PRODUCTION EFFICIENCY ON FARMS IN NORTHERN NIGERIA

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A growing concern with the capability of Nigerian agriculture to satisfy the food needs of a growing population has surfaced in recent years. The study was designed to assess and explain the potential for increasing agricultural production on farms in northern Nigeria using existing technology.

The specific objectives of the study were: first, to isolate factors which determine farm level productivity; second, to estimate the level of technical efficiency of individual producers; third, to identify factors which contribute to variations in technical efficiency within and between areas; and fourth, to draw implications for agricultural policy.

The data used in the study were obtained from farm management studies carried out by the Rural Economy Research Unit of Ahmadu Bello University in Kaduna, Sokoto and Bauchi states of Nigeria between 1966 and 1968. The study areas centered around the towns of Zaria, Sokoto and Bauchi. Within each area, three villages were selected, and a random sample of farm families was drawn from them. The entire sample consisted of 340 farmers who were interviewed twice weekly throughtout a cropping year. Information was obtained on such factors as labor use, farm expenses, crop yields, income and family structure.

Several techniques were utilized in an attempt to ascertain what factors were associated with more successful farms. Farms were first grouped on the basis of gross value of output per man and per acre. An attempt was then made to determine in what ways more successful farmers differed from those less successful. Two types of production functions also were fitted to the data for each study area. First, a conventional Cobb-Douglas production function was estimated using Ordinary Least Squares techniques. Second, a frontier production function was fitted to the data for each area using linear programming procedures. The latter function was used to estimate the output that individual farms might have achieved if they had been able to attain the level of performance of the most efficient farmers.

The results of the analysis revealed significant differences in output per man within each area as well as between areas. The principal factors contributing to differences in output per farm were total area cultivated, the imputed cost of seed and cuttings (which reflects both the crop mixture and the density of planting), and the amount of labor employed. Significant inter-area differences in marginal productivities for a number of factors (measured at the mean level of factor use) were revealed by the Cobb-Douglas production functions.

The results obtained from the analysis of farm-level data from northern Nigeria are not entirely consistent with the prevailing view that no appreciable increase in agricultural production can be obtained from traditional farms without introducing new technology. The analysis makes clear that there are substantial variations in technical efficiency among farms. Efficiency scores based on the frontier production function ranged

from .67 to 1.00. Appreciable deviations from optimal factor combinations also were found for land and hired labor. Technical efficiency is closely associated with farm size, labor use, crop mixtures and the proportion of fallow land.

The results suggest that it is possible to obtain modest increases in output by drawing on the experiences of more efficient farmers -- without major investments, at least in the short run.

BIOGRAPHICAL SKETCH

Ndanusa Braimah Mijindadi was born on October 10, 1944 in Zugbie, near Lokoja, Nigeria. He received his early education at Catholic schools at Agenebode and Lokoja, Saint Augustine's College - Kabba, Federal School of Science in Lagos and various local Qu'ranic schools in Nigeria.

Ndanusa was admitted into Ahmadu Bello University in 1966, where he received the Bachelor of Science (Honours) degree in Agriculture in 1969. In the same year, he became a staff member of Ahmadu Bello University where he worked for a year as an Assistant Research Fellow-in-training in plant pathology.

Ndanusa entered the University of Leeds in 1970 where he completed the requirements for the Master of Arts degree in Agricultural Economics in June 1972.

Upon completion of his Master's program at Leeds, he returned to Ahmadu Bello University where he assumed the position of Extension Specialist in Farm Management - a position he held until his admission into Cornell in September 1976.

Ndanusa is returning to his Extension Specialist's position at Ahmadu Bello University, Nigeria, in October 1979.

He is married to Berkisu Bernice Mijindadi. The Mijindadi's have three children, A'isha, Mohammed and Maimuna.

This thesis is dedicated to Ndagi Alhaji Yusufu without whom I might never have gone to College; to Berkisu and our children: A'isha, Mohammed and Maimuna, for their love and understanding; and in memory of Baba Umoru Amioya and Uman Alhaji Usuman, who passed away while I was pursuing my studies at Cornell.

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CHAPTER 1

INTRODUCTION

Problem Statement

In spite of Nigeria's oil revenues, agriculture remains the most important source of income and employment for a large proportion of her citizens. About 70 percent of the country's population is estimated to derive its livelihood from agriculture (FMANR, 1974).

The interdependence which should exist between agriculture and the non-agricultural sectors for a nation's balanced economic growth has long been recognized by economists (Ayazi, 1968). Agriculture should provide not only food for a population but should also serve as a source of raw materials for agro-related industries.

In recent years, the capabilities of Nigerian agriculture in meeting such roles have been called into question (FMANR, 1974, p. 23). Official statistics indicate that food supply has not kept pace with increased demand. Estimates of Nigeria's food deficits for 1975 in the subsistence grain crops, for example, are put at 170, 552, and 1,018 thousand tons for millet, sorghum and maize, respectively (FMANR, op. cit. p. 339).

The causes of short falls in food supply can be traced to various factors: high population growth rates, usually estimated to be between 2.5 and 3 percent per annum; an accelerated rate of urbanization; and increased per capita incomes. The food situation is further worsened by declining farm productivity. Evidence of the latter abound in various official and research publications. Using 1964/65 as a base period, for

example, the index of production of basic food crops in Nigeria failed to reach 100 in the nine-year period between 1968 and 1975 (Table 1-1). Food shortages and declining farm productivity have given rise to frequent and substantial increases in food prices, as well as to increased food importation (Ojo, 1977, p. 15).

TABLE 1-1. INDEX NUMBERS OF CROP PRODUCTION AND FOOD IMPORTS: NIGERIA 1960-1975

Year	Index of Crop Production (1964/65 = 100)	Index of Quantity of all food imports into Nigeria (1965 = 100)
1960/61	82	105
1961/62	92	106
1962/63	92	108
1963/64	103	98
1964/65	100	118
1965/66	102	100
1966/67	89	132
1967/68	89	99
1968/69	80	74
1969/70	90	115
1970/71	94	150
1971/72	87	214
1972/73	63	204
1973/74	72	234
1974/75	82	199
1975/76	82	271

SOURCES: Ojo, M.O. "Food Supply in Nigeria 1960-1975," Economic and Financial Review, Vol. 15; No. 2, Dec. 1977. Central Bank of Nigeria, Lagos, pp. 12-19.

The constraints to increased farm production especially in the northern states of Nigeria appear to be a combination of various factors: low and variable rainfall, inefficient crop husbandry practices, such as the non-use of improved inputs, low plant populations, late planting, labor shortages and inadequate weeding (Norman, 1970; Kowal and Kassam 1972; FMANR, 1974). Farm level studies in various parts of northern Nigeria show that labor and capital shortages constitute the major constraints on agricultural production. For example, Norman found that "the amount of land that a family can handle during the labor bottleneck period fundamentally determines the level of agricultural activity during the rest of the year" (Norman and Pryor; 1978). Labor shortage is aggravated by other factors: (i) human labor is the sole source of farm energy as there is a lack of draft animals and capital equipment (ii) the rate of rural-urban migration of youths who would normally be responsible for food production has increased in recent years (Essang and Mabawonkun, 1974).

In addition to labor problems, the unavailability of capital at critical times may impose a limit on the extent to which farmers can purchase other farm inputs -- better seed, fertilizer, non-family labor, etc. Government backed credit programs are usually advocated as an essential part of traditional agricultural development strategy and a means to provide and generate farm capital (AID, 1973). But there is some evidence that making capital available in the form of credit does not necessarily provide the expected incentive to increased farm productivity. King concludes from a study of cooperatives in Kano villages: "In many cases the farmers' environment of social obligations and non-farm investment

opportunities may make it rational for him to use available capital for purposes other than agricultural capital." (King, 1975)

Justification

Nigeria's third National Development Plan (1975-1980) has the overall objective of increasing the standard of living of her people. Given that most of the population depend on agriculture for their livelihood, this objective calls for policies directed at increasing farm level productivity. It is evident from the National Plan that government interests have moved away from the large scale settlement schemes of the sixties to more 'evolutionary' approaches. Programs such as the National Accelerated Food Production Project, World Bank Rural Development Projects and Operation Feed the Nation, place emphasis on integrated approaches involving the use of improved seed, extension services and credit. The common objective of the various projects is to motivate producers to adopt yield augmenting practices (Sprague et al., 1972; Central Planning Office Lagos, 1975; IITA 1977).

However, to be better able to motivate producers, it is important to have a clear understanding of factors which prevail at the farm level--particularly those that affect farm performance. Such an understanding is important for at least two reasons: (i) recent studies of traditional agriculture in East Africa and Pakistan have shown large efficiency differentials among farmers (Shapiro, 1976; Khan and Maki, 1979). (ii) In Nigeria there is also some indication that existing farm resources may not be efficiently utilized by producers. For example, separate studies by Are and Olayide show that average farmers' yields for most food and 'cash' crops are less than 40 percent of the potential yield for the best

Table 1-2. Average Yields of Major Crops by Main Producing States and Their Yield Potential - Nigeria (1968/69)

Crops	States - Yields Per Acre			Potential[a] Yield
	Kaduna	Sokoto-Niger	Kano	
Millet	438	394	498	1,840
Sorghum	410	409	510	2,000
Rice (upland)	840	1,160	367	3,000
Groundnuts	443	600	579	1,968
Cowpeas	134	251	204	2,400

SOURCE: Olayide, et. al. (1972; pp. 78-80).

[a] Potential yield is defined as output per acre which would be obtained if firms employ the best practice with existing technology. Potential yield figures in Table 1-2 are those obtained under experimental conditions but using local varieties and technology. And states' yield data are based on results from various farm surveys and reports of Ministries of Agriculture.

varieties in use (Are, 1970; Olayide et al., 1972). Olayide also provides yield data by states for each of the various food crops grown in Nigeria. One striking feature of the information, is the range in yield of crops. For example, the range in average millet yields among states is from 282 to 582 pounds, and for sorghum from 409 to 615 pounds (Olayide et al., 1972, p. 79).

Work by the Rural Economy Research Unit of Ahmadu Bello University in the north of Nigeria also shows wide variations in rural incomes. In Zaria, for example, while 19.3 percent of farmers had annual incomes below 1,000 shillings, 17 percent had incomes above 3,000 shillings (RERU, 1972; p. 11). It is not clear, however, to what extent such variations are related to farm labor productivity.

While indications of declining farm productivity and inefficiency can be gleaned from the literature, no study has been done to assess and explain differences in productive efficiency among Nigerian farmers.

A study of productive efficiency is needed to: (i) identify the magnitude of the constraints within which farmers operate (ii) to ascertain if there are opportunities for increasing farm output without major farm investments. This is particularly important given the limited resource environment of traditional farmers. Finally, identifying those factors which affect farm productivity and performance will enable one to devise more appropriate farm policies.

Study Objectives

More specifically, the objectives of the study are to:

a) isolate factors which determine farm level productivity

b) estimate the level of technical efficiency of individual producers

c) identify factors which contribute to variations in technical efficiency both between and within regions

d) draw implications for agricultural policy

Outline of Subsequent Chapters

The literature on farm productivity in traditional agriculture with special reference to Africa is summarized in Chapter 2. The data on which the study is based are described in Chapter 3. Farm management survey data relating to farmers in Kaduna, Sokoto and Bauchi states of Nigeria are used for the study. Alternative methodological approaches applicable in the measurement of productive efficiency are discussed in Chapter 4. Regression analysis is employed in meeting the first of the study objectives. The results are presented in Chapter 5. It is recognized that the underlying assumption of equal efficiency among producers in the use of average production functions may not be met in practice. However, production function analysis is appropriate if one wishes to estimate the extent to which total output can be imputed to the factors from which it is produced.

Frontier production function analysis is used in identifying the gap between actual and potential output and the potential gains in efficiency (Chapter 6). Frontier functions are useful for at least two purposes: first, such functions can indicate the potential for increasing farm output if firms employ the best practice in a given production technology level; second, they can be used to identify the expansion path which firms not currently using the best practice ought to follow.

In Chapter 7, an attempt is made to explain differences in technical efficiency among farmers. Regression analysis is employed to identify the extent to which selected management related variables contribute to

to technical efficiency.

A summary of the results and their policy implication is presented in Chapter 8.

CHAPTER 2

LITERATURE REVIEW: PRODUCTION EFFICIENCY IN TRADITIONAL AGRICULTURE -- SPECIAL REFERENCE TO AFRICA

The efficiency of resourse use has long been an area of concern for economists. In the Wealth of Nations, Smith states:

> "Whatever be the soil, climate, or extent of territory of any particular nation, the abundance or scantiness of its annual supply must depend first on the skill, dexterity and judgement with which its labor is generally applied" (Smith, 1776; p. 1).

The literature on farm and labor productivity in traditional agriculture appears to have passed through at least two phases.

In the fifties and early sixties, economic development theories regarding farm productivity in less developed countries were based mainly on models derived from the concepts of surplus labor and disguised unemployment. Notable among the proponents were Lewis and Ranis and Fei (Lewis, 1954; Ranis and Fei; 1961). The general argument was that on small farms, workers could be removed from agriculture without a noticeable effect on output. Lewis describes a two-sector model and investigates the expansion of the industrial sector as it is "nourished" by supplies of cheap labor from the subsistence (agricultural) sector. He sees development as consisting of the reallocation of surplus agricultural labor whose contribution may have been zero, to industry where they become a productive part of the labor force at a wage equal to or tied to the institutional wage in agriculture. Mellor and Stevens in a

study of farms in a Thai village actually reached the conclusion that a substantial proportion of the farm workers had zero marginal physical product (Mellor and Stevens, 1956).

The publication of Schultz's Transforming Traditional Agriculture may be regarded as marking the beginning of the second phase. Schultz criticized the surplus labor doctrine saying that, "it rests on a shaky conception of labor productivity and is not consistent with any relevant data" (Schultz, 1964). He used data from India and elsewhere to support his view that the marginal productivity of labor in traditional agriculture is not zero. Schultz then advanced his "efficient but poor hypothesis," which states that, "there are comparatively few significant inefficiencies in the allocation of factors of production in traditional agriculture".

There are two principal implications from this hypothesis. First, no appreciable increase in agricultural production is possible by reallocating the factors at the disposal of farmers. And second, to have agricultural progress modern factors must be supplied to and used by farmers.

Since Schultz's book was published in 1964, several studies have been undertaken all over the developing world in an attempt to test the efficient but poor hypothesis (Welsch, 1965; Chennareddy, 1967; Yotopoulos, 1967; Sahota, 1968). Most of these studies have confirmed Schultz's hypothesis.

What is often overlooked is the very restrictive definition of traditional agriculture used by Schultz and for which he meant his thesis to apply. He defines traditional agriculture as "a particular type of economic equilibrium", where the states of the arts and the state of

perference and motives for holding and acquiring sources of income have remained constant over a long period. And he states very emphatically that not all poor communities have the economic attributes of traditional agriculture. "A serious adversity of nature, a drought followed by famine -- large changes in relative prices of products -- advance in knowledge useful in agricultural production - any poor agricultural community that is adjusting its production to one or more of these circumstances is excluded from the traditional agriculture to which the efficient but poor hypothesis applies," (Schultz, 1964; pp. 37-38).

A third phase in traditional farm production theory appears to be emerging: In a study of technical efficiency of Tanzanian cotton farmers' Shapiro concluded that "output could be increased by 51 percent, if all farmers achieved the same levels of technical efficiency that were achieved by the best farmers in the sample, with the same inputs and technologies" (Shapiro, 1974).

Shapiro's conclusion suggests that Schultz's efficiency hypothesis may not be be applicable to all of traditional agriculture; and that there are areas where inexpensive development policies can raise farmers closer to the more efficient levels achieved by the better farmers.

Section 2

In this section literature on farm productivity in Africa is summarized. The emphasis is on pinpointing factors which have been identified as affecting farm productivity. East and Central African studies are first summarized. This is followed by a presentation of findings of West African studies with special emphasis on those done in northern Nigeria.

East and Central African Studies

One of the earliest farm management studies conducted in East Africa was designed to obtain estimates of labor requirements for individual crop enterprises in Kenya (Clayton, 1956). Clayton's objective was to use the data in devising farm plans aimed at intensifying, "African agriculture," and to relate labor needs with its availability.

The data collected were not actually from farmers plots but from "demonstration holdings". Two such holdings were studied. One in the Star/Kikuyu grass zone of Nyanza Province and the other in the Central Province. The former comprised of 3.46 acres on which crops grown included maize, beans, sweet potatoes and coffee. The running of the holding was estimated to require 4,200 hours (an equivalence of 300 days annually if a family of two worked 7-8 hours a day). The second farm was much larger, 11.9 acres, grew similar crops as the first but used oxen. Labor requirement was found to be 8,500 hours. Although productivity estimates were not part of the study, Clayton mentions that the viability of the plans in these areas would depend on adequate human nutrition, soil fertility and cash income.

Rukandema's work is one of the more recent studies of Kenyan farmers. His aim was to isolate the major constraints to expanded agricultural output on small farms. One village was selected from each of two sublocations in the Kakamega district of Western Kenya differentiated on the basis of population density. Maize was the dominant crop. It was so predominant that, "a good estimate of maize production provided a fairly accurate picture of economic activity in the area," (Rukandema, 1977; p. 56).

Regression analysis with maize yields per acre as dependent variable showed interesting results: a) the correlation between acreages planted and yield was positive. b) observed sowing and weeding labor were not strongly associated with yield differences, which is unexpected. Rukandema also found that yields could be enhanced by increased plant density and reduced by late sowing. In agreement with Norman's work in Nigeria, Rukandema found that intercropping enhanced yields. The influence of schooling was, however, not found to be important.

In a fairly comprehensive study in Zambia, Elliot et al. studied farm labor productivity in terms of decision-making at three levels: the environmental situation of the farmers, government services at district levels and decisions made by the Central government in relation to education, health and prices (Elliot et al., 1970). Using indices to represent factors such as good farm practices, experience and knowledge of farming, formal education, general awareness and the incidence of sickness, Elliot and associates found that 49% of production per acre was explained by reference to basic farm inputs, e.g. labor, oxen and tractor power while 38% was explained by the "range of social variables" used in the equation.

In Massel's study of Rhodesian farmers, separate functions were estimated for three crops; corn, millet, and peanuts, each relating output to a set of observed inputs used in production. Marginal productivity of weeding labor was found to be low but positive. Productivities of land, organic manure, fertilizer and skilled management were considerably higher than that of weeding labor. However, Massel found little evidence of potential gains from reallocation on the average farm (Massel, 1967).

West African Studies

One of the most frequently cited early studies is Haswell's survey of Gambian farms in Genieri - a Madinka village in 1947/49. Haswell's objective was to describe the nature of farming, determine what is good and bad farming within "native practice", measure variations in initiative and to foresee possible improvements (Haswell, 1953). The major crops were millet, groundnut and rice. Haswell's work indicated that the density of plant population coupled with the amount of weeding "may have been" very important factors in determining yields of millet. For groundnut, early sowing was also important. Wide variations were found between compounds both in crop emphasis and quantity of inputs. Other sources of differences were "social structure and social cohesion". For example, descendants of founder settlers, who were the priviledged class, had easier access to larger and better farmland as compared to the "strangers".

Spencer and Byerlee studied labor use, income and productivity in Sierra Leone during the 1974/75 farming season.

They found that producers of staple crops such as rice had the lowest returns as compared to farmers who grew vegetables and oil palm. Average returns were found to be similar among regions, although substantial differences in incomes existed between the traditional and the more modern farm type groups. (Spencer and Byerlee, 1977).

A number of farm level studies were conducted in Northern Nigeria during the 1960's. The first was Lunning's 1961-62 study in Sokoto Province. The study involved 30-40 families from each of seven villages. Lunning's findings indicate that size of family is related to acreage under cultivation. Regression models of output against farm size, labor

and recurrent expenditures, show expenditures to be the most important determinant of gross returns from major crops, and labor, the least. The ratio of the marginal product of labor to its opportunity cost was o.72. A t-test on the variance of the marginal value product of labor led to the conclusion that "the hypothesis that labor is applied in an efficient way could not be rejected," (Lunning, 1967).

Another series of studies were initiated by Norman in Northern Nigeria in the late 1960's. One of the most publicized of these is the Zaria villages survey. The Zaria studies are actually part of a larger study covering other areas: Kwara, Bauchi and Sokoto, carried out by the Rural Economy Research Unit of Ahmadu Bello University, beginning in 1965. The studies were designed to overcome the paucity of data on indigenous farming practices and to provide basic information for planners and extension workers. One other aim was to provide a more rational basis for technical research workers in determining research priorities. In the Zaria studies, detailed farm input and output data were collected from 124 farmers. These studies indicate that the seasonal nature of farm work results in labor shortages at peak periods of labor demand. Norman's results also lend support to Lunning's earlier findings that the number of family members is important in determining farm size. Regression analysis indicates that land quality was the most important contributor to farm productivity. The analysis further indicates that hired labor was almost six times as productive as family labor. Tests of significance to ascertain whether or not the marginal value product of inputs differed significantly from their opportunity costs showed that, in general, the differences were significant (Norman, 1972).

A more recent study was conducted by Matlon in an area South-west of Kano in Northern Nigeria in 1974/75. Matlon's major objective was to construct "a detailed poverty profile based on a comprehensive income concept". Matlon's findings of relevance are; total farm size showed nc strong association with income; and the greater incomes of the highest income strata were largely attributable to earnings from off-farm sources. Production function analysis indicated that production elasticities for fertilizer and labor were higher for low income households than for the middle and upper income groups. Matlon also found that the marginal value product of labor increased with income status. In agreement with Norman's studies, land generally had higher productivity (measured at the mean of inputs) relative to its cost, than had other factors of production (Matlon, 1977, pp. 216-226).

Section 3: Measurement and Definitional Problems

The characteristics of traditional agriculture in Africa pose special measurement and definitional problems for which satisfactory solutions have not been found. This makes it difficult to compare the results of studies conducted in different areas and at different times.

Most of the problems are related to a combination of the following: a) barriers to communications attributable in part to inexperienced enumerators or their lack of familiarity with local conditions. b) the practice of intercropping which makes the collection of information on individual crops difficult. c) the measurement of labor input and the need to use a weighting scheme which accounts for differences in age and sex; and d) the lack of standard weight measures for farm products as opposed to volume measures (Yang, 1965; Hunt, 1969; Norman, 1973).

No consensus has emerged on the labor equivalence issue. There are essentially two opposing viewpoints. One is that women and children are as efficient as men in the tasks they perform. The implication here is that equal weights should be used for all sexes and ages. Based on his study of rice farmers in Sierra Leone, for instance, Spencer argues that is is difficult to divide a sample into different age classes "since farmers cannot tell their ages." He also states that women and children rarely participate in jobs for which they are less efficient than adult males," (Spencer, 1972). The opposing viewpoint is that the productivity of labor in farm operations differs with age and sex. This implies a need to use different ratios for age and sex in converting labor input figures to man equivalents.

In situations where men and women manage different fields as in East Africa and where it has been shown that farms managed by women may achieve similar or higher productivity than those managed by men, neglecting differences in sexes is understandable (Rukandema, 1977). But in areas where women participate very little in farm work and even when they do only in minor farm operations, "some attempt at differentiation appears to be much better than assuming that all workers make equal contributions to productivity," (Connell and Lipton, 1977, p. 53).

One shortcoming in equivalent ratios generally in use is that calculations which lead to them are never given. This makes them appear to be, "pulled out of a hat." In a more recent work, Spencer provides a possible basis for differentiation. Relative wage rates are used in computing conversion ratios (Spencer and Byerlee, 1977). This is based on the assumption that male and female labor are perfectly substitutable over the range of labor type combinations in a given sample, and that the

wage rates adequately reflect the marginal productivity of labor. Despite possible criticisms that the assumption of perfect substitution may not necessarily hold for the sexes in all farm operations (a point which Spencer recognizes), and the fact that farm wage rates may be determined by factors, such as family ties and the status of the employer, this approach does provide some measure of the farmer's own valuation of the different classes of labor, and therefore is useful. The mean national farm wage rates in Sierra Leone indicates that men, women and children receive .54, .42 and .28 leones per day respectively, at the time of Spencer's study in 1974/75. This works out to be man-equivalents of 1.00, .75 and .50 for men, women and children - ratios exactly the same as those used by Norman in his Nigerian studies.

Conclusion

While it is recognized that the studies reviewed in Section 2 may have employed different definitions for some concepts especially labor, several conclusions appear to be warranted:

First, seasonal labor shortages may constitute an important constraint to higher farm production;

Second, land quality and the use of modern inputs enhance farm output; and

Third, intercropping frequently is associated with a higher value of output per unit of land.

The data from Northern Nigeria, which serve as a basis of the subsequent analysis will be used to test whether these conclusions apply to other areas as well. But the principal use of the data will be to determine whether or not it is possible to draw on the experience of more

"successful" farmers to improve the incomes of other farmers. To do so, one must first identify "successful" farmers, and then ascertain why they are successful. If there is little difference among farmers in yields, labor efficiency, or crop mixtures, this suggests that little can be done to improve the lot of farmers without introducing new technology or additional inputs. But if substantial differences exist, then it is possible to design an extension program based on the experience of the more successful farmers. In essence one must ascertain whether there is evidence of what Leibenstein calls "X-efficiency", that is the capacity of some individuals or firms to get more output from a given set of resources than other individuals or firms. Under such circumstances, as he points out ..

> "A situation may arise in which managers are exceedingly poor (in ability). This can lead to a great deal of variation in output for similar amounts of capital and labor and for similar techniques" (Leibenstein, 1966)

Thus, in studying production efficiency, information needs to be obtained regarding the dispersion of individuals or firms around the mean. As pointed out by Massel and Johnson, efficient allocation on the average farm is necessary but not a sufficient condition for efficiency on individual farms (Massel and Johnson, 1968; p. 53).

An understanding of individual farm performance is essential to ascertain whether or not it is possible to exploit known practices used by the more successful farmers to increase output. In a situation where the improved input distribution system is known to be inefficient and where farmers have limited investment capital, a positive answer to the question posed above can open up new and cheaper development policy alternatives -- at least in the short run.

CHAPTER 3

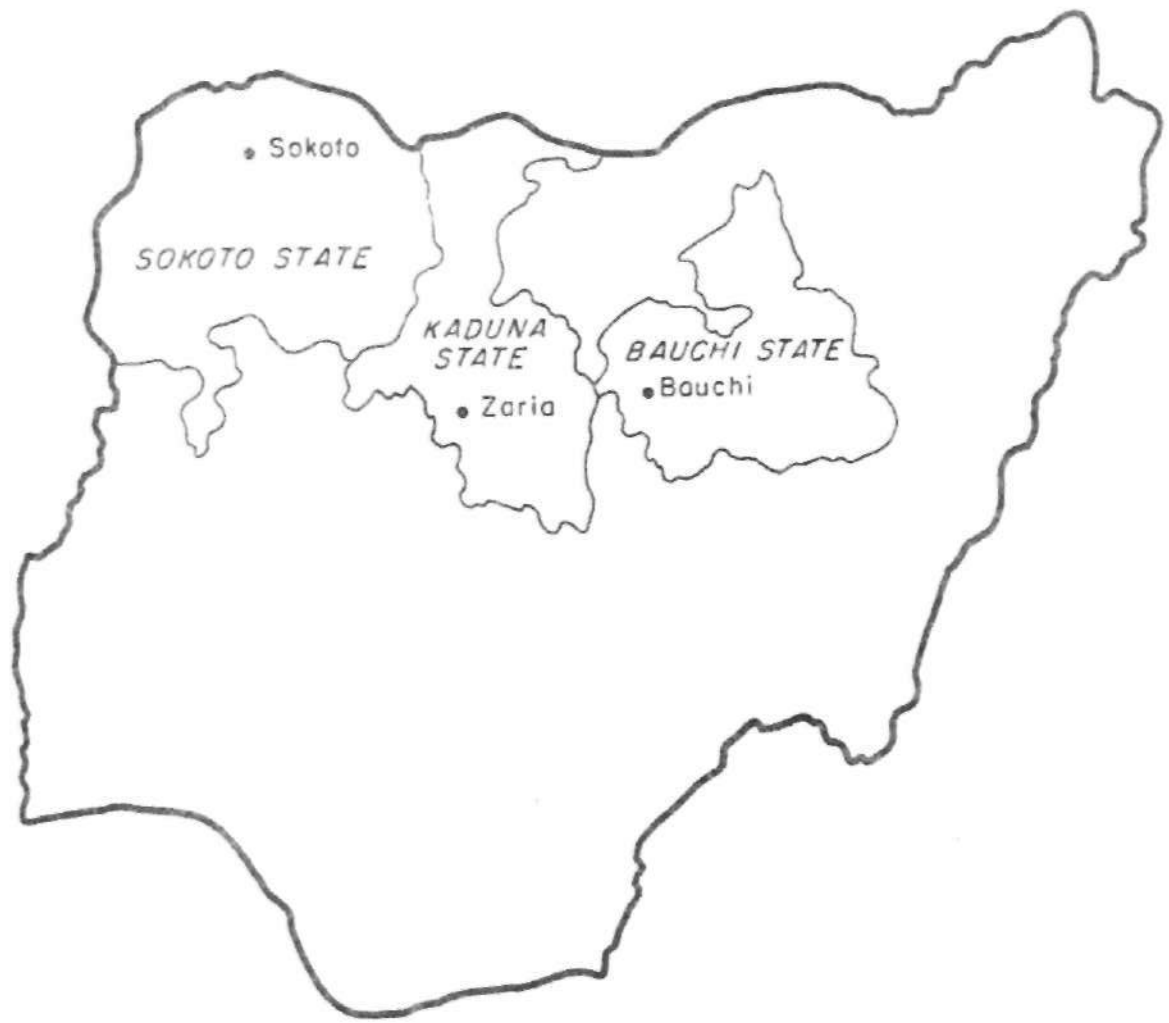
THE STUDY AREAS: GROSS COMPARISON OF FARM PRODUCTION PATTERNS

This chapter has two main objectives: first to present and compare resource utilization and farm output in the study areas; and second, to identify factors related to output per man. The presentation is in six sections: section 1 gives an outline of the survey methodology used in data collection as well as the physical environment of the three areas from which the data are drawn. Section 2 compares resourse utilization, crop mixtures and yields among areas. In section 3, data relating to producers' incomes and output are presented. Section 4 deals with factors of production which may contribute to differences in output per man; section 5 examines the extent to which crop combinations and yields differ by farm productivity class. The last section examines the influence of other factors - farm size, proximity to urban center, age and family structure - on labor productivity.

Section Ia: Survey Methodology

The data used in this study were obtained from farm management studies carried out by the Rural Economy Research Unit of the Institute of Agricultural Research, Ahmadu Bello University in three states in Nigeria (Figure 3-1). The studies centered around the town of Zaria

FIGURE 3-1. MAP OF NIGERIA SHOWING STUDY AREAS WITHIN THEIR RESPECTIVE STATES



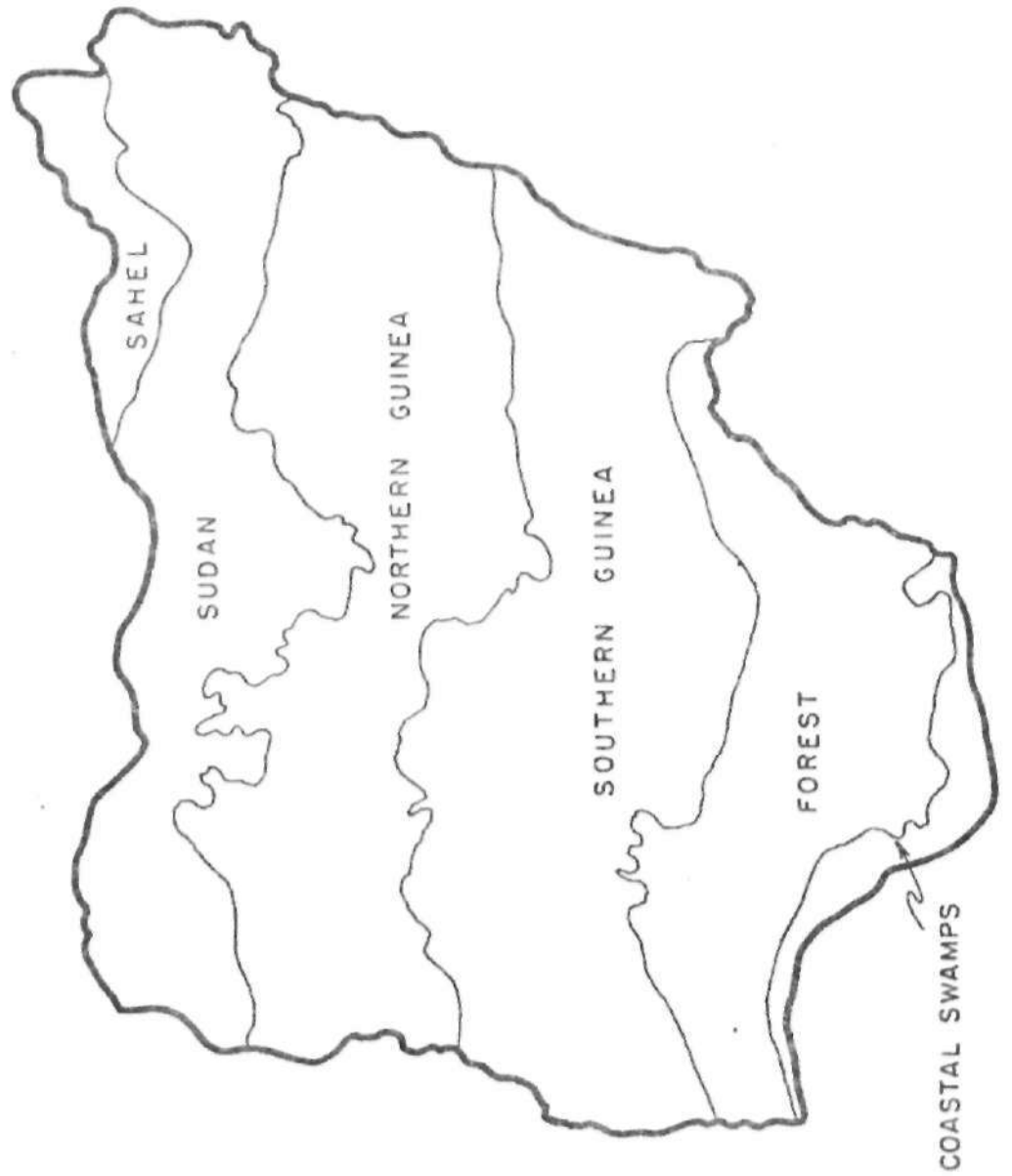


FIGURE 3-2. ECOLOGICAL ZONES OF NIGERIA

Sokoto and Bauchi and were undertaken between 1966 and 1968.[1] Within each area three villages were selected. A major criteria used in village selection was that villages differ in ease of access to the main city in the area. (Figures 3.3 and 3.4).

In selecting farm families to participate in the survey, a census of the inhabitants was first undertaken in each village. From the frame so obtained, a random sample was selected. The entire sample consists of 340 farmers: 124 in Zaria, 100 in Sokoto and 116 in Bauchi. Farmers were interviewed twice weekly throughout a cropping year to obtain information on labor use, farm expenses, crop yields, farm incomes and selected sociological variables. Some characteristics of villages included in the study are presented in Table III-1.[2]

Section 1b: Physical Environment

Farm production patterns are to some extent influenced by ecological factors such as climate and soils. Some of the characteristics of the physical environment in the three study areas are given in Table III-2. Zaria and Bauchi are situated in the Northern Guinea zone while Sokoto is in the Sudan. (Figure 3.2). The zones differ with respect to climate and soils. Table III-2 shows that temperatures in the three areas are fairly similar. However, there are differences in the amount and duration of

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1 The fact that the data on which the study is based were collected a decade ago would tend to give an impression of outdateness. There are at least two reasons why this is not a serious problem: First, previous work based on the data (Norman; 1972, 1976) gives results which are in general agreement with those from studies based on more recently collected data in the same general area (Matlon 1977). Second, official statistics indicate that agricultural conditions have remained very much the same over the decade. For example, with 1964/65 as a base period, the index of food production in Nigeria failed to reach 100 in the nine year period between 1966 and 1975 (Ojo, 1977).

2 For a detailed account of the survey methodology see Norman (1973).

TABLE 3-1. VILLAGES INCLUDED IN THE STUDY

Variable	STUDY AREAS AND VILLAGES								
Specification	Zaria			Sokoto			Bauchi		
	Hanwa	Doka	Dan Manhawayi	Takatuku	Kaura Kimba	Gidan Karma	Bishi	Nasarawa	Nabayi
Population density/sq ml.	709	396	81	479	308	273	High	Inter-mediate	Low[a]
Proximity to Urban Center	Near	Inter-mediate	Remote	Near	Inter-mediate	Remote	Near	Inter-mediate	Remote
Sample Size	38	44	42	31	31	38	40	37	39
Sampling Percent	43.2	28.8	38.5	23.9	16.0	32.2	37.0	38.9	49.4
Average Farm Size (acre)	7.3	9.8	11.9	7.2	6.7	14.8	8.2	7.4	13.5
Percent Fadama	5.5	12.2	8.4	2.8	38.8	2.0	0.0	16.2	0.0
Percent Fallowed	2.5	26.8	21.2	5.2	1.0	3.7	17.6	28.0	48.2
Percent of farmers that owned cattle	43.4	0.0	0.0	29.0	64.5	21.0	15.0	0.0	30.0
Year of Survey	April 1966 to March 1967			April 1967 to March 1968			April 1967 to March 1968		

[a] Population data are not available for Bauchi villages.

TABLE 3-2. PHYSICAL ENVIRONMENT IN THE STUDY AREAS

Variable	Zaria	Sokoto	Bauchi
Location	11°11'N	13°01'N	10°17'N
	7°38E	5°15'E	9°49'E
Ecological Zone	Northern Guinea	Sudan	Northern Guinea
Mean Monthly Temperature			
(Min.)	57	59	55
(Max.)	95	104	98
Rainfall Total (ins.)	43.9	29.6	43.4
Evaporation (ins. from open surface)	74.6	65.8	57.6
Population Density (persons per square mile)	80	128	62

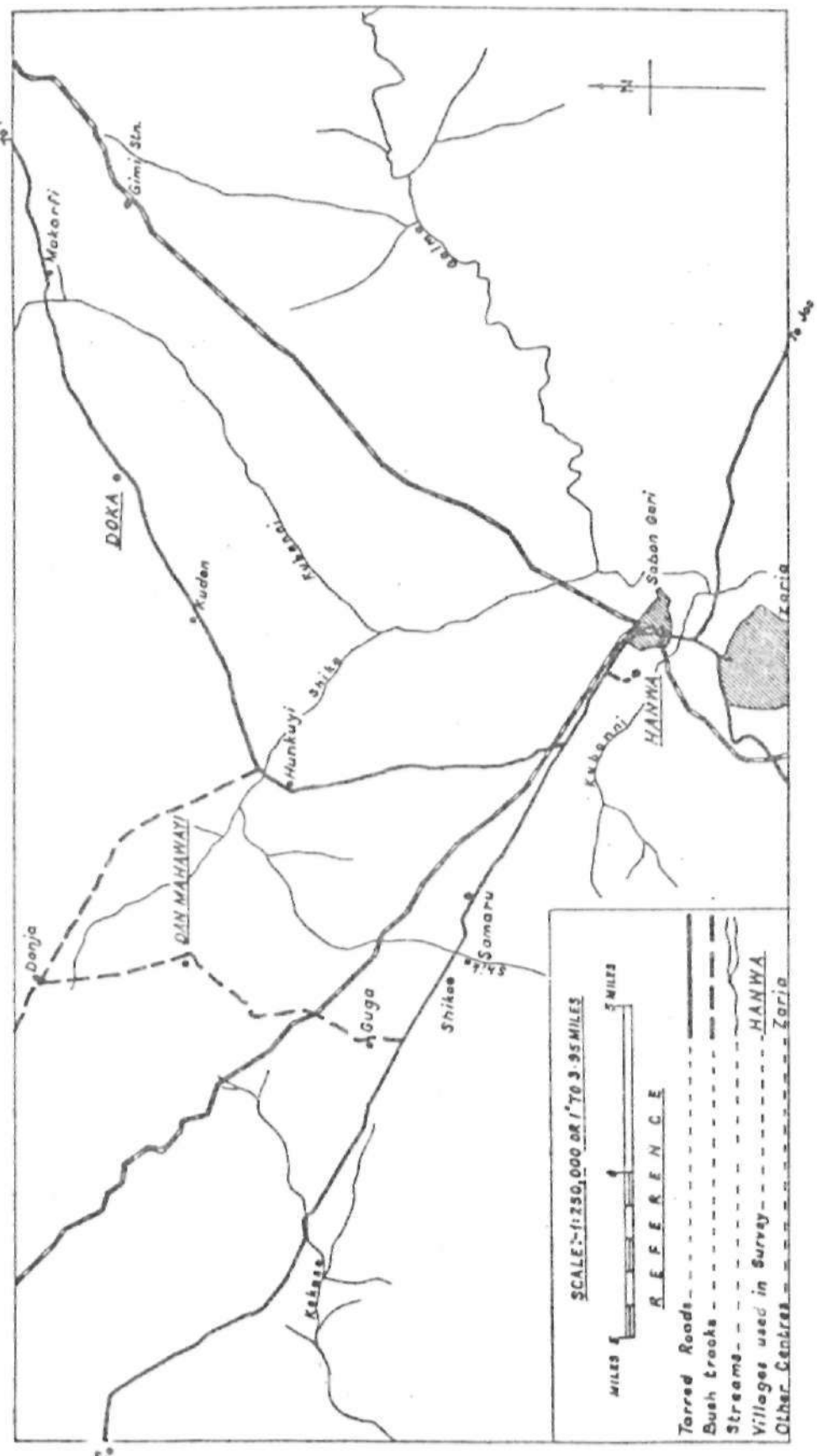
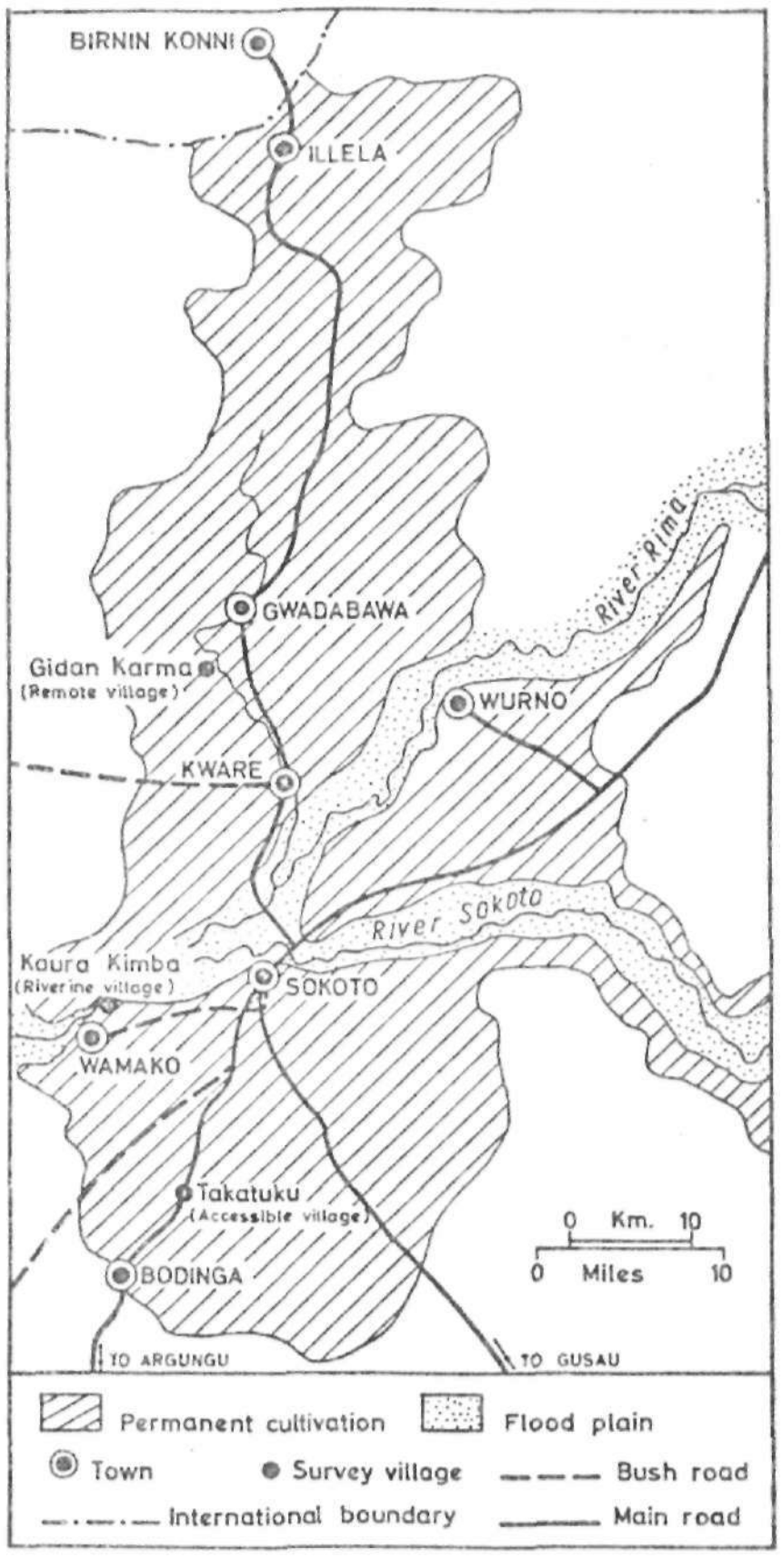


FIGURE 3.3. LOCATION OF ZARIA VILLAGES

SOURCE: NORMAN, D.W. (1974 a) p. 3

FIGURE 3-4. LOCATION OF SOKOTO VILLAGES



SOURCE:
GODDARD, A.D. et al. (1974) p.2

rainfall. Thus while Sokoto has an annual mean rainfall of 29 ins. and a rainy season which lasts 90 - 140 days, Zaria and Bauchi average about 43 inches of rain distributed over 130 - 190 days. These differences not withstanding, rainfall in each of the study areas is usually considered adequate for a good rainfed crop. (Norman and Hays, 1978)

In the Sudan zone most of the soils are developed in aeolian sand or in alluvial material which would imply that the soils are easily worked. The soils in the Northern Guinea zone are mostly sedentary on sedimentary rocks or on basement complex (Kilnkenberg, 1976, pp. 109-110).

Finally, Table III-2 shows that Sokoto has the highest population density - 128 persons per square mile, compared to 80 and 62, for Zaria and Bauchi respectively.

Section 2. Resource Utilization[1]

In all three areas, average farm size was less than 10 acres (Table III-3). Usufructuary rights to the use of land which is considered to be the property of the community remains the predominant form of land tenure. However, inheritance is the most important means of land acquisition. Two types of farm land may be differentiated: upland farms (gonan kudu), cultivated only in the rainy season and lowland farms (gonan fadama) which may be cultivated in both wet and dry seasons, as the water table is closer to the ground's surface. Over 90 percent of cultivated land in all areas belongs to the former category. Table III-3 indicates that the amount of land fallowed is lowest in Sokoto, the most densely populated area and highest in Bauchi, the least populated.

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[1] This Section draws heavily on previous work by staff of the Rural Economy Research Unit of Ahmadu Bello University, in the same study areas.

TABLE 3-3. LAND UTILIZATION - AVERAGE FOR FARMING FAMILIES

Variable	Zaria	Sokoto	Bauchi
Land:			
Farm size in acres (and number of fields)	9.7 (6.2)	9.9 (5.8)	9.7 (6.8)
Land Tenure, percent inherited (others)	64.9 (35.1)	70.1 (29.9)	92.3 (7.7)
Farm composition:			
Upland (acre)	8.8	8.9	9.3
Lowland (acre)	0.9	1.0	0.4
Percent of land Fallow	16.8	3.3	31.3
Percent cultivated land devoted to:			
Sole crops	23.0	3.3	46.2
Crop mixtures	77.0	90.9	53.8
Cultivated land per man equivalent	1.2	1.7	1.3
Cultivated land per male adult (acre)	2.1	3.3	2.3

Intercropping remains an important system of cultivation and the proportion of cultivated land devoted to the practice ranges from 90 percent in Sokoto to 54 in Bauchi. Norman has given an account of the reasons for intercropping - which include the need for security and maximization of total crop output (Norman, 1974).

Labor

Average family size ranged from 5.6 persons in Sokoto to 8.5 in Zaria. A total of 398 man-day equivalents were spent on farm work in Zaria, 316 in Sokoto and 276 in Bauchi[1]. In general, male adults undertook over 70 percent of total farm work while female labor accounted for less than 2 percent. The low female labor participation in farm work is attributable to a religious influence - the Muslim practice of auren kulle (seclusion of married women).

Labor may be hired during peak periods of farm work, usually between May and August. Hired labor accounted for 14 percent of total farm labor.

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1 In calculating man equivalents of labor use, the following conversion ratios were employed:

Male adults 15 years and above:	1.00
Female adults 15 years and above:	0.75
Large children 7-15 years	0.50
Small children less than 7 years and Adults above 65 years:	0.00

These equivalence ratios are from Norman (1972, p. 17). The basic assumption underlying the use of equivalence ratios are two: a) that physical labor productivity is positively correlated with age and b) that the physical productivity of women is lower than that of men. However, superior productivity of men and adults in agriculture may not hold true for all farm operations. If task specific data are available more realistic weights could be derived. Such data were not collected in this study.

TABLE 3-4. MEAN LABOR INPUT ON FARMS

Variable	Zaria	Sokoto	Bauchi
Family size (man equivalent)	8.5 (4.9)	5.6 (3.5)	6.0 (3.6)
Total man-day equivalents worked on family farm	397.9	315.8	275.9
Percent composition:			
Male adults	73.9	75.3	75.2
Female adults	0.4	1.4	3.8
Big children (7-14 years old)	9.5	7.8	9.8
Hired Labor	16.2	15.5	11.2
Farm work per male adult:			
Hours per day	5.1	5.9	5.5
Man-days per year	293.9	237.9	207.4
Days worked off farm (Male adult)	185.4	174.1	148.5

During slack periods of farm work male adults spend a considerable amount of time in off-farm activities. Off-farm employment may be in traditional occupations (leatherwork, pot-making, hunting, tailoring, petty-trading) or in "modern" services (e.g. as messengers, nightwatchmen or commission agents in nearby cities). The average number of days so spent ranged between 185 in Sokoto and 148 in Bauchi.

Capital

Table III-5 indicates that the amount of capital invested in agriculture in the three areas is low. The mean inventory value of durable capital, for example, was only ₦7.9, while average farm cash expenses amounted to only ₦16.4.[1] However, inter-area differences are evident. Bauchi farmers had the least inventory value for durable capital, ₦4.14 compared to Zaria and Sokoto farmers with ₦11.52 and ₦8.18 respectively.

On the average, the largest component of cash expenses was hired labor which accounted for 57 percent of total expenses. Expenses on fertilizer were very low and accounted for only 5 percent of overall farm expenditure; Bauchi farmers purchased no inorganic fertilizer.

Management

Sociologists generally associate managerial ability with age, literacy and the family structure to which decision-makers belong (Buntjer, 1970; Savage, Littlejohn, 1977). In Table III-6, information related to these factors is presented.

Families can be divided into two types of units: iyali or single family units and gandu or multiple family units. The iyali consists of

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[1] ₦ (Naira = Nigerian currency) = $1.58 (U.S. dollars) March 1979.

TABLE 3-5. CAPITAL UTILIZATION ON FARMS (NAIRA)

Variable	Zaria	Sokoto	Bauchi
Inventory value of durable capital (Total)	11.52	8.18	4.14
Percent breakdown:			
Crops (buildings, Tools, equipment)	3.9	17.4	14.8
Livestock:			
Cattle	82.5	60.8	63.2
Others, i.e. - goats, poultry etc.	13.6	21.8	22.0
Farm cash expenses (Total)	25.04	15.86	8.31
Percent breakdown:			
Land	4.4	3.8	3.6
Other durables	13.1	25.4	34.8
Seed	11.9	13.2	2.8
Fertilizer	3.3	4.9	--
Hired labor	63.9	49.5	57.1
Marketing costs	3.4	3.2	1.7
Actual weight of fertilizer applied per acre:			
Organic (lb)	2105.6	1993.6	313.6
Inorgainc (lb)	1.49	.35	0.0

TABLE 3-6. MANAGEMENT RELATED FACTORS

Factor	Zaria	Sokoto	Bauchi
Average age of household heads (years)	43	44	44
Family Organization			
Percent single family unit	51	72	62
Percent multiple family unit	49	28	38
Years of Qu'ranic schooling by household head	9.7	7.3	4.2

a single married man with his wife (wives) and dependent children. The gandu consists of two or more male adults (usually married), with their wives and children.

Table III-6 indicates that the iyali form of family organization is more common. The average age of farmers in the study area was 43.7 years. The degree of formal education was negligible. However, years spent by household heads in religious education which consists of studying the Qu'ran (the Islamic holy book) ranged between 9.7 years in Zaria, to 4.2 in Bauchi.

Section 2b. Crop Emphasis and Yield

Table III-7 indicates that between 70-80 percent of total cultivated land was devoted to four crops: millet, sorghum, cowpeas and groundnuts. On the average, land put under sorghum and millet accounted for 56 percent of cultivated land.[1] However, there are inter-area differences in crop emphasis. While millet is the most important crop in Sokoto, sorghum is more important in Zaria and Bauchi. Only 2.2 percent of farm land is taken up by groundnuts in Sokoto as compared to 10.8 and 8.1 percent in Zaria and Bauchi respectively. Except in Zaria, cotton is not an important crop.

The large variations between areas in crop yields should also be noted: i) Yields of sorghum in Sokoto villages are only 27 percent of the crop's yield in Zaria. ii) Rice yields in Sokoto are about three

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[1] Given the practice of intercropping, these figures are based on a computation of adjusted acreages: each crop in a mixture is allocated an acreage calculated by dividing the acreage of the crop mixture by the number of crops in the mixture. (Norman, 1972, p. 76)

TABLE 3-7. RELATIVE CROP EMPHASIS BY AREAS

Variable Specification	Adjusted Crop Area as Percent of Total Cultivated Land		
	Zaria	Sokoto	Bauchi
Millet	19.7	33.7	20.7
Sorghum	28.7	17.9	47.9
Groundnut	10.8	2.2	8.1
Cowpeas	11.0	28.0	5.7
Sugarcane	5.9	0.6	0.9
Rice	1.1	4.8	2.8
Cotton	9.5	0.0	0.0
Cassava	2.3	4.8	2.5
Tomatoes	0.3	0.0	0.0
Peppers	1.4	0.0	0.0
Percent of total farm area under above crops	90.7	92.0	86.6
Mean cultivated acreage	7.9	9.6	6.4

TABLE 3-8. MEAN YIELDS OF MAJOR CROPS BY AREAS

Crop	Mean Yields in Pounds Per Acre		
	Zaria	Sokoto	Bauchi
Millet	730	1650	705
Sorghum	1255	342	1219
Groundnut	1126	124	272
Cowpeas	288	128	68
Rice	149	404	207
Cassava	704	1564	1585

times their yields in Zaria. iii) In Bauchi cassava yields more than double the crop's yields in Zaria.

Section 3. Income and Output Per Man

Table III-9 gives income and labor productivity data by study areas. In the top half of the table, figures are calculated employing actual product prices in the study areas at the time of the surveys. In the bottom half of the table, however, output figures are adjusted for inter-area comparability by use of uniform prices. The uniform price for each crop is defined as an average of the price of the crop in the three study areas. The use of a uniform price is deemed appropriate for a number of reasons. First, official statistics indicate a decline in cost of living indices during the years 1966-1968 when the studies were undertaken[1]. Second, the decline in prices appears to be related to a decline in grain prices. However, the decline in grain prices was not the result of a large crop but rather a general deflation in the economy of the study regions. (FMANR, 1974)

In a deflation, prices of commodities may decline by different degrees in different areas. Hence using actual prices in interregional comparison of incomes and output can lead to some distortions[2].

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1 Annual Reports, Central Bank of Nigeria and Annual Abstracts of Statistics Federal Office of Statistics Lagos (various issues).

2 An alternative method to adjust output figures for a more accurate comparison would be to deflate farm returns by the Consumer Price Index (CPI). However, the CPI was not used because the composition of the output as used in its construction may not necessarily be the same for all three areas.

Calculation of output per man was done in two steps. First the gross value of crop output was computed:

$$GVCROP = \sum_{i=1}^{N} Pi\ Qi \quad ------ (3\text{-}1)$$

where,

GVCROP = gross value of crop output

Pi = uniform price = average price of crop i for the three areas.

Qi = total production of the crop

N = number of crops grown in the areas.

In the second step GVCROP was divided by the number of man-equivalents in the household:

$$\frac{GVCROP}{M.E.}$$

$$M.E. = M.A. + (F.A. \times 0.75) + (L.C. \times 0.50)$$

where

M.E. = Man equivalents

F.A. = Female adults

L.C. = Large children

Section 3b. Income and Output Comparisons

Table III-9 indicates that disposable income, excluding cattle income, averaged ₦161 for the entire sample. Disposable income was highest in Zaria. In general, crop production constitutes the major component

TABLE 3-9. INCOME AND OUTPUT PER MAN BY STUDY AREAS

Income	Zaria	Sokoto	Bauchi
		(All values in Naira)	
Actual Prices			
Gross Revenue from Crop Production	199	164	88
Net Farm Income	167	140	76
Off-Farm Income	39	44	36
Disposable Income (excluding cattle income)	198	181	105
Disposable Income (including cattle income)	250	214	128
Uniform Prices			
Gross Value of Crop Output	180	167	109
Output per Family man equivalent	37	49	32
Output per Family man day equivalent	0.44	0.58	0.40

of disposable income - accounting for at least 60 percent in all areas. There were substantial differences in farm incomes -- ₦167 in Zaria and ₦76 for Bauchi villages.

There was less variation in off-farm incomes, but intervillage differences can be observed (Appendix 1). For villages close to the cities for example, off-farm occupations account for 33 percent of disposable income. The corresponding statistics for intermediate and remote villages are 16 and 23 percent respectively.

An analysis of variance performed on both net farm income and disposable income by region and by villages showed that observed differences were significant in both cases at the one percent level.

The bottom half of Table III-9 shows that output per man, on the average, is highest in Sokoto, ₦49 and lowest in Bauchi, ₦32. Differences between areas and villages were also found to be significant at the one percent level. Duncan's multiple range test at the 5 percent level revealed the top subset of villages to be Kaura Kimba and Gidan Karma, both of which are Sokoto villages. The lowest subset of villages consisted of the three Bauchi villages, Hanwa in Zaria and Takatuju in Sokoto. Possible explanation for these differences in income is that Kaura Kimba has an unusually high proportion of gonan fadama (38.8 percent). In addition, the highest percentage of farmers who owned cattle lived in this village. In Gidan Karma, the next highest village in terms of labor productivity, average farm size was the largest (14.8 acres as compared to 10 for the entire sample). These results would imply that probable sources of high labor productivity are land quality, use of manure (more readily available through cattle ownership) and a large farm area.

Section 4. Factors Characterizing Output Per Man

The frequency distributions of household heads disaggregated by output per man and for each area are presented in Fig. III-5. In general the three distributions are negatively skewed. In Bauchi, for example 91 percent of farmers had output per man below 60. The corresponding percentage for Zaria and Sokoto are 85 and 68 respectively.

To better identify factors that may explain differences in labor productivity, the sample in each area was stratified into three on the basis of output per man. The strata are a) the top or first quintile - Class 1; b) the second, third and fourth quintiles - Class 2: and c) the bottom or fifth quintile - Class 3.

A number of observations can be made concerning the mean levels of use of various factors of production, and income, by labor productivity class (Tables III-10a - 10c).

a) Both total and hired labor use are positively related to output per man. But no correlation between labor productivity and the number of residents in the farmer's household is apparent.

b) Total cultivated farm size as well as gonan fadama acreage are positively related to output per man. Except for Sokoto, the top class had more land left fallow than the other classes.

c) There is a positive relationship between labor productivity and the use of fertilizer. In general, the bottom strata used the least amount of both manure and inorganic fertilizer. There appears to be no consistent positive relation between the use of manure and the number of cattle owned. For example, in Zaria while the bottom stratum owned on the average 3.4 cattle, they used 5.8 tons of manure, compared to the top

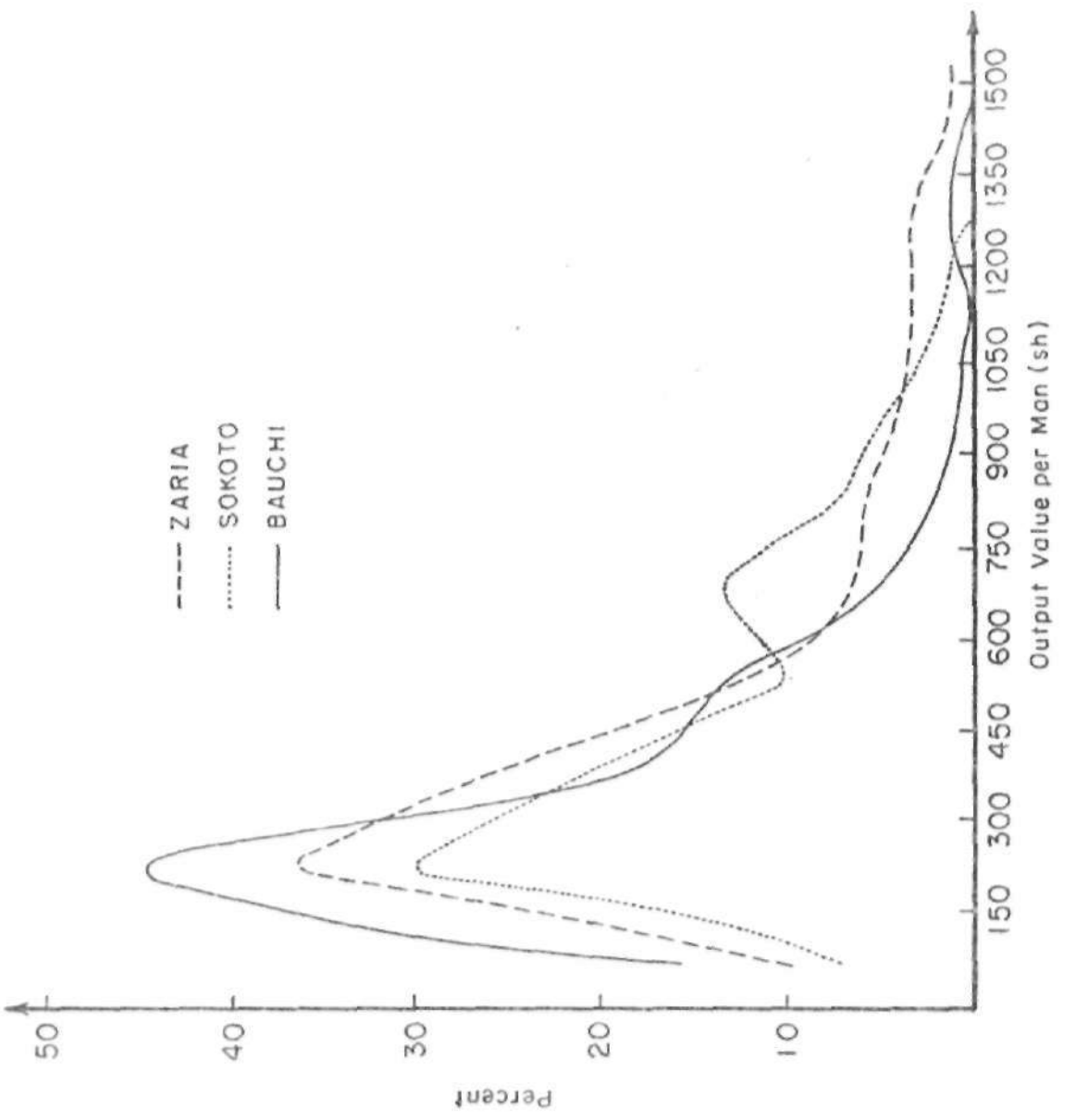


FIGURE 3-5. PERCENT FREQUENCY DISTRIBUTION OF OUTPUT PER MAN IN THE THREE AREAS

TABLE 3-10a. RELATIONSHIPS BETWEEN OUTPUT PER MAN AND PRODUCTION CHARACTERISTICS (ZARIA)

Production Characteristics	Values by Output per Man Strata 1	2	3
Output per Man (₦)	>54.9	19.2-54.9	<19.2
Total Labor (man days)	511.7	398.1	279.0**
Hired Labor (man days)	162.8	44.1	26.3**
Number of Residents in Household	7.5	9.0	7.6
Total Cultivated Land (acres)	13.8	7.1	4.1**
Cultivated Fadama (acres)	1.2	0.7	0.2**
Fallowed Land (acres)	2.0	1.9	1.2
Total Organic Manure (tons)	8.6	7.6	5.8
Number of Cattle Owned	1.7	3.4	3.4
Inorganic Fertilizer Cost (₦)	0.5	0.1	0,1
Off-Farm Income (₦)	40.6	37.2	43.6
Disposable Income (₦)	332.9	184.2	102.4*

* Differences significant at 5% level

** Differences significant at 1% level

TABLE 3-10b. RELATIONSHIPS BETWEEN OUTPUT PER MAN AND PRODUCTION CHARACTERISTICS (SOKOTO)

Production Characteristics	Values by Output per Man Strata 1	2	3
Output per Man (₦)	>71.03	21.29-71.0	<21.29
Total Labor (man days)	377.2	314.4	258.5
Hired Labor (man days)	113.8	39.1	13.4**
Number of Residents in Household	5.1	5.8	5.6
Total Cultivated Land (acres)	15.8	8.8	5.5**
Cultivated Fadama (acres)	1.8	0.8	0.1*
Fallowed Land (acres)	0.1	0.5	0.3
Total Organic Manure (tons)	9.3	7.9	0.0
Number of Cattle Owned	2.9	1.3	0.3*
Inorganic Fertilizer (₦)	0.1	.03	0.0
Off-Farm Income (₦)	29.3	46.6	52.5*
Disposable Income (₦)	287.7	173.4	96.6**

* Differences significant at 5% level

** Differences significant at 1% level

TABLE 3-10c. RELATIONSHIPS BETWEEN OUTPUT PER MAN AND PRODUCTION CHARACTERISTICS (BAUCHI)

Production Characteristics	Values by Output per Man Strata 1	2	3
Output per man (₦)	>48.2	16.3-48.2	<16.3
Total Labor (man days)	258.8	319.4	158.0**
Hired Labor (man days)	37.5	31.5	22.3
Number of Residents in Household	4.4	6.8	5.1**
Total Cultivated Land	7.7	6.9	3.1**
Cultivated Fadama (acres)	0.0	0.4	0.1**
Fallowed Land (acre)	6.3	3.2	0.8*
Total Organic Manure (tons)	1.4	1.5	0.5
Number of Cattle Owned)	2.9	0.5	1.3
Inorganic Fertilizer (₦)	0.0	0.0	0.0
Off-Farm Income (₦)	26.7	37.5	38.5
Disposable Income (₦)	134.7	110.6	58.7**

* Differences significant at 5% level

** Differences significant at 1% level

stratum who owned 1.7 cattle but used 8.6 tons of manure. Very small amounts of inorganic fertilizer were used in the study villages; the least amount was used by the lowest strata. No fertilizer was used by the Bauchi farmers in the survey.

d) Off-farm income is negatively related with farm output per man. For instance, for the sample as a whole, off-farm income constituted up to 54 percent of the disposable income of the bottom strata but only 14 percent of the income of the top strata. However, off-farm incomes were not high enough to compensate for differences due to farm output.

e) In Zaria and Sokoto, the average disposable income for the bottom strata was only about one-third of the average for the top strata. The corresponding statistics for Bauchi is 44 percent. An analysis of variance on the disposable income by output per man class indicated that differences in disposable income between labor productivity strata were significant at the 1 percent level.

In order to assess the degree to which output per man is influenced by the various factors of production discussed above, correlation coffi-cients were calculated. Results presented in Table III-11 show output per man and disposable income to be moderately correlated, ($r = .62$). Other variables showing statistically significant effects on labor productivity are: cultivated land area, cost of seed, expenditure on hired labor, fadama area, and use of inorganic fertilizer. It is of interest that inorganic fertilizer use has a higher correlation coefficient with output per man (.27) than organic manure (.14).

TABLE 3-11. PEARSON CORRELATION COEFFICIENTS BETWEEN OUTPUT PER MAN, MAJOR INPUTS, DAYS OFF-FARM AND DISPOSABLE INCOME (ENTIRE SAMPLE)

	Variable	1	2	3	4	5	6	7	8	9	10
1	Output per Man Equivalent	1.00	.58	.34	.14	.27	.43	.43	.08	-.08	.62
2	Total Cultivated Land		1.00	.29	.27	.37	.69	.56	.33	.11	.76
3	Cultivated Fadama			1.00	.14	.17	.46	.31	.44	-.08	.48
4	Total Organic Manure				1.00	.07	.19	.33	.33	.27	.38
5	Inorganic Fertilizer (cost)					1.00	.39	.45	.07	.08	.41
6	Seed and Seedcuttings (cost)						1.00	.55	.36	.08	.71
7	Hired Labor							1.00	.05	.15	.54
8	Family Labor								1.00	.09	.49
9	Days Off-Farm (male adults)									1.00	.33
10	Disposable Income										1.00

Section 5: Effect of Crop Mix and Yields on Output per Man

Crop enterprise selection is an important aspect of farm decision-making. Matlon's work shows there is a positive relationship between income class and the emphasis given to high value crops, e.g. peppers (Matlon, 1977).

The main objectives of this section are to assess the relative importance of subsistence and "cash" crops for farmers grouped on the basis of output per man and to estimate the relative yields of different crops by labor productivity strata[1]. In order to obtain the data presented in Table III-12, the crops grown by sample household heads in the three areas were first classified into three categories as follows:

i) subsistence crops: sorghum and millet[2]

ii) common cash crops: these consist of all other crops common to the three regions. There are a total of twelve crops in this group - groundnut, cowpeas, maize, rice, cassava, cocoyams, sweet potatoes, sugar cane, okra, onions, hemp and tobacco.

iii) area specific crops: these are crops grown in one or two of the areas but not in all three areas[3]. These include yams and irish potatoes for Zaria, indigo in Sokoto, and beniseed in Bauchi.

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1 The word "cash" is only used by convenience. "Subsistence" crops could also be sold for cash; and some crops classified as cash crops may be partly consumed by the farm family (e.g. cowpeas).

2 Simmons in a consumption survey of Zaria villages estimates that sorghums and millets provide 72 percent of the total calorie intake of households, (Simmons, 1976).

3 Climatic factors constitute the major reasons for area specificity of some crops. For example, relatively low rainfall in Sokoto precludes the cultivation of yams.

The output value of the three categories of crops were then calculated by output per man class (Table III-12).

Subsistence crop emphasis is highest in Bauchi, accounting for 79 percent of the gross value of output. In Zaria the corresponding proportion is 45 percent. Except in Bauchi, subsistence crop emphasis is greatest for the lowest strata. In Zaria, for instance, the relative importance of subsistence crops for the bottom strata is double that of the top strata.

Cash crop emphasis is highest in Zaria where cash crop value is 45 percent of total output value. Except for Zaria, the relationship between cash crop emphasis and output per man is not consistently positive. In Zaria while 54 percent of total output value of the first stratum is from cash crops, (i.e. higher than that for any other productivity class), in Bauchi the top stratum gave less emphasis to cash crops -- 14 percent - compared to 22 for the bottom class.

Area specific crops are most important in Zaria villages, where, on the average, they make up 10 percent of total output. The top class gave most emphasis to area specific crops, 15 percent of the total output value as compared to 5 percent in the third class.

Observed inter-area differences in crop emphasis appear to reflect variations in the degree of urbanization among the three areas. Thus the more urbanized areas have higher cash crops emphasis.

Relative Crop Yields

In Table III-13, crop yields per acre are expressed as a ratio, with the denominator equal to the average crop yield for the area. In Zaria, relative yields for millets, sorghum and rice are lowest for the first strata. However, differences between output per man class for the first

TABLE 3-12. RELATIONSHIPS BETWEEN OUTPUT PER MAN AND VALUE OF CROP PRODUCTION

Crop Category	Value of Crop Production as Percent of Gross Crop Value by Labor Productivity Class								
	Zaria			Sokoto			Bauchi		
	1	2	3	1	2	3	1	2	3
Subsistence Crops	0.31	0.43	0.62	0.67	0.62	0.70	0.86	0.73	0.77
Common Cash Crops	0.54	0.47	0.33	0.29	0.34	0.28	0.14	0.26	0.22
Area Specific Crops	0.15	0.10	0.05	0.03	0.01	0.0	0.0	0.0	0.01

TABLE 3-13a. RELATIONSHIPS BETWEEN OUTPUT PER MAN AND CROP YIELDS (ZARIA)

Crop	Yield per Acre as Percent of Average Yield for Area		
	Values by Output per Man Class		
	1	2	3
Millet	0.84	1.04	1.05
Sorghum	0.87	1.05	0.99
Rice	0.64	1.13	0.96
Cowpeas	0.74	1.17	0.72
Cassava	1.23	0.95	0.91
Groundnut	1.14	1.05	0.67
Cotton	1.47	1.01	0.44
Onions	1.81	1.05	n.p.[a]
Peppers	1.76	1.03	0.11*
Sugar Cane	1.27	1.19	0.13**
Weighted Average Yield Relative	0.93	0.95	0.66*

[a] n.p. = not planted

* Differences significant at 5% level

** Differences significant at 1% level

TABLE 3-13b. RELATIONSHIPS BETWEEN OUTPUT PER MAN AND CROP YIELDS (SOKOTO)

Crop	Yield per Acre as Percent of Average Yield for Area		
	Values by Output per Man Class		
	1	2	3
Millet	1.29	0.94	0.88*
Sorghum	1.50	0.96	0.63*
Rice	1.24	1.06	0.57
Cowpeas	1.72	0.96	0.40**
Cassava	1.23	1.02	0.69
Groundnut	n.p.	1.16	1.50*
Sugarcane	0.52	1.26	0.69
Weighted Average Yield Relative	1.19	0.92	0.77**

n.p. = not planted

* Differences significant at 5%

** Differences significant at 1%

TABLE 3-13c. RELATIONSHIPS BETWEEN OUTPUT PER MAN AND CROP YIELDS (BAUCHI)

Crop	Yield per Acre as Percent of Average Yield for Area		
	Values by Output Per Man Class		
	1	2	3
Millet	1.35	0.93	0.88
Sorghum	1.13	0.94	1.05
Rice	0.76	1.21	0.57
Cowpeas	0.52	1.21	0.80
Cassava	0.25	1.53	0.05
Groundnut	1.36	0.92	0.90
Onions	0.57	1.46	n.p.
Sugarcane	0.41	1.48	0.08
Weighted Average Yield Relative	1.04	0.96	0.88

n.p. = not planted

* Difference significant at 5%

** Difference significant at 1%

two crops are not significant. For all the other crops except cowpeas the top class has yields above average and higher than the other strata. Those in the lowest output per man class grew no onions and had a much lower relative yield for peppers as compared to the higher productivity classes.

In Sokoto, except for groundnut and sugar cane, yield relatives for the top stratum were above average and higher than for the other classes. Groundnut was not produced by the top class. This group also had the lowest yield relative for sugar cane.

Results for Bauchi also show lowest yield relatives for the bottom class, except for cowpeas. Cowpea yields for the top stratum are 52 percent of the sample average, compared to 80 percent for the lowest class.

In general yield differences were less for subsistence crops as compared to cash crops. It is also of interest that yield relatives are below average for a number of crops in the bottom strata. The last row or Table III-13 presents an overall yield index by output per man strata. To calculate the yield index the following formula was used:

$$YI = \sum_{i=1}^{N} wi \; Yi^{R} \qquad - - - - (3\text{-}2)$$

where

YI = Yield index

Yi^{R} = relative yields of crop i defined as $\frac{Y_1}{\bar{Y}_1}$, i.e. ratio of yield per acre of crop i to mean yield for the area.

Wi = Weight attached to crop i defined as, $\frac{vi}{GVCROP}$, i.e. value of crop i as a proportion of the gross value of crop output for the area

N = Number of crops, which is 10 for Zaria, 8 for Bauchi and 7 for Sokoto[1].

In all areas, inter-strata differences in the yield index though evident are not as large as the individual crop yield relatives. In Zaria where the difference is largest, the bottom class has a yield index two-thirds of the top class. Difference in the yield index are smallest in Bauchi where the third stratum has a yield index almost 85 percent of that of the first.

In Table III-14, measures of the extent to which various factors are related to yield are presented. A number of observations can be made:

i) In general, yield is negatively correlated with cultivated land area. The coefficient is significant in Zaria and Bauchi.[2]

ii) In all three areas yield is positively related to labor use.

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[1] The criterion used in selecting crops included in this calculation is that at least 0.1 percent of total cultivated acreage is devoted to it.

[2] A possible explanation is that with traditional technology, intensity of land use tends to decline with increasing farm size. This is in agreement with findings in India where large farms are usually less intensively cultivated than smaller farms (Sahota, 1968).

TABLE 3-14. CORRELATION COEFFICIENTS BETWEEN YIELD INDEX[a] AND OTHER FACTORS - ALL AREAS

Variables	Zaria	Sokoto	Bauchi
Total Cultivated Land (Acres)	-0.177	-0.117	-0.198
Total Labor per Acre (man days)	0.349	0.391	0.336
Fertilizer Cost per Acre (0.1 naira)	0.278	0.191	0.207
Seed Value per Acre (0.1 naira)	-0.042	0.387	0.390
Intercropping Index (Intercropped area as proportion of total cultivated land)	0.211	0.019	0.160
Fallow Average Proportion	-0.009	-0.256	-0.155
Level of Significance of r			
5%	0.174	0.195	0.187
1%	0.228	0.254	0.244

[a] Yield index based on Sorghum, millet, groundnut and cowpeas.

iii) A positive correlation is also observed between yield and fertilizer. But the coefficient is not significant for the Sokoto sample.

iv) Except in Zaria, seed cost is positively correlated with the yield index.

v) Although the intercropping index coefficient consistently has a positive sign, it is significant only for the Zaria sample.

vi) Fallow acreage proportion is negatively correlated with yield. However, the coefficient is significant only for the Sokoto sample.

Determinants of Yield

In this subsection an attempt is made to identify factors associated with higher crop yields. A yield index based on the four major crops: sorghum, millet, groundnut and cowpeas is computed as in equation 3-2.[1] With the yield index as the dependent variable, Ordinary Least Square regression methods are employed to estimate the following model:

$$YI = f(X_1, \frac{X_2}{X_1}, \frac{X_3}{X_1}, \frac{X_4}{X_1}, \frac{X_5}{X_1}, \frac{X_6}{X_1}, D_1, D_2, e) \text{ - - - - - } 3\text{-}3$$

YI = Yield index

X_1 = Total cultivated land area (acres)

X_2 = Total labor (man day equivalents)

X_3 = Total fertilizer value (in 0.1 naira)

X_4 = Seed cost (in 0.1 naira)[2]

X_5 = Total land area under crop mixtures (acre)

X_6 = Total land area fallowed

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1 These crops occupy between 70 and 80 percent of total cultivated land area.

2 X_3 and X_4 were originally measured in shillings. One shilling ≡ 0.1 naira or 10 kobo in current Nigerian currency.

D_1 = Location dummy for nearby villages

D_2 = Location dummy for intermediate village

e = Error term

Both linear and log-linear forms[1] of the model are estimated for each area.

Estimated coefficients are presented on Tables III-15 and III-16; t-statistics and the rank of each variable based on the size of the beta coefficients (β^*) are also given.[2]

The tables indicate that:

1) The estimated models have a low predictive power. For example, the coefficient of multiple determination corrected for the degrees of freedom indicate that only 35 percent of the variability in the yield index is explained by the variables considered for Sokoto (log-linear model). The $\bar{R}^2$ is lower for other areas -- 0.30 and 0.28, for Bauchi and Zaria respectively.

In all areas, labor, seed, and fertilizer have statistically significant coefficients.

2) Differences in the relative importance of included variables are evident:

a) In Zaria for example, labor and fertilizer constitute the major explanatory variables. The linear model indicates that on the average an

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[1] Standardizing some of the explanatory variables and the dependent variable by cultivated land area, which is also a regressor affects the interpretation of the coefficient for land in the log-linear model. Its coefficient is the sum of the coefficients of those variables standardized by X_1, less 1.

[2] $\beta^*_i = \beta_i \frac{\sigma xi}{\sigma YI}$

TABLE 3-15. FACTORS EXPLAINING YIELD (LINEAR MODEL) DEPENDENT VARIABLE: YIELD INDEX BASED ON SORGHUM, MILLET, GROUNDNUT AND COWPEAS

Variable Specification	Areas and Coefficients								
	Zaria			Sokoto			Bauchi		
	Coefficient	t-value	Rank	Coefficient	t-value	Rank	Coefficient	t-value	Rank
Constant	0.451			0.802			0.477		
Labor (man-day per acre)	0.002	2.85	1		0.58	6	0.003	1.87	2
Fertilizer value per acre	0.002	0.67	3	0.001	1.44	4	0.005	1.52	4
Seed Cost/Acre	-0.001	0.50	8	0.026	2.89	2	0.019	3.80	1
Cultivated Acreage	-0.002	0.50	6	-0.006	1.11	5	-0.011	0.94	5
Intercropping Index	0.091	0.63	5	-0.177	0.84	7	0.239	1.73	3
Fallow Index	-0.015	0.75	4	-0.722	2.47	3	-0.009	0.13	8
Location Dummy-Nearby	0.100	1.33	2	-0.306	3.32	1	0.069	0.60	6
Location Dummy-Intermediate	-0.023	0.37	7	-0.047	0.50	8	-0.049	0.39	7
R^2 ($\bar{R}^2$)	0.194	(0.138)		0.374	(0.319)		0.265	(0.211)	
S.E.	0.272			0.279			0.437		
d.f. for t-test	114			90			106		

TABLE 3-16. FACTORS EXPLAINING YIELD (LOG-LINEAR MODEL) DEPENDENT VARIABLE: YIELD INDEX BASED ON SORGHUM, MILLET, GROUNDNUT AND COWPEAS

Variable Specification	Areas and Coefficients: Zaria			Sokoto			Bauchi		
	Coefficient	t-value	Rank	Coefficient	t-value	Rank	Coefficient	t-value	Rank
Constant	-2.040			-1.567					
Labor (man-day per acre)	0.290	2.76	1	0.121	1.09	3	0.295	2.29	2
Fertilizer value per acre	0.077	2.56	2	0.138	2.42	2	0.050	1.43	4
Seed Cost per acre	0.076	1.40	3	0.215	1.99	4	0.239	3.32	1
Cultivated Acreage	0.025	0.35	6	0.022	0.26	8	-0.043	0.54	6
Intercropping Index	0.001	0.01	8	0.099	0.63	7	0.071	1.27	5
Fallow Index	0.008	0.29	7	-0.017	0.65	6	-0.011	0.21	8
Location Dummy-Nearby	0.098	0.93	4	-0.545	4.32	1	0.046	0.41	7
Location Dummy Intermediate	-0.060	0.67	5	-0.075	0.52	5	-0.162	1.125	3
R^2 ($\bar{R}^2$)	0.283	(0.234)		0.408	(0.356)		0.303	(0.250)	
S.E.	0.388			0.386			0.445		
d.f. for t-t	114	90		90			106		

additional man-day equivalent to the acre will increase the yield index by 0.002; while the log-linear model suggests that a 10% increase in per acre labor use would result in a 2.9% increase in the yield index.

b) In Zaria and Bauchi, nearby location is positively associated with yield, but in Sokoto the coefficient is negative and is the most important explanatory variable.[1]

c) In Bauchi, seed and labor are the most important explanatory factors.

Section 6. Influence of Farm Size and Other Factors on Farm Productivity

In previous sections intervillage variations in farm size and some factors not directly involved in farm production were discussed. Such factors include remoteness from urban centers, ownership of cattle, and family structure. This section examines the association between these factors and labor productivity.

Farm Size:

An implicit assumption in most land reform programs in developing countries is that small farm sizes which characterize traditional agriculture contribute to low farm income and inadequate returns to labor. However, in a recently completed study in Kano, Nigeria, "farm size showed no strong association with income class" (Matlon, 1977, pp. 104-110).

Data on the relationship between farm size and farm incomes are shown in Table III-17. The table shows disposable income and returns to labor to be positively related to farm size. Farmers with higher

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[1] The significant negative coefficient for the village closest to the urban center in Sokoto may be a reflection of lower soil fertility.

TABLE 3-17. RELATIONSHIPS BETWEEN FARM SIZE AND OUTPUT - ENTIRE SAMPLE

Farm Size (ha)	Family Labor Man-days	Hired Labor Man-days	Off-farm Income	Disposable Income	Farm Returns per Family Man-day Equivalent	Farm Returns per Family Man-equivalent	Number of Observations
1	177.9	20.1	42.99	84.70	0.29	22.28	34
2	210.4	26.4	37.59	100.69	0.37	28.77	86
3	273.5	27.4	36.35	130.07	0.42	34.53	84
4	355.9	31.1	39.02	178.39	0.48	42.89	53
5	329.9	74.5	51.20	203.63	0.54	43.72	32
6	364.6	81.9	19.25	260.59	0.72	60.17	19
7	458.0	54.1	58.26	281.60	0.64	56.71	12
8	414.5	240.6	46.03	340.12	0.62	87.42	6
9	333.9	150.8	40.03	306.85	0.76	56.15	5
10 & above	371.1	308.1	46.65	500.90	1.06	97.77	9

cultivated land area also employed more labor. However, no clear relationship is apparent between farm size and off-farm income.

Proximity to Urban Centers

Table III-18 indicates that both disposable income and labor productivity are inversely related to proximity to urban centers.[1] However, off-farm incomes are highest for villages closest to the cities. Norman and Pryor show that while trading activities "are more important with increasing remoteness of villages, modern services were the dominant source of off-farm income in villages closest to the urban area" (Norman and Pryor, 1978).

Low output per man observed for the nearby villages appears to be related to a higher population density and smaller farm sizes. The average farm size for Hanwa, Takatuku and Bishi for example was 7.6 acres as compared to 13.6 for the villages furthest from the towns.

The intensity of land use expressed in terms of the proportion of total farm size cultivated is lowest for the most remote villages, .75 as opposed to .91 for the nearby villages.

Finally the higher labor productivity observed in the most remote villages was not related to land quality.

Ownership of Cattle

The role of livestock in agriculture - e.g. as a potential source of farm power, capital and manure - is very well known in the north of Nigeria (Norman and Pryor, 1978). Since only crop residues are fed to cattle it can also be assumed that cattle owners also obtain a value from their crops over and above actual crop output.

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[1] A possible relationship between nearby locations and poor soil quality was noted earlier in Section 5.

TABLE 3-18. PROXIMITY TO CITIES AND OUTPUT PER MAN

Variables	Villages in Order of Proximity		
	Nearby	Intermediate	Distant
	Hanwa Takatuku Bishi	Doka Kaura Kimba Nasarawa	Dan Manhawayi Gidan Karma Nabayi
Population Density persons per square mile	594	337	177
Output per Man (₦)	29.64	40.22	46.88
Output per Man-Day (₦)	0.38	0.43	0.59
Output per Cultivated Acre (₦)	18.67	24.15	16.18
Disposable Income (₦)	155.91	154.49	172.71
Off-Farm Income (₦)	51.59	25.99	41.01
Farm Size (acres)	7.6	8.2	13.40
Farm Size per Resident	1.2	1.2	2.4
Cultivated Land as Percent of Farm Size	.91	.78	.75
Cultivated Fadama (acres)	0.2	1.4	0.3

TABLE 3-19. EFFECTS OF CATTLE OWNERSHIP ON INCOME AND OUTPUT PER MAN

Study Area and Cattle Ownership	Income and Output by Region and Cattle Ownership in Naira				
	Net Farm Income	Off-Farm Income	Disposable Income	Output Per Man	Number of Cases
Zaria					
Own no Cattle	160.41	43.99	196.52	38.45	106
Own Cattle	208.44	10.40	208.91	32.47	18
Sokoto					
Own no Cattle	130.57	47.76	171.98	43.79	63
Own Cattle	164.46	38.34	196.11	58.88	37
Bauchi					
Own no Cattle	72.53	34.93	100.78	30.55	101
Own Cattle	87.30	40.54	132.67	42.09	15
Entire Sample	128.80	39.46	161.33	39.16	340

Table III-19 indicates that farmers who own cattle tend to have higher net farm incomes.

Except in Bauchi villages, non-cattle owners appear to complement their farm earnings through higher off-farm incomes. However, cattle owners earn higher disposable incomes, and, except for Zaria farmers, also have a higher value of output per man. A t-test on output per men by ownership and non-ownership of cattle for the entire sample showed that observed differences are significant at the 1 percent level.

Family Structure and Age

Composite family structures called gandu traditionally characterized the study area. In recent years, however, the gandu has come "under stress owing to the impact of modernization," (Buntjer, 1970; p. 157). There is therefore, a tendency for the gandu to be superseded by single family units - iyali. (Norman and Pryor, 1978; p. 65)

Various researchers have discussed the possible effects of the break-up of the gandu on farm production and on the adoption of better farm practices. Buntjer, working in Zaria, viewed the gandu as "an authority structure" in which the subordinates not only view time spent on the gandu farm "as an imposition" but also "feel that modern agriculture could be carried out better," outside the composite units (Buntjer, 1970). Work by Tiffen in Gombe villages indicates that farmers heading joint family units are more likely than farmers in iyali to adopt certain innovations, especially those related to the ox-plough (Tiffen, 1973). However, Edache's work in Kano showed "no real differences" between the two classes of family organization as far as the use of the ox-plough is concerned (Edache, 1978). Norman, Pryor and Kroeker explain that arguments for both gandu and iyali acceptance of new techniques depend on various

factors: location of the farmer, the resources at the farmer's disposal, the enterprises pursued, etc. (Norman et al., 1976). The objective of this subsection is to assess inter-area differences between different types of family organization with respect to input utilization, output per man and crop yields.

i) The data in Table III-20 (a-c) confirm the superior position of the gandaye with respect to resource endowments particularly land and labor, as has been shown by Norman and Pryor (1978), and Edache (1978).

ii) The higher organic manure used by farmers in the gandu appears to be related to the larger number of cattle they owned.

iii) Inter-area differences with respect to fertilizer use is evident: Zaria farmers in the gandu spent more then those in iyali on fertliizer. In Sokoto, however, the reverse is the case. The mean variable cost of fertilizer for farmers in the iyali system was 1.45 while the overall average for the gandu was 0.87. Differences in fertilizer and seed expenses between the different types of gandu are also apparent: gandaye of brothers spend 1.13 on fertilizer compared to 0.60 for gandaye of father and sons. In Bauchi, very little fertilizer was purchased by farmers. But the little amount that was spent was by farmers in the iyali.

iv) Tables III-20 (a-c) also show that average expenditures on seed were generally higher for farmers in the gandu. In Zaria and Sokoto, however, observed differences in seed expenditures are small when expressed on a per unit area basis -- implying that seed costs are in part related to farm area.

With the exception of Zaria, farmers in the iyali system had higher labor productivity than those in the gandu. Output per man for multiple family units of brothers was higher than for units of father and sons.

TABLE 3-20a. RELATIONSHIPS BETWEEN FAMILY STRUCTURE AND FACTORS OF PRODUCTION (ZARIA)

Production Factors	Variable Values by Family Structure	
	Iyali	Gandu
Labor		
Man Equivalent in Household	3.2	6.6
Hired Man-days	44.6	86.6
Total Man-days	283.7	519.8
Land		
Total Cultivated Land (Acre)	5.0	10.9
Cultivated Lowland	0.5	0.8
Other Inputs		
Total Organic Manure (Tons)	3.9	11.1
Organic Manure per Acre (Ton)	0.8	1.0
Number of Cattle Owned	0.9	5.3
Inorganic Fertilizer (Cost ₦)	0.1	0.3
Variable Cost of Fertilizer ₦	0.4	1.1
Imputed Cost of Seed (₦)	8.2	19.5
Cost of Seed per Cultivated Acre (₦)	1.6	1.8
Output Per Man (₦)	36.8	38.4
Yield Index	0.85	0.93
Number of Observations	64	60

TABLE 3-20b. RELATIONSHIPS BETWEEN FAMILY STRUCTURES AND FACTORS OF PRODUCTION (SOKOTO)

Production Factors	Variable Values by Family Structure		
	Iyali	Gandu of Brothers	Gandu of Father/Sons
Labor			
Man Equivalent in Household	3.0	4.7	4.8
Hired Man Days	39.2	40.5	92.4
Total Man-Days	260.8	419.9	486.7
Land			
Total Cultivated Land (Acres)	9.4	10.8	9.5
Cultivated Lowland (Acres)	0.5	2.0	1.9
Other Inputs			
Total Organic Manure (Ton)	7.9	6.0	12.7
Organic Manure per acre (ton)	0.8	0.6	1.3
Number of Cattle Owned	0.9	1.0	3.5
Inorganic Fertilizer (₦)	0.04	0.0	0.0
Variable Cost of Fertilizer (₦)	1.5	1.1	0.6
Imputed Cost of Seed (₦)	8.0	10.9	8.81
Cost of Seed per Cultivated Acre (₦)	0.8	1.0	0.9
Output per Man (₦)	50.3	47.6	46.5
Yield Index	0.91	0.98	1.05
Number of Observations	73	18	9

TABLE 3-20c. RELATIONSHIPS BETWEEN FAMILY STRUCTURE AND FACTORS OF PRODUCTION (BAUCHI)

Production Factors	Variable Values by Family Structure			
	Iyali	Gandu of Brothers	Gandu of Father/Sons	Gandu of Other Types
Labor				
Man Equivalents in Household	2.9	3.9	5.2	5.5
Hired Man-days	26.2	27.1	47.9	35.0
Total Man-days	228.6	318.7	383.9	417.2
Land				
Total Cultivated Land (acre)	5.7	7.7	7.5	7.9
Cultivated Lowland	0.1	0.7	0.2	0.1
Other Input				
Total Organic Manure (tons)	0.9	1.8	1.8	6.8
Organic Manure per Cultivated Acre (tons)	0.2	0.2	0.2	0.9
Number of Cattle Owned	1.1	0.5	1.6	0.0
Imputed Cost of Seed (₦)	3.4	9.5	5.5	3.7
Cost of Seed per Cultivated Acre (₦)	0.6	1.2	0.7	0.5
Output per Man (₦)	32.8	39.0	25.6	28.9
Yield Index	0.88	0.96	1.20	1.20
Number of Observations	75	23	15	3

In Zaria the difference in labor productivity between gandu and iyali[1] farmers is not significant. However, in Sokoto and Bauchi observed differences were significant at the 5 percent level.

Tables III-20 (a-c) show very small differences in the overall crop yield index between family structure classes; however, farmers in the gandu had slightly higher crop yields. Attempts to explain differences in farm productivity arising from the influence of family structure are usually centered on two somewhat contradictory premises: on the one hand it is argued that families headed by younger farmers tend to use more improved practices (Buntjer, 1970); on the other hand, "older farmers have more experience." (Norman and Pryor, 1978)[2]

Tables III-21 (a-b) examine the influence of age of household heads on use of fertilizer, output per man and crop yields for Sokoto and Bauchi. The rate of fertilizer use was highest for the middle age classes. In general farmers above 60 years incurred no fertilizer expense. Use of organic manure, which is lowest for the youngest farmers, appear to be related to the number of cattle owned.

Tables III-21 (a-b) also indicate that output per man equivalent is highest for the youngest age class and lowest for the oldest class. Overall, while output per man was ₦54.44 for farmers below 30 years, the mean returns to labor for the older four classes was ₦36.20

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1 It may be noted that heads of gandaye of brothers, tend to be younger than heads of gandaye of father and sons.

2 It has also been suggested that the breakup of gandu into nuclei units may result in an increase in the dependent per worker ratio. (Norman, et al., 1979). This would imply that farmers in iyali type family structures have a greater incentive to work harder than those in gandu.

TABLE 3-21a. RELATIONSHIPS BETWEEN AGE OF HOUSEHOLD HEAD AND SOME PRODUCTION CHARACTERISTICS (SOKOTO)

Variables	Variable Values by Age Classes				
	Age				
	0-30	31-40	41-50	51-60	>60
Cultivated Land Area (Acre)	11.5	8.4	9.5	9.1	9.8
Fertilizer Use: Variable Cost (Kobo/Acre)	7.5	22.0	9.1	19.8	0.0
Organic Manure Tons/Acre	0.7	0.9	1.0	1.0	0.9
Number of Cattle Owned	0.8	1.5	1.1	2.3	1.7
Gross Value of Crop Output (₦)	185.7	145.7	169.7	179.0	149.5
Output Per Man (₦)	67.1	45.4	44.1	45.5	41.8
Crop Yield Index (1 = mean)	0.8	1.0	0.8	1.1	0.8
Number of Observation Cases	21	26	22	22	9

TABLE 3-21b. RELATIONSHIPS BETWEEN AGE OF HOUSEHOLD HEAD AND SOME PRODUCTION CHARACTERISTICS (BAUCHI)

Variables	Variable Values by Age Classes				
	Age				
	0-30	31-40	41-50	51-50	>60
Cultivated Land Area (Acre)	5.2	5.7	7.2	7.4	6.3
Fertilizer Use: Variable Cost (Kobo/Acre)	0.2	0.0	0.0	0.0	0.0
Organic Manure Tons/Acre	0.1	0.2	0.2	0.3	0.1
Number of Cattle Owned	0.2	0.8	0.1	3.6	0.0
Gross Value of Crop Output (₦)	94.9	88.2	135.1	130.8	83.6
Output Per Man (₦)	41.8	28.3	34.0	29.7	20.9
Crop Yield Index	1.20	0.8	1.0	1.0	0.7
Number of Observations	23	34	26	25	8

Except for the oldest farmers (above 60 years), who consistently had the lowest crop yield index, differences in crop yields between age classes were small.

Summary

The major conclusions that can be drawn from the analysis of factors related to differences in output per man are as follows:

i) With respect to resource utilization, the largest component of cash expenses is for hired labor (57 percent of total farm expenditure). Very little inorganic fertilizer is used by farmers.

ii) There are inter-area differences in crop emphasis and yields: while millet is the most important crop grown in Sokoto, sorghum is the dominant crop in Zaria and Bauchi.

iii) There are significant differences in net farm income, disposable income, and value of farm output per man between areas and between villages in the same area. Sokoto farmers have highest value of farm output per man, ₦ 49.37 while Bauchi farmers have the lowest, ₦ 32.04.

iv) Output per man is significantly correlated with land area, cost of seed, labor and fertilizer use. Major determinants of yield are labor, seed and location.

v) Contrary to Matlon's findings for South-west Kano, income and output per man show strong positive relationships with farm size.

vi) In general, output per man is higher for farmers in the iyali system. But there are differences between types of gandu. Farmers in gandu of brothers used more fertilizer and had higher labor productivity than those in gandu of father and sons.

vii) Finally, the only significant relationships between age of operator and factors affecting production were with respect to fertilizer use and output per man. Fertilizer use was highest for middle age classes (40-60 years) but output per man was greatest for the youngest age class (below 30 years).

CHAPTER 4

MEASUREMENT OF PRODUCTION EFFICIENCY-
ALTERNATIVE METHODOLOGICAL APPROACHES

The concept of efficiency is concerned with the relative performance of the processes used in transforming given inputs into output. Economic theory distinguishes between at least two types of efficiency: a) allocative efficiency, which refers to the choice of an optimum combination of inputs consistent with relative factor prices; and b) technical efficiency, which refers to the ability of firms to employ the "best practice" in an industry so that not more than the necessary amount of a given set of inputs is used in producing the "best" level of output (Timmer, 1970, p. 100; Carlsson, 1972). The degree to which a) and b) are achieved, is commonly referred to as production efficiency (French, 1977, p. 95).

The majority of studies of production efficiency in traditional agriculture have concentrated on the allocative aspects (e.g. Sahota, 1968; Massel, 1968; Welsch, 1965; Norman, 1970). An exception is Shapiro's study of Tanzanian cotton growers (Shapiro, 1974), which includes an analysis of technical efficiency.

The objective in this Chapter is to evaluate alternative methodological approaches relevant to the measurement of farm level production efficiency. The approaches discussed include the following: farm business performance measures, the average produdtion function, linear programming and the frontier production function.

Section 1. Farm Business Performance Measures

Decision makers are interested in higher net income. In measuring the extent to which this goal is attained, returns to specific parts of the farm business are usually considered - e.g. returns to labor and management, capital efficiency, or output per unit land area. (Castle, Becker and Smith, 1972; Milligan and Davis, 1978) Computed measures for individual farms are then compared with the average for similar farms in a given area or to values calculated for representative or synthetic farms. Farm performance measures are useful for identifying the strong and weak points in farm organization. However, they have limitations. First, conditions that apply on the average for an area, may not apply on individual farms; second, while such net income measures may be a good indication of success, they do not indicate how successful farmers got to be successful. In other words, they may not answer the questions as to what factors are associated with success and what can be done to improve farm performance.

Section 2. Average Production Functions

Production functions describe the relationship between inputs and output given a known way of organizing production. An analysis of the underlying function is a common approach in both industry and agriculture in the study of labor productivity.

Various functional forms can be used (Heady and Dillon, 1964). Guides as to the selection of an appropriate form for a particular situation are related essentially to three considerations. These are: i) the nature of the problem, ii) the type of relationship deemed to exist between inputs and output, and iii) the constraints or assumptions implied

by the particular function.[1] Production functions may be estimated by single equation or simultaneous equation procedures (Marschak and Andrews, 1944). However, most studies of farm productivity using cross-sectional data have used the single equation approach and the Ordinary Least Squares (OLS) estimating procedures (Massel and Johnson, 1967; Youmans and Schu, 1972)

Most statistical problems encountered in the estimation of production functions are related to the violation of the basic assumptions of the OLS model. Two such problems are discussed: simultaneous equation bias and specification error.

Simultaneous Equation Bias

Single equation estimates are said to have simultaneous equation bias when the equation is a member of a system of equations, and some of the independent variables (besides the dependent variable) are functions of distrubance terms in the equations. Some of the earliest writers on this issues were Marschak and Andrews (1944). They emphasized that economists cannot measure the effects of changing amounts of inputs on output the way field agricultural research workers can. While the latter determines the level of inputs to use, the labor and capital resources used by the firm studied by an economist are determined by the firm. The implication is that the equation estimated should capture the various decisions involved.

Consider a firm's production function of the general form:

$$Y = f(X_1, \ldots X_k, e) \qquad (4\text{-}1)$$

where Y = output, X's = inputs and e = disturbance term

[1] More is said about alternative functional forms in Chapter 5.

Marschak and Andrews demonstrate that the equations related to the firm's choice of input levels should also be included in the model.

If profit maximization is the goal, firms attempt to produce at a level at which marginal value productivities are equal to input costs. For equation (4-1)

$$\frac{\delta Y}{\delta X_1} = \frac{\delta[f(X_1 \ldots . X_k, e)]}{\delta X_1} \quad - - - - \quad 4\text{-}2$$

and profit maximization implies

$$\frac{\delta Y}{\delta_{X1}} = \frac{P_{X1}}{PY} \qquad \text{and}$$

$$(\frac{\delta Y}{\delta_{X1}})\ PY = P_{X1}$$

where, $\frac{dy}{d_{X1}}$ is the marginal physical product of a factor of production, P_{X1} is its price and P_y is the output price. Considering only two inputs, factor demand equations derived from (4-1) and (4-2) are of the form:

$$X_1 = f_1(Y, P_y, P_{X1}, e_1) \qquad (4\text{-}3)$$

$$X_2 = f_2(Y, P_y, P_{X2}, e_2) \qquad (4\text{-}4)$$

Thus in a two input, output situation, one is confronted, not just with the production function (4-1) but with (4-3) and (4-4) as well.

The above situation indicates that the regressors may not be independent of the error term, in which case OLS estimates will give inconsistent results.

Johnston suggests that other estimation techniques, such as indirect least squares, two-stage least squares, and Limited Information Likelihood methods could be used instead of OLS to give consistent estimates (Johnston, 1972, pp. 253-263).

However, Mundlak and Hock have shown that with appropriate model specification, single equation models may be almost free of simultaneous equation bias. They distinguish between transmitted and untransmitted disturbances. It is assumed that the distrubance term consists of two terms.

Again using equation (4-1):

$$e = e_1 e_2 \qquad (4\text{-}5)$$

one of the e's is transmitted to the inputs, while the other is not. The transmitted disturbance e_1 is regarded as affecting input decisions - decisions which the producer is aware of. The untransmitted disturbances are those not affecting input decisions since accurate information is absent. Mundlak and Hock argue that if one specifies most of the factors accounting for e_1, the bias transmitted to the inputs will be small. Firm effects and time effects are said to be the major components of the transmitted disturbance so that their elimination would reduce the transmitted component of e to negligible proportions (Mundlak and Hock, 1965, pp. 818-852).

The final choice between single and simultaneous equation models would, of course, depend not only on the statistical properties, but also on the purpose for which the estimates are desired and the availability of appropriate data.

Specification Bias

Griliches defines specification error as a situation in which one or more of the following occur: exclusion of variables, using approximations in representing regressors, inappropriate aggregation of output and/or inputs, or comitting "various other sins of omission and commission." Griliches has shown that such errors can lead to a bias in the estimates of parameters and returns to scale.

The general multiple regression model may be written as

$$Y = X\beta + \alpha \qquad (4\text{-}6)$$

where, Y, is a column of vector of values taken by the dependent variable, X is a matrix of values of all the independent variables, β, is a column vector of parameters and, α, a column vector of disturbances. Assume equation (4-6) is the true representation of the existing relationship. However, due to some specification error, the model estimated is

$$Y = \bar{X}\,\bar{\beta} + \bar{\alpha} \qquad (4\text{-}7)$$

Thus instead of obtaining an estimate of, β, and estimate of $\bar{\beta}$ is obtained:

$$\bar{\beta} = (\bar{X}'\bar{X})^{-1}\,\bar{X}'y \qquad (4\text{-}8)$$

If (4-6) is substituted into (4-8) and the expected value of the estimator taken we get

$$E(\bar{\beta}) = E(\bar{X}'\bar{X})\;\;\bar{X}'\;(X\beta + e) \qquad (4\text{-}9)$$
$$= (\bar{X}'\bar{X})^{-1}\,\bar{X}'\,Xe$$

If $(\bar{X}'\bar{X})^{-1}\,\bar{X}'X = P$ then $E(\bar{\beta}) = Pe$ (rather than being equal to β)

Thus each of the estimates in $\bar{\beta}$ may be biased; and is actually a weighted sum of all the parameters in the true specification. The elements of P can be thought of as coefficients that would be obtained from a regression of the X (the excluded variables) on the $\bar{X}$, the variables included in the estimated model (Griliches, 1957, pp. 9-10). The sign of P is used to evaluate the direction of bias in estimates involving a specification error.[1]

The implication is that the effect of the omission of a relevant variable from an equation, for instance, would depend on the extent to which the excluded variable is correlated with any of the included variables. If it is positively correlated, the estimated parameter of at least one of the included variables will be biased upwards; and if negetively correlated, the bias would be downwards. Griliches also demonstrates that disregarding quality differences between inputs has effects similar to the omission of a relevant variable. For example, he argues that higher quality labor is usually positively associated with capital input and that the omission of the former will result in an overestimation of the returns to capital and an underestimation of the returns to labor. He suggests that this may explain why, so often, studies of production functions have indicated unreasonable low returns to labor but very high returns to capital.

Specification bias can be reduced by improving the specification of a production function - care being taken to ensure that the model does not overlook quality differences in inputs, and that relevant major

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[1] In practice P may not be known - except perhaps when one is correcting for multicollinearity, for example.

variables are included prior to estimation. However, a common reason for commiting a specification error is the lack of knowledge as to the correct specification of the regression equation. In that case, one would wish to be able to test whether or not an equation has been misspecified. Four such tests have been developed by Ramsey (1969). The tests are based on the assumption that if the model is correctly specified, the regression disturbances will exhibit the expected properties of zero mean and constant variance of the OLS model. However, if some specification error is committed, the conditions will no longer hold. One of the tests can be illustrated.

Consider the general regression model

$$Y = X\beta + e \qquad 4\text{-}10$$

where β, is a column vector of parameters and all other variables are as previously defined for equation (4-6). Under correct specification

$$\hat{e} \sim N(0, \sigma^2 e^{\intercal}) \qquad 4\text{-}11$$

but if the model was misspecified

$$\bar{e} \sim N(A'V, \bar{\sigma}^2 I) \qquad 4\text{-}12$$

where $A'V$ is the net contribution of the omitted variable(s) to the conditional mean of the dependent variable (net, in the sense that one is considering the effect of the omitted variables given the regressors.) Thus under the alternative hypothesis one may write $\bar{e}$ as

$$\bar{e} = A'V + u \qquad 4\text{-}13$$

where the vector u is normally distributed with null mean vector.

To test for specification error, $\bar{e}$ is regressed on $A'V$ and an F-test performed on the estimated regression. However, V is unknown. But it can be approximated by a linear sum of the vector q_j.

$$q_j = a' i_{\hat{y}}(2) \qquad 4\text{-}14$$

$\hat{y}^{(2)}$ = the vector formed from the squares of elements of the vector of least-squares estimates of the dependent variable.

$a'i$ = the ith row of the matrix A, which is derived from the sums of squares and cross-products of all the independent variables (Theil, 1965, p. 1072). Thus, one considers the regression:

$$\bar{e}_i = \alpha_0 + \alpha_1 q_{i1} + \alpha_2 q_{i2} + \ldots + u_i \qquad 4\text{-}15$$

$$(i = 1, 2, \ldots N\text{-}K)$$

where N is number of observations

K is number of variables (in the original model)

u is assumed to be normal with zero mean.

An F-test on the joint significance of the α's is then applied.

Under the null hypothesis that ideal conditions hold, the regression coefficient estimators have zero expected values and the covariance matrix of e, is $\sigma^2 I_{N-K}$. Under the alternative hypothesis that the mean vector of $\bar{u}$ is $A'V$, one or more of the estimated coefficients will have nonzero means, i.e. the multiple correlation coefficient is nonzero.

Section 3. Linear Programming Techniques

Linear Programming (LP) techniques can be applied to problems aimed at optimizing a linear objective function given production activities and available resource levels. The technique may be used to generate optimal enterprise and resource combinations for a given production situation.

However, LP techniques do present some problems, especially when applied to traditional agriculture. Some of these problems are partly related to the basic assumptions of the model. For example, the objective function usually used implies that profit maximization is the sole goal of farmers. This may not be true for small traditional farmers who would also be interested in meeting food subsistence requirements.

However, there are methods which are used to incorporate multiple objectives and farmer preferences in an LP model. For instance, the objective function can be replaced by a weighted sum of the components of a vector of valued producers' goals, e.g.

$$\text{Maximize} \quad Z(X) = \sum_{K=1}^{P} w_K Z_K(X) \qquad 4\text{-}19$$

where, $Z(X)$ = the p-dimensional vector of objectives (Cohon and Marks, 1975).

$w_K \geq 0$, for all k and is the weight attached to each of the objectives.

Another problem in the use of the LP model is the reliability of generalizing from an LP solution based on the activities and resources of 'representative', 'average' or 'synthetic' farms to the behaviour of individual farmers. The argument is that farmers do not possess equal amount of resources nor do they respond alike to changes in economic stimuli so that the estimate of an optimum plan may not be applicable to all farmers.

Day has defined some conditions which should indicate the extent to which component firms should be alike in order for a single model to

represent the aggregate of the individual decision problems, without distortion (Day, 1963). The conditions include the following: that all firms have identical matrices of input and output coefficients; that firms have only proportional variations in net return expectations; and that firms have only proportional variations in constraint vectors. Day provides proof that firms satisfying the above conditions are more likely to meet the condition in which

$$P^* = \frac{1}{N} \sum_{n=1}^{N} P_n \qquad 4\text{-}20$$

where P^* is the average marginal net revenue productivities of resources in the set or group

P_n is the vector of the marginal net revenue productivities of resources of individual firms

N is the number of firms.

In practice these conditions are hard to satisfy. Attempts to make LP solutions based on a 'representative' or 'average' farm more applicable to individual farm planning have proceeded via the following steps. The sample is first stratified by a factor or factors on the basis of their importance or quality. Activities and constraints are then specified for each strata, and different LP models developed for each class.

However, Day points out that behavioral phemnomna such as management may lead to a considerable degree of proportional variation that would not exist on purely technical grounds. This would imply that such variations cannot be captured by either of the two approaches discussed above.

One way to explore how much distortion is caused by 'proportionality' would be to perform parametric programming and ranging analysis on the components of the constraints and net return vectors.

Finally, an important limitation of LP with respect to the objectives of this study should be noted. Linear Programming is mainly a procedure for providing normative solutions -- the course of action which ought to be taken given the objective and constraints specified in the model. This is in contrast to a positive approach which can explain "why producers in fact provide a somewhat different pattern of production and resource use" (Heady and Candler, 1958, pp. 8-10).

Section 4. The Frontier Production Function

The earliest use of the frontier production function concept was by Farrell, who applied it in measuring efficiency in U.S. Agriculture (Farrell, 1957). Farrell rejected the conventional production function approach on the ground that its results would represent only average levels of efficiency. Instead he suggested a method which consisted of plotting input per unit output observations as points in a space of a suitable dimension. Farrell then estimates the frontier function by fitting an envelope of the type shown in figure 4-1, to the scatter of points in the input plane. Other firms can then be compared to those on the frontier.

Farrell's measure of efficiency consists of two components, technical efficiency and price efficiency. He demonstrates that these measures are not only different but also states that economic efficiency is really a product of the two. Consider figure 4-2 and assume constant returns to scale and a single output, two inputs situation. The production function can be described by the isoquant SS'.

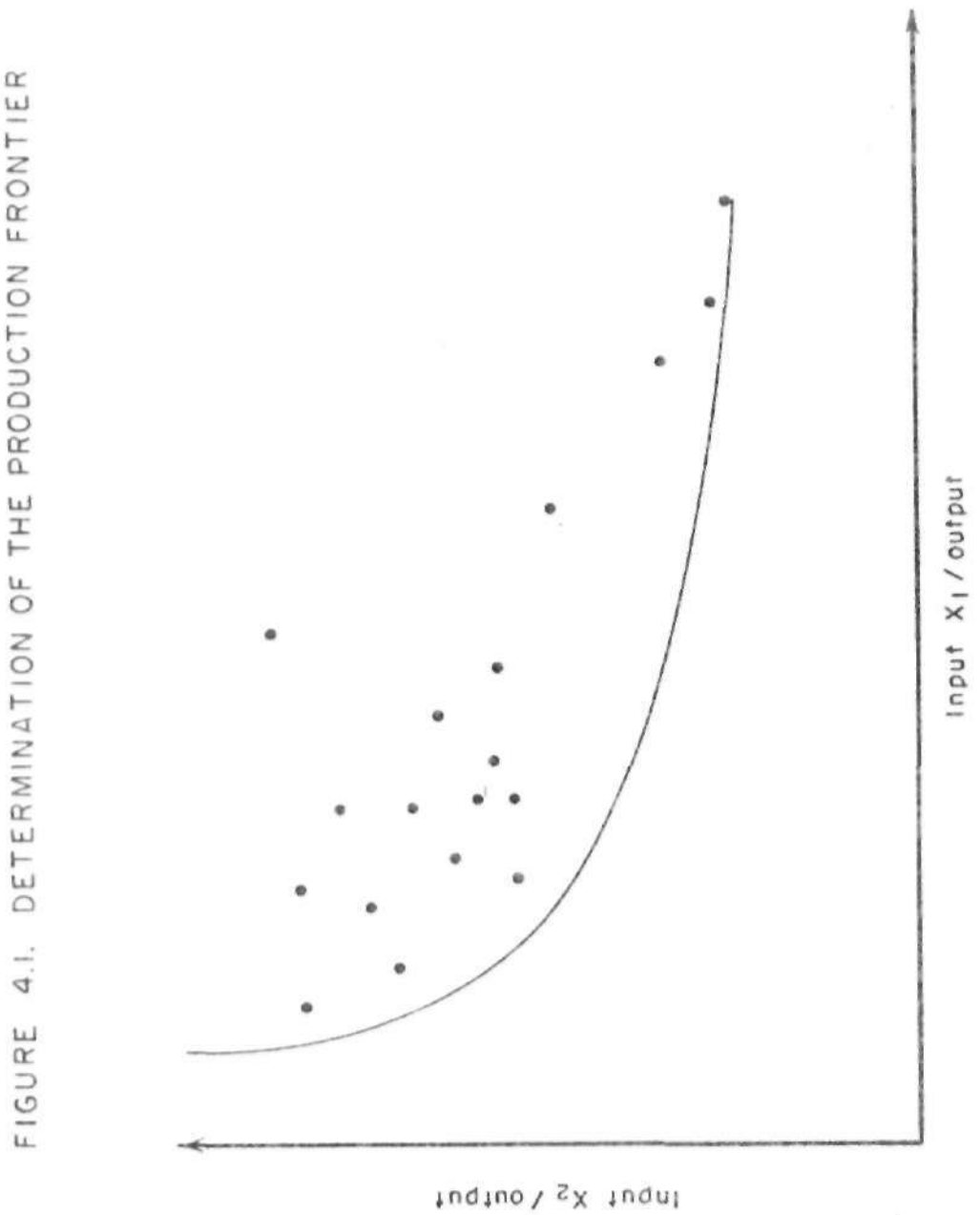


FIGURE 4.1. DETERMINATION OF THE PRODUCTION FRONTIER

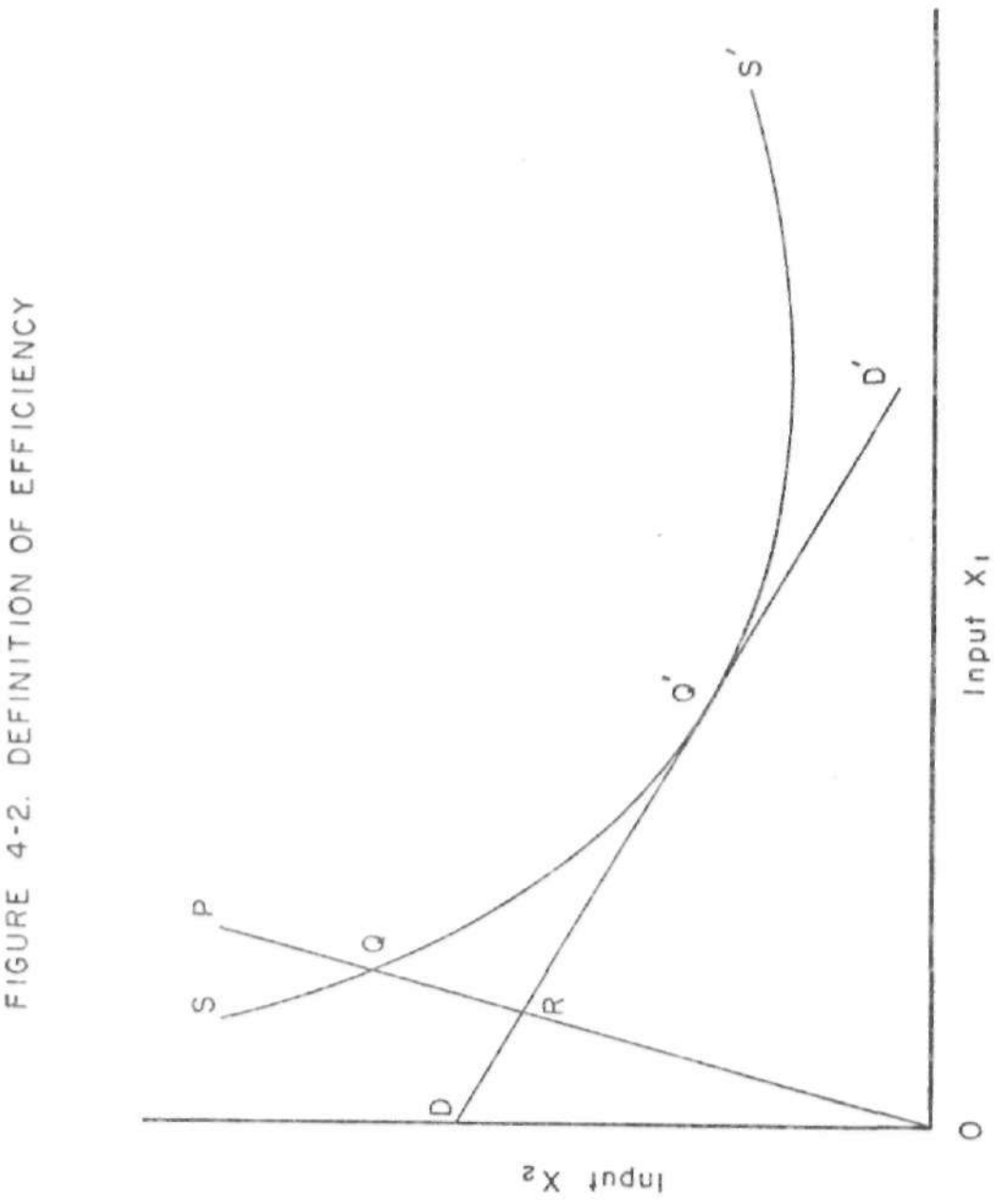


FIGURE 4-2. DEFINITION OF EFFICIENCY

Let DD' be the price line, Q' is the optimum combination of inputs X_1 and X_2. However, for a firm not producing at Q' but at P, for example, the ratio $\frac{OP}{OQ}$ measures the extent to which the same amount of output could be produced with a smaller quantity of inputs. This is the measure of technical efficiency. The ratio $\frac{OR}{OQ}$ measures the fraction of cost for which the output could be produced if the relative use of inputs were altered. This is the measure of price efficiency. However, the "overall" efficiency at P is given by

$$\frac{OR}{OQ} \cdot \frac{OQ}{OP} = \frac{OR}{OP} .$$

Farrell's work has not escaped some criticism. Aigner and Chu (1968) point out that the method is not general enough, since the assumptions imply that it is not possible to use it in estimating a production function which conforms to the law of variable proportions. Nerlove makes two other criticisms. First, that Farrell's method does not permit comparison of firms in an imperfectly competitive industry; and second, that the measure neglects differences in the environment of the different firms. The last point is "crucial to any definition of relative economic efficiency. In general, some attempt must be made to standardize environment--or else the measure will not only reflect differences in efficiency but also the degree to which the environment of a particular firm is favorable or unfavorable" (Nerlove, 1965, p. 90).

In a later work by Farrell and Fieldhouse, some methods are presented for applying the Farrell method to conditions involving increasing returns to scale. One of these consits of grouping observations according to output and estimating the function for each output group (Farrell and

Fieldhouse, 1962). Nerlove's criticism that Farrell's approach neglects environmental differences between firms does not appear to be so crucial either, since firms could also be grouped on locational basis prior to estimation. This has been shown by Seitz (1970).[1]

Since Farrell's approach was published, a number of workers have applied it or variants of it to various efficiency problems. Examples are work by Seitz on efficiency measures for steam-electric generating plants, Aigner and Chu's study of the primary metals industry, Timmer's efficiency measures in U.S. agriculture and Kelly's work in the New South Wales' egg industry (Seitz, 1970; Aigner and Chu, 1968; Timmer, 1970; Kelly, 1977). Consequently, the technique itself has undergone some development, it terms of the estimation approaches used.

Two such approaches are discernible from the literature: Boles uses a linear programming approach (Boles, 1966). The basic unit of observation is a productive activity or firm in which a specified bundle of inputs has produced some quantity of a single product. To estimate the technically "efficient unit isoquant", each activity is standardized to yield one unit of output so that the jth standardized activity P_j is given by:

$$P_j = [x_{1j}\ x_{2j} \cdot \cdot \cdot \cdot x_{mj}]' \qquad 4\text{-}21$$

(1,2...m) = factors of production

x_{ij} = quantity of factor i used per unit product and is given by:

$$x_{ij} = \frac{X_{ij}}{Q_j} \qquad 4\text{-}22$$

---

[1] While this may be feasible for nonagricultural firms, it is not as easy to completely correct for environmental differences in farm production Climatic and soil factors could be highly localized.

where, Q_j is the quantity of the single product and, X_{ij} is the total quantity of factor, i, used in the production of the jth activity.

There are as many LP problems as there are activities or firms. And the objective is to classify each of the n points either as 100 percent efficient or if less than a hundred percent, to compute a technical efficiency index.

The jth LP problem is,

$$\text{Maximize } Z_o = V'X \qquad 4\text{-}23$$

$$AX \leq P_j \qquad 4\text{-}24$$

$$X \geq 0$$

Z_o = value of the objective function

A = A constant coefficient matrix formed by the n productive activities.

V is an nxl vector of ones and the efficiency index is given by $\frac{1}{\bar{Z}_o}$

where $\bar{Z}_o$ is the optimum value of the objective function. The sequence of steps is as follows:

At the start of computations, a firm is selected that used the minimum quantity of some factor in production. Its input factor levels are used as the contraints, and the simplex algorithm is used to obtain the optimum solution. Any firm in the optimum basis is classified as 100 percent efficient. If the activity or firm whose resource levels were used as constraints is not on the basis, it is less than a 100 percent efficient and its efficiency index is computed. The process of selecting an activity or firm with the minimum level of some input as constraints is repeated until all activities or firms have been classified.

There is at least one potential problem with Boles' approach. The fact that the classification of firms is based on different right hand side values may give efficiency measures in favor of firms with larger levels of inputs.

A second approach is that developed by Aigner and Chu (1968). Linear programming methods are also employed. But in contrast to Boles' approach, the same right hand side values are used to rank all firms. Furthermore, no initial assumption is made with respect to scale effects. This generality is achieved at the cost of specifying a functional form for the hyperplane. As pointed out by Timmer, the cost may be small if the form assumed gives a good fit and behaves according to economic logic (Timmer, 1970, pp. 111).

To illustrate the method consider the Cobb-Douglas Production Function:

$$Y_j = \sum_{i=0}^{m} \alpha i \, Xij + e_j \qquad 4\text{-}25$$

(Y and X in logs)

where

Y_j = logarithm of output of firm j, (j = 1 . . . n)

Xi = logarithm of amount of input i used by firm j (j = 1, 2...m)

αi = parameters to be estimated

e_j = logarithm of the random disturbance term

The frontier function is defined as one in which the estimated parameters $\hat{\alpha}_i$ satisfy

$$\Sigma \hat{\alpha i} \, Xij = \hat{Y}_j \geq Y_j \qquad 4\text{-}26$$

Where $\hat{Y}_j$ = potential output.

Only technically efficient firms will have $\hat{Y}_j = Y_j$. All other firms will have an output less than their potential as indicated by the frontier production function.

Timmer (1970) has presented a method of using linear programming to solve the problem posed by (4-26).

Timmer suggests minimizing the sum of the error terms implicit in (4-26).

If it is assumed that all $e_j \geq 0$, equation (4-26) can be written as:

$$\sum_{i=0}^{m} \hat{\alpha}_i X_{ij} - e_j = Y_j \qquad 4\text{-}27$$

Summing over all firms, say n, this becomes,

$$\sum_{j=1}^{n} e_j = \sum_{j=1}^{n} \sum_{i=0}^{m} \hat{\alpha}_i X_{ij} - \sum_{j=1}^{n} Y_j \qquad 4\text{-}28$$

This can be solved for $\sum_{j=1}^{n} e_j$ to give,

$$\sum_{j=1}^{n} e_j = \sum_{j=1}^{n} \sum_{i=0}^{m} \hat{\alpha}_i X_{ij} - \sum_{j=1}^{n} Y_j \qquad 4\text{-}29$$

For any particular data set the $Y_{j's}$ are constant so that the sum of the error terms may be minimized by minimizing:

$$\sum_{j=1}^{n} \sum_{i=0}^{m} \hat{\alpha}_i X_{ij} \qquad 4\text{-}30$$

alone. The double summation can be simplified by dividing by the number of firms, n, so that the objective function becomes:

$$\text{Minimize} \quad \sum_{i=0}^{m} \hat{\alpha}_i \bar{X}_i \qquad 4\text{-}31$$

Where:

$$\bar{X}_i = \frac{1}{n} \sum_{j=1}^{n} X_{ij}$$

X_o = one

The problem to be solved then becomes

$$\text{Minimize} \quad \hat{\alpha}_o + \hat{\alpha}_1 \bar{X}_1 + \ldots + \hat{\alpha}_m \bar{X}_m$$

Subject to:

$$\hat{\alpha}_o + \hat{\alpha}_1 X_{11} + \hat{\alpha}_2 X_{21} + \ldots + \hat{\alpha}_m X_{m1} \geq Y_1$$

$$\vdots \qquad \vdots \qquad \vdots \qquad \vdots \qquad \vdots$$

$$\hat{\alpha}_o + \hat{\alpha}_1 X_{1n} \quad \hat{\alpha}_2 X_{2n} + \ldots + \hat{\alpha}_m X_{mn} \geq Y_n$$

$$\hat{\alpha}i \geq 0$$

The right hand side values of the constraint are the actual output of individual firms. The problem is essentially to solve for the optimal levels of resource use. The activities in the basis will be in terms of inputs. The shadow prices on the restriction in the basic solution represent the coefficients in the frontier function. And the index of technical efficiency is given by $\frac{Y_j}{Y_j}$, where Y_j is the actual output of each producer

and $\hat{Y}_j$ is the potential output given the level of resources used by each producer. The potential output obtainable for each firm is calculated by multiplying the resource levels of individual firms by the coefficient values in the frontier production function. Only technically efficient firms will have $Y_j = \hat{Y}_j$.

An objection common to all envelop approaches is that only marginal data are used since the bulk of the firms do not enter the frontier (Bressler, 1966, p. 130). To ensure that the frontier is not determined by 'marginal' observations alone, a "chance - constrained frontier" may be estimated (Aigner and Chu, 1962; Timmer, 1970). This implies that equation (4-26) is translated from a deterministic inequality to a probabilistic statement:

$$P_r \left[\sum_{i=0}^{m} \alpha_i X_{ij} \geq Y_j \right] \geq P \qquad 4\text{-}32$$

where P is an externally specified probability level with which the equation is to hold.

To estimate the probabilistic frontier production function, the deterministic model is first estimated. The most efficient firms obtained from the programming model are then discarded. Thus the first (100-P) percent of efficient firms are discarded until the specified level of P is reached. An alternative is to correct for 'outliers' by discarding efficient firms one at a time until estimated coefficients appear to stabilize (Timmer, 1970, p. 115).

Section 5. Relative Efficiency and the Profit Function

Lau and Yotopoulos have developed an alternative approach for measuring efficiency. They use a profit function "rather than a production function," for the following reasons:

> ". . . the test of efficiency should meet at a minimum three requirements. i) It should account for firms that produce different quantities of output from a given set of measured inputs of production. This is the component of differencec in technical efficiency. ii) It should take into account that different firms succeed to varying degrees in maximizing profits, i.e. in equating the value of the marginal product of each variable factor to its price. This is the component of price efficiency. iii) The test should also take into account that firms operate at different sets of market prices." (Yotopoulos, 1972, pp. 11-12)

The Lau and Yotopoulos model consists of a single profit equation and a series of equations expressing the derived demand function for each variable input. The profit equation expresses profit level as a function of variable input prices and fixed input quantities (Lau and Yotopoulos, 1971 and 1972).

Consider a firm with a production function

$$Y = F(X_1 . . . X_m; Z_1 . . . Z_n) \qquad 4\text{-}33$$

where

Y = output

$X_1 \ldots X_m$ = variable inputs

$Z_1 \ldots Z_n$ = fixed inputs

Profit, defined as "current revenue less current total variable costs," can be written as:[1]

$$\Pi = P[F(X_i....X_m;\ Z_1....Z_n)] - \sum_i^m c_i' X_i \qquad 4\text{-}34$$

where:

Π = profit

P = unit price of output

c_i' = unit price of the ith variable input.

The "Unit-output-Price" Profit is given by dividing (4-34) by the price of output.

$$\Pi = F[X_1 - -X_m\ ;\ Z_1...Z_n) - \sum_{i=1}^m c_i X_i \qquad 4\text{-}35$$

To derive a profit function, equation (4-33) is solved for the optimal quantities of variable inputs X_i^*'s. This is expressed as a function of the normalized prices of the variable inputs, c, and of the quantities of fixed inputs

$$X_i^* = f_i(c,\ Z),\ i = 1...m \qquad 4\text{-}36$$

where c, the normalized price is defined as

$$c_i = \frac{c_i'}{P} \qquad 4\text{-}37$$

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[1] This is really a definition of gross margin and not profit. But it will be referred to as profit after the proponents of the model (Lau and Yotopoulos, 1971).

with all terms as previously defined.

By substituting (4-36) into (4-34) the profit function is obtained:

$$\Pi = P[F(X_1^* \ldots\ldots X_m^* ; Z_1 \ldots\ldots Z_n) - \sum_{i=1}^{m} c_i X_i^*] \qquad 4\text{-}38$$

This gives the maximized value of the profit for each set of values

$$[p ; c_i \ldots . c_m^{'} ; Z_1 \ldots Z_n].$$

Since the terms in square brackets in (4-38) are essentially a function of c and Z, it can be rewritten as

$$\Pi = pG^* (c_1 \ldots c_m ; Z_i \ldots Z_n) \qquad 4\text{-}39$$

hence the profit function is given as:

$$\Pi = \frac{\Pi}{p} = G^*(c_1 \ldots c_m ; Z_1 \ldots . Z_n) \qquad 4\text{-}40$$

The input demand functions are given by differentiating (4-40) with respect to the normalized price

$$X^* = \frac{\delta \Pi^* (c,Z)}{\delta c_i} \qquad 4\text{-}41$$

Since the demand equation are obtained directly from the profit function without working through the production function, explanatory variables are 'truly' exogenous and the problem of simultaneous equation bias can be avoided. Hence OLS can be used in estimating the Lau-Yotopoulos model. In using the model for efficiency analysis, it is either specified for different groups of firms or for individual firms. Firm or group specific technical efficiency parameters may then be introduced to allow for neutral

differences in production function, e.g. environmental factors, managerial ability, etc. Third, allocative efficiency is incorporated by introducing firm or group specific and variable input specific parameters which are multiplied by the normalized price of each input.

Thus the production function for each group of firms may be given by

$$Y = AF(X_1 - -X_m; Z_1 \ldots\ldots Z_n) \qquad 4\text{-}42$$

and the profit function by

$$\Pi^* = AG^*(k_1c_1/A \; ; \; \ldots\ldots k_mc_m/A \; ; \; Z_1 \ldots . Z_n) \qquad 4\text{-}43$$

where A's are technical efficiency parameters

k's are pricing efficiency parameters.

Lau and Yotopoulos contend that the analysis may proceed in terms of the profit model without the necessity of estimating the underlying function if the firms are profit maximizers and price takers.

There have been at least three applications of the profit function as developed by Lau and Yotopoulos: a) the authors applied it to farm level data from India to determine whether or not there is any difference in the relative efficiency among small and large farms (Lau and Yotopoulos, 1972); b) O'Connor and Hammonds have used it in their study of efficiency in the U.S. meat retail systems (O'Connor and Hammonds, 1976); and c) Trosper has employed the proceedure to determine the relative ranching efficiency of Northern Cheyenne Indian ranchers and their 'American' neighbors (Trosper, 1978).

Section 6. Approaches Employed in This Study

In the chapters that follow production function analysis and the Aigner and Chu, and Timmer approach are employed to study production efficiency on traditional farms in northern Nigeria.

Production functions are used for at least two reasons: first they are useful in identifying the extent to which total output can be imputed to the specified factors of production, thereby meeting one of the study objectives. Second, production function analysis provides the information needed in determining marginal factor productivity and allocative efficiency in resource utilization.

The approach developed by Aigner and Chu (1968) and later extended by Timmer (1970) is preferred to others, for the analysis of technical efficiency, for a number of reasons: a) Farrell's technique of constructing a unit isoquant is useful and relatively easy to work with in a two factor situation. But in a six or seven factor case, as in the sample employed in this study it can be very cumbersome as a means of examining efficiency of resource use. b) In the approach proposed by Boles, it was noted that the number of L.P. problems solved is exactly equal to the number of firms. There are 340 farm firms involved in this study. Thus to use Boles' method, up to 340 L.P. problems would have to be solved before all firms are classified by the efficiency measure! This would be very costly and time consuming. c) The profit function as developed by Lau and Yotopoulos requires that firm specific prices of variable inputs be explicitly specified. Such data are not available in this instance.

Finally, the fact that a functional form is specified for the hyperplane in the Aigner - Chu - Timmer model, makes it possible to compare results obtained with those of the average production function of the same form. Such a comparison can give an initial indication of factors that contribute to efficiency differentials.

CHAPTER 5

DETERMINANTS OF FARM PRODUCTIVITY--A PRODUCTION FUNCTION ANALYSIS

In Chapter three, the utilization of farm resources as well as factors related to output per man were examined and compared for the three areas, Zaria, Sokoto and Bauchi. This chapter has three major objectives: 1) to determine the relative importance of factors which affect total output; 2) to make an interarea comparison of marginal value productivities at the mean level of resource use; 3) to assess the extent to which farmers on the average allocated resources in order to arrive at the equality of marginal value productivity to marginal factor cost.

The organization of this chapter is as follows: the first section discusses the classification of variables and alternative specification of the model used in the analysis. In the second section the choice of the algebraic or functional form of the production function is considered. Section 3 presents the regression estimates arising from the models. In Section 4, results are summarized from an examination of the sample data with respect to the fulfillment or violation of some Ordinary Least Squares assumptions. In the final Section, an analysis of the main results is presented - the emphasis is on resource productivity and allocative efficiency.

Section 1. Classification of Variables

On the basis of the analysis reported in chapter three and previous studies in the north of Nigeria (Norman, 1972; Matlon, 1977) the following variables are considered relevant in the production function analysis: gross value of output, land, labor, fertilizer and seed. Each of these variables is described below.

Adjusted gross value of crop output is the dependent variable. Ideally, the dependent variable in a production function analysis should be in physical units. However, the practice of intercropping, prevalent in the study region, necessitates the use of some common basis in aggregating the output from the mixture of crops grown. Hence physical units of crop output are multiplied by the respective average product prices and aggregated to obtain the gross value of output. To permit meaningful interarea comparison uniform crop product prices were used for all three areas.[1]

The area actually cultivated is considered a better measure of land input than total farm size. The latter includes both cultivated and fallowed land. But total cultivated land does not capture differences in land quality. It can be shown that omission of the quality of resources can bias estimated coefficients in production function analysis (Griliches, 1957). Data on soil properties are not available. Hence, to reduce the effect of a land quality bias, two land variables are defined and included in the model: cultivated lowland area, and cultivated upland area. As was indicated in Section 2 of Chapter 3, lowland areas have a higher water

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[1] For details regarding this adjustment see Section 3 of Chapter 3.

table and can be used to raise two crops in a year (in contrast to one crop in upland areas). Both variables are measured in acres.

Labor is measured in man-days. Two labor variables are specified: hired labor and family labor. Family labor is in man-day equivalents and thus includes older children, female and male adult family labor.[1] Despite the use of hired and family labor (rather than total labor) the above specification ignores an important aspect of labor use: the influence of the type of farm operation performed by labor. Examples are the use of labor for land preparation, weeding and harvesting. Second, the variables family and hired labor do not tell anything about the timeliness of labor use. Data on these variables are, however, not available.

Two fertilizer variables are specified: organic and inorganic. Since very little inorganic fertilizer was used by farmers in the areas, an alternative specification of the variables is to use an aggregate of the two. But such an aggregation would imply that the two inputs are perfect substitutes, i.e., equivalent in quality. It is true that organic fertilizer can be used in place of inorganic fertilizer. However, the substitutability ratio is not known and is not likely to be on a 1:1 basis. Organic fertilizer is measured in physical units--tons; while inorganic fertilizer is in value terms. Specifying the latter in value terms is not likely to create a significant bias for one reason: At the time of the survey fertilizer was sold to farmers at uniform prices in all three areas.

The seed variable is based on an imputed cost of planted seed and cuttings. An imputed value is used because planted seeds were obtained

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[1] Detailed on equivalent ratios are presented in Chapter 3.

from the quantity saved from the previous year's harvest. The seed variable serves as a proxy for planting density. In this respect, it is hypothesized that the estimated elasticity of the seed variable could be positive or negative. Work by Andrews on sorghums shows that low planting densities may lead to low yields because local varieties may not make a complete canopy at flowering time (implying an inefficient use of sunlight). On the other hand very high densities increase the risk of inducing moisture stress towards the end of the season--which might result in crop failure (Andrews, 1976, p. 55).

In view of the above classification of variables, the general form of the production function specified for each area is

$$Y = f(X_1, \ldots X_7, e) \qquad 5\text{-}1$$

where

Y = adjusted gross value of crop output (in 0.1 naira)

X_1 = total cultivated lowland area (in acres)

X_2 = total cultivated upland area (in acres)

X_3 = hired labor (in man-days)

X_4 = family labor (in man-day equivalents)

X_5 = quantity of organic fertilizer (in tons)

X_6 = inorganic fertilizer (in 0.1 naira)

X_7 = planted seed and cuttings (imputed cost in 0.1 naira)

e = disturbance term.

Alternative Specifications

In Chapters 2, and 3 the use of appropriate man-equivalent ratios to convert child and female labor was discussed. Where no consistent

aggregate index exists for family labor any equivalent ratio used can lead to error in the estimated labor coefficient.

One may also question the validity of specifying a single hired labor variable. Hired labor consists of three classes of labor: kwadago, hired labor paid for on an hourly basis; jinga, contracted labor paid for on a piece-rate basis; and gayya, voluntary communal labor which involves no formal wages, but some food and drinks are usually offered to the employee.

In order to assess if quality differences[1] exist in these different classes of labor, alternative specifications are examined in which family and hired labor are disaggregated. Models which include dummy variables for villages and cattle ownership also are considered.

Section 2. Choice of Functional Form

The usual guides to the selection of an appropriate algebriac form in production function analysis include: a) the consistency of the chosen function with the objectives of the investigation b) knowledge of the relationships that exist between variables and c) a consideration of existing theories of the science involved. (Heady and Dillon, p. 102-107).

Economic theory with respect to resource allocation in traditional agriculture indicates that there are "comparatively few significant inefficiencies in the allocation of factors of production" (Schultz, 1964, p. 37). Previous work in the study regions seem to support this theory (Norman, 1972). The theory assumes perfect competition and implies that farmers are operating in the second stage of the neoclassical production

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[1] Such differences may show up through varying contributions to total output.

function--a stage characterized by positive but declining marginal productivity of inputs.

Given the focus of this chapter (specified in its introduction), the search for an appropriate functional form reduces to identifying a function which not only facilitates the realization of the objective of the analysis but also exhibits declining and positive marginal productivity of resources. Functional forms that satisfy the above conditions include: the quadratic, square root, Cobb-Douglas and the transcendental.

A basic objection to the use of the quadratic and square root functions in productivity analysis is the large number of coefficients that have to be estimated. In a two regressor model for example these two forms require the estimation of five parameters (i.e., two each for the linear and square root/square terms and an interaction term). The large number of estimated coefficients results in a loss in degrees of freedom. And for the quadratic form, the coefficients may not be significant "in a probability sense" (Heady and Dillon, p. 98).

The transcendental function exhibits increasing, decreasing and negative marginal returns, either singularly, in pairs or all three simultaneously (Halter, et. al. 1957, p. 966). To estimate the transcendental function for a given assumption with respect to marginal productivity, certain restrictions must be imposed on the model. Besides, solutions can only be obtained by iterative procedures. In addition, to these complex estimating procedures the number of coefficients estimated in a transcendental function is twice the number of regressors (assuming a log transformation of the function). Thus for this function there is also a loss in the degrees of freedom--though to a less extent compared to the quadratic and square root functions.

The Cobb-Douglas production function, besides permitting the phenomenon of decreasing and positive marginal productivity (without additional complex computations), has other advantages: a) estimated coefficients are the elasticities of production--percentage change in output from a one percent change in an input b) marginal productivity of resources can be easily computed and c) it provides a direct test of economic rationality since it accounts for only the second stage of the production function.

A common criticism of the Cobb-Douglas production function is its assumption of constant elasticities of production. (Ulveling and Fletcher, 1970). This criticism may be valid where production technologies differ within a sample of farmers since production elasticities can be expected to vary for different levels of technology. In the three samples used in this study there is a uniform level of technology (i.e., traditional). In any case, knowledge of elasticities over different parts of the function is not an objective of this chapter.

In view of the above considerations the Cobb-Douglas production function is employed in the analysis that follows.

Section 3. Estimating Equation and Results

The variables specified in Section 1 are incorporated in a Cobb-Douglas production function to yield the following equation:

a) Main Model:

$$\ln Y_j = \alpha_o + \beta_1 \ln X_{1j} + \beta_2 \ln X_{2j} + \beta_3 \ln X_{3j} + \beta_4 \ln X_{4j} + \beta_5 \ln X_{5j} + \beta_6 \ln X_{6j} + \beta_7 \ln X_{7j} + e_j \qquad 5\text{-}2$$

where all variables are as previously defined in equation (5-1), $\beta^{(s)}$ are parameters to be estimated, e is the disturbance term and α_o

is the intercept.

Equations were estimated separately for Zaria, Sokoto and Bauchi. However, in the Bauchi sample no farmer used inorganic fertilizer, hence, X_6, is omitted for all Bauchi estimates.

Results of Main Model

Table 5-1 presents the estimated coefficients and their t-values for the main model.[1]

The $\bar{R}^2$, the coefficient of multiple determination adjusted for degrees of freedom indicates that, for the Zaria sample, 78 percent of the variance in total output is associated with the factors of production specified in the model. The $\bar{R}^2$ is lowest in Bauchi (.68).

The regression coefficients are the elasticities of production for the individual factors: thus in Zaria for example, a 10% increase in upland area is associated with a 3.6% increase in the gross value of output. All factors have positive elasticities smaller than one, implying diminishing but positive marginal returns. A summary of other results follows:

a) The elasticity of cultivated lowland is significant at the .05 level in Zaria and Bauchi. Although the coefficient is not significant in Sokoto, it is larger than its standard error.

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[1] Freund and Debertin have shown that t-tests cannot be used on more than one variable in an equation or on more than one equation for a certain variable -- on the grounds that the probability of erroneous rejection refers only to any one significance test. (Freund and Debertin, 1975). The use of the test and the terminologies related to statistical significance in the presentation of results is by convenience. The limitations of the test is recognized.

TABLE 5-1. ESTIMATED COEFFICIENTS: COBB-DOUGLAS PRODUCTION FUNCTION ZARIA, SOKOTO AND BAUCHI (OLS)

(MAIN MODEL) DEPENDENT VARIABLE: GROSS VALUE OF CROP OUTPUT (ADJUSTED FOR DIFFERENCES IN PRICES)

Explanatory Variables	Zaria		Sokoto		Bauchi	
	Coefficient	t-value[a]	Coefficient	t-value	Coefficient	t-value
Constant	4.394		3.798		4.291	
Cultivated Lowland (Acres)	0.054	2.35	0.038	1.48	0.066	2.20
Cultivated Upland (Acres)	0.361	5.31	0.194	2.28	0.521	6.44
Hired Labor (Man Days)	0.034	3.16	0.073	4.77	0.014	1.17
Family Labor (Man Days)	0.242	3.33	0.255	3.05	0.335	3.38
Organic Fertilizer (Tons)	0.034	2.94	0.007	0.15	0.014	1.33
Inorganic Fertilizer (Cost in 0.1 naira)	0.019	1.11	0.030	0.77	--	--
Seed/Cuttings (Cost in 0.1 naira)	0.212	3.70	0.412	4.17	0.038	0.57
$\bar{R}^2$	0.786		0.714		0.686	
Standard Error of Estimate	0.365		0.397		0.386	

[a] The degrees of freedom for the t-test are: Zaria = 116, Sokoto = 92, Bauchi = 109.

b) In all three areas elasticities are highest for cultivated upland and family labor--both of which are significant at .01 level. The relatively lower elasticities for land in Sokoto may be a reflection of lower fertility levels.

c) Hired labor consistently has lower production elasticities relative to family labor. This is probably due to the lower amount of hired labor used (i.e. relative to family labor). The elasticities of hired labor are all statistically significant except in Bauchi where the coefficient also has the lowest value.

d) The two fertilizer variables have relatively low elasticities. In Zaria, however, the coefficient of organic fertilizer was significant at the .01 level. The low levels of inorganic fertilizer used, and the low nutrient content of organic fertilizer may have contributed to their observed low elasticities.

e) The coefficients of the seed/cuttings variable--a proxy for planting density is high and significant for Zaria and Sokoto at the .01 level. Possible explanations for the high values are: 1) potential measurement error in imputing costs and 2) high correlation of the variable with cultivated land area. With respect to the former, cotton-seed, a major input in Zaria, for example, was not costed since it was issued free to farmers by the government. It is also possible that the coefficient reflects the appropriate contribution of the seed/cuttings variable to total output.

f) For all areas the sum of the elasticities is close to one, i.e. 0.956, 1.009 and 0.988 for Zaria, Sokoto and Bauchi respectively. This implies constant returns to scale in all areas. Thus a given percentage

TABLE 5-2. BETA-COEFFICIENTS AND RANK OF EXPLANATORY VARIABLES: COBB-DOUGLAS PRODUCTION FUNCTION: ZARIA, SOKOTO, BAUCHI

Explanatory Variables	Zaria		Sokoto		Bauchi	
	Beta	Rank	Beta	Rank	Beta	Rank
Cultivated Lowland	0.146	5	0.120	5	0.174	3
Cultivated Upland	0.316	1	0.2395	3	0.535	1
Hired Labor	0.152	4	0.324	2	0.065	5
Family Labor	0.181	3	0.2390	4	0.285	2
Organic Fertilizer	0.137	6	0.009	7	0.077	4
Inorganic Fertilizer	0.049	7	0.042	6	--	-
Seed/Cuttings	0.292	2	0.449	1	0.051	6

increase in all inputs will result in an equal percentage increase in output.

To determine the relative importance of the different factors in contributing to total output, beta coefficient (β^*) are computed for regressors in the main model.[1] The beta coefficients and their ranks (in order of magnitude) are given in Table 5-2. The table shows cultivated lowland area, seed/cuttings, and family labor (in that order) to be the most important contributors to total output in the Zaria sample. In Sokoto, hired labor replaces family labor in the above ordering of variables; while in Bauchi, cultivated lowland, cultivated upland and family labor have the highest ranks.

Alternative Specifications

Tables 5-3 through 5-5 present estimated coefficients and their t-values for the four alternative specifications.

In general the results demonstrate the stability of the main model. This is evident in the values of the coefficient of multiple determination and the standard error of estimate. In addition, estimated coefficients (except in one instance) are reasonably consistent with the results of the main model.

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[1] $\beta_i^* = \beta_i \frac{\sigma x_i}{\sigma y}$

(Beta coefficient)

where

$\hat{\beta}_i$ = estimated coefficient and

σ_{Xi} and σ_y are standard deviation of the independent and dependent variables respectively. (Goldberger pp. 197-198).

A more specific examination of selected parameters follow:

a) In all areas the hypothesis of zero parameter for the female adult labor variable is not rejected. The elasticity of children labor is statistically significant only for the Bauchi sample. In Zaria and Sokoto, the contribution of male adult labor is greatest. The results confirm the validity of using some conversion factor less than one in expressing female and child labor in man equivalents.

b) There are inter-area differences in the relative contribution of different sources of non-family labor. In Zaria, only hourly paid labor has a significant elasticity (significant at the 0.05 level). In Bauchi and Sokoto, however, the coefficient is not significant. In Sokoto, contract labor has a higher elasticity than other forms of hired labor.

It may be noted that disaggregating hired labor in the Bauchi sample produces what appears to be results superior to those obtained from using the main model. For example, while the elasticity for hired labor (aggregated) is 0.014 for the main model, it is 0.105 for contract labor in the alternative model. Thus aggregating the hired labor variable appears to have masked the effect of contract labor.

c) With the inclusion of intercept shifting village dummies, the parameter of the least remote village has a negative sign in Sokoto and Buachi. This would imply a lower intercept for nearby villages than for other villages. The hypothesis of equal intercepts for three villages in

TABLE 5-3. ALTERNATIVE SPECIFICATIONS: ESTIMATED COEFFICIENTS - ZARIA

Explanatory Variables	Disaggregating Family Labor	Disaggregating Hired Labor	Including Village Dummies	Including Cattle Ownership Dummies	Main Model Coefficients
	(Coefficients and t-values in brackets)				
Constant	4.66	4.02	4.58	4.461	4.39
Cultivated Lowland	0.057 (2.49)	0.051 (2.25)	0.056 (2.43)	0.064 (2.78)	0.054 (2.35)
Cultivated Upland	0.381 (5.63)	0.312 (4.50)	0.414 (5.75)	0.329 (4.75)	0.361 (5.31)
Hired Labor	0.033 (3.00)	--	0.031 (2.58)	0.028 (2.59)	0.034 (3.16)
Contract Labor	--	0.031 (1.13)	--	--	--
Daily Paid Labor	--	0.060 (2.40)	--	--	--
Communal Labor	--	0.041 (1.17)	--	--	--
Family Labor	--	0.299 (3.98)	0.189 (2.48)	0.226 (3.13)	0.242 (3.33)
Male Adult Days	0.197 (2.81)	--	--	--	--
Female Adult Days	0.020 (0.46)	--	--	--	--
Older Children Days	0.018 (1.05)	--	--	--	--
Organic Fertilizer	0.033 (2.75)	0.029 (2.50)	0.024 (2.00)	0.028 (2.39)	0.034 (2.94)
Inorganic Fertilizer	0.021 (1.17)	0.013 (0.74)	0.022 (1.29)	0.026 (1.48)	0.019 (1.11)
Seed/Cuttings	0.198 (3.41)	0.205 (3.61)	0.196 (3.43)	0.234 (4.10)	0.212 (3.70)
Village Dummy Least Remote	--	--	0.202 (2.06)	--	--
Village Dummy Intermediate	--	--	0.143 (1.53)	--	--
Cattle Ownership Dummy	--	--	--	0.247 (2.13)	--
$\bar{R}^2$	0.783	0.796	0.791	0.792	0.786
SE	0.367	0.356	0.361	0.359	0.365
d.f. for t-test	114	114	114	115	116

TABLE 5-4. ALTERNATIVE SPECIFICATION: ESTIMATED COEFFICIENTS - SOKOTO

Explanatory Variables	Disaggregating Family Labor	Disaggregating Hired Labor	Including Village Dummies	Including Cattle Ownership Dummies	Main Model Coefficients
	(coefficients and t-values in Brackets)				
Constant	4.379	3.431	3.758	3.752	3.798
Cultivated Lowland	0.039 (1.50)	0.021 (0.92)	0.005 (0.18)	0.035 (1.36)	0.038 (1.48)
Cultivated Upland	0.161 (1.88)	0.185 (2.41)	0.263 (2.98)	0.198 (2.33)	0.194 (2.28)
Hired Labor	0.073 (4.62)	--	0.047 (2.76)	0.068 (4.24)	0.073 (4.77)
Contract Labor	--	0.114 (3.26)	--	--	--
Daily Paid Labor	--	0.058 (1.48)	--	--	--
Communal Labor	--	0.079 (2.75)	--	--	--
Family Labor	--	0.342 (4.44)	0.226 (2.82)	0.258 (3.11)	0.255 (3.05)
Male Adult Days	0.148 (2.76)	--	--	--	--
Female Adult Days	0.002 (0.05)	--	--	--	--
Older Children Days	0.003 (0.14)	--	--	--	--
Organic Fertilizer	0.043 (0.91)	-0.088 (1.95)	0.048 (0.94)	-0.009 (0.18)	0.007 (0.15)
Inorganic Fertilizer	0.029 (0.71)	0.011 (0.31)	0.032 (0.84)	0.029 (0.74)	0.030 (0.77)
Seed/Cuttings	0.418 (4.17)	0.345 (3.79)	0.405 (4.22)	0.415 (4.23)	0.412 (4.17)
Village Dummy Least Remote	--	--	-0.237 (1.87)	--	--
Village Dummy Intermediate	--	--	0.289 (1.68)	--	--
Cattle Ownership Dummy	--	--	--	0.103 (1.12)	--
$\bar{R}^2$	0.706	0.770	0.740	0.715	0.714
Standard Error	0.403	0.356	0.379	0.396	0.397
d.f. for t-tests	90	90	90	91	92

TABLE 5-5. ALTERNATIVE SPECIFICATION: ESTIMATED COEFFICIENTS - BAUCHI

Explanatory Variables	Disaggregating Family Labor	Disaggregating Hired Labor	Including Village Dummies	Including Cattle Ownership Dummies	Main Model Coefficients
	(Coefficients and t-values in Brackets)				
Constant	5.442	3.967	4.309	4.172	4.291
Cultivated Lowland	0.073 (2.28)	0.047 (1.62)	0.064 (1.73)	0.070 (2.36)	0.066 (2.20)
Cultivated Upland	0.576 (7.10)	0.468 (5.92)	0.485 (5.55)	0.491 (6.08)	0.521 (6.44)
Hired Labor	0.009 (0.75)	--	0.019 (1.46)	0.012 (1.02)	0.014 (1.17)
Contract Labor	--	0.105 (3.62)	--	--	--
Daily Paid Labor	--	-0.042 (1.23)	--	--	--
Communal Labor	--	0.014 (0.58)	--	--	--
Family Labor	--	0.391 (4.07)	0.347 (3.47)	0.360 (3.67)	0.335 (3.38)
Male Adult Days	0.040 (0.73)	--	--	--	--
Female Adult Days	-0.001 (0.05)	--	--	--	--
Older Children Days	0.048 (2.52)	--	--	--	--
Organic Fertilizer	0.011 (1.01)	0.016 (1.56)	0.018 (1.63)	0.012 (1.15)	0.014 (1.33)
Inorganic Fertilizer	--	--	--	--	--
Seed/Cuttings	0.119 (1.65)	0.027 (0.42)	0.052 (0.77)	0.042 (0.65)	0.038 (0.57)
Village Dummy Least Remote	--	--	-0.121 (1.17)	--	--
Village Dummy Intermediate	--	--	-0.097 (0.72)	--	--
Cattle Ownership Dummy	--	--	--	0.242 (2.22)	--
$\bar{R}^2$	0.667	0.712	0.684	0.697	0.686
Standard Error	0.398	0.370	0.387	0.379	0.386
d.f. for t-tests	107	107	107	108	109

each area was tested.[1] The hypothesis was rejected only for Sokoto. This indicates that differences between Sokoto villages are statistically significant. The value of the intercept for the Sokoto village was calculated and found to be 3.758 for the most remote village, 4.047 for the intermediate and 3.521 for the least remote village.

d) The use of a dummy variable to allow for a shift in the intercept for cattle ownership showed no appreciable affects on estimated coefficients for any of the three samples. However the hypothesis of equal intercept for cattle owners and non-cattle owners was rejected in two of the areas , Zaria and Bauchi.[2]

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1 This is an F-test (Ben-David and Tomek, 1965). The relevant F-statistic is given by:

$$F_{(v1,v2)} = \frac{SSE_M - SSE_A}{SSE_A} \cdot \frac{V_2}{V_1}$$

where

SSE_M = Sum of squared residuals for estimated main model

SSE_A = Sum of squared residuals for the alternative model

V_1 = Degrees of freedom of main model minus degrees of freedom of alternative model.

V_2 = Degrees of freedom of alternative model.

2 The main model will be used in subsequent analysis for one major reason: except for the Bauchi sample, estimated coefficients are similar to those obtained for the main model.

Section 4. Analysis of Multicollinearity and Heteroscedacticity

Econometric theory suggests that the violation of basic OLS assumptions may lead to lack of significance of estimated coefficients and produce inefficient results. These problems could arise if: a) there is a high degree of multicollinearity among regressors and b) if regression residuals do not have common variances (heteroscedasticity). These two issues were examined with respect to the main model (Appendices 2 and 3).

With regards to multicollinearity: i) the simple correlation matrix indicates multicollinearity is not a serious problem in all three samples. ii) an alternative analysis based on an application of Klein's rule, confirms the non-severity of multicollinearity only for the Zaria sample; and shows the seed/cutting variable to contribute most to multicollinearity in the Sokoto and Bauchi samples. iii) an adjustment for multicollinearity involving the omission of the seed/cutting variable from the estimated equation for the two areas produced results, inferior to those obtained with the original model.[2]

Hence, subsequent analysis will be based on the original model without adjusting for multicollinearity.

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[1] Because the results arising from the examination are not employed in subsequent analysis, they are only summarized in this section.

[2] The omission of the seed cutting variable is merely exploratory. This variable was earlier shown to be one of the most important explanatory factors in the model. Thus the deletion of the variable has no practical justification.

With respect to the analysis of the regression residuals, the following conclusions are drawn:

i) A plot of residuals for all three samples indicates that none of the residuals lie three or more standard deviations from the mean (Appendix 3).[1]

ii) The null hypothesis of equal village residual variances was rejected only for Zaria.

iii) A correction for heteroscedasticity based on an application of Weighted Least Squares, gave results with negative elasticities for cultivated lowland and organic fertilizer. Negative elasticities appear meaningless since it is not logical that production would decline if either of these factors are increased.[2]

Hence, the model adjusted for heteroscedasticity is not used in subsequent analysis.

Section 5. Estimates of Marginal Value Products

In this section estimated coefficients mostly based on the main regression (Table 5-1) are employed in the calculations of marginal value productivity (MVP) at the geometric mean of resourse use.[3] The section

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[1] This is strictly a test for outliers. The presence of outliers is usually regarded as a potential contributor to unequal residual variances (Draper and Smith, 1967).

[2] The high level of sensitivity of some variables to the adjustment made is shown to be related to the lack of variability within the sample for the factors concerned (Appendix 3).

[3] $MVP = \beta_i(\frac{\overline{Y}}{\overline{X}_i})$

where β_i = estimated coefficient; $\overline{Y}$ and $\overline{X}_i$ are geometric mean of the dependent and independent variables respectively.

also includes discussions on: a) tests of interarea differences in marginal value prodicutivites and b) equality of marginal value productivity with marginal factor cost.

Marginal Value Productivity

Calculated MVP's for resources are presented in Table 5-6. The table indicates that marginal value productivities are all positive. Except for total family labor differences between regions are evident. Factor specific observations can be made.

a) Land: An acre of cultivated lowland has a marginal productivity four times that of an acre of cultivated upland in Zaria. In Sokoto the ratio of marginal productivity of lowland relative to upland is slightly over ten. The higher productivity of lowland area is expected. Lowland area has a higher soil water table and while two crops can be raised in such farm land in a year, only one crop can be raised on upland farms. The MVP for cultivated lowland in Bauchi appear unreasonably high. A bias in the estimated coefficient or perhaps some measurement error is probably responsible for the high MVP.[1]

The marginal value productivity for upland area is highest in Bauchi 92.1 shillings[2] which is about equal to the value estimated for the Zaria sample 90.6 shillings. However, both of these MVP's are more

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[1] This may also be due to the low level of the inputs used. The very high MVP for organic fertilizer in Bauchi may be due to similar influences.

[2] One shilling is equivalent to 0.1 Naira - the current Nigerian currency.

TABLE 5-6. MARGINAL VALUE PRODUCTIVITIES OF RESOURCES: ESTIMATES FOR ZARIA, SOKOTO AND BAUCHI

Resources	Marginal Value Products (Shillings by Areas)[a]		
	Zaria	Sokoto	Bauchi
Cultivated Lowland (Acre)	344.8	405.0	2268.9[b]
Cultivated Upland (Acre)	90.6	39.8	92.1
Hired Labor (Man Days)	8.4	15.9	2.9
Family Labor (Man Days)	1.1	1.5	1.4
Organic Fertilizer (Tons)	41.2	1.5	348.5[b]
Inorganic Fertilizer (Cost in 0.1 naira)	1408.9[b]	3226.6[b]	—
Seed and Cuttings (Cost in 0.1 naira)	3.5	8.6	1.1

[a] Shillings were the original units of measurement. One shilling is equivalent to 10 kobo or 0.1 Naira, the current unit of Nigerian currency.

[b] These values appear unreliably high and will not be used in subsequent analysis.

than twice the corresponding estimate for the Sokoto sample. The low MVP for upland area in Sokoto appear to be a combined effect of its drier climatic and poorer soil conditions.[1] Table 5-7 shows that on the average, rainfall-evaporation deficits is highest for Sokoto. And Norman's description of upland soils in Sokoto point clearly at their low fertility:

> "Upland soils on the other hand are derived from deeply weathered parent material of very low fertility. Those suited to wet season agriculture may be described in general terms as very permeable, brown and orange loose sands, with a small proportion of silt and clay." (Norman, 1976, p. 2).

b) Labor: Table 5-6 indicates that the MVP of famliy is generally lower than the MVP of hired labor.

There are at least three reasons why low MVP of family labor can occur on the same farms with a high MVP for hired labor:

i) It is possible that the weighting scheme used in aggregating the various components of family labor resulted in a downward bias in estimated marginal productivity. Although the equivalent ratios used in converting female and child labor to man-days should have reduced such a bias, it may not have completely removed it. In any case quality differences in hired labor are likely to be less serious than in family labor.

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[1] In general, calculated MVP's, except where otherwise indicated, appear reasonable. Norman's work in Zaria show MVP's of 95 and 383 shillings for gona and fadama respectively (Norman, 1972). And Lunning's earlier work in Sokoto indicates MVP of 1.62 shillings for labor (Lunning, 1967).

TABLE 5-7. RAINFALL - EVAPORATION DEFICITS[a]

ALL STUDY AREAS

Region	Mean Annual Rainfall (ins)	Mean Annual Evaporation (ins)	Deficit (ins)
Zaria	43.9	74.6	30.7
Sokoto	29.6	65.8	36.2
Bauchi	43.4	57.6	14.2

[a] These are mean values over a number of years. Rainfall data specific to survey year are not available.

SOURCE: Kowal, J.M. and D.T. Knabe, Agroclimatological Atlas of the Northern States of Nigeria. Zaria, Nigeria Ahmadu Bello University Press (1972).

ii) It can be argued that unlike hired labor, family labor is actually a "joint input" to crop production and other household non-farm activities (Brown and Salkin, 1974). The implication is that the MVP for family labor on family farms may not reflect the demand of non-farm household responsibilities on farmers. It is conceivable that the mental and physical pressures of such responsibilities can result in a low family labor productivity. While it is not denied that hired labor may have similar responsibilities, the presence of a reward in form of wage offers an incentive, absent in the case of family labor.

iii) Another potential reason is that hired labor is only hired in crucial situations where and when the marginal returns are likely to be high. This is in contrast to family labor which is more like a fixed factor.

The relatively low MVP for labor in the Bauchi sample may be partly a reflection of the smaller quantity of farm capital per worker observed in the Bauchi data (Table 5-8). The table indicates that the inventory value of durable capital as well as farm cash expenses per worker in Bauchi were about half the values in the other two areas.

c) Fertilizer: The relatively low marginal productivity for organic fertilizer in Sokoto may be partly due to the low soil moisture (discussed with respect to the land variable) and which could hinder the uptake of fertilizer by crop plants.

TABLE 5-8. FARM CAPITAL PER WORKER (AREAS)

Region	Family Size in Man-Equivalents	Inventory Value of Durable Capital per man (In Naira)	Farm Cash Expenses per man (₦)
Zaria	4.9	0.24	0.51
Sokoto	3.5	0.23	0.45
Bauchi	3.6	0.12	0.23

Tests of Significance of Inter-Area Differences in Marginal Value Productivities

The objective in this subsection is to determine which inter-area differences in marginal value productivites are significant. The underlying question is whether resources could be transferred from one area to another, thereby increasing the returns to the resources concerned.

To compare the MVP of resourse X_i in area a, with the MVP of the same resource in area b, for example, the following proceedure is followed:

1) The coefficient β' for resource X_i in area b necessary to equate its marginal value productivity with the value obtained for area a, is computed from the relationship:

$$\beta'b = \hat{\beta}_a \cdot \frac{\bar{Y}a\ \bar{X}b}{\bar{Y}b\ \bar{X}a}$$

where

$\hat{\beta}_a$ = estimated coefficient in Region a

$\bar{Y}$ and $\bar{X}$ = geometric mean of output Y and input X_i respectively.

2) A t-test is then employed to determine if $\beta'b$ is significantly different from $\hat{\beta}b$, the actual elasticity for area, b.

The results arising from the tests are presented in Table 5-9.

The figures presented in Table 5-9 are the coefficients necessary to equalize the MVP's for the given factors of production in the region in the left margin with the MVP's of the same resource in the region at the top of the right hand columns. For cultivated lowland, for example, an elasticity of 0.063 would have been necessary to equate the MVP of cultivated lowland in Zaria with the MVP of the same resource in Sokoto.

TABLE 5-9. INTER-AREA COMPARISON OF DIFFERENCES IN MVP'S: ELASTICITIES NECESSARY TO EQUATE MVP OF A RESOURCE IN ONE AREA TO THE MVP OF SAME RESOURCE IN ANOTHER AREA

Resources and Areas for Which Test Made	Needed Coefficients and Their t-test Ratios (in Brackets)		
	Zaria	Sokoto	Bauchi
Lowland:			
Zaria	--	0.063 (0.39)[a]	--
Sokoto	0.032 (0.24)[a]	--	--
Bauchi	--	--	--
Upland:			
Zaria	--	0.158 (2.98)	0.367 (0.09)[a]
Sokoto	0.442 (2.92)	--	0.449 (3.00)
Bauchi	0.512 (0.11)[a]	0.225 (3.65)	--
Hired Labor:			
Zaria	--	0.065 (2.82)	0.012 (2.00)
Sokoto	0.408 (22.33)	—	0.013 (4.00)
Bauchi	0.040 (2.17)	0.077 (5.25)	--
Family Labor:			
Zaria	--	0.319 (1.055)[a]	0.315 (1.00)[a]
Sokoto	0.193 (0.75)[a]	--	0.215 (0.05)[a]
Bauchi	0.273 (0.82)[a]	0.360 (0.05)[a]	--
Family Male Adult Labor:			
Zaria	--	0.207 (0.14)[a]	0.040 (2.21)
Sokoto	0.141 (0.13)[a]	--	0.028 (2.26)
Bauchi	0.196 (2.84)	0.206 (3.02)	--
Seed/Cuttings:			
Zaria	--	0.525 (5.49)	0.069 (2.51)
Sokoto	0.166 (2.51)	--	0.055 (3.64)
Bauchi	0.116 (1.18)[a]	0.286 (3.76)	--
Organic Fertilizer:			
Zaria	--	0.001 (3.00)	--
Sokoto	0.194 (3.89)	--	--
Bauchi	--	--	--

[a] Difference not significant at .05 level

On the other hand, the elasticity of cultivated lowland in Sokoto would have to be reduced from 0.038 to 0.032 to equate the MVP of cultivated lowland in Sokoto to what it is in Zaria.

The table shows that it is only for family labor and cultivated lowland that observed inter-area differences in MVP's are not significant. The results suggest that farm resources such as hired labor, seed and fertilizer could be reallocated geographically with consequent gains in farm productivity.

Equality of Marginal Value Productivity and Marginal Factor Costs

The analysis discussed in this subsection is restricted to those variables for which estimates of marginal factor costs are available -- land and labor. The objective here is to determine the extent to which farmers on the average allocated resources in order to arrive at the equality of their MVP's to their marginal factor costs (MFC).[1]

Table 5-10 presents the ratio of MVP's to MFC's for cultivated upland and labor. The average wage rate for hired labor was used to value family labor. Family male adult labor is included in the analysis (and valued at the same wage rate for hired labor) since the bulk of family labor used consisted of male adult labor (Chapter 3). Both land rents and wage rates are based on Norman (1972); Norman et al., (1976); Norman and Pryor, (1978). Although there was no direct cash

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[1] It is recognized that in traditional agriculture, the goal of security and food self-sufficiency may be more important than that of profitability implied in allocative efficiency. In view of this, deviations from allocative efficiency may be regarded as the penalty farmers have to pay to achieve their security goal.

TABLE 5-10. RATIO OF MARGINAL VALUE PRODUCTIVITY TO MARGINAL FACTOR COST[a]: SELECTED FACTORS

Factors[1]	Ratios by Regions		
	Zaria	Sokoto	Bauchi
Cultivated Upland	6.47	3.62	9.21
Total Hired Labor	3.73	10.58	2.12
Total Family Labor	0.51	1.01	1.03
Family Male Adult Labor	0.47	0.74	0.16

[a] The MFC values used are:

	Zaria	Sokoto	Bauchi
Land (acre)	14.0	11.0	10.0
Labor (man day)	2.24	1.50	1.36

(in shillings)

transactions for land, rent was in the form of bundles of millet and sorghum. The grain from exchanged bundles was valued and divided by the average field size to arrive at the value for rent.

The ratios presented in Table 5-10 show some inter-area differences: For example, the MVP for upland is at least nine times its rental value for Bauchi. The corresponding statistics for Sokoto and Zaria are 3.6 and 6.5 respectively. The ordering of the ratios for the three areas with respect to hired labor is the reverse: highest for Sokoto 10.6 and lowest for Bauchi, 2.1.

Theoretically an MVP/MFC ratio of 1.0 is accepted as evidence of allocative efficiency. On the other hand, a ratio greater than 1.0 implies too little and inefficient use of a resource, while a ratio less than 1.0 suggest excessive use and inefficient use of resources. Thus the results imply that on the average, at least for Sokoto and Bauchi, family labor was allocated efficiently in farm production.

There are at least three possible explanations for the high MVP of hired labor relative to its wage rate.

a) Imperfect knowledge on the part of farmers as to the contribution of hired labor to farm output--resulting in the use of less than adequate amount of labor even if it were possible to hire more labor.

b) Lack of alternative employment alternatives for labor which would make farmers monopsony buyers of labor so that wage rates are driven below their market price for labor.

c) A shortage of labor available for hiring at the times needed but existent social contraints such as kinship ties, and the traditional law of reciprocity in farm help, contribute in keeping wage rates down.

From the original data and what is known of the regions, the third explanation is more plausible since it is in agreement with the phenomena of labor shortages experienced by farmers at certain times of the farm year, and the practice of gayya--or communal labor in all three regions.

The low MVP/MFC ratio for family labor may be a reflection of the use of a higher opportunity cost, for family labor, than is actually appropriate. This raises a basic question with respect to the valuation of farm family labor: Is it valid to value farm family labor at the ongoing wage rate? This question is outside the scope of this section's discussions. However, it is conceivable that the true opportunity cost of marginal family labor is less than the ruling wage rate. This observation is especially true in a situation where some family members are not free to enter the labor market (e.g. the practice of auren kulle, the seclusion of wives common among Hausa Muslims, who constitute the bulk of the sample of farmers participating in this study).[1]

Deviation From Allocative Efficiency

Calculated MVP/MFC ratios can provide further information. Since the equality of MVP and MFC provide a measure of allocative efficiency, the extent to which the MVP of a resource Xi should be changed to arrive at its equality with MFC is provided by:[2]

$$cx_i = \left(\frac{ax_i - bx_i}{ax_i}\right) 100 = (1 - 1/r)^{100}$$

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1 As mentioned in the previous subsection, a contributing factor to the relatively low MVP of family labor is that it is treated as a fixed input.

2 Based on Shapiro, 1977.

where

cx_i = the absolute value of the required percentage change in MVP of resource Xi.

ax_i = MVP of Xi

bx_i = MFC of Xi

$r = ax_i/bx_i$

Table 5-11 presents computed values for cx_i. The results show, for example, that in Zaria, farmers on the average should have reallocated upland area so as to change its MVP by 85 percent to achieve allocative efficiency.

The results suggest that there are appreciable deviations from allocative efficiency with respect to land and labor in the study regions. This is at variance with conclusions of most studies on traditional agriculture (Schultz. 1964; Sohata, 1968). However, the conventional test for allocative efficiency involves the use of a t-test to examine the null hypothesis of equality of MVP with MFC. But, the t-test provides the probability of error only for finding that MVP is different from MFC and cannot provide information on the probability of a type II error such as accepting a null hypothesis of MVP = MFC when the hypothesis is false (Shapiro, 1977, p. 92).[1]

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[1] A Canadian study shows that apparent inequality between MVP's and MFC's may within broad limits have little effect upon total profits, so that an effort to bring about equality may not be as remunerative as it superficially appears (Trifon, 1961).

It was not possible to examine this issue in this case. Trifon employed profit functions which require individual observations on input and output prices. These are not available for the sample used in this study.

TABLE 5-11. PERCENTAGE CHANGE REQUIRED IN MARGINAL VALUE PRODUCTIVITY TO EQUATE IT TO MARGINAL FACTOR COST (SELECTED FACTORS)

Resources	Percentages[a] By Regions		
	Zaria	Sokoto	Bauchi
Cultivated Upland	85	73	89
Total Hired Labor	73	91	53
Total Family Labor	96	1	3
Family Male Adult Labor	113	35	525

[a] Percentages are rounded to nearest whole number

Summary

The main findings of this chapter are as follows:

a) The major factors contributing to total farm output are cultivated upland farm area, planted seed/cuttings, and labor.

b) Multicollinearity was not a serious problem. But the OLS assumption of homoscedasticity appears to have been violated for the Zaria villages due especially to the high residual variances of Dan Manhawayi. But the reestimated model gave illogical results.

c) Observed inter-area differences in marginal resource productivity (baring those for family labor and lowland area) were found to be signigicant, suggesting that gains could be achieved by shifting farm resources between areas.

d) Calculations of needed adjustments in MVP's to equate it with MFC's for land and labor showed appreciable deviations from resource allocative efficiency.

In conclusion, there is at least one limitation in the above analysis--as in any average production function approach. While it gives insight into the issue of productivity and resource allocative efficiency on the average, it does not reflect the efficiency of resource use by individual farmers. This will be the subject of the next chapter.

CHAPTER 6

POTENTIAL VERSUS ACTUAL OUTPUT - A FRONTIER PRODUCTION FUNCTION ANALYSIS

An important conventional wisdom with respect to traditional agriculture is that farmers operating within such systems are highly efficient given the resources and technology available to them (Schultz, 1964; Welsch, 1965; Sahota, 1968; Norman, 1970). The acceptance of this viewpoint by most national governments of third world countries has led to farm policies with a high emphasis on capital investments e.g. tractorization, improved varieties of seed, mineral fertilizers and the introduction of farm practices, some of which are alien to the farmers concerned (e.g. sole rather than intercropping). The high proportion of failure of agricultural programs, especially in tropical Africa (Lele, 1975), would suggest that a potential alternative would be to build upon farmers' traditional techniques.[1,2] If farmers obtain the best output possible with available resources, then past policies may be valid. However, if some farmers perform better than others with the same resources and technology, there may be scope for increasing output without major investments -- at least in the short run.

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1 There are some success stories e.g. Uboma in eastern Nigeria. However, such programs are exceptions, and extension contacts far beyond those generally available to producers are usually involved.

2 The suggested alternative is based on the fact that farmers continue to use a number of traditional practices in spite of years of extension advice to the contrary.

Causes of Inefficiencies

There are at least three reasons why firms may produce below their potential:

1. The effects of random elements in the production process, e.g., drought, disease outbreak, etc.
2. Presence of allocative inefficiencies -- an inability on the part of producers to choose optimum combinations of inputs consistent with relative factor prices.
3. Existence of technical inefficiencies -- an inability to produce the 'best' level of output with available resources and given technology level. Technical inefficiencies may be related to X-inefficiency, i.e., inefficiency resulting from motivational and non-market conditions which prevent producers from working hard enough, performing operations early enough, or from searching adequately for appropriate output increasing information (Leibenstein, 1966).

Parts of Chapter 5 dealt with allocative efficiency. The primary goal of this chapter is to generate firm specific technical efficiency indices and to employ computed indices in identifying gaps between actual and potential output. The hypotheses to be examined can be stated as follows: there are technical inefficiencies in traditional agriculture and that such inefficiencies can give rise to a considerable gap between actual and potential output.

The organization of this chapter is as follows: Section 1 summarizes alternative approaches used to measure technical efficiency. In the second section, the model employed in the analysis is presented. Section 3 presents estimated coefficients of the frontier production function with

a discussion of their sensitivities. Factors that characterize outlier observations are also examined. In section 4, individual farmer efficiency indices are computed. Included is an inter-area comparison of the distribution of computed indices. Section 5 deals with the relationships between efficiency and level of resource utilization. In section 6, the relationships between estimated efficiency scores and other performance measures -- specifically output per family man equivalent and average cost of production -- are examined. In the last section, technical efficiency indices are used to estimate potential losses in gross value of output from inefficiencies for least efficient, intermediate and top performers.

Section 1. Alternative Measures of Technical Efficiency[1]

Several approaches have been used to measure technical efficiency. These are the unit isoquant approach (Farrell, 1957); the programming approach in output-input space (Aigner and Chu, 1968); a chance constrained frontier production function approach (Timmer, 1970); and the experimental or "engineering" approach (Herdt and Mendac, 1978).

Farrell's approach operates in a factor-factor space and assumes that the efficient production function can be represented by a unit isoquant. The isoquant (which is the frontier) is a locus of points which indicates the minimum quantities of resources required to produce one unit of output with varying input proportions. Technical efficiency is measured by comparing a firm's inputs' ratio with those on the frontier.

The Aigner and Chu programming approach employs linear or quadratic programming techniques to obtain a frontier production function by minimizing the sum of deviations of an "average" production function subject

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[1] These approaches are only summarized here. A fuller discussion is given in Chapter 4.

to the constraint that all deviations are of one sign.

The chance constrained or probabilistic frontier production function approach is really an extension of the Aigner and Chu's approach. However, they differ in that while the earlier approach is deterministic, in the Timmer approach, the sensitivity of estimated coefficients to the influence of potential outliers is taken into account.

In the Herdt and Mandac approach, frontier coefficients are developed by fitting a quadratic regression equation to data gathered from experiments conducted on farmers' fields. Technical efficiency is judged by comparing actual farmers' output to output obtained by researchers on fields adjacent to the farmers. The researchers' output level is assumed to lie on the frontier.[1]

A major difficulty with Farrell's approach is that it is not general enough: "Many types of production cannot be characterized within his models. For example, it is not possible to estimate with his method, a production function which conforms to the Law of Variable Proportions." (Aigner and Chu, 1968, pp. 830-831). The criticism is appropriate since in a theoretical sense isoquants are assumed convex to the origin - thus eliminating the portion of the function over which output decreases with increases in factor utilization (Seitz, p. 510)[2]

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[1] This paper was brought to my attention by Randolph Barker, Cornell University.

[2] Seitz, however, argues that this restriction may not be severe since this area of the function may not be the relevant range.

The Aigner and Chu's approach, like all envelope approaches, has at least one shortcoming: Only marginal data are used since the bulk of the firms do not enter the frontier (Bressler, 1966).

The experimental or engineering approach is not a feasible approach for this study. The type of experimental data required by the methodology are not available.

The deterministic and chance contrained frontier production function approaches are used in the analysis that follows. The approaches are more general than Farrell's. As indicated in Chapter 7, Farrell's technique of constructing a unit isoquant may be relatively easy to work with in a two factor situation. But in a six or seven input case, as in the sample employed in this study it can be very cumbersome as a means of examining production performance. Furthermore, the chance constrained function reduces the problem of random errors in the data set since a non-deterministic approach is employed. This permits a given percentage of observations to lie outside the frontier surface. Lastly, the frontier function is based on an attainable standard and represents the best use of available resources by the farmers themselves.

Section 2. The Model

The frontier function operates in total output-input space. A functional form for the hyperplane is first specified. In this case the Cobb-Douglas production function is selected. The Cobb-Douglas is chosen for two reasons:

1. Its use gave reasonably good and logical results in the average production function analysis of Chapter 5.
2. Its use in this chapter will permit direct comparison with the results of that chapter.

Assumptions

An important assumption in the use of the approach is that technical efficiency is subsumed within the disturbance term of the chosen function. Hence the linear programming objective function is the sum of the disturbances. It is further assumed that:

1. Disturbances are all of the same sign so that all observed points in the production space lie on or below the frontier.[1]
2. Specification errors as well as errors of measurement in all variables are negligible.

The model is developed as follows.

The Model[2]

Consider the Cobb-Douglas Production Function.

$$Y_j = \sum_{i=o}^{m} \alpha_i X_{ij} + e_j \quad \text{(Y and X in logs)} \ldots \qquad (1)$$

Y_j = logarithm of the output of firm j

X_i = logarithm of the level of input i used by firm j

α_i = parameters i.e. elasticity of inputs

e_j = logarithm of the random error term

To make this a frontier function:

Error terms are constrained to one side of the estimated production surface. Thus (1) is estimated such that:

$$\sum_{i=o}^{m} \hat{\alpha}_i X_{ij} = \hat{Y}_j \geq Y_j \qquad (2)$$

---

[1] This assumption holds true only for the deterministic frontier function and not for the probabilistic function.

[2] This model was summarized earlier in Chapter 4. In this chapter operational details are included.

where, $\hat{Y}_j$ = potential output and Y_j = actual output.

If it is assumed that $\hat{e}_j > o$, (2) is rewritten as:

$$\sum_{i=o}^{m} \hat{\alpha}_i X_{ij} - e_j = Y_j$$

Summing over all j's:

$$\sum_{j=1}^{n} \sum_{j=1}^{m} \hat{\alpha}_i X_{ij} - \sum_{j=1}^{n} e_j = \sum_{j=1}^{n} Y_j$$

and

$$\sum_{i=1}^{n} e_j = \sum_{j=1}^{n} \sum_{i=o}^{m} \hat{\alpha}_i X_{ij} - \sum_{j=1}^{n} Y_j$$

Y_j's are constant for any sample. This is because for any data set, the vector of $\hat{\alpha}_i$'s that minimizes $\sum_{j=1}^{n} e_j$ for a value of ΣY_j will minimize it for any vector of Y_j's -- including zero. Hence the term may be dropped with no consequence.

Hence

$$\sum_{j=1}^{n} e_j \sim \sum_{j=1}^{n} \sum_{i=o}^{m} \hat{\alpha}_i X_{ij}$$

Dividing by n, gives

$$\sum_{j=1}^{n} e_j \sim \sum_{i=o}^{n} \hat{\alpha}_i \bar{X}_i$$

Where

$$\bar{X}_i = \frac{1}{n} \sum_{i=1}^{m} X_{ij}$$

The problem then is to minimize

$$\sum_{j=1}^{m} e_j \quad \text{subject to} \quad \sum_{i=o}^{n} \hat{\alpha}_i X_{ij} \geq Y_j, \; \hat{\alpha}_i \geq o$$

or

$$\text{Min } z = \sum_{i=o}^{m} \hat{\alpha}_i \overline{X}_i$$

$\overline{X}_o$ = column of ones (intercept)

s.t

$$\sum_{i=o}^{m} \hat{\alpha}_i X_{ij} \geq Y_j \qquad (j = 1, 2 \ldots n)$$

$$\hat{\alpha}_i \geq o$$

Expanded form:

$$\text{Min } z = \hat{\alpha}_o \overline{X}_o + \hat{\alpha}_1 \overline{X}_1 + \hat{\alpha}_2 \overline{X}_2 + \ldots + \alpha_m \overline{X}_m$$

s.t

$$\hat{\alpha}_o X_{o1} + \hat{\alpha}_1 X_{11} + \hat{\alpha}_2 X_{21} + \ldots + \hat{\alpha}_m X_{m1} \geq Y_1$$
$$\hat{\alpha}_o X_{o2} + \hat{\alpha}_1 X_{12} + \hat{\alpha}_2 X_{22} + \ldots + \hat{\alpha}_m X_{m2} \geq Y_2$$
$$\vdots \qquad\qquad \vdots \qquad\qquad \vdots \qquad\qquad \vdots$$
$$\hat{\alpha}_o X_{on} + \hat{\alpha}_1 X_{1n} + \hat{\alpha}_2 X_{2n} + \ldots + \hat{\alpha}_n X_{mn} \geq Y_n$$

$$\hat{\alpha}_i \geq o$$

m = number of factors n = number of observations

Points of Departure

Four points of departure from a conventional Linear Programming model should be noted:

1. The objective function minimizes the mean resource levels used for the production of given levels of output rather than the usual minimization of cost or the maximization of profit.
2. The matrix of constraints is given by individual farm observations of inputs in contrast to the input-output coefficients of the conventional LP model.
3. The level of the constraints, i.e., "the right hand side values" is represented by individual farm output levels.
4. Activities in the basis will be the coefficients, i.e., -- with a_o being the intercept of the frontier production function and $a_1 \ldots a_m$ the elasticities of the respective factors.[1]

But in the primal form (as presented above) the number of constraints is equal to the number of observations and is greater than the number of activities (i.e., number of factors). Hence it may be more efficient and easier to solve the dual of the problem (Agrawal and Heady, 1972, p. 74).

The dual problem may be written thus:

$$\text{Max } Z = \sum_{j=1}^{n} w_j Y_j \qquad (j = 1 \ldots\ldots n)$$

$$\text{s.t} \quad \sum_{j=1}^{n} w_j X_{ij} \leq \bar{X}_i \qquad (i = o, 1 \ldots m)$$

$$w_j \geq o$$

[1] Strictly speaking the intercept is given by the anti-log of a_o.

In an expanded form:

$$\text{Max } Z = w_1 Y_1 + w_2 Y_2 + \ldots + w_n Y_n$$

s.t

$$w_1 X_{01} + w_2 X_{02} + \ldots + w_n X_{on} \leq \bar{X}_o$$

$$w_1 X_{11} + w_2 X_{12} + \ldots + w_n X_{1n} \leq \bar{X}_1$$

$$w_1 X_{21} + w_2 X_{22} + \ldots + w_n X_{2n} \leq \bar{X}_2$$

$$\vdots \qquad\qquad \vdots$$

$$w_1 X_{m1} + w_2 X_{m2} + \ldots + w_n X_{mn} \leq \bar{X}_m$$

$$w_j \leq o$$

w_j = "shadow prices" i.e., the elasticities.

In the dual form, the following observations may be made:

1. The objective function maximizes the level of output produced from given levels of inputs. (There are as many activities as there are observations.)
2. The matrix of restrictions is given by the individual firm observations of factors of production as specified in the starting production function.
3. The levels of the constraints, i.e., the right hand side values are represented by the mean levels of resource use.
4. The "shadow prices" in the LP output provides the required $\hat{\alpha}_i$'s of the primal, i.e., the elasticities of factors in the frontier function.

A Chance Constrained Function

The procedure as presented above estimates the frontier coefficients using the entire sample. However, it is possible that firms may be efficient by chance (i.e., because of error of observations or some other problems). Chance constrained programming admits random data variations and permits constraint violation up to specified probability limits (Charnes and Cooper, 1963). The method may therefore, be viewed as an attempt to eliminate random cases from the estimated frontier function.

To derive a chance constrained frontier from the dual of the problem, the constraint of the model is replaced by a probabilistic statement. Instead of the deterministic inequality the constraint statement becomes

$$P_r \left[\sum_{j=1}^{n} w_j X_{ij} \leq \bar{X}_i \right] \geq P$$

where P is a specified probability level with which the equation is to hold. The frontier function is deterministic when $P = 100$ and probabilistic when $P < 100$.

The following procedure is used in obtaining the probabilistic frontier coefficients: First, the deterministic frontier production function is estimated. Second, the most efficient firms are discarded in stages until estimated coefficients appear to have stabilized.

In the dual form the objective function and restriction become:

$$\text{Max } Z = \Sigma w_j Y_j \qquad (j = 1 \ldots, n-p)$$

s.t

$$\sum_{j=1}^{n-p} w_j X_{ij} \geq \bar{X}_i(a)$$

$$w_j \geq o$$

Where p is the number of observations indicated by the constrained level P and (a) implies that the mean resource levels are adjusted accordingly.

Section 3. Estimated Frontier Production Function Coefficients

Tables 6-1 through 6-3 present estimated frontier coefficients. The columns labelled Frontier 100 are the results arising from fitting the deterministic function; while Frontiers 98, 96, and 95 are results obtained from removing the top 2,4, and 5 percent technically efficient farmers respectively, i.e., the chance constrained functions. The area's estimated average production function coefficients from Chapter 5 are reproduced in the last column of each table for ease of comparison. The last frontier function reported for each area represents the P level at which the function appears to have stabilized.

Results for the Zaria Sample, Table 6-1, indicate the following:

1. Cultivated lowland and inorganic fertilizer are not in solution for the Frontier 100 estimates. This could mean either of two things: that farmers on the frontier did not use any appreciable amount of these resources or that they used too much of the resources relative to the constraint level so that excess capacity gives rise to zero "shadow prices -- elasticities.[1]
2. With just two percent of the observations removed the estimated coefficients change remarkably. All factors are in solution, and estimated coefficients show large differences.

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[1] A more detailed examination will be undertaken for the Sokoto results.

TABLE 6-1. FRONTIER PRODUCTION FUNCTION COEFFICIENTS AND THEIR SENSITIVITY TO REMOVAL OF TOP PERFORMERS: DEPENDENT VARIABLE: GROSS VALUE OF CROP OUTPUT (ADJUSTED) - ZARIA

Variables	Frontier 100	Frontier 98	Frontier 96	Average Production Function Coefficients
Intercept	4.952	6.167	5.884	4.394
Cultivated Lowland	a	0.036	0.025	0.054
Cultivated Upland	0.414	0.614	0.540	0.361
Hired Labor	0.032	0.012	0.033	0.034
Family Labor	0.194	0.040	0.091	0.242
Organic Fertilizer	0.008	0.021	0.021	0.034
Inorganic Fertilizer	a	0.001	a	0.019
Seed	0.234	0.091	0.097	0.212

[a] Not in Solution

3. Frontier 96 results show that the coeffieicnts of at least three variables, seed, organic and inorganic fertilizer are almost identical to those of the same variables in the previous frontier estimates.
4. A comparison of the relatively stable frontier (Frontier 96) and the average production function results show the major differences between the two to be: the higher intercept and larger upland coefficient for the frontier function. The results suggest that an increase in the upland area would increase total output by a higher amount for farmers on the frontier than it would for Zaria farmers on the average. For example, while a 10 percent increase in upland area would result in a 5.4 percent increase in output for farmers on the frontier, the corresponding increase for farmers on the average is 3.6 percent.

The following observations are made from the Sokoto results (Table 6-2):

1. The absence of both upland and the lowland variables in Frontier 98 estimates is rather puzzling. A closer examination of the resource endowments of farmers defining the frontier indicated that while the constraint capacity was set at 6.3 and 0.12 acres for upland and lowland area respectively, farmers on the frontier had on the average 11.68 and 0.24 acres of the resources. With respect to farmers on Frontier 100 none of them used inorganic fertilizer. These confirm the plausibility of the explanation

TABLE 6-2. FRONTIER PRODUCTION FUNCTION COEFFICIENTS AND THEIR SENSITIVITY TO REMOVAL OF TOP PERFORMERS: DEPENDENT VARIABLE: GROSS VALUE OF CROP OUTPUT (ADJUSTED) - SOKOTO

Variables	Frontier 100	Frontier 98	Frontier 96	Frontier 95	Average Function
Intercept	1.612	1.683	1.228	1.161	3.798
Cultivated Lowland	0.133	a	a	a	0.038
Cultivated Upland	a	a	0.454	0.433	0.194
Hired Labor	0.056	0.058	0.124	0.125	0.073
Family Labor	0.519	0.641	0.716	0.707	0.255
Organic Fertilizer	a	0.325	0.119	0.099	0.007
Inorganic Fertilizer	a	0.010	0.006	0.007	0.030
Seed	1.051	0.579	0.353	0.396	0.412

[a] Not in optimal solution.

offered earlier in this section, i.e., it is conceivable that non-use of resources or excess capacity with respect to farmers on the frontier gives rise to zero elasticities.

2. The coefficients appear to have stabilized at Frontier 95.[1] The intercept, and all variables (except organic fertilizer) have estimated values very similar to the coefficients for the last frontier function.

3. A comparison of the stable or 95 percent probabilistic frontier to the average production function shows the intercept for the frontier to be lower (1.16 versus 3.79). This suggests that at low levels of resource use predicted output would be lower for the more efficient producers. However, the elasticity of most of the factors are higher for the frontier than the corresponding elasticities of the average function.

Estimated frontier production function coefficients for Bauchi (Table 6-3) indicates that:

1. Frontier 100 coefficients do not include family labor -- implying excess capacity on the part of farmers on the frontier.

2. With two percent of the top performers removed there is a 25 percent decline in the value of the intercept; family

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[1] The same estimates obtained for the Frontier 95 function were obtained for P = 94. Hence Frontier 95 results are reported.

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[1] The same estimates obtained for the Frontier 95 function were obtained for P = 94. Hence Frontier 95 results are reported.

TABLE 6-3. FRONTIER PRODUCTION FUNCTION COEFFICIENTS AND THEIR SENSITIVITY TO REMOVAL OF TOP PERFORMERS: DEPENDENT VARIABLE: GROSS VALUE OF CROP OUTPUT - BAUCHI

Variables	Frontier 100	Frontier 98	Frontier 96	Average Function
Intercept	8.001	5.202	5.033	4.291
Cultivated Lowland	0.205	a	a	0.066
Cultivated Upland	0.758	0.677	0.513	0.521
Hired Labor	0.039	0.037	0.022	0.014
Family Labor	a	0.121	0.180	0.335
Organic Fertilizer	0.005	0.005	0.010	0.014
Seed	0.049	0.158	0.132	0.038

a Not in Solution

labor is in solution; but cultivated lowland is excluded.[1]

3. At Frontier 96, estimated coefficients including the intercept do not differ greatly from results for the previous frontier.

A comparison of average production function coefficients and Frontier 96 estimates shows the major differences to be in the higher intercept, as well as a higher coefficient for hired labor and seed for the frontier function. The average production function, however, has a family labor coefficient almost twice that of the same variable in the frontier function.

In summary, high production elasticity for upland area constitute the major difference between estimated frontier and average production functions in Zaria. In Bauchi the sources of differences are in the higher frontier elasticities for seed and hired labor. In Sokoto, however, higher elasticities for the frontier function were observed in all but two inputs, seed and inorganic fertilizer.

The value of the intercepts would imply that at low levels of input usage, predicted output would be higher for the more efficient farmers in Zaria and Bauchi. In Sokoto, however, the lower constant term for the frontier function relative to the average function implies a lower predicted output value at low level of factor usage.

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[1] The exclusion from solution of those variables for which farmers that determine the frontier have excess capacity or do not use appreciable amounts of specific inputs may not necessarily be a disadvantage of the approach. At least it ensures that the coefficients that are eventually used to determine efficiency indices are based on resources whose levels are generally within the reach of farmers on the average.

Range Analysis

The stability of Linear programming solucations is usually examined by parametizing the resource levels on the right hand side of the constraint matrix. However, the approach used in this analysis requires that the mean level of resources be used as right hand side values. Thus, changing the constraint levels will not be consistent with the methodology.

The stability of the stable frontier is assessed by analyzing the range of the mean resource levels before a basis change would occur. Table 6-4 indicates the percentage reduction or increase in the mean resource level before a change in the estimated frontier coefficients would occur. In Zaria and Bauchi, for example, estimated coefficients are most sensitive to changes in family labor, seed and upland variables. In Zaria for instance, only a 1.2 percent reduction or a 3.9 percent increase in the amount of family labor would change estimated Frontier 96 coefficients.

The Sokoto coefficients would be least sensitive to changes in the level of family labor. An increase or decrease of up to 30 percent in specified levels would be necessary before changes occur.

Resource Use and Performance of Outliers Relative to Other Observations

The rationale for excluding the first (100-P) percent of efficient firms until the resulting estimated coefficients appear to have stabilized is the possibility that "these firms may be efficient because of errors of observations or other problems" (Timmer, 1970, p. 115). It is, however, possible that extreme observations are not the product of data errors but actually reflect truly efficient firms. In that case one would be losing

TABLE 6-4. SENSITIVITY OF STABLE FRONTIER PRODUCTION FUNCTION COEFFICIENTS: RANGE OF MEAN RESOURCE LEVELS OVER WHICH RESULTS HOLD

Variables	Percentage Reduction and Increase in Mean Resource Levels Before Coefficients Would Change								
	Zaria (Frontier 96)			Sokoto (Frontier 96)			Bauchi (Frontier 95)		
	Mean	Reduction	Increase	Mean	Reduction	Increase	Mean	Reduction	Increase
Cultivated Lowland (acres)	0.7	42.1	26.3	0.9	74.0[a]	208.2[a]	0.2	9.7[a]	11.2[a]
Cultivated Upland (acres)	7.2	10.4	13.5	8.9	30.4	20.0	6.2	13.1	6.5
Hired Labor (man-days)	66.1	45.3	285.4	50.6	84.7	85.7	30.7	58.5	13.8
Family Labor (man-days)	333.1	1.2	3.9	273.4	33.3	35.6	249.0	4.0	3.4
Organic Fertilizer (tons)	7.6	91.5	19.3	8.7	34.1	46.7	1.2	26.7	30.0
Inorganic Fertilizer (₦)	0.02	41.2[a]	5.8[a]	0.01	41.6	186.7	(b)		
Seed/Cuttings (₦)	1.34	2.3	1.5	0.8	8.8	29.3	0.5	6.9	12.4

[a] This is the percentage change before a shadow price would be obtained.

[b] Not used by farmers in this area.

some otherwise valuable information which can result in a bias in the estimated frontier function. There are no statistical tests for identifying genuine outliers in frontier fuention analysis. However, it is useful to examine the factors that characterize excluded observations. In this sub-section the mean level of resource use and performance of outliers relative to other observations are examined (Tables 6-5a to 6-5c).

i) There is no consistent pattern in resource utilization by outliers relative to other observations. For example in Zaria, the outliers had the highest lowland acreages (2-3 times the area for other farmers) and used the least amount of hired labor and organic fertilizer (in both cases less than half of the amounts used by the entire original sample). In Sokoto and Bauchi, however, outliers had the least lowland and upland areas. Furthermore, while outliers in Sokoto used the lowest quantity of hired labor (about one third of the entire mean sample value) the use of hired labor by outlier observations in Bauchi is about equal to the average for the area.

ii) Data relating to farmers on the stable frontier for Sokoto (Table 6-5b) indicate that the low intercept for the Sokoto frontier function (Table 6-2) may be partly related to low levels of resource endowments (e.g. land).

iii) Three performance measures, net farm income per family man equivalent, gross margin per acre and total cost of production per naira output are also presented in Tables 6-5a to 6-5c.

In Zaria and Bauchi outliers performed better than other observations with respect to all three measures. In Sokoto, however, outliers had the

TABLE 6-5a. RESOURCE LEVELS AND PERFORMANCE OF OUTLIERS RELATIVE TO OTHER OBSERVATIONS (ZARIA)

Variables	Outliers	Farmers on Stable Frontier	Stable Sample	Entire Original Sample
Lowland Area (acre)	1.88	0.97	0.67	0.72
Upland Area (acre)	6.42	6.90	7.22	7.18
Hired Labor (man-days)	28.40	40.57	66.14	64.62
Family Labor (man-days)	339.10	442.14	333.09	333.33
Organic Fertilizer (tons)	3.38	6.39	7.61	7.44
Inorganic Fertilizer (Naira)	0.07	0.00	0.02	0.02
Seed/Cuttings (Naira)	1.93	1.47	1.34	1.37
Net Farm Income per Man (Naira)	70.67	51.57	33.65	35.14
Net Farm Income per Acre (Naira)	38.89	33.62	22.98	23.62
Cost per Naira Output (Naira)	0.11	0.12	0.18	0.18

TABLE 6-5b. RESOURCE LEVELS AND PERFORMANCE OF OUTLIERS RELATIVE TO OTHER OBSERVATIONS (SOKOTO)

Variables	Outliers	Farmers on Stable Frontier	Stable Sample	Entire Original Sample
Lowland Area (acre)	0.26	0.31	0.94	0.91
Upland Area (acre)	3.95	6.37	8.92	8.67
Hired Labor (man-days)	16.40	71.63	50.64	48.93
Family Labor (man-days)	143.05	237.96	273.43	266.91
Organic Fertilizer (tons)	5.93	5.13	8.77	8.63
Inorganic Fertilizer (Naira)	0.0	0.03	0.01	0.003
Seed/Cuttings (Naira)	0.19	0.52	0.87	0.84
Net Farm Income Per Man (Naira)	32.99	38.52	42.85	42.37
Net Farm Income Per Acre (Naira)	22.45	24.98	16.99	17.27
Cost Per Naira Output (Naira)	0.09	0.13	0.14	0.14

TABLE 6-5c. RESOURCE LEVELS AND PERFORMANCE OF OUTLIERS RELATIVE TO OTHER OBSERVATIONS (BAUCHI)

Variables	Outliers	Farmers on Stable Frontier	Stable Sample	Entire Original Sample
Lowland Area (acre)	0.18	0.59	0.24	0.24
Upland Area (acre)	4.16	7.16	6.22	6.13
Hired Labor (man-days)	34.55	10.25	30.66	30.83
Family Labor (man-days)	158.30	328.09	249.03	245.12
Organic Fertilizer (tons)	4.76	0.82	1.19	1.34
Seed/Cuttings (Naira)	0.31	0.69	0.46	0.46
Net Farm Income Per Man (Naira)	40.42	37.02	21.44	22.25
Net Farm Income Per Acre (Naira)	29.69	22.14	11.93	12.69
Total Cost per Naira Output (Naira)	0.08	0.06	0.15	0.14

lowest return to labor. Farmers on the stable frontier also have lower return to labor than the mean value for the entire sample. However, the gross margin is highest for farmers on the stable frontier.

It is difficult to draw generalizations given the inter-area differences in the above results. One observation can, however, be made: Farmers that constitute outliers appear to have used relatively large or small amounts of inputs (e.g. 1.88 acres of lowland in Zaria and 0.26 acres in Sokoto, as compared to 0.72 and 0.91 acres of lowland for Zaria and Sokoto respectively for farmers on the average). It is possible that such wide differences are a result of measurement or data errors.

Section 4. Regional Efficiency Differentials

The primary reason for estimating frontier production function coefficients is to have a common basis for correcting for the differential use of factors of production. A technical efficiency index can then be computed for individual firms. This is done by dividing the firm's actual output by its potential output. The potential output is obtained by multiplying the firms resource levels by the corresponding estimated frontier function coefficients and summing over the number of resources in the optimal solution.

$$\sum_{i=o}^{m} \hat{\alpha}_i X_{ij} = \hat{Y}_j,$$

and

$$\frac{Y_j}{\hat{Y}_j} = \text{TEI} \quad \text{(Technical Efficiency Index)}$$

where

$\hat{a}_o$ = intercept

$\hat{a}_i$ (i=1 ... m) = estimated coefficients

X_{ij} = logarithm of the amount of inputs

$\hat{Y}_j$ = potential output of firm j

Y_j = actual output of firm j

Thus the index is a reflection of how each firm employs the inputs available to it relative to the best practice in the sample.

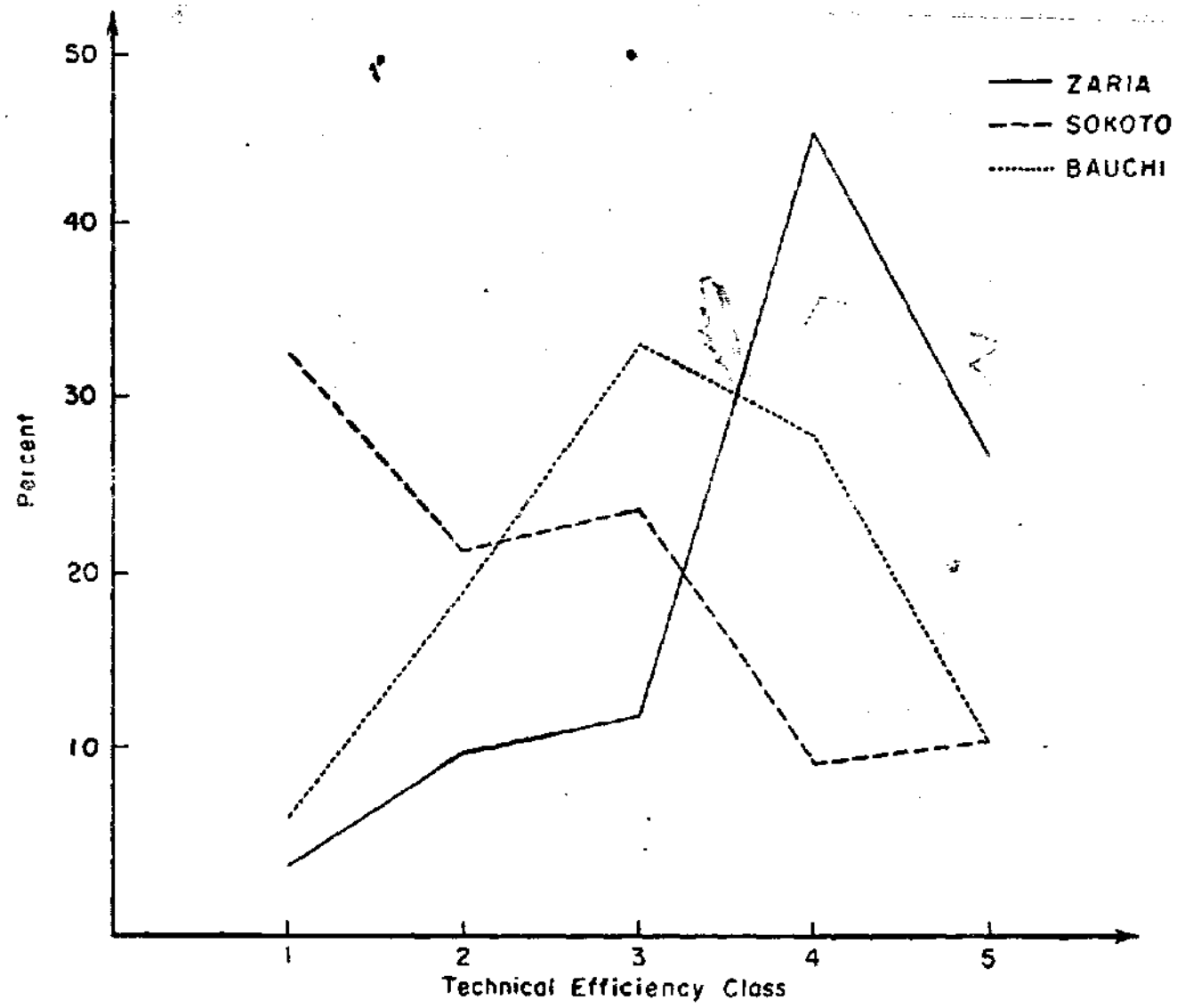
The frequency distribution of efficiency indices are presented in Table 6-6. Two sets of efficiency indices were generated -- one based on estimated Frontier 100 coefficients and the second on the stable probabilistic Frontier coefficients. The following pattern may be noted:

1. Efficiency scores based on the deterministic frontier tend to be lower than those based on the probabilistic frontier.
2. Without correcting for outliers the distribution of efficiency indices have very dissimilar distribution patterns (Figure 6-1).
3. The Sokoto sample appears most affected by outliers, for instance while a third or 33 percent of the farmers have efficiency scores at least 20 percent away from the deterministic frontier, only 4 percent of the farmers are in that efficiency class for the probabilistic frontier (after removing the first 5 top performers).

TABLE 6-6. DISTRIBUTION OF TECHNICAL EFFICIENCY INDICES: FRONTIER 100 AND STABLE FRONTIER

Technical Efficiency Score	Percentage Distribution by Area					
	Zaria		Sokoto		Bauchi	
	F 100	F 96	F 100	F 95	F 100	F 96
Range = Class						
Lowest through 0.799	4.0	2.5	33.0	-	6.9	2.7
0.800 - 0.849	10.5	8.4	22.0	12.6	19.8	6.3
0.850 - 0.899	12.9	16.0	24.0	26.3	33.6	19.8
0.900 - 0.949	45.2	41.2	10.0	27.4	28.5	36.9
0.950 - 1.00	27.4	31.9	11.0	33.7	11.2	34.2
Number of Farmers with score of 1.0	7	8	5	6	6	10
Number of Farmers (total in sample)	124	119	100	95	116	111
Mean Efficiency Score	0.919	0.923	0.843	0.916	0.884	0.927
Coefficient of Variation	0.055	0.056	0.085	0.057	0.63	0.056
Minimum Efficiency Score	0.738	0.748	0.676	0.806	0.742	0.770

FIGURE 6.1. DISTRIBUTION OF EFFICIENCY SCORES BEFORE STABLE COEFFICIENTS (BASED ON FRONTIER 100)



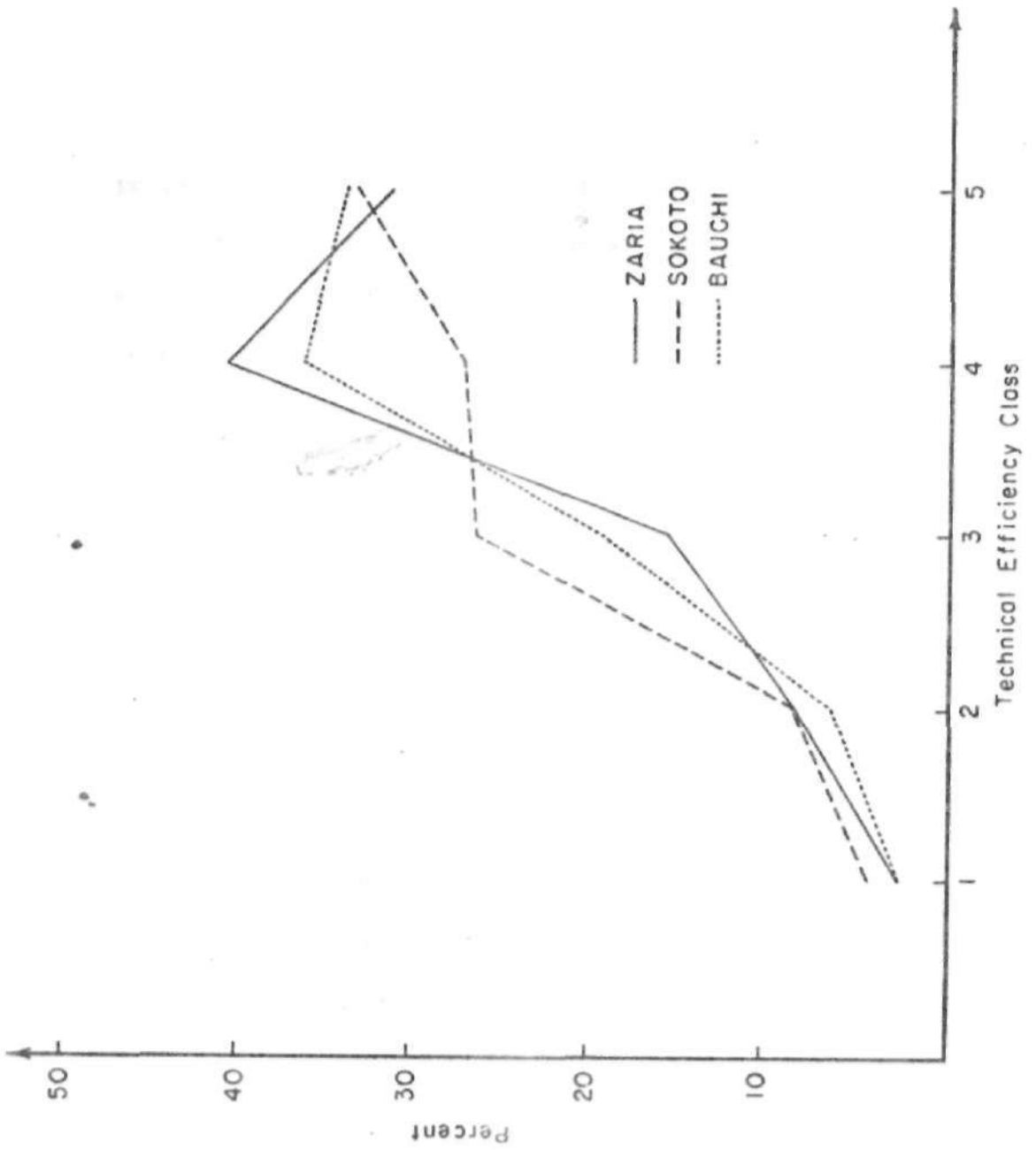


FIGURE 6.2. DISTRIBUTION OF EFFICIENCY SCORES USING STABLE FRONTIER COEFFICIENTS

4. With respect to the probabilistic frontier efficiency distribution, the following observations are evident:

   a. In any area between 9 and 12.6 percent of farmers had efficiency scores at leat 15 percent away from the frontier.

   b. The least technically efficient farmer in Zaria is 25 percent away from the efficient function. The corresponding statistic for Sokoto and Bauchi are 20 and 23 percent respectively.

   c. On the average, efficiency scores were at least 8 percent away from the frontier for all areas.

One of the interesting aspects of the results of this section is the similarity in the samples' distribution of the stable frontier efficiency indices (Figure 6-2). The coefficient of variation of the indices is virtually the same for all three samples. This may be an indication of the possible generality of such efficiency differentials among farmers in other areas (i.e., those with similar agricultural conditions).

Section 5. Technical Efficiency and Level of Resource Use

In technologically more advanced agriculture, it is usually argued that better managers tend to use more of most inputs and that the scale of operation of the production process is one of the sources of factor productivity and technical change (Timmer, 1970, p. 419; Nadiri, 1970, p. 141). In this subsection, the extent to which the level of resource use differ for the different technical efficiency classes is examined.

Table 6-7 through 6-9 present the mean levels of various factors of production applied per unit farm area by technical efficiency class.

TABLE 6-7. RESOURCE UTILIZATION BY TECHNICAL EFFICIENCY CLASS - ZARIA
(Based on Sample with Outliers Omitted)

Technical Efficiency Class	Mean Level of Resource Use							
	Upland Acres	Lowland Acres	Family Labor Man-Days per acre	Hired Labor Man-days per acre	Organic Fertilizer tons/acre	Inorganic Fertilizer Naira/acre	Seed Naira per acre	Total Variable Cost Kobo per acre
Lowest through 0.779	2.01	0.0	80.34	0.79	0.52	0.0	0.66	0.74
0.800-0.849	5.61	0.29	45.98	5.69	0.20	0.0	0.92	2.33
0.850-0.899	6.21	0.51	51.37	7.54	0.89	0.02	1.94	3.86
0.900-0.949	6.54	0.55	61.82	5.85	1.17	0.10	1.48	2.77
0.950-0.999	9.83	1.08	64.91	11.40	1.26	0.36	2.14	6.12
Most Efficient 1.00	6.87	0.85	52.48	8.55	1.16	0.0	1.75	4.10
Analysis of Variance								
F-Statistic	1.530	3.089*	0.495	1.320	1.038	1.148	2.337*	3.539*
Degrees of Freedom	5,113							

* Differences significant at the 5% level.

TABLE 6-6. RESOURCE UTILIZATION BY TECHNICAL EFFICIENCY CLASS - SOKOTO
(Based on Sample with Outliers Omitted)

Technical Efficiency Class	Mean Level of Resource Use							
	Upland Acres	Lowland Acres	Family Labor Man-Days per acre	Hired Labor Man-Days per acre	Organic Fertilizer tons/acre	Inorganic Fertilizer Naira/acre	Seed Naira per acre	Total Variable Cost Naira per acre
Lowest through 0.849	9.41	0.32	45.60	1.02	2.05	0.01	0.99	1.40
0.850-0.899	9.62	1.11	35.99	4.10	1.19	0.00	0.91	1.67
0.900-0.949	9.84	0.94	38.33	7.93	1.56	0.00	0.83	1.73
0.950-0.999	7.68	1.22	50.41	9.53	1.16	0.00	0.94	2.55
Most Efficient 1.00	6.37	0.31	98.22	7.08	1.25	0.02	0.96	2.85
Analysis of Variance								
F-Statistic	0.656	0.665	1.964	1.155	0.492	2.956*	0.557	2.694*
Degrees of Freedom	4,90							

*Differences significant at the 5% level.

TABLE 6-9. RESOURCE UTILIZATION BY TECHNICAL EFFICIENCY CLASS - BAUCHI
(Based on Sample with Outliers Omitted)

Technical Efficiency Class	Mean Level of Resource Use						
	Upland Acres	Lowland Acres	Family Labor man-days/acre	Hired Labor man-days/acre	Organic Fertilizer tons/acre	Seed Naira per Acre	Total Variable Cost Naira/acre
Lowest through 0.799	2.98	0.0	41.01	12.64	0.0	0.58	3.15
0.800-0.849	3.58	0.01	47.98	6.91	0.0	0.76	2.51
0.850-0.899	5.21	0.07	38.54	3.74	0.18	0.62	1.30
0.900-0.949	6.67	0.23	46.29	4.93	0.19	0.76	1.45
0.950-0.999	7.19	0.36	46.10	7.05	0.13	0.92	2.43
Most Efficient 1.00	6.26	0.54	51.99	1.04	0.16	0.90	1.05
Analysis of Variance:							
F-Statistic	1.750	1.008	0.441	1.538	0.814	0.358	2.239
Degrees of Freedom	5,105						

It is observed that:

a) In Zaria and Bauchi, both upland and lowland area tend to be positively related to efficiency. However, except for lowland area in Zaria where observed differences are significant (at 5% level) other differences are non-significant.

b) In Sokoto, cultivated upland show a negative but weak correlation with efficiency.

Furthermore, more technically efficient farmers tend to use more labor.

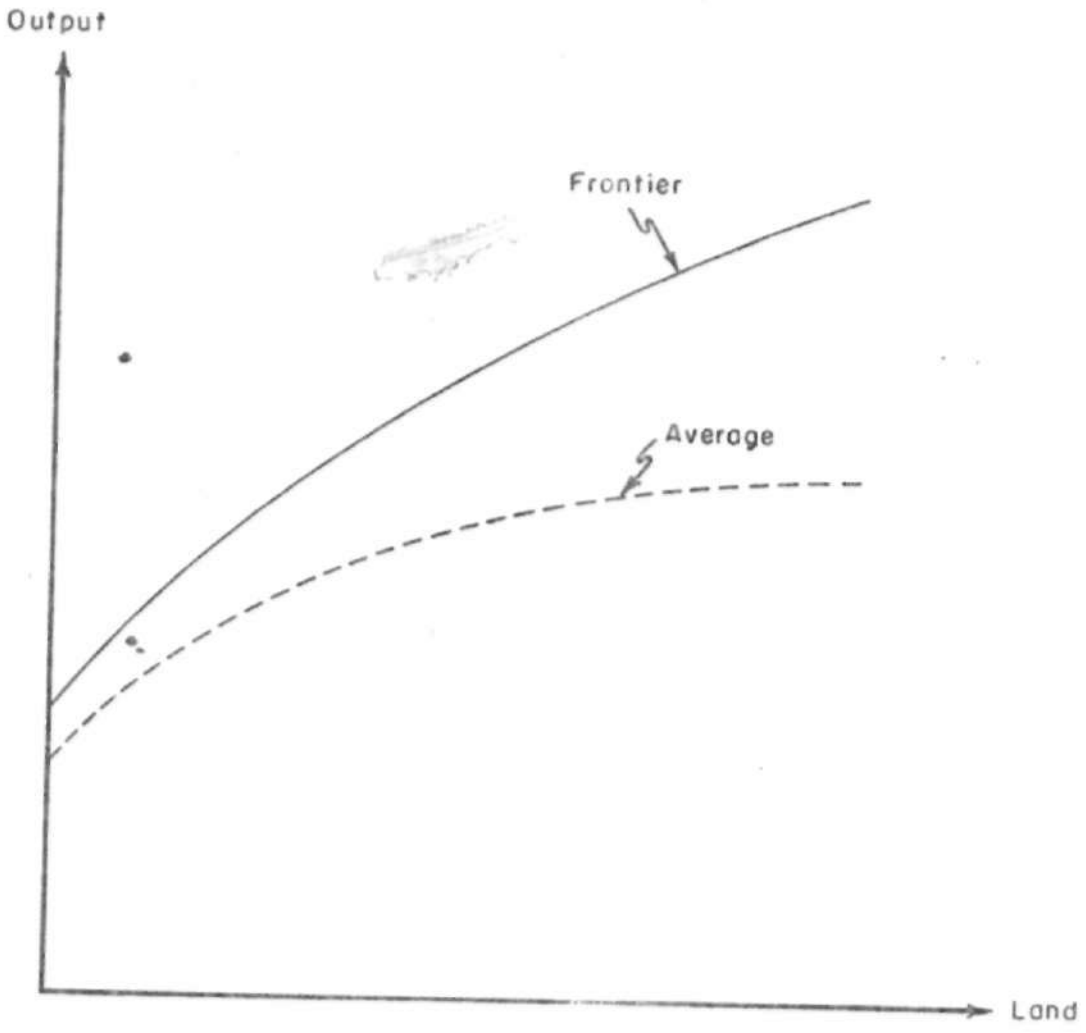
Most of the inorganic fertilizer used in the Sokoto sample is that used by the most technically efficient class.

c) In Zaria and Sokoto the tables indicate significant differences between efficiency categories in variable cost per acre.

Sensitivity of Predicted Output to Farm Size

In this subsection the extent to which the shape of the "stable" frontier and average production function is affected by increasing farm size is briefly examined. Predicted output levels are plotted against varying levels of upland area with all other factors held constant at the mean levels of resource use. If the frontier function is highly related to farm size the shapes of the function would appear as illustrated in Figure 6-3. If this hypothesis is correct, it means that the more efficient producers invariably have larger acreages. Thus, land reform programs or inheritance laws which result in subdivision of farm land among cultivators may not achieve the dual goals of equity and efficiency.

FIGURE 6.3. HYPOTHETICAL SHAPE OF FRONTIER RELATIVE TO AVERAGE FUNCTION IF FRONTIER FUNCTION GREATLY INFLUENCED BY FARM SIZE



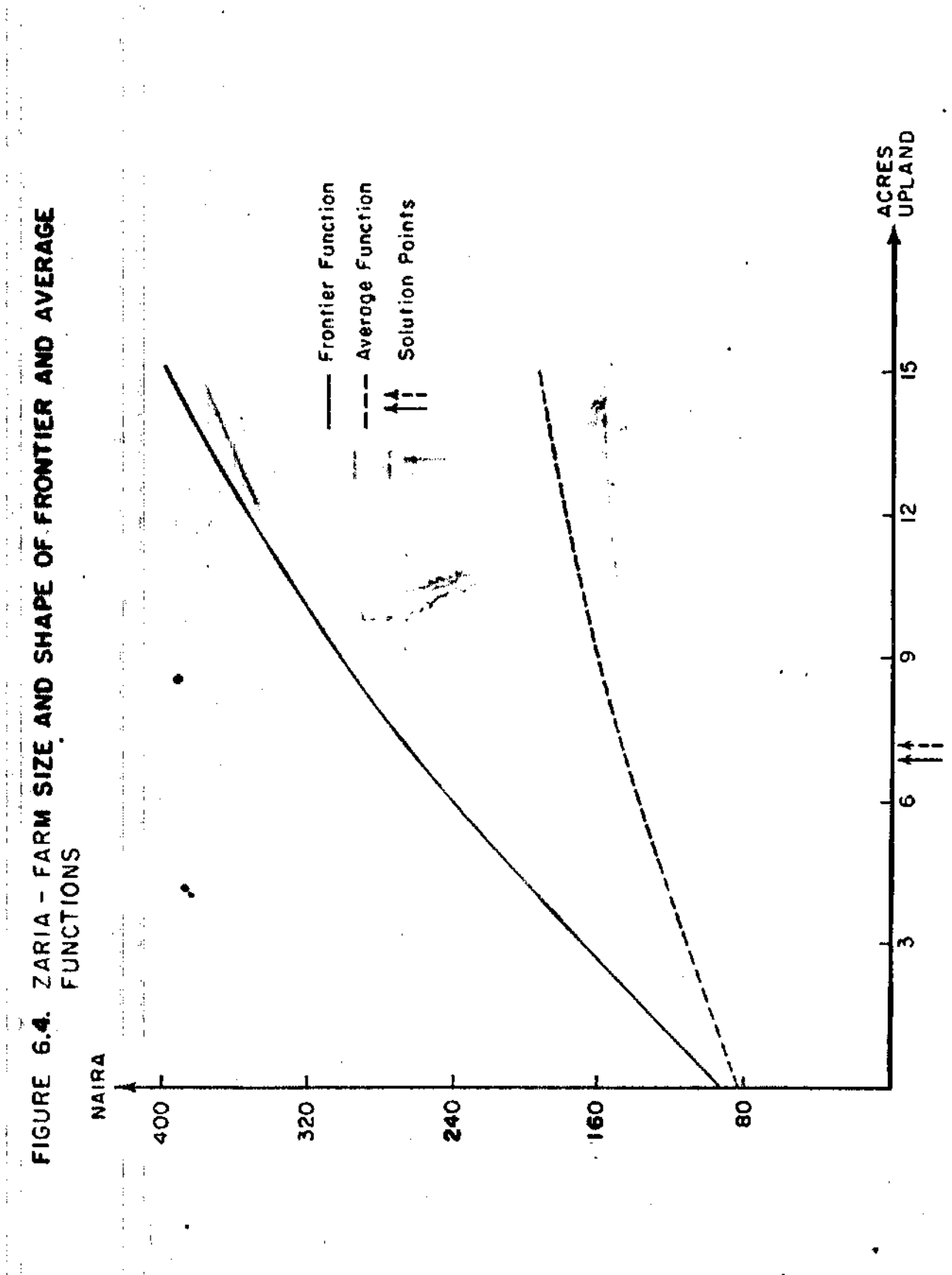


FIGURE 6.4. ZARIA – FARM SIZE AND SHAPE OF FRONTIER AND AVERAGE FUNCTIONS

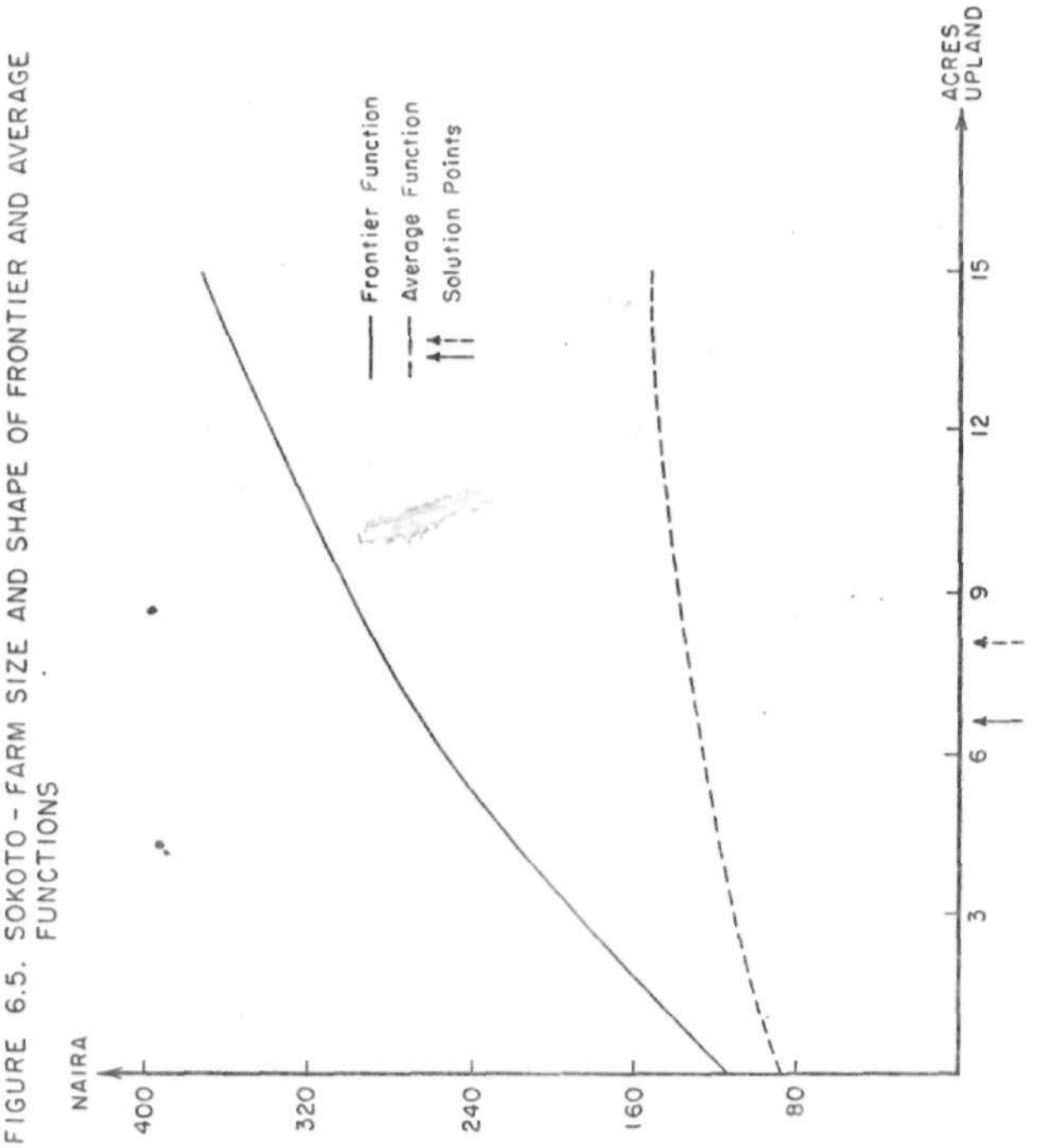
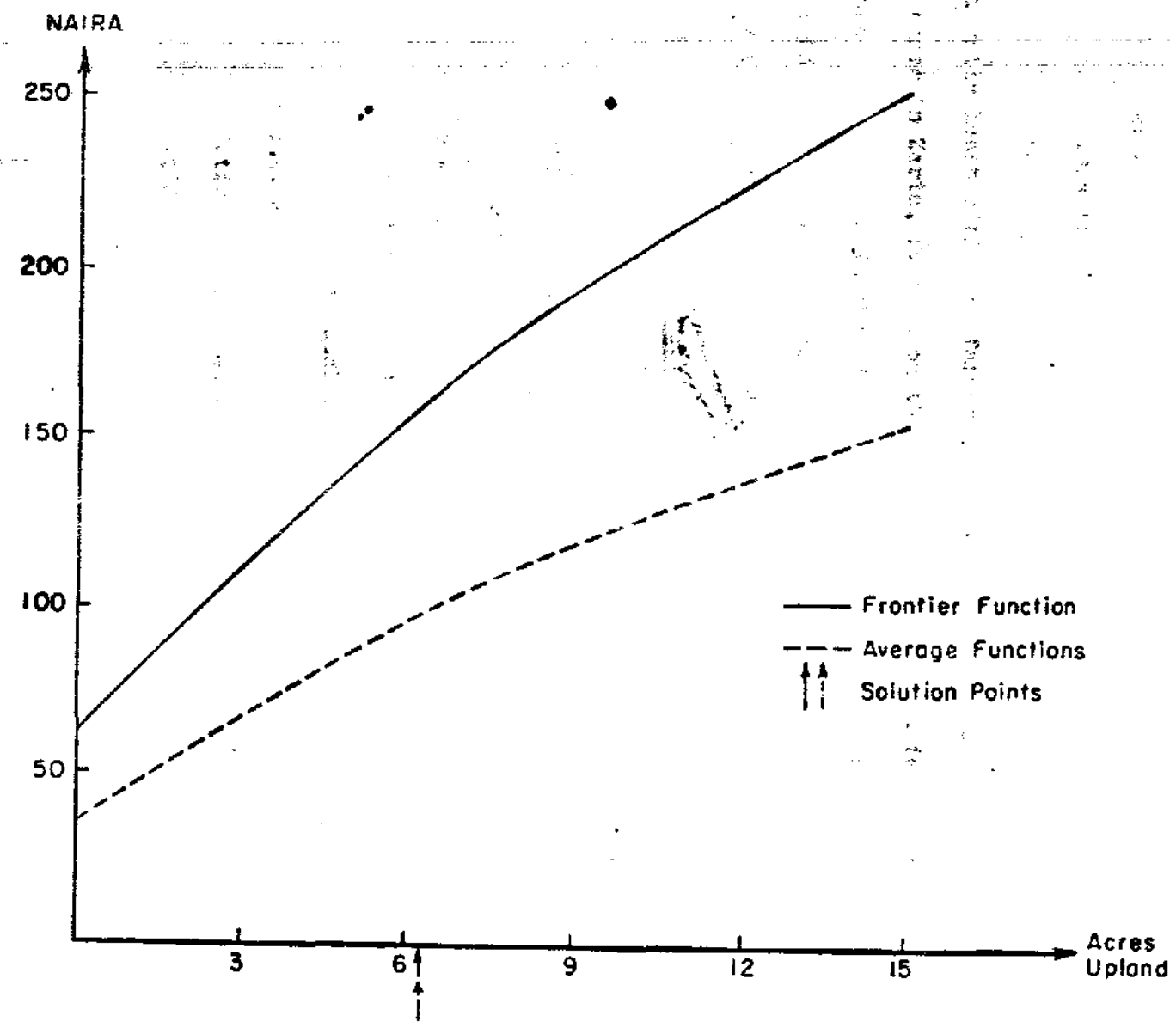


FIGURE 6.5. SOKOTO - FARM SIZE AND SHAPE OF FRONTIER AND AVERAGE FUNCTIONS

FIGURE 6.6. BAUCHI - FARM SIZE AND SHAPE OF FRONTIER AND AVERAGE FUNCTIONS



Figures 6-4 through 6-6 show the plotted functions. The graphs confirm that the frontier function is further away in space than the average production function. Furthermore, the frontier function tends to fan away from the average function -- implying that farm size is associated with efficiency. This is consistent with the result of the previous section with respect to resource utilization. For example, Table 6-6a indicates that while least efficient farmers have total cultivated upland area of two acres in Zaria, farmers on the frontier have upland farm size of almost seven acres. It should be noted, however, that other factors other than farm size are also important contributors to technical efficiency (Table 6a to Table 6c and Chapter 7)

Section 6. Relationships Between Technical Efficiency and Other Performance Measures

In his article on X-efficiency, Leibenstein discusses possible interpretations for observed inefficiencies: "Inputs may have a fixed specification but yield a variable performance ... depending on the exact nature of their employment." Another interpretation offered by Leibenstein is the effects of the "residual in economic growth analysis." One of the ways the residual manifests itself is "through cost reduction in the production of existing commodities without inventions or innovations" (Leibenstein, 1966).

In this subsection the relationship between computed technical efficiency indices and two commonly used farm management performance measures, output per man and average cost is ascertained. It is recognized that not all the differences in average cost and labor productivity are attributable to differences in technical efficiency. However, a positive

relationship between computed technical efficiency indices and other farm performance measures would be reassuring at least with respect to the efficacy of the methodology, as well as indicate the potential sources of inefficiencies.

Table 6-10 indicates for all areas statistically significant differences between output per man for the different efficiency classes. In Zaria for example, while the least technically efficient farmers have output per man of ₦11.15, the top performing class has output per man almost five times as high. In all areas, observed differences are significant at the 1 percent level.

The relationship between total cost[1] of production per naira output and technical efficiency scores (except for the lowest class in Zaria with a relatively low average cost) also indicate significant differences between efficiency classes -- especially for Bauchi (Table 6-11). In that area, while average cost is .60 naira per naira of crop output for the lowest technically efficient farmers it is only .14 naira for top performers.

Figure 6-7 is based on the Dauchi results; and indicates clearly a declining average cost but increasing output per man as technical efficiency increases.[2]

---

[1] Includes cash and imputed cost of factors.

[2] The great differences between performance measures given the relatively little differences in efficiency indices are rather puzzling. A possible explanation is that more efficient farmers may have given more emphasis to higher valued crops (Chapter 7).

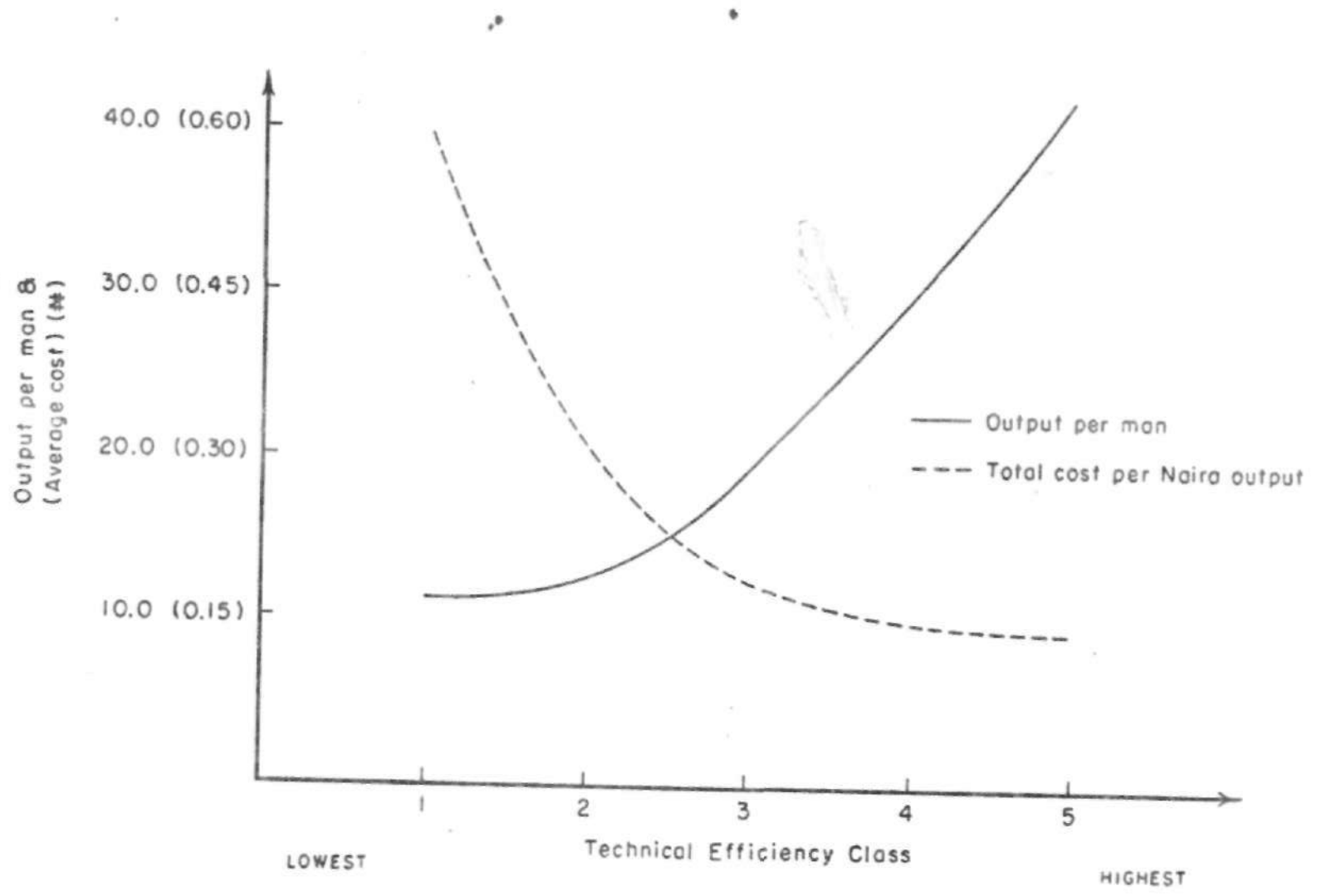
TABLE 6-10. RELATIONSHIP BETWEEN TECHNICAL EFFICIENCY AND OUTPUT PER MAN

Technical Efficiency Class (Stable Coefficients)	Output per Family Man Equivalent (Naira)		
	Zaria	Sokoto	Bauchi
Lowest through 0.799 = 1	11.15	-	11.33
0.800 - 0.849 = 2	17.79	29.55	12.30
0.850 - 0.899 = 3	25.68	45.02	19.69
0.900 - 0.949 = 4	33.39	45.69	31.36
0.950 - 1.000 = 5	51.12	65.50	42.36
Analysis of Variance			
F-Statistic	8.992	4.734	9.419
Degrees of Freedom	(4,114)	(3,91)	(4,106)

TABLE 6-11. RELATIONSHIP BETWEEN TECHNICAL EFFICIENCY AND TOTAL COST OF PRODUCTION PER NAIRA OUTPUT

Technical Efficiency Class (Based on Stable Coefficients)		Total Cost Per Naira of Output (Naira)		
		Zaria	Sokoto	Bauchi
Lowest =	1	0.14	-	0.60
	2	0.22	0.18	0.31
	3	0.23	0.16	0.19
	4	0.12	0.14	0.15
Highest =	5	0.18	0.14	0.14
Analysis of Variance				
F-Statistic		8.992	4.734	9.419
Degrees of Freedom		(4,114)	(3,91)	(4,106)

FIGURE 6.7. RELATIONSHIPS BETWEEN TECHNICAL EFFICIENCY AND OTHER PERFORMANCE MEASURES (BAUCHI)



The results of this section imply that in general more efficient farmers achieve their levels of output with relatively low levels of labor input and at a lower total cost than less efficient farmers. The close relationship between output per man and computed technical efficiency indices also implies that results of the preliminary analysis of Chapter 3 based on output per man classification may not be very far from what obtains if an overall efficiency index as developed in this chapter were used as the classification criteria.

Section 7. Estimated Losses from Technical Inefficiency

Theoretically, a farmer's actual output given his input levels and technology level would be equal to his potential output if he operates on the frontier production function. The distribution of efficiency indices in Section 4 indicates that in any of the three samples, less than 10 percent of the farmers are on the efficient frontier -- implying that a large proportion of farmers have output levels below their potential.

In this section the magnitude of losses due to technical inefficiency for least efficient, intermediate and top performers is computed and compared. Tables 6-12 through 6-14 present actual and potential output values by technical efficiency class. The gap between the two is then expressed as a percentage of actual output value to arrive at the estimated loss. The following conclusions are based on the tables:

1. Least efficient performers (i.e., farmers more than 15 percent away from the frontier) lost as high as 35.7 percent of their actual output in Sokoto. The corresponding statistics for Bauchi and Zaria are 29.3 and 23.7 percent respectively.
2. Intermediate performers (with efficiency scores between 15 and

TABLE 6-12. ESTIMATED LOSS FROM TECHNICAL INEFFICIENCY:

LEAST EFFICIENT, INTERMEDIATE AND TOP PERFORMERS

(Based on Stable Frontier Production Function Coefficients for Zaria)

Technical Efficiency Score	Actual Output (₦)	Potential Output (₦)	
Least Efficient performers: Bottom 5 percent (Individual cases)			
0.748	17.69	23.65	
0.768	14.44	18.80	
0.801	45.97	57.39	
0.804•	37.91	47.15	
0.824	22.16	26.89	
0.838	88.76	106.94	
Mean:	37.82	46.80	
Intermediate and Top Performers:			
0.850-0.899 (Intermediate)	95.28	109.27	(19)[a]
0.900-0.949	147.24	159.18	(49)
0.950-1.000	290.31	297.75	(38)
Area Average:			
0.923	174.33	188.87	

[a] Numbers in brackets are number of observations in technical efficiency class.

TABLE 6-13. ESTIMATED LOSS FROM TECHNICAL EFFICIENCY:

LEAST EFFICIENT INTERMEDIATE AND TOP PERFORMERS

(Based on Stable Frontier Production Function Coefficients for Sokoto)

Technical Efficiency Score	Actual Output (₦)	Potential Output (₦)
Least Efficient Performers: Bottom 5 percent (Individual cases)		
0.676	99.58	147.31
0.714	224.93	315.03
0.763	32.99	43.24
0.766	52.46	68.48
0.828	119.88	144.48
Mean:	105.97	143.77
Intermediate and Top Performers:		
0.850-0.899 (Intermediate)	168.82	192.94 (25)[a]
0.900-0.949	180.25	194.86 (26)
0.950-1.000	196.19	201.22 (32)
Area Average:		
0.916	172.33	188.13

[a] Numbers in brackets are number of observations in technical efficiency class.

TABLE 6-14. ESTIMATED LOSS FROM TECHNICAL INEFFICIENCY:

LEAST EFFICIENT, INTERMEDIATE AND TOP PERFORMERS

(Based on Stable Frontier Production Function Coefficients for Bauchi)

Technical Efficiency Score	Actual Output (₦)	Potential Output (₦)	
Least Efficient Performers: Bottom 5 percent (Individual Cases)			
0.742	21.39	28.83	
0.752	23.45	31.18	
0.761	20.48	26.91	
0.765	12.73	16.64	
0.782	37.46	47.90	
0.807	37.36	46.29	
Mean:	25.48	32.96	
Intermediate and Top Performers:			
0.850-0.899 (Intermediate)	57.57	66.17	(22)[a]
0.900-0.949	103.83	112.86	(41)
0.950-1.000	161.32	166.31	(38)
Area Average:			
0.927	107.39	115.85	

[a] Numbers in brackets are number of observations in technical efficiency class.

FIGURE 6.8. POTENTIAL AND ACTUAL OUTPUT: LEAST EFFICIENT PERFORMERS

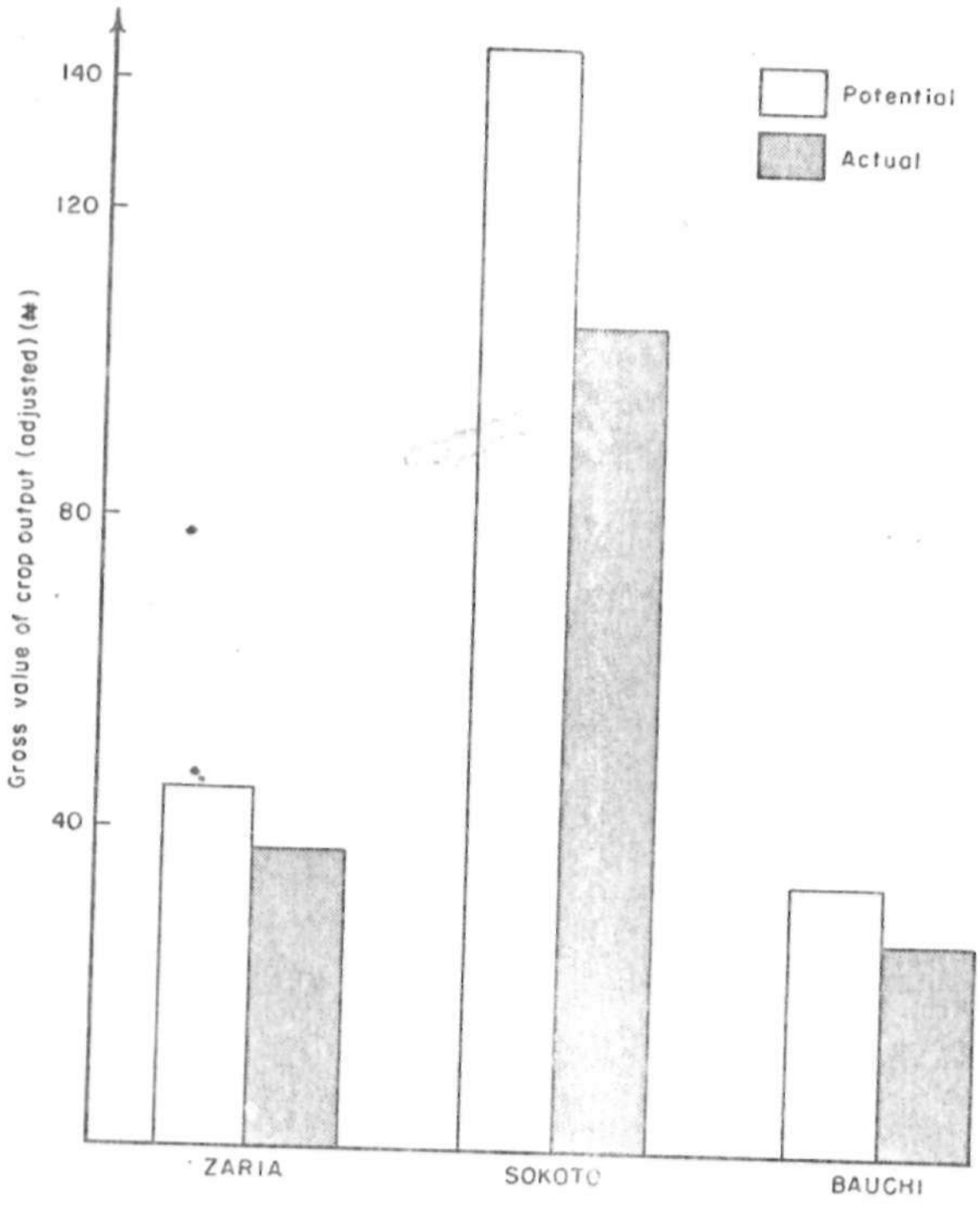


FIGURE 6.9. POTENTIAL AND ACTUAL OUTPUT: INTERMEDIATE PERFORMERS

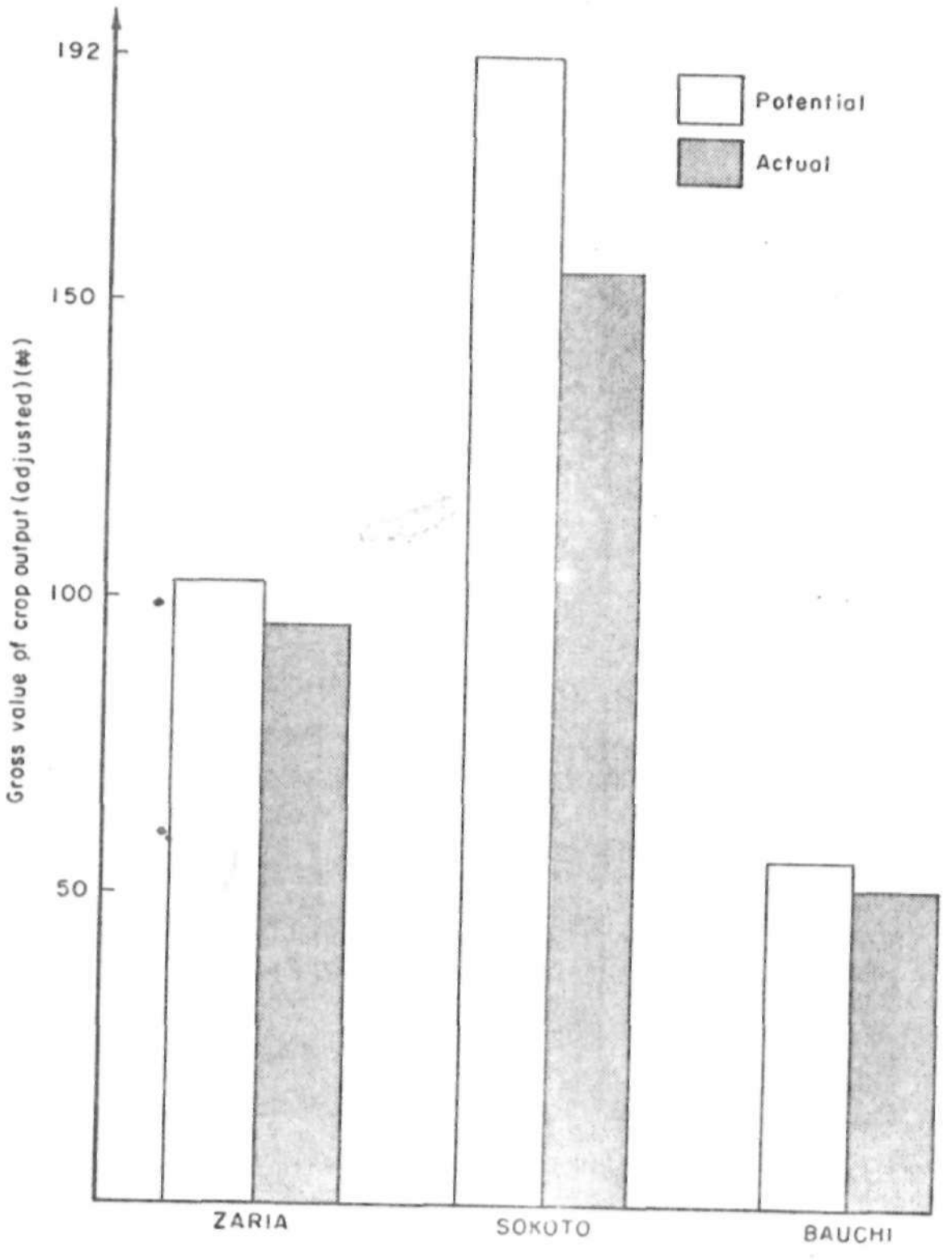
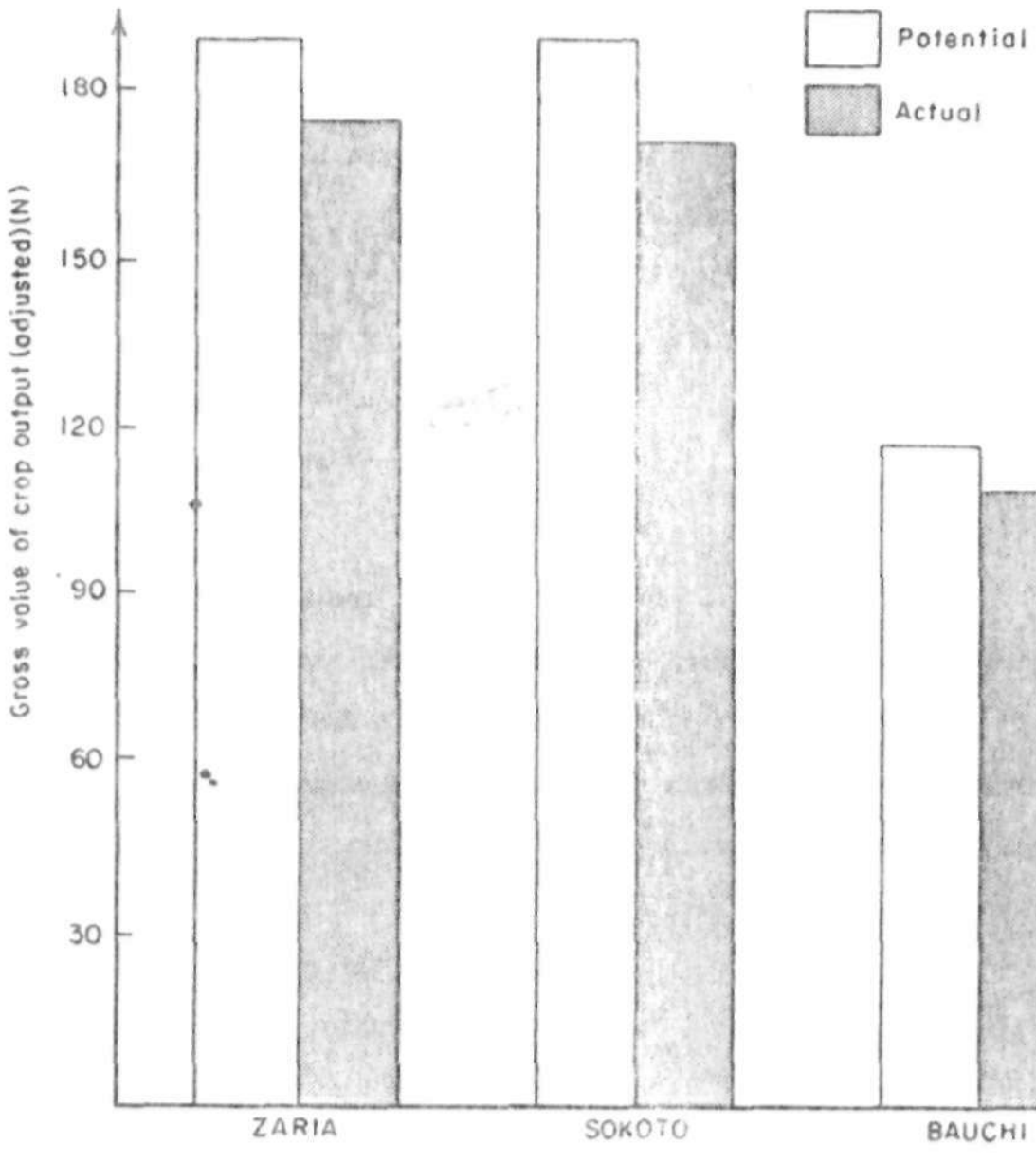


FIGURE 6.10. POTENTIAL AND ACTUAL OUTPUT: AREA AVERAGE



10 percent away from the efficient frontier) incurred losses between 14 and 15 percent of their actual output.

3. Even top performers (farmers with efficiency scores of 0.95 - 1.00) could have obtained about 3 percent more than they did.
4. And on an area sample average, losses ranged between 8 and 9 percent of actual output.

Figures 6-8 through 6-10 summarize the results in histograms of actual and potential output values. The figures indicate that losses tend to be greatest in Sokoto. They also illustrate high inter-area differences in gross value of crop output (especially at the intermediate and lowest efficiency levels). Furthermore, both tables and figures show a close and positive relationship between efficiency class and actual output value.

Summary

The major findings of this chapter are as follows:

i) Results obtained from the probabilistic frontier production function indicate that elasticities are higher for upland area in Zaria, seed and hired labor in Bauchi, and all included variables (except seed and inorganic fertilizer) in Sokoto, than those based on average relationships. The employment of these resources are likely to be the sources of technical efficiency differentials.

ii) Estimated technical efficiency indices indicate that the least efficient farmers could obtain gross value of output (based on the probabilistic production function) which is 20 to 25 percent above actual output. In each area 9-12 percent of farmers had efficiency scores 15 percent off the efficiency frontier while average area indices were about 8 percent away from the frontier.

iii) A comparison of technical efficiency indices and other farm performance measures show declining average cost and increasing output per man with increasing technical efficiency.

In conclusion: The above results imply that the hypothesis stated at the beginning of this chapter cannot be rejected: there are technical inefficiencies in traditional agriculture, and such inefficiencies can give rise to a considerable gap between actual and potential output.

The results imply that there may be some scope for increasing farm output at little cost and without major investments in traditional farms.

However, an understanding of the causes of observed efficiency differentials is important if appropriate programs are to be designed to tap gains from inefficiency gaps. What constraints prevent farmers from attaining their potential? Are these within their reach? What determines technical efficiency? Answers to these questions will be explored in the next chapter.

CHAPTER 7

DETERMINANTS OF TECHNICAL EFFICIENCY

Observed differentials in technical efficiency may be attributed to at least four sets of factors:

i) differences in managerial ability;

ii) the employment of different levels of technology - indicated by the quality or type of inputs employed;

iii) different environmental factors - soil quality, rainfall, solar radiation, etc. and

iv) non-economic and non-technical factors which can prevent some farmers from working hard enough on their plots and thus failing to achieve the best level of farm output.

Previous attempts to explain variations in technical efficiency have tended to focus on factors somewhat exogenous to the ability and control of producers. Examples of such studies are Muller's work on the role of information (Muller, 1974), and Shapiro's study on the role of modernization (Shapiro and Muller, 1977).[1]

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[1] An exception is Matlon's and Newman's work in which the role of selected management factors are examined (Matlon and Newman, 1979).

In this chapter, an attempt is made to identify factors, endogenous to the farming milieu, which may have contributed to observed efficiency differences.

The remainder of this chapter is organized as follows: In Section 1, variables hypothesized to be associated with technical efficiency and the rationale for their selection are discussed. In Section 2, a correlation analysis of technical efficiency and the selected factors is examined. The third section looks at the relationship between efficiency and crop mix. In Section 4, the extent to which selected factors contribute to variation in efficiency is assessed. In the last section, the results obtained are discussed.

Section 1. Hypothesized Factors

Managerial Ability

Although managerial ability is generally known to be an important input in farm production, there is no single measurable input called management. Thus a primary difficulty in examining managerial influence lies in conceptualizing what constitutes management. The function of management is traditionally thought of as consisting of observation, analysis, decision-making, action-taking and the acceptance of economic responsibility (Castle, Becker and Smith, 1972, pp. 4-6). These aspects of management imply the gathering of relevant information, an application of the manager's knowledge in organizing and interpreting available information, and the application of the decision-maker's skill, effort and ability in the production process.

Three variables, sole cropping, fallowing and crop mix, are examined in this class of factors.[1] In the study areas, crops are traditionally grown in mixtures (more than one crop on the same piece of land at a time). Until recently, experimental work and extension advice in the northern states of Nigeria had emphasized the superiority of sole cropping over intercropping (in terms of crop output and use of resources.) This notwithstanding, farmers continue to grow their crops mostly in mixtures. Work by Norman indicates that while intercropping may depress yields of individual crops, the average value per unit area of crops grown in mixtures is higher than that obtained when the crops are grown in sole stands (Norman, 1972; Norman and Pryor, 1978)

The intercropping variable is represented as the proportion of total cultivated land put under sole crops. It is hypothesized that sole cropping is negatively correlated with efficiency.

Land fallowing is an important aspect of a crop rotation system. A fallow period after a number of harvests from a piece of land permits regeneration of soil fertility. Research in other parts of Africa also indicates that land fallowing in semi-arid areas (like parts of northern Nigeria) may help to conserve soil moisture -- thereby improving the yield of the following crop (Whiteman, 1975, p. 305).

The fallow variable is the proportion of total farm size under fallow.

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[1] Data limitation precludes an examination of other management related factors, e.g. technical knowledge possessed by individual producers and the timing and adequacy of farm operations.

The choice of enterprise is an important aspect of firm decision-making.[1] The type of crops grown are determined by the interaction of various factors. These include both "endogenous and exogenous variables" (Norman et al., 1979). Endogenous factors include the goals and resource base of the farmers, while the exogenous variables consist of physical and biological factors, (soils, weather) and the influence of external institutions (government support systems for certain crops, prices, etc.).

To the extent that most of these factors operate uniformly in a given area (an important exception is the resource base) differences in crop emphasis may be a reflection of managerial capacity.

Work in the sourthern part of Kano state indicates that there is a positive relationship between income status and emphasis given to high valued crops, like peppers (Matlon, 1977).[2] Vegetable crops also feature prominently in programming solutions.[3]

Two crop variables are included in the analysis: a subsistence crop value, i.e. the combined value of millet and sorghum as a proportion of gross crop value, and a vegetable value - combined value of peppers, okra and onion, as a ratio of gross value. In areas where vegetable crops are not important, e.g. Sokoto, similar indexes are used for the more important crops - rice and sugar cane.

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[1] Crop rotations and intercropping are strictly speaking aspects of choice of enterprise. However, in this sub-section the emphasis is on choice of specific crops rather than on type of husbandry practice.

[2] Some higher valued crops such as peppers and tomatoes are usually grown on lowland fields. In this respect, resource quality may also influence the decision to grow such crops.

[3] Eric Crawford, personal communications.

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[3] Eric Crawford, personal communications.

Resource Utilization and Technology

The influence of four factors are examined under this category: farm size, labor shortages, fertilizer use and variable cost per unit cultivated area.

Farm size: Small farm size is usually identified as a key contributor to low farm income in traditional agriculture. However, work related to the influence of farm size on efficiency has not given consistent results. In India, for instance, Lau and Yotopoulos found smaller farms to be more efficient that larger farms (Lau and Yotopoulos, 1971, p. 107). But in Pakistan, greater efficiency appears to be associated with larger farms (Khan and Maki, 1979, p. 67).

The farm size variable is defined as the ratio of cultivated land to the mean cultivated acreage for the area, (i.e. relative farm size).

Labor: Norman's work in Zaria villages suggests that seasonal variation in weather conditions, especially rainfall, gives rise to labor bottleneck periods. "The amount of land that a family can handle during the labor bottleneck period fundamentally determined the level of agricultural activity during the rest of the year" (Norman and Pryor, 1978, p. 120).

The availability of adequate amount of labor can, therefore, be expected to affect farm performance. The relationship between efficiency and one labor related factor, hired labor as a proportion of total labor, is examined.

Other Farm Inputs: Increased farm production would depend to some extent on services obtained from purchased inputs -- fertilizer, improved seeds, better tools, etc. However, expenses for crop production in the study areas tended to be very low. In Chapter 3, for example, mean cash expenses are shown to amount to only ₦16.4 (about $25). The fact that

farm work is undertaken largely by use of hand tools, and the absence of farm buildings (except rumbuna - grain stores) implies that fixed costs are a negligible part of farm expenses.

Two variables are examined under this sub-group of factors: a) fertilizer value as a proportion of total cost of production and b) variable cost per cultivated acre.

Non-Economic Variables

Sociologists argue that the developmental cycle of households makes different demands on its farm resources and that it can be very difficult to decide whether observed differences in wealth and production performance in a peasant society are evidence of class polarization, an historical process, managerial ability or a substantive process[1] (Shanin, 1972). The developmental cycle is expressed in such processes as the birth and growth of children, aging and dying of parents and the process of fission by which new households are born (Robertson and Hughes, 1978).[2]

The relationships between efficiency and two sociological factors related to the substantive process is examined: age and family structure.

Age: The influence of age on farming ability is somewhat ambivalent in the socio-economic literature. On the one hand are researchers who link youth with a higher physical effort and innovativeness (Rogers, 1962, p. 174, Buntjer, 1973). On the other hand are those who argue

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[1] A substantive process refers to the routine changes which occur within a society and which serve to maintain its structure (Robertson and Hughes, 1978).

[2] This article was brought to my attention by John Cleave of the World Bank.

that given the nature of traditional agriculture, especially the non-use of improved technology, the experience that the farmer has acquired over the years is likely to be more rewarding than youthfulness in terms of managerial ability (Norman and Pryor, 1978, p. 67). The latter viewpoint provides the motivation for including age in the analysis of this chapter.[1] The age variables are defined as dummy variables -- and take the value of 1 for age of household head: 40-50, 51-60, >60; and zero otherwise (below 40).

As is indicated in Chapter 3, the traditional form of family organization is the gandu - a composite family structure. In recent years, however, the breakup of gandaye into simple family units has been observed to be on the increase. Buntjer's view probably sums up the view of sociologists on the expected effect of the change:

> "Gandu is an authority structure, in which the subordinates not only view time spent on the gandu farm as an imposition, but also feel that modern agriculture could be carried out better outside the composite units." (Buntjer, 1970, pp. 9-10)

This would imply that farmers that belong to the iyali system are likely to be more motivated to farm better than those that belong to the gandu. Leibenstein has emphasized that X-inefficiency may arise from losses due to motivational dificiencies of firm members:

> "Because of incomplete contracts there will always exist some degree of effort discretion for firm members -- different efforts between principals and agents -- imply the possibility of the choice of non-optimal effort positions" (Leibenstein, 1978, p. 205).

The family structure variable is specified as a dummy variable, which is one for iyali and zero for gandu.

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[1] The main consideration that led to this choice is the fact that there was very little use of improved inputs by farmers in the samples.

Environmental Factors

Village dummy variables are included to capture the possible effects of environmental factors, expecially population density. Villages are assigned the values of one if they are least remote (highest population density) or intermediately located (with respect to the urban center). The village dummy is zero if a village is the most remote.

Section 2. Correlation Analysis

This section examines the correlations between selected factors and technical efficiency. Results arising from the correlation analysis are reported in Table 7-1. The following observations may be made:[1]

1) It is only for the Sokoto sample that the age variables show any significant coefficients. The youngest age class variable, (<40), is positively correlated with efficiency - significant at the 10 percent level. The age class 40-50 is negatively correlated with efficiency (significant at .05 level).

ii) In general, the iyali (simple) family structure is negatively correlated with technical efficiency. The coefficient is significant at the one percent level for the Bauchi sample.

This result may be a reflection of the inferior position of iyali farmers with respect to the quality of farm resources (Chapter 3, Section 6).

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[1] Reported coefficients (Table 7-1) are partial correlation coefficients after controlling for the effect of farm size. Control for the effect of farm size is considered appropriate following the results of Chapter 6, Section 5, which show positive relationships between farm size and efficiency.

TABLE 7-1. FACTORS SIGNIFICANTLY CORRELATED WITH TECHNICAL EFFICIENCY.
(PARTIAL CORRELATION COEFFICIENTS -- CONTROLLING FOR FARM SIZE)

Specification of Factors	Partial Correlation Coefficients		
	Zaria	Sokoto	Bauchi
Sociological			
Age of Household Head	n.a.		
Overall		-0.109	-0.036
<40		0.175*	-0.070
40-50		-0.220**	0.156
Iyali Family Structure	-0.080	-0.066	-0.245***
Farm Practice			
Fallow Acreage Ratio	0.088	-0.313***	0.334***
Crop Mix			
Millet and Sorghum Value Proportion	-0.451***	-0.083	-0.180*
Onion, Peppers, Okra Proportion	0.292***	-0.134	0.339***
Inputs			
Hired Labor as Proportion of Total Labor	0.055	0.363***	-0.068
Variable Cost per Acre	0.235***	0.319***	0.037
Location			
Least Remote Village	0.192**	-0.395***	-0.242***
Intermediate Village	0.159*	0.269***	0.229**

* Significant at 10%

** Significant at 5%

*** Significant at 1%

iii) The fallow index is significantly related to efficiency in Bauchi and Sokoto. But, while the coefficient is positive for the former, it is negative for the latter.

iv) Farmers that derive a high proportion of their crop value from subsistence crops (sorghum and millet) tend to be less efficient than those that earn relatively more from high valued crops (e.g. peppers).

v) It is only for the Sokoto sample that the labor variable shows any significant correlation. The hired labor proportion has the hypothesized positive sign.

vi) In Zaria and Sokoto, variable cost per acre is significantly related to efficiency.

vii) In two of the regions, Sokoto and Bauchi, least remote villages (high population density) show negative correlations with efficiency (both significant at the 1% level).

Section 3. Individual Crop Emphasis

Since crop value proportion appears to be correlated with efficiency, a tabular analysis is undertaken in this section to look at the relationship between individual crop emphasis and efficiency. To arrive at the statistics reported on tables 7(2-4), the mean size of the adjusted land area put under each of the major crops is expressed as a percentage of total cultivated land. This is then disaggregated by efficiency class. The tables indicate that:

i) In Zaria, vegetable crops - okra, peppers, onions - tend to be grown almost solely by the more efficient farmers. Sugar cane production is also positively related to efficiency. For

TABLE 7-2. RELATIONSHIPS BETWEEN CROP EMPHASIS AND EFFICIENCY (ZARIA)

Technical Efficiency Class (index)	Mean Size as a Percentage of Total Cultivated Area										
	Sorghum	Millet	Groundnut	Cotton	Cowpea	Rice	Sugar Cane	Okra	Pepper	Onions	Observations
Lowest through 0.799	40.3	23.5	16.8	10.7	0.0	0.0	0.0	0.0	0.0	0.0	2
0.800 - 0.849	35.9	31.3	18.3	2.6	4.2	2.6	1.5	0.1	0.1	0.0	10
0.850 - 0.899	26.8	20.3	14.0	11.0	11.6	0.7	4.3	2.2	0.3	0.0	19
0.900 - 0.949	28.9	22.2	9.9	7.5	10.0	2.4	3.9	2.8	1.6	2.2	49
0.950 - 0.999	26.8	19.9	11.9	6.9	10.1	0.8	9.7	2.2	1.5	3.0	31
Most Efficient 1.00	27.0	20.5	10.4	3.5	8.8	1.0	8.9	3.2	2.6	3.7	8
Analysis of Variance:											
F-statistic	1.589	2.280	1.569	1.148	1.696	0.398	3.511	1.101	1.987	0.738	0.581
Degrees of Freedom	5,113										

TABLE 7-3. RELATIONSHIP BETWEEN CROP EMPHASIS AND EFFICIE Y (SOKOTO)

Technical Efficiency Class (Index)	Mean Size as a Percentage of Total Cultivated Area									
	Sorghum	Millet	Groundnut	Cotton	Cowpea	Rice	Sugar Cane	Okra	Peppers	Observations
0.800 - 0.849	12.8	37.6	6.7	--	26.2	0.3	1.7	--	--	12
0.850 - 0.899	18.3	33.5	4.3	--	26.5	4.8	0.7	--	--	25
0.900 - 0.949	18.6	33.2	1.7	--	28.6	5.5	0.3	--	--	26
0.950 - 0.999	18.0	29.0	1.4	--	25.7	12.7	0.0	--	--	26
Most Efficient 1.00	14.7	34.0	4.2	--	20.4	7.1	0.4	--	--	6
Analysis of Variance:										
F-statistic	0.865	1.301	1.945			1.074	2.677	4.651		
Degrees of Freedom	4,90									

TABLE 7-4. RELATIONSHIPS BETWEEN CROP EMPHASIS AND EFFICIENCY (BAUCHI)

Technical Efficiency Class	Mean Size as a Percentage of Total Cultivated Area								
	Sorghum	Millet	Groundnut	Cotton	Cowpea	Rice	Sugar Cane	Onions	Observations
Lowest through 0.799	21.3	22.9	4.2	--	40.1	4.1	0.0	0.0	2
0.800 - 0.849	41.8	13.9	16.1	--	12.3	12.5	0.0	0.0	7
0.850 - 0.899	42.5	24.6	14.9	--	9.8	1.6	0.0	0.0	22
0.900 - 0.949	50.8	17.6	12.3	--	8.8	2.5	3.7	0.1	41
0.950 - 0.999	42.8	22.6	12.9	--	6.3	5.1	6.5	0.9	29
Most Efficient 1.00	53.1	14.9	9.1	--	8.8	5.3	2.6	2.1	10
Analysis of Variance:									
F-statistic	1.246	0.801	0.521	--	3.050	1.220	0.814	1.911	1.124
Degrees of Freedom	5,105								

instance, while farmers with efficiency indices 0.90 to 1.00 put almost one-tenth of their farm land under sugar cane, the mean for the sample is only a half of that, i.e. one twentieth. Analysis of variance shows observed differences to be significant at the .01 level.

ii) In Sokoto, vegetable crops are not important. But rice emphasis is highest for the more efficient class. Farmers 10 percent or less away from the frontier put on the average a tenth of their land under rice. This compares with 6.7 percent for the entire sample.

iii) For the Bauchi sample, cowpea emphasis tends to be highest for the least efficient class. But this should be interpreted with caution, given the small number of observations in the least efficient class. Sugar cane again tends to be grown only by the more efficient class, though observed differences are not significant.

It is worth noting that rice, sugar cane and to some extent peppers and onions, are essentially lowland crops (i.e. grown on fadama plots).

Section 4. Determinants of Technical Efficiency

In this section, an attempt is made to further explain differences in technical efficiency. The objective is to quantify the contribution and relative importance of selected factors.

Regression analysis using Ordinary Least Squares estimating techniques are employed. The function estimated is:

$$\frac{Y_j}{\hat{Y}_j} = f(X_{ij}, \ldots X_{kj}; Z_{ij} \ldots Z_{mj}; S_{ij} \ldots S_{nj}; D_1, D_2, e)$$

$$j = (1 \ldots n)$$

where,

$\frac{Y_j}{\hat{Y}_j}$ = the dependent variable, i.e. the individual efficiency scores computed from the stable frontier.

$X_{ij} \ldots X_{kj}$ = management related factors.

$Z_{ij} \ldots Z_{mj}$ = factors related to the quality and quantity of inputs used.

$S_{ij} \ldots S_{nj}$ = sociological variables

D_1 and D_2 = zero-one variables used to reflect environmental factors.

e = a disturbance term.

A linear functional form is estimated.[1] Separate equations are estimated for each regional sample. Estimated regression coefficients are reported in Tables 7-5 to 7-7.

About 50 percent of the variability in the efficiency indices for the Zaria sample is associated with the factors specified in the model. The coefficient of multiple determination is, however, lower for the other two regions: 0.36 for Sokoto and 0.31 for Bauchi.

Each estimated regression coefficient represents an estimated change in the technical efficiency index in response to a one unit change in the

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[1] There is no theoretical basis to direct the use of another form.

TABLE 7-5. DETERMINANTS OF TECHNICAL EFFICIENCY: REGRESSION COEFFICIENTS AND RELATIVE IMPORTANCE OF SELECTED VARIABLES (ZARIA)

Variable Specification	Regression Coefficients	t-value	Beta Coefficients	Rank
Constant	0.929			
Management Related Factors:				
Sole Cropping Index	-0.003	0.14	0.010	10
Fallow Acreage Index	0.009	3.33	0.237	4
Sorghum, Millet Value Proportion	-0.123	6.03	0.498	1
Peppers, Onions, Okra value Proportion	0.095	2.50	0.191	5
Resource Utilization				
Relative Farm Size	0.011	2.20	0.189	6
Fertilizer Value as Proportion of Total Cost of Production	0.002	0.19	0.014	9
Hired Labor: Proportion of Total Labor	0.032	1.45	0.119	7
Sociological Factors				
Iyali Family Structure	-0.003	0.37	0.030	8
Location				
Least Remote Village	0.053	5.16	0.476	2
Intermediate Village	0.034	3.82	0.315	3

$R^2(\bar{R}^2)$ = 0.503 (0.456); d.f. for t-test = 108

TABLE 7-6. DETERMINANTS OF TECHNICAL EFFICIENCY: REGRESSION COEFFICIENTS AND RELATIVE IMPORTANCE OF SELECTED BARIABLES (SOKOTO)

Variable Specification		Regression Coefficients	t-value	Beta Coefficients	Rank
Constant		0.973			
Management Related Factors:					
Sole Cropping Index		-0.047	1.04	0.123	9
Fallow Acreage Index		-0.157	3.01	0.309	2
Sorghum, Millet Value Proportion		-0.010	0.22	0.049	12
Peppers, Onions, Okra Value Proportion		0.073	0.97	0.274	5
Resource Utilization					
Relative Farm Size		-0.028	3.11	0.366	1
Fertilizer Value as Proportion of Total Cost of Production		-0.0001	0.03	0.002	14
Hired Labor: Proportion of Total Labor use		0.075	2.58	0.278	3
Sociological Factors					
Iyali family structure		-0.009	0.81	0.082	10
Age of Household Head:	40-50	-0.021	1.59	0.165	7
	51-60	-0.003	0.24	0.028	13
	>60	-0.026	1.48	0.142	8
Location					
Least Remote Village		-0.029	1.38	0.251	6
Intermediate Village		-0.031	1.34	0.274	4

$R^2(\bar{R}^2)$ = 0.361 (0.248); d.f. for t-test = 80

TABLE 7-7. DETERMINANTS OF TECHNICAL EFFICIENCY: REGRESSION COEFFICIENTS AND RELATIVE IMPORTANCE OF SELECTED VARIABLES (BAUCHI)

Variable Specification		Regression Coefficients	t-value	Beta Coefficients	Rank
Constant		0.883			
Management Related Factors					
Sole Cropping Index		-0.002	0.13	0.014	13
Fallow Acreage Index		0.021	2.86	0.282	1
Sorghum, Millet Value Proportion		0.012	0.31	0.049	9
Peppers, Onions, Okra, Value Proportion		0.144	1.64	0.180	3
Resource Utilization					
Relative Farm Size		0.022	2.75	0.257	2
Fertilizer Value as Proportion of Total Cost of Production		-0.005	0.55	0.047	10
Hired Labor: Proportion of Total Labor use		0.068	1.65	0.168	4
Sociological Factors					
Iyali Family Structure		-0.015	1.40	0.135	6
Age of Household Head:	40-50	0.0001	0.01	0.001	14
	51-60	0.004	0.31	0.029	12
	>60	-0.029	1.61	0.148	5
Location					
Least Remote Village		-0.004	0.03	0.034	11
Intermediate Village		0.013	0.64	0.115	8

$R^2(\bar{R}^2)$ = 0.305 (0.204); d.f. for t-test = 96

particular factor - other variables held constant. It should be recalled that the maximum value of the dependent variable is 1.0.

To determine the relative importance of each explanatory factor, beta coefficients are computed for each of the variables. The results indicate that the relative importance of the selected factors differ between areas.

A summary of other results follows:

i) In all areas, an increase in the proportion of sole cropping to total cultivated land would decrease efficiency. The coefficient is significant for the Sokoto sample.

ii) The fallow index has a significant coefficient in all areas. In Sokoto, however, the coefficient is negative.

iii) In Zaria, the coefficients of the two crop variables confirm earlier results -- negative relations between efficiency and value of subsistence crops in contrast to a positive relationship for higher valued peppers, onions and okra.

iv) The coefficient for farm size is significant in all three areas. However, in Sokoto an increase in farm size is associated with a decline in efficiency.

v) Fertilizer use was not an important contributor to variations in efficiency.

vi) In all areas the hired labor variable has a positive and significant coefficient.

vii) Farmer membership of the iyali family structure tends to decrease technical efficiency. However, the coefficient is significant only for the Bauchi sample.

viii) In general age is not an important contributor to technical efficiency. The only significant age coefficient is the negative effect of the oldest age class in Bauchi.

ix) Proximity to an urban center does not appear to be an important determinant of technical efficiency in Bauchi villages. The results for the other two samples are, however, not consistent. In Zaria, location dummies for the least remore and intermediate villages have positive and significant coefficients. But in Sokoto, both coefficients are negative. Though not significant, they are higher than their standard errors.

Finally, an examination of the beta coefficients and their ranking (in order of magnitude) show crop mix, location, and the fallow index to be the most important contributor to technical efficiency in Zaria. In Sokoto and Bauchi farm size, fallow index and proportion of hired labor feature as the most prominent determinants of efficiency.

Section 5. Discussion

At this point, a discussion of the above results is in order.

a) The results with respect to the influence of farm size are not consistent for all regions. It is possible that the positive coefficient for Zaria and Bauchi is related to the fact that larger acreages permit better rotations and longer fallow periods necessary to regenerate fertility. But hte negative coefficient for Sokoto is likely to be a reflection of a different factor. Mean cultivated land area is largest for Sokoto (e.g. 9.68 acres as compared to 6.7 for Bauchi). A larger size of holding entails having more fields. Goddard reports a correlation

coefficient of 0.60 (significant at one percent) between number of fields and size of holding, for the same sample (Goddard et al., 1971, p. 23). Fields are usually located at great distances from one another. The implication is that a large percentage of total working hours may be wasted in travelling between the home and the various fields. In Mairiga village, also in Sokoto State, Hazell found that as much as 15 percent of the average working day could be so wasted (Hazell, 1978, p. 26). Furthermore, in a situation of excessive land fragmentation, very small and remote fields may receive less manure. Small fields may also be by-passed when land improvement and conservation measures are undertaken by farmers (Goddard et al., 1971, p. 31). And usually, size is inversely related to land quality.

b) A closer examination of the negative relationship between the subsistence crop value index and efficiency was undertaken. For all regions, correlation analysis indicated significant negative correlations (e.g. -0.405 for Bauchi) between variable cost per acre and the combined sorghum/millet value index. This is in contrast to the positive correlation between costs and crops like rice/sugar cane, peppers/onions/okra. This implies that efficiency reducing effects observed for the subsistence crops is probably indicative of the relatively lower investments put into their production. The greater concentration of the farmers' efforts and capital resources on non-subsistence crops is likely to be a response to their relatively higher product prices.[1]

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[1] The relationships between efficiency, costs and profitability is examined in a subsequent subsection.

c) The positive correlation between fallow index and efficiency in Zaria and Bauchi is seen as a reflection of the value of crop rotations in traditional crop husbandary practices. In Sokoto, however, the use of other good management practices are likely to be more important than rotations that include fallowed acreages.

d) The relative importance of the proportion of hired labor as a determinant of technical efficiency is probably a reflection of the role of peak season labor availability.[1] If this is the case, it implies that farmers that cannot afford to use hired labor when it is needed are likely to use resources available to them less efficiently. Since hiring labor is dependent on available capital, it also implies that cash availability would be related to efficiency. This interpretation would be consistent with Matlon's findings that efficiency is correlated with liquidity and income status (Matlon and Newman, 1979).

Efficiency, Cash Availability and Profitability

Tables 7-8 through 7-10 examine the relationships between technical efficiency, cash availability and profitability.

Disposable income has been used as a measure of cash availability (Matlon, 1977; and Matlon and Newman, 1979). It should be noted, however, that a higher proportion of disposable income at the farm level is actually net farm income which may not be available until the end of the cropping season. In other words, disposable income at the end of a given crop year may not give a good indication of the potential source of farm

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[1] It may also be a reflection of the relative inefficient use of family labor -- unrelated to seasonal effects. This would be consistent with results on marginal value productivities of labor presented in Chapter 5.

TABLE 7-8. RELATIONSHIPS BETWEEN EFFICIENCY, CASH AVAILABILITY AND PROFITABILITY

(BASED ON STABLE SAMPLE) ZARIA

Technical Efficiency Class	Non-Crop Income	Variable Cost per Acre	Net Farm Income per family man equivalent	Net Farm Income per man day (total labor)	Gross Margin per acre	Number of Observations
			(All values in Naira)			
Lowest through 0.799	17.57	0.74	6.41	0.11	8.46	2
0.800 - 0.849	18.70	2.33	17.57	0.27	10.50	10
0.850 - 0.899	14.35	3.86	23.59	0.30	14.86	19
0.900 - 0.949	19.27	2.77	33.43	0.39	23.37	49
0.950 - 0.999	14.53	6.12	43.46	0.51	30.00	31
1.00	10.01	4.11	47.78	0.54	31.82	8
Analysis of Variance						
F-statistic	0.550	3.539	6.345	8.394	17.325	
Dif.	5,113					

TABLE I-9. RELATIONSHIPS BETWEEN EFFICIENCY, CASH AVAILABILITY AND PROFITABILITY

(BASED ON STABLE SAMPLE) SOKOTO

Technical Efficiency Class	Non-Crop Income	Variable Cost per Acre	Net Farm Income per family man equivalent	Net Farm Income per man day (total labor)	Gross Margin per acre	Number of Observations
			(All values in Naira)			
Lowest through 0.799	--	--	--	--	--	--
0.800 - 0.849	13.79	1.40	25.44	0.26	9.37	12
0.850 - 0.899	20.69	1.67	38.76	0.41	12.99	25
0.900 - 0.949	22.86	1.73	40.29	0.56	15.69	26
0.950 - 0.999	20.15	2.55	58.37	0.66	23.81	26
1.00	20.56	2.84	38.52	0.44	24.98	6
Analysis of Variance						
F-statistic	0.384	2.694	4.005	3.439	10.503	
Dif	4,90					

TABLE 7-10. RELATIONSHIPS BETWEEN EFFICIENCY, CASH AVAILABILITY AND PROFITABILITY (BASED ON STABLE SAMPLE) BAUCHI

Technical Efficiency	Non-Crop Income	Variable Cost per	Net Farm Income per family man Equivalent	Net Farm Income per man day (total labor)	Gross Margin per acre	Number of Observations
			(All values in Naira)			
Lowest through 0.799	5.37	3.15	1.37	0.05	1.16	2
0.800 - 0.849	26.58	2.51	7.50	0.15	6.08	7
0.850 - 0.899	10.33	1.29	13.06	0.20	7.75	22
0.900 - 0.949	12.25	1.44	21.86	0.25	11.32	41
0.950 - 0.999	20.83	2.42	28.24	0.33	15.09	29
1.00	8.37	1.05	32.19	0.44	20.71	10
Analysis of Variance						
F-statistic	1.119	2.239	7.333	13.845	27.673	
Dif	5,105					

capital for that same year. The amount of cash at the beginning of the crop season would be a better determinant of access to farm inputs. Since analysis is based on cross-sectional data for one time period, such information is not available.

Other factors affecting availability of capital are the amount of income earned by households from cattle, small livestock and off-farm sources. This is the component of disposable income earned during the course of a cropping season. This statistic is computed for each efficiency class (Tables 7-8 to 7-10). Statistics on variable costs per acre and three measures of profitability -- farm income per family man equivalent, farm income per man day (based on total labor use) and gross margin -- are also presented.

In general, the table indicates non-significant relationships between within-season liquidity and technical efficiency. On the other hand, there is a positive relationship between efficiency, variable cost per acre and profitability.

The point here is that liquidity *per se* may be necessary but not a sufficient condition for better farming efficiency. What appears to be a sufficient complement is actual and appropriate investments on the farm.[1]

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[1] It should be emphasized that this is not necessarily in disagreement with Matlon's point "that low income farmers may have operated in a more constrained environment" (Matlon, 1979, p. 29). It only asserts that actual farm investments may be a more realistic determinant of efficiency than liquidity.

Summary

The main findings of this chapter are as follows:

1) Major factors contributing to variations in technical efficiency are crop mix, rotations, farm size, hired labor proportion and location.

2) High valued crops feature more prominently in the crop mix of the more efficient farmers.

3) Except in Sokoto, the indigenous husbandry practice of land fallowing enhanced technical efficiency. This is seen as an indication of the value of crop rotations.

4) Technical efficiency can be increased with more hired labor. This is probably a reflection of the shortage of peak season labor.

5) Sole cropping is negatively correlated with efficiency. The coefficient is significant for the Sokoto sample.

6) There is a strong relationship between farm size and technical efficiency. But the sign of this relationship differs for the areas. It is positive in Zaria and Bauchi where population densities are low enough to permit fertility increasing rotations. It is, however, negative in Sokoto where excessive land fragmentation may have resulted in inefficient labor utilization. Larger farm sizes in the Sokoto area may also imply that a higher ratio of less productive land was used by farmers.

7) Efficiency appears to be negatively correlated with proximity to urban centers -- a possible reflection of poorer environmental factors. It is suggested that the positive association between efficiency and the least remote village in Zaria is a reflection of the greater emphasis given to high valued crops in that area (Chapter 3, Section 5), and a more efficient marketing system in Hanwa, relative to that in other nearby villages.

CHAPTER 8

SUMMARY AND CONCLUSIONS

This chapter presents a summary of the study, followed by conclusions and policy implications of the results. In the final section, limitations of the study and suggestions for future research are discussed.

Section 1. Summary of Study.

A growing concern with the capability of Nigerian agriculture to satisfy the food needs of an expanding population has surfaced in recent years. Frequent and substantial increases in food prices and a continuing rise in the national food import bill are but two of the commonly observed results of lagging internal production. Besides adverse environmental factors, (e.g. low and variable rainfall in the northern states), and the non-use of improved production methods, experiments with varieties and technologies used by farmers also indicate that available resources may not be efficiently utilized by producers. Concerned state and national governments have, sometimes hurriedly (e.g. Operation Feed the Nation), instituted programs directed at increasing farm level production. But rational agricultural policy must be based on a clear understanding of factors which prevail at the farm level. Is it possible to exploit known technology used by successful farmers to increase output? With this in mind the study was designed to achieve the following objectives:

1. To isolate factors which determine farm level productivity;
2. To estimate the level of technical efficiency of individual producers; and
3. To identify factors which contribute to variations in technical efficiency.

Farm management survey data relating to Kaduna, Sokoto and Bauchi states were used for the study. Within each area, three villages were selected. A major criteria used in village selection was that they differ in ease of access to the main city in the area. The entire sample consisted of 340 farmers who were interviewed twice weekly throughout a cropping year to obtain information on labor use, farm expenses, crop yields, income and some sociological variables.

A number of farm performance measures were examined: output per man, yield, and gross value of crop output (adjusted to permit inter-area comparison). Efficiency was also examined -- within the context of both allocative and technical efficiency. The analytical framework employed consisted of a combination of sorting, averaging, tabular analysis, analysis of variance and correlation analysis. Production functions were also estimated; the traditional average production function was estimated by Ordinary Least Squares techniques, while the frontier production function (of more recent development), was estimated by Linear Programming methods.

The results show some significant differences in the performance measures examined both within and between areas. More specifically, the main results arising from the study are:

i) There are significant differences within areas in output per man and in net farm income. Factors closely associated with differences in labor productivity are cultivated land area, planting density and labor use. Output per man is inversely related to proximity to urban centers. This was shown to be related to a higher population density and smaller farm sizes.

ii) Crop yields are inversely related to farm size. It is suggested that this is a reflection of poorer land quality with increasing farm size. Fertilizer use, labor and seed rate constitute the major determinants of yield.

iii) The major factors contributing to total farm output are cultivated upland area, seed/cuttings and labor use. The study revealed significant inter-area differences in marginal resource productivities with respect to all included variables (except family labor and cultivated lowland). This result suggests that farm inputs -- such as hired labor, seed and fertilizer -- could be reallocated geographically with consequent gains in farm productivity.

iv) Computations of the ratios of marginal value product (at mean value of inputs) indicate that family labor tends to be allocated efficiently in farm production. However, appreciable deviations from allocative efficiency were found for land and hired labor (Table 8-1). This may have been due to imperfections in factor markets.

v) Technical inefficiencies also exist in the study areas and could give rise to a considerable gap between actual and the potential level of

TABLE 8-1. RATIO OF MVP/MFC AND PERCENTAGE CHANGE REQUIRED IN MVP TO EQUATE IT TO MFC

SELECTED FACTORS -- ALL AREAS

Variable	MVP/MFC[a]	Zaria		Sokoto		Bauchi	
		Required Change in MVP (%)	MVP/MFC	Required Change in MVP (%)	MVP/MFC	Required Change in MVP (%)	
Cultivated Upland	6.47	85	3.62	73	8.21	89	
Hired Labor	3.73	73	10.58	91	2.12	53	
Family Labor	0.51	96	1.01	1	1.03	3	

[a] MVP = Marginal Value Product
MFC = Marginal Factor Cost

TABLE 8-2. LOSSES[a] AND OUTPUT PER MAN (₦) BY TECHNICAL EFFICIENCY CLASS

Technical Efficiency Class	Losses From Inefficiency	Output per family man equivalent	Net Farm[b] Income per man day	Losses From Inefficiency	Output per family man equivalent	Net Farm Income per man day	Losses From Inefficiency	Output per family man equivalent	Net Farm Income per man day
				(Output and Net Farm Income in Naira)					
Least Efficient Performers	23.7	11.15	0.11	35.7	29.55	0.26	29.35	11.33	0.05
Intermediate Performers	14.7	25.68	0.30	14.3	45.02	0.41	14.9	19.60	0.20
Top Performers	2.5	51.12	0.51	2.6	65.50	0.62	3.1	42.36	0.44
Area Average	8.3	35.95	0.40	9.2	50.15	0.50	7.9	31.07	0.36

[a] Losses are in percentages and are defined as the difference between actual and potential output expressed as a percentage of actual output.

[b] Based on total labor.

output.[1] Computations of individual efficiency indices[2] show that nine to twelve percent of farmers in each area have efficiency scores more than 15% below the most efficient farmers'. And calculations of potential losses from technical inefficiencies indicate that least efficient farmers could have obtained between 23 and 35 percent more output if they had been able to achieve the level of output predicted by the frontier function (Table 8-2). Technical efficiency is closely associated with farm size, labor use, crop mixtures and the practice of rotations with a fallow proportion.

Conclusions and Policy Implications

The major conclusions of the study are:

1. The findings of the study are not entirely in support of the conventional belief that no appreciable increase in traditional agricultural production is possible by reallocating the factors at the disposal of farmers. The analysis makes clear that there are appreciable dispersions in individual technical efficiencies (output value per unit input). Efficiency scores ranged between 0.67 and 1.0.[3] This would suggest that it is possible to increase output by drawing on the experience of more efficient farmers -- without major investments, at least in the short run.

However, the applicability of this conclusion needs to be examined in some detail. For example, are factors contributing to variations in technical efficiency those that farmers can do something about or are less efficient farmers victims of constraints imposed by external factors which they can do very little about?

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[1] Technical efficiency is defined as gross value of output per unit input.

[2] These are based on elasticities derived from frontier production functions.

[3] It may be recalled that mean efficiency scores were relatively high (0.91).

The study shows that both crop yields and technical efficiency can be increased by hiring more labor (Chapter 3 and Chapter 7). However, it is known that there is no landless class in the study areas (Norman and Pryor, 1978).; Hence the time when hired labor is needed is likely to be the time when all available labor is busy on family farms. Furthermore, labor bottleneck periods tend to coincide with periods when cash resources are low, thereby inhibiting the ability of farmers to hire more labor. (Norman, et al., 1979). The important point here is that limited cash resources coupled with the shortage of labor that can be hired at crucial periods of farm work may limit the applicability of a policy recommendation which points to the need for extra labor. Thus the need for the development and extension of labor augmenting technologies is evident.[1] It should, however, be noted that the appropriateness of such technologies for a traditional farming environment may be problematic. For example, crop specificity characteristic of easily available herbicides has made their application to crop mixtures difficult.[2]

2. The positive and significant relationships between efficiency and factors such as farm size and high valued crops -- grown mainly on fadama plots -- (Chapter 6, Section 5), and the important role of the

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[1] Examples of such technologies are herbicides, oxen and ox-drawn equipment, and tractorization.

[2] Even if herbicides suitable for crop mixtures were available, farmers who use no fertilizer may be worse off if they apply herbicides. Research indicates that persistent herbicides destroy organic manure build-up such as would result from fallowing.

seed variable as a determinant of farm productivity (Chapter 5), suggest that observed differences in farming efficiency may in part be due to differences in the quantities and qualities of the resources employed. Inequalities in input distribution among output per man strata were in fact revealed by the analysis of factors characterizing labor productivity (Chapter 3). It is, therefore, possible that farmers do not have equal access to factors of production.

The implication is that improved farming efficiency may not be possible without an improvement in the resource base of farmers. Given the low level of income and farm expenditures in the area (Chapter 3), an improvement in the resource base (e.g. land quality), may require financial resources beyond that at farmers' disposal. This leads to the familiar issue of ensuring the availability and utilization of farm inputs, including credit, when and where they are needed through appropriate distribution and extension systems. It should be noted, however, that the mere availability of cash, though necessary, is not a sufficient condition for improved farm performance. As was shown in Chapter 7, there is no strong association between income earned during the course of the cropping season and technical efficiency. Work by King on farmers' cooperatives in Kano also demonstrated that credit made available to producers may be rationally considered for uses other than investment on the farm (King, 1975). Besides the potential use of available cash in non-farm investments, there is growing evidence that improved inputs and credit introduced into traditional societies in Nigeria can be monopolized by traditional leaders, village elites, and "power groups" such as traders (Hill, 1972; Agbonifo, 1974; and King, 1975).

The main point here is two-fold: a) the need to demonstrate to farmers the relative profitability of farm investments and b) a need to ensure that all farmers have equal access to available supplies. Unless equal access is ensured, some farmers may be left out of the development process.

3. In general the analysis of technical efficiency (Chapter 7) showed indigenous farm practice of fallowing (rotations) to be positively related to technical efficiency -- even after controlling for the influence of farm size. It was also found that the sole cropping index was negatively correlated with the efficiency index. Detailed crop husbandry recommendations are available for improved production of sole crops, but no such recommendations are available for crop mixtures. Besides, recommendations tend to assume continuous cropping. Research into indigenous farming systems which has been started in recent years at the Institute for Agricultural Research, Zaria and IITA, Ibadan, both in Nigeria, need to be encouraged. Besides developing recommendations that are relevant to crop mixtures, work needs to be done in devising appropriate rotations, especially for areas where land availability constitutes no problem.

4. Observed dispersions in efficiency indices also raise another question: should extension efforts give more emphasis to least efficient farmers? A crucial factor in answering this question would be the ease with which in practice such farmers can be identified. The positive relationships shown to exist between technical efficiency and commonly used performance measures such as output per man and gross margins (Chapters 6 and 7) suggest that an identification based on such measures, though not

equivalent to technical efficiency, are mostly consistent with it. In any case, the viability of a two tier extension effort is likely to depend on availability of funds and extension staff.

In conclusion, with the possible exception of fallowing (crop rotations) and sole cropping, most of the factors which contribute to observed efficiency and profitability differences (e.g. hired labor, farm size, and higher valued crops) may, in fact, be related to constraints imposed by the system under which the farmer operates -- in other words, factors which the farmer can do very little about.

Section 3. Limitations of Study and Suggestions for Further Research

A major limitation of the study is the lack of data on the timing of, and extent to which, specific farm operations such as planting and weeding were carried out by individual farmers. These are expecially important in the analysis of technical efficiency (Chapter 7).[1] There is no doubt that late planting and weeding, for example, have deleterious effects on yield. The difficulties inherent in the collection of such information in indigenous cropping environments, should, however, be recognized: First, the practive of intercropping implies that one will be hard put to specify the optimal time for field operations such as planting and weeding. For example, while the optimal date for planting a sole crop of cotton may be well defined, the optimal time to sow a

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[1] It is fair to mention that the data were not collected with the type of analysis employed in this study in mind. The major aim was "to overcome the paucity of accurate data on indigenous farm practices -- and determine what farmers are doing and -- ought to be doing" (Norman, 1972).

cotton/sorghum/millet mixture will not be that clear. Second, operations, e.g. plantings, are usually spread over a number of weeks. This necessitates a choice as to which of the plantings constitutes the main one.

One criteria that has been used to judge the adequacy of planting time is with reference to the number of weeks after the initiation of rains individual farmers started planting (Matlon and Newman, 1979). But the problem is that rain can be very localized -- and may not begin on the same day or fall on all fields even in the same village. This suggests that comparison with a single time period (the initiation of rains) may in fact not be realistic.

The above points should not be taken as a defence for the lack of the said data, but merely to indicate the problems that potentially interested researchers should consider.

The fact that risk was not considered in specific terms constitutes a second limitation of the study. The importance of risk analysis derives from the fact that decision making involves a choice between alternatives some or all of which have outcomes with differing degrees of uncertainty. Is it possible, for instance, that farmers shown to be less efficient are simply risk averse -- i.e. giving emphasis to less uncertain production alternatives given the resources available to them and the other constraints they face.

Thus a possible expansion of the present work is to add a consideration of risk to the analytical framework. One way to approach this is to use a stochastic production function as opposed to the deterministic average production function employed in the analysis of Chapter 5. This would make it possible to capture the element of risk aversion.

It is worth noting that in an ideal situation, a cross-section time series data of inputs, output and prices would be needed to do justice to the question of risk in farm production. Such data are not available.

The methodology employed in the analysis of technical efficiency does have some limitations. For example, in determining the stable frontier function, outliers were excluded until estimated coefficients appear to have stabilized (Chapter 6). This does not appear very neat. One is faced with a number of questions: Is it possible that some of the observations provide information useful to the subject under study? If one or more observations are admitted to be outliers, how is one sure others are not? In a situation where two or more outlier observations have the same efficiency index, in what order should they be excluded?

Outlier detection techniques in regression analysis are based on some definite verifiable methods, e.g. that standardized residuals are not more than two or three standard deviations from their mean. Finding a method capable of differentiating real outliers in frontier function analysis which employ linear programming techniques appears to be a potential area for research.

In conclusion, frontier function analysis can indicate the potential for increasing farm output if firms employ the best practice in a given production technology. It also permits the stratification of firms by efficiency of input usage (i.e. all inputs). Such a categorization makes it possible to examine factors that contribute to observed efficiency differentials.

However, a major limitation of the technique should be noted: It is likely that farmers shown to be technically efficient by a frontier function analysis do not have high indices of efficiency for all resources considered. For example, in Sokoto, farmers on the frontier had mean returns per man, lower than those for farmers on the average.

Thus efficient producers may indeed have relatively low indices for some important production factors, (e.g. labor), without the fact being revealed in a frontier function analysis. Should such a situation obtain, observed technical efficiencies may be misleading indicators of managerial performance -- at least with respect to the particular input(s) in question.

APPENDICES

APPENDIX A . INCOME AND OUTPUT PER MAN BY VILLAGES USING ACTUAL AND UNIFORM PRICES

Income	Zaria		Sokoto				Bauchi		
	Hanwa	Doka	Dan Manawayi	Takatuku	Kaura Kimba	Gidan Karma	Bishi	Nasarawa	Nabayi
Actual Prices	(All Values in Naira)								
Gross Revenue From Crop Production	212.21	187.95	197.16	89.31	182.19	210.54	83.80	94.26	85.56
Net Farm Income	179.05	166.02	158.25	83.87	157.52	179.69	71.15	80.65	76.31
Off Farm Income	46.72	23.46	48.65	65.48	26.25	41.68	45.45	28.78	32.14
Disposable Income Excluding Cattle Income	215.43	182.29	199.16	142.39	177.53	215.09	109.85	102.13	102.45
Disposable Income Including Cattle Income	385.35	182.29	199.16	150.16	265.19	223.69	163.28	102.13	117.81
Uniform Prices									
Gross Value of Crop Output	186.01	174.76	180.00	88.85	194.28	208.61	106.48	109.47	110.81
Output per Man	30.56	40.50	40.87	26.76	53.75	64.25	31.00	28.55	36.42
Output per Man day	0.40	0.47	0.44	0.37	0.43	0.87	0.35	0.38	0.48

APPENDIX B

ANALYSIS OF MULTICOLLINEARITY

Multicollinearity refers to a situation in which interrelationships among independent variables is so strong, as to render the individual effects of the variables on a dependent variable difficult to separate. As Maddala points out, the problem is not one of existence or nonexistence, but of how serious or problematical it is." (Maddala, p. 183).

The procedure adopted in this analysis is as follows:

a) The simple correlation matrix of independent variables is first examined to identify the pattern and degree of interrelationship between pairs of variables.

b) The second step is to identify the variables that contribute most to multicollinearity by a measure of each explanatory variable's dependence on other independent variables.

c) Finally the model is reestimated without the most multicollinear variable.

Tables B-1(a-c) present correlation matrices for the three samples. The maximum correlation coefficients for the Zaria sample are between cultivated upland and seed/cuttings (0.763), cultivated upland and hired labor (0.733), and cultivated lowland and seed/cuttings (0.682).

For Sokoto, the highest correlation coefficient is that between cultivated upland and seed/cuttings, while for the Bauchi sample it is that for cultivated lowland and seed/cuttings.

TABLE B-1a. CORRELATION MATRIX: REGRESSORS USED IN COBB-DOUGLAS PRODUCTION FUNCTION (ZARIA)

Variables	1	2	3	4	5	6	7
Cultivated Lowland	1.000	0.487	0.311	0.326	-0.046	0.416	0.682
Cultivated Upland		1.000	0.733	0.395	0.299	0.519	0.763
Hired Labor			1.000	-0.003	0.356	0.515	0.629
Family Labor				1.000	0.278	0.068	0.303
Organic Fertilizer					1.000	0.056	0.105
Inorganic Fertilizer						1.000	0.416
Seed/Cuttings							1.000

TABLE B-1b. CORRELATION MATRIX: REGRESSORS USED IN COBB-DOUGLAS PRODUCTION FUNCTION (SOKOTO)

Variables	1	2	3	4	5	6	7
Cultivated Lowland	1.000	-0.131	0.466	0.616	0.151	-0.042	0.407
Cultivated Upland		1.000	0.208	-0.153	0.048	0.069	0.747
Hired Labor			1.000	-0.022	0.191	0.128	0.343
Family Labor				1.000	0.426	-0.032	0.244
Organic Fertilizer					1.000	-0.038	0.143
Inorganic Fertilizer						1.000	0.036
Seed/Cuttings							1.000

TABLE B-1c. CORRELATION MATRIX: REGRESSION USED IN COBB-DOUGLAS PRODUCTION FUNCTION (BAUCHI)

Variables	1	2	3	4	5	6	7
Cultivated Lowland	1.000	-0.023	-0.024	0.418	0.396	--	0.856
Cultivated Upland		1.000	0.406	0.634	0.315	--	0.268
Hired Labor			1.00	0.242	0.137	--	0.103
Family Labor				1.000	0.446	--	0.623
Organic Fertilizer					1.000	--	0.427
Seed/Cuttings							1.000

If the conventional rule of considering a correlation coefficient of |0.80| and above is applied, then it is only in the Bauchi sample that this occurred, and only between one pair of variables, cultivated lowland and seed/cuttings (Heady and Dillon, p. 137). This would imply that multicollinearity is not a serious problem in the samples.

However, the |0.8| 'rule of thumb' may be valid only when there are just two explanatory variables in an equation. Maddala demonstrates that in the case of more than two regressors the simple correlations could all be low and yet multicollinearity could be very serious (Maddala, p. 185).[1] This necessitates an examination of alternative measures.

Severity of Multicollinearity

There are some suggestions in the literature of tests which can be applied to the sample's matrix of correlation coefficients in order to assess the seriousness of multicollinearity. Two such tests are discussed here. The first involves a computation of the determinant of the matrix of zero-order correlation coefficients. The extent to which the determinant departs from singularity becomes a measure of the severity of multicollinearity (Haivtosky, 1968). The second test uses an approximate chi-square distribution of the determinant of correlation matrix (Farrar and Glauber, 1967). The chi-square distribution is given by:

$$\chi^2_{|x^t x|} \quad v = - [N - 1 - 1/6 (2n + 5)] \log |x^t x|$$

---

[1] Maddala gives an example of a model with three explanatory variables. (X_1, X_2, X_3) in which $X_1 + X_2 = X_3$, a situation of perfect multicollinearity. However, the correlation coefficient between any pair of variables was quite low (p. 185).

where,

v = 1/2 (n-1) = degrees of freedom

N = number of observations

n = number of independent variables

Two assumptions are crucial to the development of the Haivtosky and Farrer-Glauber tests:

a) That multicollinearity can be defined in terms of departures from orthogonality in an independent variable set.

b) That the nature of the population from which the independent variables were generated is such that the distribution of the variables is multivariate normal (Farrar and Glauber, pp. 100-101).

The second assumption permits probability levels to be used as a cardinal measure of the extent to which the variable set is interdependent.

The assumptions on which the tests are based are not strictly relevant to the problem of multicollinearity: first, the second assumption refers to a population -- in practice one works with a sample. Second, all that the tests show is that the variables are not independent (Maddala, 1977). p. 186). The tests are not applied to this study.

Individual Variable's Dependence on Other Explanatory Variables

In identifying which variables in a regression are highly multicollinear, a procedure based essentially on Klein's rule appear most appropriate. Klein states that "intercorrelation of variables is not necessarily a problem unless it is high relative to the overall degree of multiple correlation" (Klein, p. 101). Where there are more than two variables in

a regression, the word intercorrelation is interpreted as the multiple correlation of each explanatory variable with the other explanatory variables (Maddala, p. 185).

Thus multicollinearity would be regarded as a problem only if:

$$R^2_y < R^2 \times i$$

where

$$R^2_y = R^2 Y \cdot X1 \ldots XM \text{ and}$$

$$R^2_{xi} = R^2 X_i \cdot \text{ other X's}$$

And the magnitude of the regression F-statistic resulting from regressing each independent variable on other regressors is regarded as a cardinal measure of the extent to which individual variables are affected by multicollinearity (Farrar and Glauber, pp. 101-104).

Table 2 presents regression F-statistic and the coefficient of multiple determination adjusted for degrees of freedom, which results from regressing each independent variable on other explanatory variables. A comparison of the $\bar{R}^2 y$ of the main model (Table 5-1) with the $\bar{R}^2 x_i$, indicate that multicollinearity is not a serious problem for the Zaria sample. In the other two regions, however, $\bar{R}^2 y < \bar{R}^2 x_i$ in three instances in Sokoto, and two in Bauchi.[1] The size of the F-statistic shows that in Sokoto the variables contributing most to multicollinearity are seed/cuttings, cultivated lowland and cultivated upland, in that order. In Bauchi, the two variables are seed/cuttings and cultivated lowland.

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[1] It is not clear how many instances $R^2 y$ has to be greater than $R^2 X_i$ before multicollinearity is regarded as serious.

TABLE B-2. ANALYSIS OF MULTICOLLINEARITY: IDENTIFYING VARIABLES CONTRIBUTING MOST TO MULTICOLLINEARITY

Region	Measures of Each Explanatory Variables Dependence on Other Regressors: Regression F-Statistic and Adjusted R^2 in Brackets							
	Cultivated Lowland	Cultivated Upland	Hired Labor	Family Labor	Organic Fertilizer	Inorganic Fertilizer	Seed/ Cuttings	$\overline{R}^2$ Main Model
Zaria	23.91	66.15	51.05	15.94	8.98	12.41	56.38	
	(0.53)	(0.76)	(0.71)	(0.42)	(0.28)	(0.36)	(0.73)	0.79
Sokoto	59.68	64.33	18.38	30.01	8.08	0.80	73.35	
	(0.78)	(0.79)	(0.51)	(0.64)	(0.30)	(0.04)	(0.81)	0.71
Bauchi	94.65	31.75	4.37	37.79	8.46	--	109.01	
	(0.81)	(0.57)	(0.13)	(0.61)	(0.24)	--	(0.82)	0.69

Adjustment for Multicollinearity

Suggested solutions in the literature for multicollinearity include: dropping variables most affected, the acquisition of new data with less collinearity and the use of ridge regressions (Johnston, p. 164). The approach adopted here is to re-estimate the main model for Sokoto and Bauchi with the seed/cutting variable omitted because it contributes most to multicollinearity.

The results from eliminating the seed/cutting variable are summarized in Table B-3.

In the Sokoto sample, the $\bar{R}^2$ is reduced dramatically while the standard error of estimate is larger. Both of these statistics remain unchanged for the Bauchi sample.

The results imply that the effects of the seed/cutting variable is being captured by the two land variables in the re-estimated regressions -- a confirmation of the high correlation between cultivated land area and the omitted variable (Tables B-1(a-c). The size of the $\bar{R}^2$ and standard error of estimate for the Sokoto sample tend to imply that the original model has a superior explanatory power than the re-restimated equation. If indeed the seed/cutting variable is a relevant variable in the main models, its omission should cause a bias in the re-estimated coefficients of the included variables with which it is correlated. The observed positive bias in the two land variables appear to be consistent with the sign of the correlation between the omitted and land variables.

TABLE B-3. ADJUSTMENT FOR MULTICOLLINEARITY BY EXCLUSION OF THE SEED/CUTTINGS VARIABLE: ESTIMATED COEFFICIENTS - SOKOTO AND BAUCHI

Explanatory Variables	Sokoto			Bauchi		
	Coefficient	t-value	Coefficients Before Adjustment	Coefficient	t-value	Coefficients Before Adjustment
Constant	4.486		3.789	4.327		4.291
Cultivated Lowland	0.088	3.59	0.038	0.076	3.12	0.066
Cultivated Upland	0.491	9.74	0.194	0.535	7.04	0.521
Hired Labor	0.087	5.43	0.073	0.015	1.25	0.014
Family Labor	0.359	4.17	0.255	0.355	3.81	0.335
Organic Fertilizer	-0.002	0.04	0.007	0.014	1.37	0.014
Inorganic Fertilizer	0.029	0.69	0.030	--	--	--
$\bar{R}^2$	0.664		0.714	0.688		0.686
Standard Error of Estimate	0.431		0.397	0.385		0.386

d.f. for t-test: Sokoto = 93, Bauchi = 110

APPENDIX C

ANALYSIS OF RESIDUALS

For OLS to be efficient, the assumption that residuals have a common variance i.e., --homoscedasticity--should not be violated. Heteroscedasticity would render tests based on variances (e.g., t-test) biased and the OLS estimates inefficient.

An underlying hypothesis in the analysis that follows is that residual variability in gross value of crop output is likely to differ among villages in each area sample.

All computations employ the main model without adjustment for multicollinearity.

A three step proceedure is followed:

a) Plots of residuals are examined in an attempt to detect any outliers; the presence of outliers is generally considered a contributing factor to unequal residual variances (Anscombe and Tuckey, 1963; Draper and Smith, 1967).

b) Village residual variances are computed and the hypothesis of equal variances tested and

c) Weighted Least Squares is used to re-estimate the model where the assumption of homoscedasticity appear to have been violated.

The plots of residuals, Figures 1-3 indicate that none of the residuals lies three or more standard deviation from the mean - the conventional criterion for identifying outliers (Draper and Smith, 1967, p. 94).

FIGURE 1 PLOT OF STANDARDIZED RESIDUAL (ZARIA)

SEQNUM	RESIDUAL	-2.0	-1.0	0.0	1.0	2.0
1	0.1743459			I *		
2	0.8401359E-01			I*		
3	0.1687323			I *		
4	-0.2951713E-01			*		
5	0.2785003			I *		
6	0.5043162E-01			I*		
7	0.9362960E-01			I*		
8	0.2348902E-01			*		
9	0.2490099			I *		
10	0.3845780E-01			*		
11	0.3865597			I *		
12	-0.4479175E-01			*I		
13	0.2814445			I *		
14	0.1781853			I *		
15	0.5402818			I *		
16	0.1088059			I*		
17	0.2718585			I *		
18	-0.8358705E-01			*I		
19	-0.1422626			* I		
20	-0.7908152		*	I		
21	-0.1736899			* I		
22	-0.1794613			* I		
23	-0.2589554			* I		
24	0.2703378			I *		
25	-0.5242927		*	I		
26	-0.8646613E-01			*I		
27	0.3792289			I *		
28	-0.2720734			* I		
29	0.5119753			I *		
30	-0.3926960E-01			*		
31	0.5444756			I *		
32	0.2263776			I *		
33	0.3000795			I *		
34	0.8281017E-01			I*		
35	0.1298797			I *		
36	-0.3309466			* I		
37	-0.1183845E-01			*		
38	-0.1325624			* I		
39	-0.4154336		*	I		
40	0.1071326			I*		
41	-0.1128325			*I		
42	-0.3203963		*	I		
43	-0.5675859		*	I		
44	-0.2678568E-01			*		

45	0.4102752E-01	I*
46	0.2679608	I *
47	-0.8778429E-01	*I
48	0.2003682	I *
49	0.2034268	I *
50	0.4599087	I *
51	0.3571906	I *
52	0.2946881	I *
53	-0.2724926	* I
54	0.6991285E-01	I*
55	0.1012833	I*
56	0.3693423	I *
57	-0.4240534	* I
58	0.2387013	I *
59	0.3899941	I *
60	-0.3627369	* I
61	0.2806457	I *
62	-0.6522250E-01	*I
63	0.2360995	I *
64	-0.9948906E-02	*
65	0.1237920	I *
66	-0.7596290E-01	*I
67	0.5991629	I *
68	-0.2017431	* I
69	0.5619988	I *
70	-0.3503506E-01	*
71	-0.7149523E-01	*I
72	0.1179637E-01	*
73	-0.1621212	* I
74	-0.3544855E-01	*
75	0.5478476	I *
76	-0.3696597	* I
77	0.3096611	I *
78	-0.2208856	* I
79	0.3617204	I *
80	-0.1448462	* I
81	-0.2159584	* I
82	-0.7907966	* I
83	-0.1043547	*I
84	0.2085375	I *
85	0.3331578	I *
86	0.8404613E-01	I*
87	0.5572492	I *
88	-0.8821011	* I
89	-0.6879340	* I
90	-0.2546623	* I
91	0.2541963	I *
92	-0.2593766	* I
93	0.6018388	I *
94	-0.1809814	* I
95	-0.8942046	* I
96	-0.1917789	* I
97	0.2734970E-01	*
98	-0.5990895	* I

99	0.0107259	
100	-0.6400547	
101	-0.1597256	
102	-0.5886545	
103	-0.4055049	
104	0.6148748E-01	
105	0.7673747	
106	-0.4404498	
107	-0.1699935	
108	-0.5483175	
109	0.8592689E-01	
110	-0.1633871	
111	-0.5637078	
112	0.1031472	
113	0.2625359	
114	0.2368699	
115	0.6582056E-01	
116	-0.5011600E-02	
117	-0.4761932	
118	0.2192494	
119	0.1048919	
120	-0.2648501	
121	0.7747520	
122	0.2885520	
123	-0.7201535E-01	
124	-0.5506394	

FIGURE 2: PLOT OF STANDARDIZED RESIDUAL (SOKUTO)

SEQNUM	RESIDUAL	-2.0	-1.0	0.0	1.0	2.0
1	0.1717303			I *		
2	0.5201143			I	*	
3	0.5628371			I	*	
4	-0.3174942		*	I		
5	-0.5736877		*	I		
6	-0.1881690		*	I		
7	0.1038579			I*		
8	0.5225202			I	*	
9	0.3823203			I	*	
10	0.3181203			I	*	
11	0.3347921E-01			*		
12	-0.9196211		*	I		
13	-0.7498909		*	I		
14	0.1963889			I *		
15	-0.7925898E-01			*I		
16	-0.7150412E-02			*		
17	-0.4447102		*	I		
18	0.2073177			I *		
19	-0.2345671		*	I		
20	0.5908696E-01			I*		
21	-0.3068504		*	I		
22	-0.4255583		*	I		
23	-0.5614290		*	I		
24	-0.8477634E-01			*I		
25	-0.4651101		*	I		
26	-0.4273092		*	I		
27	-0.7045516		*	I		
28	0.2889049			I *		
29	-0.4756013		*	I		
30	-0.1783267		*	I		
31	-0.4296191E-02			*		
32	0.3149228			I *		
33	-0.3047120		*	I		
34	0.2468280E-01			*		
35	-0.5557762		*	I		
36	0.1666501			I *		
37	0.9544623E-01			I*		
38	-0.3417936		*	I		
39	0.4729127			I	*	
40	0.3064823			I	*	
41	-0.3136249E-01			*		
42	0.2611567			I	*	
43	-0.1467796E-01			*		
44	0.1611692			I *		

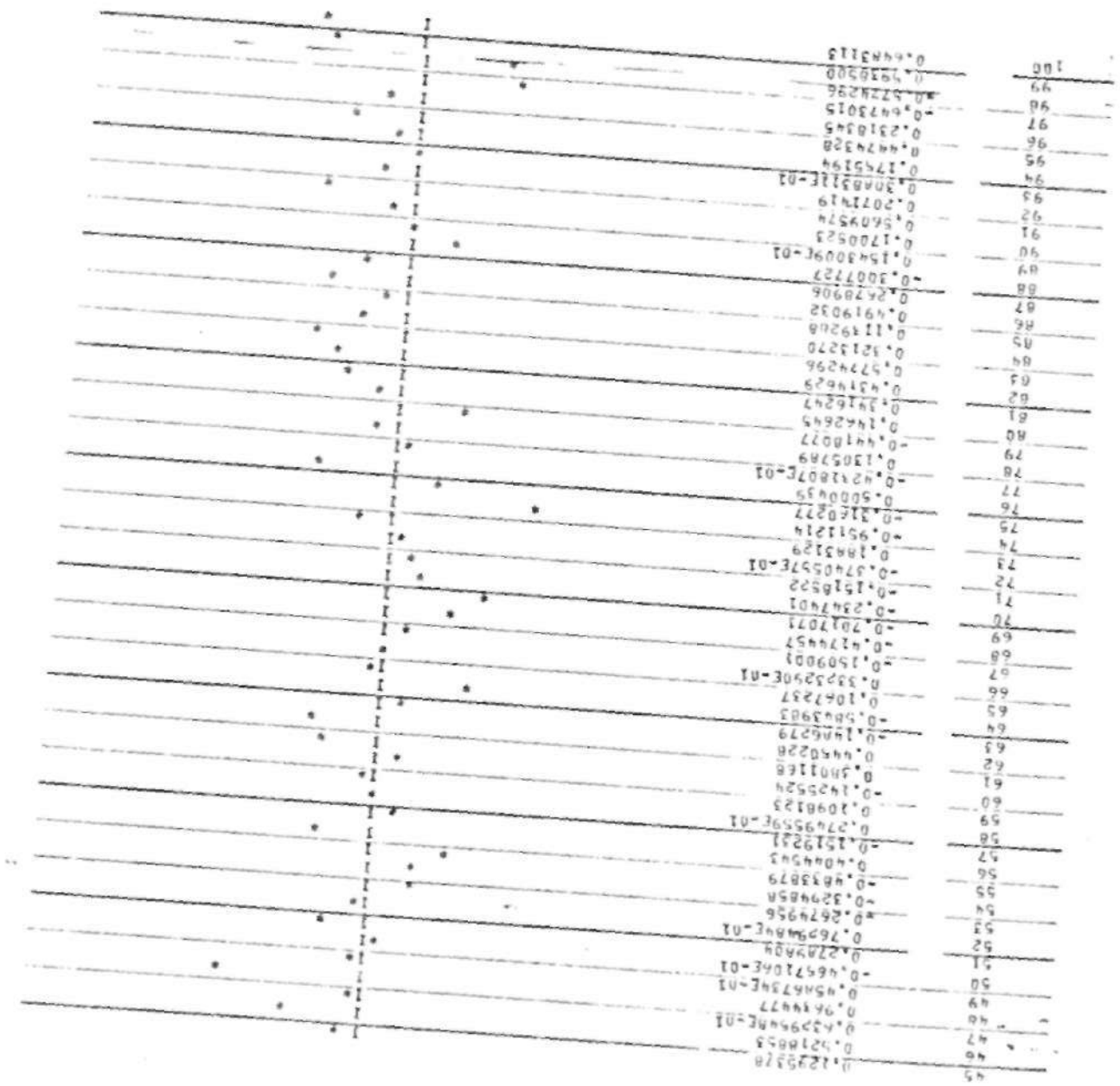


FIGURE 3 PLOT OF STANDARDIZED RESIDUAL (BAUCHI)

SEQNUM	RESIDUAL	-2.0 -1.0 0.0 1.0 2.0
1	0.1773774	I *
2	-0.2002258	* I
3	-0.8813754E-01	*I
4	-0.9745997E-01	*I
5	0.2014402	I *
6	-0.2430471	* I
7	-0.2428011	* I
8	-0.6259464	* I
9	0.1362152E-01	I
10	0.4823710E-01	I*
11	0.4468234E-01	I*
12	-0.2633579	* I
13	-0.1363654	* I
14	-0.3603874E-01	*I
15	-0.9979950	* I
16	0.4574256E-01	I*
17	-0.4382892	* I
18	0.1781564	I *
19	-0.2310148	* I
20	-0.2092404	* I
21	0.8841827	I *
22	-0.3220493E-01	*
23	0.1465332	I *
24	-0.3524472	* I
25	-0.3669057E-01	*I
26	0.4847060	I *
27	0.3237290	I *
28	0.1736510	I *
29	0.3662087	I *
30	0.2910870	I *
31	-0.4281057	* I
32	-0.5671691	* I
33	0.6675508E-01	I*
34	-0.2248980	* I
35	0.1903285	I *
36	-0.1178128	* I
37	-0.7766849E-01	*I
38	0.3383542	I *
39	0.1742574	I *
40	0.4851222E-01	I*
41	0.3211109	I *
42	-0.4111830	* I
43	0.2324016	I *
44	-0.2860484	* I

45	-0.2121791E-01	
46	0.1958826	
47	0.9284513	
48	0.2613462	
49	0.1362023	
50	0.1398593	
51	-0.9216891E-01	
52	-0.4214635	
53	0.7753554E-02	
54	-0.3103864	
55	0.3602904	
56	-0.1340677E-01	
57	0.7277734	
58	-0.2849923	
59	-0.3648976	
60	0.1912186	
61	-0.1969424	
62	-0.2245417	
63	-0.4058204	
64	-0.2911321	
65	0.5020678	
66	-0.3623959	
67	0.2742876	
68	-0.7270370	
69	0.4473597	
70	-0.2746800E-01	
71	-0.4965906E-01	
72	0.1524141	
73	0.2534593	
74	-0.1384384	
75	-0.2308153	
76	-0.3345619	
77	-0.3484420	
78	0.4602706	
79	0.5279739	
80	-0.1427708	
81	-0.1926934E-01	
82	0.4213051	
83	0.1149235	
84	-0.3609849E-01	
85	0.3940025	
86	-0.3101356E-01	
87	-0.4389950E-01	
88	0.1468123	
89	-0.2358613	
90	0.3616677	
91	0.4800087E-01	
92	-0.8059279	
93	0.2507847	
94	0.3906518	
95	-0.4016142	
96	0.3537644	
97	-0.3709356	
98	0.8489094	

99	0.4681729	I *
100	-0.1626262	* I
101	0.1660227	I *
102	-0.3644731	* I
103	0.3834967	I *
104	0.5060437	I *
105	-0.1541895	* I
106	-0.3946510	* I
107	0.6092404	I *
108	-0.2161844	* I
109	-0.4383144	* I
110	-0.1403633	* I
111	-0.4483113	* I
112	-0.5290751	* I
113	-0.4840322	* I
114	1.020312	I *
115	-0.7367922	* I
116	0.2496036	I *

Village residual variances are computed for the three areas and are presented in Table C-1. The hypothesis of equality of variances is tested using the F-statistic. It is only for Zaria villages that the null hypothesis of equal variances is rejected at the 5% level. Residual variances for Dan Manhawayi--the most remote village from Zaria urban center is significantly different from the residual variance of other two villages at the 5% level of significance (Table C-2). It is concluded that residual variances are heteroscedastic for the Zaria sample.

Adjusting for Heteroscedastacity

One way to correct for heteroscedasticity in regression analysis is to use Generalized Least Squares (Theil, p. 244). Assume the original regression model is given by:

$$Y = XB + e$$

where:

Y = a column vector of the dependent variable

X = a matrix of values of all independent variables

B = a column vector of parameters

e = a column vector of disturbances.

With heteroscedasticity the OLS assumption

$E(e'e) = \sigma^2 I$ is now replaced

by:

$$E(e'e) = \sigma^2 i\Omega$$

where:

Ω = a diagonal matrix with the σ_i on the diagonal, so that

TABLE C-1. ANALYSIS OF RESIDUALS: AREA RESIDUAL

VARIANCES COMPUTED FROM COBB-DOUGLAS PRODUCTION FUNCTION

	Regions and Residual Variances		
Villages	Zaria	Sokoto	Bauchi
Hanwa	0.0739		
Doka	0.0905		
Dan Manhawayi	0.2181		
Takatuku		0.1584	
Kaura Kimba		0.1012	
Gidan Karma		0.1578	
Bishi		0.1083	
Nasarawa		0.1207	
Nabayi		0.1903	

$$\text{Residual Variance} = \frac{\sum_{i=1}^{n} (e_i - \bar{e})^2}{n}$$

where:

e = village residuals

$\bar{e}$ = mean of village residuals

n = village sample size

TABLE C-2. ANALYSIS OF RESIDUALS: TEST OF EQUALITY OF VILLAGE RESIDUAL:VARIANCES: COMPUTED F-STATISTIC AND CRITICAL VALUES

Regions and Villages	Villages and F-Statistics		
Zaria	Hanwa	Doka	Dan Mahawayi
Hanwa	--	1.22 (1.75)	2.95 (1.74)
Doka		--	2.41 (1.61)
Sokoto	Takatuku	Kaura Kimba	Gidan Karma
Takatuku	--	1.56 (1.84)	1.01 (1.81)
Kaura Kimba		--	1.56 (1.80)
Bauchi	Bishi	Nasarawa	Nabayi
Bishi	--	1.11 (1.82)	1.76 (1.81)
Nasarawa		--	1.57 (1.83)

Figures in brackets are critical F-Statistic at appropriate degrees of freedom and for the 5% level of significance.

$$\Omega = \begin{bmatrix} \sigma_1 & o & . & . & . & . & o \\ . & & & & & & . \\ . & & & \sigma_2 & & & . \\ . & & & & & & . \\ o & o & . & . & . & . & \sigma_3 \end{bmatrix}$$

σ_i are standard deviations of residuals for the three villages of Zaria.

The GLS estimator is given by:

$$\hat{B} = (X' \Omega^{-1} X)^{-1} X' \Omega^{-1} y$$

Where the estimate of variances are known (as in this situation) it can be shown that an application of Weighted Least Squares (WLS) is a special case of GLS (Theil, p. 244). The procedure is accomplished by weighting the original data (Y_j and X_{ij}) by the reciprocal of the standard deviation of the corresponding village disturbances. Thus the transformed model becomes:

$$\ln \frac{Y_j}{\sigma_j} = \ln \frac{1}{\sigma_j} + \sum_{i=1}^{7} \ln \frac{X_{ij}}{\sigma_j} + \frac{e_j}{\sigma_j}$$

$j = 1 \ldots . n$ observations

σ_j = standard deviation

The equation is fitted with $\frac{1}{\sigma_j}$ as an additional regressor. And the constant term is suppressed (Maddala, p. 265). However, the resulting R^2 is a spurious number since the original dependent variable has been

TABLE C-3. ADJUSTMENT FOR HETEROSCEDASTICITY: ESTIMATED PARAMETERS

COBB-DOUGLAS PRODUCTION FUNCTION - ZARIA

Explanatory Variables	After Adjustment (WLS) Coefficients	t-value	Before Adjustment (OLS) Coefficients	t-value
Cultivated Lowland	-0.055	2.09	0.054	2.35
Cultivated Upland	0.157	1.73	0.361	5.31
Hired Labor	0.049	3.43	0.034	3.16
Family Labor	0.766	11.63	0.242	3.33
Organic Fertilizer	-0.014	0.89	0.034	2.94
Inorganic Fertilizer	0.001	0.03	0.019	1.11
Seed/Cuttings	0.420	5.93	0.219	3.70

Degrees of freedom for t-test = 115 after adjustment, 116 before adjustment.

TABLE C-4. MEASURE OF VARIABILITY IN ZARIA

SAMPLE: COEFFICIENT OF VARIATION

Variables	Mean	Standard Deviation	Coefficient of Variation
Cultivated Lowland (Acre)	0.721	0.819	1.136
Cultivated Upland (Acre)	7.183	6.586	0.916
Hired Labor (Man-Days)	64.620	134.001	2.074
Family Labor (Man-Day Equivalent)	333.331	196.314	0.588
Organic Fertilizer (Tons)	7.439	11.986	1.611
Inorganic Fertilizer (10 kobo)	1.731	8.247	4.765
Seed/Cuttings (10 kobo)	136.69	177.303	1.297

transformed. But estimated coefficients and their standard errors do apply to the original untransformed equation (Snipper and Tomek, 1978, p. 23). The results of the transformed equation for Zaria, the only area where the assumption of homoscedasticity appeared to have been violated are presented in Table C-3. The results from the original model are also given in the same table for ease of comparison.

In general, estimated coefficients and the t-values are different in the two models. Three variables, hired labor, seed/cuttings and family labor appear relatively stable (barring the increased coefficient for family labor). However, the elasticity of cultivated upland is greatly reduced. There is a change in sign in the coefficient for cultivated lowland and organic fertilizer. Negative elasticities in this case appear meaningless since it is not logical that production would actually decline if any of these two factors were increased. A conclusion which can be drawn from the table is that production elasticities for the variables whose coefficient appear unstable are more sensitive than the others to variations in the quantities of inputs. A possible explanation for such a high level of sensitivity to the adjustments made is a lack of high variability within the sample for the variables concerned.

One measure of variability is the coefficient of variation (defined as the standard deviation divided by the mean). The coefficient of variation is computed for variables in the Zaria sample to assess the plausibility of the explanation offered above. Table C-4 indicates that variability for cultivated upland and family labor are relatively less than the variability for the other variables. This is perhaps one of the reasons behind the apparent instability of the elasticities of these variables.

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