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By

SANGARI, Dalhatu Umari

THE DEPARTMENT OF GEOGRAPHY
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A COMPARATIVE ANALYSIS OF TRADITIONAL AND MODERN SYSTEMS OF IRRIGATED AGRICULTURE IN THE DONGA RIVER BASIN, GONGOLA STATE

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BY

DALHATU UMARU SANGARI
B.Sc. (GEOG.), M.Sc. (LAND DEVELOPMENT) BUK

BEING

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ABSTRACT

This study compares the relative productivity and profitability of traditional and modern irrigation with a view to assessing the impact of 'modernization' of indigenous irrigation on the agricultural economy of the peasants in the Donga River Basin of Gongola State of Nigeria. The study covers specifically the analyses of the physical environment, farm management characteristics in terms of factors of production and their relationships, the productivity of irrigation, the cost and benefits of irrigation farming, as well as the constraints and potentials of irrigation farming. Three irrigation types are practised in the study area; the flood recession, manual and pump irrigations. The flood recession irrigation is the dominant form of irrigation practice, followed by the modern pump irrigation.

The study adopts an ecology-management strategy system, input-output system and utility function approaches. Using these approaches, ecological characteristics, defined in terms of farming resource

availabilities, farming management practices and farm output are seen as interrelated components of irrigation farming. Their functional relationships and their influences are studied in order to identify and analyse which of these variables of farming exert strong influence on the productivity and profitability of traditional and modern irrigation farming.

Data for the study were derived from fieldwork, that involves both physical measurements of variables and questionnaire administration. In the questionnaire survey, 364 farmers comprising 26 farmers each from the 14 irrigation locations were sampled for detailed investigation.

The variables of irrigation production were first of all analysed separately to elicit the general patterns of production, resource allocation and utilization in irrigation cultivation. The variations in patterns of production resource utilization were compared among the types of irrigation by the analysis of variance and t-test statistics. With regard to the utilization of production resources, it was found that significant variations exist between the three irrigation types and under each irrigation type between different topographical sites.

The functional relationships between the variables of irrigation production and rates of land and water utilization, and productivity, were examined using the statistical models of simple correlation and regression analyses.

Using the correlation technique, it was found that strong associations exist between water application and man-days in both the traditional and modern irrigation systems suggesting that water application in irrigation farming is labour intensive. Using the simple regression technique, it was found that site location of farms determines the intensity of land use in manual irrigation but determines the rate of water use under the flood recession and pump irrigations. It was also found , using the multiple regression technique, that production cost, water input and methods of land acquisition exert influence on the sizes of land cultivated under the manual irrigation. Under the pump irrigation production cost, methods of land acquisition, water input and site location of farms exert significant influence on the sizes of land cultivated. Production cost is necessary in irrigation for the acquisition and utilization of factors of production.

The results of the regression analysis further show that only production cost, income and land cultivated exert the strongest influences on crop yields of the flood recession irrigation farming. The lack of significant influence of water input on crop yield under the flood recession irrigation attests to its adaptability to the natural residual soil moisture conditions. Under the manual irrigation the most important factors determining crop yield, in order of importance, are production cost, frequency of water application, degree of intercropping, water input and soil moisture retention. Under pump irrigation, crop yield was found to be significantly influenced by income, methods of land acquisition, soil moisture retention, frequency of water application and degree of intercropping.

The cost of irrigation farming is influenced by the quantities and levels of inputs of production. The traditional irrigation types are the most favoured because of their minimal values of production inputs. The profitability of irrigation farming is determined by farm productivity and costs of production.

The biggest problems of pump irrigation in the area, and indeed throughout the developing countries, are shortages of fuel, risk of mechanical breakdown, lack of spare parts and qualified mechanics to repair pumps. The depletion of residual soil moisture and the heavy buckets are the major limitations to the traditional flood recession and manual irrigation practices respectively.

There are considerable potentials for the sustenance and expansion of irrigation farming in the Donga River Basin area, based on traditional and modern practices. But these can only be possible if the major limitations of irrigation practices are overcome.

The major conclusions and recommendations of this study are likely to apply to other savanna regions of Africa and other developing countries that have indigenous and imposed irrigation practices, and are interested in sustainability of irrigation farming.

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Errors of facts, analysis and interpretation remain, however, my sole responsibility.

DEDICATION

THIS THESIS IS DEDICATED TO MY CHILDREN MOHAMMED DAHIRU DALHATU AND YAKUBU DANLAMI DALHATU.

CERTIFICATION

This is to certify that this work was carried out by Dalhatu Umaru Sangari in the Department of Geography, University of Ibadan, Ibadan, Nigeria.

SUPERVISOR
Dr. F.O. Akintola,
B.Sc., Ph.D (Ibadan),
Reader in Geography,
University of Ibadan, Nigeria.

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CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION

Irrigation describes those practices by human agency that are adopted to supply water to an area, so as to reduce the length and the frequency of the periods in which a lack of soil moisture is the limiting factor to plant growth. It also involves the control of excess soil moisture through drainage and the adoption of cropping practices, and farming systems to optimize water use (Adams, 1987; Carruthers and Clark, 1981 and Ruthenberg, 1980).

Irrigation may be generally classified into two; traditional and modern, on the basis of irrigation materials used and the mode of operation. Traditional irrigation is essentially characterized by the use of simple and traditional materials that are locally available, such as shadufs and buckets for drawing water, and have minimal environmental impacts outside the immediate project area. Water sources for this system are mainly residual soil moisture, farmers' locally dug shallow wells, ponds and other natural depressions. There is virtually no government or other external organizations' assistance and interference; it is under local responsibility, sponsored, controlled and operated by local people in response to their wishes and felt need. There are about 1 million hectares of land under the traditional irrigation farming in Nigeria (Adams, 1986; Adams and Carter, 1987 and Olukosi and Isitor, 1990).

Modern irrigation farming, on the other hand, has come to be viewed as part of the technological improvement that is capable of radically altering agricultural production systems (Baba, 1984). Modern irrigation is centrally planned, controlled and coordinated, and has been tied to a bundle of external inputs ranging from the technical advice and guidance of experts to the structural installation of modern engineering works and pumping stations. The provision of essential factors of production is normally through the assistance of specialized government agencies. In Nigeria there are about 30,000 hectares of land under the modern irrigation, a practice that started around 1918 along the

Sokoto-Rima valley (Adams, 1985 and 1986).

Generally speaking, in agriculture, it is difficult to tell which direction farmers are moving because agricultural activities and practices are evolutionary. In some cases both the traditional and modern agriculture make use of the same production resources (for instance, chemical fertilizers). However, for the purposes of this study, the use of the imported water pump in irrigated agriculture is used as the basis for classifying irrigation farming practices into modern and traditional. This is because water application is most central in irrigation farming and the water pump is a product of western technology developed to ease water application process.

1.2 PROBLEM OF THE STUDY

The development or adoption of an appropriate strategy by governments in third world countries in intervening meaningfully in traditional agricultural production has remained problematic since colonial times. The ill-fated groundnut schemes in Nigeria and

Tanganyika, for example, in the early post war period were costly failures owing to drought, mis-management and high costs of opening up new land (Grove, 1989 and Schliephake, 1987). Furthermore, wholesale transfer to the colonies of western farming systems which evolved out of a highly technologically developed industrial culture have not worked.

Unfortunately, independent African countries, including Nigeria, continued with the export-oriented agricultural development policies and programmes that were used by the Europeans in the immediate post-colonial period. The governments in independent African countries have endeavoured to extend such western farming methods to the farming population at large through extension services (Areola, 1982 and Grove, 1989). For example, in Ghana the tractor-hiring scheme, that was extended into the post-independence period, became disastrous owing partly to the difficulties experienced in keeping the machinery in working order. According to Grove (1989), in more recent times, state farms, which epitomized modern production system (due to the use of modern production factors), in Mozambique and Ethiopia have failed to produce efficienctly.

The food crisis that hit many African countries in the 1970s onward was as a result of this lack of foresight and courage to tackle the problem of adapting traditional food crop production system to meet the needs of the ever growing population and the modern industrial economy. The debate on the promotion of agricultural productivity and self-sufficiency in food in African and Third World countries since the 1970s has centred around such issues as; the desirability of western-styled farming vis-a-vis traditional farming: the desirability of the modernization of farm management practices and the adoption of an appropriate technology to achieve this; the institutional framework for promoting agricultural productivity, such as the National Accelerated Food Production Programme, the Operation Feed the Nation and the Green Revolution Programme; the appropriate agricultural planning unit; including experiments with integrated river basin development approach and the integrated rural development approach. These programmes were conceived with the belief that modern structures, better farming implements, improved seeds, among others, would increase farm productivity and income.

These issues have been clearly reflected in the debates that have accompanied the development of irrigation farming in Nigeria and other African countries (Adams, 1983, 1984 and 1987; Erhabor, 1982 and Wallace, 1979 and 1980). The strategy of capital intensive modern irrigation in particular has been the subject of much debate and criticism since the colonial times (see Adams, 1983, 1984, 1985 and 1987; Baba, 1985; Bird, 1984; Borden, 1984; Cantor, 1970; Griffith, 1984; Matlock, 1985; Olofin, 1980; Palmer-Jones, 1980 and 1984; Siam, 1984 and Wallace, 1980).

The modern irrigation practices, including the use of water pumps, are new introductions to the existing traditional irrigation practices that have been with us for ages. As mentioned already, the shift in emphasis from traditional to modern irrigated agriculture is based on the belief that modernization of farming operations is crucial to increased agricultural production. However, the performance of the new production system has been disappointing. Even when apparent success has been attained, it has not always been sustained. The disappointing performance in itself signifies a failure on the part of planners in Nigeria and other developing countries to grasp the implications of new production system (Areola, 1982). Thus, the problem of irrigated agriculture in Nigeria and other developing countries is basically that of modernization.

Furthermore, the failure of agricultural development schemes in African and other developing countries has caused many people to react against the western technical innovations involved in modernization and to advocate for building on existing indigenous knowledge and methods of production. It is generally recognized that farmers in the developing countries had accumulated knowledge about the means of coping with the environment in which they operate (Adams and Carter, 1987). This means that the traditional irrigation system has great potentials for improving the income of farm families. In spite of its great potentials, attention is not paid to it and this perhaps explains why governments in developing countries, including Nigeria, have not properly considered its development. Consequently, indigenous agricultural knowledge, despite being ignored or overridden by policy makers, is the single largest knowledge resource not yet mobilized in the agricultural development enterprise (Adams and Anderson, 1988 and Richards, 1985).

In more recent times, with the occurrence of the unpredictable drought, famine and more importantly the foreign exchange shortages, confidence in the modern ways of farming has diminished. Greater willingness is being shown to consult the local people and learn from them (Grove, 1989 and Metzner, 1981). Thus, there is a growing concensus that developing countries would probably reap greater benefits and develop a more lasting irrigation farming culture if they were to concentrate and improve upon their age-old traditional irrigation and flood-plain farming systems (Adams, 1985; Adams and Carter, 1987; Grove, 1989; Matlock, 1985; Richards, 1985 and Turner, 1986). But the operational details, costs and benefits of this modern irrigation have not been fully studied in order to assess its value over and above the age-old traditional irrigation and flood land farming practices. This is the central issue that the present study attempts to tackle.

1.3 AIM AND OBJECTIVES OF THE STUDY

The aim of the study is to compare the relative productivity and profitability of traditional and modern irrigation farming with a view to assessing the impact of 'modernization' of indigenous irrigation farming on the agricultural economy of the peasants.

The following specific objectives shall be pursued;

(i) To analyse the physical environment in terms of resource endowment (land and water) of traditional and modern irrigation farming so as to understand relationships between resource use and environment.

(ii) To study farm management characteristics of traditional and modern irrigation farming, in terms of factors of production, and to describe variations in patterns of use of variable factors of production between and within traditional and modern irrigation farming.

(iii) To examine relationships between factors of production and size of land irrigated under traditional and modern irrigation farming.

(iv) To show how crop yields vary and examine the nature of relationships between crop yields and factors of production under traditional and modern irrigation farming.

(v) To identify and analyse constraints of traditional and modern irrigation farming, and to suggest ways of improvement.

1.4 REVIEW OF PREVIOUS STUDIES

Previous evaluations of irrigation farming in Sudano-Sahelian parts of Nigeria and other African countries centred predominantly on the general environmental, political and socio-economic impacts (Adams, 1983, 1984, 1985 and 1987; Baba, 1984 and 1985; Bird, 1984; Borden, 1984; Griffith, 1984; Hotchkiss and Bell, 1987; Matlock, 1985; Olofin, 1980; Palmer-Jones, 1980 1984; Rydzewski, 1990; Siam, 1984 and Wallace, 1979 and 1980).

Although these studies have yielded very valuable information concerning irrigation performance, they did not consider performance in terms of agricultural productivity at the micro-level. These studies are therefore of little relevance to the study of irrigation productivity of the small-scale irrigation farming. This implies that much could be learned from studies of irrigation productivity.

Specifically, studies by Adams (1984); Adams and Anderson, (1988); Matlock, (1985); Richards (1985 and 1988); Rydzewski, (1990) and Turner (1984, 1985 and 1986), were fundamentally ecological, though some of them touch on the economics of irrigation farming (Turner, 1984 and Rydzewski, 1990). More often than not, the ecological influences of irrigation production were studied independent of the economic influences. Where they were studied together, it was done in isolation of their functional relationships with the production of output. This does not adequately show the nature and strength of relationships between resources of production and output. The understanding of the relevance or otherwise of traditional and modern irrigation practices depends on functional relationships between production resources and output. These relationships can only be understood if the ecosystem, production function and utility function approaches are used jointly to study irrigation productivity. These approaches provide both the essential ecological and socio-economic backgrounds to the practice of irrigation.

Agricultural productivity, which expresses the relationships between inputs and yields, has now been accepted to be important in the conceptualization and evaluations of irrigation agriculture. Of all the few attempts made to study agricultural productivity in irrigation at the micro-level, that of Erhabor (1982) and Nwa (1981) appear to be outstanding. They focused their evaluation on the efficiency of resource use, relative to productivity, under the small-scale technology. They showed how the water pump was more efficient in water utilization, and, hence crop yield generation over the traditional shaduf system, and vice versa in terms of cost of production.

The relevance of the shaduf system, however, as a traditional method of irrigation, has diminished since Erhabor (1982) and Nwa (1981) did their work. What is of relevance in traditional irrigation farming is flood recession farming (Adams, 1986; Adams and Carter, 1987; Richards, 1985 and Voh, 1984), which has not received much attention in the literature of land resources. Although Erhabor, (1982) used the production function model in his study of productivity in irrigation, he did not consider the flood recession farming.

Furthermore, Adams (1987) compared two different approaches; large and small scales to water resources development for irrigation. His approach was essentially ecological, although he was concerned with other agricultural aspects, like cropping strategies and yields.

Adams (1987), like Nwa (1981), did not show the production function of resource use under the two different technologies. It is therefore difficult for them to judge adequately which of the two technologies of irrigation production is more efficient in production resources utilization.

Again, the basis of Adams's (1987) comparison was inadequate because of the limitations of the different scales of operation. It should be realized that, farming conditions and problems vary often considerably with different scales of operation. Thus, the main gap in the research base is in the functional relationships between production resources (both natural and non-natural) and crop output in traditional and modern irrigation.

The 1970s witnessed the development of two strategies; the River Basin Development schemes and the World Bank Assisted Agricultural Development Projects, among others, as the main routes towards achieving increased agricultural productivity. These schemes and projects introduced the use of modern water pumps in irrigation (Adams, 1989 and Williams, 1988).

Huge sums of money, in the form of foreign exchange, were expended in the procurement of water pumps and their essential components, fertilizers and foreign expertise, among others (Palmer-Jones, 1980 and Wallace, 1980). According to Williams (1988), the dollars committed to the provision of the modern factors of production have escalated since 1981.

However, with the introduction of the Structural Adjustment Programme (SAP) in 1986, Nigeria experiences crisis in foreign exchange and this makes it difficult for the government to import the needed spare parts to maintain existing irrigation water pumps. Also, because of long familiarity with the pump irrigation, farmers tend to consider the traditional shaduf irrigation as outdated and rigid, in terms of its engineering structures, as reflected by its diminishing importance in production enterprise. The existing problems associated with the pump and shaduf irrigation could probably create the tendency for irrigation farmers and the government to shift their attention to the neglected traditional flood recession irrigation practices.

A study of traditional flood recession irrigation is therefore necessary in order to highlight its advantages and limitations over and above the pump and shaduf irrigation, and vice versa. Adams (1986) and Voh (1984) have drawn attention to the possibility that flood recession farming conditions constitute a more manageable environment for crop production. According to Adams (1986) the comparison of productivity of traditional and modern farming practices is relevant to the on-going debate on sustainable based development. This study was carried out in the area with predominant flood recession irrigation practice and therefore takes into account the short comings of the earlier studies outlined above in terms of irrigation productivity.

1.5 CONCEPTUAL FRAMEWORK

A farming system includes inputs of land, water, labour, capital and management which are applied to production in order to produce products and income (Mellor, 1973). The functioning of the farming system requires that a number of interrelated decisions be made about the quantities and ratios of the inputs to be used, and the desired quantities and combinations of products. These decisions are influenced by the total environment in which the farmer operates.

According to Gregor (1970); Moss (1972) and Tarrant (1974), this total environment can be divided into three basic theoretical approahces within which agricultural productivity can be analysed. The first assumes that the physical environment controls agricultural productivity; the second can be called economic determinism where uniform producers react in a uniform and rational manner to economic circumstances; and the third recognizes a set of influences on agricultural productivity that is not based on economic or physical environmental factors. These influences include the identifiable aims and objectives towards risk aversion which are important in agricultural productivity.

The three theoretical approaches to the analysis of agricultural productivity helped in the formulation of some basic questions in this study; why are some irrigation farms located on some sites and others not; how does the irrigation farmer allocate his available production resources, namely water, labour and fertilizer, among others, in such a way as to maximize his production and income. Attempts shall be made to answer these questions using the concepts of ecosystem, production function and utility function.

1.5.1 Ecosystem

This is the oldest approach and it is basic in agricultural geography, because the distinguishing feature of agricultural domains, defined by their natural aptitude for certain farming operations and their ineptitude for others, is an indispensable basis for agricultural productivity. The ecosystem concept has been successfully employed as a method of approach to the analysis of land use patterns and agricultural systems in particular. The conceptual basis of the ecosystem theory is that land use patterns of agricultural systems depend on the physical environment and its conditions, whether beneficial or harmful, that define the physical potential of the farming system (Barrow, 1987; Mellor, 1973; Morgan, 1972; Morgan and Munton, 1971, and Richards, 1985).

Studies in developing countries reveal a high degree of ecological perception on the part of the indigenous cultivation, as indicated by the farmers' ability to select those systems of production and techniques of management that make the most efficient use of available environmental resources. The farmer's use of his resources will depend on his perception of them rather than any objective measure of their characteristics. His perception of their value for alternative production systems will depend on his background, information and ability, and his yardstick will be based on his past experience of them (Morgan and Munton, 1971).

Furthermore, the scale of farming operation may be determined by the relative disposition of the land and the water resources. The aim is to find water resources closer to the land. Farmers' water management strategies, for example, are designed to take care of contigencies. Two techniques are of paramount importance here. The first is to move up and down slopes exploiting sites with different drainage, soil moisture and fertility characteristics (Holmes, 1986). The fact of being on the move up and down a slope as a regular feature of the cultivation strategy permits some degree of rolling adjustments-dwelling longer or moving out of any given site as farmers see how the season is progressing (Richards, 1988).

According to Moss (1972), the concept of ecosystem can be used to evaluate relationships that exist in real places and thus to bring out the ecological background to the use of biological resources. He specifically used the concept to show the character of plant soil systems. Morgan (1972) also used the ecosystem concept to show the relationship between peasant agriculture and productivity. Although the approach was used by Morgan (1972) and moss (1972) to show relationships between use of biological resources and the environment, taking a whole ecological zone, it could also be used to show the ecological background to the use of resources in different land facets within an ecological zone. Turner (1984) and Adams (1987), for example, have used this approach to demonstrate how some sites can be used during the first part of the dry season and how some sites are too wet at the beginning of the dry season, and can only be used when the surface water has dried out. In the context of this study, topography of specific sites shall be used to mean the total environmental factor in evaluating land and water use in traditional and modern irrigation, rather than a whole distinctive ecological zone. This is because of the influence of topography on other geographical elements, such as micro-climate and soils, among others.

Again, farmers select and maintain a suite of crop varieties well adapted to this process of rolling adjustments (Grove, 1989 and Richards, 1988). Typically, farmers will pay attention to where a crop variety does better on the topographic profile, and whether its duration or other growth characteristics (ability to withstand drought, weeds and neglect) are suited to its purpose within the system as a whole (Richards, 1988).

However, George (Gregor, 1970), cautions against any tendency to over-emphasize the force of physical barriers to agriculture. According to him the relations between farming and the environment present a variety of actions and reactions of which the lines of force differ according to the technological capacities and the abilities for organization of the farmers.

1.5.2 Production Function

Production is a process whereby inputs are transformed into output. The principles of production are the same irrespective of where production occurs. It normally involves the proper combination of a wide variety of non-homogeneous productive factors and relevant agronomic practices in such a way as to achieve optimum production results (Barlowe, 1978 and Mellor, 1973). The relationship between inputs and output can be characterized by a production function. Production function describes the way in which the quantity of a particular product depends upon the quantities of particular inputs used (Ogunfowora, et al., 1974 and Toussaint and Bishop, 1958).

The theory of modernization of agriculture may be represented by a production function depicting agricultural output as a function of various inputs, some used in traditional and modern agriculture alike, others used only in modern agriculture and still others used only in traditional agriculture (Mellor, 1973). The low productivity of traditional inputs is due to lack of technological change that are needed to complement them. Thus, new inputs will cause an increase in the productivity of the existing resources of a traditional agriculture (Mellor, 1973 and Toussaint and Bishop, 1958). The effects of new inputs may be viewed as shifting the production functions for traditional inputs upward and extending them. Agricultural modernization is thus more than a process of increasing the productivity of the traditional resources already employed.

A particular relationship between output and quantities of a useful input always occurs when the quantities of the inputs are allowed to vary while quantities of all other inputs are held constant. Where farmers respond to the production function and choose optimum crops at different locations; they would be providing direct proof of the principle of land use competition but not of ecological principle of land use. However, the two ideas are related, because the nature of any production function is partly dependent on land quality (differences in slope), labour productivity and other factors of production. Viewed in this way, there is no conflict between man-land and economic views of spatial variations in land use (Found, 1971).

Furthermore, a basic premise of traditional economic theory is that the motivating force behind men's action is the attempt to maximize income. To the farmer, then, the way a particular land use contributes to his income is vital; and the price he receives for the product associated with the land use is of first importance (Barlowe, 1978 and Found, 1971). According to Barlowe (1978), many conclusions in economic analysis involve simple cause-and-effect reasoning with the assumption of "other things being equal". Attention is therefore focussed on particular factors that may have significance in the explanation of economic behaviour.

Economic considerations arise from the fact that a choice between alternative production functions must be made. If a producer is interested in maximizing net return from the use of his resources he will wish to employ some production function in preference to others.

In using a production function, we assume that inputs are combined in a particular way. Two production functions may be quite different even if the same input is used in producing one kind of output. The difference between functions is therefore due to difference of technique in how the inputs are used in producing the output (Found, 1971 and, Toussaint and Bishop, 1958). However, the difference in production function could reflect differences in slope, labour productivity or other factors relating to factors of production. When the quantity of products which can be obtained from a particular quantity of inputs is increased, this is known as technological improvement (Toussaint and Bishop, 1958). According to Found (1971) this reflects a comparative advantage of one over the other. Cost differences are involved between techniques; a producer would choose the technique which gives the greater output for any given input level.

The production function has been the traditional tool for analyzing problems of resource productivity and returns to scale. It provides a direct measurement of the parameters of resource productivity (Ogunfowora, et al., (1974), Bagi (1981), Erhabor (1982) and

Ogunfowora, et al., (1974) have found the use of production function adequate in their evaluation of the efficiency of resource use in production framework. Similarly, Johnny (1981) used the concept of production function to evaluate the productivity of traditional upland rice farming. Since one of the emphases of this study is on productivity, the production function approach will be similarly used to evaluate the productivity of traditional and modern irrigation farming.

A number of functional forms; quandratic, linear, spillman, square root, power and variants of these are possible in production function studies. One of the simplest production decisions involves the effects of varying the quantity of one input on the amount of product produced. Therefore, the linear function will be used as the lead equation. In this case, production function can be represented by the functional form:

$Y = f(x_1, x_2, \ldots x_n)$, which states that Y (the quantity of product Y) is dependent on the quantities of n different inputs, namely $x_1, x_2, x_3, \ldots x_n$ (Found 1971, Ogunfowora, et al., 1974 and Toussaint and Bishop, 1958). This approach will be used in this study as a means of estimating the efficiency of resource use under traditional and modern irrigation production.

In accordance with the traditional characteristics of economic man, the objective in deciding what quantities of inputs to use for a given production level is to maximize the return of production (Found, 1971). As satisfactory economic returns have to be obtained from costly technological innovations, the economic importance of limitations will depend on the overall profitability of the farming system (Morgan and Munton, 1971).

However, Grigg (1980) opines that, although classical work on agricultural production assumed that farmer is a rational profit maximizer, this assumption can now rarely be made, as other factors can be shown to influence farmers' decision. This brings to mind the concept of utility function.

1.5.3 Utility Function

A production function which typically assumes the producer's objective is maximization of expected returns implies that farmers disregard risk. Risk can be regarded within such models, however, by making restrictive assumptions about the producer's risk attitudes. In irrigation farming, farmers may have other goals with respect to irrigation besides increasing expected returns. They may also view irrigation as a way to manage risk (Ilbery, 1978 and Toussaint and Bishop, 1958).

Where a farmer satisfies some basic assumptions about behaviour, then a utility function exists which expresses his preference for income or other outcome of concern. According to Ilbery (1978), variations do exist in the degree farmers are commercially oriented and this is often expressed by the fact that farmers have other goals apart from pure profit maximization. He further used the utility function to demonstrate how farmers' decision may be expected to reflect a wide range of goals with regard to profit and security, from market orientation to pure self-sufficiency. Most people regard monetary returns as an intermediate rather than a final goal. For them, money is a means to the attainment of more ultimate ends. When the profit-maximization process conflicts with these ends, they will often settle for less money and more security (Barlowe, 1978 and Ogungbile and Ologunde, 1986).

Utility function can be used to evaluate irrigation management strategies including choice of crops and amount of water applied. Strategies which maximize expected profit do not maximize expected utility for all the utility functions used. This demonstrates the importance of considering irrigators' willingness to accept risk when evaluating irrigation strategies (Toussaint and Bishop, 1958). Patil and Jha (1981) used the concept of utility function to show the overriding traditional emphasis on security and to explain the lack of specialized production, and why all producers tend to grow the same crops regardless of agronomic conditions or comparative advantage. Found (1971) has also found the utility approach useful in the analysis of land use and he used the term 'utility' to describe the most general common denominator for comparative value.

However, the application of the concept of utility function becomes difficult when products cannot be measured or their prices determined (Found, 1971). Both Barlowe (1978), Found (1971), Ilbery (1978) and Mishan (1971) have solved the problems of cognitive structures (due to the difficulties of relating the concept to scientific measurement) by translating the real values of production enterprise into utility to a business-like operator. The concept of utility assumes that any enterprise must have usefulness or utility if they are to have economic values (Barlowe, 1978).

Utility is defined as a numerical measure of a decision maker's relative preference for possible consequences (FAO, 1984). It is thus the use value, and, hence economic value of the enterprise (Barlowe, 1978), Found, 1971 and Mishan, 1971). One of the premises on which traditional economic theory is based is that decision makers can evaluate, on a common comparative scale, all inputs and outputs of landuse. Market price has been used in all cases as the common yardstick. Comparing the expected utility of alternative acts is equivalent to a comparison of the decision maker's degrees of preference for these alternatives and enables the most preferred act to be selected (FAO, 1984 and Found, 1971).

Decision theory implies that the appropriate choice criterion, which is the expected utility, is necessary in order to compare set of possible consequences of any act with set of possible consequences of any other act. The utility of the consequence of any act can be denoted U(cij) and thus the expected utility of the j-th act, denoted U(aj), is given by;

$$U(aj) = \sum_i P_i \; U(cij)$$
$$= P_{iu}(cij) + P_2 \; U(c_{2j}) + \ldots P_i \; U(cij)$$

where U is the utility of production enterprise, which is determined by cij factors.

However, it is difficult to operationalize the concept of utility. Found (1971) has already mentioned the problems in using traditional economic models arising from the problems in measuring utility to land use. This study has acknowledged therefore this inherent problem and does not intend to go beyond the comparison of the use of factors of production relative to yield and income generation. Yield and income are value scales with which to compare the utility of production enterprise. It has been argued that if individual utility is used to replace market value or price, then much of the existing theory is generally applicable.

In this study yield and income shall be used to refer to utility since they are measurable and have economic value. The perception of farm practice depends upon the anticipated output and value, among others.

As seen above, the agricultural practices of the farmer are conditioned by his relationship to the community, just as it is by the ecological limitations of his environment, and by the materials and techniques at his disposal. There is therefore no single model of a peasant cultivator. This implies that the three concepts that address the farmers' total environment must be seen to operate together. Again, this study has as its main objectives the development of operational relationships between the various factors of production and to demonstrate the use of the relationships in achieving crop productivity. Therefore, the approach adopted in this study involves the consideration of the ecosystem, production and utility functions of irrigation farming.

1.6 HYPOTHESES TO BE TESTED

The hypotheses stated to guide the study are:

(i) Size of irrigation land and amount of water use are affected by the physical location of traditional and modern irrigation farms.

(ii) Size of land cultivated is a function of site location, volume of water, size of labour, quantities of fertilizers, cropping patterns, land tenure and cost of production under traditional and modern irrigation farming.

(iii) Crop yield varies with site location, month of irrigation, methods of land acquisition, size of land cultivated, frequency of water application, volume of water, size of labour, quantities of fertilizers, cropping patterns, cost of production and income within and between irrigation types.

(iv) There is no relationship between cost of production and income within and between irrigation types.

CHAPTER TWO

THE STUDY AREA

2.1 INTRODUCTION

The Donga River Basin offers both resource opportunities and problems that affect the development of irrigated agriculture. The understanding of the physical characteristics of the area is crucial to the understanding of the need for irrigation.

The area, located within the Guinea savanna zone of Nigeria, has rainfall for about five months in the year. The short rainy season constrains cultivation to one cropping season each year. Therefore, the use of water for irrigation forms an important aspect of the agricultural practice in the area. Irrigation practice is further helped by the presence of many favourable conditions created by the existence of numerous terraces and fadama lands, which are of great agricultural importance both for rainfed and irrigated crops.

2.2 LOCATION

The Donga River Basin lies in the south-western parts of Gongola State and extends between latitudes $6^{o}30'$ to $8^{o}20'$ north and longitude $9^{o}50'$ to $11^{o}30'$ east, and covers a total area of 17,000 square kilometres.

2.3 PHYSICAL CHARACTERISTICS

2.3.1 Geology

The importance of geology in irrigation development lies in its influence on soil and land type. In the area four major geological divisions of varying significance to agricultural development, can be identified (MRT, 1978);

(1) The basement complex rocks, which cover most of the catchment area south and east of the Donga and Suntai areas.

(2) The upper cretaceous sedimentaries, which underline the Donga and Bantaje plains.

(3) The tertiary rocks, which underlie a comparatively small area of the Mambilla plateau, and

(4) Recent alluvium of the Donga and Suntai rivers.

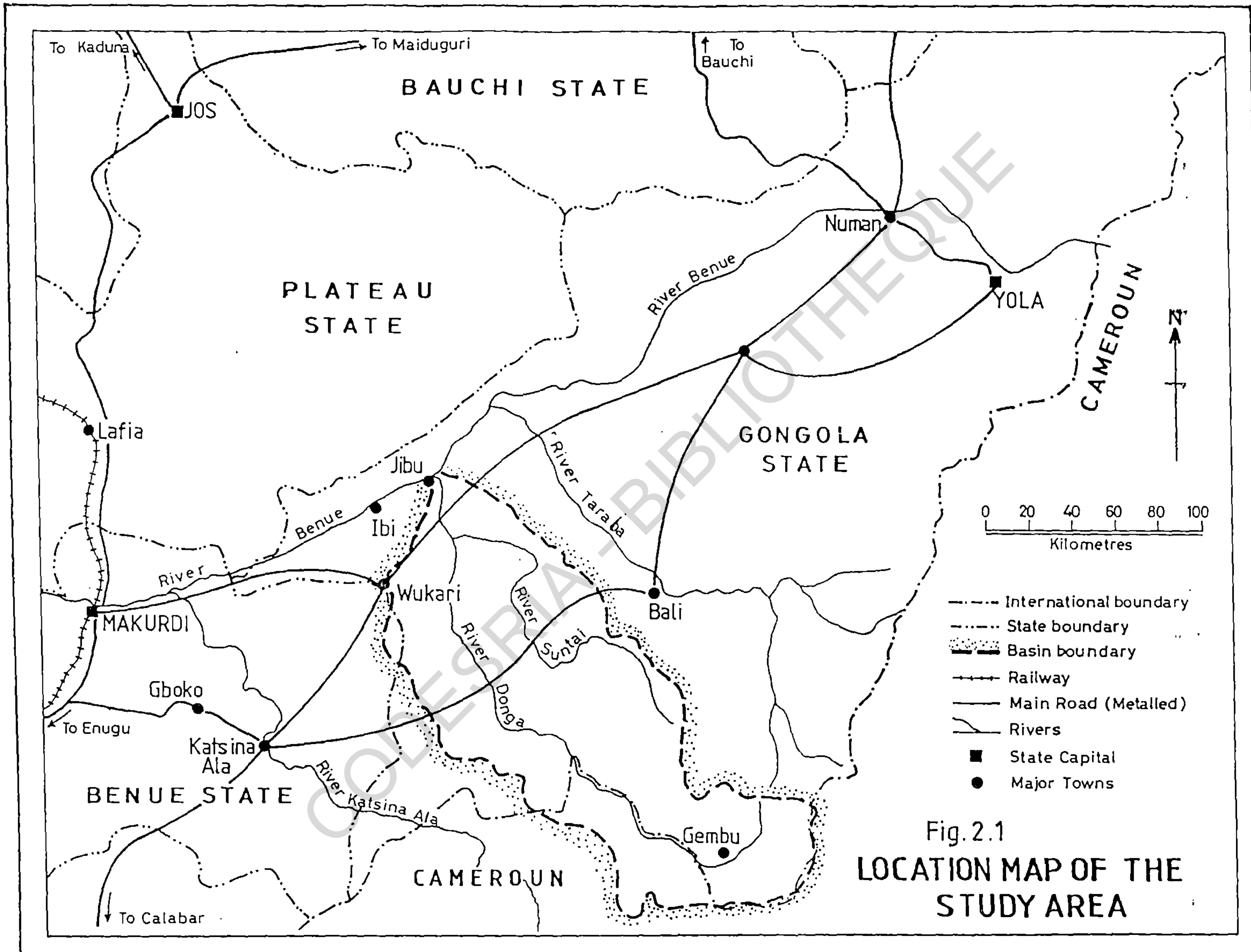


Fig. 2.1
LOCATION MAP OF THE STUDY AREA

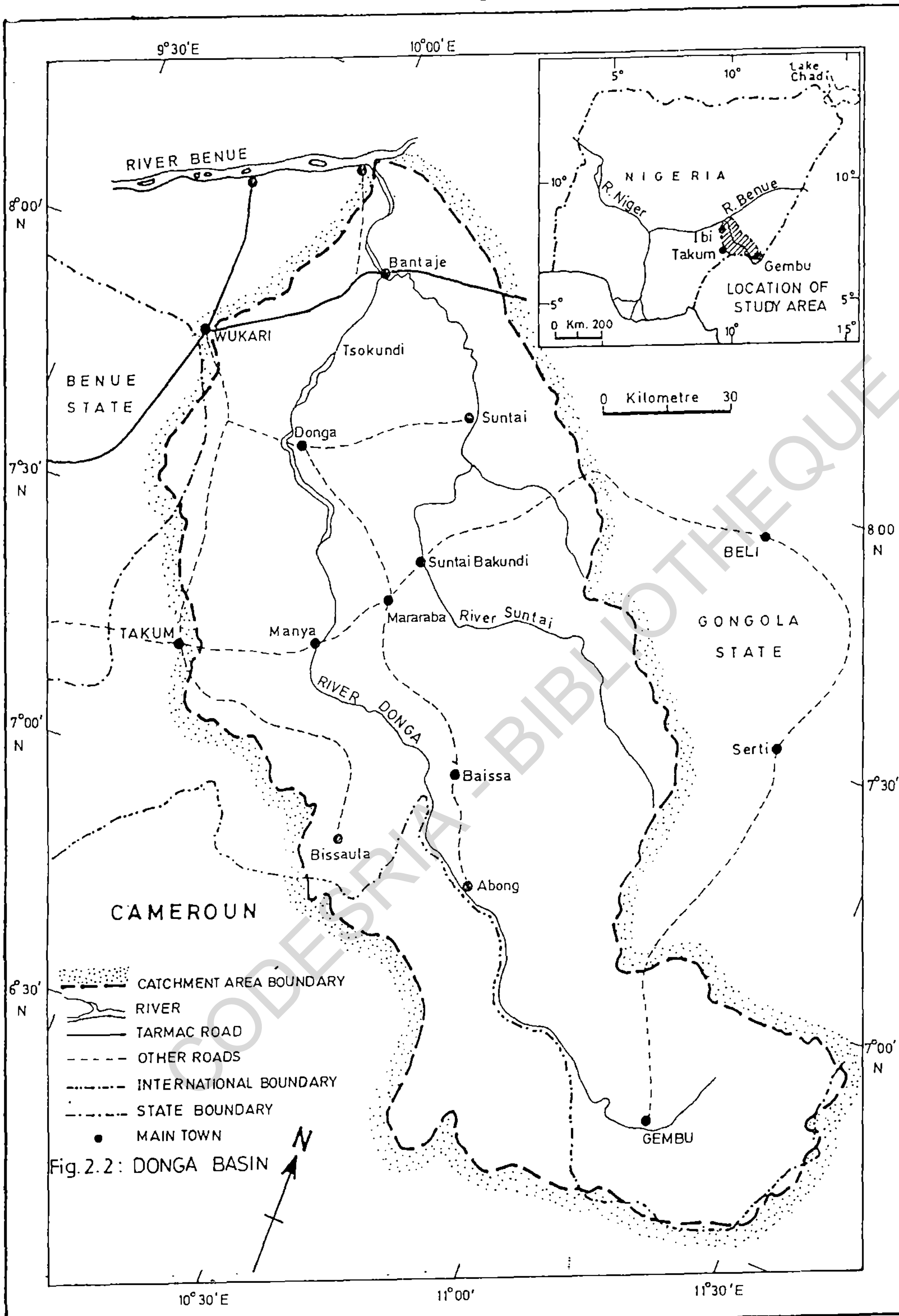


Fig. 2.2: DONGA BASIN

Source: M.R.T. (1978)

Most water supplies are obtained from surface sources; rivers, streams and relatively shallow wells.

2.3.2 Landforms and Soils

The area can be regarded to be a flood-plain fadama, which is of considerable importance for irrigation since agriculture depends on the river flood regime.

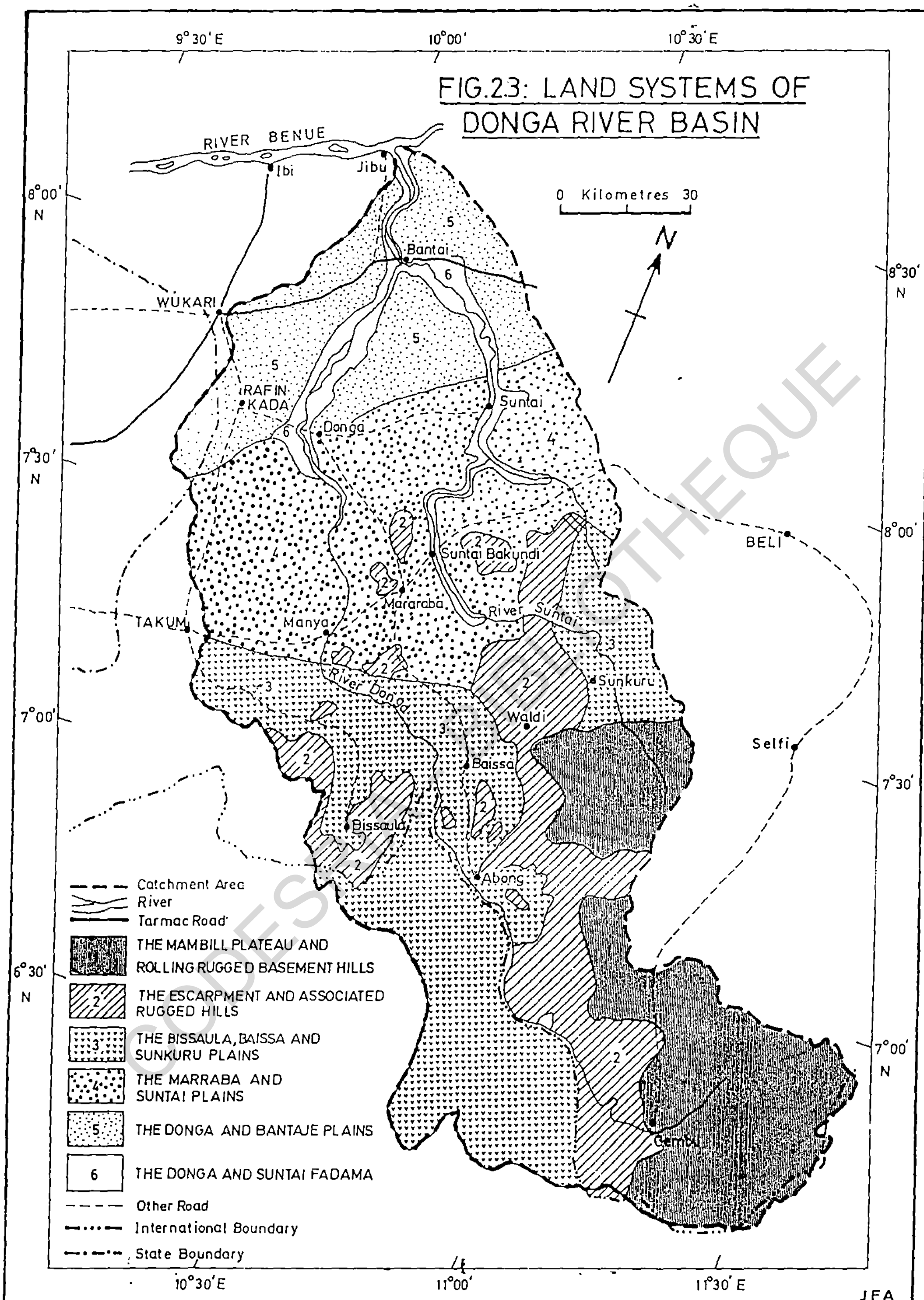
The terrain of the basin varies from rolling grasslands in the south to low flood plains adjoining the Benue in the north. There are about six different landforms in the area (Fig. 2.3); the Mambilla plateau; the escarpment and associated rugged hills; the Bissaula, Baissa and Sunkuru plains; the Mararraba and Suntai plains; the Donga and Bantaje plains; and the Donga and Suntai Fadama.

Generally the soils of the area can be divided into three; soils of the upper catchment, middle catchment and lower catchment.

2.3.3 Vegetation

The area lies within the Guinea savanna vegetation zone of Nigeria. The Basin has a broad range of vegetation according to climatic zone and altitude. On the

FIG.23: LAND SYSTEMS OF DONGA RIVER BASIN



Source: M.R.T. (1978)

Mambilla Plateau, montane grassland communities predominate. In the middle Donga valley and surrounding hills the vegetation consists of a typical Guinea savanna, and typical forest species. The lower catchment supports a dominantly Guinea savanna vegetation in which most of the naturally occurring woodland has been converted to tree savanna under the influence of human occupation, featuring bush clearing and burning for cultivation, and hunting as well as cattle grazing.

The vegetation of the Donga and Suntai fadamas is mainly grassland with trees on the levees, sedges in the depressions and riparian forest in few areas south of Tsokundi.

2.3.4 Climate

The climate is the Guinea savanna type. It is typically tropical climate with two clear seasons; wet and dry. The climate of the area is very much influenced by its distance from the coast. The characteristics of the major climatic elements are described below.

(a) Rainfall

The area is considered as a low rainfall area. The agricultural growing season for rainfed cultivation is confined to the rainy months; beginning in April extending until October. The mean rainfall (Table 2.1), from the nearby meteorological station at Ibi (28 km to the study area), are based on 30 years record (1959-89) and can be taken to be representative of the average rainfall condition of the Basin.

The need to use a set of rainfall data for a long period of time has already been emphasized by Jackson (1977). Table 2.1 shows that rainy season reaches its peak in September, with about 186.5mm. Land preparation for irrigation normally begins with the end of rains in November. Irrigation practices continue until the early rains arrive in April of the following year.

The total and the duration of the rains affect the level of water available in the Donga, Suntai and other tributary rivers and in the fadama lands for irrigation. Variability of both the annual and monthly distribution of rainfall is a serious limitation to agricultural

TABLE 2.1: SOME LONG TERM MEAN CLIMATIC DATA (1959-89) FOR THE METEOROLOGICAL STATION

Month	Rainfall (mm)	Temperature (°C)	Evaporation (mm)
January	2.0	34.6	0.011
February	0.8	37.0	0.012
March	17.9	37.6	0.011
April	61.8	35.9	0.007
May	123.9	32.7	0.004
June	144.9	31.0	0.003
July	148.3	30.0	0.002
August	177.2	29.9	0.002
September	186.5	30.3	0.002
October	106.9	31.5	0.003
November	6.4	33.4	0.006
December	0.4	34.2	0.009
Mean	81.4	33.2	0.006

Source: Meteorological Registers: IBI Met. Station (1989) development in the area. Where irrigation is not practised, agriculture is at a standstill from the end of harvest in October and November until the planting rains arrive in the following April.

(b) Temperature

The temperature, as indicated in Table 2.1, shows a sharp peak of 37.6°C in March which is also the time of lowest river flow due to low rainfall. The temperature falls to 35.9°C with the onset of the rains which reduces it to the low levels, in April and remains steady throughout the height of the rains in May - October. At the end of the rains it rises again until March of the following year, and this period (November-March) coincides with irrigation season in the area.

(c) Evaporation

Table 2.1 above shows that evaporation is highest in February with about 0.012 millimetres with the lowest in July - September. The data again show that evaporation rises from November to March in the Basin and the amount of evaporation during this period is greater than the rainfall figures. The amount of rain which falls between December to February indicates that more than two times the amount of rain which falls could be evaporated during the same period. This results in an acute water shortage and this underlies the importance of irrigation. In fact this period in which evaporation is greater than rainfall coincides with the period of irrigation in the area.

2.4 WATER SOURCES

Water resources development for irrigation forms a crucial aspect of agricultural development in the area. The elements of water resources of prime significance to the study are the consequence of its availability, development, utilization and management on agricultural development. The various sources of water are precipitation, surface water flow (rivers, streams and ponds) and ground water, with the surface water being significantly relevant as far as irrigation development in the area is concerned. The river Donga, which floods the valley fadamas and terraces, receives the bulk of its water supply from the Mambilla plateau (about 1750 meters high). River Suntai, the largest tributary of the Donga River, rises from east of Baissa and joins the Donga river at Gindin Dorowa near Bantaje. The joint waters of the Donga and Suntai Rivers enter the River Benue near Jibu town, contributing about 145000 Mm^3 of water per annum to the Benue (MRT, 1978). Both the rivers Donga and Suntai receive a number of tributary streams that, though relatively small, offer considerable potential for development.

The period of lowest flow is in March, after which rainfall on the Mambilla Plateau causes river flows to rise again. The flow reaches a small peak in September, drops slightly and then reaches its highest values in late October, after which there is a rapid water recession. With flood water recession diverse agricultural activities; dry season irrigation and residual soil moisture cultivation are supported.

2.5 LAND RESOURCES DEVELOPMENT

Agriculture is the principal livelihood of the people in the area. It is an important agricultural region with about 20,000 and 12,000 hectares being developed through the traditional and modern systems of irrigation on the Donga and Suntai fadamas respectively. There is also a number of tributaries of Rivers Donga and Suntai with considerable areas of fadama lands (about 21,000 hectares) being developed through irrigation (UBRBDA, 1989). The land resources potentials of the basin attract people from near and far places to cultivate available land.

2.5.1 Irrigation Development

The area has a long history of traditional irrigation, based on the use of locally constructed Shaduf, buckets and watering cans. It is usually associated with the valley and the floodable parts of the low terrace. The traditional irrigation, as practised in the area, can be classified into two; basin and flood recession. The basin irrigation involves the use of hand buckets, calabash, the construction of simple basins and field channels (both main and distributory) for water control and management. From the survey, it was found that flood recession farming was the dominant form of irrigation, involving about 45.6 per cent of the sampled irrigation farmers. It was mainly concentrated in the Donga, Baissa and Tsokundi sectors of the study area. Flood recession farming is relatively old in the area and according to oral history, it was the oldest form of water management strategy for irrigation practice in the area. Traditional bucket (manual) irrigation used to be an important form of irrigation in the area, but with the introduction of the engine pumps in the early 1970s, its importance has declined considerably. During the survey period, for instance, only 13.7 per cent of the sampled farmers were found to be practising the manual irrigation farming, as compared with about 40.7 per cent of them found to be practising the pump irrigation.

The fadamas of the area (about 500 hectares) have been targeted to be developed with irrigation facilities and adequate flood protection. A pilot scheme, however, covering about 300 hectares has been established, out of which 120 hectares were fully irrigated. Furthermore, a pilot farm of 100 hectares was established in

1981 at Bantaje as a fore-runner of the Suntai irrigation scheme. About 600 hectares had been developed and cultivated (UBRBDA, 1989).

It has been estimated that the irrigation schemes in the area would cost ₦181.2 million and they are expected to be completed in 1996, subject to availability of funds. As at now about ₦10 million had been incurred on the schemes (UBRBDA, 1989).

2.5.2 Land cultivated

At the Donga scheme, about 28 hectares were cultivated in 1979, producing only 2.81 tonnes of rice and maize combined (0.10 tonnes/ha^{-1}); this increased to 415 hectares in 1984 producing only 4.54 tonnes (0.01 tonnes/ha^{-1}). The hectarage declined to 394.4 in 1985 producing only 0.7 tonnes (0.002 tonnes/ha^{-1}) of crops (Table 2.2).

Table 2.2 shows that the yield of vegetables is the only measure of productivity while the combined yields of crops do not measure productivity. It is difficult to say how much was realized from each crop. Therefore there is a limit to which we can rely on the combined

TABLE 2.2: THE DONGA IRRIGATION SCHEME: AREA CULTIVATED AND YIELD REALIZED

Years	Area cultivated (Hectares)	Yield realized (Tonnes)	Tonnes/ha^{-1}
1978	8*	1.88	0.24
1979	28*	2.81	0.10
1980	40*	4.1	0.10
1981	110**	7.13	0.06
1982	155**	8.2	0.05
1983	255**	10.1	0.04
1984	415*	4.54	0.01
1985	394.4***	0.7	0.002

* = Rice and Maize

** = Rice, Maize and Vegetables

*** = Vegetables only

Source: UBRBDA, 1985

crop yields as a measure of productivity.

However, the data in Table 2.3 provide a good measure of productivity since yields are presented for single

TABLE 2.3: THE BANTAJE IRRIGATION SCHEME (RICE ONLY): AREA CULTIVATED AND YIELD REALIZED

Years	Area Developed (Hectares)	Area Planted (Hectares)	Yield Realized (Tonnes)	Tonnes/ha^{-1}
1981	150	100	60	0.60
1982	200	150	28.2	0.19
1983	200	200	231.2	1.16
1984	500	500	1124.1	2.25
1985	500	272.2	750.3	2.76
1986	500	300	803.8	2.68
1987	500	50	86.7	1.73
1988	500	150	250	1.67

Source: UBRBDA, 1988

crop only. Data in Table 2.3 show that cultivated area rose from 100 hectares with 60 tonnes (0.60 tonnes/ha^{-1}) of rice realized in 1981 to 500 hectares in 1984, realizing 1124.4 tonnes (2.25 tonnes/ha^{-1}). This declined to 150 hectares, with only 250 tonnes (1.67 tonnes/ha^{-1}) in 1988 (Table 2.3).

2.5.3 Problems of Irrigation

(a) Drainage

At the Donga irrigation scheme, the problem of drainage arises when irrigation water is released and farmers are not in the fields to utilize it. This results in the breakdown of field channels, though the scheme has provision for drainage.

At the Bantaje scheme, in the 1987 and 1988 cropping seasons, there were serious floods due to high river flows. Between 50-60 hectares of rice farms were lost to flood in 1988 alone at the Bantaje scheme (UBRBDA, 1988). Also the flood caused irregularities in fertilizer application, with farmers applying fertilizer once instead of twice as recommended, for fear that it would be washed away by flood if applied.

(b) Management

Irregularities in water supply at the Donga scheme are partly due to problems of poor design. The scheme was designed in such a way that water application is done twice per week, but most farmers want irrigation water more than twice.

Similarly, there is the problem of farmers in one block demanding water at the time it is meant officially for another block. Water recession at the pumping station of the Donga scheme is frequent. In 1984, for example, there was water recession and an incised channel was created from the other side of the river bed to allow for water transfer. But because of percolation in the exposed channel sand coupled with the distance, the water did not get to the pumping point. The consequence of the shortage of irrigation water at the scheme was that only 4.5 tonnes were actually realized from the 415 hectares cultivated (Table 2.3).

(c) <u>Cultural Resistance to Innovation</u>

At both the Donga and Bantaje schemes, farmers rejected the directive by the Upper Benue River Basin Development Authority to grow the short high-yielding rice variety (FARO 18). This was because farmers had been customarily familiar with the cultivation of the long local variety (BIRUWA). Cultivating the high-yielding rice variety requires farmers to observe and buy the necessary farming inputs for which they lack the capital. According to the Upper Benue River Basin Development Authority (1989), farmers at the Donga and Bantaje schemes were found applying an average of 31.25 kilogrammes of chemical fertilizers per hectare instead of the recommended 200 kilogrammes per hectare, required for improved varieties.

2.6 THE ROLE OF GOVERNMENT IN IRRIGATION FARMING

The pump irrigation farming, which epitomizes an aspect of the modernization process in irrigation development, was first introduced by the Irrigation Division of the defunct Benue-Plateau State in 1974. It was later promoted by the Gongola State Ministry of Agriculture and Natural Resources in 1976. The pump irrigation was further extended in scope with the establishment of the Upper Benue River Basin Development Authority in 1976. The authority later in 1978 took over the

Donga and Suntai irrigation schemes and installed three big pumping machines at different locations along the Donga River.

These government agencies did little to monitor its use in order to ascertain the impact of adaptability of the modern irrigation practice on agricultural production in the area. The privatization drive of the Federal Government to sell out the non-water components of the River Basin Development Authorities (RBDAs) in the country was responsible for the least impact. During the survey period, virtually everything owned by the UBRBDA was grounded, including the powerful engine pumps installed along the river Donga for irrigation purposes.

The decision to privatize the non-water components of the RBDA's was taken in view of their dismal performance in terms of crop yields and income generation. What the Upper Benue River Basin Development Authority does now, like all others, is the provision and maintenance of irrigation water sources. The decision has affected farmers, especially of the Donga and Bantaje schemes, who depended on the UBRBDA for irrigation water supply.

The creation of the Gongola State World Bank sponsored Agricultural Development Programme (GADP) in 1989, as an important part of a continuing national programme to increase agricultural production is expected to give a boost to irrigation development in the area.

However, it was found that farmers in the area in addition to farming, also did some other off-farm jobs, such as trading, tailoring and some were civil servants (Table 2.4). These off-farm occupations

TABLE 2.4: OTHER OCCUPATIONS COMBINED BY FARMERS IN THE DONGA IRRIGATION SCHEME

Occupations	No. of Farmers	%
Farming only	313	86.0
Farming/Trading	34	9.3
Farming/Tailoring	6	1.6
Farming/Civil Servants	11	3.0

N = 364

Source: Fieldwork, 1990

of the farmers, coupled with their levels of education (Table 2.5) are bound to affect the rate at which any induced change in irrigation and indeed agriculture will be accepted.

TABLE 2.5: LITERACY LEVELS OF FARMERS IN THE DONGA IRRIGATION SCHEME

Literacy levels	No. of Farmers	%
Primary	80	22.0
Post-primary	14	3.8
Adult Education	128	35.2
Others	142	39.0

N = 364

Source: Fieldwork, 1990

2.7 SUMMARY

In this chapter a descriptive view of the study area, in terms of location, physical features, types of irrigation practiced and socio-economic characteristics of the farmers, is presented. In Chapter Three, the methodology used to test the hypotheses stated in Chapter One is presented. Chapter Four discusses the differences in the topographic sites and their influence on irrigation land use. The influence of the topographic sites on irrigation water use is examined in Chapter Five.

The analysis of the farm management characteristics of irrigation practice with respect to production resource allocation,and utilization, and the effects of factors of production on size of land cultivated are examined in Chapter Six. Chapter Seven deals with the productivity of irrigation practices, their costs and accrued farm production benefits. Also discussed in Chapter Seven are the effects of production factors on crop yields. The major conclusions of the study with respect to implications to theory and irrigation planning are discussed in Chapter Eight.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 RESEARCH PROCEDURE

The methodology by which the data were collected for the study involved two main stages, the prefield and field stages. The prefield stage, undertaken between October and November, 1989, included an extensive reconnaissance survey of the study area. The reconnaissance survey was done to familiarize the researcher with, and to give field impressions of the current irrigation practices, and to identify areas where the traditional and modern irrigation farms were mostly concentrated in the area. From the pilot survey, a map of the study area was drawn to provide the sampling frame, from where the 15 specific sampling points; Donga, Gundu, Suntai, Baissa, Bibinu, Tsokundi, Tunari, Bantaje, Gindin-Dorowa, Nyankwala, Tapare, Gwiwar Kogi, Jibu, Dogon-Ruwa and Kole were identified and considered for the detailed field survey. The sampling locations were chosen based on their predominance in the practice of irrigation farming in the study area. In these areas, 14 irrigation projects, both traditional and modern were found to be practised. However, for the purposes of identification and reference, the areas within which the 14 irrigation projects were located were later grouped into 5 main centres; Donga, Baissa, Tsokundi, Bantaje and Jibu (Table 3.1), according to their relative location and traditional association with the 5 centres.

TABLE 3.1: IRRIGATION LOCATIONS

Centres	Irrigation Locations
Donga	Donga, Gundu and Suntai
Baissa	Baissa and Bibinu (taken as one)
Tsokundi	Tsokundi and Tunari
Bantaje	Bantaje, Gindin-Dorowa, Nyankwala, Tapare and Gwiwar-Kogi
Jibu	Jibu, Dogon-Ruwa and Kole

Source: Pilot Survey, 1989

Under the prefield investigation, a pilot work on the administration of the prepared questionnaires was done to judge their adequacy or otherwise. The problems anticipated, such as that of response and relevance of the questions, during the actual fieldwork were noted during the pilot work. Asking direct questions on income, for example, was replaced by questions on marketing of products. Six research assistants were employed in the administration of the questionnaires to the farmers, but were closely monitored to help them when problems arose. All the measurements of the physical parameters were done by the researcher himself.

3.2 SOURCES OF DATA

Data for the study were derived primarily from fieldwork and acknowledged published data. The target population for the study were the 14 irrigation schemes, 6 traditional and 8 modern, scattered throughout the study area. Because of the acknowledged paucity of data on population size practising traditional and modern irrigation in the sampled locations, data were derived from a sample of

364 farmers. From this sample, 26 farmers in each of the 14 irrigation schemes were interviewed and the physical elements of their farm plots measured over the period December 1989 - May 1990. Table 3.2 gives the number and percentage of farmers studied.

TABLE 3.2: FARMERS SAMPLED IN THE 5 IRRIGATION CENTRES

Irrigation Centre	No. of farms	Percentage of farms	No. of Farmers	Percentage of total sample
Donga	3	21.4	78	21.4
Baissa	1	7.1	26	7.1
Tsokundi	2	14.3	52	14.3
Bantaje	6	42.9	156	42.9
Jibu	2	14.3	52	14.3
Total	14	100	364	100

Source: Fieldwork, 1990

It is important to mention the fact that the target population (farmers) live in the same geographical-cum-cultural region, it is conceivable therefore that they are characteristically the same. In addition, the samples were drawn from widespread locations within the Donga River Basin.

3.2.1 Fieldwork

The actual fieldwork covered the operational period of the traditional and modern irrigation in the area.

(a) Measurement of Physical Elements

The field work involved the investigation of traditional and modern irrigation practices, the technology involved and the measurement of their physical elements. These physical elements include the site location, slope of the land, the size of plots owned and cultivated. Also the problems associated with the land under the traditional and modern irrigation were investigated. The sources and quantities of water used, problems of water sources and water use were measured and identified. The size of field basins and channels, and the distances between irrigated plots and water sources were similarly measured. The size of landholding was measured in square metres and converted to hectares. This was done for each of the 364 samples. The volume of water used was measured in litres and distances in metres.

The volume of water utilized by the sampled farmers was calculated by multiplying the number of calabashes or buckets of water used per day by the volume of the lift device. This was multiplied again by the total number of irrigation applications per season to give the seasonal volume of water used. However, for the modern irrigation, the rate of discharge of water from the pump was calculated and multiplied by the total number of water application in the irrigation season to get the seasonal volume of water used. This was not done for the flood recession farmers since no water application was involved. But for those flood recession farmers who did supplementary irrigation, the supplemental amount was calculated in the manner described above.

(b) Questionnaire Administration

The second aspect of the fieldwork, that was done along side the physical measurements, was the administration of questionnaires on other factors of production and the elements controlling their utilization and management under the traditional and modern irrigation. In all data were collected on 184 variables which relate to the characteristics of the traditional and modern irrigated agriculture in the area (Appendix 1). The variables investigated fall into physical and socio-economic aspects, some of which include land, water, tenurial arrangement, literacy level, occupation, labour, soil fertility maintenance, investment capital, cropping patterns, agricultural marketing, government assistance and constraints of irrigation farming.

The production resources used such as the labour, water and fertilizer were quantified to see how much of each was effectively used per unit area of landholding (per hectare). This enables us observe the level of their collective influence on the productivity of irrigation farming. The factors of production were measured and expressed in their respective appropriate units (for instance, fertilizer was measured and expressed in kilogrammes). The labour input was quantified in man-days for all the farming activities; from land preparation to crop harvesting. The man-days were calculated by multiplying the number of days worked by the number of farm workers.

Since inputs are tradable items, their costs were obtained and used to calculate the cost of those that were obtained from personal sources. The market values of family labour, inherited land and reserved seedlings were used for farmers who used them. As regards the engine pumps, their depreciation costs were used. The depreciation cost was obtained by dividing the total cost of purchase by the service age or the number of years the pumps were in use.

3.3 CROP YIELD

Crops yields were measured as the farmers harvested from one plot to another. In the case of intercrops, the estimates were made as when each crop was harvested. The purpose of yield measurement was to show the outcome (productivity) of the farmers' efforts under the traditional and modern irrigation. The crop yields were measured in bags and sacks, and their weights determined (Table 3.3).

TABLE 3.3: A SCALE OF WEIGHTS OF CROPS (KILOGRAMMES)

Cros	Weights (kg) per bag and basket
Vegetables	20**
Tomatoes	25**
Pepper	50*
Onion	85*
Okro	50*
Beans	85*
Maize	85*
Wheat	85*

Key:

* = bags
** = baskets

Source: Farm Centre Donga, 1990 and market survey, 1990.

The weights of the crops in Table 3.3 were expressed in kilogrammes and converted to tonnes, which is a standard unit of yield measurement (1000 kilogrammes = 1 tonne).

3.3.1 Prices of Irrigated Crops

The selling prices of the crops vary according to seasons and were obtained from the market survey carried out in the major centres. The centres serve as the major markets for the products, whilst Wukari is the largest market in the area. The prices of the various dry-season crops were obtained in each of the five main centres. The average price for each irrigated crop and the guaranteed minimum price for wheat are presented in Table 3.4. The market prices at the five centres were used to cost the products realized by the farmers. However, for those who recorded sales on the farm, the money obtained was considered as such in the income calculation. The benefit of production or profitability is expressed as the return on the project less the cost of production.

It should be noted that all the variables of production were measured and expressed per hectare (Appendix 2) and their mean values derived.

TABLE 3.4: MEAN MARKET PRICE FOR IRRIGATED CROPS FOR 1989/90 IRRIGATION SEASON.$

Crops	Prices (N)/Bag and baskets
Vegetables	20**
Okro	40*
Tomatoes	40**
Pepper	50*
Onion	200*
Beans	400*
Wheat	600*
Maize	85*

KEY

* = bags

** = baskets

$ = The means were compiled from the five farm locations

Source: Market Survey, 1990

3.4 STATISTICAL ANALYSES

The computer facilities of the International Institute of Tropical Agriculture (IITA), based on the VAX system, were used for the statistical analyses.

The statistical analytical package used was the SAS (Statistical Analysis System), a software system for large scale survey data analysis.

3.4.1 Univariate Descriptive Statistics

The descriptive tests such as the one-way frequency tables and the two-way cross-tabulation frequency tables were done. The one-way frequency tables show the distribution of variable values.

3.4.2 Regression Analysis

In testing hypotheses, both the simple and multiple regression statistical models were used to examine whether or not functional relationships exist between the size of hectares cultivated, a dependent variable, and man-days, volume of water, fertilizer application, site location, time of irrigation, methods of land acquisition, cost of land, investment capital and value of inputs of production, the independent variables. Also relationship was established between crop yield, a dependent variable and the size of land cultivated, man-days, volume of water, fertilizer application, site location, time of irrigation, methods of land acquisition, frequency of water application, cropping patterns, value of inputs of production and value of farm products, the independent variables.

The stepwise regression model was used to provide the regression equations from a set of independent variables on a step by step basis. Stepwise regression identifies the independent variables of explanation that provide the strongest relationships with the dependent variable in descending order. Thus, the independent variable with the highest contribution to variations in the dependent variable is shown, followed by the independent variable with the next highest contribution and so on.

Regression analysis enables us to predict changes or variations in the dependent variables. The regression formula used is given as;

$$Y = a + B_1 X_1 + B_2 X_2 + B_3 X_3 \dots + B_k X_k$$

where Y = dependent variable

X_k = independent variables

B_k = Coefficients

(Blalock, Jr., 1979)

3.4.3 Correlation Analysis

The purpose of the correlation analysis is to establish the strength and direction of relationship between two variables (whether the sets of variables are related). These sets of variables include man-days per hectare and water input per hectare; man-days per hectare and fertilizer application per hectare, among others.

3.4.4 Test of Significance

Both the t-test and the analysis of variance are used to test the significance of different sample means. The t-test is used for comparing two sample means of irrigation subsets while the analysis of variance is used to simultaneously compare, using the F test, the means of the three or more irrigation types. Since measurements were based on interval scale data, the comparison of arithmetic means is found appropriate.

CHAPTER FOUR

LAND USE IN TRADITIONAL AND MODERN IRRIGATION

This chapter deals with the analysis of the influence of topography on land use in traditional and modern irrigation. The hypothesis examined is that; irrigation land use is affected by the physical location of irrigation farms. The alternative hypothesis, H_1 is that; land use is not affected by the physical location of irrigation farms. The hypothesis derives from the ecosystem theory that land use patterns and their techniques of management depend on the physical location and its conditions, that define the physical potential of the farming system (Barrow, 1987; Mellor, 1973; Morgan, 1972; Morgan and Munton, 1971 and Richards, 1985).

The physical environment is the central focus of the ecosystem theory and is discussed in terms of the topography of land on which irrigation farms are located. The ecosystem approach is adopted to provide the framework for the analysis of the effects of topography on land use in irrigation practices. Also the simple regression statistical test is used to obtain a description of relationship between land use and topography as an indication of possible causality.

In this study, topography of irrigated land is defined on the basis of two recognized land units; the low-lying and the raised lowland sites. The land units were recognized by the break in slope. It should be taken with caution that the break in slope was not necessarily marked, like serious steepening of the slope or deep undercutting. Therefore, the terms low-lying and raised lowland sites are used to refer to the levels of farm sites relative to river and stream channels.

It should be noted that the two land units, taken to represent two ecological sites, are land facets within the Donga fadama land system. These sites differ with respect to topography, water availability, length of residual soil moisture retention and crop combination, among others as will be seen in this and subsequent chapters. The ecological differences of the two sites tend to affect land resources users' relations with the environment in terms of resource utilization and management.

The low-lying sites, which Turner (1985) calls main-stream fadama, occurs along the banks of rivers Donga and Suntai, and other streams. The low-lying sites are not more than an average of 6 meters from the main river channels (Table 4.1).

TABLE 4.1: SITE LOCATION AND AVERAGE DISTANCE BETWEEN IRRIGATED FARMS AND WATER SOURCES (M)

Site	Irrigation Type		
	Flood Recession	Manual	Pump
Low-lying	4.6	5.2	6.0
Raised lowland	68.4	30.0	96.7
N	166	50	148

Source: Fieldwork, 1990

The raised lowland sites are above the low-lying sites and sometimes directly above the river and stream channels. The raised lowland is sometimes called the floodplain terrace and was, on the average, 68.4, 30.0 and 96.7 meters respectively in the flood recession, manual and pump irrigation (Table 4.1). But where they were directly above river and stream channels, as found in the southern banks of the Donga River, they were 30 meters away from the river channel, as seen in the case of the raised lowland sites under the manual irrigation (Table 4.1).

The objective of this chapter is to see how these land units (low-lying and raised lowland sites) have affected the use of land for irrigation development under the traditional and modern irrigation technologies.

4.1 EFFECTS OF SITE LOCATION ON IRRIGATION PRACTICE

The fadama lands that were actually cultivated during the period of investigation could be regarded as stream and riverside fadamas, according to Turner's (1985) classification of Northern Nigerian fadamas. By her definition, stream and riverside fadamas are fadamas that begin from a stream and river channels to the point at which a recognisable floodplain develops. The boundaries with the upland are usually distinct. The two recognized land units constitute the land resources of the area that farmers use for irrigation cultivation, both under the traditional and modern systems.

The flood recession farmers raise irrigated crops mainly by depending on the residual soil moisture left on the low-lying sites by the retreating floodwaters. Based on their long experience of the ecological requirements of their crops and the flooding pattern, they locate their plots strategically in order to take maximum advantage of the available residual soil moisture (Figure 4.1). This suggests therefore the relevance of the low-lying sites of fadama to flood recession farming since no water application was involved. The low-lying sites have the capacity of retaining residual soil moisture in the mud for a long time under natural conditions to sustain crops.

Similarly, the location of irrigation farms under the manual and pump irrigation on the low-lying sites was done in order to be close to irrigation water sources, in addition to its advantage of the residual soil moisture. The need to be close to irrigation water sources was informed by the lack of adequate water pumps, with long syphons that could lift and carry water respectively to the irrigated plots, located farther away.

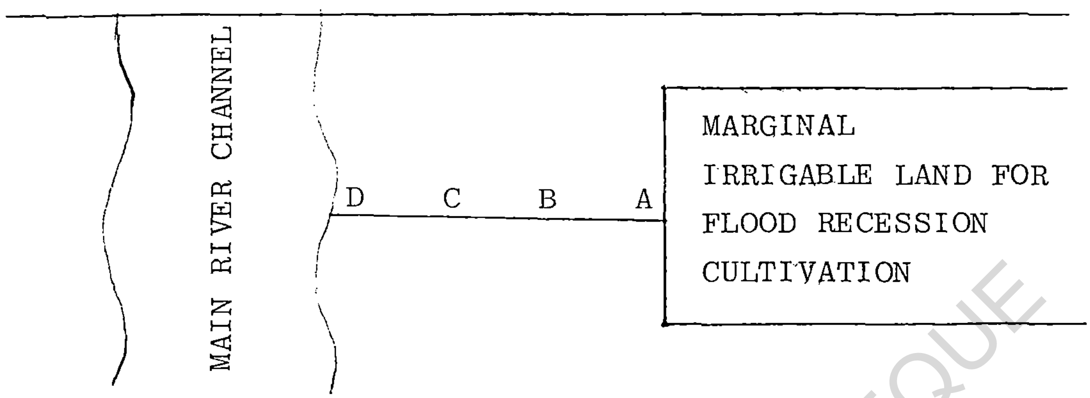


Figure 4.1: A Flood Recession Farm in the Donga River Basin.

KEY

A = The point at which flood water from the river channel stops during inundation.

B = When flood water recedes to point B, mostly in mid September, the receded area (between A and B) is planted with crops.

C = When flood water further retreats to point C, the receded area (area between B and C) is cultivated.

D = By the time flood water recedes finally to the main river channel (point D), the area between C and D is cultivated, and by this time the cultivated maize and beans in points A-C would be ready for harvest.

Note: Not drawn to scale.

The manual and pump irrigation farmers therefore avoid selecting the raised lowland sites that would demand of them to raise water with extra labour for irrigation cultivation.

The raised lowland sites were cultivated under the irrigation regime on account of the physical barrier of the low-lying sites that remained uncultivated during the survey period. The uncultivated low-lying sites could have been suitable for cultivation, but were waterlogged at the time farmers commenced irrigation. Farmers therefore avoided the waterlogged low-lying sites by locating their farms farther away on the raised lowland areas. This tends to agree with the view that waterlogging, among others, is a threat to sustainable agriculture (IIMI, 1990).

The raised lowland sites which the farmers selected, due to lack of suitable low-lying sites, were located within an average range of 30.0 to 96.7 meters away from the river and stream channels (Table 4.1). It was easier for the farmers to cultivate these raised lowland sites since water was drawn from nearby sources to irrigate crops. Irrigation farmers in the area are aware of the consequences of late planting in irrigation and realize the extent to which their irrigated crops depend upon flood regime and weather conditions.

The two land units vary significantly with respect to degrees of slope within the three irrigation types (Table 4.2).

TABLE 4.2: RESULTS OF T-TEST FOR SITE LOCATION OF FARMS AND AVERAGE DEGREES OF SLOPE

	Irrigation Types					
	Flood Recession		Manual		Pump	
	i	ii	i	ii	i	ii
Mean	0.03	0.50	0.92	0.00	0.97	0.21
Std. Error	0.01	0.50	0.04	0.00	0.02	0.12
T-Value	-4.24		11.59		12.41	
Probability	0.0001**		0.0001**		0.0001**	

** Significant at the 0.05% level.

Key

i = Low-lying sites
ii = Raised lowland sites

Source: Fieldwork, 1990

The variations in degrees of slope of farm sites under the three irrigation types is due to farmers' conscious decision to locate their farms in such a way that the flow of irrigation water from water sources to the farms follow the natural gradient of the site. The location of irrigated plots on the low-lying sites (Table 4.2) is done in order to facilitate the flow of irrigation water to the farms by gravitation. The faster movement of water by gravitation to the farm ensure that the amount lost due to seepage and evaporation is minimized. This is because of the reasonable amount of water that gets into the farms to irrigate crops. The raised lowland sites of the manual and pump irrigation farms are fairly flat land, with some farms under the manual irrigation having zero degrees of slope (Table 4.2).

The raised lowland sites slope up gradually from the river and stream channels. As a result of the effects of topography, floodwater received recedes easily to the main river and stream channels after the end of rains. This pattern creates drier conditions on the raised lowland sites and poses limitations to the full utilization of the land resources for irrigation.

Furthermore, irrigated plots that do not slope gently from water sources are prepared and laid out manually for the construction of field water intake channels. The water intake is done to create a slight slope away from water sources so that the intake channels could lead water to all parts of the farms.

4.2 EFFECTS OF SITE LOCATION ON FARM SIZES

The observed sizes of land cultivated were expressed in terms of hectares and ratios. The ratios of land owned to land cultivated, usually expressed in per cent terms, is the intensity of utilization of farmland resources in an irrigation season (Table 4.3).

In terms of the size of land cultivated, there is a contrast between the flood recession, manual and pump irrigation. The data in Table 4.3 show that an average of 1.09 hectares and 1.94 hectares, representing 62.0 per cent and 77.0 per cent of irrigated plots owned by farmers were effectively put into production under the flood recession and pump irrigation respectively

TABLE 4.3: AVERAGE HECTARES OF LAND OWNED, CULTIVATED AND LAND USE INTENSITY

Irrigation Type	Average Hectares		
	Owned	Cultivated	Intensity (%)
Flood recession	2.39	1.09	62.0
Manual	3.14	0.66	49.0
Pump	3.05	1.94	77.0
N	166	50	148

Source: Fieldwork, 1990

during the 1989/90 irrigation season. The manual irrigation has the lowest average rate of land utilization of 0.66 hectares, representing 49.0 per cent of the total land owned (Table 4.3).

Both the analysis of variance and t-tests are used to test the significance of the variations in mean values of variables of production at two levels; between the three irrigation types and under each type between different topographical sites. Table 4.4 shows that there is significant variation in land resource endowment, that is the amount of land available per farmer, between the flood recession, manual and pump irrigation.

TABLE 4.4: ANALYSIS OF VARIANCE FOR AVERAGE SIZE OF LAND OWNED (HECTARES)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F	Probability
Due to irrigation types	2	41.89	20.95		
Error	361	1923.07	5.33	3.93	0.02**
Total	363	1964.97			

** Significant at the 0.05% level

Source: Fieldwork, 1990.

Similarly, both Tables 4.5 and 4.6 show that the hectares of land cultivated and percentage of land cultivated under the three irrigation types vary significantly.

TABLE 4.5: ANALYSIS OF VARIANCE FOR AVERAGE SIZE OF LAND CULTIVATED (HECTARES)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F	Probability
Due to irrigation types	2	85.84	42.92		
Error	361	311.64	0.86	49.72	0.0001 **
Total	363	397.48			

** Significant at the 0.05% level.

Source: Fieldwork, 1990

TABLE 4.6: ANALYSIS OF VARIANCE FOR AVERAGE PERCENTAGE OF LAND CULTIVATED (HECTARES)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F	Probability
Due to irrigation types	2	$3.3E^{6}$	16921.57		
Error	361	$4.6E^{7}$	1281.36	13.31	0.0001**
Total	363	$4.9E^{7}$			

** Significant at the 0.05% level.

Key

E^{6} means there are six positive figures

Source: Fieldwork, 1990.

The sizes of land owned within the traditional flood recession and manual irrigation were also found to vary significantly according to farms relative physical location (Table 4.7).

TABLE 4.7: RESULTS OF T-TEST FOR AVERAGE SIZE OF LAND OWNED (HECTARES)

	Irrigation Type					
	Flood recession		Manual		Pump	
	i	ii	i	ii	i	ii
Mean	2.34	4.50	2.49	5.20	2.99	3.43
Std Error	0.14	1.74	0.36	1.68	0.19	0.68
T-Value	-2.35		-2.41		-0.62	
Probability	0.02**		0.02**		0.43*	

** Significant at the 0.05% level
* Not significant at the 0.05% level

Key

i = Low-lying sites
ii = Raised lowland sites

Source: Fieldwork, 1990

However, hectares of land owned by the pump irrigation farmers do not vary significantly according to site location (Table 4.7).

It was further observed that variations in land utilization occur according to the physical site location of farms (Table 4.8).

TABLE 4.8: RESULTS OF T-TEST FOR AVERAGE HECTARES OF LAND CULTIVATED

	Irrigation Type					
	Flood recession		Manual		Pump	
	i	ii	i	ii	i	ii
Mean	1.10	0.75	0.72	0.48	1.97	1.68
Std Error	0.06	0.21	0.05	0.08	0.11	0.19
T-Value	0.98		2.18		0.95	
Probability	0.33*		0.03**		0.34*	

** Significant at the 0.05% level

* Not significant at the 0.05% level

Key

i = Low-lying sites

ii = Raised lowland sites

Source: Fieldwork, 1990

The agro-ecological constraints of the raised lowland sites, in terms of lack of adequate and dependable soil moisture and water, among others, were responsible for the observed low rates of land utilization. This tends to confirm Essiet's (1987) assertion that in the savanna parts of Nigeria, moisture deficit is a limiting factor to agricultural production.

Statistically significant variations in land utilization under the manual irrigation occur according to land facet but not under the flood recession and pump irrigations (Table 4.8). The lack of significant variation in land utilization according to site under the flood recession and pump irrigations may not indicate completely that there are no differences among the treatments. It may be that real treatment differences do exist but the survey was probably not sensitive enough to detect them at the desired level of probability.

The difficulties of raising water to higher levels, due to the problems of the heavy bucket lift device that was manually and repeatedly carried between water sources and irrigated plots, posed limitations to the sizes of land that were cultivated on the raised low-land sites. However, the use of water pumps has enabled farmers to raise water to greater heights, and, hence lack of significant variations in the sizes of land cultivated within the pump irrigation. Similarly, soil moisture availability influenced the sizes of land cultivated under the flood recession irrigation irrespective of the topography.

It should be noted that the primary concern of the irrigation farmers was the availability of soil moisture and water for irrigation no matter how small the hectares cultivated were. Table 4.8 shows that none of the irrigation farmers under the three irrigation types cultivated up to an average of 2.0 hectares of land due to the limitations posed by lack of adequate soil moisture and water sources, albeit land owned were more than an average of 5.20 hectares (Table 4.7). It was a rational land use decision that farmers only cultivated parts of their land that were sufficiently flooded and close to water sources. This suggests that the sustainability and relevance of irrigation cultivation are tied to soil moisture and water availability, among others.

It is instructive to note that farm sites that were considered unproductive for irrigation, due to their agro-ecological limitations, were put into use for wet season cultivation; with rice cultivated on the low-lying sites while maize, guinea corn and millet are grown on the raised lowland sites.

4.2.1 Relationship Between Land Cultivated and the Location of Farm Sites

Furthermore, the size of land cultivated was regressed on site location of farms in order to estimate their functional relationship. The zero-order correlation coefficients between land use, a dependent variable and site location of farms, an independent variable, are shown in Table 4.9. Table 4.9 shows that site location is positively correlated with land use.

Similarly, both Tables 4.10 and 4.11 show that land use is positively correlated with site location.

TABLE 4.9: ZERO-ORDER CORRELATION COEFFICIENT MATRIX FOR SITE LOCATION AND LAND USE IN FLOOD RECESSION IRRIGATION

	Site Location X_1	Land Use X_4	Water X_6
X_1	1.0000		
X_4	0.0766	1.0000	
X_6	0.1797	-0.4744	1.0000

Correlations that exceed /0.32/ are significant at the 0.01% level.

Source: Fieldwork, 1990.

TABLE 4 10: ZERO-ORDER CORRELATION COEFFICIENT MATRIX FOR SITE LOCATION AND LAND USE IN MANUAL IRRIGATION

	Site Location X_1	Land Use X_4	Water X_6
X_1	1.0000		
X_4	0.3004	1.0000	
X_6	0.1887	-0.3308	1.0000

Correlations that exceed /0.32/ are significant at the 0.01% level.

Source: Fieldwork, 1990.

TABLE 4.11: ZERO-ORDER CORRELATION COEFFICIENT MATRIX FOR SITE LOCATION AND LAND USE IN PUMP IRRIGATION

	Site Location X_1	Land Use X_4	Water X_6
X_1	1.0000		
X_4	0.0786	1.0000	
X_6	0.1651	-0.3209	1.0000

Correlations that exceed /0.32/ are significant at the 0.01% level.

Source: Fieldwork, 1990.

The size of land cultivated was measured in hectares while site location of farms was measured on nominal scale and defined as a dummy independent variable. According to Ayeni (1986) and Haines (1978), the use of dummy variables allows for the use of regression analysis to produce the same information as is obtained by means of such seemingly distinct analytical procedures as analysis of variance, among others. In this study, the site location is defined either as 1, if farm is located on the low-lying site and zero, if otherwise.

The simple regression model is used to test the hypothesis that irrigation land use is affected by the physical location of irrigation farms. In framing and testing the hypothesis, other factors controlling land use are held constant, but are included in the analysis of relationships in management practices.

Land use as a function of site location in flood recession irrigation is presented as a mathematical relationship and this produces a regression model of the form:

$Y = 0.8000 + 0.7429X_1$, where Y is the size of land cultivated (X_4) and X_1 is the site location of farms. The analysis of variance for the regression equation gives the F value as 0.59, which is not significant at the 0.05% level.

The results of the regression analysis are summarized in Table 4.12. The conclusion of the regression analysis is that we reject the hypothesis of dependence, that is, that there is no functional dependence of land use on site location under the flood recession irrigation. The lack of significant relationship is due to the reliance of flood recession irrigation practices on residual soil moisture availability irrespective of site location of

TABLE 4.12: REGRESSION RESULTS OF LAND USE AND SITE LOCATION OF FARMS UNDER THE FLOOD RECESSION IRRIGATION

Independent variable	b Coefficient	Std. Error of Mean	F	Probability
Site location (X_1)	0.7429	0.9697	0.59	0.47*

Intercept = 0.8000

* Not significant at the 0.05% level
Source: Fieldwork, 1990

farms. The higher degrees of slope of the raised flood receded farms (Table 4.2) confirms that topography is not an important determinant of land use in flood recession irrigation. The raised flood receded plots are found on enclosed depressions, without river or stream channels. It did not matter to the farmers whether the site they cultivated slopes gently from water sources or not, since water application was not involved except those who did supplementary irrigation. What is therefore of relevance to flood recession farming is the availability of residual soil moisture retained on the mud of chosen sites irrespective of the topographic orientation of land.

Under the manual irrigation, land use as a function of site location gives a regression model of the form: $Y = 0.4833 + 0.2325X_1$, where Y is size of land cultivated (X_4) and X_1 is the site location of farms.

The analysis of variance gives the F value as 4.76, and is significant at the 0.05% level. We can therefore accept the hypothesis of dependence, that is, that land use in manual irrigation is affected by site location of farms. The results of the regression analysis are summarized in Table 4.13.

TABLE 4.13: REGRESSION RESULTS OF LAND USE AND SITE LOCATION OF FARMS UNDER THE MANUAL IRRIGATION

Independent variable	b Coefficient	Std Error of Mean	F	Probability
Site location (X_1)	0.2325	0.1065	4.76	0.03**

Intercept = 0.4833

** Significant at the 0.05% level.

Source: Fieldwork, 1990

The relative significance of topography in affecting the rate of land utilization could be attributed to the watering process involved in manual irrigation. The water lifting devices of the buckets and shadufs are heavy and repetitive, and farmers tend to avoid cultivating large sizes of farms located higher up relative to water sources.

Under the pump irrigation the regression equation model produced is of the form:

$Y = 1.6842 + 0.2902X_1$ where Y is the size of land cultivated (X_4) and X_1 is the site location of farms.

The analysis of variance gives the F value as 0.91, which is not significant at the 0.05% level. We can therefore reject the hypothesis that size of land utilized is not influenced by site location. The results of the regression analysis are presented in Table 4.14.

TABLE 4.14: REGRESSION RESULTS OF LAND USE AND SITE LOCATION OF FARMS UNDER THE PUMP IRRIGATION

Independent variable	b Coefficient	Std Error of Mean	F	Probability
Site location (X_1)	0.2902	0.3045	0.91	0.34*

Intercept = 1.6842

* Not significant

Source: Fieldwork, 1990

Land utilization under the pump irrigation may be rather affected by the availability of water and the use of water pump. The use of water pumps enables farmers to raise enough water necessary for cultivating higher hectarages irrespective of the relative locations of farms, things being equal.

4.3 EFFECTS OF SITE LOCATION ON FIELD BASINS AND WATER CONVEYANCE CHANNELS

Field basins refer to the small level subdivisions of plots within the larger irrigated farms (Figure 4.2), constructed for the purposes of water control and management for crops. The water conveyance channels are the intake channels through which irrigation water is transported to farms to water crops. The field basins and intake channels, commonly called the control structures, constitute the main irrigation infrastructure of the surface (manual and pump) irrigation.

The variety of field basin sizes and intake channels are dictated by the topographic conditions of farm sites (Table 4.15).

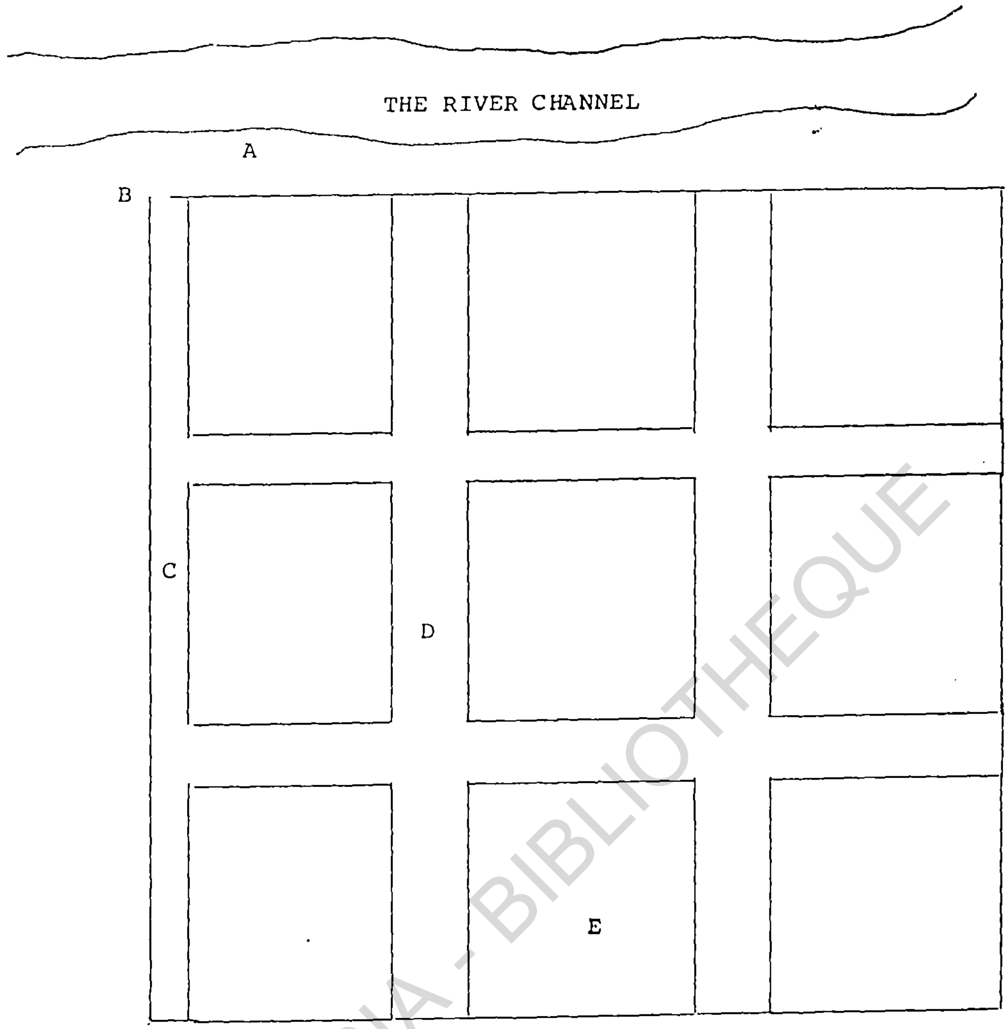


Fig. 4.2: Surface Irrigation in the Donga River Basin

K E Y

A = Point of pump installation

B = The point at which irrigation water entered the farm.

C = Intake channel

D = Field conveyance channels

E = The basins where irrigated crops were raised.

NOTE: Not drawn to scale

TABLE 4.15: RESULTS OF T-TEST FOR SITE LOCATION OF FARMS AND AVERAGE SIZE OF FARM PLOTS' BASINS (m^2)

	Irrigation Type			
	Manual		Pump	
	i	ii	i	ii
Mean	335.24	274.67	325.38	288.26
Std. Error	13.21	33.28	8.36	20.60
T Value	1.86		1.60	
Probability	0.07*		0.11*	

*Not significant at the 0.05% level

Key
i = Low-lying sites
ii = Raised lowland sites

Source: Fieldwork, 1990

All the flood recession farmers did not construct basins like the manual and pump irrigation farmers because water application is not involved. The availability of irrigation water on the low-lying sites made farmers to construct large basins with the assurance that there was enough water to flood the large basins (Table 4.15).

Secondly and more importantly, the need to practice intercropping on the small hectares put into cultivation was also responsible for the large sizes of field basins. This is done so that two or more crops are planted within the basins and according to their level of flood tolerance. Table 4.16, for example, shows that there were differences in the cropping patterns observed on the low-lying and raised lowland sites.

Table 4.16 shows that many irrigated crops were cultivated on low-lying sites with large basin sizes. By contrast, few crops were cultivated on the raised lowland sites, with small basin sizes (Tables 4.15 and 4.16). The variations observed in the sizes of basins, though motivated by various agronomic reasons, are not significant within the manual and pump irrigation (Table 4.15).

4.4 THE EFFECTS OF SITE ON LAND PROBLEMS

With respect to irrigated land problems, some irrigation farmers encountered problems of physical nature while preparing their land for irrigation.

TABLE 4.16: SITE LOCATION OF FARMS AND CROP COMBINATION

Crop combination	Site	Irrigation Type					
		Flood recession		Manual		Pump	
		No. of farms	%	No. of farms	%	No. of farms	%
Vegetables only	Low-lying	6	3.61	15	30.00	30	20.27
	Raised lowland	–	–	2	4.00	5	3.38
Wheat only	Low-lying	4	2.41	2	4.00	42	28.38
	Raised lowland	1	0.60	–	–	10	6.76
Maize only	Low-lying	129	77.71	1	2.00	5	3.38
	Raised lowland	2	1.20	1	2.00	–	–
Tomatoes only	Low-lying	1	0.60	2	4.00	5	3.38
	Raised lowland	–	–	1	2.00	–	–
Maize/Veg.	Low-lying	12	7.23	9	18.00	10	6.76
Wheat/Maize	Low-lying	1	0.60	–	–	8	5.41
Maize/beans	Low-lying	2	1.20	–	–	–	–
	Raised lowland	1	0.60	–	–	–	–
Okro/tomatoes	Low-lying	1	0.60	6	12.00	7	4.73
	Raised lowland	–	–	–	–	2	1.35
Pepper/tomatoes	Low-lying	1	0.60	1	2.00	14	9.46
	Raised lowland	–	–	4	8.0	–	–
Pepper/onion	Low-lying	5	3.01	2	4.0	2	1.35
	Raised lowland	–	–	4	8.00	1	0.68
Veg./onion	Low-lying	–	–	–	–	3	2.03
Veg./onion/pepper	Low-lying	–	–	–	–	1	0.68
	Raised lowland	–	–	–	–	1	0.68
Tomatoes/pepper/veg.	Low-lying	–	–	–	–	2	1.35

Source: Fieldwork, 1990

These problems were mostly associated with the ruggedness of the terrain, depletion of the residual soil moisture and waterlogging. Waterlogging on the raised lowland sites was caused by the presence of pools which retained flood water and this resulted in the slow retreat of flood water into the river channel. The cracking of the terrain, due to the dryness of the residual soil moisture, is also a common land problem.

A number of ad hoc land management solutions were devised by the farmers to overcome the land problems of soil moisture dryness, cracking of the terrain and waterlogging. The waterlogged land was left to drain off before it was put into use. The implication of this interim solution was that, it could take time, beyond the optimal planting dates for irrigation, for the waterlogged areas to drain off.

4.5 SUMMARY

This chapter has focused primarily on the effects of topography of farm site on land use for irrigation.

As established earlier, the approach was based on the principle of landuse patterns of agricultural practices, that depend on the physical environmental conditions. This involved the quantitative measurement of rate of land utilization in different physical site locations.

In this chapter it was established statistically that land use varies significantly between the flood recession, manual and pump irrigation. Under manual irrigation land use was found to be dependent on site location, but not so under the flood recession and pump irrigations. The reason for the dependence of land use on site location under manual irrigation is due to the difficulty of carrying water to farms on raised lowland sites.

The findings reported in this chapter confirm with those of previous investigations. This suggests that the topography - land use approach adopted in the analysis of utilization of the environmental resource is appropriate. In the next chapter a similar approach will be adopted to analyse relationships between topography and use of water, another important environmental resource, in irrigation cultivation.

CHAPTER FIVE

WATER UTILIZATION IN TRADITIONAL AND MODERN IRRIGATION

This chapter examines water use in irrigation and how it is affected by topography, in terms of the physical location of irrigation farms. The hypothesis examined is that; irrigation water use is affected by the physical location of irrigation farms. The alternative hypothesis, H_1 is that; water use is not affected by the physical location of irrigation farms. The hypothesis stated is based on the deduction of ecosystem theory that farmers select those practices and techniques of management that make the most efficient use of the environmental resources available.

The ecosystem approach is adopted for the analysis of the effects of topography on water use. The simple regression statistical technique is used to investigate whether functional relationship exists between topography and water use. Water use is discussed in a chapter because it is the most crucial environmental factor in determining the level of irrigation practice.

5.1 EFFECTS OF SITE ON IRRIGATION WATER SOURCES

Most irrigated plots were located on the low-lying sites to take advantage of soil moisture resources and their closeness to water sources (Table 5.1).

Farmers in the area, due to long familiarity with the traditional flood recession cultivation, selected the low-lying sites where natural residual soil moisture conditions could sustain crops throughout the dry-season. Flood recession farmers who used sources of water other than the residual soil moisture did that as supplement to the depleted soil moisture (Table 5.1).

The most important sources of water for irrigation in the area were the free-flowing Donga and Suntai Rivers utilized by 66.00 per cent and 95.27 per cent of the manual and pump irrigation farmers respectively (Table 5.1). The sloping up of the raised lowland sites prevented the retention of adequate residual soil moisture due to the short period of flood. Thus, most farms on the raised lowland sites depended for water supply on the river channels, with few plots relying on the residual soil moisture.

TABLE 5.1: SITE LOCATION OF FARMS AND IRRIGATION WATER SOURCES

Irrigation Type	Site	Sources of Water									
		River channel		Natural depressions		Residual moisture		Residual moisture/ river channel		Dug pit	
		No. of farms	%	No. of farms	%	No. of farms	%	No. of farms	%	No. of farms	%
Flood recession	Low-lying	5	3.01	3	1.81	151	90.96	2	1.20	1	0.6
	Raised lowland	-	-	-	-	3	1.81	-	-	1	0.6
Manual	Low-lying	28	56.00	7	14.00	-	-	-	-	3	6.0
	Raised lowland	5	10.00	2	4.00	-	-	-	-	5	10.0
Pump	Low-lying	124	83.78	2	1.35	-	-	-	-	3	2.0
	Raised lowland	17	11.49	1	0.68	-	-	-	-	1	0.6

Source: Fieldwork, 1990

The dependence on rivers as the main sources of water for irrigation in the area was sequel to the lack of suitable natural depressions. Thus, little use was made of ground water resources and access to it for irrigation purposes was normally by the hand-dug pits (Table 5.1). Pits were only dug by farmers where plots were located on sites without stream and river channels. Again shallow excavations were dug in the dried river and stream beds to supply irrigation water in times of water recession. Farmers did not drill tube wells and washbores for irrigation purposes.

The implication of dependence on rivers and residual soil moisture (Table 5.1) as main sources of water for irrigation, is the threat it poses to sustainable irrigation especially in time of drought, soil moisture depletion and river water recession.

5.2 WATER LIFTING DEVICES

Three main irrigation devices; the petrol-powered engine pump, the simple bucket lift and the shaduf were used in drawing irrigation water to the farms. The traditional bucket lift and the shaduf were locally derived while the engine pump and its associated components, such as the hose pipe and spare parts were imported.

The operational bottlenecks resulting from frequent pump breakdown posed constraints to irrigation water use. Table 5.2 shows that two-thirds of the pumps broke down once every week while 0.3 per cent of them broke down thrice every week due to old age and lack of maintenance.

TABLE 5.2: FREQUENCY OF WATER PUMP BREAKDOWN PER WEEK

Frequency/Week	No. of Pumps	Percentage
No. breakdown	242	66.5
3/week	1	0.3
2/week	41	11.3
1/week	80	22.0

Source: Fieldwork, 1990

The problems of breakdown were further compounded by the difficulties in obtaining original spare parts and service personnel. It was found that about 33.2 per cent of the pump users complained of serious problems of repairs. Sometimes minor repairs had to be taken to Wukari (32 km) and Takum (68 km), far away from the main irrigation production areas. At Wukari and Takum it took several days to get a damaged water pump repaired, thereby leaving crops for days without water. For these farmers it was difficult to water manually because of the long familiarity with the pump irrigation.

Furthermore, fuel scarcity was an operational problem to the pump irrigation. Pumps stopped during watering due to lack of fuel and farmers travelled long distance to obtain it. The problem of petrol was serious since pump users relied only on road side petrol sales in the absence of a petrol filling station in the actual irrigation production areas. The nearest petrol filling stations were at Gidin Dorowa, 8 kilometres away from Bantaje, which has the highest concentration of irrigation locations and at Wukari, 32 kilometres from Donga with the second highest concentration of irrigation locations in the area (Table 3.2).

However, the traditional water lifting devices of the bucket and shaduf had no operational problem of such magnitude. The problems common to them especially bucket lifts, were mostly leakage, the time it took in drawing water and the weight of the bucket that was repeatedly carried between the plots and water sources.

The effects of the operational problems associated with the pumps and the traditional lifting devices coupled with the sites of farms, were reflected in the average hours farmers spent in drawing water (Table 5.3).

TABLE 5.3: ANALYSIS OF VARIANCE FOR AVERAGE HOURS OF IRRIGATION FOR IRRIGATION TYPES

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F	Probability
Due to Irrigation Types	2	4485.25	2242.63		0.0**
Error	361	2334.53	6.47	346.79	
Total	363	6819.79			

** Significant at the 0.05% level

Source: Fieldwork, 1990

The average daily hours of irrigation between the three irrigation types vary significantly (Table 5.3).

The observed variations in the average daily hours of water application on farms on different topographical sites under the flood recession and manual irrigation are significant but not under the pump irrigation (Table 5.4).

TABLE 5.4: RESULTS OF T-TEST FOR SITE LOCATION OF FARMS AND AVERAGE HOURS OF IRRIGATION

	Irrigation Type					
	Flood recession		Manual		Pump	
	i	ii	i	ii	i	ii
Mean	0.33	0.50	5.74	3.50	7.83	7.95
Std	0.13	0.50	0.38	0.51	0.29	0.86
T Value	-0.20		3.02		-0.14	
Probability	0.84*		0.004**		0.89*	

** Significant at the 0.05% level

* Not significant at the 0.05% level

<u>Key</u>

i = Low-lying sites

ii = Raised lowland sites

Source: Fieldwork, 1990

Under the manual irrigation higher average daily hours of water application were recorded in farms located on the low-lying sites due to their closeness to water sources. However, the difficulty in carrying, for example, a 25 litre bucket filled with water from water sources to the farm was tedious and the manual irrigation farmers often spent an average of 3.50 hours in daily water application on the raised lowland sites. In modern irrigation farmers who spent an average of 7.95 hours in daily water application on the raised lowland sites (Table 5.4) were the users of new water pumps. The flood recession farmers who did supplementary irrigation spent, on the average, 0.33 hours and 0.50 hours in daily water application on the low-lying and raised lowland sites respectively (Table 5.4).

5.3 EFFECTS OF SITE ON CONDITIONS FOR WATER APPLICATION

Water application, on the average, was done once, twice and thrice per week. Farmers who cultivated the low-lying sites applied irrigation water thrice weekly in order to keep the soils at field capacity and to sustain crop growth. The frequencies of water application, in addition to site location, depended on factors such as the appearance of cultivated crops, nature of the soil and the farmers' inclination for watering (Table 5.5). It was found that farmers whose water application was guided by both the physiological appearance of crops and soils cultivated the low-lying sites (Table 5.5).

TABLE 5.5: SITE LOCATION OF FARMS AND CONDITIONS FOR WATER APPLICATION

Irrigation Type	Site	Conditions for Irrigation							
		Appearance of crops		Appearance of soils		Any day		Appearance of crops and soils	
		No. of farms	%	No. of farms	%	No. of farms	%	No. of farms	%
Flood recession	Low-lying	-	-	3	37.50	-	-	4	50.00
	Raised lowland	-	-	-	-	1	12.50	-	-
Manual	Low-lying	4	8.16	12	24.49	6	12.24	16	32.65
	Raised lowland	-	-	6	12.24	2	4.08	3	6.12
Pump	Low-lying	2	1.35	21	14.19	9	6.08	97	65.54
	Raised lowland	2	1.35	1	0.68	-	-	16	10.81

Flood Recession N = 8; Manual N = 50; Pump N = 148

Total = 206

Source: Fieldwork, 1990

The width of the intake channels on the raised lowland sites was wider than those found on the low-lying sites, especially under the pump irrigation (Table 5.6).

TABLE 5.6: RESULTS OF T-TEST FOR SITE LOCATION OF FARMS AND AVERAGE WIDTH OF WATER INTAKE CHANNELS (m)

	Irrigation Type			
	Manual		Pump	
	i	ii	i	ii
Mean	32.34	29.92	32.08	36.68
Std. Error	1.42	3.24	0.62	1.14
T Value	0.78		-2.16	
Probability	0.44*		0.03**	

** Significant at the 0.05% level
* Not significant at the 0.05% level

Key

i = Low-lying sites
ii = Raised lowland sites

Source: Fieldwork, 1990

The variations in the sizes of water intake channels are significant within the pump irrigation and not significant within the manual irrigation (Table 5.6). The reason for having such wide water intake channels was to transport easily available irrigation water in large volumes to irrigated plots. Sometimes, the width of water intake channels was widened as a result of collapse of intake channel walls. The loss and collapse of intake channel walls were mainly the results of the predominant sandy nature of soils of the low-lying sites. For the pump irrigation farmers, the problem of loss and collapse of intake channel walls was accentuated further by the powerful flow of pumped irrigation water from the river channel.

5.4 FACTORS OF IRRIGATION WATER APPLICATION

As would be expected the length of time and rate of irrigation water application influenced the average volume of irrigation water applied and this varied from one irrigation type to another (Table 5.7).

TABLE 5.7: AVERAGE VOLUME OF IRRIGATION WATER APPLIED (m^3/ha^{-1}) PER FARMER

Irrigation Type	Average Volume (m^3/ha^{-1})	N
Flood recession	135.20	8
Manual	172.02	50
Pump	127.76	148

Source: Fieldwork, 1990

The observed average litres of irrigation water applied were converted to cubic meters (m^3), a standardized international system of unit. A litre of water is equivalent to $10^{-3}m^3$ (Donahue, R.L., et al, 1990). Table 5.7 shows that the manual irrigation farmers, applied the highest average volume of water per hectare whilst the modern pump irrigation farmers applied the least volume per hectare. The flood recession farmers who applied irrigation water did that as supplement to the depleted residual soil moisture, and the average supplemental amount was higher than the volume of water use by the pump irrigation farmers (Table 5.7).

The result of the analysis of variance gives the F value of 10.20, which implies that there is no significant variation in the average volume of water applied between the three irrigation types (Table 5.8).

TABLE 5.8: ANALYSIS OF VARIANCE FOR AVERAGE IRRIGATION WATER APPLIED (m^3/ha^{-1})

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F	Probability
Due to Irrigation Types	2	$5.4E^{10}$	$2.7E^{10}$		
Error	361	$9.5E^{11}$	$2.6E^{9}$	10.20	0.0001**
Total	363	$1.0E^{12}$			

** Significant at the 0.05% level

Source: Fieldwork, 1990

Water application between the three irrigation types (Table 5.8) have profound effects on the practice of intercropping within the irrigation schemes (Table 4.16). It was rare to see pepper, tomatoes and okro on the raised lowland plots as a result of their lack of moisture and water availability. Hence, these crop combinations are associated mainly with the low-lying sites. Beans were cultivated only under the flood recession farming (Table 4.16) because of their ability to survive depletion in the residual soil moisture. The lack of significant variations in the average volume of water used between the three irrigation types was also observed within the flood recession and manual irrigation (Table 5.9). However, the average

TABLE 5.9: RESULTS OF T-TEST FOR SITE LOCATION OF FARMS AND AVERAGE VOLUME OF WATER APPLIED (m^3/ha^{-1})

	Irrigation Type					
	Flood recession		Manual		Pump	
	i	ii	i	ii	i	ii
Mean	148.09	45.00	189.42	116.91	136.46	68.68
Std. Error	$8.1E^6$	0	$2.5E^6$	$5.2E^6$	$1.2E^6$	$1.6E^6$
T Value	4.45		1.33		2.02	
Probability	0.67*		0.19*		0.05**	

** Significant at the 0.05% level

* Not significant at the 0.05% level

Key

i = Low-lying sites

ii = Raised lowland sites

Source: Fieldwork, 1990

volumes of water applied vary significantly within the pump irrigation.

In pump irrigation, water availability, coupled with the infiltration of soils of the low-lying sites created the tendency for the pump users to apply higher volumes (Table 5.9).

5.5 RELATIONSHIP BETWEEN WATER USE AND FARMS SITES

The simple regression analysis is employed to further test the hypothesis which states that, water use is affected by site location of farms. Water use was measured in litres per hectare while site location, as seen before, was defined as a dummy variable. Water use as a function of site location in flood recession irrigation is presented as a mathematical relationship and this yields a regression model of the form:

$Y = 4.5E^{6} + 1.0E^{7}X_1$, where Y is water input (X_6) and X_1 is the site location of farms.

The analysis of variance gives the F value as 0.20, which is significant at the 0.05% level. We therefore accept the hypothesis that water use in flood recession irrigation is affected by site location of farms. Water is a crucial production factor in irrigation and the need to locate farms on sites that guarantee available water and soil moisture resources became the dominant alternative explanation to the independence of land use and site location. We can therefore intuitively say that site location affects land use through water availability. Tables 4.9, 4.10 and 4.11 show statistically that negative correlations exist between water use and land use though, this may be due to the indirect influence of water on land use.

The results of the regression analysis are summarized in Table 5.10.

TABLE 5.10: REGRESSION RESULTS OF WATER USE AND SITE LOCATION OF FARMS UNDER THE FLOOD RECESSION IRRIGATION

Independent Variable	b Coefficient	Std. Error of Mean	F	Probability
Site location (X_1)	$1.0E^7$	$2.3E^7$	0.20	0.67*

Intercept = $4.5E^6$

* Not significant at the 0.05% level

Source: Fieldwork, 1990

Under the manual irrigation, the functional relationship between water use and site location produces a regression model of the form:

$Y = 1.1E^7 + 7.2E^6 X_1$, where Y is water input (X_6) and X_1 is the site location of farms.

The analysis of variance gives the F value as 1.77 and is not significant at the 0.05% level. We therefore reject the hypothesis of dependence, that is, that water use is dependent on site location. The use of water is influenced by its availability no matter the topography of sites it is found. This means that water use in manual irrigation is not dependent on site location of farms.

The regression results are presented in Table 5.11.

TABLE 5.11: REGRESSION RESULTS OF WATER USE AND SITE LOCATION OF FARMS UNDER THE MANUAL IRRIGATION

Independent variable	b Coefficient	Std. Error of Mean	F	Probability
Site location (X_1)	$7.2E^6$	$5.4E^5$	1.77	0.19*

Intercept = $1.1E^7$

* Not significant at the 0.05% level

Source: Fieldwork, 1990

The regression model of the functional relationship between water use and site location of farms in pump irrigation is of the form:

$Y = 6.8E^{6} + 6.7E^{6}X_1$, where Y is the water input (X_6) and X_1 is the site location of farms.

The analysis of variance gives the F value as 4.09 and is significant at the 0.05% level. We can therefore accept the hypothesis of dependence, that is that water use in pump irrigation is affected by site location of farms. The pump users located their farms on sites that ensured available water supply for irrigation. Where farms were located far away from water sources, farmers intensified their water utilization efforts by pumping water to higher and far away sites.

The regression results are summarized in Table 5.12.

TABLE 5.12: REGRESSION RESULTS OF WATER USE AND SITE LOCATION OF FARMS UNDER THE PUMP IRRIGATION

Independent Variable	b Coefficient	Std. Error of Mean	F	Probability
Site location (X_1)	$6.7E^{6}$	$3.3E^{6}$	4.09	0.05**

Intercept = $6.8E^{6}$
** Significant at the 0.05% level

Source: Fieldwork, 1990

5.6 EFFECTS OF SITE ON WATER MANAGEMENT

The observed water management strategies of farmers were ad hoc being embarked upon only when problems of water utilization were manifested. The major problem of water use is lack of powerful engine pump, associated mainly with bucket lift and old engine pumps. The distance between water sources and plots, coupled with water fluctuation, left pumping points far away which made it difficult to get sufficient water to the farms.

One of the ad hoc strategies to the problem of irrigation water use was the maintenance of water sources. Water sources were maintained in order to make them recharge more water for irrigation. Channel maintenance was often done to coincide with the time farmers were in the farms for other operations, such as water application and weeding. This was done to save labour, rather than going to the farms on separate days for channel maintenance only. While the manual and pump irrigation farmers maintain their water sources to make them sustainable, the flood recession farmers have two alternatives to the problem of residual soil moisture depletion; to either supplement the depleted soil moisture with water or to accept the outcome.

A management practice in vogue among the flood recession and manual irrigation farmers is to use water in rotation from jointly dug pits. The rotation is done such that one farmer uses irrigation water at a time to ensure its rational and sustainable use by the joint owners. The users of water pumps did not practice water use in rotation. The water pumps they use are individually acquired and the pits dug personally. In addition to that pump users mostly depend on the free flowing streams and river channels for irrigation water supply (Table 5.1). It is entirely, therefore, the sole responsibility of each pump user to maintain the points at which he pumps irrigation water to the farms.

On the first day of irrigation, farmers start from the top-end and on the next irrigation day, they begin from the bottom-end. This principle of alternate water application is based on the understanding that the part that is first irrigated does not immediately need water. In this manner the problem of drainage is controlled.

Excess water is drained off by creating an outlet in the last basin. The implication of such disposal of excess irrigation water is that it would flow into the adjacent farm, that might not be needed especially when the farmer had alreay irrigated.

5.7 SUMMARY

In this chapter it was statistically tested that water use does not vary significantly between the flood recession, manual and pump irrigation, but significant and no significant variations exist in water use within the pump and, flood recession and manual irrigation types respectively.

The hypothesis that; water use is affected by site location of farms was tested using the simple linear regression equation. Under the manual irrigation the hypothesis of dependence of water use on site location was rejected but was accepted under the flood recession and pump irrigation types. Thus, the alternative hypothesis for the flood recession and pump irrigation is that; water use is not affected by site location of farms. Farms could be located at any topographic site provided water is available and accessible to users.

The evidence on relationships between water use and topography shown in this chapter conforms with those of previous studies. In the next chapter attempt shall be made to examine irrigation farm management practices, in terms of relationships and interrelationships between the environmental and socio-economic factors of production. The analysis of the relationships and interrelationships will facilitate our understanding of the operation of irrigation enterprise under the traditional and modern technologies.

CHAPTER SIX

FARM MANAGEMENT PRACTICES IN TRADITIONAL AND MODERN IRRIGATION

This chapter focuses on irrigation farm management practices in terms of the use of factors of production, relationships and interrelationships between the various factors of production and the extent to which they vary. The chapter is used to discuss the hypothesis that; size of land cultivated is a function of site location, volume of water, size of labour, quantities of fertilizers, cropping patterns, land tenure and cost of production. The alternative hypothesis H_1 is that; size of land cultivated is not a function of these factors of production.

The main objective of this chapter therefore is to estimate the quantities of observed inputs of production and reasons for input resource allocation and utilization. Both the correlation and regression analyses are used to obtain a description of relationships and interrelationships between the various variables of production, in order to test the hypothesis.

6.1 EFFECTS OF SITE ON LABOUR USE

The importance of labour as the most important factor of production cannot be over-emphasized. The number and availability of labour, affect, to a very large extent, the level of farm productivity and efficiency.

It was found that the family labour was the most important source of farm labour, accounting for 55.5 per cent of the farmers' sources of farm labour. The remaining 44.5 per cent came from hired labour, to supplement the family labour. The number of labour (man-days) involved in production process varied from one irrigation type to another (Table 6.1).

TABLE 6.1: AVERAGE LABOUR INPUTS (Man-days/ha^{-1}) PER FARMER

Irrigation Type	Average Man-days/ha^{-1}	N
Flood recession	98.63	166
Manual	140.38	50
Pump	151.03	148

Source: Fieldwork, 1990.

Table 6.1 shows that the pump irrigation farmers used the highest labour input, with an average of 151.03 man-days per hectare. The flood recession farmers, however, were the least users of labour input, with a per hectare average of 98.63 man-days per farmer (Table 6.1).

The results of the analysis of variance show that the observed variations in the average man-days are statistically significant between the irrigation types (Table 6.2).

TABLE 6.2: ANALYSIS OF VARIANCE FOR AVERAGE LABOUR INPUTS (Man-days/ha^{-1})

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F	Probability
Due to irrigation types	2	2.2E^{7}	1.1E^{7}		
Error	361	5.0E^{8}	1.3E^{6}	8.17	0.0003**
Total	363	5.2E^{8}			

** Significant at the 0.05% level

Source: Fieldwork, 1990

Furthermore, it is clear from Table 6.3 that the use of labour inputs varies within the three irrigation types on account of the site location of farms; with higher man-days associated mainly with the raised low-land sites.

TABLE 6.3: RESULTS OF T-TEST FOR SITE LOCATION OF FARMS AND AVERAGE LABOUR INPUTS (Man-days/ha^{-1})

	Irrigation Type					
	Flood recession		Manual		Pump	
	i	ii	i	ii	i	i
Mean	96.56	182.10	129.49	174.88	157.56	106.74
Std. Error	5.15	109.58	13.55	31.47	14.90	11.16
T Value	-2.37		-1.52		1.30	
Probability	0.02**		0.13*		0.20*	

** Significant at the 0.05% level
* Not significant at the 0.05% level

<u>Key</u>

i = Low-lying sites

ii = Raised lowland sites

Source: Fieldwork, 1990

Variatons in labour use within the manual and pump irrigation are not statistically significant (Table 6.3).

Farms on the low-lying sites under the pump irrigation were large in sizes (Table 4.8) which required farmers to use more man-days to be able to fulfil all the necessary farming operations. The higher man-days, though proportionally small, tend to agree with Ruthenberg's (1980) view that the provision of controlled water supplies and careful water delivery are connected with a high labour input. However, this evidence tends to contradict Crosson's (1984) and Doorenbos's (1974) assumption that the use of modern technology saves labour.

The low man-days observed in the traditional flood recession and manual irrigation enabled farmers to allocate their time to off-farming occupations (Table 2.4). This is significant because the proceeds from these off-farming occupations formed the capital base for investment in irrigation farming, among other sources (Table 6.4). The personal capital for investment was mostly derived from the sale of rainfed crops and savings from other subsidiary occupations (Table 2.6).

TABLE 6.4: SOURCES OF INVESTMENT CAPITAL FOR IRRIGATION

Sources	Irrigation Type					
	Flood recession		Manual		Pump	
	No. of farmers	%	No. of farmers	%	No. of farmers	%
Personal	163	98.19	46	92.00	143	96.64
Money lender	-	-	-	-	2	1.36
Fellow farmer	3	1.81	2	4.00	-	-
Relatives	-	-	2	4.00	3	2.03
N	166		50		148	

Source: Fieldwork, 1990

6.2 FERTILIZER APPLICATION

Fertilizer is generally regarded as anything or material which when added to the soil supplies nutrients to plants. It may be natural organic compounds, such as manure or crop residues or industrially produced chemical fertilizers. The use of chemical fertilizers is crucial in sustaining soil fertility and increasing yield level of crops.

The users of chemical fertilizers, especially the wheat farmers believed that the only way they could reap benefits from the wheat farms was, among other agronomic practices, through effective use of reasonable quantities of chemical fertilizers.

The flood recession farmers resorted to the use of animal manure since no water application was involved, except for few of them who did supplementary irrigation. It was dangerous to apply chemical fertilizers where small volume of irrigation water was applied. This is because proper fertilization is often accompanied by water application in order to enable the two inputs of production form a proper solution for the easy intake of the soil.

It was observed that the pump irrigation farmers used higher quantities of fertilizers, with an average of 225.79 kilogrammes per hectare while the flood recession irrigation farmers used the least fertilizer amounts (Table 6.5).

The observed mean values of fertilizer application vary significantly between the flood recession, manual and pump irrigation farms (Table 6.6).

TABLE 6.5: AVERAGE FERTILIZER APPLICATION (Kilogrammes/ ha^{-1}) PER FARMER

Irrigation Type	Average kg/ha^{-1}	N
Flood recession	135.75	156
Manual	155.79	45
Pump	225.79	148

Source: Fieldwork, 1990

TABLE 6.6: ANALYSIS OF VARIANCE FOR AVERAGE FERTILIZER APPLICATION (Kilogrammes/ha^{-1})

Sum of Squares	Degrees of Freedom	Sum of Squares	Mean Squares	F	Probability
Due to irrigation types	2	$6.3E^{7}$	$3.1E^{7}$		
Error	344	$2.5E^{9}$	$7.4E^{6}$	4.29	0.01**
Total	346	$2.6E^{9}$			

** Significant at the 0.05% level

Source: Fieldwork, 1990

Furthermore, farms located on the low-lying sites under the pump irrigation seem to record higher quantities of fertilizer application than farms on the raised lowland sites. The raised lowland farms have higher fertilizer appplication than the low-lying farms in flood recession and manual irrigation (Table 6.7).

TABLE 6.7: RESULTS OF T-TEST OF SITE LOCATION OF FARMS AND AVERAGE FERTILIZER APPLICATION (kg/ha^{-1})

	Irrigation Type					
	Flood recession		Manual		Pump	
	i	ii	i	ii	i	ii
Mean	134.94	166.67	145.55	203.13	236.14	156.58
Std. Error	13.71	29.46	16.06	22.87	35.86	15.72
T Value	-0.37		-1.59		0.85	
Probability	0.71*		0.12*		0.29*	

* Not significant at the 0.05% level

Key

i = Low-lying sites

ii = Raised lowland sites

Source: Fieldwork, 1990

Farmers cultivating the raised lowland sites in pump irrigation were limited to applying small quantities of fertilizers because of inadequate water to form proper solution for the easy intake of the soil, among others. Though there are variations in fertilizer application within the three irrigation types, the variations are not statistically significant (Table 6.7).

6.3 CORRELATION ANALYSIS OF VARIABLES OF IRRIGATION PRODUCTION

The Pearson-product moment correlation was used to examine the extent to which various production factors, which are the explanatory variables, used in irrigation were correlated. The coefficients of correlation, it should be noted, were not determined by equal sample sizes because zero values in some variables were taken as not applicable and thus did not enter the correlation equation.

Table 6.8 gives a summary of the description of the variables of irrigation farming used as explanatory variables. The correlation coefficients between the various production variables of the flood recession irrigation are shown in Table 6.9.

TABLE 6.8: DESCRIPTION OF VARIABLES OF IRRIGATION FARMING

Variable Names	Description
X_1	Site location of farms
X_2	Months of irrigation
X_3	Methods of land acquisition
X_4	Size of land cultivated
X_5	Irrigation frequency
X_6	Water input
X_7	Man-days
X_8	Fertilizer application
X_9	Cropping patterns
X_{10}	Crop yields
X_{11}	Production cost
X_{12}	Income

TABLE 6.9: ZERO-ORDER CORRELATION COEFFICIENT MATRIX FOR COMPONENTS OF FLOOD RECESSION IRRIGATION USED AS VARIABLES OF EXPLANATION

	Site loc. X_1	Irrig. month X_2	Land acq. X_3	Land cultivated X_4	Irrig. Freq. X_5	Water used X_6	Man-days X_7	Fertilizer X_8	Inter-cropp. X_9	Yields X_{10}	Prod. cost X_{11}	Income X_{12}
X_1	1.00											
X_2	0.57	1.00										
X_3	0.26	-0.04	1.00									
X_4	0.08	0.02	-0.19	1.00								
X_5	-0.20	0.03	-0.28	0.12	1.00							
X_6	0.18	0.00	0.33	-0.47	-0.28	1.00						
X_7	-0.18	-0.28	0.16	-0.25	0.04	0.60	1.00					
X_8	-0.03	-0.05	0.06	-0.12	-0.00	0.57	0.11	1.00				
X_9	-0.06	-0.22	-0.24	-0.02	0.24	0.41	0.21	-0.03	1.00			
X_{10}	0.01	-0.01	0.09	0.02	0.50	-0.06	0.13	0.02	0.14	1.00		
X_{11}	-0.05	-0.08	0.04	-0.10	0.34	-0.09	0.24	0.44	0.12	0.51	1.00	
X_{12}	-0.03	0.01	-0.01	-0.09	0.18	-0.23	0.30	0.19	-0.08	0.16	0.45	1.00

Correlations that exceed /0.32/ are significant at the 0.01% level

Source: Data analysis, 1990

Table 6.9 shows that under the flood recession irrigation, site location (X_1), on one hand, and month of irrigation (X_2), methods of land acquisition (X_3), size of land cultivated (X_4) and water application (X_6) on the other, are positively correlated. However, negative correlations exist between site location and the other variables of explanation (Table 6.9). The positive and negative correlations observed between the various components of flood recession irrigation suggest that increase and decrease in some will lead to increase and decrease respectively in others.

Under the manual irrigation, it was similarly observed that site location positively correlates with month of irrigation, methods of land acquisition, size of land cultivated and water application (Table 6.10). The negative correlations between the variables of production indicate that increase in any one of them does not lead to increase in any other. The positive correlations are indications of influence of any variable over any other.

TABLE 6.10: ZERO-ORDER CORRELATION COEFFICIENT MATRIX FOR COMPONENTS OF MANUAL IRRIGATION USED AS VARIABLES OF EXPLANATION

	Site loc. X_1	Irrig. month X_2	Land acq. X_3	Land cultivated X_4	Irrig. Freq. X_5	Water used X_6	Man-days X_7	Fertilizer X_8	Inter-cropp. X_9	Yields X_{10}	Prod. cost X_{11}	Income X_{12}
X_1	1.00											
X_2	0.51	1.00										
X_3	0.22	0.15	1.00									
X_4	0.30	0.22	-0.10	1.00								
X_5	-0.30	-0.16	-0.16	-0.17	1.00							
X_6	0.19	0.20	-0.04	-0.33	-0.06	1.00						
X_7	-0.21	-0.10	-0.04	-0.36	0.03	0.52	1.00					
X_8	-0.24	-0.32	0.16	-0.51	0.13	0.09	0.25	1.00				
X_9	-0.14	-0.09	-0.01	0.02	0.15	0.06	0.31	0.15	1.00			
X_{10}	-0.20	0.04	0.03	-0.21	0.02	-0.17	0.34	0.41	0.36	1.00		
X_{11}	-0.23	-0.23	0.02	-0.57	0.20	0.06	0.34	0.81	0.21	0.53	1.00	
X_{12}	-0.15	-0.18	0.16	-0.29	0.04	-0.21	0.18	0.42	0.24	0.59	0.47	1.00

Correlations that exceed /0.32/ are significant at the 0.01% level

Source: Data analysis, 1990

However, with the exception of methods of land acquisition, site location appears to be positively correlated with all the other variables of pump irrigation (Table 6.11). A change in method of land acquisition for the purposes of pump irrigation practice will not lead to a change in site location of pump irrigation farms. The positive and negative signs indicate positive and negative correlations respectively among the variables of pump irrigation (Table 6.11).

6.4 THE EFFECTS OF FACTORS OF PRODUCTION ON FARM SIZES

This section looks at the functional relationships between land cultivated and other factors of production. This is done using the stepwise regression equation where land cultivated, the dependent variable, is regressed on other factors of production, the independent variables. In order to estimate the determinants of size of land cultivated under irrigation regime, I defined the site location as X_1; month of irrigation as surrogate for soil moisture retention as X_2; methods of land acquisition as X_3; frequency of irrigation as X_5; volume of water as X_6; man-days as X_7; fertilizer as X_8; cropping patterns as X_9; cost of land as X_{12} and source of investment as X_{13} as explanatory variables of irrigation land cultivation (Table 6.8).

TABLE 6.11: ZERO-ORDER CORRELATION COEFFICIENT MATRIX FOR COMPONENTS OF PUMP IRRIGATION USED AS VARIABLES OF EXPLANATION

	Site loc. X_1	Irrig. month X_2	Land acq. X_3	Land cultivated X_4	Irrig. Freq. X_5	Water used X_6	Man-days X_7	Fertilizer X_8	Inter-cropp. X_9	Yields X_{10}	Prod. cost X_{11}	Inco[illegible] X
X_1	1.00											
X_2	0.09	1.00										
X_3	-0.08	0.15	1.00									
X_4	0.08	0.09	0.20	1.00								
X_5	0.09	0.08	-0.20	-0.13	1.00							
X_6	0.17	0.09	0.07	-0.32	0.41	1.00						
X_7	0.11	-0.10	-0.15	-0.25	0.12	0.39	1.00					
X_8	0.07	-0.24	-0.20	-0.13	0.29	0.17	0.37	1.00				
X_9	0.11	0.04	-0.43	-0.31	0.31	0.13	0.24	0.18	1.00			
X_{10}	0.07	0.08	-0.30	-0.09	-0.08	-0.08	0.14	0.05	0.24	1.00		
X_{11}	-0.01	-0.16	0.07	-0.42	0.14	0.31	0.58	0.27	0.12	-0.01	10.00	
X_{12}	-0.05	-0.11	-0.06	- 0.00	-0.05	-0.06	0.16	0.05	0.06	0.38	0.12	1.

Correlations that exceed /0.32/ are significant at the 0.01% level.

Source: Data Analysis, 1990

The zero-order correlation coefficients, already given in Tables 6.9, 6.10 and 6.11, show that the explanatory variables are orthogonal, and, hence there would be no problem of multicollinearity. Table 6.10 shows that collinearity appears only in one case and so it is not a serious problem. In practice, however, absolute orthogonality is not often met as there is some degree of correlation between explanatory variables (Ayeni, 1986). The correlations, as seen in Tables 6.9, 6.10 and 6.11, are not high enough as to impair the accuracy and stability of the parameters of regression models.

In traditional manual irrigation, out of the ten variables of explanation of land cultivated that were included in the regression equation, only production cost, water, site location and methods of land acquisition were found to be important and this gives a regression model of the form:

$$Y = 1.0E^{4} - 3.0E^{-5}X_{11} - 7.7E^{-8}X_{6} + 0.2319X_{1} - 0.1994X_{3}$$

where Y is the size of land cultivated (X_4), X_{11} is the production cost, X_6 water input, X_1 is site location, and X_3 methods of land acquisition. Production cost

(X_{11}) was derived by adding all the money farmers expended in the provision and use of essential factors of production. Production cost (X_{11}) and water input (X_6) were measured on interval scale and standardized to unit area; Naira per hectare and litres per hectare respectively. Site location (X_1) of farms and methods of land acquisition (X_3), measured on nominal scale, are dummy variables. The importance of dummies has already been mentioned in Chapter Four.

The value of F is given as 12.15, which is significant at the 0.05% level. We therefore accept the hypothesis of dependence of size of land cultivated (X_4) on site location (X_1), month of irrigation (X_2), methods of land acquisition (X_3), volume of water (X_6), man-days (X_7), fertilizer (X_8), cropping patterns (X_9) and cost of production (X_{11}) under the manual irrigation. The results of the regression analysis are summarized in Table 6.12.

It is important to note that the four important variables jointly explained 54.86 per cent of the observed variations in sizes of land cultivated (X_4) under the manual irrigation (Table 6.12). Production cost (X_{11}),

TABLE 6.12: REGRESSION RESULTS OF LAND CULTIVATED AND THE FOUR FACTORS OF PRODUCTION UNDER THE MANUAL IRRIGATION

Independent variables	b Coeffi-cients	Std. Error of b	Multiple R	Level of expl.(%)	Increase level of expl.(%)	Probability
Prod. cost (X_{11})	$-3.0E^{-5}$	$5.7E^{-5}$	0.583	34.19	34.19	0.0001**
Water (X_6)	$-7.7E^{-8}$	$2.2E^{-8}$	0.681	46.43	12.24	0.004**
Site (X_1)	0.2319	0.1021	0.708	50.11	3.68	0.09*
Land acq. (X_3)	-0.1994	0.0973	0.741	54.86	4.74	0.05**

Intercept = 1.0861

** Significant at the 0.05% level
* Not significant at the 0.05% level

Source: Fieldwork, 1990

the most important explanatory variable, accounted for 34.19 per cent of the variations in land cultivated (X_4) under the manual irrigation. Water input (X_6) contributed 12.24 per cent of the variations in land cultivation. The zero coefficients imply that all farmers used water input (X_6) all in cultivation. The low percentage contribution of site location (X_1) of farms and methods of land acquisition (X_3) indicates that they did not determine much the sizes of land cultivated.

What determined the sizes of land cultivated was the availability of water. However, the bucket lift device involved in manual irrigation was heavy and this tends to limit its influence on the sizes of land cultivated, since in irrigation, water is a fundamental constraint. The low percentage of production cost was essentially due to the minimal amount of farming inputs used which tends to lower cost of production, and, hence save the farmers some money.

It should be noted that the b coefficients are low due to essentially the scale of measurement. Interval scale data such as land, labour, fertilizer, water and production cost were measured per hectare and this tends to affect the b coefficients.

In the regression equation of land cultivated (X_4) on the explanatory variables under the flood recession irrigation, 158 observations were deleted due to zero values and were taken as missing values. None of the remaining 8 values met the 0.1500 significance level for entry into the regression model.

Under the pump irrigation, five factors of production were observed to be important in the regression model (Table 6.13). These production factors, which were defined in a manner earlier stated, include production cost (X_{11}), means of land acquisition (X_3), water input (X_6), site location (X_1) and man-days (X_7) and the regression equation produced is of the form:

$$Y = 1.9106 - 2.4E^{-5}X_{11} + 0.7142X_3 - 2.6E^{-7}X_6 + 0.4954X_1 + 0.0011X_7$$

where Y is land cultivated (X_4), X_{11} is the production cost, X_3 is the method of land acquisition, X_6 is the water input, X_1 is the site location of farms and X_7 is the man-days.

The analysis of variance for the regression of land cultivated on the five factors of production gives an F ratio of 12.51 and is significant at the 0.05% level. We therefore accept the hypothesis that size of land cultivated is a function of production factors. However, under the pump irrigation only production cost (X_{11}), methods of land acquisition (X_3), water input (X_6), site location (X_1) and man-days (X_7) were found to determine size of land cultivated (X_4) rather than all the factors of production as hypothesized. The results of the regression analysis are summarized in Table 6.13.

TABLE 6.13: REGRESSION RESULTS: LAND CULTIVATED AND THE FIVE FACTORS OF PRODUCTION UNDER THE PUMP IRRIGATION

Independent variables	b Coefficients	Std. Error of b	Multiple R	Level of expl.(%)	Increase level of expl.(%)	Probability
Prod. Cost(X_{11})	$-2.4E^{-5}$	$4.8E^{-6}$	0.430	18.53	18.53	0.0001**
Land acq. (X_3)	0.7142	0.1969	0.480	23.07	4.54	0.004**
Water (X_6)	$-2.6E^{-7}$	$7.0E^{-8}$	0.526	27.67	4.60	0.003**
Site loc.(X_1)	0.4954	0.2644	0.544	29.64	1.96	0.05**
Man-days (X_7)	0.0011	0.0007	0.556	30.88	1.25	0.11*

Intercept = 1.9106

** Significant at the 0.05% level

* Not significant at the 0.05% level

Source: Fieldwork, 1990

Table 6.13 shows that only the first independent variable, production cost (X_{11}), makes strong contributions to the variations observed in land cultivated (X_4) under the pump irrigation. Production cost (X_{11}) alone accounted for 18.53 per cent of the 30.88 per cent explanation jointly accounted by the five variables. The four variables; means of land acquisition (X_3), water input (X_6), site location (X_1) and man-days (X_7) together explained only 12.35 per cent of the variations observed in land cultivated (X_4). The contribution of man-days (X_7) was not significant (Table 6.13). The reasons for the relative importance of cost of production (X_{11}) in affecting land cultivated (X_4) under the pump irrigation may be attributed to the use of the expensive water pumps and higher fertilizer, among others, that required high financial expenses in their provision. Table 6.11 shows a positive correlation between fertilizer application and production cost. The zero coefficients of production cost (X_{11}) and water input (X_6) indicate that farmers used them all.

However, site location of farms (X_1) and methods of land acquisition (X_3) are not very important determinants of variations in land utilization (X_4) for irrigation. Irrigation farms of the pump type could be located at any site provided farmers had enough money to buy water pumps to enable them lift water to higher and farther away sites from water sources. The interest in acquiring and using water pump in irrigation was motivated by its efficiency in water application. However, water pump efficiency was sometimes lowered considerably, as reflected by its low percentage contribution to land use, due to serious technical problems associated mainly with old age and lack of spare parts for maintenance.

Again, 69.12 per cent of the observed variations in land cultivated (X_4) under the pump irrigation was accounted by the unexplained variance. Only five of the ten variables of explanation that entered into the regression equation were observed to be important. This implies that the unexplained variance could not be due to any of the observed factors of production. We can however say that the 69.12 per cent of the unaccounted explanation may be due to the managerial skills of farmers, among others, in using factors of production.

The results in tables 6.12 and 6.13 reveal that not all the explanatory variables originally entered into the regression model were important in influencing the variations observed in land cultivated. The individual contributions of the important independent variables to the variations in land cultivated were less than 40 per cent and less than 20 per cent respectively under the manual and pump irrigation (Tables 6.12 and 6.13). The small contribution, therefore, implies that the quantities of production factors used did not provide adequate explanations, and, hence not effective in influencing variations in irrigation land cultivation both under the traditional manual and pump irrigation. Size of land cultivated is therefore not entirely a function of a combination of site location of farms, volumes of water, size of labour, fertilizer, cropping patterns, land tenure and cost of production both under the traditional and modern irrigation. Thus, the use of factors of production under the modern irrigation technology, symbolized by the water pumps, has no much relevance over their use under the traditional practice of irrigation in determining the rates of variations in irrigation land utilization.

6.5 CROPPING STRATEGIES

Cropping strategies constitute an important factor influencing the allocation and utilization of production resources. The type of crops grown by farmers are chosen based on environmental and socio-economic constraints to production.

The Donga survey shows that eight different varieties of crops (vegetables, okro, tomatoes, pepper, onion, beans, maize and wheat) were being cultivated. All the crops, with the exception of beans, were found to be cultivated under the manual and pump irrigation. Beans, in addition to other crops, was cultivated mainly under the flood recession irrigation (Table 4.17).

In terms of cultivation, a quasi-zoning system or crop specialization was apparent on the basis of irrigation type. Wheat was the predominant crop grown under the pump irrigation. The manual irrigation was predominant in the cultivation of vegetables (Table 4.17).

The survey also shows a recognisable series of inter-cropping. The cropping strategy of maize and beans, being the basic elements of the flood recession farming, was in response to their tolerance of relatively short period of residual soil moisture. The strategy was a direct result of the farmers' long years of experience and skill in managing their ecological environment (flood regime). Maize and beans, for example, were planted mostly in September to coincide with the beginning of flood water recession (Table 6.14). The commencement of irrigation in September

TABLE 6.14: SITE LOCATION OF FARMS AND MONTHS OF IRRIGATION COMMENCEMENT

Irrigation type	Site	Months of Irrigation							
		September		October		November		December	
		No. of farmers	%	No. of farmers	%	No. of farmers	%	No. of farmers	%
Flood recession	Low-lying	25	15.06	136	81.93	1	0.60	-	-
	Raised lowland	2	1.20	1	0.60	-	-	1	0.60
Manual	Low-lying	7	14.00	30	60.00	-	-	1	2.00
	Raised lowland	4	8.00	3	6.00	1	2.00	4	8.00
Pump	Low-lying	22	14.86	8	58.11	16	10.81	5	3.38
	Raised lowland	5	3.38	9	6.08	4	2.70	1	0.60

Flood recession N = 166
Manual N = 50
Pump N = 148

Total 364

Source: Fieldwork, 1990

was sometimes delayed till October depending on the level of flood regime. This was done in order to follow the residual soil moisture as the flood water receded.

Table 6.14 shows again that farmers who commenced cultivation in September had their plots located on the low-lying sites mostly, though irrigation generally commenced in October. Any period after the first week of October was considered late for flood recession farming. This is because of the high degree of risk associated with the unpredictable nature of flood regime.

It was observed that irrigated crops were grown, either in single or mix stands, for various reasons (Table 6.15). Table 6.15 shows that most crops were cultivated to ensure better use of inputs under the flood recession regime. However, the wheat growers opined that it was cultivated in single stand, not because it would ensure better use of inputs and generate more yield in single stand, but because of the pressure put on them by the extension agents of the Ministry of Agriculture and Natural Resources, the sponsors of the wheat programmes.

TABLE 6.15: CROPS GROWN FOR VARIOUS REASONS

Irrigation types	Better input use	Security	Inputs maximization	Economic grains
Flood recession	Vegetables Wheat Maize Tomatoes Pepper Onion	Maize Beans	Maize Okro Tomatoes Pepper Onion	Maize
Manual	Vegetables Wheat Maize Tomatoes Okro		Vegetables Maize Okro Tomatoes Pepper Onion	Vegetables Maize Okro Tomatoes
Pump	Vegetables Wheat Maize Tomatoes Okro		Vegetables Maize Okro Tomatoes Wheat Pepper Onion	Pepper Tomatoes Vegetables Onion

Source: Fieldwork, 1990

The main drawback of the single cropping strategy is its vulnerability to unpredictable incidence of pests and diseases, and other climatic hazards, for which the farmers have no insurance cover. For the flood recession farmers, who cultivated crops in single stands (Appendix 3), the dangers were great since crops survival depended on the residual soil moisture. In case of outbreak of pests, diseases or drought occurrence, the farmers would lose the entire crop. The need to maximize inputs use influenced the choice of crops, mostly grown in mixed stands (Appendix 3) under the manual and pump irrigation (Table 6.15).

By planting together crops with varying planting and harvesting dates, and growth habits, plant nutrients in different soil layers are better exploited and light energy is more effectively intercepted. For instance, it was observed that, in the mixture of maize and beans complex (Appendix 3) the beans, which were intercropped in between the rows of maize, climbed on the maize stalks, exposing their leaves to the light without excessive shading of the maize leaves.

In addition, the traditional concern of certainty, security of subsistence and aversion of risk is demonstrated by the flood recession farmers' preference to grow maize and beans in mixed complexes because of thier ability to survive on the residual soil moisture. The range of the residual soil moisture conditions tolerated by maize and beans ensured that some yield was assured whenever the soil moisture was available. In case of total failure of the residual soil moisture, the beans were expected to grow well with the depleted soil moisture whilst the maize would yield something. This means that the intercropping of beans with maize (Appendix 3) was a risk aversion strategy of the flood recession farmers (Table 6.15). Thus, the beans provided insurance against maize failure. At pronounced failure of soil moisture, the two crops would, however, fail altogether. Therefore, the question of crop security borders on the availability of soil moisture resources, no matter how low it is to sustain crops that are most tolerant of extreme soil moisture deficiency.

With the exception of maize and beans under the flood recession irrigation, none of the crops was cultivated for security reasons in manual and pump irrigation (Table 6.15). The manual irrigation farmers, because of the problem of the bucket lift, made sure that available water drawn was maximally utilized rather than maximizing the use of land.

Furthermore, the need to maximize economic gains influenced the choice of some crops (Table 6.15) and crop combination (Appendix 3). Crops grown in mixed stands, in addition to the maximization of cost of purchasable inputs, enabled the farmers to get additional income. For example, the cultivation of vegetables in mixture of maize was favoured under the traditional flood recession and manual irrigation (Appendix 3) because of the short growing season of vegetables. This ensured to the farmers double cropping of vegetables during the 1989/90 irrigation season before maize was completely harvested.

It is instructive to note that the land cultivated by farmers was found mostly to be small (Table 4.4).

Again, farmers were interested in cultivating a variety of crops (Table 6.15) which the small plots could not contain separately to the level of their expectation Therefore, it was a rational land resources use decision to plant varieties of crops in the same plot. Since farmers were observed not to use agro-chemicals, mix-cropping could be considered to be a solution, among others, to the problem of unforeseen pest invasion. The perils associated with pests and diseases could be reduced and better distributed in mixed stands. In this case the mixed crops will serve as security to farmers in case of failure of any of the intercrops.

6.6 SUMMARY

It is seen in this chapter that the amounts of labour and fertilizer inputs utilized by farmers varied significantly between the flood recession, manual and pump irrigation schemes. Specifically labour use varies significantly within the flood recession irrigation, but variations in labour use within the manual and pump irrigation are not significant. Variations in the use of fertilizers are not significant within the three irrigation types. It was statistically established that the rate of land utilization in irrigation is affected only by some factors of production, notably production cost, methods of land acquisition, water input, site location and man-days, rather than all factors of production.

The next chapter focuses on the analysis of factors of productivity and profitability in traditional and modern irrigation. The discussion in the chapter will facilitate our understanding of the yield generation and cost-effectiveness of the traditional and modern irrigation practices.

CHAPTER SEVEN

PRODUCTIVITY IN TRADITIONAL AND MODERN IRRIGATION

Productivity is measured by yield levels of production enterprise and profitability is measured in terms of the values of inputs of production and values of farm production. This chapter therefore measures in quantitative terms, the yields of crops realized and their relationships with factors of production. This chapter is used to test the hypothesis that; crop yield varies with site location, soil moisture retention, methods of land acquisition, size of land cultivated, frequency of water application, volume of water, man-days, fertilizers, cropping patterns, cost of production and income. The alternative hypothesis, H_1 is that; crop yield does not vary with these factors of production.

The production function approach is used to determine the effects of inputs of production in the production of crops under the traditional and modern irrigation technologies. Similarly, the utility function approach is adopted in this chapter to provide explanations for resource allocation and utilization relative to crop yield under irrigation management. Attempt is also made to estimate the values of inputs of production and values of farm products, and to show how they vary within and between traditional and modern irrigation. The hypothesis that; there is no relationship between cost of production and income between and within irrigation types is tested in this chapter. The alternative hypothesis, H_1 is that; there is relationship between cost of production and income between and within the three irrigation types. The simple analysis of variance and t-test shall be used to test the hypothesis.

7.1 FACTORS OF CROP YIELDS

Farmers bought and used factors of production on varieties of crops, planted in mixed complexes. It is difficult to know exactly what inputs and quantities of inputs of production went into the production of specific crops. Therefore, the total yields of crops were used, rather than individual crop yields, in estimating the productivity of the three irrigation types. However, the data on total yields should be used with caution since they do not adequately measure productivity of specific crops.

During the survey, it was observed that farmers realized various levels of crop yields; ranging from an average of 0.34 tonnes per hectare under the flood recession irrigation to an average of 1.84 tonnes per hectare under the pump irrigation (Table 7.1).

TABLE 7.1: AVERAGE CROP YIELDS (Tonnes/ha^{-1}) PER FARMER

Irrigation Type	Average tonnes/ha^{-1}	N
Flood recession	0.34	166
Manual	1.69	50
Pump	1.84	148

Source: Fieldwork, 1990

The result of the analysis of variance shows that there are significant variations in crop yields between the three irrigation types (Table 7.2). The significant variations in crop yields between the three irrigation types (Table 7.2) are not however reflected within the irrigation types (Table 7.3).

TABLE 7.2: ANALYSIS OF VARIANCE FOR AVERAGE CROP YIELD (Tonnes/ha^{-1})

Source of variation	Degrees of Freedom	Sum of squares	Mean squares	F	Probability
Due to irrigation types	2	193.82	96.91		
Error	361	6641.73	18.40	5.27	0.01**
Total	363	6835.55			

** Significant at the 0.05% level

Source: Fieldwork, 1990

TABLE 7.3: RESULTS OF T-TEST FOR SITE LOCATION OF FARMS AND AVERAGE CROP YIELDS (Tonnes/ha^{-1}

	Irrigation Type					
	Flood recession		Manual		Pump	
	i	ii	i	ii	i	ii
Mean	0.34	0.29	1.29	2.94	2.02	0.65
Std. Error	0.03	0.05	0.42	1.53	0.60	0.31
T Value	0.28		-1.45		0.87	
Probability	0.78*		0.15*		0.39*	

* Not significant at the 0.05% level

<u>Key</u>

i = Low-lying sites

ii = Raised lowland sites

Source: Fieldwork, 1990

7.2 CORRELATION ANALYSIS OF VARIABLES OF CROP YIELDS

Because of the difficulties of estimating the exact quantities of inputs of production for specific crops, the total crop yields were used, rather than individual crop yields in both the correlation and regression analyses.

A look at the coefficients of correlation in Table 6.9 reveals that positive relationships exist between crop yields and pairs of factors of production, other than month of irrigation and water input under the flood recession irrigation. Changes in month of irrigation and water input will not lead to changes in crop yields of the flood recession irrigation. The positive correlations merely reflect the common effect of the upward trend on the positively correlated variables.

However, site location (X_1), land cultivated (X_4) and water input (X_6) are negatively correlated with crop yields (X_{10}) while the remaining factors are positively correlated with crop yields (X_{10}) under the manual irrigation (Table 6.10). The methods of land acquisition (X_3), land cultivated (X_4), frequency of irrigation (X_5) and water input (X_6) are negatively correlated with crop yields (X_{10}) under the pump irrigation (Table 6.11). Changes in these factors of production will not lead to changes in crop yields (X_{10}). The positive correlations indicate that a high score on one variable is likely to record a high score on the other variable or vice versa.

It is important to note that it is the water application process that distinguishes fundamentally pump irrigation from traditional irrigation, but the results in Tables 6.9, 6.10 and 6.11 show that water input (X_6) is not positively correlated with crop yields (X_{10}) under both the modern pump and traditional irrigation schemes. Relatively speaking, the negative correlation between crop yields (X_{10}) and inputs of production generally reveals the weak ability of these inputs in affecting crop productivity under irrigation regime.

7.3 PRODUCTION FUNCTION OF FARMING VARIABLES ON CROP YIELDS

Regression analysis offers one possibility of identifying the production function of variable inputs in production of crops. In order to estimate the production function of factors of production on crop yields, production factors are defined as; site location (X_1); soil moisture retention (X_2); methods of land acquisition (X_3); land cultivated (X_4); frequency of water application (X_5); volume of water (X_6); man-days (X_7); fertilizer application (X_8); cropping patterns (X_9); cost of production (X_{11}) and income (X_{12}) as explanatory variables of crop yield generation. The size of land cultivated (X_4), frequency of irrigation (X_5), volume of water (X_6), fertilizer (X_8), man-days (X_7), production cost (X_{11}) and income (X_{12}) were measured on interval scale and standardized to per unit area (hectare). On the other hand, site location (X_1), month of irrigation (X_2), methods of land acquisition (X_3) and cropping patterns (X_9) were measured on nominal scale and defined therefore as dummies. The eleven explanatory variables are orthogonal (Tables 6.9, 6.10 and 6.11) and as such included in the regression equation.

Under the flood recession irrigation, only three out of the eleven factors of production were observed to be relevant to the crop yield realized and this yields a regression model of the form:

$$Y = -0.1865 + 0.0011X_{11} - 0.0004X_{12} + 0.4811X_4,$$

where Y is the estimated crop yields (X_{10}), X_{11} is the production cost, X_{12} is the income and X_4 is the land cultivated.

The analysis of variance for the regression equation gives the value of F as 17.54, and is significant at the 0.05% level. The conclusion from the result of the analysis of variance is that we accept the hypothesis of dependence of crop yield (X_{10}) on three of the factors of production.

The results of the regression analysis are summarized in Table 7.4. The three important variables in the

TABLE 7.4: REGRESSION RESULTS OF THE ESTIMATED YIELD OF CROPS AND THE THREE FACTORS OF PRODUCTION UNDER THE FLOOD RECESSION IRRIGATION

Independent variables	b Coeffi-cients	Std. Error of b	Multiple R	Level of expl.(%)	Increase in level of expl. (%)	Probability
Pro. cost (X_{11})	0.0011	0.0002	0.653	42.61	42.61	0.08*
Income (X_{12})	-0.0004	0.0001	0.920	84.60	41.99	0.01**
Land (X_4)	0.4811	0.2214	0.964	92.94	8.34	0.10*

Intercept = -0.1865

** Significant at the 0.05% level
* Not significant at the 0.05% level

Source: Fieldwork, 1990

equation accounted for 92.94 per cent of the variation observed in crop yields (X_{10}), with the remaining 7.06 per cent being accounted by the unexplained variance. The cost of production (X_{11}) and income (X_{12}) explained 42.61 per cent and 41.99 per cent respectively of the observed variations in crop yields (X_{10}) of the flood recession irrigation (Table 7.4). The relative lack of importance of water input (X_6), fertilizer application (X_8) and other factors of production attests to the adaptability of the flood recession irrigation farming to the natural residual soil moisture conditions and locally mobilized production resources.

The high percentage contribution of production cost (X_{11}) to yield generation capacity of flood recession farming (Table 7.4) may be attributed to the use of hired labour, employed mainly for land preparation, weeding and harvesting of crops. There is a positive correlation between cost of production (X_{11}) and labour input (X_7) (Table 6.9), implying that a per hectare increase in man-days (X_7) will result to a per hectare increase in cost of production (X_{11}) and vice versa.

In the regression equation of crop yield (X_{10}) on factors of production under the manual irrigation, five production factors were observed to be important; production cost (X_{11}), frequency of irrigation (X_5), cropping pattern (X_9), water input (X_6) and month of irrigation (X_2) and the equation for estimating yield is of the form:

$$Y = -0.4977 + 0.0027X_{11} - 1.5685X_5 + 1.3691X_9 - 3.3E^{-7}X_6 + 1.5984X_2,$$

where Y is the estimated crop yield (X_{10}), X_{11} is the production cost, X_5 is the frequency of irrigation, X_9 is the cropping pattern, X_6 is the water input and X_2 is the month of irrigation.

The F value for the regression is given as 12.46, and is significant at the 0.05% level. The conclusion here is that we accept the hypothesis of dependence of crop yield on five factors of production under the manual irrigation scheme.

The results of the regression analysis are summarized in Table 7.5.

TABLE 7.5: REGRESSION RESULTS OF THE ESTIMATED YIELD OF CROPS AND FIVE FACTORS OF PRODUCTION UNDER THE MANUAL IRRIGATION

Independent variables	b Coeffi-cients	Std. Error of b	Multiple R	Level of expl.(%)	Increase in level of expl. (%)	Probability
Prod. Cost (X_{11})	0.0027	0.0004	0.586	34.30	34.30	0.0001**
Irrig. Freq. (X_5)	-1.5685	0.4093	0.703	49.40	15.10	0.001**
Inter cropp.(X_9)	1.3691	0.5290	0.743	55.17	5.77	0.03**
Water (X_6)	$-3.3E^{-7}$	$1.6E^{-7}$	0.763	58.18	3.01	0.10*
Irrig. Month (X_2)	1.5984	0.8712	0.784	61.50	3.32	0.07*

Intercept = -0.4977

** Significant at the 0.05% level

* Not significant at the 0.05% level

Source: Fieldwork, 1990

The results in Table 7.5 show that the five factors of production, taken together, explained 61.50 per cent of the variations observed in crop yields (X_{10}). But the cost of production (X_{11}) seems to be the most important variable in explaining the observed variations in crop yield (X_{10}) under manual irrigation, accounting for 34.30 per cent. Frequency of water application (X_5) accounted for 15.10 per cent of the variations observed in crop yields (Table 7.5). Water input (X_6) was observed not to be significant, although it explained 3.01 per cent of the variations in crop yield (X_{10}).

Similarly, under the pump irrigation, five of the eleven factors of production used in the regression equation were important, though in varying degrees. The important factors of production in the regression equation are income, methods of land acquisition, month of irrigation, frequency of irrigation and cropping patterns, and the regression model obtained is of the form:

$$Y = 2.7164 + 0.0003X_{12} - 3.9146X_3 + 2.9211X_2 - 1.9660X_5 + 2.0882X_9,$$

where Y is the estimated crop yield (X_{10}), X_{12} is the income, X_3 is the method of land acquisition, X_2 is the month of irrigation, X_5 is the frequency of irrigation and X_9 is the cropping pattern.

The F-ratio of the regression equation is 11.10, which is significant at the 0.05% level. Similarly, we accept the hypothesis of dependence of crop yield (X_{10}) on the five factors of production. Table 7.6 gives the summary of regression results.

TABLE 7.6: REGRESSION RESULTS OF THE ESTIMATED YIELD OF CROPS AND THE FIVE FACTORS OF PRODUCTION UNDER THE PUMP IRRIGATION

Independent variables	b Coeffi-cients	Std. Error of b	Multiple R	Level of expl.(%)	Increase in level of expl.(%)	Probability
Income (X_{12})	0.0003	0.0001	0.373	13.93	13.93	0.0001**
Land acg. (X_3)	-3.9146	1.1283	0.467	21.80	7.87	0.0002**
Irrig. month (X_2)	2.9211	1.2344	0.496	24.58	2.78	0.02**
Irrig. Freq. (X_5)	-1.9660	0.8241	0.516	26.59	2.01	0.05**
Cropp. Patterns(X_9)	2.0882	1.1141	0.533	28.39	1.80	0.06*

Intercept = 2.7164

** Significant at the 0.05% level
* Not significant at the 0.05% level

Source: Fieldwork, 1990

The five variables of explanation, together, accounted for only 28.39 per cent of the variations observed in crop yield (X_{10}). Income (X_{12}) accounted for the highest explanation (13.93 per cent) of the variations in crop yields (X_{10}) observed (Table 7.6). All the five factors with the exception of irrigation frequency (X_5), were observed to be significant (Table 7.6).

Although the signs of the coefficients for methods of land acquisition (X_3) and frequency of water application (X_5) did not comply with the a priori expectations, the coefficient for methods of land acquisition (X_3) was found to be statistically significant while that of frequency of water application (X_5) was not (Table 7.6). The negative sign of the coefficients for frequency of water application (X_5) under the manual and pump irrigation (Tables 7.5 and 7.6) indicates a high intensity of water resource use in irrigation production. Efforts should therefore be made to increase the rate of water resource use in manual and pump irrigation as a way of achieving impressive crop yields, among others.

The method of water application, as has already been hinted, using the water pump is what distinguishes fundamentally the modern pump irrigation from the traditional flood recession and manual irrigation practices. However, water seems not to be important in explaining the observed variations in crop yields of both the flood recession, manual and pump irrigation types (Tables 7.4, 7.5 and 7.6). It can be suggested therefore that the only difference between the use of modern pumps and the residual soil moisture is basically in terms of the physical presence of water pumps and not in terms of their effects on crop yield generation.

The results in Tables 7.4, 7.5 and 7.6 reveal that not all the eleven explanatory variables used in the regression equations were important in explaining the observed variations in crop yields. Again, while some factors of production were important in one irrigation type, they were not in others. While water input, for example, was an important determining factor of crop yield under the manual irrigation, it was not in both the flood recession and pump irrigation types. Again while income was important in flood recession and pump irrigation, it was not in manual irrigation (Tables 7.4, 7.5 and 7.6). Fertilizer application and labour are important inputs of production, but were observed not to be important determinants of crop yield variations in both the traditional and modern irrigation (Tables 7.4, 7.5 and 7.6).

Furthermore, in all the three irrigation types, each important factor of production contributed below 50 per cent (Table 7.4) and in some cases below 40 per cent (Tables 7.5 and 7.6). This evidence tends to show that variations in crop yields under irrigation farming do not depend on all the explanatory variables of site location, months of irrigation, methods of land acquisition, land cultivated, frequency of water application, volume of water, man-days, fertilizers, cropping patterns, production cost and income as earlier hypothesized.

The correlation coefficients in Tables 6.9, 6.10 and 6.11 have already shown that both positive and negative correlations exist between crop yields and the explanatory variables in traditional and modern irrigation. Thus crop yield generation in both the three irrigation types is determined only by some of these observed factors of production rather than by all the factors, and these factors vary from one irrigation type to another.

7.4 EXPECTED AND OBSERVED CROP YIELDS

The yields of crops observed per hectare were compared with the expected yields per hectare. The expected figures were obtained from the experimental research farm of the Upper Benue River Basin Development Authority. The figures, represent what would be expected under good management. Instead of using the observed tonnes for each crop and for each sample, the observed average tonnes per crop were used for the purposes of comparison with the expected tonnes. The data in Table 7.7 provide good measures of productivity of irrigation production since crop yields are given per hectare by crop types, as against their expected yield per hectare.

TABLE 7.7: EXPECTED AND OBSERVED MEAN YIELDS OF CROPS

Irrigation type	Crop type	Observed mean tons/ hectare	Expected tons/ hectare	Shortfall from expected	Observed as % of expected
Flood recession	Okro	1.4	20	-18.6	7.0
	Vegetables	1.1	20	-18.9	6.0
	Onion	0.3	2	- 1.7	15.0
	Beans	0.1	2.5	- 2.4	4.0
	Maize	2.1	2.5	- 0.4	84
	Pepper	0.6	20	-19.4	3.0
	Tomatoes	1.0	20	-19	5.0
Manual	Okro	0.9	20	-19.1	4.5
	Vegetables	0.7	20	-19.3	3.5
	Onion	0.4	2	- 1.6	20.0
	Wheat	0.3	2.5	- 2.2	12.0
	Maize	2.5	2.5	0	100.0
	Pepper	1.3	20	-18.7	6.5
	Tomatoes	1.3	20	-18.7	6.5
Pump	Okro	5.0	20	-15	25.0
	Vegetables	2.9	20	-17.1	14.5
	Onion	0.5	2	- 1.5	25
	Wheat	2.9	2.5	0.4	116
	Maize	1.9	2.5	- 0.6	76.0
	Pepper	4.5	20	-15.5	22.5
	Tomatoes	2.2	20	-17.8	11.0

Source: Fieldwork, 1990

A look at the yield gaps in Table 7.7 reveals that the crop yields estimated in both the traditional and modern irrigation were generally low compared to the potential or expected productivity that could be attained from them, all things being equal.

In terms of productivity, maize records the best performance under the three irrigation types. This is due, inter alia, to the two cropping cycles of maize under adequate agronomic practices. After the first harvest, water and fertilizer applications were done to allow the stands to bear fruits for the second harvest.

Again, the high productivity of maize can be attributed to its higher marketability, in terms of demand and selling prices, which encouraged its growers to pay particular attention to its cultivation. A sack of maize, for example, was sold at ₦85 in the 1989/90 season (Table 3.4) and that was considered a good price. In addition to double cropping and marketability, the impressive yield of 2.1 tonnes per hectare, as against the expected 2.5 tonnes per hectare of maize under the flood recession farming was aided by supplementary irrigation. Maize was thus sustained beyond what would have been possible under the natural residual soil moisture conditions.

The results in Table 7.7 again show that the productivity of maize under the traditional flood recession and manual irrigation was higher than its productivity under the modern pump irrigation. The maize growers under the pump irrigation belonged to the category of pump users who experienced water pump breakdown (Table 5.2). With the exception of maize, the productivity of all crops is relatively higher under the pump irrigation because of the ability to meet crops's high water requirements (Table 5.7). The same reason of double cropping and higher marketability applied to pepper, tomato and vegetable cultivation under the three irrigation types. The expected yields of pepper, tomatoes and vegetables were inhibited by the menace of pests and failure in soil moisture, among others.

It has already been seen that crop yields are negatively correlated with water application and use of soil moisture resources (Tables 6.9, 6.10 and 6.11). Failures in water supply and soil moisture resources are attributed to problems of breakdown of water lifting devices and depletion in the residual soil moisture. The unpredictable pest invasion, it should be noted, was only partially controlled with the application of local ash, due to the relative lack of agro-chemicals (pesticides).

The consequence of the menace of pests and failure in water supply, and soil moisture resources is the performance of crops below their expected production levels. Pepper, tomato and vegetable production, for example, recorded shortfalls of 15.5 tonnes, 17.8 tonnes and 17.1 tonnes per hectare respectively under the pump irrigation. The shortfall was above 18 tonnes for the three crops under the manual and flood recession irrigation (Table 7.7). Again under utilization of land (Table 4.3), which was attributed to lack of adequate water and soil moisture resources, among others, leads to the observed gap in yield for most crops (Table 7.7). The lack of adequate and dependable water sources and soil moisture resources make farmers to have little control over their ecological conditions in which they work.

The production of wheat under pump irrigation was above the expected level, with a surplus of 0.4 tonnes per hectare. A production deficit of 2.2 tonnes per hectare of wheat was observed under the manual irrigation. The adaptability of wheat cultivation to the pump irrigation is attributed to the fact that it is a water demanding crop, and water use efficiency was better associated with the pump irrigation, in terms of volume than with other irrigation types (Table 5.7).

Again, the evidence on the productivity efficiencies of crops, other than maize in the three irrigation types and wheat under pump irrigation only (Table 7.7), tends to conform with the productivity efficiency in most parts of the developing countries, which is below 50 per cent and in some cases, below 20 per cent (Areola, 1990). The evidence on the productivity efficiency (Table 7.7) goes contrary to the assumption that farmers would achieve higher yields if they took advantage of available improved factors of production and modern management practices (Areola, 1990).

Furthermore, it is clear that crops with higher yields (Table 7.7) are mostly the intercrops (Table 4.16).

Tables 6.9, 6.10 and 6.11 show that crop yields and inter-cropping are positively correlated under the three irrigation types. The higher the degree of inter-cropping, the higher the crop yields, other things being equal. From the farmers' point of view the amount and variety of products available from intercropped farms is a major attraction. The attraction of higher crop defines farmers' utility with respect to the type of cropping pattern adopted. Intercropping is seen by farmers as a measure of maximizing returns of land, labour, fertilizer and other resources use, and reduces variability of yields. These provide sufficient basis for farmers' preference of intercropping to monocropping. The usefulness of production enterprise, it should be noted, is basically seen from the perspectives of the accruing crop yields.

The positive correlation between crop yields and cropping patterns tends to agree with Abalu's (in Adams's, 1984) and Richards's (1983) observation that intercropping, among others, is capable of producing higher crop yields. Plants of the same species compete more intensively with each other than do some plants of different species due to differences in terms of root systems and period of peak water and other requirements of different species. Intercrops make the best use of available resources, free from internal competition, and, hence the relative higher crop yields (Tables 4.16 and 7.7).

7.5 VALUES OF INPUTS

The traditional and modern irrigation were found to make use of essential factors of production that involved some financial expenses. The land farmed, pump, petrol, spare parts, service, chemical fertilizers, bucket/calabash and labour input cost money. The depreciation value of irrigation materials was used in the calculation of the value of inputs. Also the transport for conveying the physical factors of production to the farm and for conveying harvested products home and to the markets - all cost the farmers money. The money the farmers expended in the provision of these essential factors of production represent the value of inputs, which in this study is referred to as the cost of production.

Farm resources such as labour, fertilizer and water are applied to the various crops which are mixed on the farms and it is usually difficult to work out the economic cost of the share used by a particular crop within a multiple cropping system. In irrigation, cost of production was observed to vary from one irrigation type to another, with the pump irrigation recording the highest average production cost of ₦3,041.63 per hectare (Table 7.8).

TABLE 7.8: AVERAGE VALUE OF PRODUCTION INPUTS (₦/ha^{-1}) PER FARMER

Irrigation Type	Average Cost (₦/ha^{-1})	N
Flood recession	920.54	166
Manual	1176.83	50
Pump	3041.63	148

Source: Fieldwork, 1990

The average cost of production per hectare in the flood recession, manual and pump irrigation schemes in the Donga river basin are presented in Table 7.8. The observed variations in the cost of production for the different irrigation types are statistically significant (Table 7.9).

TABLE 7.9: ANALYSIS OF VARIANCE FOR AVERAGE VALUES OF PRODUCTION INPUTS (₦/ha^{-1})

Source of variation	Degrees of Freedom	Sum of Squares	Means Squares	F	Probability
Due to irrigation types	2	3.7E^{10}	1.8E^{10}		
Error	361	8.4E^{10}	2.3E^{8}	80.70	0.0001**
Total	363	1.2E^{11}			

** Significant at the 0.05% level

Source: Fieldwork, 1990

The high cost of production under the pump irrigation (Table 7.9) can be attributed to the high cost of water pum[p] labour and the recurrent cost of petrol, spare parts and service charge. The need to apply enough water to crops in order to ensure high crop yields, and, hence high income, for example, influenced farmers' decision to acquire and use the expensive water pumps. Thus, the usefulness of water pump in irrigation is seen from the perspective of its efficiency in water application over the traditional lifting devices.

During the survey period, it was observed that the average cost of a new irrigation water pump was ₦6,700, representing an increase of over ₦1,500 over the 1984 price and of ₦6,200 over the 1982 price. Similarly, chemical fertilizers were sold at ₦60 per bag as against the subsidized official price of ₦20 per bag.

The lower cost of production observed under the traditional flood recession and manual irrigation types (Table 7.8), however, can be attributed to the local sourcing of production resources; like the bucket lift device, few labour (Table 6.1) and the use of small quantities of chemical fertilizers, compared with that used by the pump users (Table 6.5).

The high cost of production observed on the raised lowland sites (Table 7.10) was due to their ecological conditions that require effective agronomic practices in terms of utilization of adequate farming inputs (Tables 6.3 and 6.7).

Although the average cost of production varies between the flood recession, manual and pump irrigation farms

TABLE 7.10: RESULTS OF T-TEST FOR SITE LOCATION OF FARMS AND AVERAGE VALUES OF PRODUCTION INPUTS (₦/ha^{-1})

	Irrigation Type					
	Flood recession		Manual		Pump	
	i	ii	i	ii	i	ii
Mean	915.95	1106.56	1092.95	1442.43	3036.29	3077.90
Std. Error	42.36	138.73	98.47	214.59	199.41	582.69
T value	-0.70		-1.65		-0.07	
Probability	0.48*		0.11*		0.94*	

* Not significant at the 0.05% level

Key

i = Low-lying sites
ii = Raised lowland sites
Source: Fieldwork, 1990

(Table 7.9) it does not vary significantly between low-lying and raised lowland sites under each irrigation type (Table 7.10). This latter conclusion can be attributed to the lack of significant variations in the observed utilization of most production inputs between low-lying and raised lowland sites (Tables 4.8, 5.9, 6.3 and 6.7).

While there is a strong positive correlation between cost of production and crop yield under the traditional flood recession and manual irrigations (Tables 6.9 and 6.10), the correlation between cost of production and crop yield is negative under the pump irrigation (Table 6.11). This suggests that a per hectare increase in inputs of production, in terms of their cost, will only marginally increase crop yields under the pump irrigation.

The positive correlation between cost of production and yields of crops under the traditional irrigation implies that the available inputs were effectively utilized. The higher quantities of inputs of production under the pump irrigation could only be of benefit if they were effectively managed and utilized by farmers. It is not the quantities of production inputs and their use under modern practice, per se, that determine crop yields, but the manner in which the quantities of production inputs are managed and utilized for crops, no matter how small they are and how traditional the practice is.

Irrigation farmers, like most farmers, are limited by lack of capital for investment and as such their production objectives are often to maximize crop yield at lower costs. The decision to maximize crop yield influences their choice of management in terms of the type and intensities of land use, and the type and quantities of inputs to be used, among others. For the flood recession and manual irrigation farmers, whose cost of production positively correlates with crop yield (Tables 6.9 and 6.10), implying that a high score of one leads to a high score of another, traditional irrigation management system meets their production objectives, and hence, it is taken to be useful. Therefore, the flood recession and manual irrigation are attractive to them because of their reasonable yield levels relative to cost of production.

In addition to the lack of relationship between cost of production and yields of crops (Table 6.11), the shortages of fuel, risk of mechanical breakdown and lack of mechanics to repair pump, as already seen in chapter 5, make the pump irrigation much more risky for an individual farmer. The low cost of production, however, of the traditional irrigation practices are within the reach of farmers.

7.6 VALUES OF PRODUCTION

Generally, values of production provide an important quantitative measure by which total productivity of resources used on the farm is evaluated. Since one of the main objectives of the study is on irrigation profitability, the total values of crops cultivated by each of the sampled farmers were estimated (Appendix 2). The observed values of production were derived from the sale of farm products and these are referred to as farm income.

It was observed that the pump irrigation has the highest average gross values of farm products (₦6,512.45) realized per hectare mainly from the sale of wheat (Table 7.11).

TABLE 7.11: AVERAGE VALUES OF PRODUCTION (₦/ha^{-1}) PER FARMER

Irrigation Type	Values (₦/ha^{-1})	N
Flood recession	1839.53	166
Manual	2452.98	50
Pump	6512.45	148

Source: Fieldwork, 1990

The flood recession irrigation has the lowest gross values of production of ₦1,839.53 per hectare as against ₦2,452.98 per hectare under the manual irrigation (Table 7.11). The values of production observed vary significantly between the three irrigation types (Table 7.12). The guarantee minimum price of ₦600.00

TABLE 7.12: ANALYSIS OF VARIANCE FOR AVERAGE VALUES OF PRODUCTION (₦/ha^{-1})

Source of variation	Degrees of Freedom	Sum of Squares	Mean Squares	F	Probability
Due to irrigation types	2	$1.8E^{11}$	$9.0E^{10}$		
Error	361	$9.5E^{11}$	$2.6E^{9}$	34.33	0.0001**
Total	363	$1.1E^{12}$			

** Significant at the 0.05% level
Source: Fieldwork, 1990

per bag (₦7,058.85 per tonne) of wheat appears to be the highest offered for irrigated crops in the area during the 1989/90 irrigation season (Table 3.4). The high crop yields under the flood recession irrigation were derived mainly from vegetables and maize which were sold at ₦20 per basket and ₦85 per bag (₦1000 per tonne each), lower than the wheat (Table 3.4). The differences in the market prices for wheat, vegetables and maize, therefore, accounted for the differences in the observed average values of production under the flood recession, manual and pump irrigation (Table 7.12).

Although higher average values of production were observed for farms located on the raised lowland sites, they do not seem to vary significantly with those derived from the low-lying sites under both the traditional and modern irrigation schemes (Table 7.13).

TABLE 7.13: RESULTS OF T-TEST FOR SITE LOCATION OF FARMS AND AVERAGE VALUES OF PRODUCTION (₦/ha^{-1})

	Irrigation Type					
	Flood recession		Manual		Pump	
	i	ii	i	ii	i	ii
Mean	1821.99	2144.79	2250.85	3093.06	6351.31	7606.48
Std. Error	115.10	654.70	357.71	903.94	690.01	1730.01
T value	-0.42		-1.04		-0.65	
Probability	0.67*		0.30*		0.51*	

* Not significant at the 0.05% level

Key: i = Low-lying sites; ii = Raised lowland sites

Source: Fieldwork, 1990

The lack of significant variation in the average values of farm production under the flood recession, manual and pump irrigation types is due to the lack of significant variation in crop yields between them (Table 7.3). The correlation between crop yields and values of farm production in both the flood recession, manual and pump irrigation is positive, and, hence confirms the a priori expectation (Tables 6.9, 6.10 and 6.11). Under the manual irrigation, for example, the raised lowland farms have higher crop yields (Table 7.3) and higher values of farm production (Table 7.13). The evidence agrees with the a priori expectation of the higher the crop yield, the higher the values of production, all things being equal, as reflected by their positive correlation (Table 6.10).

7.7 NET VALUES OF PRODUCTION

The net values of production were derived from the sale of products and are simply the values of products minus the values of inputs (cost of production). The farmers' dependence on the production of crops that have consumer acceptability was necessary because of the high cost involved in the use of factors of production (Table 7.8). Farmers always indicate their desire to obtain increase in crop yields and attract farm income higher than what they expended in obtaining inputs of production. It was the profit motives in production that made 40.7 per cent of the farmers to obtain the water pumps, as seen in Chapter Two, as a means of obtaining higher crop yields. This is based on the recognition of the efficiency of water pumps in irrigation water application. Investment in terms of purchase of inputs was, therefore, seen in relation to costs and anticipated income that would accrue from production.

The performance under the traditional and modern irrigation, based on the observed mean values of farm production (Table 7.11) was analysed in relation to the mean values of inputs (Table 7.8) to give the mean benefits of production. This was simply done by subtracting the cost farmers expended in obtaining production inputs from the values of production (Appendix 2). The profitability value is often referred to, in this study, as the benefit of farm production (Table 7.14).

TABLE 7.14: AVERAGE FARM PRODUCTION BENEFITS PER FARMER (₦/ha^{-1})

Irrigation Type	Benefits (₦/ha^{-1})	N
Flood recession	918.99	166
Manual	1276.15	50
Pump	3470.82	148

Source: Fieldwork, 1990

As already hinted, because of the problem of estimating the quantities of inputs of production used for specific crop types, which made it difficult to estimate the cost of production per given crop, the total values of inputs were subtracted from the total values of production to give the profitability of irrigation enterprise.

Table 7.14 shows that the pump irrigation was the most profit-effective irrigation in terms of the accrued production benefits, with an average production benefit of ₦3,470.82. None of the flood recession farmers realized up to an average of ₦1,000.00 as farm profit, after the deduction of operational expenses (Table 7.14). The observed average farm production benefits under the three irrigation types were found to vary significantly between them (Table 7.15).

TABLE 7.15: ANALYSIS OF VARIANCE FOR AVERAGE FARM PRODUCTION BENEFITS (₦/ha^{-1})

Source of variation	Degrees of Freedom	Sum of Squares	Mean Squares	F	Probability
Due to irrigation types	2	$5.4E^{10}$	$2.7E^{10}$		
Error	361	$9.5E^{11}$	$2.6E^{9}$	10.20	0.0001**
Total	363	$1.0E^{12}$			

** Significant at the 0.05% level.

Source: Fieldwork, 1990

The relationship between cost of production and farm income under the three irrigation types is measured by the benefit of farm production; that is farm income minus cost of production equals farm production benefit. The results of the analysis of variance in Table 7.15 gives the F-value as 10.20 and is significant at the 0.05% level. We therefore accept the null hypothesis, H_o of independence between cost of production and farm income between the flood recession, manual and pump irrigation. The significant variation in the benefit of farm production is attributed to the significant variation in the cost of production (Table 7.9) and farm income (Table 7.12) between the three irrigation types.

The benefits of farm production realized from the three irrigation types differed according to the physical location of the farms. For example, the raised lowland farms have higher benefits of production than the low-lying farms (Table 7.16), but the variations are not statistically significant within each of the three irrigation types.

The observed variation in the farm production benefit within the three irrigation types is not significant at the 0.05% level (Table 7.16). The conclusion here is that we reject the null hypothesis, H_o of independence between cost of production and farm income within the three irrigation types. The alternative hypothesis, H_1 here is that there is relationship between cost of production and farm income under each of flood recession, manual and pump irrigation. The reason for the relative lack of significant variation in the benefit of farm

TABLE 7.16: RESULTS OF T-TEST FOR SITE LOCATION OF FARMS AND AVERAGE FARM PRODUCTION BENEFITS (₦/ha^{-1})

	Irrigation Type					
	Flood recession		Manual		Pump	
	i	ii	i	ii	i	ii
Mean	916.04	1038.23	1157.90	1650.63	3315.02	4528.58
Std. Error	103.25	607.49	326.30	825.32	695.98	1725.91
T value	-0.18		-0.67		-0.63	
Probability	0.85*		0.51*		0.53*	

*Not significant at the 0.05% level

Key

i = Low-lying sites

ii = Raised lowland sites

Source: Fieldwork, 1990

production within them can be attributed to the lack of significant variation in the cost of production (Table 7.10) and farm income (Table 7.13).

The results of the analysis of variance (Table 7.10) and t-test (Table 7.13) indicate that while the cost of production and farm income seem to vary significantly between the three irrigation management practices, they do not vary significantly for low-lying and raised lowland sites under each irrigation type. Thus while irrigation management practices vary with respect to cost of production and farm income, the different topographic farm sites almost have equal capacity to generate profits when put into irrigation production.

7.8 SUMMARY

The results obtained in this chapter indicate that the pump irrigation has the highest crop yield of 1.84 tonnes per hectare as against 1.69 and 0.34 tonnes per hectare realized in manual and flood recession irrigation respectively. The yields were observed to vary significantly between the irrigation types, but this significant variation is not evident in low-lying and raised lowland sites under each irrigation type.

The production function model of crop yield/inputs reveals that the most important factors that influence crop yields under the flood recession irrigation are, in order of importance, production cost, income and land cultivated. In manual irrigation, factors such as production cost, frequency of irrigation, degree of intercropping, water input and soil moisture retention were observed to determine crop yields. Under the pump irrigation the most important factors that influence crop yields are income, methods of land acquisition, soil moisture retention, frequency of irrigation and intercropping. The financial aspects of irrigation production in terms of production cost and income are by far the most important factors that determine crop yields both in traditional and modern irrigation. Capital base could therefore be a critical factor that affects crop yield generation in irrigation production.

It is established statistically that both cost of production and production benefit are higher in pump irrigation than in flood recession and manual irrigations. Production cost and benefit of farm production vary significantly between the three irrigation types but not significantly for low-lying and riased lowland sites under each irrigation type.

The major findings and conclusions of the study with respect to their implications for planning are highlighted in the next chapter.

CHAPTER EIGHT

SUMMARY OF CONCLUSIONS

8.1 SUMMARY OF FINDINGS

This study has adopted both the ecosystem, production function and utility function approaches to provide the framework for the analysis of the effects of topography on land and water use and secondly to determine the effects of inputs of production on sizes of land cultivated and crop yields under the traditional and mordern irrigation technologies.

The main conclusions of the study are as follows: In manual irrigation site location of farms determines land use but does not determine water use. Under the flood recession and pump irrigation, site location of farms does not determine land use but determines water use. Irrigation farms are located on sites that ensure available water supply and soil moisture resources for crops sustenance, irrespective of land topography. While land use varies significantly, water use does not vary significantly between the three irrigation types. The variations in sizes of land cultivated are such that average size of cultivated land is smallest in the manual irrigation and highest in the pump irrigation. However, the average size of cultivated land was found not to vary significantly for low-lying and raised lowland sites under each irrigation type. The observed average size of irrigated farm in Donga River Basin was found to be greater than the average size of 0.2 hectares for non-irrigated farms thereby confirming what Turner (1984) observed in the fadama lands of North Central Nigeria. The evidence on land use tends to confirm Adam's (1984) observation that individual holdings of land on African irrigation schemes are small in extent and vary in sizes.

Water use per hectare was found not to vary significantly within the flood recession and manual irrigations. Under the pump irrigation, however, water use varies significantly due to the ability of some pump users to lift water to higher levels. The variations in water use are such that the pump irrigation has the highest value of water input, in addition to the larger land use. The evidence shows that water use is associated with land use. The lower volume of water used under the flood recession irrigation is expected because water application is not often done.

Water management strategies are designed to take care of contingencies. For example, water application is done by the flood recession farmers only in an advent of depletion in soil moisture in order to sustain crop growth beyond the level provided by the natural soil moisture conditions. Also water use rotation and excavation of dried river and stream beds are part of the ad hoc strategies designed to ensure the sustainability of water resource use. The resulting problems of land and water use are direct response processes to the physical conditions of the cultivated farm sites.

Both labour use and fertilizer application vary significantly between the three irrigation types. Labour use varies significantly only within the flood recession irrigation while fertilizer application varies significantly within the three irrigation types. As expected the pump irrigation has the highest labour use and fertilizer application with the flood recession irrigation having the least labour use and fertilizer application.

The pump irrigation farmers, who are the higher users of labour and fertilizer inputs, are also the higher users of land and water inputs. The higher use of inputs of production is motivated by the economic need to maximize utility of their farm plots. On the other hand, the flood recession farmers, who are the least users of land and water inputs, are also found to be the least users of labour and fertilizer inputs. The use of low quantities of inputs of production is guided by the need to minimize the loss to investment in an advent of depletion in the unpredictable residual soil moisture, among others.

The high man-days and fertilizer application of the pump irrigation agree with Ruthenberg's (1980) view that modern water management for irrigation is connected with high labour and fertilizer inputs. The evidence, however, contradicts Crosson's (1984) and Doorenbos's (1974) assumption that the use of modern technology saves labour.

Furthermore, it is statistically established that not all factors of production are important in affecting the sizes of land cultivated both under the traditional and modern irrigation farming. Production cost, water input and methods of land acquisition are the only factors that exert significant influence on the sizes of land cultivated under the manual irrigation. Under the pump irrigation production cost, methods of land acquisition, water input and site location of farms appear to exert significant influence on the sizes of land cultivated. Production cost is necessary in irrigation farming for the acquisition and utilization of factors of production.

The productivity of irrigation farming is influenced by the conditions of both the physical resources and the irrigation materials. The variation in crop yield is significant between the three irrigation types but not under each type for farms at different site locations. Crop yield is highest under pump irrigation but lowest under flood recession irrigation. The pump irrigation farmers use highest quantities of inputs of production and has highest crop yields. This implies that high crop yields are associated with high usage of inputs of production, all things being equal. However, the observed crop yields under pump irrigation farming in Donga basin are generally below the world average of nearly 4 tonnes per hectare (Baba, 1984).

The production function model of crop yield/ inputs reveals that the factors determining crop yields under the flood recession irrigation, in order of importance, are production cost, income and land cultivated. Five factors of production namely, production cost, frequency of irrigation, soil moisture retention, water input and months of irrigation are important for crop yield under the manual irrigation. Under the pump irrigation crop yield depends on five factors namely, income, methods of land acquisition, months of irrigation, frequency of irrigation and cropping patterns. Out of the five factors , income exerts the strongest influence on crop yield.

The cost of production in irrigation is determined by the quantities and levels of inputs of production. Production cost varies significantly between the three irrigation types, but does not vary significantly within them. The most favoured irrigation type is the flood recession irrigation with minimal cost of production. The pump irrigation has the highest cost of production because of the higher usage of inputs of production.

The profitability of irrigation farming is influenced by farm productivity and values of production inputs. Farm production benefits are observed to vary significantly between the three irrigation types, but these do not vary significantly within them. The variations in the farm production benefit are such that it is highest in the pump irrigation and lowest in the flood recession irrigation. The pump irrigation has the highest farm production benefit because it has the highest crop yields, resulting from the higher utilization of quantities and amounts of inputs of production, among others. Also significant variations in farm production benefit between the three irrigation types are attributed to the significant variations in the cost of production, crop yields and farm income between them. On the other hand, the lack of significant variations in farm production benefits within the three irrigation types is attributed to the lack of significant variations in production cost and farm income within them.

Shortages of fuel, risk of mechanical breakdown and lack of spare parts, and mechanics to repair pumps are the major limitations of the pump irrigation. The major barriers limiting the expansion of cultivated land, and, hence yield and income of the traditional flood recession and manual irrigation farming are the depletion in the unpredictable soil moisture resources and the heavy nature of buckets which are manually lifted respectively.

8.2 THEORETICAL IMPLICATIONS OF THE STUDY

The combined operation of the effects of site location, relationships between inputs and output and the degree of usefulness of a given enterprise to the farmer is in agreement with the findings of quite a number of previous studies in the area of agricultural productivity. Therefore, this study is an extension of our existing knowledge of the functional relationships between the various processes involved in irrigation production. The theory that the physical environment controls agricultural productivity implies that the technique of management depends upon the ecological characteristics of the chosen sites.

The production function approach has been of tremendous value in estimating the effects of inputs of production on crop yields as an indication of possible causality. The approach facilitates the appraisal of farmers' resource allocation decision affecting farm production and is necessary for predictions about relationship between input-output of production. The empirical evidence established in this study suggests that irrigated agricultural output is a function of a combination of some inputs of production rather than all the observed factors of production. This means that output of farm production could not simply be defined on the basis of the relationship with the observed inputs of production alone.

In addition, the utility function approach to irrigation production is of relevance to the study of farm productivity. For instance, the approach has provided valuable information concerning the basis on which peasant farmers allocate resources of production, as against conceived notions of purely profit maximization. Farmers are limited by funds to invest and as such their production objective is to maximize the utility of their farm plots. The decision on yield maximization influences his selection of the type and intensities of land use and type of quantities of inputs to be used, among others. For the traditional irrigation whose production cost positively correlates with crop yields, it can be concluded that the traditional irrigation management practices meet farmers' production objectives.

The importance of the ecosystem in influencing agricultural productivity under irrigation regime is enormous, and this tends to have limitations to future expansion of irrigation farming. The availability of the ecological resources, such as the residual soil moisture and water sources are necessary for the sustainability and expansion of irrigation production in the area. These resources are in short supply and this has been the major threat to sustainable irrigation.

The reliance on mostly rivers, streams and residual soil moisture makes irrigation practice generally rigid, and, hence susceptible to vagaries of weather. Thus, farmers have little control over their ecological conditions in which they work and this is a hallmark of unsustainable development. There are other numerous problems; technical due to breakdown of irrigation materials and agronomic due to menace of pests. Both the ecological and technical limitations to irrigation development are worthy of consideration by policy makers interested in promoting irrigation development.

With the adoption and use of modern inputs, especially the expensive water pumps and chemical fertilizers, farmers have moved essentially into the market economy. Market incentives, especially credit facilities and price incentives (guaranteed price), as in the case of wheat production, would assume some importance in the production programme of farmers. Farmers are constrained by funds, as reflected by their inability to sink wells, washbores and tubewells, to exploit the vast underground water resources to supplement surface water sources and thereby limiting the size they would have otherwise cultivated.

8.3 CONTRIBUTIONS TO IRRIGATION PLANNING

The most important lesson from the findings of this study is that it would be futile for us to expect higher productivity of crops, and, hence higher income in irrigation cultivation. According to present trends, crops cannot be grown throughout the dry season due to lack of adequate water, and this is a major constraint to crop production and sustainability. In order to enhance the income of farmers, it is therefore necessary to drill tubewells and washbores to increase sources of water to farmers, thus increasing their water utilization rates. Where fuel and spare parts are not assured,simple manually operated water pumps (hand pumps) should be provided in place of petrol - water pumps.

Also the low contribution of other factors of production is a major constraint to crop production and income generation to farmers. More use should be made of inputs of production in order to shift their production function and utility upward. This therefore implies the need for an effective access to credit facilities at reasonable interest rates to farmers to enable them increase their level of input use. Thus, to ensure improved irrigation production, economic incentives, among others, should be superimposed on the physical ones.

Furthermore, in countries where there is shortage of foreign exchange, like Nigeria, care must be taken to avoid technical solution, like the use of water pump that relies on imports of equipment and of spare parts. Simple low-cost development programmes, such as fadama rehabilitation, that ensures sustained and continuous use of water and soil moisture resources for crop production can be undertaken. Floodplain rehabilitation re-establishes the natural flooding pattern and involves the opening and improvement of natural water courses to carry water into suitable floodplain sites. This would lead us to the development of an appropriate approach to irrigation development, and, hence more lasting and sustainable irrigation culture.

The specific issue arising from the present study concerns the estimate of inputs of production used per crop type in multicropping system, as a necessary condition for measuring productivity of specific crop types. There is need for further research on this important methodological issue of productivity of individual crop types.

Furthermore, the recommended fadama rehabilitation should be preceded by research into their environmental and socio-economic implications. This will likely prevent them from becoming another sources of problem, like the existing modern irrigation schemes in Nigeria and other developing countries.

8.4 CONCLUSION

Irrigated agriculture is important in the Donga River Basin and other parts of Nigerian savanna environment because of the low rainfall that restricts cultivation to one cropping season each year. Also the relevance of irrigation cultivation lies on the presence of the numerous terraces and fadama lands that created suitable irrigation conditions.

Irrigation is generally needed to provide water for year-round agricultural production to satisfy some of the national aims and objectives of agricultural development which include: the achievement of national economic efficiency, amelioration of drought damage and stabilization of agricultural output, and more importantly the modernization of the rural economy.

The pressure of survival and the need for additional food supplies demand that we should endeavour to face real issues of irrigation development. The issues of agricultural productivity of irrigation raised in this study are important and must therefore be complied with if we are to seriously tackle the problem of irrigated agriculture in the area and indeed in Nigeria as a whole. Any attempt to neglect these essential issues equals futility in our agricultural policies, similar to those started since the colonial times.

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APPENDIX I

QUESTIONNAIRE

A COMPARATIVE ANALYSIS OF TRADITIONAL AND MODERN SYSTEMS OF IRRIGATED AGRICULTURE IN THE DONGA RIVER BASIN, GONGOLA STATE.

Ph.D RESEARCH QUESTIONNAIRE

1. (a) Code number ____________ (b) Scheme location _____

   (c) Plot location (topography) ____________________

   (d) Plot orientation (natural gradient) ______________

   (e) Size of basins (layout) ______________________

   (f) Size of water conveyance channel _______________

2. Type of irrigation systems: (a) Traditional

   (i) Shaduf/bucket

   (ii) Flood recession

   (b) Modern (i) Pump

3. Cost of irrigation materials: (a) Shaduf/bucket

   (b) Engine pumps

4. Literacy level: (i) Primary; (ii) Post-primary; (iii) Adult education; (iv) Others (specify) _________

5. Family size ________________________

6. Occupation: (i) Main _______________

   (ii) Others (specify) _____________

7. Years involved in irrigation ____________________

8. Since you started irrigation, have you ever stopped?

   (i) Yes

   (ii) No

9. Who introduced you to the culture of irrigation?

   ____

10. Which month in the year do you start irrigation? _____

11. How many times do your irrigation materials break down in a week? (i) Shaduf/bucket

    (ii) Pumps

12. a. Is there any problem with reparis? (i) Yes; (ii) No

    b. If Yes, explain the nature of the problem __________

    c. Who repairs the materials for you? _________________

    d. Where is he from? ____________________________________

    e. About how much do you spend in repairs this season? _____________________

13. a. Source of petrol _________ (b) Cost of petrol _______

    c. How often do you get petrol? _________________________

14. a. Means of land acquisition: (i) Inherited

    (ii) Rented; (iii) Leasehold; (iv) Pledged

    (v) Bought; (vi) Freehold; (iv) Others (specify) _____

b. Cost of land if; ii, iii and v above ___________

c. Size of land owned _______ (d) Size cultivated _____

e. Are the plots found in different locations?

(i) Yes

(ii) No

15. How much land do you think you need to engage in profitable irrigation? ______________________________

16. a. Who prepares your land?

(i) Yourself (ii) UBRBDA (ii) GAMA (iv) GADP

b. Reasons for the above ____________________________

c. Cost of land preparation ___________________________

17. a. Have you ever sold any or a part of your plots this season? (i) Yes (ii) No

b. Reasons for the above ____________________________

18. a. Do you own upland plot? (i) Yes (ii) No

b. Reasons for the above ____________________________

c. Size of the upland plot __________________________

19. a. Nature of land problem ____________________________

b. How is the problem solved _________________________

20. a. Major problems of land tenure in the area ________

b. How do the problems affect your irrigation practice? ____

c. How are the problems solved? _____________________

21. a. Do you fence your plots (i) Yes (ii) No

Reasons for above ______________________________

____

22. What is your main crop(s)? ________ Subsidiary ________

b. Why do you choose them as your main crops? ________

____

23. Source and cost of seedlings

Seeds	Sources	Cost
1.		
2.		
3.		
4.		
5.		

24. Source of irrigation water (i) Dug pit; (ii) residual moisture (iii) natural depressions (iv) river channel (v) Sprinkler (vi) Others (specify) ____________________

b. How many people use the source this season? __________

c. Any reason ____

d. Are all users from one family? (i) Yes (ii) No

e. If No, specify ____________________________________

25. Do you use the source of water by rotation

(i) Yes (ii) No

b. Give reasons for the above ____________________

26. In case of dug pit, how is the digging done: (i) Family labour (ii) jointly by the users (iii) Others (specify) ______________________________

b. Cost of digging in case of hired labour ________

27. Frequency of clearing/maintaining your source of water? (i) Everyday (ii) Weekly (iii) Monthly (iv) As the water level goes down (v) Others (specify) ______

____

28. Do you have any knowledge of the amount of irrigated water you used? (i) Yes (ii) No

(b) Give reasons ____________________________

29. How do you determine when to apply water?

(i) appearance of crop (ii) appearance of the soil

(iii) any day you feel like irrigating

(iv) Others (specify) __________________________

30. Volume of calabash/bucket, in litres (to be measured)

_____________________ (b) Frequency of irrigation on cro

Crops	Hours of irrigation/day	No. of irrigation/week
(i)		
(ii)		
(iii)		
(iv)		
(v)		

31. Approximate distance between irrigated plot and source of irrigation water (in metres) ___________

b. Is the distance satisfactory (i) Yes (ii) No

c. Give reasons _______________________________________

32. Problems of irrigation water supply components

Components	Problems	Solutions
Source of water		
Field channels		
Field basins		
Shaduf/buckets		
Pumps		

b. What is the interval in the occurrence of the problems above?

c. How frequent do you maintain your field channels and basins?

33. How do you dispose of drainage water?

b. Who manages the source of water for you?

(i) UBRDA (ii) GADP (iii) Yourself

(iv) Committee of farmers

c. What is your assessment of irrigation water supply?

(i) V/Good (ii) Good (iii) Satisfactory

(iv) Poor (v) V/Poor

d. Give reasons ______________________________

____

34. Labour input

Labour categories	Size of labour	No. of days and hours worked/week Mon. Tues. Wed. Thur. Fri. Sat.
Family: Male adult Female adult Children		
Hired: Male adult Female adult		

b. Cost of hired labour ₦ ____________________

c. What type of work do hired workers do for you?

(i) Land preparation (ii) Planting (iii) Weeding

(iv) Water application (v) Harvesting

35. Means of soil fertility maintenance

(i) Manure (ii) Chemical fertilizers (iii) Both

b. Give reasons for the above ____________________

c. Manure (source) ____________________

(i) Distance between source and farm

(ii) Mode and cost of transport

(iii) Number and cost of bags used

(iv) Type of crops used on

d. Chemical fertilizer (source)

(i) Number and cost of bags used

(ii) Distance from the source

(iii) Mode and cost of transport

(iv) Type of crops used on

e. Assessment of fertilizer supply: (i) V/Good

(ii) Good (iii) Fair (iv) Poor (v) V/Poor

f. Give reasons ____________________

36. Source of investment capital: (i) Personal (ii) Locål money lender: (iii) Fellow farmer (iv) Bank (v) Relatives (vi) Government (vii) Others (specify) ________________________

a. If it is loan, how much is the amount? ________

b. Is the amount adequate? (i) Yes (ii) No

d. Give reasons ________________________

37. Do you practice inter-cropping? (i) Yes (ii) No

b. Which crops do you inter-cropped? ____________

c. Give reasons ________________________

38. Quantity of irrigated crops produced this season

Crops	Qty. (bags/sacks)
1.	
2.	
3.	
4.	
5.	

39. How do you dispose of your harvests?

(i) Family consumption (ii) Sale (iii) Both

(iv) Others (specify) ________________________

b. If they are sold, to whom? (i) Middlemen

(ii) Cooperative Society (iii) Local market

(iv) Government agents (UBRBDA/GADP)

(v) Others (specify) ______________________

c. How much do you realise from the sale? ________

d. How much of the quantities do you consume locally ______________________________

e. Assessment of market situation: (i) V/Good

(ii) Good (iii) Fair (iv) Poor (v) V/Poor

f. Give reasons ____________________________

40. Means and cost of transporting products to home and markets/bags? (i) Head porterage (ii) Bicycle (iii) Motor cycle (iv) Vehicle (v) Hired labour (vi) Drought Animal

b. Problems of transporting harvest home and to the markets ______________________________

41. Can you recommend your main crops to be irrigated in the area? (i) Yes (ii) No

b. Give reasons __________________________

c. Is traditional/modern irrigation a profitable enterprise? (i) Yes (ii) No

d. Give reasons __________________________________

42. Which of these agencies operate in this area?

(i) UBRDA (ii) GADP (iii) MANR (iv) GAMA

(v) Others (specify) ____________________

b. What kind of help do you get from them? ______

____

43. Approximate distance between your home and farm

____

44. State as many as you can problems of traditional/ Modern irrigation practice in this area generally

____

b. How can these problems above be solved? ______

____

45. What comments or suggestions do you have for improving on traditional/modern irrigation practice in this area? ____________________________________

____

Dalhatu Umaru Sangari

Date: ______________

APPENDIX 2

VARIABLES OF IRRIGATION PRODUCTION BY SAMPLES

Samples	Land Owned (Hectares)	Land Cultivated (Hectares)	Ratios of Land Owned & Cultivated	Water (Volume/ ha^{-1})	Labour (Man-Days/ ha^{-1})	Fertilizer (K9/ ha^{-1})	Yield (Tonnes/ ha^{-1})	Values of Inputs/ ha^{-1}	Values of Produdcts/ ha^{-1} (N)	Farm Benefits/ ha^{-1} (N).
MANUAL IRRIGATION										
8	2.8	0.8	0.29	4500	27.00	125.00	0.21	851.25	2125.00	1273.75
10	2.8	1.6	0.57	22500	22.50	62.50	0.19	589.38	1859.40	1270.02
15	2.4	0.6	0.25	90000	36.00	166.67	0.02	1173.33	12000.00	10826.67
23	0.4	0.4	1.00	135000	63.00	250.00	0.20	1387.50	1600.00	212.50
25	0.4	0.4	1.00	59760	126.00	250.00	10.54	2112.50	6700.00	212.50
26	0.4	0.4	1.00	89640	210.00	500.00	5.79	3732.50	4400.00	667.50
33	2.4	0.4	0.17	179280	48.00	250.00	0.20	2212.50	500.00	-1712.50
42	0.8	0.8	1.00	90000	83.75	62.50	0.44	933.30	875.00	-58.75
43	0.2	0.2	1.00	450000	360.00	250.00	7.82	2835.00	1900.00	-935.00
44	0.4	0.4	1.00	315000	126.00	125.00	0.85	967.50	650.00	-317.50
45	0.6	0.6	1.00	210000	252.00	83.33	1.93	806.67	933.30	126.63
48	1.6	1.6	1.00	67500	52.50	31.25	0.85	478.13	650.00	171.87
58	1.2	1.2	1.00	112500	112.00	208.33	0.65	1354.17	1416.70	445.87

60	0.4	0.4	1.00	180000	72.00	125.00	5.29	1462.50	3200.00	1737.50
73	0.4	1.2	0.50	45000	168.00	208.33	4.43	1354.17	3400.00	2045.83
85	0.8	0.8	1.00	1440	63.00	125.00	0.40	873.75	375.00	-498.75
86	1.2	1.2	1.00	12600	42.00	41.67	1.67	769.17	966.70	197.53
92	0.4	0.4	1.00	54000	63.00	62.50	0.02	792.50	900.00	107.50
98	0.6	0.6	1.00	65000	70.00	0.00	0.50	813.33	566.70	-246.63
110	12.0	0.2	0.02	5040	144.00	250.00	0.29	2145.00	5750.00	3605.00
111	6.0	0.4	0.07	4033	72.00	0.00	0.17	895.00	3750.00	2855.00
114	12.0	0.6	0.05	253	120.00	250.00	2.07	903.33	1000.00	96.67
146	12.0	0.2	0.02	5040	144.00	250.00	0.29	2145.00	5750.00	3605.00
166	4.8	0.4	0.08	180000	65.00	0.00	0.85	872.50	400.00	-472.50
169	2.0	0.8	0.40	315000	63.00	62.50	0.02	862.50	575.00	-287.50
176	4.1	0.4	0.10	180000	70.00	125.00	0.04	867.50	1750.00	882.50
200	2.0	0.4	0.20	315000	216.00	125.00	0.23	1060.00	2375.00	1315.00
207	12.0	0.8	0.07	112500	84.00	125.00	0.38	1192.50	3000.00	1807.50
221	2.0	0.8	0.40	56250	42.00	62.00	0.04	687.50	950.00	262.50
236	6.0	0.8	0.13	78750	126.00	62.00	0.05	956.25	900.00	-56.25
239	2.0	0.2	0.10	450000	336.00	250.00	0.06	2035.00	2100.00	65.00
244	2.0	0.4	0.20	315000	144.00	375.00	0.20	1195.00	2750.00	1555.50

247	2.0	0.4	0 20	315000	108 00	125.00	0.04	1032 50	750 00	-282.50
250	2.0	0.8	0.40	225000	144.00	62.50	0.16	746 25	1718 80	972.55
251	2 0	0.4	0 20	630000	216.00	250.00	0.33	1517 50	3437 50	1920.00
252	5.0	0.8	0.16	112500	144.00	125.00	0.40	841 25	2750.00	1908.75
276	2 0	0.4	0 20	675000	288.00	125.00	0.20	1117 50	1250.00	132.50
283	6.0	1.2	0 20	90000	75.58	83.33	0.50	754.17	600.00	-154.17
285	6.0	0.8	0.13	90000	220.50	62.50	0.07	800.50	2400.00	1600.00
286	2.0	0.8	0.40	157500	287.50	125.00	0.16	721.25	1718.80	997.55
299	0.4	0.4	1.00	59760	126.00	250.00	10.54	2112.50	6700.00	4587.50
315	2.0	0.8	0.40	422100	115.20	125.00	1.89	703.75	1718.80	1015.05
321	2.0	0.8	0.40	315000	144.00	187.50	0.21	886.25	2250.00	1363.75
322	2.0	0.8	0.40	202500	120.00	187.50	0.15	923.75	1587.50	663.75
327	2.0	0.4	0.20	504000	384.00	125.00	0.25	1087.50	2800.00	1712.50
328	2.0	0.8	0.40	252000	192.00	125.00	0.11	497.50	1125.00	627.50
330	2.0	0.8	0.40	202500	168.00	62.50	0.08	470.00	500.00	30.00
338	0.8	0.8	1.00	141750	126.00	125.00	0.73	1038.75	875.00	-163.75
342	15.0	1.0	0.07	289.44	201.60	0.00	3.86	595.00	3450.00	2855.00
346	0 6	0.4	0 67	1440	336.00	0.00	18.18	2062.50	10950.00	8887.50

MIN. VALUES	0.20	0.20	0.20	253.33	22.50	31.25	0.02	470.00	375.00	-1712.50
MIN. VALUES	15.00	1.60	1.00	675000.00	384.00	500.00	18.18	3732.50	12000.00	10826.67
MEAN VALUES	3.14	0.66	0.49	172021.60	140.33	155.79	1.69	1176.83	2452.98	1276.15
STD. DEVIATION	3.57	0.33	0.38	165580.31	91.23	94.69	3.46	651.94	2450.46	2221.54
STD. ERROR OF MEAN	0.51	0.05	0.05	23654.33	12.90	14.12	0.49	92.20	346.55	314.17
C.V.	113.7	50.6	77.8	94.3	65.0	60.8	205.1	55.4	99.9	174.1

FLOOD RECESSION IRRIGATION

5	0.4	0.4	1.00	0	168.00	125.00	0.23	895.00	2125.00	1230.00
7	8.0	1.2	0.15	0	105.00	1250.00	0.28	2920.83	2833.33	-87.50
9	4.0	0.8	0.20	45000	14.40	125.00	0.36	1166.25	3612.50	2446.25
12	12.0	1.6	0.13	0	207.00	62.50	0.13	616.25	1325.13	708.88
17	0.8	0.8	1.00	0	315.00	125.00	0.16	737.50	1593.75	856.25
18	2.0	2.0	1.00	63000	126.00	75.00	0.05	1315.00	4000.00	2685.00
28	5.2	2.0	0.38	0	63.00	150.00	0.85	1175.00	850.00	-325.00
31	2.0	1.6	0.80	0	123.38	156.25	0.34	1325.00	800.00	-525.00
36	4.0	4.0	1.00	0	37.80	50.00	0.98	692.50	977.50	285.00
37	1.6	1.6	1.00	0	78.75	62.50	0.63	1120.00	556.25	-563.75
38	3.6	1.6	0.44	0	78.75	125.00	0.16	630.00	1593.75	963.75
39	1.2	1.2	1.00	0	84.00	125.00	0.58	825.83	566.67	-259.16

40	3.6	1.2	0.33	0	63.00	41.67	0.15	766.67	1487.50	720.83
46	1.2	1.2	1.00	0	30.00	41.67	0.18	416.67	1841.67	1425.00
49	2.0	2.0	1.00	0	48.00	100.00	0.17	679.00	1700.00	1021.00
50	0.8	0.8	1.00	0	45.00	187.50	0.76	793.75	437.50	-356.25
51	2.0	2.0	1.00	0	36.00	25.00	0.21	666.00	2257.50	15915.00
52	1.6	1.6	1.00	56250	37.50	125.00	0.38	512.50	593.75	81.25
53	0.8	0.8	1.00	0	63.00	62.50	0.33	836.25	418.75	-417.50
54	0.2	0.2	1.00	0	144.00	250.00	0.20	2025.00	2125.00	100.00
55	0.8	0.8	1.00	0	54.00	125.00	0.59	995.00	1425.00	430.00
56	1.6	1.6	1.00	0	90.00	31.25	0.28	587.50	562.50	-25.00
59	2.4	2.4	1.00	0	50.00	166.67	0.18	891.67	1841.67	923.00
65	1.6	1.6	1.00	0	101.25	93.75	0.56	903.00	531.25	-371.75
66	1.6	1.6	1.00	0	90.00	93.75	0.63	910.00	637.50	-272.50
67	1.2	1.2	1.00	0	98.00	125.00	0.67	971.67	637.50	-334.17
68	1.6	1.6	1.00	0	105.00	125.00	0.20	1098.75	2018.75	920.00
69	2.8	2.0	0.71	0	105.00	125.00	0.27	1310.00	2635.00	1325.00
75	0.8	0.8	1.00	0	45.00	187.50	0.76	748.75	1187.50	438.75
76	8.0	1.2	0.15	0	105.00	1250.00	0.28	2920.83	2833.33	-87.50
79	0.8	0.8	1.00	0	210.00	125.00	0.02	856.25	1500.00	643.75

80	1.6	1.6	1.00	0	85.50	93.75	1.38	893.75	543.75	-350.00
81	2.4	2.4	1.00	0	56.00	104.17	0.17	722.92	1700.00	977.08
82	2.0	2.0	1.00	0	19.80	75.00	0.19	689.50	1870.00	1180.50
83	2.0	0.5	0.25	0	193.20	500.00	0.74	3680.00	7310.00	3630.00
84	0.4	0.4	1.00	0	36.00	62.50	0.03	792.50	500.00	-292.50
87	1.2	1.2	1.00	0	144.00	166.67	0.22	906.67	2125.00	1218.33
88	1.6	1.6	1.00	0	78.75	93.75	0.16	806.25	1593.75	787.50
89	0.4	0.4	1.00	0	36.50	125.00	0.75	820.00	850.00	30.00
90	0.8	0.8	1.00	0	93.00	125.00	0.75	805.00	743.75	-61.25
91	2.4	2.4	1.00	0	72.00	104.17	0.16	785.42	1629.17	843.75
93	1.2	1.2	1.00	0	78.00	83.33	0.42	734.17	425.00	-309.17
94	0.8	0.8	1.00	0	79.50	62.50	0.13	865.00	1275.00	410.00
95	2.4	2.4	1.00	0	50.00	83.33	0.13	690.83	1275.00	584.17
96	2.0	2.0	1.00	0	108.00	100.00	0.45	691.00	467.50	-223.50
97	1.2	1.2	1.00	0	72.00	166.67	0.16	881.67	1558.33	676.66
98	0.8	0.8	1.00	0	90.00	125.00	0.38	895.00	425.00	-470.00
100	0.8	0.8	1.00	0	22.50	125.00	0.30	1217.50	2975.00	1757.50
101	1.6	1.6	1.00	0	73.50	93.75	0.17	690.00	1700.00	1010.00
102	0.8	0.8	1.00	0	105.00	125.00	0.19	1055.00	1912.50	857.50

103	2.8	2.8	1.00	0	65.14	89.29	0.23	810.71	2276.79	1466.08
108	1.6	1.6	1.00	0	32.25	93.75	0.17	722.50	1700.00	977.50
109	2.0	2.0	1.00	0	63.00	75.00	0.20	677.50	850.00	172.50
112	9.2	0.2	0.02	0	504.00	250.00	0.17	1475.00	2275.00	800.00
119	1.6	1.6	1.00	0	83.75	156.25	0.18	1025.00	1859.38	834.38
120	4.0	2.4	0.60	0	43.75	104.17	0.23	1020.83	2302.10	1281.27
145	4.0	2.4	0.60	22500	119.42	208.00	0.14	3154.17	10000.00	6845.83
147	0.8	0.8	1.00	0	210.00	125.00	0.03	856.25	1500.00	643.75
148	0.8	0.8	1.00	0	79.50	62.50	0.13	865.00	1275.00	410.00
149	0.8	0.8	1.00	0	105.00	125.00	0.88	1055.00	1912.50	857.50
150	2.0	2.0	1.00	0	126.00	50.00	0.04	1315.00	4000.00	2685.00
151	1.2	1.2	1.00	0	144.00	166.67	0.22	906.67	2125.00	1218.33
152	2.4	2.4	1.00	0	50.00	83.33	0.18	816.67	1841.70	1025.03
153	0.8	0.8	1.00	0	93.00	125.00	0.75	805.00	743.80	-61.20
154	1.6	1.6	1.00	0	90.00	62.50	0.63	883.75	637.50	-252.25
156	1.2	1.2	1.00	0	72.00	166.67	0.16	881.67	1558.30	676.63
158	3.2	0.4	0.13	0	72.00	125.00	0.25	970.00	2550.00	1580.00
161	4.0	0.4	0.10	0	45.00	0.00	0.13	675.00	1275.00	600.00
164	4.4	0.4	0.09	0	67.20	0.00	0.75	690.00	850.00	160.00

165	5.6	0.8	0.14	0	36.00	62.50	0.12	650.00	1062.50	412.50
170	0.8	0.8	1.00	0	31.50	125.00	0.15	552.50	1487.50	935.00
172	4.0	1.2	0.30	0	84.00	83.33	0.14	848.33	1416.70	568.37
173	4.8	2.8	0.58	102857	42.00	71.43	2.30	1048.21	1114.30	66.09
174	4.0	0.8	0.20	0	63.00	0.00	0.75	905.00	743.80	-159.20
178	2.4	0.4	0.17	0	60.00	62.50	0.13	830.00	1275.00	445.00
179	2.4	0.4	0.17	0	90.00	0.00	0.15	1025.00	1487.50	462.50
180	2.0	0.8	0.40	0	30.00	125.00	0.11	1142.50	1062.50	-80.00
182	1.6	0.8	0.50	0	28.75	187.50	0.11	713.75	9568.80	8855.05
183	1.2	0.4	0.33	0	43.25	125.00	0.10	980.00	1062.50	82.50
185	2.0	0.8	0.40	0	31.50	62.50	0.13	518.75	1275.00	756.25
186	0.8	0.4	0.25	0	45.00	125.00	0.13	655.00	1275.00	620.00
187	1.6	0.4	0.25	0	54.00	125.00	0.10	817.50	1062.50	245.00
188	1.2	0.8	0.67	0	60.00	0.00	0.75	425.00	743.80	318.80
189	2.0	0.4	0.20	0	54.00	125.00	0.33	1055.00	3187.50	2132.50
192	2.0	1.0	0.50	0	72.00	100.00	0.21	639.00	2125.00	1486.00
193	1.2	0.4	0.33	0	54.00	125.00	0.18	742.50	1700.00	957.50
196	2.0	0.8	0.40	0	72.00	1262.50	0.16	530.00	1593.80	1063.80
197	2.0	0.4	0.20	0	54.00	125.00	0.13	855.00	1275.00	420.00

198	2.4	1.6	0.67	0	54.00	93.75	0.19	629.38	1859.40	1230.02
199	2.0	0.4	0.20	0	54.00	125.00	0.15	1972.50	1487.50	-485.00
201	1.6	0.4	0.25	0	108.50	62.50	0.10	672.50	1062.50	390.00
202	2.0	0.4	0.25	0	27.00	187.50	0.16	727.50	1593.80	866.30
203	4.0	0.8	0.40	0	45.00	62.50	0.10	741.25	956.30	215.05
204	1.6	0.4	0.25	0	54.00	125.00	0.23	832.50	2125.00	1292.50
205	2.0	0.8	0.40	0	36.00	62.50	0.13	577.50	1275.00	699.50
206	2.8	0.4	0.14	0	162.00	125.00	0.23	1042.50	2125.00	1082.50
208	2.8	0.8	0.29	0	95.50	125.00	0.21	1156.25	2125.00	968.75
209	4.0	1.2	0.30	0	120.00	166.67	0.23	890.00	2266.70	1376.70
213	0.8	0.8	1.00	0	63.00	125.00	0.04	806.25	1381.30	575.05
214	0.4	0.4	1.00	0	63.00	125.00	0.75	662.50	850.00	187.50
215	2.0	0.8	0.40	0	63.00	62.50	0.15	537.50	1487.50	950.00
216	2.0	2.0	0.10	0	252.00	125.00	0.15	1050.00	1275.00	225.00
217	0.8	0.8	1.00	0	52.50	62.50	0.18	731.25	1700.00	968.75
218	2.0	1.2	0.60	0	90.00	83.33	0.17	635.83	1770.80	1134.97
219	0.4	0.4	1.00	0	72.00	125.00	0.15	1087.50	1487.50	400.00
220	2.4	1.2	0.50	0	90.00	83.33	0.15	758.33	1487.50	729.17
223	6.0	0.8	0.13	0	105.00	125.00	0.63	556.25	637.50	81.25

224	6.0	0.8	0.13	0	189.00	62.50	0.19	906.25	1806.30	900.05
225	2.0	0.8	0.40	0	126.00	62.50	0.11	643.75	1168.80	525.05
226	1.6	1.6	1.00	0	67.50	125.00	0.19	673.75	1859.40	1185.65
228	6.0	0.8	0.13	0	72.00	62.50	0.13	783.75	1859.40	1185.65
229	2.0	0.8	0.40	0	54.00	62.50	0.11	692.50	1062.50	370.00
232	2.0	0.4	0.20	0	72.00	125.00	0.15	1060.00	1487.50	427.50
233	2.0	0.4	0.20	0	90.00	250.00	0.20	1197.50	1912.50	715.00
234	2.0	0.8	0.40	0	108.00	187.50	0.18	740.00	1700.00	760.00
235	2.0	0.4	0.20	0	108.00	125.00	0.33	1310.00	3437.50	2127.50
241	5.2	2.0	0.38	0	67.20	50.00	0.16	582.00	1930.00	1348.00
242	5.2	2.0	0.38	0	63.00	62.50	0.16	433.75	1593.75	1160.00
243	6.0	0.4	0.07	0	54.00	125.00	0.35	910.00	3400.00	2490.00
249	2.0	0.4	0.20	0	144.00	250.00	0.10	1070.00	1062.50	-7.50
258	0.8	0.8	1.00	0	90.00	125.00	0.88	780.00	8500.00	7720.00
261	5.2	1.6	0.31	0	63.00	93.75	0.16	566.25	1593.75	1027.50
262	6.0	1.6	0.27	0	84.00	62.50	0.29	480.63	2921.88	24441.25
264	5.6	2.4	0.43	0	252.00	62.50	0.18	585.42	2020.83	1435.41
271	2.0	0.4	0.20	0	84.00	125.00	0.18	1097.50	1700.00	602.50
270	2.0	0.4	0.20	0	90.00	125.00	0.33	1242.50	1387.50	1953.00
277	6.0	1.6	0.27	0	94.50	93.75	0.16	731.25	1540.63	809.38

278	2.0	0.8	0.40	0	126.00	62.50	0.08	651.25	743.75	92.50
280	6.0	1.2	0.20	0	168.00	83.33	0.83	718.33	850.00	131.67
281	6.4	0.8	0.13	0	157.50	62.50	0.19	626.25	1912.50	1286.25
282	6.0	0.8	0.13	0	157.50	125.00	0.25	743.75	2550.00	1806.25
287	1.6	0.4	0.25	0	84.00	0.00	0.13	675.00	1275.00	600.00
288	0.8	0.8	1.00	0	105.00	62.50	1.50	571.25	1275.00	703.75
291	2.0	2.0	1.00	0	63.00	75.00	0.20	677.50	850.00	172.50
292	1.2	0.4	0.33	0	54.00	125.00	0.18	742.50	1700.00	957.50
293	0.8	0.8	1.00	0	63.00	125.00	0.20	806.25	1381.25	575.00
296	1.6	0.4	0.25	0	54.00	125.00	0.23	832.50	2125.00	1292.50
297	1.6	1.6	1.00	0	78.75	93.75	0.16	806.25	1593.75	787.50
301	0.8	0.8	1.00	0	105.00	62.50	1.51	1133.75	1277.50	143.75
302	0.4	0.4	1.00	0	168.00	125.00	0.23	895.00	2125.00	1230.00
303	1.6	1.6	1.00	0	78.75	62.50	0.63	1120.00	556.25	-563.75
308	3.2	0.4	0.13	0	72.00	125.00	0.25	970.00	2550.00	1580.00
309	1.6	1.6	1.00	0	90.00	93.75	0.63	910.00	637.50	-272.50
310	2.4	2.4	1.00	0	60.00	62.50	0.42	706.67	1629.17	922.50
312	1.6	0.4	0.25	0	84.00	0.00	0.13	675.00	1275.00	600.00
314	2.0	0.4	0.20	630000	283.00	250.00	0.10	1107.50	2312.50	1205.00

316	2.0	0.8	0.40	36000	252.00	187.50	0.19	658.75	2287.50	1628.75
318	2.0	0.8	0.40	0	72.00	187.50	0.15	852.50	1825.00	972.50
319	2.0	0.8	0.40	0	105.00	125.00	0.11	621.25	1187.50	566.25
324	0.8	0.8	1.00	126000	130.00	125.00	3.81	4750.00	3750.00	-1000.00
326	2.0	0.8	0.40	0	168.00	62.50	0.15	1182.50	1612.50	430.00
329	2.0	0.8	0.40	0	168.00	125.00	0.63	411.25	712.50	301.25
331	2.0	0.4	0.20	0	336.00	125.00	0.50	735.00	4887.50	4152.50
332	2.0	0.4	0.20	0	288.00	125.00	0.53	760.00	5312.50	4552.50
334	2.0	0.8	0.40	0	144.00	62.50	0.16	536.25	1593.75	1057.50
335	2.0	0.4	0.20	0	288.00	125.00	0.43	1210.00	4250.00	3040.00
337	0.4	0.4	1.00	0	336.00	250.00	0.53	1300.00	5312.50	4012.50
344	4.4	4.0	0.91	0	21.60	37.50	0.43	158.25	425.00	266.75
345	1.6	1.6	1.00	0	72.00	0.00	0.17	565.63	1700.00	1134.32
351	2.0	0.8	0.40	0	168.00	62.50	0.15	1182.50	1612.50	430.00
352	2.0	1.2	0.60	0	60.00	83.33	0.14	520.00	1416.67	896.67
356	4.0	1.2	0.30	0	84.00	83.33	0.11	848.33	1062.50	214.17
359	1.6	1.6	1.00	0	72.00	0.00	0.75	565.63	743.75	178.12
360	0.4	0.4	1.00	0	336.00	250.00	0.53	1300.00	5312.50	4012.50
362	4.0	0.4	0.10	0	45.00	0.00	0.18	725.00	1700.00	975.00
363	1.2	1.2	1.00	0	98.00	125.00	0.67	971.67	637.50	-334.17

MIN. VALUES	0.20	0.20	0.02	22500.00	14.40	25.00	0.02	158.[illegible]5	418.75	-1000.00
MIN. VALUES	12.00	4.00	1.00	630000.00	504.00	1262.50	3.81	4750.00	10000.00	8855.00
MEAN VALUES	2.39	1.09	0.62	135200.89	98.63	135.75	0.34	920.54	1839.53	918.99
STD. DEVIATION	1.84	0.70	0.37	202865,77	72.34	167.14	0.41	534.65	1458.58	1308.53
STD. ERROR OF MEAN	0.14	0.05	0.03	71723.88	5.61	13.38	0.03	41.50	113.21	101.56
C.V.	76.9	64.1	59.0	150.1	73.4	123.1	120.3	58.1	79.3	142.4

PUMP IRRIGATION

1	0.2	0.2	1.00	324000	633.60	4000.00	0.17	8420.00	8400.00	-20.00
2	2.0	2.0	1.00	162000	118.80	750.00	13.63	2531.50	20500.00	17968.50
3	1.2	1.2	1.00	225000	455.00	1250.00	0.20	3166.70	9166.70	6000.00
4	0.8	0.2	0.25	450000	1728.00	500.00	0.30	18085.00	12975.00	-5110.00
6	2.4	2.4	1.00	60000	245.00	312.50	6.24	2343.80	11900.00	-1153.80
11	2.0	2.0	1.00	28500	252.00	200.00	4.15	1808.00	5250.00	3442.00
13	1.6	1.6	1.00	78750	288.75	468.75	15.47	2959.40	7500.00	4540.60
14	1.6	1.6	1.00	45000	322.50	312.50	51.25	2406.30	30000.00	27593.70
16	0.8	0.8	1.00	135000	147.00	375.00	4.36	3855.00	4050.00	195.00
19	1.6	1.6	1.00	90000	210.00	187.50	0.86	2745.60	9687.50	6941.90
20	2.4	1.2	0.50	90000	150.00	208.33	0.04	2193.30	4166.70	1973.40

21	2.4	1.6	0.67	112500	180.00	218.75	18.00	1800.00	9000.00	7200.00
22	2.0	2.0	1.00	72000	105.00	125.00	13.63	1590.00	18500.00	16910.00
24	1.2	1.2	1.00	90000	147.00	166.67	1.83	3498.30	3863.30	365.00
27	2.0	1.2	0.60	45000	105.00	250.00	3.43	3458.30	2600.00	-858.30
29	0.4	0.4	1.00	135000	360.00	375.00	0.86	6215.00	700.00	-5515.00
30	0.8	0.8	1.00	270000	210.00	125.00	1.07	4237.50	750.00	-3487.50
32	1.2	1.2	1.00	120000	108.00	208.33	1.59	2545.80	3450.00	904.20
34	2.4	0.8	0.33	180000	112.50	125.00	0.02	3295.00	525.00	-2770.00
35	5.2	2.0	0.38	54000	105.00	500.00	0.03	1751.50	1600.00	-151.50
41	2.0	2.0	1.00	180000	210.00	500.00	0.02	2760.00	3500.00	740.00
47	4.0	4.0	1.00	45000	100.80	125.00	0.78	1080.00	1265.00	185.00
57	4.0	2.4	0.60	150000	112.00	125.00	2,37	1588.30	2200.00	611.70
61	10.0	2.4	0.24	90000	140.00	125.00	0.50	3430.80	5250.00	1819.20
62	2.0	2.0	1.00	216000	151.20	375.00	1.24	2760.00	850.00	-1910.00
63	1.6	1.6	1.00	67500	67.50	156.25	0.21	3743.80	2525.00	-1218.80
64	3.2	3.2	1.00	67500	131.25	156.25	0.04	2396.90	1875.00	-521.90
70	2.8	2.8	1.00	77143	120.00	178.57	0.06	1928.60	10625.00	8696.40
71	1.2	1.2	1.00	150000	210.00	125.00	0.04	2675.00	2000.00	-675.00
72	4.0	2.4	0.60	90000	87.50	145.83	0.40	2777.90	2083.30	-694.60

74	1.6	1.6	1.00	135000	67.50	125.00	0.32	3398.80	1325.00	-2073.80
77	10.0	2.4	0.24	90000	140.00	125.00	0.50	3430.80	5250.00	1819.20
78	1.6	1.6	1.00	45000	322.50	312.50	51.25	3812.50	30000.00	26187.50
104	2.0	2.0	1.00	7200	162.00	150.00	0.19	4125.00	13500.00	9375.00
105	1.2	1.2	1.00	90000	210.00	166.67	0.19	4833.30	1350.00	8666.70
106	0.8	0.8	1.00	225000	220.50	250.00	0.50	7253.80	3750.00	-3503.80
107	6.0	4.0	0.67	54000	147.00	100.00	0.19	2450.00	20013.00	17563.00
113	10.8	0.4	0.04	135000	54.00	375.00	5.74	12412.50	5450.00	-6962.50
115	4.0	2.8	0.70	46286	56.00	107.14	0.71	1910.00	5142.90	3232.90
116	4.8	1.6	0.33	18000	78.75	156.25	0.13	4684.40	9375.00	4690.60
117	4.0	2.4	0.60	22500	119.42	208.33	0.14	4091.70	10000.00	5908.30
118	1.2	1.2	1.00	2400	52.50	125.00	0.13	3524.20	9000.00	5475.80
121	8.0	2.0	0.25	18144	126.00	200.00	0.13	3705.00	9000.00	5295.00
122	8.0	2.8	0.35	19286	90.00	142.86	0.93	2867.90	6428.60	3560.70
123	2.4	2.0	0.83	43000	60.00	250.00	0.15	4660.00	10500.00	5840.00
124	2.8	2.8	1.00	7500	63.00	20.83	0.10	1134.80	750.0	-384.80
125	4.0	2.4	0.60	45000	73.50	83.33	0.14	3406.70	10000.00	6593.30
126	2.0	2.0	1.00	27000	168.00	200.00	0.14	4426.00	9600.00	5174.00
127	2.4	2.4	1.00	15000	112.00	104.17	0.23	3120.80	16250.00	13129.20

128	1.6	1.6	1.00	13500	110.25	125.00	0.23	4757.50	32625.00	27867.50
129	2.0	2.0	1.00	14400	168.00	100.00	0.13	3457.00	9000.00	5543.00
130	4.0	4.0	1.00	189000	147.00	125.00	0.18	2760.00	12900.00	10140.00
131	8.0	2.8	0.35	19286	150.00	142.86	0.14	2329.60	9642.90	7313.30
132	3.2	3.2	1.00	33750	151.88	187.50	0.18	2227.50	12750.00	10522.50
133	1.6	1.6	1.00	33750	162.75	312.50	0.50	2477.50	3375.00	897.50
134	3.2	2.4	0.75	59760	16.00	62.50	0.15	2856.70	10500.00	7643.30
135	1.6	1.6	1.00	4896	126.00	125.00	0.15	2571.90	10500.00	7928.10
136	2.8	2.8	1.00	41966	150.00	178.57	0.14	1996.40	9857.10	7860.70
137	2.4	1.2	0.50	35280	55.00	125.00	0.20	2476.70	14000.00	11523.30
138	3.2	3.2	1.00	135000	97.13	156.25	0.16	1803.10	11250.00	9446.90
139	8.0	2.0	0.25	18144	126.00	200.00	0.13	2505.00	9000.00	6495.00
140	4.0	4.0	1.00	189000	147.00	125.00	0.18	2197.50	12900.00	10702.50
141	2.0	2.0	1.00	27000	168.00	200.00	0.14	3376.00	9600.00	6224.00
142	2.4	1.2	0.50	35280	55.00	125.00	0.20	2476.70	14000.00	11523.30
143	3.2	2.4	0.75	59760	16.00	62.50	0.15	2856.70	10500.00	7643.30
144	2.0	2.0	1.00	7200	162.00	150.00	0.19	3000.00	13500.00	10500.00
155	1.2	1.2	1.00	360000	259.00	166.67	0.43	4236.70	30000.00	25763.30
157	2.0	2.0	1.00	90000	36.00	75.00	0.04	1366.50	1250.00	-116.50

159	1.2	1.2	1.00	300000	168.00	166.67	0.75	3656.70	5000.00	1343.30
160	12.0	2.0	0.17	216000	126.00	100.00	0.60	2434.00	4200.00	1766.00
162	4.0	0.8	0.20	270000	210.00	250.00	7.01	2091.30	3400.00	1308.70
163	4.0	4.0	1.00	108000	63.00	100.00	1.80	1316.00	870.00	-446.00
167	4.0	1.6	0.40	225000	168.00	156.25	0.88	4918.80	6000.00	1081.20
168	1.2	1.2	1.00	240000	98.00	166.67	0.25	1190.00	283.30	-906.70
171	2.8	2.8	1.00	90000	54.00	125.00	0.93	1007.50	3000.00	1992.50
175	1.6	1.2	0.75	210000	84.00	83.33	0.02	1505.80	1050.00	-455.80
177	4.8	2.8	0.58	154286	51.43	214.29	0.06	1857.50	1071.40	-786.10
181	5.2	1.6	0.31	112500	27.00	93.75	0.81	1338.10	1171.90	-167.20
184	1.2	1.2	1.00	3600	4.80	41.67	0.02	1507.50	1000.00	-507.50
190	2.0	2.0	1.00	144000	100.80	75.00	0.02	1853.50	1500.00	-353.50
191	6.0	4.0	0.67	108000	108.00	162.50	0.04	1232.80	1625.00	392.20
194	10.0	4.8	0.48	90000	45.00	83.33	0.02	872.10	1062.50	190.40
195	6.0	1.6	0.27	157500	53.75	125.00	0.06	1031.30	687.50	-343.80
210	2.0	2.0	1.00	63000	75.60	125.00	0.10	1130.00	460.00	-670.00
211	6.0	0.4	0.07	180000	120.00	125.00	0.12	6665.00	1900.00	-4765.00
212	6.0	2.4	0.40	90000	120.00	83.33	0.04	787.10	1666.70	879.60
222	4.0	4.0	1.00	54000	90.00	125.00	0.02	1337.50	750.00	-587.50

227	2.0	0.8	0.40	315000	108.00	187.50	0.34	2408.80	3000.00	591.20
230	2.0	2.0	1.00	126000	64.80	150.00	0.02	1156.00	1050.00	-106.00
231	2.0	1.6	0.80	78750	81.00	1250.00	0.12	4808.10	812.50	-3995.60
237	3.6	0.8	0.22	180000	294.00	62.50	0.11	4540.00	1775.00	-2765.00
238	5.6	4.4	0.79	98182	95.46	45.45	0.10	897.00	6954.50	6057.50
240	4.0	1.2	0.30	240000	147.00	125.00	0.14	3702.50	10000.00	6297.50
245	2.0	0.8	0.40	405000	144.00	125.00	0.04	3716.30	875.00	-2846.30
246	2.0	0.4	0.20	315000	105.00	375.00	0.02	3992.50	2250.00	-1742.50
248	2.0	1.6	0.80	157500	108.00	187.50	0.13	3703.80	1890.60	-1813.20
253	2.4	0.8	0.33	225000	84.00	187.50	0.16	10140.00	1593.80	-8546.20
254	1.2	0.8	0.67	225000	126.00	125.00	0.28	10611.30	6625.00	-3986.30
255	2.4	1.6	0.67	157500	126.00	125.00	0.43	3503.80	23562.50	20058.70
256	2.4	0.8	0.33	225000	126.00	187.50	0.21	4443.80	5343.80	900.00
257	2.8	1.2	0.43	210000	84.00	83.33	0.25	3823.30	1062.50	-2760.80
259	4.0	2.0	0.50	144000	100.80	175.00	0.65	1355.50	4500.00	3144.50
260	1.2	1.2	1.00	360000	350.00	208.33	0.43	5175.00	21416.70	16241.70
263	3.2	0.8	0.25	270000	135.00	187.50	0.02	2651.30	1800.00	-8511.30
265	4.8	4.8	1.00	90000	105.00	104.17	0.22	1368.80	9724.00	8355.20
266	2.8	2.8	1.00	64286	120.00	107.14	0.17	1132.10	1669.60	537.50
267	2.4	2.4	1.00	180000	140.00	83.33	0.26	3619.20	14352.10	10732.90

268	2.0	1.6	0.80	157500	144.00	93.75	0.14	1766.90	2006.30	239.40
269	8.0	6.0	0.75	36000	126.00	183.33	0.68	1601.00	4800.00	3199.00
270	2.0	0.4	0.20	1350000	432.00	375.00	0.15	3842.50	2737.50	-1105.00
273	6.0	4.8	0.80	45000	90.00	135.42	0.08	1280.63	5250.00	3969.37
274	6.0	2.4	0.40	180000	180.00	145.83	0.02	1720.00	7000.00	5280.00
275	2.0	1.6	0.80	337500	144.00	93.75	0.24	1529.38	2703.10	1173.72
279	8.0	8.0	1.00	54000	63.00	50.00	0.55	706.50	3900.10	3193.60
284	6.0	6.0	1.00	72000	112.00	83.33	0.60	1024.00	4200.00	3176.00
289	1.2	1.2	1.00	225000	455.00	1250.00	0.02	3583.33	9166.70	5583.37
290	2.0	1.2	0.60	45000	105.00	250.00	3.43	5125.00	2600.00	-2525.00
294	2.0	2.0	1.00	90000	36.00	75.00	0.01	2633.00	1250.00	-1383.00
295	4.0	1.2	0.30	240000	147.00	125.00	0.14	5619.17	10000.00	4380.83
298	2.0	1.6	0.80	157500	108.00	187.50	0.13	3703.75	6953.10	3249.35
300	2.4	1.6	0.67	157500	126.00	125.00	0.14	5410.00	3312.50	-2097.50
304	6.0	4.8	0.80	45000	90.00	1354.17	0.75	3058.96	5250.00	2191.04
305	3.6	0.8	0.22	180000	294.00	62.50	0.04	9603.75	1775.00	-7828.75
306	2.0	2.0	1.00	180000	210.00	500.00	0.02	3810.00	3500.00	-310.00
307	2.0	0.8	0.40	315000	108.00	187.50	0.38	5195.00	3000.00	-2195.00
311	4.0	0.8	0.20	270000	210.00	250.00	7.01	4622.50	3400.00	-1222.50

313	2.0	1.2	0.60	43333	192.00	125.00	0.11	1226.67	1145.80	-80.87
317	1.2	1.2	1.00	90000	336.00	83.33	2.30	2031.67	2033.30	1.63
320	2.0	1.6	0.80	157500	72.00	93.75	0.81	1363.75	859.40	-405.35
323	2.0	2.0	1.00	113400	67.00	75.00	0.85	1316.00	1000.00	-316.00
325	2.0	1.0	0.50	108000	100.80	100.00	2.95	2035.00	2430.00	395.00
333	1.0	1.0	1.00	64800	151.20	0.00	2.29	1336.00	1520.00	184.00
336	1.0	1.0	1.00	27000	151.20	100.00	3.21	1019.00	3840.00	2821.00
339	0.8	0.8	1.00	45000	72.00	125.00	0.65	1292.50	937.50	-355.00
340	0.8	0.8	1.00	81000	52.50	187.50	2.34	1547.50	1650.00	102.50
341	2.4	0.8	0.33	97200	90.00	187.50	2.28	1966.25	3187.50	1221.25
343	1.0	1.0	1.00	100800	317.50	100.00	3.40	1143.00	2600.00	1457.00
347	2.0	2.0	1.00	17928	72.00	200.00	0.04	1518.00	1550.00	32.00
348	3.2	3.2	1.00	135000	131.25	93.75	0.20	1110.63	2625.00	1514.37
349	1.6	1.6	1.00	37350	168.00	93.75	0.06	1484.38	3750.00	2265.62
350	2.0	2.0	1.00	12600	126.00	150.00	2.01	1661.00	1970.00	309.00
353	1.0	1.0	1.00	64800	151.20	0.00	2.29	1336.00	1520.00	184.00
354	1.2	1.2	1.00	3600	4.80	41.67	0.01	835.00	1033.30	198.30
355	0.8	0.8	1.00	45000	72.00	125.00	0.65	3935.00	937.50	-2997.50
357	2.0	2.0	1.00	90000	36.00	75.00	0.06	1233.00	1020.00	-213.00

358	2.4	0.8	0.33	97200	90.00	187.50	2.28	1966.25	60076.30	58110.05
361	2.0	1.0	0.50	108000	100.80	100.00	3.68	2035.00	2530.00	495.00
364	1.6	1.6	1.00	37350	168.00	93.75	0.04	1434.38	3125.00	1690.62
MIN. VALUES	0.20	0.20	0.04	2400.00	4.80	20.83	0.01	706.50	283.33	-8546.25
MIN. VALUES	12.00	8.00	2.50	1350000.00	1728.00	4000.00	51.25	18065.00	60076.25	58110.00
MEAN VALUES	3.05	1.94	0.77	127757.73	151.03	225.79	1.84	3041.63	6512.45	3470.82
STD. DEVIATION	2.25	1.24	0.34	137802.02	159.75	378.46	6.40	2292.71	7785.94	7842.54
STD. ERROR OF MEAN	0.19	0.10	0.03	11327.26	13.13	31.32	0.53	168.46	640.00	644.65
C.V.	73.7	64.0	44.6	107.9	105.8	167.6	347.2	75.4	119.6	119.6

SOURCE: FIELDWORK, 1990

APPENDIX 3

REASONS FOR CROPPING PATTERNS IN THE DONGA RIVER BASIN

Irrigation type	Cropping patterns	Reasons							
		Better use of inputs		Security		Inputs maximization		Economic gains	
		No	%	No	%	No	%	No	%
Flood recession	Vegetabile only	6	3.61	-	-	-	-	-	-
	Wheat only	5	3.01	-	-	-	-	-	-
	Maize only	131	78.92	-	-	-	-	-	-
	Tomatoes only	1	0.60	-	-	-	-	-	-
	Maize/Veg.	-	-	-	-	10	6.02	2	1.20
	Maize/beans	-	-	3	1.80	-	-	-	-
	Okro/tomatoes	-	-	-	-	1	0.60	-	-
	Pepper/tomatoes	1	0.60	-	-	-	-	-	-
	Pepper/Onion	1	0.60	-	-	4	2.41	-	-
Manual	Vegetables only	16	32.00	-	-	1	2.00	-	-
	Wheat only	2	4.00	-	-	-	-	-	-
	Maize only	2	4.00	-	-	-	-	-	-

	Tomatoes only	3	6.00	–	–	–	–	–	–
	Maize/vegetables	–	–	–	–	8	16.00	1	2.00
	Okro/tomatoes	–	–	–	–	5	10.00	1	2.00
	Pepper/tomatoes	–	–	–	–	5	10.00	–	–
	Pepper/onion	–	–	–	–	5	10.00	1	2.00
Pump	Vegetables only	32	21.62	–	–	3	2.03	–	–
	Wheat only	52	35.14	–	–	–	–	–	–
	Maize only	5	3.38	–	–	–	–	–	–
	Tomatoes only	5	3.38	–	–	–	–	–	–
	Maize/Veg.	–	–	–	–	9	6.08	–	–
	Wheat/maize	–	–	–	–	8	5.41	–	–
	Okro/tomatoes	1	0.68	–	–	8	5.41	–	–
	Pepper/tomatoes	–	–	–	–	12	8.11	1	0.68
	Pepper/onion	–	–	–	–	2	1.35	–	–
	Veg./onion	–	–	–	–	1	0.68	1	0.68
	Veg./onion/pepper	–	–	–	–	1	0.68	1	0.68
	Tom./pepper/veg.	–	–	–	–	1	0.68	–	–

Source: Fieldwork, 1990