be written out directly from Table V. 1.

Land	Acres	Net Return	Labour Hours
Maize (1)	1.0	90/–	210
Maize (2)	1.0	53/–	114
Groundnuts	1.0	215/–	326
Millet	1.0	117/–	206
		475/–	856

In addition, the total supply of 100 hours of labour in each period has to be adjusted for one acre of each crop plan. Assuming that 10 acres is available as usual, the linear programme then selects which crops can be grown in addition to the basic rotation. The results of the calculations work out as follows:—

Land	Acres	Net Returns
Maize (1)	0.53	48/-
Groundnuts	0.48	102/-
Millet	0.62	71/-
	1.63	221/-
Fallow	4.38	—
Rotation	4.00	475
	10.01	696 sh.

This result can be compared with the solution obtained when no specific crop rotations were imposed.

	Free Solution	Government Solution
Maize (1)	1.72	1.53
Maize (2)	—	1.00
Groundnuts	1.62	1.48
Millet	1.88	1.62
Fallow	4.78	4.38
Total	10.00	9.99
Net Return	724 sh.	696 sh.

The final difference of 5 per cent. in the net return obtainable from the two solutions must surely be regarded as a significant tribute to the originators of the Government planned rotation.

If the 100 hour restriction is lifted from the harvest time periods, the programme tends to follow the previous example and select more groundnuts than can be handled at harvest. The same procedure applied then could be used here. By holding the total area available for groundnuts at two acres, the possible area of millet could be looked at, and if that exceeds its plan, other plans still could be considered. At all times, the final selection must be kept within the limits laid down for each plan.

VI

SOME CONCLUSIONS EMERGING FROM THE ANALYSIS

This paper has been prepared as a detailed study of the labour problem in subsistence agriculture in Central Africa, and is concerned with little else. It must therefore be regarded as a contribution to the general store of knowledge about such systems of agriculture without being the final word on the subject. A great deal of detail has been presented in these pages so that the material is available to others for extension work, the further testing of hypotheses and the like. The original survey of Chiweshe Reserve in 1960-61 was so arranged that a budget study and a migration study could also be written. These two reports are not yet ready for publication. Both reports, however, should be regarded as further contributions to the broader picture, and they will be so presented that others can use the results as well.

The analysis of the labour inputs in peasant agriculture carried out in these pages must itself be regarded as exploratory. The variability of labour use is so high that cross-sectional analysis as used in Chapter III possibly hides more differences than it explains. Thus each main table of the variations in hours per acre used for each crop should be checked by a regression analysis, or an analysis of variance, or a combination of both. Since one of the main purposes of investigating labour use is to make recommendations as to more efficient use of labour in the reserve, such variation in the basic data must be systematically reduced before the main analysis can even begin.

These considerations are not quite so important in Chapter IV where the broad pattern of subsistence is examined. As long as the sample area is reasonably representative of the reserve as a whole, then the "average" budget of a holding allows certain policy issues to be examined. It was seen, in fact, that the social cost of subsistence in terms of market values varied between 15 and 25 per cent. of output under different assumptions. It was also seen, however, that when policy issues which depended on data not typical or average, where examined, then the results were much more tentative.

Then in Chapter V, when individual farm programmes were examined, it was seen that crop plans had to be based on small subgroups of the total sample so as to get representative data of improved producers. The best analysis of all would probably be based on the accurate records of one holding at a time. In the present analysis, it was felt that insufficient accuracy was obtained in the field to subject "representative" holdings to the detailed programming technique. It seems doubtful whether sufficiently good records could be obtained under present conditions by the diary method used in this survey. The possibility could be explored of daily timing of a few cultivators through one season to get the right type of data.

In both chapters IV and V it is assumed that the labour records are sufficiently "good" to proceed with a mathematical technique of finding optimum net returns. The technique itself is accurate and has its own checks built into it, hence the real question to be asked is how good is the basic data? As already outlined above, both Chapters rely on labour averages, those in Chapter V being far more carefully chosen than that in Chapter IV. There are two parts to the answer to these questions. If the crop plan is not based on a single farm record, then the plan is a synthetic one and not a real one. Any results drawn from the plan are to a certain extent synthetic too. The degree of this kind of error will be related to how much the averaging process smoothes individual labour inputs particularly. On the other hand, the synthetic plan may be a good one, approximating nearly to what an individual would do, but it may be quite untypical if spread over five acres if it were originally based on three. This is the problem which was found in the programming solutions in Chapter V. The programme kept selecting acreages of groundnuts, and then millet, which exceeded the limits laid down in the original plans. When this happens there is a good case for building up the final planning budget by steps, provided the order in which the crops should be included is already known. With the detailed seasonal labour requirements used throughout this study, this order of priority may not always be immediately apparent.

The treatment of the seasonal problem in this paper is also exploratory. If timeliness of operation is crucial in peasant agriculture, then very broad labour supply categories of several weeks or months cannot be appropriate. If a certain weeding operation is not carried out at the beginning of January, it is of little use doing it at all. Thus making labour available over the whole of January may still not provide enough at the crucial period. In this case labour cannot be transferred from the end of the month to the beginning of the month without sacrificing something else. More research is probably needed here to identify just how long the crucial period is. There is always the possibility that it might be shorter than 10 days!

In one sense, the average plans based on several improved holdings compensate for any over-rigidity in the 10 day timeliness assumption. The individual holdings used in each plan do show wider variations in labour input per acre than the average plan. If these individual requirements had been used in the programming, then the peak demands would be even greater. This would mean, in turn, that individual families would only be able to cope with even smaller cultivated areas than before. It is hoped that some balance has in fact been achieved between this rigidity in the seasonal labour restriction and individual labour use in any one period.

Further work is required to investigate the scope for increased use of labour at crucial weeding and harvest times. Current investigations into the pattern of labour use over the growing season among improved farmers in the Native Purchase Areas will throw some light on this problem. The restrictive effects of holding all land utilisation plans to existing harvest labour requirements were discussed in both Chapters IV and V. In Chapter IV, the excess labour required at harvest was only of the order of 10 per cent., but for the improved farming in Chapter V, this excess demand had risen to 40 per cent. If the size of holding is restricted to eight acres, as under Native Land Husbandry Act practice, then the excess demand for labour is very much smaller.

In the single rain season regime of Southern Rhodesia, the choice of crop is very simple. There are only three main crops grown in the reserves in the higher rainfall zones, hence the programming has very few different plans to evaluate. Some variation can be introduced by setting up different plans for a single crop, as done with maize in Chapter V, and at some time in the future, cash crops such as Burley and Turkish tobacco can be incorporated as well. Only the introduction of irrigation would complicate the programmes with two crops per year and their necessarily competing demands for labour and land.

The broad conclusion that labour supply does restrict the production of greater outputs does emerge from the whole analysis. If the existing levels of yields per acre (i.e., technology) are taken as given, there is some scope for a different combination of crops where market values operate. The present composition of the crop mix has been shown to be related to the food requirements of the people, however, and could be a quite rational choice of the food mix. Indeed, if the programming procedure were worked backwards on this assumption, it would be possible to estimate the "subsistence value price" of each crop within the technical limitations. It has already been seen that maize and millet prices do tend to rise in the growing season, which is some reflection on their "value in susbsistence".

The new plans put forward in Chapter V assume a far higher level of technology, and generally incorporate more productive input-output rates for labour as well as land. These plans were shown to require much smaller acreages of land if existing family labour must be used. Further shifts to different technologies will be required if reserve cultivators are to increase their net incomes by having larger holdings. The time may not be ripe for tractor power, but the labour bottlenecks do indicate that ox-drawn implements are needed for planting and weeding operations, and speedier methods are required at harvest. Again, surveys in progress of larger African holdings in the Native Purchase Areas will illuminate how these problems are being met.

It was seen in Chapter II that there is already a considerable movement of people back into the reserve in November, December and January. Putting the harvest problem to one side for the moment, it might be possible to facilitate this seasonal migratory movement still more, rather than allow urban or estate employers to look on the matter as a poor excuse for absenteeism. It might thus be possible to enlarge the prospective size of the working members of the family at this time, so that they in turn undertake a more ambitious system of agriculture than in the past.

This is probably a rather temporary solution to the problem of encouraging the emergence of the yeoman-type peasant farmer. A farmer who does *not* want to migrate back and forth is the one really required. If farmers are willing to undertake the work and organisation required, then the improved technology can be brought in to him by Government or some other agency. By a combination of such methods, the incomes of improved farmers must surely be more than competitive with wage earning in the urban areas or on estates.

It might finally be asked whether cultivators want to improve anyway? It has been demonstrated in Chapter V that there are people who achieve good results in *all* crops. These farmers have formed the basis of the budgets put forward in that Chapter .Apart from the maize (3) plan, all the recommendations put forward are based on what farmers actually achieve in the reserve. If people in the reserve have other preferences beside good crops, then their labour use and resulting yields would have excluded them from the analysis in Chapter V. The real problem is to see a change of preferences of more people toward higher levels of production. While the choice must remain an individual one, the question of providing more clinics and schools and roads must in the long run depend on the people's emergence from a purely subsistence form of agriculture and all that this implies.

APPENDIX TO CHAPTER III.

Analysis of Variance.

The regression analysis in Table III. 5 is only one way of demonstrating that the very high variation in hours per acre per each crop has a systematic explanation. As can be seen in each of the crop tables, the average relation between hours per acre and the independent variables, size of plot and yield per acre, tends to be non-linear. Some form of curve fitting would therefore be required to find the best goodness of fit and hence the greatest reduction in the percentage standard error of estimate.

Since it is only the systematic reduction of total variance that needs to be demonstrated, an analysis of variance will indicate whether one or both explanatory factors are at work and in what proportions. These tests have been carried out for all three crops with hours per acre as the dependent variable as before, and "acres" and "yield" as the explanatory "treatments". The full analysis is shown here so that the reader can use the total sums of squares if required.

	S.S.	d.f.	M.S.	F ratio	P
Maize Plots					
"acres"	130,593	2	65,296	235.5	0.01
"yields"	115,992	4	28,998	104.6	0.01
Error	26,058	94	277.2		
Total	272,643	100			
Groundnut Plots					
"acres"	512,574	2	256,287	21.1	0.01
"yields"	713,965	3	237,988	19.6	0.01
Error	959,160	79	12,141.2		
Total	2,185,699	84			
Millet Plots					
"acres"	120,501	2	60,250	14.9	0.01
"yields"	295,078	3	98,359	24.4	0.01
Error	185,310	46	4,029		
Total	600,889	50			

It is quite clear that for all three crops the variance associated with both "acres" and "yields" is highly significant in spite of the inherently high total variance about the mean. For maize, the acres grouping is more important than the yield grouping. This reverses the relationship indicated by the regression analysis in Table III. 5. For groundnuts, the acres grouping is slightly more significant than the yield grouping, but the amount of total variance explained is a great deal less than in the maize plots. For mlilet, "yields" now explain more of the total variance than "acres", at about the same total level of explanation as for groundnuts.

APPENDIX TO CHAPTER IV.

Linear Programming Solution.

The following two examples bring out the main points in the step-by-step solution of a linear programme. The first example demonstrates the procedure when labour is the limiting factor and the second when land is the limiting factor. The second also shows the situation where the rules select one crop and then later reject it in favour of another.

Both examples are based on the distribution of crop labour requirements set out in Table IV. 1. The level of yields per acre for each crop are those set out in Chapter III and the prices of each are those discussed in Chapter IV. In theory, all the time periods set out in Table IV. 1 are relevant to the solution, but an inspection of Diagram 3 and general experience of the technique and data suggests that the first 10-day period in January, the second and third10-day periods in April and the first in May are likely to be the limiting periods. This selection saves time in computation and the omitted periods can be checked afterwards if thought necessary.

The first example is based on the propositions that family labour can supply 100 hours of work in each period, that 10 acres of land are available, and that average yields per acre can be expected. Net returns per acre for each crop will be:

Groundnuts	105/–
Millet	79.2/–
Maize	42.2/–

Starting with groundnuts, as having the highest return per unit of land, the following table of possible acreages is drawn up by dividing available time in each period by the groundnut labour requirement in each period.

Jan. 1–10	100 hours ÷ 14 = 7.14	acres
April 11–20	„ „ ÷ 36 = 2.78	„
April 21–30	„ „ ÷ 19 = 5.26	„
May 1–10	„ „ ÷ 14 = 7.14	„

In effect, the maximum acreage of groundnuts possible is determined by the period with the greatest work requirement. Any greater acreage would more than use up the available supply of labour in this period. Applying the result for April 11–20 to the available supply of land and labour, it is possible to write out the first stage in the solution.

Land, unused	7.22 acres	(10 —2.78)
Labour, Jan. 1–10 unused	61.1 hours	(100—(2.78 x 14)
Apr. 11–20 „	Nil	(100—(2.78 x 36)
Apr. 21–30 „	47.2 hours	(100—(2.78 x 19)
May 1–10 „	61.1 hours	(100—(2.78 x 14)
Crop, groundnuts	2.78 acres	
Net revenue	292/–	(2.78 x 105)

The next step in the solution involves the introduction of millet to the crop selection. Resources are available for millet in all categories except labour supply in April 11–20, which is fully taken up with the groundnut harvest. Some of the groundnut acreage must therefore be given up to allow other crops to appear. The precise amount to be given up is indicated by the relative labour requirements of groundnuts and millet in the period April 11–20. Groundnuts are more labour demanding in this period, hence a reduction in groundnut acreage will allow a more than proportionate increase in millet. In fact, for every acre given up of groundnuts, four of millet could be grown ($^{36}/_{9}$), or 0.25 of an acre of groundnuts less would allow 1 acre of millet. This ratio must then be used to correct the original labour requirements of millet (and other remaining crops) so as to preserve this equality of labour utilisation in the period April 11–20. Each period requirement for millet in Table IV. 1 is reduced by one quarter of the corresponding labour requirement for groundnuts. A comparison of available resources in the first stage of the solution, and this new set of requirements for millet indicates the acreage of millet that will be possible and which periods will now be fully utilised. It is also possible to correct the land resources in the same way as above, the unit of land corresponding to the labour requirements already referred to, being 1 acre. The calculation is as follows:

	Available Supply	Millet Requirements	Possible Acreage
Land	7.22 acres	0.75 (1—(.25x1)	9.62 acres
Jan. 1–10	61.1 hours	7.50 (11—(.25x14)	8.14 „
April 11–20	Nil (G.N. 2.78 acres)	0.25 (9÷36)	11.12 „
			3.09 „
April 21–30	47.2 hours	15.25 (20—(.25x19)	——
May 1—10	61.1	10.50 (14—(.25x14)	5.82

This the maximum acreage of millet is limited by the labour available in the last ten days of April. It pays to transfer hours of work in the period April 11–20 from groundnuts to millet up to this point. The precise acreage of groundnuts given up will be determined by the ratio 36:9 as before, i.e. one quarter of the acreage of millet as calculated above. This reduces groundnuts to 2.01 acres (2.78—(.25 x 3.09). Given these two pieces of information, it is next possible to write out the second stage of the solution.

Land, unused	4.90 acres
Jan. 1–10, unused	37.9 hours
April 11–20 „	Nil
April 21–30 „	Nil
May 1–10 „	28.7 hours
Crops, groundnuts	2.01 acres
millet	3.09 acres
Net revenue	455/–

The third stage of the solution is to bring maize into the crop selection. Again it is necessary to modify the original resource requirements of maize so as to reduce the previous acreages of groundnuts and millet exactly in proportion to the hours in April 11–20, and April 21–30 that must be given up. The original figures can be adjusted in two stages. The first to bring them into line with 2.78 acres of groundnuts in April 11–20, and secondly to bring them into line with 3.09 acres of millet in April 21–30. The first stage ratio of hours in April 11–20 is (3–36) and the second stage in April 21–30 is 0.093 (1.417÷15.25). The details are as follows.

Resource	First Stage	Second Stage
Land	0.916 (1—(1 x 0.083)	0.847 (0.916—(0.75 x 0.93)
Jan. 1–10	9.834 (11—(14 x 0.083)	9.138 (9.834—(7.5 x 0.093)
April 11–20	0.083 (3÷36)	0.060 (0.083—(.25 x 0.093)
April 21–30	1.417 (3—(19 x 0.083)	0.093 (1.417÷15.25)
May 1–10	8.834 (10—(14 x 0.083)	7.858 (8.834—(10.5 x 0.093)

These adjusted labour and land requirements for maize are then divided into the unused resources still available after the second stage of the solution.

	Available Supply	Maize Requirements	Possible Acreage
Land	4.90 acres	0.847	5.78 acres
Jan. 1–10	37.9 hours	9.138	4.14 „
April 11–20	Nil (G.N. 2.01 acres)	0.060	33.4 „
April 21–30	Nil (Millet 3.09 acres)	0.093	33.2 „
May 1–10	28.7 hours	7.858	3.65 „

The inclusion of the groundnut and millet acreage in place of hours in this calculation indicate that these crop activities have completely replaced the labour supply in these periods. Again it has been possible to calculate how much maize can be introduced by giving up **some** of the time devoted to groundnuts and millet in their peak demand periods. The new acreage for each is determined as before. That for groundnuts is 1.79 acres (2.01—(0.060 x 3.65), and for millet it is 2.75 acres (3.09—(0.093 x 3.65). This information gives the final acreage for each crop, and allows the third and final stage of the solution to be written out as follows:

Land, unused	1.81 acres
Jan. 1–10 unused	4.5 hours
April 11–20 „	Nil
April 21–30 „	Nil
May 1–10 „	Nil
Crops, groundnuts	1.79 acres
millet	2.75 „
maize	3.65 „
Net revenue	560/–

The budget for the cropping programme as a whole will be as follows:

Crop	Acres	Yield	Total hours	Total Prodn.	Net Revenue	Gross Revenue
Maize	3.65	444 lbs.	318	1650 lbs.	154	154
Millet	2.75	264 lbs.	503	726 lbs.	218	218
Groundnuts	1.79	300 lbs.	502	537 lbs.	188	188
			1323		560	560

It has been assumed that labour and land are the only inputs in this situation, hence net revenue and gross revenue will coincide.

The only proposition which is changed in the second example presented in detail is that 5 acres of land are the maximum available instead of 10. A labour supply of 100 hours per 10 day period is assumed as before, and average yields per acre and prices are accepted as reasonable.

The first stage of the solution is exactly the same as in the previous example as the time available in the period April 11–20 ensures that 2.78 acres is the greatest area of groundnuts that could possibly be grown. The second stage of this solution poses a choice between introducing maize or millet depending upon the precise rule followed in choosing the next crop. The selection data for both maize and millet and the available resources are as follows:

Available Supply		Maize		Millet	
		Requirement—	Acreage	Requirement—	Acreage
Land	2.22	0.916	2.42	0.75	2.96
Jan. 1–10	61.1	9.834	6.20	7.50	8.10
Apr. 11–20 (G.N.	2.78	0.083	33.40	0.25	11.10
Apr. 21–30	47.2	1.417	33.30	15.25	3.10
May 1–10	61.1	8.834	6.90	10.50	5.80

If the rule to take the lowest possible acreage is followed then maize should be introduced next. If the rule is followed to take the greatest revenue producer then millet would come first. Taking the first rule in this case, it can be seen that "land" is now the limiting factor in working out how much maize can be introduced. It will be remembered that in April 11–20 only $^1/_{12}$ of an acre of groundnuts need be given up for each acre of maize introduced. This proportion of 2.42 is 0.20, hence the adjusted acreage of groundnuts is 2.58 acres (2.78—0.20). The second stage of the solution can then be written out as follows:

Land, unused	Nil
Jan. 1–10 „	37.3 hours
April 11–20 „	Nil
April 21–30 „	43.8 hours
May 1–10 „	39.7 „
Crops, groundnuts	2.58
maize	2.42
Net revenue	373/–

Thirdly, can millet still be introduced to the crop selection and increase revenue? In this case, the adjusted land and labour requirements must first be worked out, and then compared with the available resources just above. Both calculation are included together in the following table.

Available Supply		Millet Requirements	Possible Acreage
Land (maize)	2.42 hours	0.818 (0.75÷0.916)	2.96
Jan. 1–10	37.3 hours	0.547 (7.5—(9.834 x 0.818)	70
April 11–20 (G.N.)	2.58 acres	0.182 (0.25—(0.083 x 0.818)	14.1
April 21–30	43.8 hours	14.091 (15.25—(1.417 x 0.818)	3.10
May 1–10	39.7 hours	3.272 (10.50—(8.834 x 0.818)	12.20

First indications here are to choose 3.10 acres of millet in the period 21–30. But following previous procedure, it should now be clear that this would more than exhaust the land available in maize and groundnuts as there is a lower possible acreage entered against "Land" where maize had found its place. The correct procedure here is to eliminate maize altogether by putting in just that amount of millet which can replace maize (2.42÷0.818=2.96 acres). As it happens this solution could have been anticipated in the second stage of the solution above as the millet acreage of 2.95 had already appeared there. It is also known that 1 acre of millet is equivalent to a loss of 0.25 acres of groundnuts in the second stage, so the final acreage of groundnuts must be 2.04 (2.78—(0.25 x 2.96).

The final solution must therefore be written in terms of the two crops chosen instead of three as before.

Land	Nil
Jan. 1–10	38.9 hours unused
Apr. 11–20	Nil
Rpr. 21–30	2.1 hours unused
May 1–10	30.0 „
Crops, groundnuts	2.04 acres
millet	2.95 „
Net revenue	449/–

In conclusion, it should be stressed that the procedure outlined above has been set out in this appendix merely to demonstrate how a linear programming problem is worked out by hand. It has been relatively easy in this case as only 3 crops are available in the context and the resource picture can be narrowed down to 5 possibilities. Greater complexity can be handled this way, but a computer would save much time if not expense.

A complete guide to linear programming is found in Heady and Candler*. In this article, the final solutions were from the standardised layout known as a Simplex Tableau described in detail in Ch. 3 of Heady and Candler. This method includes checks on the solution and the routine working out of the adjusted crop requirements at each stage.

* E. Heady and W. Candler, "Linear Programming Methods", Iowa, 1960.