SOCIO-ECONOMIC BENEFITS OF IRRIGATION USING BORROW PIT WATER

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DECLARATION

This thesis has not, in part or whole, been previously submitted by the Author for any other degree or qualification at this or any other University.

D.A. ATTAH ----------

APPROVAL

This thesis entitled, "Socio-Economic Benefits of Irrigation using Borrow Pit Water" by Daniel Aimaje Attah meets the regulation governing the award of the degree of master of Science of Ahmadu Bello University and is approved for its contribution to Knowledge and literary presentation.

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ABSTRACT

Prior' if) 1919, borrow pits excavated into clay pans to collect and retain rainfall and local run-off served as a major water supply source to the settled Fulanis in the Wawa bush of the present Bauchi state, Nigeria.

Attempts to make them a regular water supply source in later-years failed mainly due to lack of maintenance.

In the arid regions of Mexico, Arizona and Negev desert,they have been used to harvest local run-off for small-sea irrigation of food and cash crops.However,the cost of excavation makes the use of Lateritic /gravel pits for road base Construction more attractive.

The Irrigation scheme using water from 1 ater i t i (-/gravel pit at Hanwa in Zaria, Nigeria and the Socio-economic bene fits of the irrigation scheme are evaluated.

The feasibi] Lty study shows that at Least 2.53ha-m of wafer is being conserved annually and this could irrigate about 5ha of farm land. The analysis of the water shows that it is suitable for irrigation of most crops on most soils.

The economic appraisal of the irrigation scheme shows that it is viable. The benefit/cost ratio ranged from 1.2 to 3.7 and varied for each farm with an average of 1.88. It is observed that encouraging the use of borrow pits to harvest, run-off for small scale irrigation could provide solution to the decreasing food production in the country.

ACKNOWLEDGEMENT

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DEDICATION

This Thesis is dedicated to God Almighty and the service of Mankind.

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These degradations are the result of environmental pollution through man's application of his technological skills which are normally devoid of environmental considerations until very recently.

Over the years the basic problem has been the evolution of an environmentally sustainable technology to enhance man,s utilization of environment resources without endangering the continuous use of it and for the overall survival of man.

Road construction is one of such man's activities involving the use of his technological skills and this leads to the creation of borrow pits, which are where suitable materials have been excavated for road construction. These pits are found dotting the sides of most modern highways like the Kaduna-Kano dual carriage way.

Borrow pits may, also, be excavated as a deliberate policy for the purpose of collecting rainfall and run-off which could be used for agricultural as well as domestic purposes.

1.1 WATER RESOURCES DEVELOPMENT AND THE ENVIRONMENT

Prior to the 20th Century, the environmental impacts of water resources developments were not of major concern.

Infact, some of the major environment issues of the 19th century related to the impacts of other activities like deforestation

on water resources.

During the first seven decades of the 20th century, efficiency in water resources development played a key role in planning and the environmental impacts of water projects received thorough consideration only for cases in which the projects were controversial; (for example the damming of Hetch Hetchy valley in San Francisco, U.S.A), (Ortolano, L, 1979).

The first attempts to legislate a requirement that environmental factors be accounted for systematically were in the 1930's and concerned inter-agency co-ordination. These attempts and the subsequent expansion of the co-ordination requirements generally led to the consideration of a limited number of environmental factors in late stages of project planning. Such co-ordination sometimes led to the addition of project features intended to off set adverse environmental impacts.

Prior to the 1970's environmental factors received very little systematic consideration in the early stages of project planning. In assessing the impacts of alternative actions, engineering and economic factors received thorough consideration. The National Environmental Protection Act of the United States and the Federal Environmental Protection agency (FEPA) of Nigeria, established in 1970 and 1989 respectively have the potential to increase, substantially the attention

given to environmental factors in all stages of water resources planning and decision making.

However, the prospect of attaining a long-lasting increase in the attention given to environmental factors by water resources depends, significantly, on the extent to which the Public continues to place high priority on environmental quality issues.

1.2 SCOPE OF STUDY

Borrow pits generally, have both adverse impact (as a health hazard by breeding mosquitos) and positive or beneficial impact (the stored water could be exploited for small-scale irrigation) on the local environment.

In the broadest terms, the aim of the study is to assess the contribution of borrow pits in the enhancement of agricultural productivity through-small scale irrigation and the degree to which it impacts on the local environment positively or negatively.

The specific objectives were to undertake:

- The engineering feasibility of the Hanwa borrow pit in Zaria in conserving enough water for irrigation activities;

- The cash flow analysis of the production of crops through the irrigation scheme; and

- The review of other notable impacts of this pit on the local environment.

1.3 STUDY AREA

The site for this study is located at Zaria in Kaduna state of Nigeria (see fig 1.1). It is situated between latitude 11^{0} 06.6^{1} and 11^{0} 07.2^{1} North of the Equator and longitude 07^{0} 41.6^{1} East of the Greenwich Meridian. At Zaria, it is sited between km 71 and km 72 along Kaduna-Kano dual carriage way (Figure 1.2).

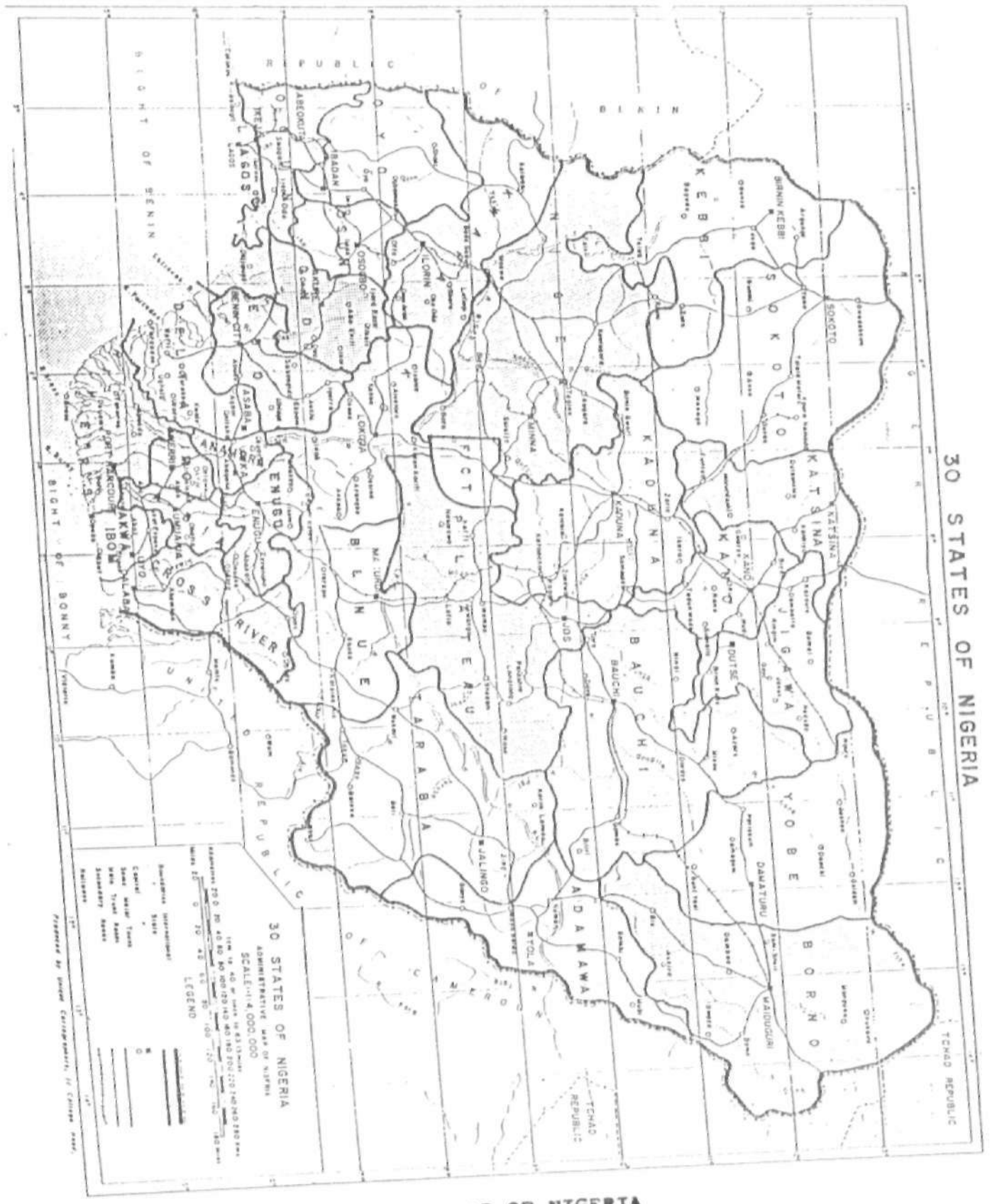


FIGURE 1.1 MAP OF NIGERIA

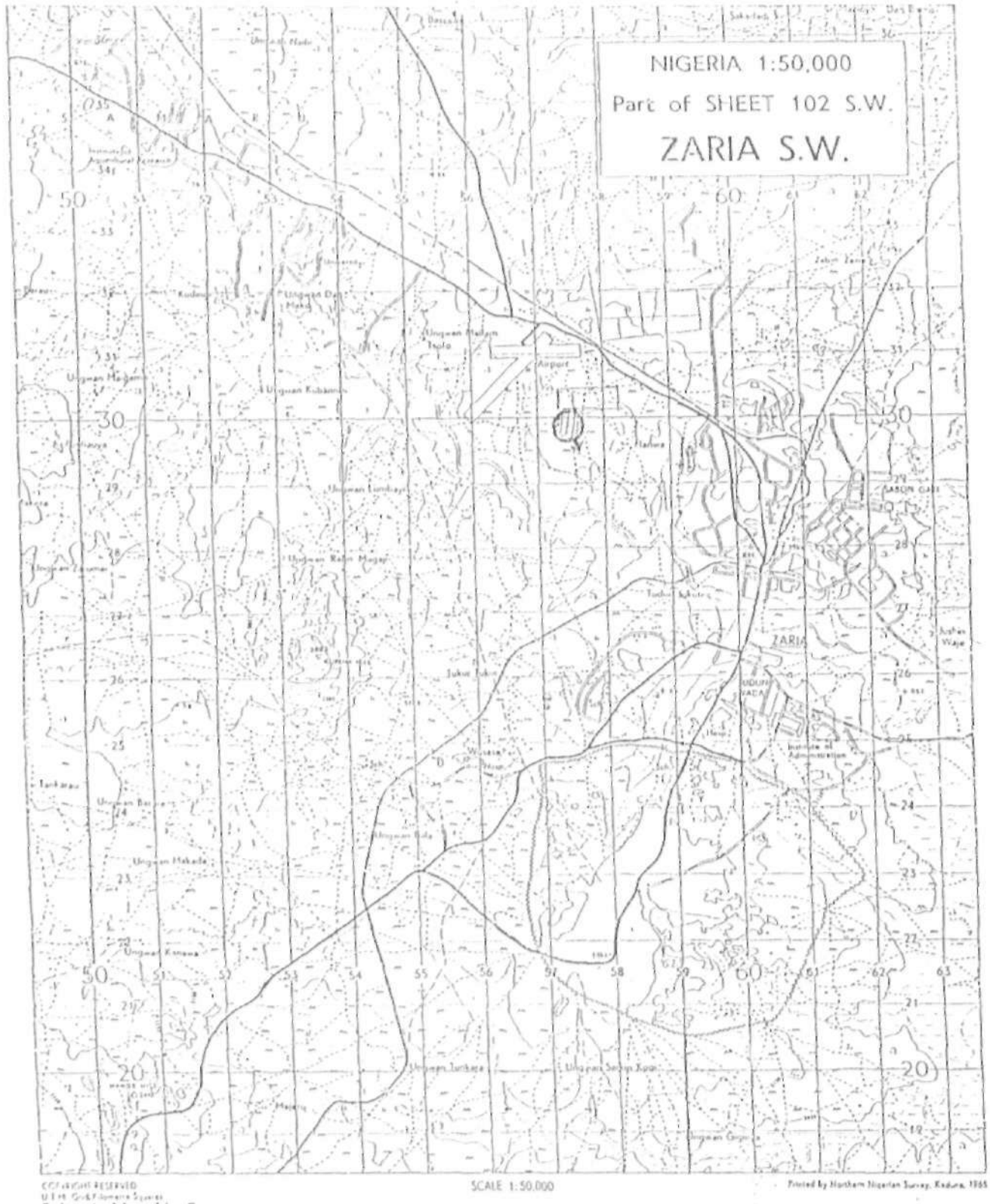


Figure 1.2 Map of Zaria.

It covers a total gross command area of 13.64ha and has a cultivable command area of 9.15ha with a net command area of 6.8ha (see fig. 1.3).

The topography of the site is fairly representative of surrounding plains which can be described as undulating plain with very broad and gentle slopes lying at an attitude of between 631m and 653m above sea level (See Figure 1.4).

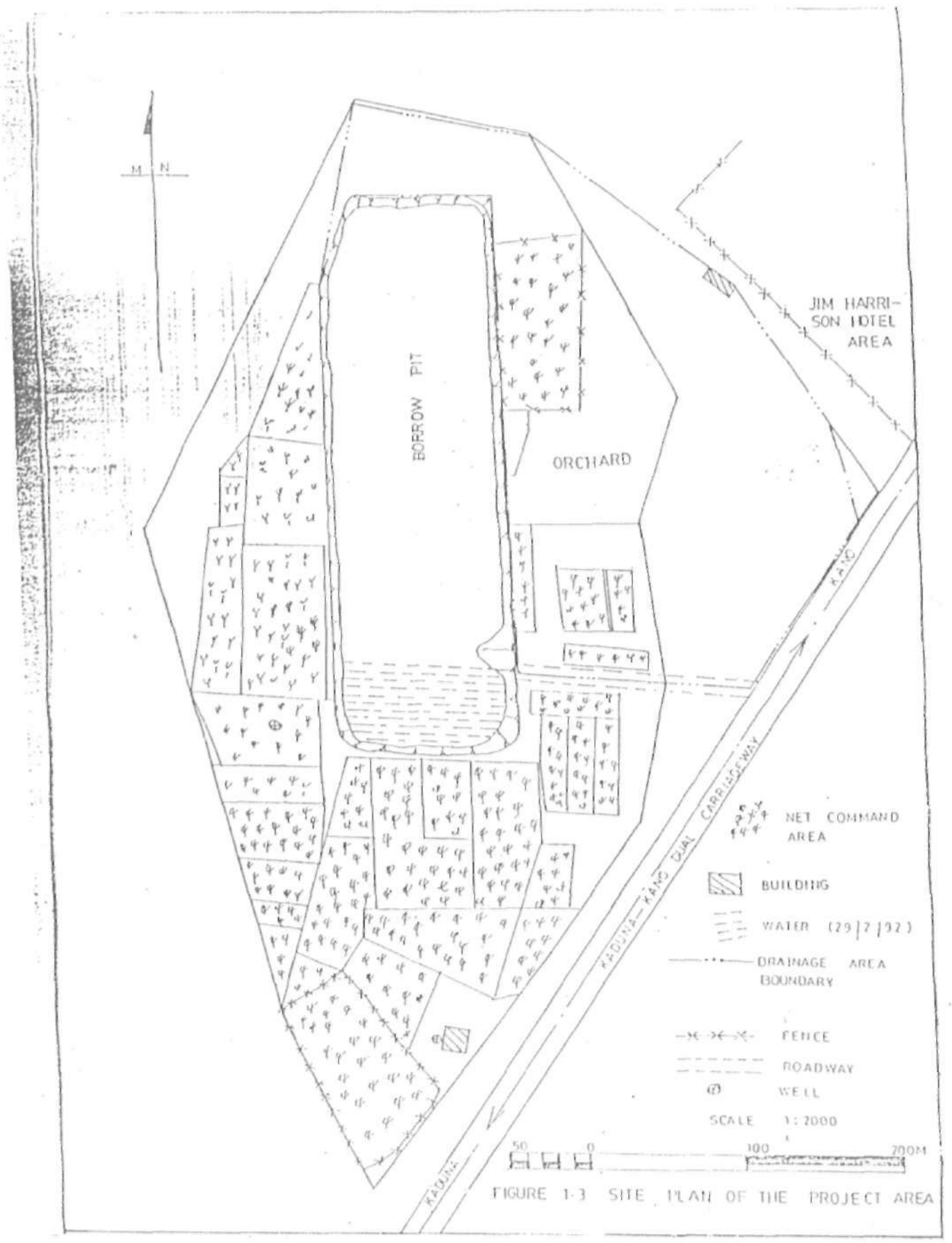


FIGURE 1-3 SITE PLAN OF THE PROJECT AREA

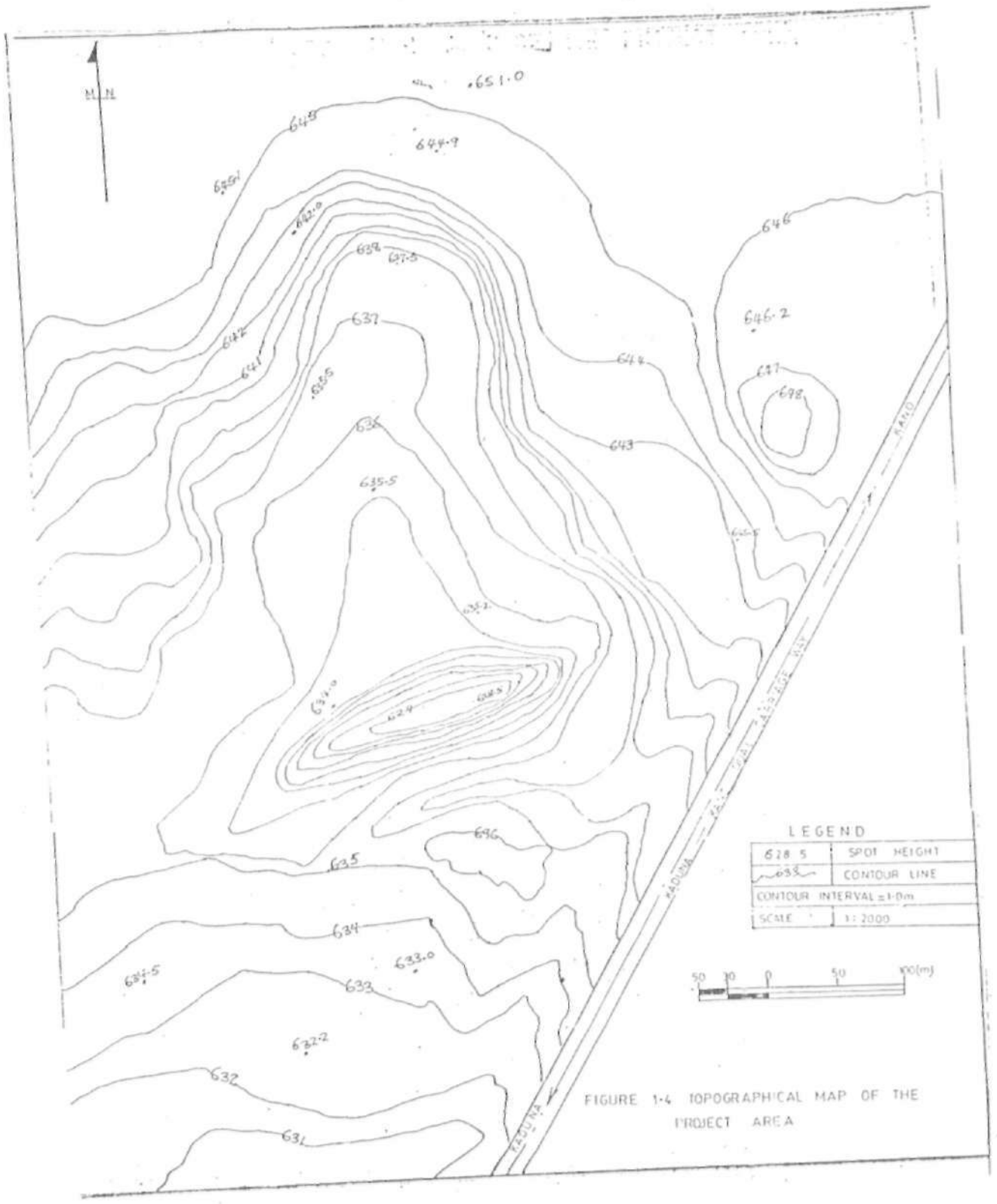


FIGURE 1-4 TOPOGRAPHICAL MAP OF THE PROJECT AREA

1.4 LAND-USE, FARMING SYSTEM AND CROPPING PATTERN

About 70% of the dry season farmers in the study area do not own their farm land. They paid between N20.00 and N200.00 or in kind irrespective of the farm size. Generally, the holding per farmer varied from 0.035ha to 0.65ha. Others even had as little as 100m^2. The average holding was 0.162ha.

The farming system was basically traditional except a wheat farmer who employed mechanization in the land preparation. However, crop rotation was well understood and extensively practiced. The irrigation of tomato and other vegetables was followed by the cultivation of maize/millet as soon as rainfall started. The cropping intensity was 100 percent.

The irrigation system was furrow for other crops but basin for the wheat. Petrol engine pumps (generally of 2.625kw capacity and either Honda or Yamaha make) were used to lift water from the pit. The water was conveyed through PVC pipes or hose or channels (where the topography permitted) to the fields and distributed by the farmers through the use of bunds.

The major irrigated crops were tomato, pepper and wheat. Maize and okra were not entirely produced by irrigation. Part of the water requirement were met by rainfall. The average yield per ha of tomato, which was the dominant crop, was 22.5 tonnes. The

yield is good though dry season yields of between 25 and 37 tonnes per ha had been recorded or reported in northern Nigeria, (Komolafe et.al 1985).

1.5. RATIONALE FOR THE STUDY

Africa is the only continent where per capita food production continues to decrease. Experience, particularly in Nigeria, has shown that food importation cannot be regard as a long-term solution.

Irrigation, which the agricultural man began to practice, at least 6,000 years ago, even earlier than he harnessed animal power, has played a major role in increasing food production by bringing into profitable cultivation large areas of land that would otherwise be unusable or only marginally productive. Irrigation and its proper use and control is one of the essential factors in the global war against hunger.

The necessity for increasing food or agricultural production in Nigeria is obvious. In recognition of this, the Northern States, in 1970 put over 10,935 hectares of arable land under irrigation. The scheme was included in the 1970-74 National Development Plan (Tyson, 1971).

Formal irrigation with full water control had only developed in

sub-sahara Africa since the colonial period and the record of achievement had been reported to be very poor. In Nigeria for instance, all the major irrigation schemes have failed to make any appreciable impact on food or agricultural production. It is more costly than in any other continent, mainly reflecting the inexperience of the domestic construction industry and the consequent dependence on imported materials. At the present time, some 0.9% of the total arable land in Nigeria is irrigated. (FAO, 1987).

Most large-scale irrigation schemes are for cash crops and other than in the arid regions, surface water constitutes the main supply source. Water requirements are, generally, high.

The present thinking favours small-scale, even one farmer type irrigation, which may initially be supplementary and therefore more easily integrated with the existing farming systems (FAO, 1984).

Various attempts have been made, in recent times to define small-scale irrigation. Perhaps the best definition of a small-scale irrigation is a scheme in which the farmers or the local community have chosen to practise irrigation and are responsible for its operation and management (Forster 1986).

There are two groups of small-scale irrigation: Traditional and promoted. The traditional irrigation has been carried out in

Africa from time immemorial and has been accepted as a normal component in agricultural practice. It includes (i) "Fadama" irrigation in the drier parts of West and Central Africa, (ii) flood irrigation along major rivers and (iii) flood-spreading 'bund' and embarkments to divert and retain flash floods in ephemeral stream flows.

Promoted small-scale irrigation comprises developments which have been introduced as a result or because of development programmes and which involves changes in the existing farming practices. Promoted small-scale irrigations, therefore, are liable to the same hazards as large-scale irrigations. There are nearly 2 million hectares of small-scale irrigation in Tropical Africa. It is therefore a significant agricultural practice, (Forster, 1986). A recent trend that has emerged in various forms, throughout the drier parts of Africa is the expansion of small-scale irrigation of food crops, fruits and vegetables for domestic consumption and sometimes cash crops in small quantities, (Stern 1986).

In addition, local run-off is being harnessed through the process of rainfall harvesting on a small-scale in extensive areas of Africa that are far removed from any permanent stream.

Such schemes have, successfully been used for even high value cash crops production in arid regions of Mexico, Arizona and the Negev desert.

Borrow pits have great potential for collecting and retaining local run-off which could be exploited on a small-scale for food production through irrigation and livestock breeding.

The borrow pit in the study area has served these purposes for the past two years. This study, therefore, becomes imperative because of the current shift in emphasis from large to small-scale irrigation projects. The study might also provide an impetus for a critical review or appraisal of the existing large - scale irrigation projects in Nigeria.

The use of borrow pits to collect local run-off which could be utilized in dry season either for irrigation or domestic purposes is not new in Nigeria. Before 1919, the settled Fulani in the Wawa Bush of Gombe Emirate in the present Bauchi State depended, especially for their dry season water, on borrow pits excavated out of clay pans which were found scattered over the area. The construction of the pits, or ponds, their maintenance including the annual removal of silt and clay which had been washed in, and the watering of livestock which were not allowed to approach the edge of the ponds, was part of the work of the slave caste. (Hocking and Thomson, 1979).

However, after 1919 when slavery became illegal and new administrative capital was set up at Gombe, the water supplies deteriorated due to lack of maintenance.

By 1956, in an attempt to make the Wawa Bush more attractive to the existing farmers and to encourage migrant Fulanis into the area, 31 ponds were mechanically dug. But by 1968 only 3 ponds still held water and thus the attempt failed (Hocking and Thomson, 1979). The reasons for the failure were mainly lack of maintenance and damage by cattle. With constantly increasing population pressure and decreasing food production, a renewed efforts to overcome the water supply problems of the arid and semi-arid regions for small-scale irrigation and livestock watering through borrow pits either intentionally excavated or created as a result of road construction is essential.

The acceptability of such a scheme depends, to a large extent, on the economic viability. This makes the economic appraisal of the scheme equally essential. Other benefits of borrow pits are:
Where they are excavated into permeable formation, they serve as an idea facility for ground water recharge.

1.6 ECONOMIC APPRAISAL

International financiers and local economic planning agencies require an economic appraisal to be include for all schemes and projects they accept to finance. Governments always want to know how a scheme will benefit their countries overall economy and how it will fit into developments elsewhere in the

country. The need for economic appraisal, the application and implications vary with countries and the circumstances prevailing in each country at the time. In all, the appraisal involves an assessment of the benefits and costs of a project to the population and the economy.

Economic benefits may be classified into three:

- Primary benefits;
- Secondary benefits; and
- Social benefits

While primary and secondary benefits can be quantified, social benefits are derived from primary and secondary benefits and cannot be valued in monetary terms.

CHAPTER 2

2.0 METHODS OF ANALYSIS AND DATA COLLECTION

2.1 METEOROLOGIC DATA

The basic Meteorological data assembled for this study were obtained from the Meteorological Department of the Nigeria College of Aviation Technology (NCAT), Zaria because of proximity (about 1.5km from the study area). The data include daily rainfall, sunshine hours, evaporation, incident solar radiation, relative humidity, wind speed, maximum and minimum temperatures, dewpoint, vapor pressure, mean sea level pressure and station pressure obtained from the aerodrome weather station. Since the annual variations of potential evapotranspiration (ETp) amounts are small compared with rainfall variation, the station coverage providing data for the computation of ETp using modified Pennman's method is more than adequate for the assessment of the rainfall pattern (a maximum of two stations per 26km^2 Wilson, 1990). The duration of data collection was eleven years (1981 - 1991). This is regard as adequate to represent the evaporation characteristics of the site. According to Woodhead and Waweru records of five years average evaporation give an estimate of long term mean (30 years) within about 10% error. (Woodhead and Waweru, 1970).

2.2 INFILTRATION MEASUREMENT

Infiltration may be defined as the process by which water enters, penetrates or wets the soil.

Four methods are commonly employed for field measurements of infiltration:

- Cylinder infiltrometers;
- Ponding;
- Block recirculating infiltrometers;
- A deduction of infiltration from evaluation of the advance phase and tail water hydrograph.

The method employed in this study was the cylinder infiltrometers and this would be subsequently described, but for others see (Walker, 1989) for detailed description.

2.2.1 CYLINDER INFILTROMETERS

The cylinder infiltrometers may be double or single ring. In the case of a double ring which was used in this study, the outer ring acts as buffer to make the infiltrating water percolates vertically and thus preserving the integrity of the measurements. The double ring cylinder infiltrometers, as the name suggests, consist of two concentric cylinders open at both ends with one edge of both cylinders sharpened to an angle of about 30^{0} to allow for easy entry or penetration into the soil. Both cylinders were 300mm high with a diameter of 230mm for the

outer ring and 155mm for the inner ring.

A suitable location, devoid of unusual surface distance, animal burrows, stones that might damage the cylinders etc, was first selected.

The cylinders were then set in place concentrically and pressed firmly into the soil, after which a wooden plank was placed over the cylinders and tampered with a hammer until the cylinders were driven to a depth of about 150mm.

The test was conducted as follows; after the installation, the volume of the cylinders above the soil surface was measured (diameter, depth). Aguage was then fixed to the inner wall of the inner cylinder so that the level changes that occurred could be measured. Water from the borrow pit, which was the irrigation water,was collected and poured quickly into the infiltrometers to an approximate depth of 100m above the soil surface.

When the water surfaced had settled, the initial guage reading and time were taken. Additional measurements were taken at periodic intervals of 5 minutes for the first 4 to 6 readings, expending to 30 to 60 minutes intervals after 8 or 9 readings. The measurement was continued until two consecutive readings over one to two hours period were approximately the same (Walker 1989).

The depth of water in the cylinders was maintained at between 60mm and 100mm by adding more water, as quickly as possible to return the surface to its approximate initial level, when it had dropped about half of the depth of the cylinders above ground surface.

The above procedure and measurements were repeated at four other locations within the site, selected subjectively. In all, five replicate measurements were obtained. These are considered adequate for one site, (Walkers 1989 and Hansen et al, 1980).

2.2.2 INFILTRATION FUNCTIONS

Both the procedures for interpreting field data and those covering surface irrigation design require that infiltration process be described mathematically. There are a number of such mathematical equations to choose from but none is as versatile as the two Kostiakov-Lewis relationships, (Walker 1989).

The simplest approximation of cumulative infiltration is:

$z = kt^{a}$ 2.1

where

z = cumulative infilitration depth (mm)

t = intake opportunity time (min.)

k and a = empirical constants

Equation 2.1 is simple, easy to define and widely used. Its major disadvantage is its inadequacy in describing infiltrattion

over long periods of time. The infiltration rate based on equation 2.1 is:

$q = akt^{a-1}$ 2.2

Since a is always less than unity, q approaches zero at infinite time.

This condition is not usually encountered in the field. Soils do, however, have extremely small infiltration rates after a long period of time, (Walker, 1989).

A more general infiltration function is the extended form of equation 2.1 given as:

$z = kt^a + f_0 t$ 2.3

where f_0 = long term steady or basic infiltration rate.

Equation 2.3 reduces to equation 2.1 if the soil intake rate at long time approaches zero or if the infiltration event is short compared with the time required for the infiltration to reach a steady rate. Equation 2.3 gives a better long term approximation on many soils. The infiltration rate using equation 2.3 is:

$q = akt^{a-1} + f_0$ 2.4

Because of its obvious advantage, equation 2.3 was used in evaluating the infiltration process or phenomenon is this study.

2.2.3. ANALYSIS OF INFILTRATION DATA

The data were analysed by graphical method - logarithmatic plot of cumulative infiltration against cumulative time. To evaluate the infiltration function, the slope of the readings near the

later part of the test was taken as the basic intake rate (f_0), while the slope of the first few data points on the logarithmatic paper was used to define a. The intercept of the horizontal axis at 1.0 gave the value of k. This procedure assumes that at short times the contribution of cumulative infiltration from the steady state term, f_0, in equation 2.3 is negligible. These assumptions are better for heavy soils than light ones. (Walker, 1989).

2.3 SOIL SAMPLING

Soil samples were collected for the determination of the following soil parameters:

- Specific gravity (gs);
- Silt and clay percentages;
- Hydraulic conductivity;
- Bulk density; and
- Field capacity (FC) and permanent wilt point moisture contents.

The void ratio and porosity were computed form the values of the bulk density, specific gravity and the unit weight of water, thus:

$$\text{Void Ratio, } e = \frac{gs\ Yw\ V}{Ws} - 1 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad 2.5$$

$$\text{Porosity, } n = 1 - \frac{Ws}{gsYwV} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad 2.6$$

Where,

gs = specific gravity

Yw = unit weight of water (g/cm^3)

v = volume of soil mass (g)

Ws = dry weight of soil mass (g)

Two samples were collected for the determination of specific gravity, silt and clay percentage and hydraulic conductivity (K).

The specific gravity was measured by the specific gravity bottle method in the laboratory.

$$\text{Specific gravity (gs)} = gt \frac{(w_2 - w_0)}{(w_2 - w_1) - (w_3 - w_4)} \quad \ldots 2.8$$

Where,

gt = specific gravity of distilled water

w_0 = weight of bottle empty (g)

w_2 = weight of bottle plus dry sample (g)

w_3 = weight of bottle plus sample plus water

w_4 = weight of bottle plus water (g).

The percent silt and clay contents were determined by quick sedimentation method in the laboratory. Thus sand percentage, s

$$= \frac{(L_1)}{(L0)} \times \frac{100}{1} \quad \ldots 2.9$$

$$\text{Silt percentage, } m = \frac{(L_0 - L_1)}{L_0} \times \frac{100}{1} \quad \ldots 2.10$$

Clay percentage, c = 100 - s - m

Where,

L_0 = initial thickness of sample in cylinder.

L_1 = sample thickness after ten seconds.

L_2 = sample thickness after 2 hours.

For the hydraulic conductivity, core samplers of diameters 105mm and height 100mm were used for the sampling and was determined in the laboratory using the falling head method (see Lambe, 1984 for details). The hydraulic conductivity was evaluated by:

Hydraulic conductivity (K) = $\frac{2.3aL}{At} \text{ Log } \frac{h_1}{h_2}$ 2.11

where,

a = cross sectional area of standpipes or tube;

L = length of soil sample in the permeameter;

A = cross sectional area of the permeameter;

t = time taken for head to fall from h_1 to h_2;

h_1 and h_2 = initial and final heads respectively.

For the determination of the field capacity and permanent wilting point and the bulk density, nine samples were taken. One sample from the center of the field, one each from a point 10m from the four edges of the field along the diagonals; and one each from the mid-north, mid-east, mid-south, and mid-west portions of the field. This is a rule of thumb used by soil scientists. The test were carried out in I.A.R. soil laboratories. The bulk density was obtained by:

Bulk density = $\frac{\text{Dry weight of soil mass}}{\text{Volume of samples}}$

The field capacity moisture contents were obtained gravimetrically after a pressure of 0.1 bar had been applied to

the soil samples. For the permanent wilting points, a pressure of 12 bars was used.

2.4 ESTIMATION OF EVAPOTRANSPIRATION (ETp)

Evapotranspiration is the combined loss of water from a given area by evaporation from the soil surface and from transpiration from plants. It is sometimes referred to as "consumptive use" of water by crops. (Kowal and Knabe, 1972 and Wilson, 1990).

Because the rate of evapotranspiration varies greatly with the ease with which water is available to crops and with the degree of the crop cover, it is advisable to, first, consider the case of unlimited water supply. This leads to the concept of potential evapotranspiration (ETp) introduced by Pennman in 1956 and defined as "the amount of water transpired in unit time by a short green crop completely shading the ground, of uniform height and never short of water (Kowal and Knabe, 1972). Sine ETp is essentially determined by climatic factors, and is not affected by plant species, it provides a means of accessing the adequacy of water supply to crops grown in various climatological areas. From the amounts and distribution of rainfall, periods of water surplus or deficit can be identified and the amount of water surplus or deficit assessed.

Estimates of ETp in this study was based on Pennman formular and

computed from the climatic factors of net incident solar radiation, mean, maximum and minimum temperatures; actual vapour pressure relative humidity, sunshine hours and station pressure. This method has been found suitable for a wide range of climatic conditions. it is also considered as the best method for estimating ETp. (Blake, 1989). The method has been use at various times for ETp computation in Nigeria. (Kowal and Knabe. 1972); Garnier, 1960 and Gilchrist, 1961)

It has made the most complete theoretical approach, showing that consumptive use is inseparably connected to incoming solar radiation.

The modified formula is given by:

$$ETp = \frac{D}{D+Y}(Rn + G) + \frac{Y}{D+Y}\,0.26(w_1 + w_2 u_2)(e_z + e_a) \ldots 2.12$$

where,

(a) $D = 33.86[0.05904(0.00738T + 0.80720)^7 - 0.00003420)]$

in mbars/°C.

T = mean temperature (°C)

(b) $Y = \frac{Cp\ P}{(0.622X)}$ (physchrometric constant)

Cp = 0.240 (Constant)

p = mean atmospheric pressure as a function of altitude

(station pressure mbar)

p can also be estimated from;

p = 1013 - 0.1055EL (mbar)

EL = elevation (m)

X = latent heat of water

= 595.5 - 0.55T

(c) $Rn = 0.77R_s - Rb.$

R_s = incident solar radiation (mm/day)

(d) $Rb = Rbo [(a R_s/R_{so}) + b]$

R_{so} = Extra terrestrial Radiation (mm/day)

a,b = empirical constants

$Rb_o = (a_1 + b_1/ea) 0.2 \times 10^{-9} (T^4_a + T^4_b)/2$

a_1, b_1 = empirical constants

Ta = mean maximum temperature (^oK)

Tb = mean minimum temperature (^oK)

(e) G = soil heat flux in $cal/cm^2/day$ = (Tpr - T)9.1

Tpr= mean air temperature for a previous time period, usually previous 3 days when daily estimates of ETp are required.

T = mean air temperature for current time period (i.e, mean air temperature of the particular day ETp estimate is required)

es = saturated vapour pressure (mbar)

ea = mean actual vapour

w_1, w_2 = wind term coefficients; some empirically determined values are:

w_1	w_2	Location	Ref. Crop.
1.10	0.0106	Mitcheu, Nebraska	alfalfa
1.75	0.0115	Kimberly, Idaho	alfalfa
1.00	0.0062	Pennman	shortgrass

u_2 = wind speed at 2m (km/day)

When the wind speed is not measured at 2m, u_2 is estimated from:

$$U_2 = U_z (2/z)^{0.2}$$

U_z = wind speed at height z(m)

values of a, b, a_1, b_1 are:

a	b	a_1	b_1	Location
0.9	0.10	0.37	-0.044	Mitchell, Nebraska
1.35	-0.35	0.35	-0.046	Davis, california
1.22	-0.18	0.33	-0.044	Kimberly, Idaho
1.20	-0.20			
1.10	-0.10			Arid-region (suggested)
1.00	-0.00			Semi-humid (suggested)
		0.39	-0.05	General

For the study, the site is located within the semi-arid region and shortgrass is a common feature of the vegetation. Based on these, the following values of the constants have been used.

w_1 = 1.00)

w_2 = 0.0062) - Pennman/shortgrass

a = 1.10)

b = -0.10) Semi-arid condition

a_1 = 0.39)

b_1 = 0.05) General Conditions

This gave;

$$ETp = \frac{D}{D + Y} (R_n) + \frac{Y}{D + Y} 0.26(1 + 0.0062u2) (e_s - e_a).$$

Assume G = 0.

$R_b = R_{bo} [1.10(^n s/R_{so}) - 0.10]$

R_{bo}= (0.39 - 0.0568-/ea) 2 x 10^{-f} ($T^i a + T^i b$)/2.

$$es = \frac{100ea}{R.H}$$

Where R.H = Relative Humidity (%)

2.5 IRRIGATION WATER QUALITY

A sample of water was collected from the borrow pit for the determination of the following standard parameters:

- Electrical conductivity (EC);
- Total solids content;
- Calcium (Ca^{++});
- Magnesium (Mg^{++});
- Sodium (Na^{+});

- Potassium (K^{+});
- Bicarbonate (HCO_3^{-});
- Chloride (Cl^{-})
- Sulphate ($SO_4^{=}$);
- Boron (B^{+++}); and
- pH Value

The procedures were as given in the standard methods for the Examination of Water and Waste-waters and as per the manufacturers' instructions where instruments were involved. (APHA, 1985).

The quality of irrigation water is determined by its soluble components:

- Total salt content, which is expressed in g/l, meg/l, ppm or by the electrical conductivity (mmhos) which gives an indication of the water quality with regard to salinity hazard;
- Ionic composition: this is important with respect to:

(i) Sodium hazard which is determined by the absolute and relative concentrations of the cations and can be evaluated through the sodium-Adsorption-Ratio (SAR) by the equation:

$$SAR = \frac{Na^{+}}{\sqrt{(Ca^{++} + Mg^{++}) / 2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 2.13$$

where Na^{+}, Ca^{++} and Mg^{++} are the concentrations of the respective ions in mg/l.

Another source of sodium hazard is percent sodium given by:

$$\text{Percent Sodium} = \frac{100Na^{++}}{Ca^{++} + Mg^{++} + Na^{+} + K^{+}} \quad \ldots\ldots\ldots\ldots\ldots\ldots 2.14$$

Sodium hazard can also be evaluated through the Exchangeable sodium percentage (ESP) given by:

$$ESP = \frac{100(-0.0126 + 0.01475\ SAR)}{1 + (-0.0126 + 0.01475\ SAR)} \quad \ldots\ldots\ldots\ldots\ldots\ldots 2.15$$

(ii) Bicarbonate Hazard:

A high concentration of bicarbonates in irrigation water may lead to the precipitation of calcium and magnesium in the soil and thus increasing the relative concentration of sodium and sodium hazard.

Eation introduced the term "Residual sodium carbonate" given by:

$$RSC = (CO_3^{--} + HCO_3^{-}) - (Ca^{++} + Mg^{++})\ mg/l \quad \ldots\ldots\ldots\ldots 2.16$$

Water containing more than 2.5 mg/ RSC is considered not suitable for irrigation; water with RSC from 1.25 to 2.5 mg/l as marginal; and water with less than 1.25 mg/l RSC as safe. (FAO, 1971 No. 9)

(iii) Chloride hazard: Chloride has, generally, no effect on the physical properties of soil and many plants are not more sensitive to it than to sulphate salts. However, excess chloride may be of special importance for some trees and vine crops. Water containing more than 20 mg/l of chloride cannot be used for agriculture under any management condition. (Hasen et al, 1980)

- Minor elements: Among the minor elements, Boron is of special interest in the classification of irrigation water. Boron is

extremely toxic to certain plants, but the concentration which will damage sensitive crops is often necessary for the normal growth of more tolerant crops. Concentration of 0.5mg/l is regarded as safe while concentrations of 4 mg/l and over are considered damaging.

It must be noted that each parameter is important and no attempt should be made to combine the rating into a single index. For example, excess boron might make a water unsuitable even though all other factors are favourable.

The hydrogen ion index is indicated by the pH value. pH value of less than or equal to 8.5 means the water is saline; about 8.5 means saline-alkali and between 8.5 and 10.0 is alkali.

The results of the water sample analysis are presented in table 4.1

LIMITING VALUE FOR IRRIGATION WATER

Evaluation Rating	EC (mm hos)	Na^+ %	SAR	Na_2CO_3 (meg/l)	Cl^- **	ES **	BORON **
1	0.5	40	3	0.5	3	4	0.5
2	1.0	60	6	1.0	6	8	1.0
3	2.0	70	9	2.0	10	16	2.0
4	3.0	80	12	3.0	15	24	3.0
5	4.0	90	13	4.0	20	32	4.0

Where,
** = (meg/l)

1 - Excellent for agriculture

6 - Cannot be used for agriculture under any management conditions
(i.e, with values greater than those in rating 5)

Source: Hausen, V. E. et al, 1980) Irrigation Principles and Practices

SALINITY VALUES IN IRRIGATION WATER

Salinity of Water (mmhos)	Salinity hazard	
< 0.25	Low	Suitable for most crops and soil.
0.25 - 0.75	Medium	Suitable for moderately salt tolerant crops.
0.75 - 2.25	High	Not suitable for low permeable soils.
> 2.25	Very high	Generally not suitable for irrigation.

Source: Civil engineer's Reference Book (1989).
Blake, L. S. (Editor).

2.6 ECONOMIC IMPACT APPRAISAL

The input data for the analysis of primary economic benefits of the irrigation scheme were obtained through the use of structured questionnaire (see appendix A5) and from oral interviews with the farmers.

The harvest of the irrigated crops was carefully monitored by the author and where this was not possible, production figures were obtained from the farmers.

The prices quoted were the unit prices of the produce on the farm at the time of harvest.

The data for the estimation of the secondary economic benefits were obtained from the Annual Abstract of Statistics of the Federal Office of Statistics and includes the gross domestic product (GDP) at current factor costs, gross domestic savings (GDS), government taxation receipts, imports expenditure and composite consumer price index which were used to compute the following marginal propensities:

- marginal propensity to save (MPS) given by:

$$MPS = \frac{GDS}{GDP} \times \frac{100}{1}$$

- marginal propensity to consume (MPC) given by:

$$MPC = 100\% - MPS$$

- marginal propensity to tax (MPT) given by:

$$MPT = \frac{\text{Taxation Receipts}}{GDP} \times \frac{100}{1}; \text{ and}$$

- marginal propensity to import (MPI) given by:

$$MPI = \frac{\text{Imports}}{GDP} \times \frac{100}{1}.$$

- The multiplier factor (m.f.) is given by:

$$m.f. = \frac{1}{(MPS) + (MPI)}$$

2.6.1 ASSUMPTIONS IN THE COMPUTATION OF FIXED COST COMPONENTS.

Fixed cost items are cost items which do not alter very much with small changes in the scale of an enterprise. For example machinery costs.

The value of these items depreciates or appreciates with time depending on the prevailing economic situation at the time. The depreciated value (which is calculated on the basis of the lending rate and the number of years from the time of purchase) is used in the computation of the total cost of production.

In this study, 1989 was used as the base or future year because the lending rate was relatively stable throughout the year as compared to the year 1990 to 1992 (the year of study).

In this study the fixed cost components were the petrol engine water pump and farm implement (hoes and cutlasses).

- The economic life of the pumps used for the irrigation is 20 years. (Linksley and Franzini, 1972).
- The economic life of the farm implement (hoes and cutlasses) is 5 years.
- The values of the water pumps and their accessories at the time of their purchase were converted to a common future (1989) values at a lending rate of 30%.

  Thus the future nominal value FNV = $(1 + i)^5$ x purchase value.

Where i = Lending rate

n = number of years from the time purchase to 1989.

- All fixed cost components and the future nominal values of petrol engine water pumps and their accessories were depreciated using the straight live approach.

2.6.2 LINKAGE COEFFICIENT CALCULATIONS

Linkage coefficient is the ratio of the cost of purchasing a basket of say tomato, in the market from marketers to the cost of purchasing the same basket of tomato on the farm (i.e, directly from the farmer). While linkage is the income received by the firms or households that is not passed on to other group by buying goods or services directly form it (the other group in this is the farmer).

2.6.2.1 LINKAGE COEFFICIENT FOR TOMATO

The cost of one basket of tomato ex-farm was =N= 30.00 in January to February 1992 and =N= 40.00 in the market.

This means that there was a weighted average mark-up of about 33% between farm and the market.

Therefore, there would be =N= 0.33 of extra income in the linked activities off the farm for every =N= 1.00 earned on the farm in tomato production. This gave a linkage coefficient for tomato of 1.33. This figure may be more if the baskets of tomato were

taken outside Zaria to as far south as Lagos. The linkage coefficients of other crops were similarly calculated.

2.6.3 MULTIPLIER FACTOR OR MULTIPLIER

The multiplier in an economy is the ratio of the change in the National Income to the change in the autonomous expenditure that brought about it. (Adegeye and Dittoh, 1985).

The multiplier measures the magnitude of the swings in equilibrium of National income that accompany shifts in autonomous expenditure.

Mathematically, the multiplier factor is given by:

$$\text{Multiplier factor (m.f)} = \frac{1}{(MPS) + (MPI)}$$

where,

MPS = marginal propensity to save assumed equal to the average percentage of the national income saved between 1981 and 1986, given by $\frac{\text{Gross Domestic Savings}}{\text{Gross Domestic Product.}}$

(ie, $\frac{\text{Row2}}{\text{Row1}}$ table 5.3)

= 0.134 (table 5.3)

MPI = marginal propensity to import (taken from Federal Government statistics for the same year) = 0.130 (Table 5.3)

Therefore,

$$m.f. = \frac{1}{0.134 + 0.130} = \frac{1}{0.264}$$

$$m.f. = 3.79$$

2.6.4 ASSUMPTIONS

The assumptions are:

- That there is no accelerator effect, that is, no further investment arising in response to the increases in national income already given;
- That there is no opportunity cost, that is, the labour would, otherwise, have been unemployed;
- That the marginal propensity to tax and import will continue to be as derived from Table 5.3;
- That the money supply expends only rapidly enough to allow the real increase in production as given in Table 5.2 column 6, to be sold at constant prices.

CHAPTER 3

3.0 PHYSICAL CHARACTERISTICS OF THE STUDY AREA

3.1 CLIMATE

The climate is characterized by a well-defined rainy season, with about 952mm long term mean annual rainfall, which normally begins in late April and ends early in October. On the average, the rainfall is greater than or equal to the potential evapo-transpiration (ETp) during the period from the end of June to the end of August and in general, lack of water does not limit production of crops this period.

The rate of potential evapo-transpiration varies from 5.3mm/day in August to 14.6mm/day in February while the free water surface evaporation varies from 2.6mm/day in August to 16.6mm/day in March.

The average total incident radiation varies from 7.4mm/day at the peak of rainfall in August to 9.4mm/day towards the end of the dry season in April.

The dry season, which lasts for about five months, is severe with low relative humidity and a drying North east Trade Wind - the hamattan.

The mean daily temperature varies from 21.4°C in January to 29.5°C towards the end of the dry season in April with an annual mean of 25.3°C.

The temperature, evaporation and incident solar radiation vary moderately from year to year with coefficients of variation ranging from 0.01 - 0.09, 0.06 - 0.32, and 0.04 - 0.09 respectively.

The standard deviation and coefficients of variation of the three weather elements are shown in Table 3.1.

3.2 VEGETATION

The site lies within the Northern guinea vegetational belt.

The vegetative cover is classified as Sudanian woodland with abundant isoberlinia. (LRDC,VOL.7,1981)

TABLE: 3.1 MEANS AND VARIATIONS OF TEMPERATURE, EVAPORATION AND RADIATION

MONTH OF THE YEAR	TEMPERATURE			EVAPORATION			INCIDENT RADIATION		
	MEAN OF THE MEAN (o/C)	STANDARD DEVIATION	COEFFICIENT OF VARIATION	MEAN (mm/day)	STANDARD DEVIATION	COEFFICIENT OF VARIATION	MEAN (mm/day)	STANDARD DEVIATION	COEFFICIENT OF VARIATION
JANUARY	21.4	1.9	0.09	13.7	1.0	0.07	8.1	0.70	0.09
FEBRUARY	24.4	1.7	0.07	16.0	1.3	0.08	9.1	0.60	0.07
MARCH	28.0	1.1	0.04	16.6	2.2	0.13	9.3	0.60	0.07
APRIL	29.5	1.0	0.03	13.7	3.5	0.26	9.4	0.65	0.07
MAY	28.1	1.2	0.04	7.8	2.5	0.32	8.7	0.50	0.06
JUNE	26.1	0.3	0.01	4.8	0.8	0.17	8.0	0.35	0.04
JULY	24.7	0.5	0.02	3.1	0.5	0.16	7.4	0.55	0.07
AUGUST	24.6	0.4	0.02	2.6	0.5	0.19	7.4	0.65	0.09
SEPTEMBER	25.2	0.4	0.02	3.1	0.2	0.07	8.3	0.60	0.07
OCTOBER	25.6	0.5	0.02	6.5	1.6	0.25	8.9	0.50	0.06
NOVEMBER	23.9	0.9	0.04	11.3	0.7	0.06	8.9	0.60	0.07
DECEMBER	22.0	1.3	0.06	12.3	0.8	0.07	7.9	0.55	0.07

Period of Data: 1981 - 1991

3.3 HYDROGEOLOGY OF PROJECT AREA

The geology of the study area may be described as comprising of the pre-cambrian basement complex which covers more than half of northern Nigeria. The basement complex includes the oldest known rock formations in Nigeria and is principally composed of metamorphic and igneous rocks, such as granites, gneiss and migmatities. Outcrops of the underlying basement complex are visible features on the pit bottom, up stream and eastern portions of the site. The average depth of the overburden is of the order of 2.5m.

Ground water occurs in the basement complex either in the weathered mantle or in the joints and fracture or fissure systems in the unweathered rock formations.

The presence of ground water in any area, therefore, depends on weather sufficient thickness and the extent of decomposed material exists to provide reservoir or weather joints and fractures or fissures are present in the rock.

Basement complex is generally known to form a poor source of ground water. The decomposed mantle is often too thin to harbour appreciable quantities of water and is also usually too clayey to be highly permeable. The average depth of well in basement complex is usually 37m. (Du Preez and Barbar 1965)

But within the study site, the water-table is relatively high about 2.90m at the lowest, which points to the existence of a permeable formation close to the surface. The presence of the ground water in the study site, therefore, could be attributed to the fissures and the weathered materials which can be observed within the pit or to parched aquifers.

The build up of high-water-table gradients during rainfalls has several important consequences for agricultural production. First, the high water table contributes to greater surface runoffs and accelerated erosion; second, because of the greater runoff, erosion, and leaching, there is considerable loss of plant nutrient. However, a greater portion of the study area is moderately drained. Runoff is relatively pronounced about 40% of the gross command area and at the sides of the pit. This is evident by the presence of a fine network of slope rills (furrows) which link up into a channel network incised to varying degrees depending on the resistance of the rock formation.

In contrast, the plains are mantled with fine detritus, which initially absorbs much of the rainfall. From the outset, runoff turns to be diffused and its subsequent
contraction into linear flows is opposed by lack surface storage and by the high sediment load.

3.4 SOIL DESCRIPTION

The study area is covered by the ferruginous tropical soils considered to be the zonal soils developed under the prevailing climatic conditions.

They are highly weathered and marked laterised by the loss of silica. The resulting free metal oxides from the high proportion of clay fraction often coat the quartz and crystalline clay particles of Kaolimite (Kowal and Knabe, 1972). Thus they may be classified as cambisols.

The bulk density of the surface soil varies from 1.4g/cm^3 to 1.6g/cm^3.

The water holding capacity is good and the final rate of intake of water by the soil is moderate (see Table 3.2).

Hydrologically, soils or soil group may be classified according to the soil-cover complexes for the purpose of hydrologic analysis of a watershed data. Four major soil groups are recognized for the primary classification of watershed soils:

- Group A (low runoff potential)
- Group B
- Group C and
- Group D (high runoff potential)(Chow, 1964)

For detailed description of the various groups see Appendix B.1 From the results of the site's soil sample analysis, the soil can be categorized into group B.

For agricultural purposes, it may be described as sandy clay loam. It is suitable for cereal, especially, maize and millet production.

The land treatment may be described as straight-row farming, that is a type of farming where ploughing, planting, cultivation and other farm operations are carried on without regard to the slope of the land (Chow, 1964)

TABLE: 3.2 SOIL PROPERTIES

SOIL CHARACTERISTICS	MEASURED VALUE	
	RANGE	MEAN
Specific Gravity	2.30 - 2.58	2.44
Bulk Density (g/cm^3)	1.4 - 1.6	1.5
Void Ratio (e)	0.47 - 0.64	0.56
Porosity (n)	0.32 - 0.39	0.36
Hydraulic Conductivity (cm/sec)	0.001-0.003	0.002
Particles Size Distribution Sand (%)		63.0
Silt (%)		25.9
Clay (%)		11.1
Field Capacity	12.3 - 27.3	18.2
Permanent Wilting Point(%)	3.4 - 9.0	5.6
Available Moisture (%)	8.6 - 19.3	12.6
Final Infiltration Rate (mm/hr).	5.4 - 38.5	22.5

Date August 1992.

3.5 WATER-BUDGET ANALYSIS:

The objective of most surface and ground water studies is to determine how much water is available for development. The objective can be achieved after the identifications of the various physical features of the hydraulic system, determination of hydraulic properties of these features, and the understanding

of how they are related to one another. This must be followed by the determination of water quantities in transit in the area. This determination is commonly refered to as water-budget analysis.

The establishment of the hydrologic balance in the soils of an area or a country is essential for the control and management of available water resources.

It is particularly important in northern Nigeria, the region within which the study area is located, for two reasons. First, the rainfall, though moderately high, is limited to one short season during which crops are grown and it is important to assess the adequacy of the rainfall of rain-fed crops; and second, irrigation schemes are being introduced and information is required on the amount of water which can be controlled and used for growing crops out of season.

Water-budget analyses are based on the premise that a balance exist between the quantity of water entering an area, changes in the amount of water stored in the area, and the water leaving the area.

This balance is expressed in the equation of hydrologic equilibrium, which, in its simplest form is:

$$I = O \pm DS \qquad 3.1$$

where ,

I = Inflow

O = outflow

DS = Change in storage.

It is apparent that each of the elements in equation 3.1 may include several different items. The most significant are:

(i) Inflow items:

- Surface inflow;
- Subsurface inflow
- Rainfall; and
- Imported water

(ii) Outflow items:

- Surface outflow;
- Subsurface outflow;
- Evapotranspiration; and
- Exported water

(iii) Storage items:

- Change in surface storage;
- Change in ground-water storage;
- Change in soil moisture.

Some of these items can be measured readily and with considerable accuracy; others are difficult, if not impossible

to measure. Among the easiest to measure are the imported and exported water. In the study area there was neither exportation nor importation of water and so the items were eliminated. The rainfall data from NCAT weather station were used because of proximity.

Changes in soil moisture could be measured with a fair degree of accuracy through the use of a neutron scatter meters. But this item was not measured in this study. However for a water-budget period of approximately one year, the storage items are not significant and thus they were ignored (Health and Trainer, 1968).

No surface and subsurface outflow from the study area and thus the items were eliminate.

The Evapotranspiration, on the other hand, is extremely difficult to measure and it was therefore determined by empirical methods.

The surface and subsurface inflow represented the surface run-off and seepage respectively in the study area. The run-off was computed using empirical equation while the seepage was estimated using Darcy's equation using well water-table depths.

This reduce the hydrologic equilibrium equation to:

$$R + Q = ETp + \text{Seepage loss} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad 3.2$$

where,

R = Rainfall

Q = Total run-off

(surface run-off + seepage)

ETp = Evapotranspiration

3.5.1. RAINFALL

3.5.1.1. RAINFALL VARIATION

Rainfall variability is characterized mostly by the mean (x) of the data and the standard deviation (s). The standard deviation measures the spread or variation of individual data. The smaller the value of, (s), the smaller the variation.

Another parameter is the coefficient of variation (CV) given as:

$$CV = \frac{s}{x} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 3.3$$

The coefficient of variation measure variation as a percentage of the mean. Values of CV less than 0.20 indicate moderate variations and for most purposes an acceptable length of data series.

The results of the analysis of the variation of rainfall in the study area is presented in table 3.3.

From the results, it is apparent that rainfall in the area is highly variable.

3.5.1.2. RAINFALL FREQUENCY

Because the variability of rainfall from year to year, criteria for planning water supplies cannot be based on average rainfall; since this would mean, in most cases, a rainfall which may occur one year out two; rather a dependable level of rainfall should be selected (say, a rainfall that can be expected three out of four years or four out of five years).

Assuming that there is no change in the factors that cause or are causing rainfall, on the basis of available records, a prediction is made on rainfall probability in future or depth of rainfall that may be expected 70%, 80% or 90% of the time.

A higher level of dependable rainfall may need to be selected during the period that crops are germinating or are most sensitive to water stress and yields are severely effected.

There are several methods of computing rainfall probability in literature. But the one most commonly used, especially for classified data distribution, is the cumulative frequency method. The rainfall frequency, by this method, is given as:

$$f = \frac{100m}{1 + n} \quad \ldots\ldots\ldots\

TABLE 3.3 RAINFALL VARIATION AND FREQUENCY

MONTH OF YEAR	MEAN TOTAL RAINFALL (mm) ±	STANDARD DEVIATION (S)	COEFFICIENT OF VARIATION (V)	DEPENDABLE RAINFALL WITH PROBABILITY OF OCCURRENCE OF (MM)				
				70%	80%	90%	95%	99%
JANUARY	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0
FEBRURY	0.3	1.1	3.67	0.0	0.0	0.0	0.0	0.0
MARCH	13.7	23.9	1.75	0.0	0.0	0.0	0.0	0.0
APRIL	27.7	29.3	1.07	0.0	0.0	0.0	0.0	0.0
MAY	121.9	74.7	0.61	80.0	67.5	52.5	42.0	22.0
JUNE	112.2	30.4	0.27	92.0	85.0	77.0	60.0	60.0
JULY	224.2	62.0	0.28	182.0	162.5	137.5	118.0	87.5
AUGUST	285.1	73.4	0.26	230.0	202.5	170.0	147.5	105.0
SEPTEMBER	130.8	50.5	0.39	92.0	76.5	57.0	42.5	17.5
OCTOBER	36.5	45.6	1.25	0.0	0.0	0.0	0.0	0.0
NOVEMBER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DECEMBER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	952.0			676.0	593.5	494.0	420.0	292.0

3.5.2 TOTAL RUN-OFF

The total run-off term is composed of two parts: the overland flow and the water that has infiltrated into the ground and move through the zone of saturation. Thus:

$$Q = Q_0 + Q_s$$

Where,

Q^0 = overland run-off

Q_s = seepage or ground water discharge.

3.5.2.1 OVERLAND FLOW

In the study area, the overland flow may be divided into two components;

- the run-off from the land surface into the pit; and
- the run-off within the pit area.

The annual run-off from the land surface into the pit was estimated empirically by:

$$Q_{10} = \frac{1.911(R)^{1.44}}{T^{1.34}_{a} \quad A^{0.0613}} \quad \text{(Laland \& Russel, 1981)} \quad .. \quad 3.5.$$

where

Q_{10} = annual run-off (cm)

R = annual rainfall (cm)

T_a = mean annual temperature (^{0}C)

A = area of land surface that drains into the pit (Km^2)

From the hydrological data,

R = 95.2cm; T_a = 25.3^{0}C; and from the survey map of the area, A

Annual run-off from land surface into the pit is 12,605m^3.

The run-off within the pit was estimated by assuming that all the rains that fall within the pit are converted to run-off because of the near impervious bottom. Thus, the run-off within the pit was estimated by:

$Q_{20} = RAp$

where,

R = annual rainfall (m)

Ap = surface area of the borrow pit

= 42960m^2.

Therefore Q_{20} = 0.952 x 42960

= <u>40898m^3</u>

Total overland run-off = $Q_{10} + Q_{20} = Q_0$

Q_0 = 40898 + 12605

= <u>53503m^3</u> per annum

3.5.2.2 SEEPAGE INFLOW INTO THE PIT

Seepage inflow is given by:

$Q_i = KiAt$ 3.6

where,

Q_i = seepage inflow quantity (m^3).

K = hydraulic conductivity of the soil material (m/day)

i = hydraulic gradient

$= \frac{\text{flow head}}{\text{length of flow path}}$

A = Cross-sectional area of flow measured perpendicular to the direction of flow (m^2)

t = flow time (day).

The average hydraulic conductivity of the soil material in the study area is 0.002cm/sec (or 1.72m/day).

The hydraulic gradient can be determined from ground water table contours or elevations of an area. To estimate the local ground water contours and flow directions, a minimum of three wells are acquired. (Todd, 1980).

In the study area, however, only two wells exist. And therefore it was not possible to estimate the local ground water contours for the area and thus possible to estimate the hydraulic gradient by this means. In the alternative, the ground water table elevations in the two wells and the distance between the wells were used to roughly estimate the hydraulic gradients, i,

as follows:

$$i = \frac{EL_u - EL_d}{L}$$

where,

EL_u = Elevation of groundwater table in the upstream well.

EL_d = Elevation of groundwater table in the downstream well (based on the ground surface topography)

L = Distance between the wells.

EL_u = 634.5m

EL_d = 630.8m

L = 221.5m

Thus,

$$i = \frac{634.5 - 630.8}{221.5} = \underline{0.0167}$$

The flow area, A, is diffused and not defined, and therefore difficult to measure, hence it was not measured or estimated. Thus the annual seepage inflow,

$Qg = 1.728 \times 0.0167 \times 273$

$= 7.88m^3$/unit area.

Note: No seepage inflow was observed in March, April, and May, hence the 273 days.

The total annual run-off therefore equals $53503m^3 + 7.88m^3$ per unit area.

Possible storage (from contour map) equals $57888m^3$ per annum.

3.5.3 EFFECTIVE STORAGE

The actual pit storage is the possible storage less evaporation and seepage outflow.

3.5.3.1 EVAPORATION

The annual amount of evaporation over the study area averages 3375.6mm. This is only 116.9mm less than evapotranspiration over the same area. There is therefore a very close relationship between the evaporation amount (Ep) and evapotranspiration (ETp).

The regression-correlation analysis of ETp and Ep data shows that they are very highly correlated with correlation coefficient of 0.93 and standard error of estimate of 1.27. This gave a regression equation of:

$ETp = 4.77 + 0.52Ep +- 1.27$

The annual evaporation loss (E_L) was estimated by:

$$E_L = A_{sw} \times Ep$$

where,

A_{sw} = average surface area of the impounded water

Ep = annual evaporation

$A_{sw} = 9648m^2$

Ep = 3.3756m.

Thus: $E_L = 9648 \times 3.3756$

$= \underline{32568m^3}$

3.2 SEEPAGE OUTFLOW

Because of the near impervious pit bottom, the seepage outflow was assumed to be negligible. Therefore,

effective pit storage = 57888 - 32568 + seepage inflow.

= 25320m^3 + seepage inflow or 7.88m^3/m^2.

The summary of the water-budget analysis is presented in Table 3.4. It shows a water deficient of 2696.4mm and a water surplus of 155.9mm. The ETp requirement is satisfied only in July and August with surpluses.

Figure 3.2 shows the histogram of the long-term mean total monthly rainfall and ETp which is lowest at the peak of rainfall.

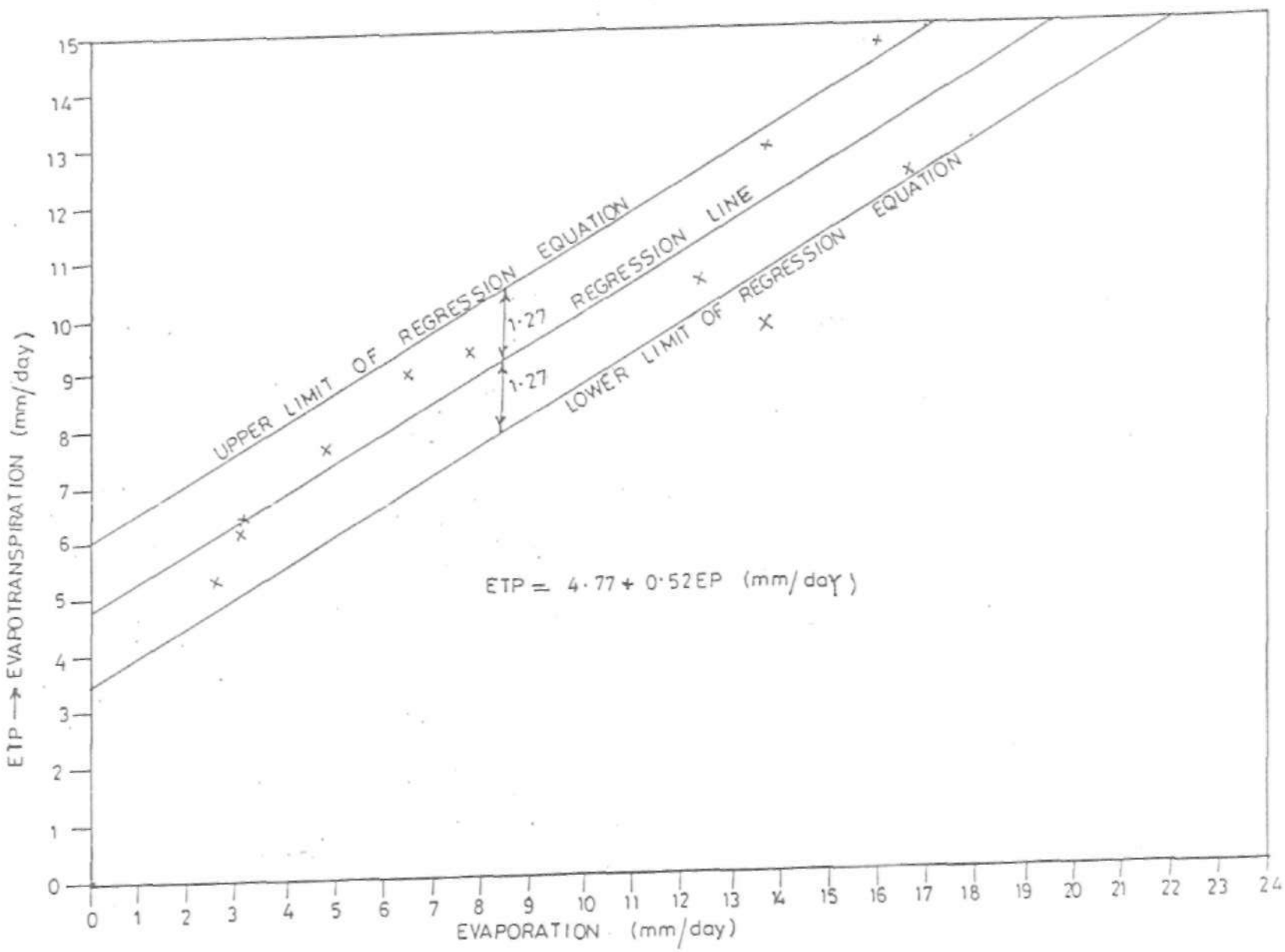


FIGURE: 3·1 EVAPOTRANSPIRATION (ETP) VERSUS EVAPORATION (EP)

TABLE: 3.4 NOTIONAL WATER BUDGET FOR THE PROJECT AREA

	ET (mm/day)	TOTAL ETP (mm)	TOTAL RAINFALL (mm)	WATER DEFICIT (mm)	WATER SURPLUS (mm)	MEAN RAINY DAYS: LENGTH OF RAINY PERIOD: 1980			
						BEGINNING OF		END OF	
						RAINY SEASON	GROWING SEASON	RAINY SEASON	GROWING SEASON
JANUARY	9.7	300.7	0.0	300.7	-				
FEBRUARY	14.6	412.5	0.3	412.2	-				
MARCH	12.3	381.3	13.7	367.6	-	x			Ø
APRIL	12.8	384.00	27.3	356.7	-				
MAY	9.3	288.3	121.9	166.4	-		x		
JUNE	7.6	228.0	112.2	115.8	-				
JULY	6.1	189.1	224.2	-	35.1				
AUGUST	5.3	164.3	285,1	-	120.8				
SEPTEMBER	6.4	192.0	130.8	61.2	-				
OCTOBER	8.9	275.9	36.5	239.4	-				
NOVEMBER	11.8	354.0	0.0	354.0	-		Ø		
DECEMBER	10.4	322.4	0.0	322.4	-				
TOTAL		3492.5	952.0	2696.4	155.9				

Ø = Irrigation (dry farming) season

x 0 Rainy/wet farming season.

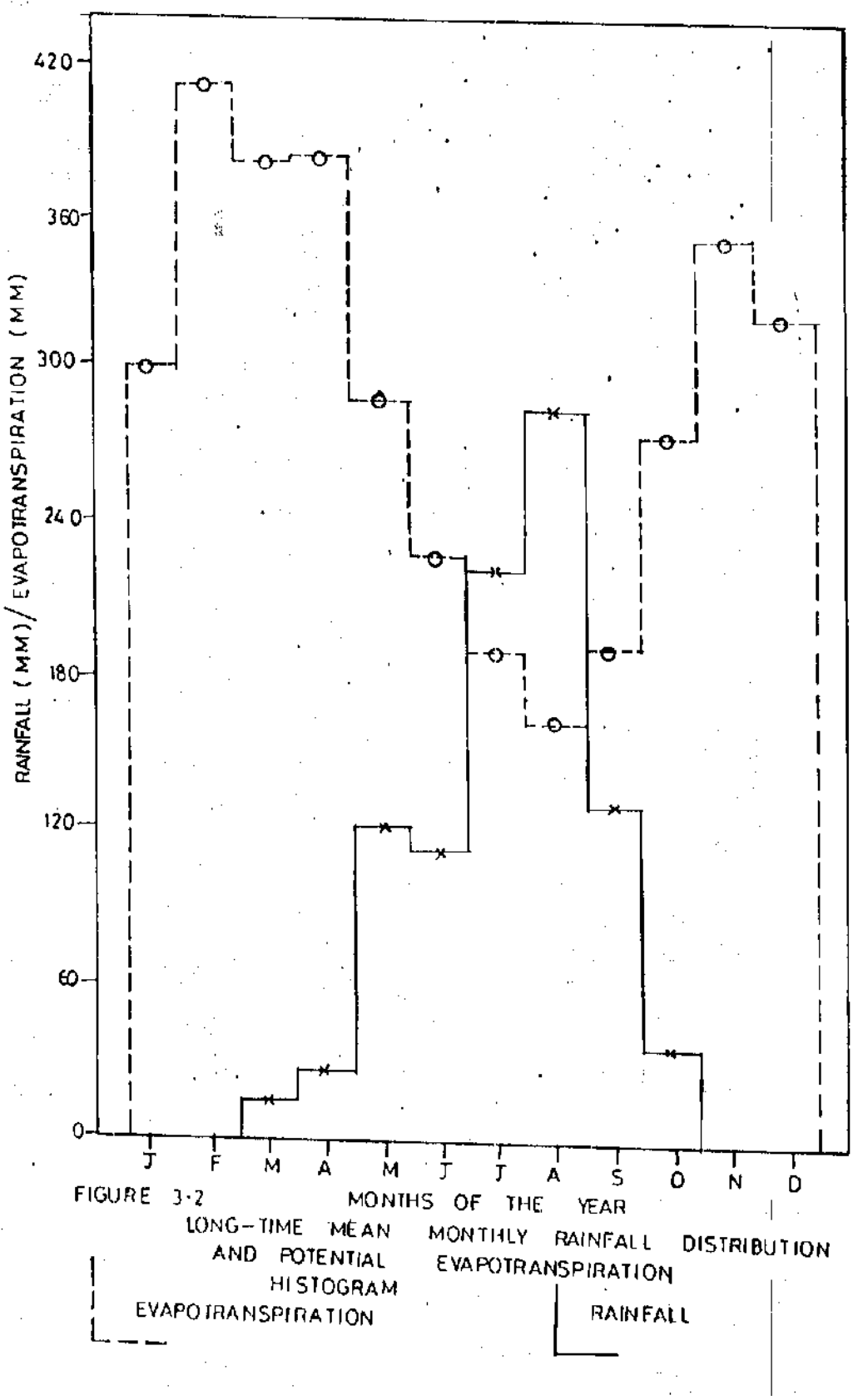


FIGURE 3-2 LONG-TIME MEAN AND POTENTIAL EVAPOTRANSPIRATION HISTOGRAM

MONTHLY RAINFALL DISTRIBUTION

3.6 SEDIMENT DEPOSITION IN THE PIT

Sand, silt and clay materials which are being washed into the pit annually by the surface run-off in the study area pose a serious threat to the survival of the irrigation scheme because it results in the reduction of the pit volume. In fact, similar schemes had failed in the past as a result of this factor (Hocking and Thomson, 1979).

In the study area, the presence of deep gullies around and within the pit indicates high erosion rate and this means high rate of sediment deposition since most of run-off is collected by the pit.

But during the period of study it was not possible to estimate the annual amount of sediment deposited.

However, it is apparent that the amount of sediment deposition is considerable and could fill up the pit and thus terminate the irrigation scheme if no measures are taken to remove the sediment on annual basis.

CHAPTER FOUR

4.0 IRRIGATION REQUIREMENTS

The calculation of gross irrigation water requirement for a given cropping pattern and intensity includes the net irrigation requirements, the evaluation of the water quality, the leaching requirement and efficiency of the irrigation system.

The net irrigation requirements (IR) is the amount of water needed to satisfy the crop water requirement (ET crop). However, part of ET crop is met by effective rainfall (Re), ground water contribution (Ge) and stored soil water (Wb).

That is:

IR = ET crop - Re - Ge - Wb.

A proper assessment of the ET crop, effective rainfall (Re), ground water contribution (Ge), stored soil water (Wb), leaching requirement (LR), and the efficiency of the supply system are essential for the computation of irrigation requirements.

A study of the save limit of salt in irrigation water and of the conditions under which saline water may best be used for irrigation is essential to complete an intelligent utilization of semi-arid and arid regions resources.

The amount and kinds of salt present in the irrigation water should be s guide to necessary management if the water is to be used successfully.

For accurate evaluation of irrigation design, project operation and irrigation scheduling, a knowledge of the infiltration phenomenon is also essential.

.1 WATER QUALITY

The results of the analysis of the irrigation or pit water in the study area are presented in Table 4.1. The high value of the total solids content is not unexpected since the pit water is mainly from surface run-off which is highly loaded with sediments.

From the result of the water analysis and allowable limiting values of the parameters in Table 4.1, the water can be described a being suitable for irrigation of most crops on most soil types. (Hausen et al, 1980, FAO, No. 7, 1971, and FAO, No. 24, 1977).

Table 4.1 Water Sample Test Results

WATER CHARACTERISTICS	TEST VALUE
Electrical Conductivity (EC)(mmhos/cm)	0.131
Total Solids (mg/l)	600.00
Calcium, Ca^{++}, (mg/l)	35.42
Magnesium, Mg^{++}, (mg/l)	90.84
Sodium, Na^{+}, (mg/l)	9.25
Potassium, k^{+},(mg/l)	5.65
Bicarbonate, HCO^{-3} (mg/l) $CaCO_3$	39.58
Chloride, Cl^{-}, (mg/l)	1.53
pH Value	7.8
Sulphate, SO^{-4}, (mg/l)	150.0
Boron, B, (mg/l)	0.0
Sodium Absorption Ratio (SAR)	1.16
Exchangeable Sodium Percent (ESP) (mg/l)	0.45
Percent Sodium (%)	6.55
Residual Sodium Carbonate RSC (mg/l)	0.0

LIMITING VALUES

Electrical Conductivity (EC) (mmhos/cm)	0.5 - 4.0
Percent Sodium (%)	40 - 90
Sodium Absorption Ratio (SAR)	3 - 13
Chloride (Cl^-) (mg/l)	50 - 600
Exchangeable Sodium (ESP) (mg/l)	4 - 24
Boron (B) (mg/l)	0.5 - 4.0
Residual Sodium Carbonate (RSC) (mg/l)	< 1.25

August 1992

4.2 CROP WATER REQUIREMENTS (ET crop)

ET crop value relates to evapotranspiration of a disease - free crop grown in large fields under optimum soil water and fertility conditions and achieving full production potential under the giving growing environment.

ET crop is given by:

$$ET\ crop = K_c ETp \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 4.1$$

where,

ET crop = crop water requirement (mm/day)

K_c = crop coefficient which is a function of crop characteristics, time of planting and stages of crop development and the general climatic conditions.

ETp = potential evapotranspiration.

Dooren Bos and Pruitt, (FAO, 1977 No. 24)

The water requirement for irrigations are based on ET crop. The water requirements as determined permit optimum production under the given growing environment.

The ET crop (mm/month) is weighted for hectarage to obtain the total ET crop for the growing season. That is, for the study area, ET crop total is given by:

$$ETcrop\ (total) = \left[\frac{1.2214}{2.5929}\right] Et\ Tomato + \left[\frac{0.08}{2.5929}\right] ET\ peppers + \left[\frac{0.65}{2.5929}\right] ET\ wheat + \left[\frac{0.35}{2.5929}\right] ET\ maize + \left[\frac{0.2915}{2.5929}\right] ET\ okra$$

: rounded off to the nearest whole number.

The results are presented in Table 4.2. From the table, the total ET crop for the growing or irrigation season is 920mm.

TABLE : 4.2 CROP WATER REQUIREMENT

MONTH OF THE YEAR	ETP (mm/day)	Kc Tomatoes	ET Tomatoes (mm/day)	ET Tomatoes (mm/month) 1.2214 ha)	Kc Peppers	ET Peppers (mm/day)	ET Pepper (mm/month) (0.08 ha)	Kc Wheat	ET Wheat (mm/day)	ET Wheat (mm/month) (0.65ha	Kc Maize	Et Maize (mm/day)	ET Maize (mm/ (0.35	Kc Okra	ET Okra (mm/day)	ET Okra (mm/month (0.29 15ha)	TOTAL
JANUARY	9.7	1.25	12.1	376	1.0	9.7	301	1.2	11.6	361	-	-	-	-	-	-	277
FEBRUARY	14,6	0.65	9.5	268	0.9	13.1	371	0.2	2.9	83	-	-	-	-	-	-	159
MARCH	12.3	-	-	-	-	-	-	-	-	-	0.3	3.7	155	0.3	3.7	155	28
APRIL	12.8	-	-	-	-	-	-	-	-	-	0.6	7.7	231	0.6	7.7	231	57
MAY	9.3	-	-	-	-	-	-	-	-	-	1.15	10.7	332	1.1	10.2	316	80
JUNE	7.6	-	-	-	-	-	-	-	-	-	0.6	4.6	138	0.6	4.6	138	34
JULY	6.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AUGUST	5.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SEPTEMBER	6.4	-	-	-	0.3	1.9	57	-	-	-	-	-	-	-	-	-	2
OCTOBER	8.9	-	-	-	0.7	6.2	192	-	-	-	-	-	-	-	-	-	6
NOVEMBER	11.8	0.3	3.5	105	1.1	13.0	390	0.3	3.5	105	-	-	-	-	-	-	88
DECEMBER	10.4	0.75	7.8	242	1.1	11.4	353	0.8	8.3	257	-	-	-	-	-	-	189
				991			1664			806			816			800	920

Tomato = 1.2214ha: peppers = 0.08ha; wheat = 0.65ha; Maize = 0.35ha; Okra = 0.2915ha

4.3. EFFECTIVE RAINFALL (Re)

The effective rainfall (Re) is the amount of rainfall that is effectively used by the growing crop(s). Not all rainfall is effective. Some part may be lost by surface run-off, deep percolation or evaporation.

Effective rainfall is related to the mean monthly rainfall, the mean monthly ET crop and the effective storage over the root zone of the crops. A number of methods for estimation of effective rainfall are available in literature. For this study area it was estimated by the evapotranspiration/rainfall ratio method developed by U.S.D.A, 1969 (reproduced in Table c.).
The effective storage over the root zone in the area = 125mm.
The corresponding correction factor was multiplied by the effective rainfall to obtain the values in Table 4.3.

4.4. GROUNDWATER CONTRIBUTION (Ge)

The contribution from ground water table is determined by its depth below the root zone, the capillary properties of the soil and the soil water content in the root zone.
Under field conditions, very detailed experiments will be required to determine the ground water contribution. And so it is not considered in the computation of the gross irrigation water requirement for the study area.

TABLE: 4.3 COMPUTATION OF EFFECTIVE RAINFALL

MONTH	TOTAL MONTHLY RAINFALL (mm)	ETcrop (Tomatoes) (mm)	Effective Rainfall (mm)	G/Water Contribution (mm)	ETcrop (Peppers) (mm)	Effective Rainfall (mm)	G/Water Contribution (mm)	ETcrop (Wheat) (mm)	Effective Rainfall (mm)	G/Water Contribution (mm)	Etcrop (Maize) (mm)	Effective Rainfall (mm)	G/Water Contribution (mm)	ETcrop (Okra) (mm)	Effective Rainfall (mm)	G/Water Contribution (mm)
JAN.	0.0	376	-	-	301	-	-	361	-	-	-	-	-	-	-	-
FEB.	0.3	268	-	-	371	-	-	83	-	-	-	-	-	-	-	-
MARCH	13.7	-	-	-	-	-	-	-	-	-	115	8	-	115	8	-
APRIL	27.3	-	-	-	-	-	-	-	-	-	231	27	-	231	27	-
MAY	121.9	-	-	-	-	-	-	-	-	-	332	114	-	316	114	-
JUNE	112.2	-	-	-	-	-	-	-	-	-	138	82	-	138	82	-
JULY	224.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AUG	285.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SEPT.	130.8	-	-	-	57	80	-	-	-	-	-	-	-	-	-	-
OCT.	36.5	-	-	-	192	34	-	-	-	-	-	-	-	-	-	-
NOV.	0.0	105	-	-	390	-	-	105	-	-	-	-	-	-	-	-
DEC.	0.0	242	-	-	353	-	-	257	-	-	-	-	-	-	-	-
TOTAL	952	991			1664	114		806			816	231		800	231	

4.5 LEACHING REQUIREMENT (LR)

The leaching requirement is the minimum amount of irrigation water supplied that must be drained through the root zone to control soil salinity at the given specific level. For sandy loam to clay loam soils with good drainage and where rainfall is low, the leaching (LR) requirement can be obtained from:

For surface irrigation methods

$$LR = \frac{EC_w}{5EC_e - EC_w} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4.2$$

Where

EC_w = electrical conductivity of irrigation water (mmhos)

EC_e = electrical conductivity of the soil saturation extract for a given crop appropriate to the tolerable degree of yield reduction.

For the crops in the study area, the Ec_e values at different degrees of yield potential are given in Table 4.4 below.

TABLE 4.4 CROP SALT TOLERANCE LEVELS

CROP	YIELD POTENTIAL 100% ECe	100% ECw	90% ECe	90% ECw	75% ECe	75% ECw	50% ECe	50% ECw	Max ECe
Tomatoes	2.5	1.7	3.5	2.3	5.0	3.4	7.6	5.0	13
Wheat	6.0	4.0	7.4	4.9	9.5	6.4	13.0	8.7	20
Maize	1.7	1.1	2.5	1.7	3.8	2.5	5.9	3.9	10
Peppers	1.5	1.0	2.2	1.5	3.3	2.2	5.1	3.4	9
Okra	2.0	1.3	3.3	2.2	5.3	3.5	8.6	5.7	15

(See, Lal, and Ruseell, 1981)

When leaching efficiency (Le) is 100 percent, the water required to satisfy both ET crop and LR equals
(ET crop - Re)/(1 - LR).

To compute the LR for the crops grown in the study area, the following assumptions were made.

(a) Leaching efficiency = 70% (medium textured soil).

(b) 90 percent yield.

From the water analysis, the electrical conductivity of the irrigation water EC_w = 0.131mm hos/cm.

Leaching Requirement for tomato, for example, is computed as follows:

Ec_w = 0.131

Ec_e = at 90% yield = 3.5

Leaching efficiency = 0.7 = Le

$$LR = \frac{0.131}{5x3.5 - 0.131} \times \frac{1}{0.7}$$

$$= 0.01$$

LR = 0.01 for 90% yield of tomato.

In a similar manner LR was calculated for maize, wheat, peppers and okra and the results are presented in Table 4.5.

TABLE 4.5. LEACHING REQUIREMENT FOR CROPS IN THE STUDY AREA

Crop	LEACHING REQUIREMENT (Lr)
Tomatoes	0.010
Wheat	0.005
Maize	0.015
Peppers	0.017
Okra	0.011

4.6 IRRIGATION EFFICIENCY (E)

To account for losses of water incurred during conveyance and application to field, an efficiercy factor is usually included when computing the project irrigation requirements. Project efficiency is divided into three stages.

(a) Conveyance efficiency (E_e): - the ratio between water received at the inlet to the fields and that released at the project headwork.

(b) Field canal efficiency (E_b): the ratio between water received at the field inlet and that received at the inlet of the block of fields.

(c) Field application efficiency (Ea): - the ratio of water directly available to crops to that received at the field inlet.

Project efficiency (Ep) is Ep = Ea. Eb. Ee.

Conveyance and field canal efficiencies are not relevant in this study because there is no controlled water distribution network

in the study area. For the same reason, the project efficiency was not considered.

Different value have been recommended for field application efficiency (Ee) for different methods of water application and soil types.

The type of irrigation practised in the study area is furrow. For furrow irrigation, the following values of field application efficiency have been recommended:

(i) 0.55 - 0.70 (U.S. (SCS)

(ii) 0.57 - (ICID).

Since there is no controlled water application in the study area, field application efficiency of 0.67 is assumed.

7. GROSS IRRIGATION SUPPLY REQUIREMENT.

The gross irrigation supply requirement for a given project hectarage is determined by:

$$v = \frac{10}{Ea} \Sigma \left[\frac{A(ETcrop - Re - Ge\ Wb}{1 - LE} \right] \quad \ldots\ldots\ldots\ 4.3$$

Where

v = gross supply volume (m^3)

Ea = field application efficiency

A = crop hectarage (ha)

Re = effective rainfall (mm/month)

Ge = ground water contribution (mm/months)

Wb = stored water at the beginning of each perio
(mm).

ETcrop = crop water requirement (mm)

LR = Leaching requirement, (fraction)

Wb and Ge are assumed equal to zero.

Therefore;

$$v = \frac{10}{Ea} \Sigma \left[\frac{A\ (ET\ crop - Re)}{1 - LR} \right]$$

From previous calculations:

Crop	hectarage (ha)	ETcrop (mm)	Re (mm)	LR
Tomatoes	1.2214	991	-	0.010
Peppers	0.0800	1664	-	0.017
Wheat	0.6500	806	-	0.005
Maize	0.3500	816	231	0.015
Okra	0.2915	800	231	0.011

Field application efficiency = 0.37

Total hectarage = 2.5929ha

$$v = \frac{10}{0.67} \left[\frac{(991 \times 1.2214)}{1 - 0.01} + \frac{((1664 - 114) \times 0.08)}{1 - 0.017} \right.$$

$$+ \frac{(806 \times 0.65)}{1 - 0.005} + \frac{((816 - 231) \times 0.35)}{1 - 0.015}$$

$$\left. + \frac{(800 - 231) \times 0.2915}{1 - 0.011} \right]$$

$$= \frac{10}{0.67}\left[222.63 + 126.15 + 526.53 + 207.87 + 167.71\right]$$

$$v = \frac{10}{0.67}(2250.89)$$

$$v = 33595.33m^3$$

or $v = 3.36$ha-m.

The gross irrigation water required to satisfy ETcrop and leaching requirement and meet the given efficiency is 3.36ha-m.

The results of the estimated actual water used by the farmers on the field are presented graphically in table 4.6. The total estimated volume of water used to irrigate the same area of farm land was $13309m^3$ or 1.33ha-m or about 0.5133ha-m per ha.
This gives a difference of about 2.03ha-m between the volume of water calculated from the assumed ET crop, and LR and the efficiency and that estimated on the field.

The high difference might be due to the assumption that the groundwater contribution (Ge) and the stored water at the beginning of each period (Wb) were zero. However, 3.36ha-m is the peak requirement which is seldomly reached in practice.

Based on the actual water use of 0.5133ha-m/ha, about 5.0ha of farm land could be irrigated in the study area from the stored water.

TABLE 4.6 FIELD ESTIMATION OF IRRIGATION WATER. Mean Pump Flow rate = 3.24l/Sec.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
FARM CODE	CROP	CROP AREA (HA)	SUPPLY DURATION	VOL./IRR. (M^3)	IRR. INTER (DAY)	CROP BASE PERIOD DAY	NO.OF IRR. (7)/(6)	TOTAL VOL./CROP SEASON(8)x(5)(M^3)
A0082MUAT	Tomato	0.0352	3	34.992	7	105	15	524.880
B0082MUAT	Tomato	0.0800	1½	17.496	5	105	21	367.416
" "	Pepper	0.0800	1½	17.496	7	121	17	297.432
C0082MSUT	Tomato	0.3000	3½	40.824	4	105	26	1061.424
D0182MMIT	Tomato	0.0583	2½	29.160	7	105	15	437.400
E0182MOHT	Tomato	0.1240	2½	29.160	4	105	26	758.160
F0182MNT	Tomato	0.0780	3	34.992	7	105	15	524.880
G0182MUT	Tomato	0.0900	4½	52.488	7	105	15	787.320
H0023MST	Tomato	0.0952	3½	40.824	4	105	26	1061.424
I0023MIT	Tomato	0.0560	2	23.328	6	105	18	419.904
J0023MMBT	Tomato	0.1517	4	46.656	5	105	21	979.776
K0023MAW	Wheat	0.6500	12	139.968	7	105	15	2099.520
L0073MT	Tomato	0.1080	4½	52.488	7	105	15	787.320
M0073MDAT	Tomato	0.0450	2	23.326	7	105	15	349.920
N0075MTM	Maize/ Tomato	0.3500	4½	52.488	7	105	15	787.320
P0085MDO	Okra	0.0675	3	34.992	7	60	9	314.928
Q0085 MMAO	Okra	0.2240	10	116.640	4	60	15	1749.600
TOTAL		2.5929						13308.624

4.8 INFILTRATION FUNCTIONS

The cumulative infiltration of the project is defined by:

$z = 2.7t^{0.57} + 0.35t$ 4.4

where t = intake time in minutes (cumulative)

z = Cumulative infiltration (mm)

TABLE: 4.7 INFILTRATION PREDICTION

CUMULATIVE TIME (MIN.)	CUMULATIVE INFILTRATION (mm)		PERCENTAGE ERROR (%)
	MEASURED	COMPUTED	
0	0	0	0.0
5	7	8.5	-21.4
10	13	13.5	-3.9
20	22	21.9	+0.5
30	29	29.3	-1.0
50	43	42.6	+0.9
70	55	54.9	+0.2
90	65	66.6	-2.5
120	83	83.4	-0.4
180	98	115.1	-17.5
240	123	145.4	-18.2
300	153	174.7	-14.2
360	180	203.4	-13.0
420	208	231.5	-11.3
480	236	259.1	- 9.8
540	259	286.5	-10.6

Mean deviation = 8.36%

The infiltration rate, q, is given by:

$$\frac{dz}{dt} = q = 2.7\ (0.57)t^{-0.43} + 0.35$$

$$q = 1.539t^{-0.43} + 0.35 \quad \ldots\ldots\ldots\ldots\ 4.5$$

where q = infiltration rate (mm/min)

Table 4.8

CUMULATIVE TIME (MIN.)	INFILTRATION RATE (MM/HR)		PERCENTAGE ERROR (%)
	MEASURED	COMPUTED	
0	0.0	0.0	0.0
5	84.0	67.2	+20.0
10	78.0	55.3	+29.1
20	66.0	46.5	+29.6
30	58.0	42.4	+26.9
50	51.6	38.2	+26.0
70	47.1	35.9	+23.9
90	43.3	34.3	+20.7
120	41.5	32.8	+21.0
180	32.7	30.9	+5.5
240	30.8	29.8	+3.4
300	30.6	29.0	+3.5
360	30.0	28.4	+5.3
420	29.7	27.9	+6.0
480	29.6	27.5	+6.8
540	28.8	27.2	+5.6

Mean Deviation = 15.55%

Equation 4.4 over estimates the cumulative infiltration (Z) initially by as much as 21% but decreases to 0.4% after two hours. On the average, the equation over estimate the cumulative infiltration by about 8.36% which is reasonable.
On the other hand, equation 4.5 under estimates the infiltration rate by about 30% initially but the error reduced to about 3.4% after three hours. The estimate is good after two hours (3 - 7 percent error). The mean deviation equals to 15.55%.

In surface irrigation, infiltration change dramatically throughout the irrigation season the water movements alter the surface structure and geometry which in turn affect infiltration rates. The linear slope of the cumulative infiltration curve continue to change with time even after 24 hours and thus the contribution to Z from the non-linear portion cannot be eliminated, and it is difficult to model. The concept of constant infiltration rate (fo), in effect, is simple characterizing constant that must somehow be fitted into filtration equation. Attempting, therefore, a precise representation of the real field infiltration phenomenona by a mathematical model would be academic. It suffices, therefore, to say that equation 4.4 and 4.5 predict cumulative infiltration and infiltration rate respectively, for the project area reasonably well and can be used to evaluate infiltration

phenomena in the area.

A major challenge exists for researchers to develop more practical methods of measuring soil properties over extensive areas than more precise determination at a point in the soil.

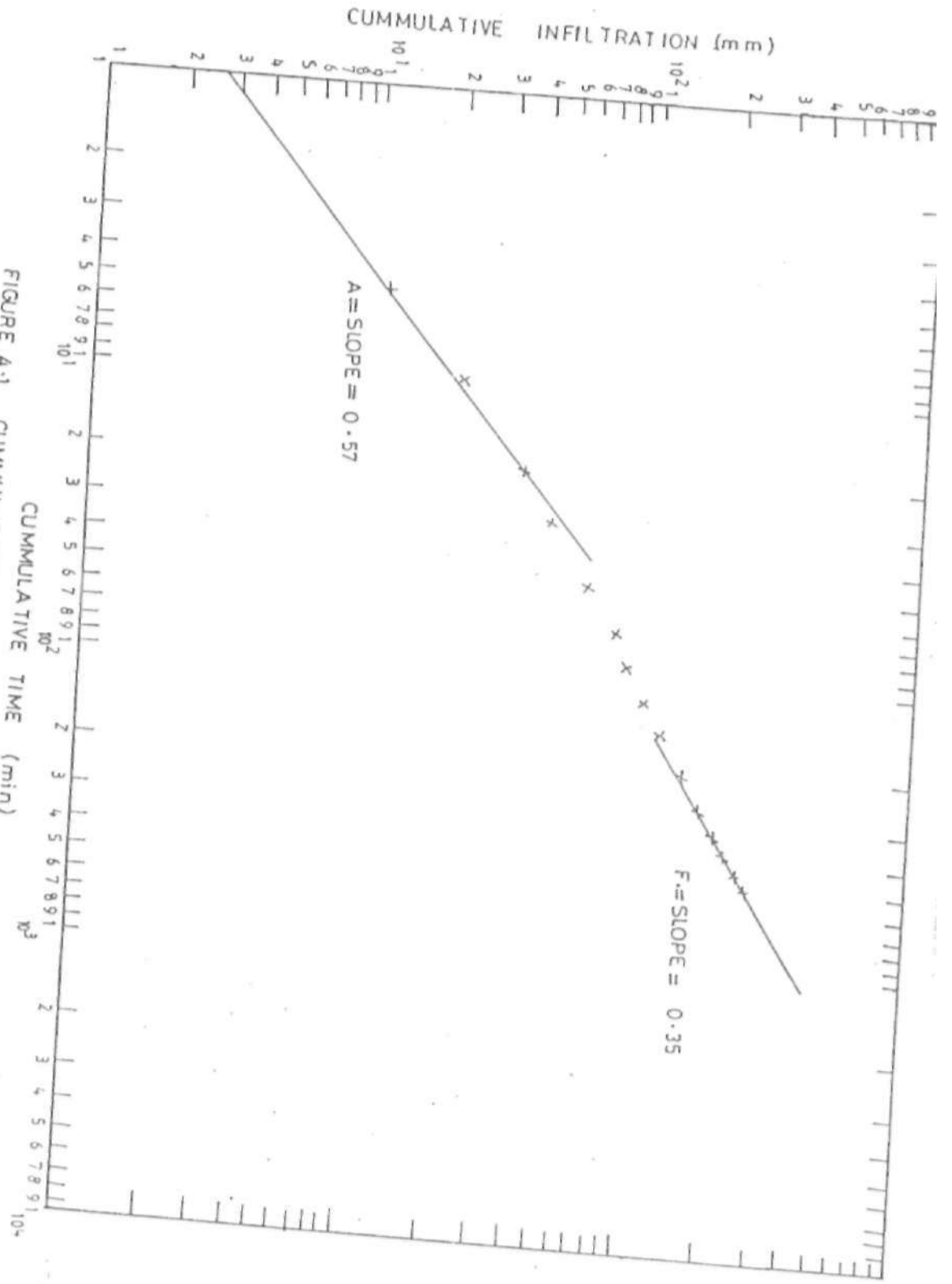


FIGURE 4·1 CUMMULATIVE INFILTRATION AGAINST CUMMULATIVE TIME

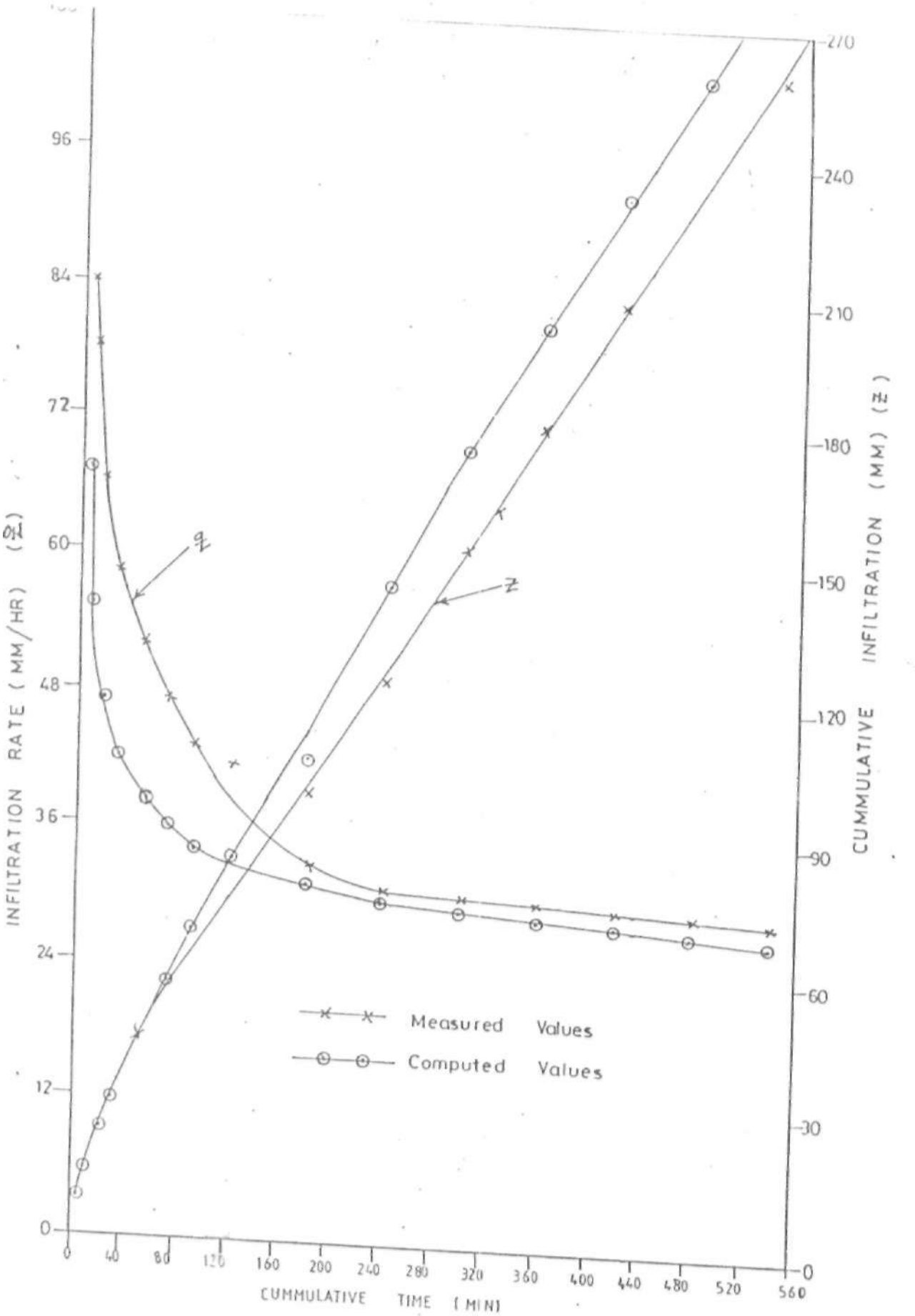


FIG 4.2 CUMMULATIVE INFILTRATION RATE AND INFILTRATION CURVES

CHAPTER 5

5.0 ECONOMIC IMPACT APPRAISAL

5.1 INPUT SUPPLY AND PRODUCT MARKETING

The major inputs required for the irrigated agriculture in the study area, apart from labour and irrigation pump, were seeds/seedlings or planting materials and fertilizer. A few required chemicals. Only about 3 of the farmers obtained their planting materials or seed from the agricultural supply at a controlled or subsidized price. Also, only one of sixteen farmers was able to buy fertilizer at government subsidized price. All the other farmers (except one who used preserved seeds) bought their seeds and fertilizer from the open market at infiltrated prices.

The consequence of this obvious. The production cost will be high; and to remain in business the farmers would have to increase the prices of their produce.

Considerable quantities of the irrigation products, especially tomato, were sold ex-farm. The maize were all sold green ex-farm. Only limited qunatities of tomato and okra were taken to a local market about 2km from the farm. The bags of pepper and wheat were all sold at the main market.

5.2 CASH FLOW ANALYSIS OF THE PRODUCTION OF CROPS

5.2.1 PRIMARY BENEFITS

Primary benefits may be measured in two ways:

(a) By the internal rate of return; and

(b) By the benefit/cost ratio.

5.2.1.1 INTERNAL RATE OF RETURN (IRR)

This is the rate of discount which, over the economic life of the scheme, allows benefits or the return on the investment to balance exactly the Capital invested. It is also called the yield of an investment.

Mathematically, it is given as:

$$IRR = \sum_{t=1}^{n} \left[\frac{B_t - C_t}{(1 + R)^t} \right] = 0$$

where,

B_t = discounted benefit in each project year

C_t = discounted cost in each project year

n = economic life of the project in years

R = discount (interest) rate.

The essential feature of discounted cash flow analysis is that a net income of say, =N= 1,000.00 ten years from now, is not worth =N= 1,000.00 now or at the present time. That is the net present value (NPV) is less than =N= 1,000.00. But the cost of

an investment which is made in a scheme today is worth =N= 1,000.00 now. If this =N= 1,000.00 were invested at 20 percent, it would be more than =N= 3,000.00 ten years from now. Conversely, =N= 1,000.00 received ten years from now will be worth less than =N= 500.00 now, because =N= 500.00 invested now would yield more than =N= 1,000.00 ten years from now if it were compounded at 10 percent interest rate per annum.

If the internal rate of return on investment in a scheme is higher than the rate of interest charged by lending agencies, then the scheme is said to be viable economically.

If it is not, secondary or social benefits may be invoked as a reason for undertaking the scheme.

It should be noted that in the project appraisal, it is tacitly assume that the entrepreneur does not have idle capital; rather that he borrows money and repays it out of earnings of the project.

For short-term schemes, IRR cannot be used to measure the benefits, rather it is the benefit/cost ratio. The irrigation scheme under investigation is a short term scheme in nature since the investment does not last more than a year.

5.2.1.2 BENEFIT/COST RATIO

The composition of a benefit/cost ratio employs the same concept as the internal rate of return. The difference is that instead of searching for the rate of interest given by the relationship between future income and cost streams, these same streams are discounted at a rate which is chosen in advance.

This rate may be the cost of borrowing the money to finance the scheme. The discounted present values of future benefits are then divided by the discounted present values of the cost stream, and the result is a benefit/cost ratio. In short-term projects, total income and total costs are used.

The results of the benefit/cost ratio analysis of the irrigation scheme in the study are presented graphically in Table 5.1

TABLE: 5.1 SEASONAL PRIMARY BENEFITS FROM THE IRRIGATION SCHEME

	(1)	(2)	(3)	(4)	(5)	(6)
	FARM CODE	NET ARABLE AREA (HA)	PRODUCTION COST ₦	GROSS INCOME ON LAND TOTAL RETURN ₦	NET FARM INCOME ₦	BENEFIT COST RATIO (4)/(3)
1.	AOO82HUAT	0.0352	400.00	724.00	324.00	1.8
2.	BOO82 MATP	0.1600	1115.00	4067.00	2952.00	3.7
3.	COO82 MSUT	0.3000	1766.00	5516.00	3750.00	3.1
4	DO182 MMIT	0.0583	498.00	1206.00	708.00	2.4
5.	EO182 MDHT	0.1240	1765.00	2622.00	857.00	1.5
6.	FO182 MNT	0.0780	1253.00	1507.00	254.00	1.2
7.	GO182 MUT	0.0900	1573.00	2324.00	751.00	1.5
8.	HOO23MST	0.0952	1657.00	2598.00	941.00	1.6
9.	IOO23MIT	0.0560	1168.00	1544.00	376.00	1.3
10.	JOO23MMBT	0.1517	1483.00	3335.00	1852.00	2.3
11.	KOO23MAW	0.6500	3043.00	3960.00	917.00	1.3
12.	LOO73MT	0.1080	1329.00	2457.00	1128.00	1.9
13.	MOO 73MDAT	0.0450	783.00	1159.00	376.00	1.5
14.	NOO75MTM	0.3500	1589.00	3391.00	1802.00	2.1
15.	POO85MDO	0.0675	366.00	460.00	94.00	1.3
16.	QOO85MMAO	0.2240	704.04	1150.00	436.00	1.6
	TOTAL	2.5929	20492.00	38010.00	17518.00	

5.2.2 SECONDARY BENEFITS

In addition to primary benefits there will be considerable secondary benefits.

Secondary benefits are those benefits which are received or enjoyed by persons and resources not employed on the scheme. They comprise the transport, processing, storage and marketing of the output of the scheme, together with the impact of increased purchasing power on the economy at large of those who work on or in association with the scheme in question. They may be as, or more significant than the primary benefits.

The specialized agencies of the United Nations often require consultants to put a value against these secondary benefits from investments, though not necessarily in quantitative terms.

The World Bank may likewise ask for them to be considered before they grant a scheme loan. The United Kingdom Overseas Development Administration, on the other hand, generally discourages the invocation of secondary benefits in support of a particular scheme. They argue that secondary benefits are normally very similar for all schemes and that they do not often help to decide which are worth financing and which are not.

The truth probably lies somewhere in between these two points of view.

It is useful but not always essential for governments and international lending agencies to know the impact of an investment in a scheme on the economy at large, even if this impact is not used to determine priorities among schemes.

One method of attempting to quantify these secondary benefits is shown in Table 5.2

TABLE: 5.2 SEASONAL SECONDARY BENEFITS FROM THE IRRIGATION SCHEME

(1)	(2)	(3)	(4)	(5)	(6)	(7)
FARM CODE	TYPE OF PRODUCTION	GROSS INCOME ON THE LAND (TOTAL RETURN) ₦	LINKAGE COEEFICIENT	LINKAGE MULTIPLIER OF 3.79	TOTAL INCRASES IN NATIONAL INCOME (3) X (5) ₦	REAL ADDITIONAL TAXATION RECEIPTS (6) x 0.0287
A0082MUAT	Tomato	724.00	1.33	5.04	3664.00	105.00
B0082HATP	Tomato	1507.00	1.33	5.04	7595.00	218.00
" "	Pepper	2560.00	1.67	6.33	16205.00	465.00
O0082MSUT	Tomato	5516.00	1.33	5.04	27801.00	798.00
D0182HMIT	Tomato	1206.00	1.33	5.04	6078.00	174.00
E0182MDHT	Tomato	2622.00	1.33	5.04	13215.00	379.00
F0182HNT	Tomato	1507.00	1.33	5.04	7595.00	218.00
G0182HUT	Tomato	2324.00	1.33	5.04	11713.00	336.00
H0023MST	Tomato	2598.00	1.33	5.04	13094.00	376.00
I0023MIT	Tomato	1544.00	1.33	5.04	7782.00	223.00
J0023MMBT	Tomato	3335.00	1.33	5.04	16808.00	482.00
K0023MAW	Tomato	3960.00	1.44	5.46	21622.00	621.00
L0073MT	Tomato	2457.00	1.33	5.04	12383.00	355.00
M0073MDAT	Tomato	1159.00	1.33	5.04	5841.00	168.00
N0075MTM	Tomato	1966.00	1.33	5.04	9909.00	284.00
" "	Maize	1425.00	2.00	7.58	10802.00	310.00
P0085MDO	Okra	460.00	1.60	6.06	2788.00	80.00
Q0085MMAO	Okra	1140.00	1.60	6.06	6908.00	198.00
TOTAL		38010.00			201803.00	5790.00

TABLE: 5.3 THE DERIVATION OF MARGINAL (AGERAGE) PROPENSITIES IN NIGERIA (BASIS FOR ESTIMATES

		1981	1982	1983	1984	1985	9886	Average for year involved presumed equal to current marginal propensities
1.	Gross Domestic product at Current Factor costs (GDP) (₦'millions)	56602.20	60483.14	63293.40	69950.25	78775.84	79740.44	41% Increase from 1981 to 1986.
2.	Gross Domestic Savings (GDS) (₦'Millions)	9569.00	8604.00	8193.00	7620.00	10693.30	9370.30	
3.	Marginal Propensity to Save (Presumed Equal to Average propensity to save (2) (MPS) (1) %	16.9	14.2	13.0	10.9	13.9	11.8	MPS = 0.134
4.	Marginal Propensity to consume presumed Equal to average propensity to consume	83.1	85.8	87.00	89.1	86.4	88.2	MPC = 0.866
5.	Marginal Propensity to Tax (Presumed Equal to average Govt Tax), Revenue as Presentage of GDP (1) (MPT)	3.9	3.7	2.7	1.9	2.4	2.6	MPT = 0.0287
6.	Marginal Propensity to import Consumer goods (presumed Equal to Average Propensity to import consumer goods) (%) (MPT)	23.9	17.7	11.5	7.3	8.0	9.8	MPI = 0.130

Source: Federal Office of Statistics, Lagos (Fed. Govt. Statistic)

This Table shows the results of a quantification of the or the effects of the irrigation scheme in the study site on the Nigerian economy at large through:

- Linkage effects;
- The multiplier effect;
- Taxation receipts; and
- The increase in national income.

5.2.2.1 LINKAGE EFFECTS

These are of two types:

(i) Backward (induced); and,

(ii) Forward (stemming).

The backward linkage of a scheme arises out of its ability to generate input from other sectors of the economy. For example, with increased production of a certain crop arising from a particular scheme, there may be an increase demand for fertilizer, or herbicides or farm equipment. This has the linkage effect of increasing the activities and incomes of those Nigerian traders who import or sell these items. Whatever backward linkage effect there may have been from the irrigation scheme in the study area was included in the value of production ex-farm and backward linkage is not therefore, listed in Table 5.2 as a separate item.

Forward linkage is likely to be much more significant. With

added tomato produc[illegible], for instance, the forward linkage effect the relative value of the increased activities of those involved in its transport, processing and marketing. The method of calculating this forward linkage arising from tomato production has been set out in section 2.6.2 in this report. The figure arrived at is 1.33 for tomato. This means that for every =N= 1.00 of additional income on the farm, there will be some 33 kobo worth of additional income in transport, processing, marketing etc.

5.2.2.2 THE MULTIPLIER EFFECTS

The multiplier effect of a scheme is the relationship between the initial increase and domestic income which arises from the scheme's direct and linkage impact and the additional income which such an increase generates. Domestic income means income which accrues to a Nigerian rather than a foreigner as a results of imports, or capital investments or dividend export.

The calculated Nigerian multiplier is 3.79 as shown in Table 5.3 and explained in 2.6.3 of this report. This means that for every naira's worth of income accruing to tomato farmers in Zaria, transporters, marketers and processors taken together; a further two naira forty-six kobo (=N= 2.46) of demand for consumer goods and services will spread throughout the economy of Nigeria, as those who grow, transport and market the tomato spend the income which the earn from the scheme on domestically produced goods

and services.

5.2.2.3 TAXATION RECEIPTS

These will arise under the foregoing assumptions if we take the marginal propensity to task through the economy and multiply it by the increase in Gross Domestic Product (GDP) arising from the economy.

The marginal propensity to tax is derived from Table 5.3 and the resulting calculations for taxation receipts are given in Table 5.2 Column 7.

5.2.2.4 INCREASE IN NATIONAL INCOME

This will arise from the linkage and multiplier effect. It is obtained by multiplying the linkage coefficient and the multiplier by the gross earnings on the scheme. The values is given in column 6, Table 5.2.

In summary, the secondary benefits are:

- That between four and six naira in extra income will be earned indirectly from the scheme for every naira earned directly from it (Table 5.2, column 3 against column 6).

- That between four and six extra jobs will be created in the economy at large for every job created on the irrigation farm (assuming that the employment ratio is the same as the

money ratio given above).

- That the additional seasonal taxes which should be collected by the government as a result of additional seasonal incomes from the irrigation scheme is =N= 5790.00.

5.2.3 SOCIAL BENEFITS

The social benefits arise out of the primary and secondary benefit and are, therefore, not additional benefit to be quantified. However, it should be noted that a most significant contribution to the national well-being is derived from more reliable employment and the resulting income engendered by the scheme.

5.2.4 THE NEGATIVE IMPACT

Many of the borrow pits along the major highways in this country do not have economic value. A good number, however, retain water, especially within the basement complex region. But in most cases, the water cannot be used for irrigation except for watering livestock.

The reasons being that during the search suitable road construction materials, the top soil he surrounding areas were removed, thus destroyi he fertility of the soil. An estimated averag .5 ha of farm land is lost as a result of every borrow excavated.

This effect can be mitigated by a programme of land reclamation; that is, top soiling the surround areas of the borrow pit after use.

Another negative impact of borrow pit is that the retained water provides a breeding ground for mosquitoes and other aquatic organisms such as schistosome (small parasitic worms) which may lead to malaria and schistosomiasis epidemics respectively.

The greatest threat to the survival of the scheme is silt deposition. This had been responsible for the failure of similar schemes in the past. If the scheme is to continue for a long time an assistance may be required from Government Agency like the Ministry of Works or Community effort by the farmers to remove the silt annually.

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5.3 CONCLUSION

The small scale irrigation scheme using borrowing pit water and its socio-economic benefits had been evaluated.

With a drainage area of 5.96 ha. and a pit surface area of 4.26 ha., enough water could be stored to irrigate at least 5.0 ha. of arable land. The water, though high in total solid content, was found to be suitable for the irrigation of most crops and on most soil types.

Based on the average yield of tomato in the area of 22.5 tonnes/ha., about 120 tonnes of tomato were produced. In addition, 160 Kg of pepper, 600 Kg of wheat, 250 Kg of maize and 620 Kg of Okra were produced from the irrigation scheme. Considering the net command area of only 6.87 ha., this may be regarded as a significant increase in food production.

The economic appraisal of the irrigation scheme shows that it is viable. The Benefit/Cost ratio ranged from 1.2 - 3.7 and varied for each farm.

The contribution of the scheme to the nation economy at large was considerable. Except increase in the national income was about =N= 0.2 million, while expected real taxation receipt by government was =N= 5,790.00. In addition, between four and six jobs (though casual) were created in the economy at large for every job created on the irrigation scheme.

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The information contained in this report will be a boost to the re-emerging concept of rainfall harvesting. Borrow pit, therefore have considerably potential for harvesting or collecting local run-off which could be used for irrigation, watering of livestock and domestic purpose. The report, though targeted at irrigated agriculture could be of considerable value in fiscal developing planning.

On the negative side, the health hazard due to mosquito infestation is not likely to be critical since the nearest dwelling house is over 200m from the pit.

5.4 RECOMMENDATION

1. The ability of the borrow pit in the study area to retain water is related to the geology. If the geology is well understood, the pit could be recreated elsewhere with smaller geological information for the same purpose. It is therefore recommended that a more detailed study of the hydrogeology of the area being undertaken. This, will in addition enable the estimation of seepage flow into the pit.

2. Government involvement should be limited to the digging of the pit and removal of silt deposit and encouragement of the local community through incentives and credit facility so that the scheme might not be liable to the same hazards as large scale

irrigation schemes.

3. Further analysis of the impounded water is recommended to establish its portability or otherwise since the local community might be using the water for other purposes in addition to irrigation.

4. It has been observed that livestock feed on the water, especially during dry season. An investigation to determine the livestock water requirement of the area is recommended.

REFERENCES

1. ADEGEYE, A.S and DITTOH, J.S (1985).
Essentials of Agricultural Economics McGrow-Hill,Book Company, U.S PP.381.

2. AHMED, A. (1982). Infiltration Rate and Related Soil Parameters for some selected samaru soils,
M.sc. Thesis,
Department of Agric Engineering
Ahmadu Bello University, Zaria, Nigeria.

3. AMERICAN PUBLIC HEALTH ASSOCIATION (1985).
Standard Methods for the Examination of Water and waste waters 16th, Edition, Washington, D.c.

4. ANNUAL ABSTRACT OF STATISTICS (1985) Federal Office of Statistics, Lagos.

5. BLAKE, L. S. (Editor) (1989) Irrigation and Drainage. In: Civil Engineering Reference Book Butter Worth Publishers, Ltd, London. PP 30/3 - 30/5

6. CAMACHO, R. F.. (1972) Economic Appraisal and Recommended Priority of Eight Land Development Schemes in Guyana; In: ICID Bulletin, Jan. PP 29 - 36.

7. CHOW, V. T. (Editor) (1964);
Hand Book of Applied Hydrolcgy, McGraw-Hill, Book Company New York, U.S.A.

8. DOORENBOS, J. (1976) Agro-Meteorological Field Stations; FAO Irrigation and Drainage, Paper No. 27 PP 80 - 91.

9. DOORENBOS, J. and PRUITT, W.D. (1977), Crop Water Requirement, FAO Irrigation and Drainage, Paper No. 24

10. duPREEZE and BARBAR, W. (Compilers) (1965), Geological Survey of Nigeria: The Distribution and Chemical Quality of groundwater in Northern Nigeria, Bulletin No. 36, Federal Republic of Nigeria.

11. FAO (1984), Small-scale Irrigation in the Context of Rural Development, Rome.

12. FAO (1987), Statistical Pocket Book, World Agricultural Statistics.

13. FAO (1971), Salinity Seminar, Baghdad, Irrigation and Drainage Paper, No.7, PP 118 -122.

14. FOSTER, L. J. (Editor) (1985),

Agricultural Dev. in Drought Prone Africa, Overseas Dev. Institute (ODI) and Tropical Agric. Ass. (TAA), London.

15. GARNIER, B. J. (1960), Map of Water Budget in West Africa, Bulletin de L'institut Francais d' Afrique, Noire, Ser. A22, Dakar, PP 709 - 722.

16. GILCHRIST, A. (1961). Evaporation in Nigeria, British West African Met. Service, Technical Note No. 6.

17. GITTCHRIST, A. (1961), Economic Analysis of Agricultural Projects., The John Hopkins University Press, Baltimore and London.

18. GOLDSMITH, E. and HILD YARD, N. (1984), Large - Dams: A special Report, The Ecologist 14 (5 - 6).

19. HANSEN, E.V.; ISRAELSON, O.W and STRINGHAM, G. E. (1960), Irrigation Principles and Practices 4th Edition, John Wiley and Sons, New York, U. S. A.

20. HEALTH, R. C. and TRAINER, F. H. (1968), Introduction to Ground-water Hydrology, John Wiley and Sons Ltd.

21. MOCKING, J. A. and THOMSONS, N. R. (1979) Land and Water Resources of West Africa Moray House College of Education, Edinburg, PP 24 - 27.

22. HOLY, M. and RIHS, I.J. (1972), Environmental Aspects Connected with Water Resources Dev. and Management, IN: ICID Bullectin, New Delhi, PP 54 - 64.

23. KOMOLAFE, M. F.; ADEGBOLA, A. A.; ARE, L. A, and ASHAYE, T. I. (1985) Agricultural Science for West African Schools and Colleges, 2nd Edition, University Press Ltd., Ibadan, Nigeria.

24. KOWAL, J.M. and KNABE, D. T. (1972), An Agroclimatological Atlas of Northern States of Nigeria, Ahmadu Bello University Press Ltd; Samaru, Zaria, Nigeria.

25. KOWAL, J. (1970); The Hydrology of a Small Catchment Basin at Samaru, Nigerian: Assessment of the Main Components of Water Budget, In: The Nigerian Agric. Journal 7 (1). PP 41 - 51

26. LAL, L. and RUSSELL, E. W. (EDITORS) (1981), Tropical Agricultural Hydrology, John Wiley and Sons Ltd.

27. LAMBE, T. W. (1984);
Soil Testing for Engineers Wiley Easter, Ltd, New Delhi, India.

28. LAND RESOURCES DEV. CENTRE (LRDC) (1981); Land Resources of Central Nigeria Vol. 7, LRDC Overseas Development Administration, England.

SLEY, R. K. and FRANZINI, J. B. (19725;
Water Resources Engineering McGraw Hill, Book Company, U.S.A.
381.

LIFSE^, R. G. (1989);
An Introduction to Positive Economics 7th Editi
ELBS/Weidenfeld and Nicolson.

MABAWONKU, w. (1984); Economic Analysis of Fish Farming in Oyo and River States of Nigeria; Journal of Econ. and Environment, VoJ• ^• No. 1, PP 28 ~ oi.

MITCHELL, R. B. (1980);
Engineering Economics, Pitman Press Ltd, Bath. India.

NORMAN, L.; TURNER, R. A. E.; and WILSON, K. R. S. (198!
The farm Business.

OLAYIDE, S.O.; OGUNFOWORA, 0.; ESSANG, S. M. and IDACIIABA, F. S. (1981); Elements of Economics, university Press Ltd, Ibadan, Nigeria.

ORTOLANO, L. (1979); Water Planning and the Environment Journal of the Water Resources Planning and Management Division, Vo] . 105, WIU , , PP 65 76.

36. PARK, C. C. (1980);
Ecology and Environmental management (A Geographical Perspective), Dawson West View Press, U. K.

37. RHODES, W. F. (Editor) (1972);
The Encyclopedia of Geochemistry and Environmental Sciences, Encyclopedia of Earth Science Series, Vol. IVA PP. 309 - 341.

38. STERN, P. H. (1986); Notes on Irrigation Potentials,
In: Agric. Development in Drought-Prone Africa ODI and TAA, London, PP 38 - 42.

39. TODD, D. K. (1980);
Ground Water Hydrology 2nd Edition, John Wiley and Sons Ltd, New York, U. S. A.

40. TYSON, Z. G. (1971); Irrigated Agriculture: A Historical Perspective, Samaru Agric, Newsletter, Vol. 13 No. 3, IRA, Samaru Zaria, Nigeria.

41. WALKER, W. R. (1989); Guidelines for Designing and Evaluating Surface Irrigation Schemes, FAO Irrigation and Drainage paper No. 45 PP 27 -34.

42. WILSON, E. M. (1990);
Engineering Hydrology 4th Edition, ELBS/Macmillan, U.K.

43. WOODHEAD, T. and WAWERU, E. S. (1970); Variability of Potential Evaporation in East Africa. In: Experimental Agriculture, 6(1) PP 51 - 56.

APPENDIX A 1: LONG - TERM MONTHLY MEAN SUMMARY (METEOROLOGIC DATA)

MONTH OF YEAR	TOTAL RAINFALL	PICHE EVAPORATION	RADIATION	SUNSHINE	RELATIVE HUMIDITY	VAPOUR PRESSURE	DEW POINT	PRESSURE AT MSL	STATION PRESSURE	MAXIMUM TEMP.	MINIMUM TEMP.	MEAN TEMP.	HIGHEST WINDFORCE OBSERVED
JAN.	0.0	13.7	8.1	7.8	18	4.5	-5.2	1013.7	939.8	29.1	13.7	21.4	4
FEB.	0.3	16.0	9.1	7.9	13	4.2	-6.7	1011.8	939.2	32.3	16.5	24.4	5
MARCH	13.7	16.6	9.3	6.9	22	8.8	2.1	1009.4	937.7	35.3	20.6	28.0	4
APRIL	27.3	13.7	9.4	7.3	40	16.5	11.5	1007.9	938.2	36.2	22.7	29.5	5
MAY	121.9	7.8	8.7	8.1	62	23.3	19.8	1009.0	937.3	33.7	22.4	28.1	5
JUNE	112.2	4.8	8.0	7.6	72	24.1	20.5	1011.4	938.9	31.1	21.1	26.1	5
JULY	224.2	3.1	7.4	6.2	79	23.9	20.3	1012.1	939.1	29.1	20.2	24.7	5
AUG.	285.1	2.6	7.4	6.3	81	24.3	20.6	1012.4	939.3	28.9	20.2	24.6	4
SEPT	130.8	3.1	8.3	7.0	76	24.4	20.6	1011.7	939.0	30.1	20.2	25.2	4
OCT.	36.5	6.5	8.9	8.1	55	19.2	15.8	1010.9	938.6	31.9	19.2	25.6	4
NOV.	0.0	11.3	8.9	8.9	24	8.4	2.7	1011.5	939.0	32.0	15.8	23.9	4
DEC.	0.0	12.3	7.9	8.2	20	5.6	-2.1	1012.8	939.4	29.7	14.3	22.0	4
TOTAL	952.0												

LATITUDE: 11o 08'N ALTITUDE: 655.91m

LONGITUDE: 07o 41'E Source: NIGERIAN COLLEGE OF AVIATION TECHNOLOGY

APPENDIX A2. MONTHLY TOTAL RAINFALL AND NUMBER OF RAINY DAYS

MONTH	1981		1982		1983		1984		1985		1986		1987		1988		1989		1990		1991	
	TOTAL RAINFALL (MM)	NUMBER OF RAINY DAYS (DAY)	TOTAL RAINFALL (MM	NUMBER OF RAINLY DAYS (DAY)	TOTAL RANIFALL (MM)	NUMBER OF RAINY DAYS (DAY)	TOTAL RAINFALL (MM)	NUMBER OF RAINY DAYS (DAY)	TOTAL RAINFALL (MM)	NUMBER OF RAINY DAYS (DAY)	TOTAL RANIFALL (MM)	NUMBER OF RAINY DAYS (DAY)	TOTAL RAINFALL (MM)	NUMBER OF RAINY DAYS (DAY)	TOTAL RAINFALL (MM)	NUMBER OF RAINY DAYS (DAY)	TOTAL RAINFALL (MM)	NUMBER OF RAINY DAYS (DAY)	TOTAL RAINFALL (MM)	NUMBER OF RAINY DAYS (DAY)	TOTAL RAINFALL (MM)	NUMBER OF RAINY DAYS (DAY)
JAN.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FEB.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.7	1	-	-	-	-	-	-
MARCH	-	-	-	-	-	-	43.2	1	64.3	2	-	-	1.0	1	-	-	-	-	-	-	42.2	2
APRIL	70.5	6	54.3	9	-	-	45.7	6	-	-	6.5	1	-	-	28.8	6	21.5	1	2.3	2	75.5	6
MAY	107.7	10	77.5	8	62.7	9	104.2	7	122.4	10	42.4	5	91.1	8	136.0	9	110.1	10	164.1	11	323.1	18
JUNE	89.1	9	112.3	8	129.3	12	97.6	9	87.2	13	69.3	11	149.1	15	157.9	11	89.3	11	152.6	15	100.3	10
JULY	256.5	14	193.8	13	132.5	15	237.4	18	350.5	17	265.6	14	247.4	18	177.8	15	146.4	15	202.7	14	255.9	15
AUG.	305.2	19	238.5	19	287.3	17	155.1	12	250.8	21	298.9	19	356.1	25	398.7	22	286.7	20	192.9	20	366.5	21
SEPT.	149.4	13	94.3	11	73.4	15	172.0	14	190.9	13	149.7	15	98.3	9	209.3	18	68.1	10	156.9	11	75.9	10
OCT.	-	-	113.2	3	0.4	1	126.2	7	5.8	2	1.7	3	35.0	3	11.4	2	64.9	5	12.0	2	30.7	2
NOV.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DEC.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.7	1	-	-
TOTAL	978.4	71	883.9	58	585.6	69	981.4	74	1071.9	78	834.1	68	978.0	79	1118.6	84	786.4	72	886.2	76	1270.1	84

SOURCE: NIGERIAN COLLEGE OF AVIATION TECHNOLOGY: ZARIA:

Table 2 Extra Terrestrial Radiation (Ra) expressed in equivalent evaporation in mm/day

Northern Hemisphere												Lat	Southern Hemisphere											
Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
3.8	6.1	9.4	12.7	15.8	17.1	16.4	14.1	10.9	7.4	4.5	3.2	50°	17.5	14.7	10.9	7.0	4.2	3.1	3.5	5.5	8.9	12.9	16.5	18.2
4.3	6.6	9.8	13.0	15.9	17.2	16.5	14.3	11.2	7.8	5.0	3.7	48	17.6	14.9	11.2	7.5	4.7	3.5	4.0	6.0	9.3	13.2	16.6	18.2
4.9	7.1	10.2	13.3	16.0	17.2	16.6	14.5	11.5	8.3	5.5	4.3	46	17.7	15.1	11.5	7.9	5.2	4.0	4.4	6.5	9.7	13.4	16.7	18.3
5.3	7.6	10.6	13.7	16.1	17.2	16.6	14.7	11.9	8.7	6.0	4.7	44	17.8	15.3	11.9	8.4	5.7	4.4	4.9	6.9	10.2	13.7	16.7	18.3
5.9	8.1	11.0	14.0	16.2	17.3	16.7	15.0	12.2	9.1	6.5	5.2	42	17.8	15.5	12.2	8.8	6.1	4.9	5.4	7.4	10.6	14.0	16.8	18.3
6.4	8.6	11.4	14.3	16.4	17.3	16.7	15.2	12.5	9.6	7.0	5.7	40	17.9	15.7	12.5	9.2	6.6	5.3	5.9	7.9	11.0	14.2	16.9	18.3
6.9	9.0	11.8	14.5	16.4	17.2	16.7	15.3	12.8	10.0	7.5	6.1	38	17.9	15.8	12.8	9.6	7.1	5.8	6.3	8.3	11.4	14.4	17.0	18.3
7.4	9.4	12.1	14.7	16.4	17.2	16.7	15.4	13.1	10.6	8.0	6.6	36	17.9	16.0	13.2	10.1	7.5	6.3	6.8	8.8	11.7	14.6	17.0	18.2
7.9	9.8	12.4	14.8	16.5	17.1	16.8	15.5	13.4	10.8	8.5	7.2	34	17.8	16.1	13.5	10.5	8.0	6.8	7.2	9.2	12.0	14.9	17.1	18.2
8.3	10.2	12.8	15.0	16.5	17.0	16.8	15.6	13.6	11.2	9.0	7.8	32	17.8	16.2	13.8	10.9	8.5	7.3	7.7	9.6	12.4	15.1	17.2	18.1
8.8	10.7	13.1	15.2	16.5	17.0	16.8	15.7	13.9	11.6	9.5	8.3	30	17.8	16.4	14.0	11.3	8.9	7.8	8.1	10.1	12.7	15.3	17.3	18.1
9.3	11.1	13.4	15.3	16.5	16.8	16.7	15.7	14.1	12.0	9.9	8.8	28	17.7	16.4	14.3	11.6	9.3	8.2	8.6	10.4	13.0	15.4	17.2	17.9
9.8	11.5	13.7	15.3	16.4	16.7	16.6	15.7	14.3	12.3	10.3	9.3	26	17.6	16.4	14.4	12.0	9.7	8.7	9.1	10.9	13.2	15.5	17.2	17.8
10.2	11.9	13.9	15.4	16.4	16.6	16.5	15.8	14.5	12.6	10.7	9.7	24	17.5	16.5	14.6	12.3	10.2	9.1	9.5	11.2	13.4	15.6	17.1	17.7
10.7	12.3	14.2	15.5	16.3	16.4	16.4	15.8	14.6	13.0	11.1	10.2	22	17.4	16.5	14.8	12.6	10.6	9.6	10.0	11.6	13.7	15.7	17.0	17.5
11.2	12.7	14.4	15.6	16.3	16.4	16.3	15.9	14.8	13.3	11.6	10.7	20	17.3	16.5	15.0	13.0	11.0	10.0	10.4	12.0	13.9	15.8	17.0	17.4
11.6	13.0	14.6	15.6	16.1	16.1	16.1	15.8	14.9	13.6	12.0	11.1	18	17.1	16.5	15.1	13.2	11.4	10.4	10.8	12.3	14.1	15.8	16.8	17.1
12.0	13.3	14.7	15.6	16.0	15.9	15.9	15.7	15.0	13.9	12.4	11.6	16	16.9	16.4	15.2	13.5	11.7	10.8	11.2	12.6	14.3	15.8	16.7	16.8
12.4	13.6	14.9	15.7	15.8	15.7	15.7	15.7	15.1	14.1	12.8	12.0	14	16.7	16.4	15.3	13.7	12.1	11.2	11.6	12.9	14.5	15.8	16.5	16.6
12.8	13.9	15.1	15.7	15.7	15.5	15.5	15.6	15.2	14.4	13.3	12.5	12	16.6	16.3	15.4	14.0	12.5	11.6	12.0	13.2	14.7	15.8	16.4	16.5
13.2	14.2	15.3	15.7	15.5	15.3	15.3	15.5	15.3	14.7	13.6	12.9	10	16.4	16.3	15.5	14.2	12.8	12.0	12.4	13.5	14.8	15.9	16.2	16.2
13.6	14.5	15.3	15.6	15.3	15.0	15.1	15.4	15.3	14.8	13.9	13.3	8	16.1	16.1	15.5	14.4	13.1	12.4	12.7	13.7	14.9	15.8	16.0	16.0
13.9	14.8	15.4	15.4	15.1	14.7	14.9	15.2	15.3	15.0	14.2	13.7	6	15.8	16.0	15.6	14.7	13.4	12.8	13.1	14.0	15.0	15.7	15.8	15.7
14.3	15.0	15.5	15.5	14.9	14.4	14.6	15.1	15.3	15.1	14.5	14.1	4	15.5	15.8	15.6	14.9	13.8	13.2	13.4	14.3	15.1	15.6	15.5	15.4
14.7	15.3	15.6	15.3	14.6	14.2	14.3	14.9	15.3	15.3	14.8	14.4	2	15.3	15.7	15.7	15.1	14.1	13.5	13.7	14.5	15.2	15.5	15.3	15.1
15.0	15.5	15.7	15.3	14.4	13.9	14.1	14.8	15.3	15.4	15.1	14.8	0	15.0	15.5	15.7	15.3	14.4	13.9	14.1	14.8	15.3	15.4	15.1	14.8

Source: FAO Irrigation and Drainage Paper No.24

APPENDIX A5

WORKSHEET NO. 1

FARMING SYSTEM DESCRIPTION DATE:_____

1. Farm:.....

2. Hectarage (Farm Size):.....

3. Tenant/Owner - Occupier:.....

4. Method of Land Preparation:.....

5. Time of Planting:.....

6. Methods of Planting:.....

7. Types of Crops Grown Area % Farm Area

   (i) ....ha .....%

   (ii) ....ha .....%

   (iii) ....ha .....%

   (iv) ....ha .....%

   (v) ....ha .....%

8. Sources of Seed/Planting Materials:.....

   .....

9. Length of Fallow:.....

10. Succession and Association of Crops:.....

    .....

11. Nature of Weed Problem, Time and Method of Control:.....

    .....

12. Pest and Diseases and their Control:.....

    .....

13. Soil Fertility Maintenance (Manurial, Fertilizer and Other Practice Used to Maintain Soil Fertility:.....

14. Time and Methods of Harvest:.....

15. Source of Labour (Family or Hired):.....

16. Number of Full-time Labour (Including the Farmer):.....

17. Number of Part-time Labour (or Hired Labour):.....

18. Sources of money for the Farming:.....

19. Principal Uses of the Money:.....

20. Sources of Credit (if any):.....

21. Principal Uses of the Credit:.....

22. Soil Types:.....

23. Irrigation Interval:

Crop Type	Irrigation Interval
(i)	.....
(ii)	.....
(iii)	.....
(iv)	.....
(v)	.....

24. Length of Time Water is Applied to the Crops:

Crop Type	Farm Size	Time
.....	.....	.....
.....	.....	.....
.....	.....	.....
.....	.....	.....

WORKSHEET No. 2

INPUTS OR VARIABLE COSTS DATE:.....

1. Cost of Seeds:

Crop	Seed Quantity	Unit Price(=N=)
(i)	.....	.....
(ii)	.....	.....
(iii)	.....	.....
(iv)	.....	.....
(v)	.....	.....

2. Cost of Casual Labour/Man-day:.....

3. Cost of Fertilizer/Manure:.....

4. Cost of Crop Protection (Cost of Pesticides/Chemicals for the Pest and Disease Control):.....

5. Full-time Labour Paid (Cost of Full-time Worker per Man-day):

.....

6. Cost of Family Labour (Full-time Worker Unpaid) Per man-day:

.....

7. Cost of Equipment/Tools:.....

8. Pumping Cost or Cost of Pump Hire:.....

9. Fuel and Oil Cost:.....

10. Cost of Hose/Plastic Pipes:.....

11. Cost of Haulage:.....

12. Cost of Repairs of the Pump/Tools/Equipment:.....

13. Taxes and Insurance:.....

14. Cost of Land:.....

15. Other Miscellaneous Variable Costs (e.g. Cost of Baskets):..

.....

16. Other Miscellaneous Over-head Cost:.....

.....

.....

WORKSHEET NO. 3

GROSS OUTPUT

Farm..... ..... Date .....

Crop	Hectarage (ha)	Yield	Price (=N=)

APPENDIX B1

B1 Hydrologic soil group Description (Chau, 1964)

GROUP A Characterized by:

- high infiltration rate even when thoroughly wetted;
- very high proportion of sands or gravels that are deep;
- well to excessively drained;
- high rate of hydraulic conductivity or water transmission.

GROUP B Characterized by:

- moderate infiltration rate when thoroughly wetted;
- moderately deep to deep
- moderately well to well drained
- moderately fine to moderately Coarse texture;
- moderate rate water transmission.

GROUP C Characterized by:

- slow infiltration rate when thoroughly wetted;
- It is layered and this impedes downward movement of water;
- moderately fine to fine texture;
- slow rate of water transmission.

GROUP D Characterized by:

- very slow infiltration rate when thoroughly wetted;
- high proportion of clay with high swelling potential;
- high permanent water-table;
- clay pan or clay at or near the surface;
- shallow soils over nearly impervious materials; and
- very slow rate of water transmission.

APPENDIX B2

Fitting Regression Equation for Evaporation (Ep) and potential Evapotranspiration (Etp).

Etp (mm)	Ep (mm)
9.7	13.7
14.6	16.0
12.3	16.6
12.8	13.7
9.3	7.8
7.6	4.8
6.1	3.1
5.3	2.6
6.4	3.1
8.9	11.3
10.4	12.3
115.2	111.5

mean (ETp) = 9.6mm = ETp

mean (Ep) = 9.29mm = Ep

Standard Deviation (S)(ETp) = 2.92

Standard Deviation (Ep) = 5.24

$\Sigma(ETp)^2 = 1199.5$

$\Sigma(Ep)^2 = 1238.03$

$\Sigma(ETp)(Ep) = 1226.69$

Regression equation is given as

ETp = a + b Ep.

a = ETp - b Ep

$$b = \frac{\Sigma(ETp)(Ep) - \frac{(\Sigma(ETp)\ \Sigma(Ep))}{n}}{\Sigma(Ep)^2 - (\Sigma(Ep))^2/n.}$$

n = 12

$$b = \frac{1226.69 - (115.2 \times 111.5)/12}{1338.03 - (111.5)^2/12.}$$

$$= \frac{122.669 - 1070.4}{1338.03 - 1036.02} = \frac{156.29}{302.01}$$

b = 0.52

a = 9.6 - 0.52 x 9.29

a = 4.77

The Regression equation is:

ETp = 4.77 + 0.52 Ep

Coefficient of Correlation α is given by:

$$\alpha = b \frac{SEp}{SETp}$$

where SEp = standard deviation of Ep

SETp = standard deviation of ETp.

$$\alpha = 0.52 \times \frac{5.24}{2.92}$$

$$= 0.93$$

$$\underline{\alpha = 0.93}$$

Standard Error of Estimate S_e^2 is

$$Se^2 = \frac{n - 1}{n - 2} (S^2 ETp) (1 - \alpha^2).$$

$$= \frac{11}{10} (2.92)^2 (1 - (0.93)^2)$$

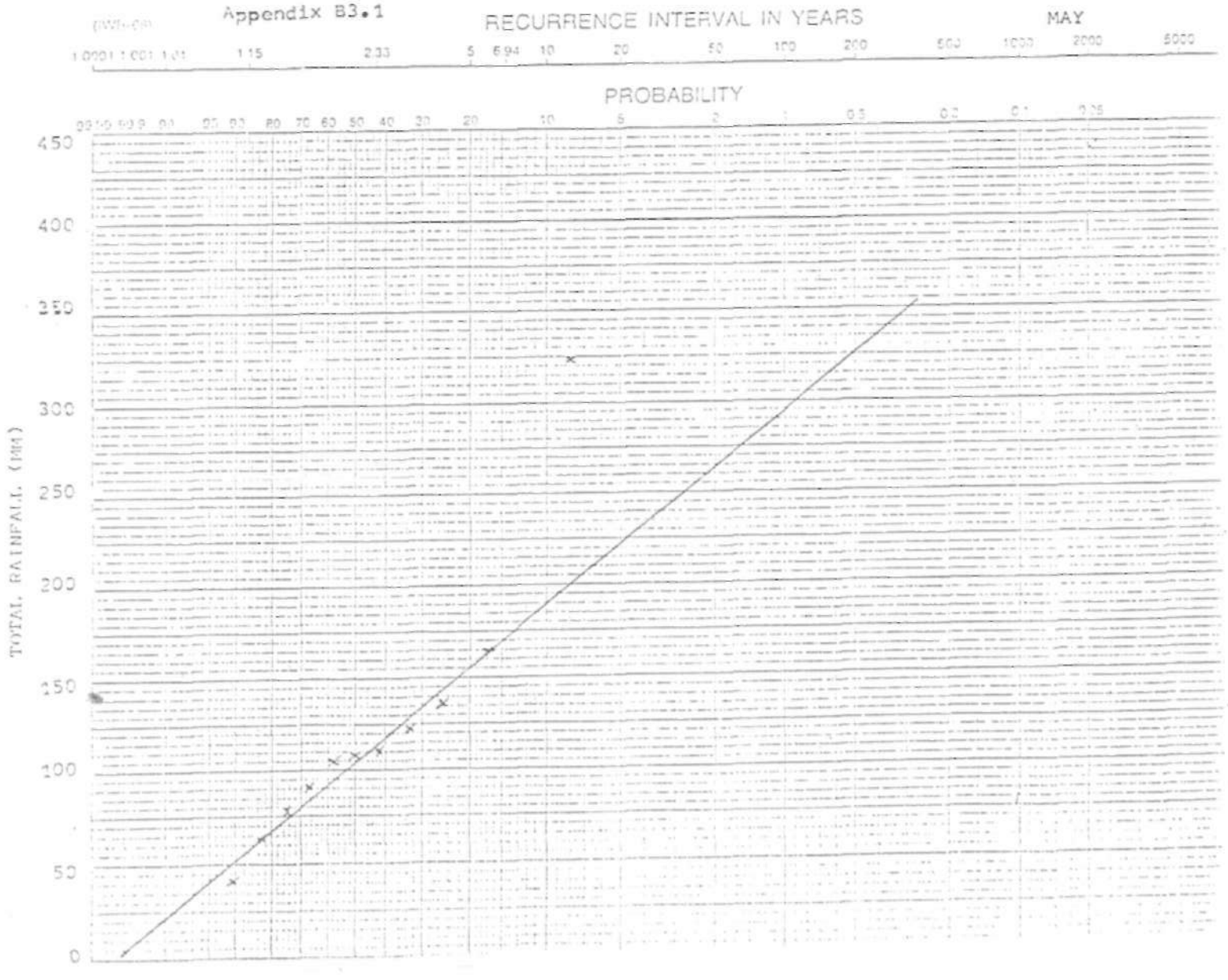
$$\underline{Se^2 = 1.27}$$

That is the estimate is correct within ± 1.27 error.

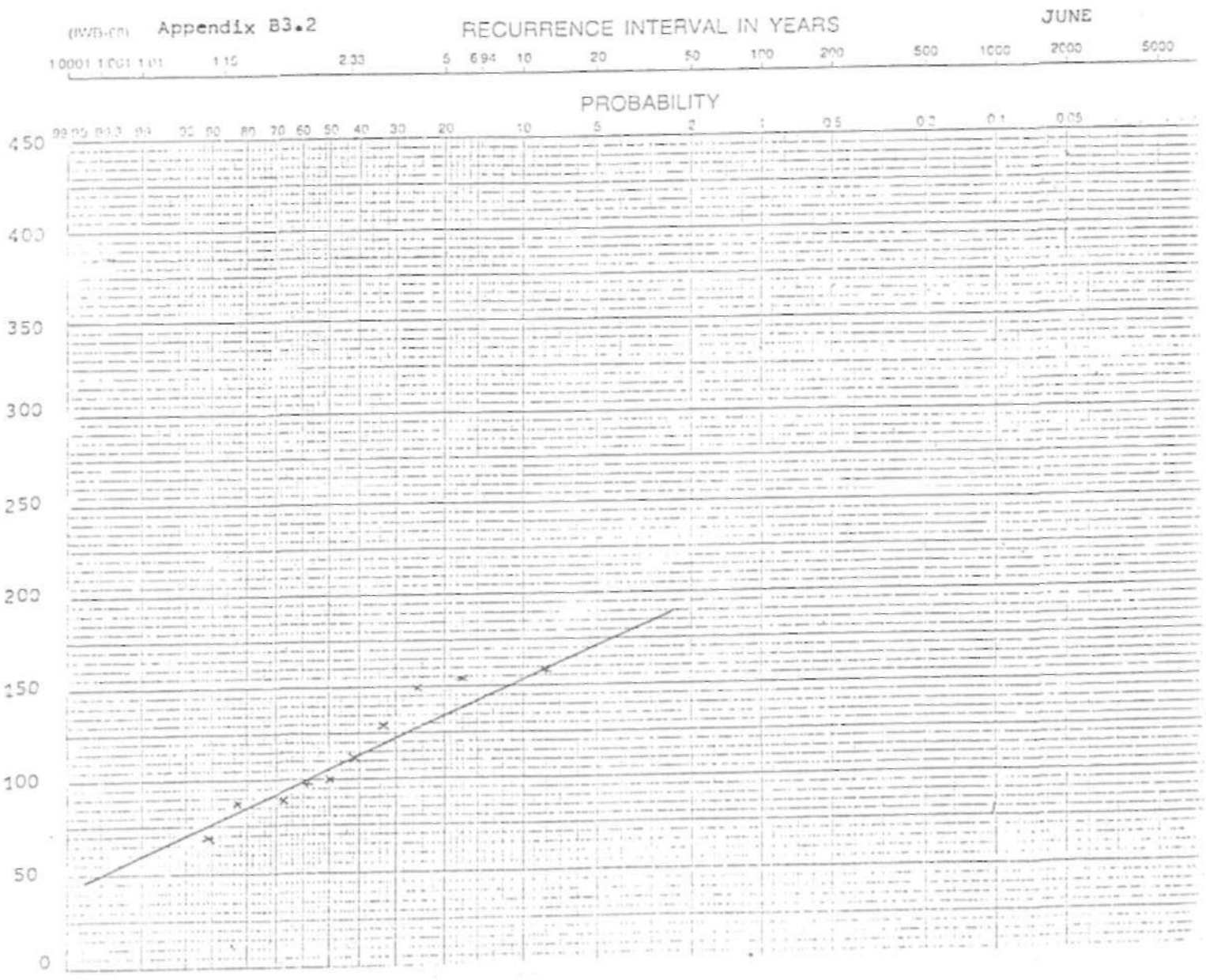
APPENDIX B9 RAINFALL CUMMULATIVE FREQUENCY

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Rainfall mm/APRIL	71	54	-	46	-	7	-	24	22	2	76
Rank,M	2	3	-	4	-	7	-	5	6	8	1
Frequency	17	25	-	33	-	58	-	42	50	67	8
Rainfall mm/MAY	108	78	63	104	122	42	91	136	110	164	323
Rank m	6	9	10	7	4	11	8	3	5	2	1
Frequency	50	75	83	58	33	92	67	25	42	17	8
Rainfall mm/JUNE	89	112	129	98	87	69	149	158	89	153	100
Rank,M.	8	5	4	7	10	11	3	1	8	2	6
Frequency	67	42	33	58	83	92	25	8	67	17	50
Rainfall mm/JULY	257	194	133	237	351	266	247	178	146	203	256
Rank,M,	3	8	11	6	1	2	5	9	10	7	4
Frequency	25	67	92	50	8	17	42	75	83	58	33
Rainfall mm/AUGUST	305	239	287	155	251	299	356	399	286	193	367
Rank,M,	4	9	6	11	8	5	3	1	7	10	2
Frequency	33	75	50	92	67	42	25	8	58	83	17
Rainfall mm/SEPT	149	94	73	172	191	150	98	209	68	157	76
Rank,M,	6	8	10	3	2	5	7	1	11	4	9
Frequency	50	67	83	25	17	42	58	8	92	33	75
Rainfall mm/OCT.	0	113	0	126	6	2	35	11	65	12	33
Rank,M,	10	2	10	1	8	9	4	7	3	6	5
Frequency	83	17	83	8	67	75	33	58	25	50	42

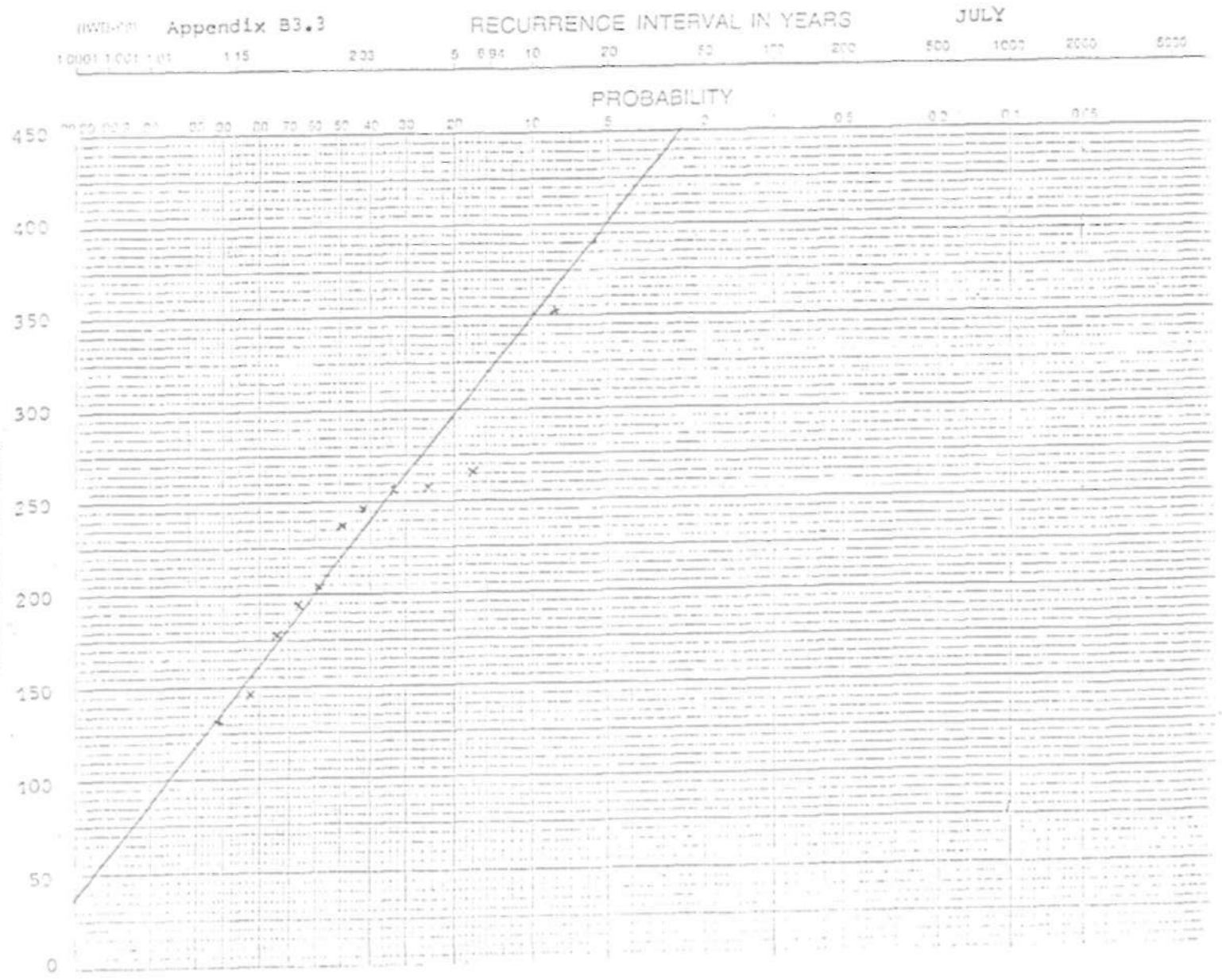
Appendix B3.1

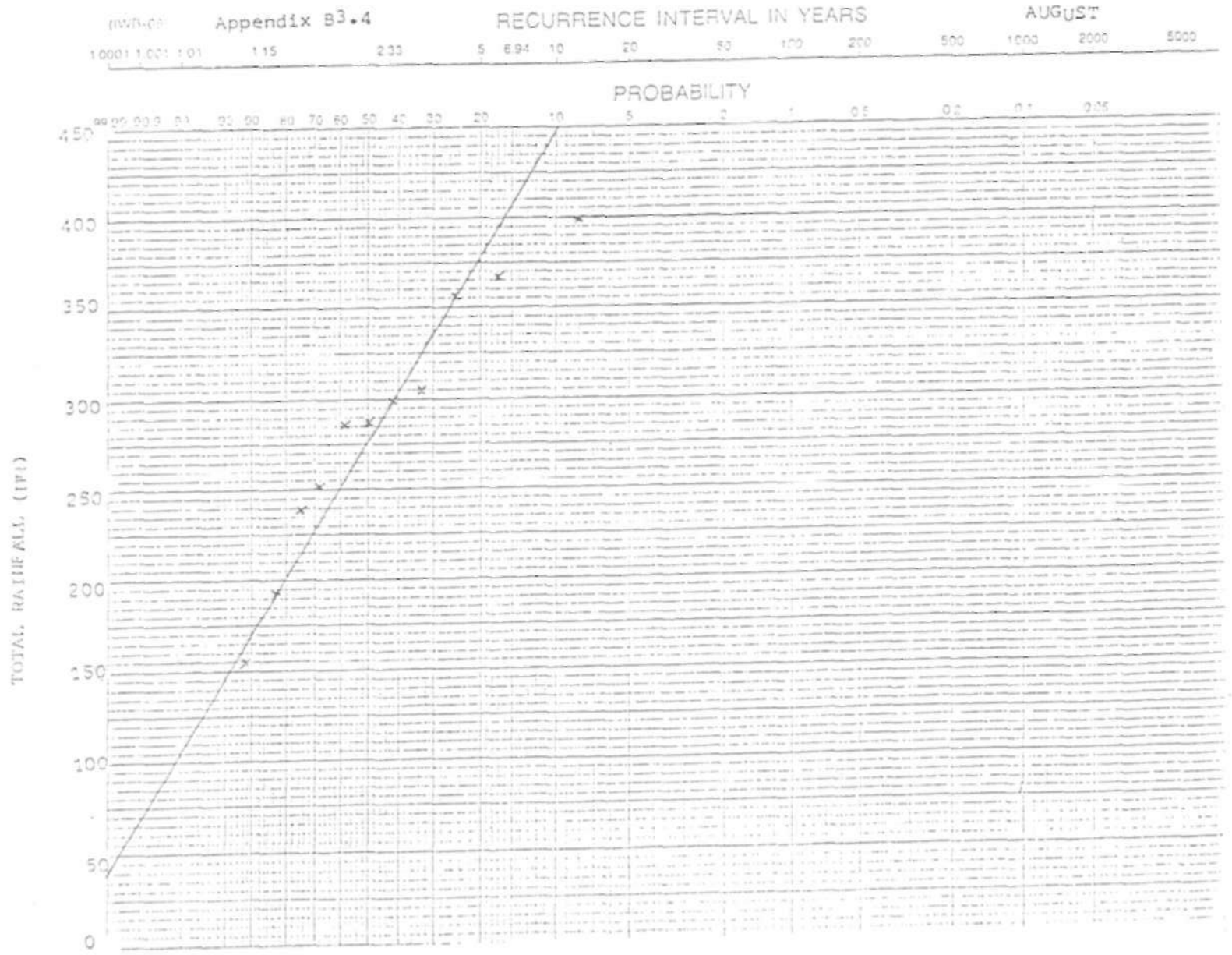


(BWB-CD) Appendix B3.2



JUNE


RECURRENCE INTERVAL IN YEARS
JULY
PROBABILITY
TOTAL RAINFALL (mm)
450
400
350
300
250
200
150
100
50
0


Appendix B3.4
RECURRENCE INTERVAL IN YEARS
AUGUST
1.0001 1.001 1.01 1.15 2.33 5 6.94 10 20 50 100 200 500 1000 2000 5000
PROBABILITY
99.9 99.8 99.5 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05
TOTAL RAINFALL (IN.)
450
400
350
300
250
200
150
100
50
0

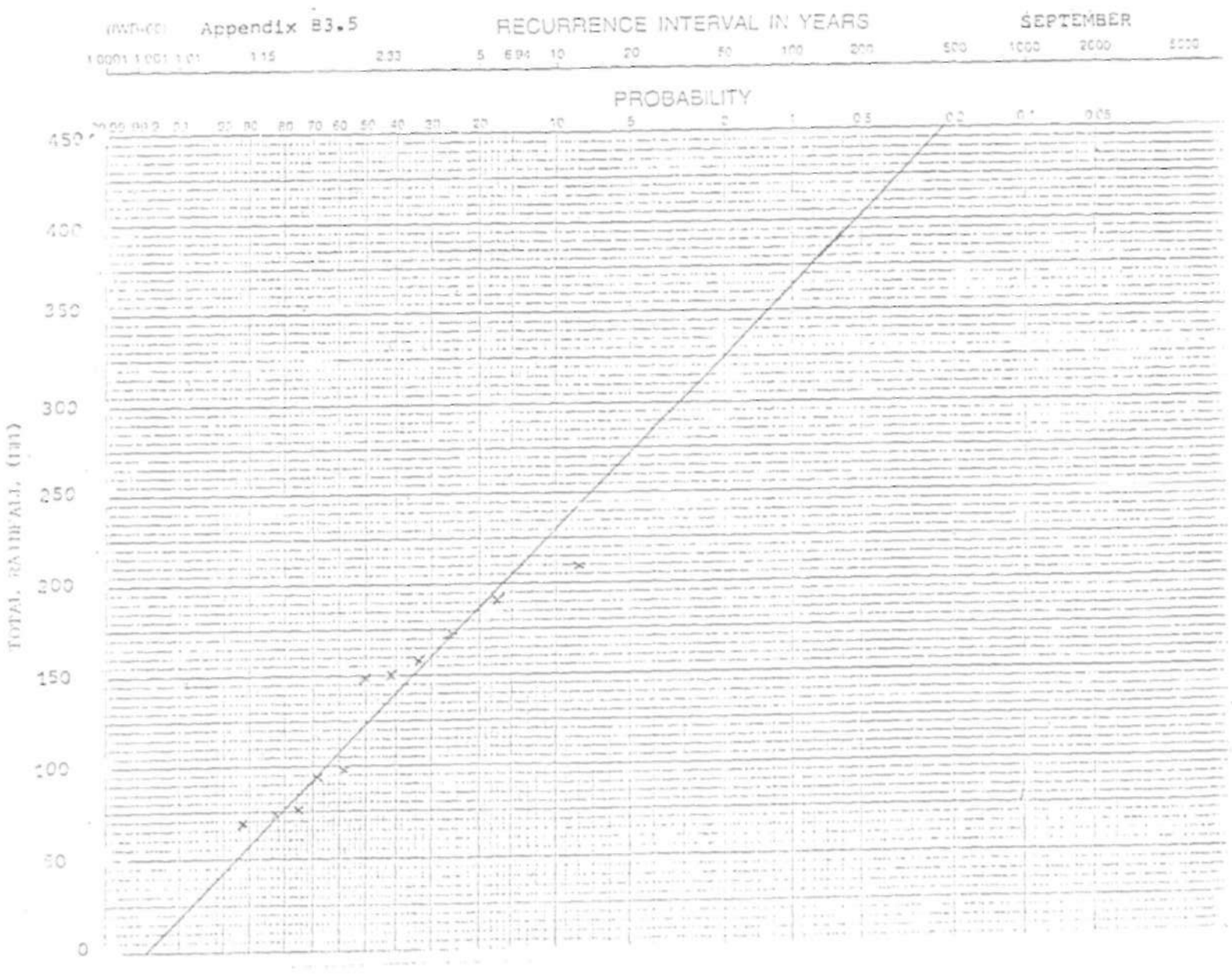

RECURRENCE INTERVAL IN YEARS
SEPTEMBER
1.0001 1.001 1.01 1.15 2.33 5 6.94 10 20 50 100 200 500 1000 2000 5000
PROBABILITY
99.99 99.9 99 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05
450
400
350
300
250
200
150
100
50
0

Table 34 Average Monthly Effective Rainfall as Related to Average Monthly ETcrop and Mean Monthly Rainfall

(USDA (SCS), 1969)

Monthly mean rainfall mm	12.5	25	37.5	50	62.5	75	87.5	100	112.5	125	137.5	150	162.5	175	187.5	200
	Average monthly effective rainfall in mm※															
Average monthly ETcrop mm	25	8	16	24												
	50	8	17	25	32	39	46									
	75	9	18	27	34	41	48	56	62	69						
	100	9	19	28	35	43	52	59	66	73	80	87	94	100		
	125	10	20	30	37	46	54	62	70	76	85	92	98	107	116	120
	150	10	21	31	39	49	57	66	74*	81	89	97	104	112	119	127	133
	175	11	23	32	42	52	61	69	78	86	95	103	111	118	126	134	141
	200	11	24	33	44	54	64	73	82	91	100	109	117	125	134	142	150
	225	12	25	35	47	57	68	78	87	96	106	115	124	132	141	150	159
	250	13	25	38	50	61	72	84	92	102	112	121	132	140	150	158	167

※ Where net depth of water that can be stored in the soil at time of irrigation is greater or smaller than 75 mm, the correction factor to be used is:

Effective storage	20	25	37.5	50	62.5	75	100	125	150	175	200
Storage factor	.73	.77	.86	.93	.97	1.00	1.02	1.04 ※	1.06	1.07*	1.08

Appendix C 1

EXAMPLE:

Given:

Monthly mean rainfall = 100 mm; ETcrop = 150 mm; effective storage = 175 mm

Calculation:

Correction factor for effective storage = 1.07

Effective rainfall 1.07 × 74 = 79 mm

Source: FAO Irrigation and Drainage Paper No. 24

APPENDIX C2 INFILTROMETER READINGS

INFILTROMETER NO.1 INITIAL M.C.= 13.2%			INFILTROMETER NO.2 INITIAL M.C. = 2.4%			INFILTROMETER NO.3 INITIAL M.C. = 19.7%			INFILTROMETER NO.4 INITIAL M.C.= 2.5%			INFILTROMETER NO.5 INITIAL M.C.= 5.0%		
CUM TIME (MIN)	CUM INF (mm)	INF RATE (mm/HR)	CUM TIME (MIN)	CUM INF (mm)	INF RATE (MM/HR)	CUM TIME (MIN)	CUM INF (MM)	INF RATE (MM/HR)	CUM TIME (MIN)	CUM INF (MM)	CUM RATE (MM/HR)	CUM TIME (MIN)	CUM INF (MM)	CUM RAT (MM/HR
0	0	-	0	0		-	-	-	0	0	-	0	0	-
5	13	156.0	5	11	132.0	5	7	84.0	5	7	84.0	5	11	132.0
10	22	132.0	10	15	90.0	10	10	60.0	10	13	78.0	10	21	126.0
15	29	116.0	15	17	68.0	20	13	39.0	20	22	66.0	20	36	108.0
20	35	105.0	20	18	54.0	30	16	32.0	30	29	58.0	30	46	92.0
25	40	96.0	30	19	38.0	50	21	25.2	50	43	51.6	50	65	78.0
35	51	87.4	40	20	30.0	70	25	21.4	70	55	47.1	70	82	70.3
45	59	78.7	60	21	21.0	90	29	19.3	90	65	43.3	90	93	62.0
55	68	74.2	90	23	15.3	120	34	17.0	120	83	41.5	120	108	54.0
75	85	68.0	120	24	12.0	150	37	14.8	180	98	32.7	150	124	49.6
95	101	63.8	180	28	9.3	210	44	12.6	240	123	30.8	210	150	42.9
125	123	59.0	240	30	7.5	270	53	11.8	300	153	30.6	270	172	38.2
155	141	54.6	300	34	6.8	330	59	10.7	360	180	30.0	330	195	35.5
185	158	51.2	360	37	6.2	390	65	10.0	420	208	29.7	390	217	33.4
215	176	49.1	420	40	5.7	450	71	9.5	480	236	29.5	450	238	31.7
275	206	50.0	480	43	5.4	510	77	9.1	540	259	28.8	510	259	30.5
335	236	42.3												
395	265	40.3												
455	292	38.5												

APPENDIX C3

EVAPOTRANSPIRATION SAMPLE CALCULATION

January

Mean incident solar radiation Rs = 8.1mm/day

Extra Terrestrial Radiation RS_0 = 13.0mm/day

Relative Humidity = 18% or 0.18

Vapour pressure ea = 4.5mbar

Wind speed = 600.75km/day

Station pressure p = 939.8mbar

Temperature:

Mean max = 29.1^0c

Mean min = 13.7^0c

Mean daily = 21.4^0c

saturation vapour pressure e_s = 25mbar

(a) $Y = \frac{0.24p}{0.622X}$

p = mean station pressure = 939.8mbar

x = 595.9 - 0.55t

= 595.9 - 0.55 x 21.4 = 584.13

$Y = \frac{0.24 \times 939.8}{0.622 \times 584.13} = \ldots\ldots\ldots 0.62$

(b) $R_{bo} = (0.39 - 0.05\sqrt{ea})\ 2 \times 10^{-9}\ (Ta^4 + T_b)^4/2$

Ta = 29.1 + 273 = 302.1k

T_b = 13.7 + 273 = 286.7^{0k}

$$R_b = (0.39 - 0.05\sqrt{4.5})\ 2 \times 10^{-9}\ \left(\frac{(202.1)^4 + (286.7)^4}{2}\right)$$

$= \underline{4.3\text{mm/day}}$

$$Rb = R_{bo} = ((1.1(8.1/13) + (-0.10))$$

$$= 4.3\ (1.1\ \frac{(8.1)}{13} - 0.10) = \underline{2.5\text{mm/day}}$$

$$Rn = 077RS - Rb$$

$$= 0.77 \times 8.1 - 2.5 = \underline{3.7\text{mm/day}}$$

$$D = 33.86\ ((0.05904\ (0.00738T + 0.8072)^7 - 0.0000342))$$

$= \underline{1.56}$

$$\frac{D}{D+Y} = \frac{1.56}{1.56 + 0.62} = \underline{0.72}$$

$$\frac{D}{D+Y} = \frac{0.62}{1.56 + 0:62} = \underline{0.28}$$

$$0.261\ (1.+0.0062 \times 600.75)\ (25 - 4.5)$$

$$= 25.2\text{mm/day}.$$

Therefore, $ETp = (0.72 \times 3.7) + (0.28 \times 25.2)$

$= \underline{9.7\text{mm/day}}$

APPENDIX C4. ESTIMATING THE FLOW RATE OF THE PUMP

Measurement taken at different locations of the command area

NUMBER OF RUN	1	2	3	4	5	6	7	8	9
VOLUME OF BUCKET (3)	0.01665	0.01665	0.01665	0.01665	0.01665	0.01665	0.01665	0.01665	0.01665
TIME TO FILL BUCKET (Sec.)	5.0	4.5	5.5	5.2	5.2	5.0	5.5	5.0	5.5
FLOW RATE m^3/sec	0.0033	0.0037	0.00303	0.0032	0.0032	0.00333	0.00303	0.00333	0.00303

MEAN FLOW RATE = 3.24×10^{-3} M^3/S = 3.241 litres/sec.

APPENDIX D1

VARIABLE PRODUCTION COSTS

FARM CODE	SEEDS/S SEEDLING (₦)	FERTILIZER (₦)	CROP (₦)	IRRIGATION (₦)	FUEL AND OIL (₦)	HAULAGE (₦)	REPAIRS & M (₦)	LABOUR (₦	LAND (₦)	TAX (₦)	TOTAL (₦)
A0082MUAT	14.00	70.00	30.00	225.00	-	24.00	-	12.00	-	15.00	390.00
BO082MATP	153.00	70.00	-	760.00	-	54.00	-	27.00	20.00	15.00	1099.00
CO082MSUT	264.00	630.00	-	416.00	-	183.00	-	90.00	150.00	15.00	1748.00
DO182MMIT	20.00	58.00	35.00	300.00	-	40.00	-	20.00	-	15.00	488.00
EO182MDHT	160.00	350.00	70.00	910.00	-	87.00	-	50.00	105.00	15.00	1747.00
FO182MNT	25.00	300.00	70.00	600.00	-	50.00	-	175.00	-	15.00	1235.00
GO182NUT	80.00	590.00	105.00	-	80.00	58.00	50.00	135.00	200.00	15.00	1313.00
HO023MST	-	270.00	40.00	1040.00	-	74.00	-	100.00	100.00	15.00	1639.00
I0023MIT	100.00	160.00	30.00	540.00	-	44.00	-	165.00	100.00	15.00	1158.00
JO023MMBT	200.00	450.00	60.00	-	220.00	95.00	48.00	48.00	50.00	20.00	1191.00
K0023MAW	680.00	910.00	-	-	144.00	30.00	50.00	1020.00	-	20.00	2854.00
L0073MT	120.00	350.00	70.00	450.00	-	70.00	-	80.00	150.00	15.00	1305.00
M0073SAT	50.00	130.00	60.00	300.00	-	33.00	-	125.00	60.00	15.00	773.00
N0075MTH	180.00	180.00	-	600.00	-	56.00	-	540.00	-	15.00	1571.00
P0085MDO	50.00	45.00	-	144.00	-	10.00	-	40.00	50.00	15.00	354.00
Q0085MMAO	-	40.00	-	-	42.00	28.00	50.00	300.00	-	15.00	475.00

APPENDIX D2 COMPUTATION OF FIXED PRODUCTION COSTS

FARM CODE	PURCHASE VALUE (₦)				DEPRECIATED VALUE (₦)				TOTAL DEPRECIATED VALUE (₦)
	TOOL/EQUIP	PUMP	SPRAYER	HOSE/PIPES	TOOL/EQUIP	PUMP	SPRAYER	HOUSE/PIPES	
AOO82MUAT	50.00	-	-	-	10.00	-	-	-	10.00
BOO82MATP	80.00	-	-	-	16.00	-	-	-	16.00
COO82MSUT	90.00	-	-	-	18.00	-	-	-	18.00
DOO182MIT	50.00	-	-	-	10.00	-	-	-	10.00
EO182DHT	90.00	-	-	-	18.00	-	-	-	18.00
FO182MNT	90.00	-	-	-	18.00	-	-	-	18.00
GO182MUT	150.00	3600.00 (1989)	-	1000.00 (1989)	30.00	180.00	-	50.00	260.00
HOO23MST	90.00	-	-	-	18.00	-	-	-	18.00
IOO23MIT	50.00	-	-	-	10.00	-	-	-	10.00
JOO23MMBT	60.00	500.00 (1983)	200.00 (1983)	200.00	12.00	121.00	111.00	48.00	292.00
KOO23MAW	-	550.00 (1982)	-	50.00	-	173.00	-	16.00	189.00
LOO73MT	120.00	-	-	-	24.00	-	-	-	24.00
MOO73MDAT	50.00	-	-	-	10.00	-	-	-	10.00
NOO75MTM	90.00	-	-	-	18.00	-	-	-	18.00
POO85MDO	60.00	-	-	-	12.00	-	-	-	12.00
QOO85MMAO	30.00	3250.00 (1989)	-	1200.00	6.00	163.00	-	60.00	229.00

APPENDIX D3 YIELD/REVENUE ESTIMATES. (1Big Basket of tomato = 33.12kg)

FARM CODE	CROP	HECTARAGE (HA)	YIELD (BASKET)	YIELD (KG)	PRICE/KG (₦)	TOTAL (₦)	YIELD/HA (KG)
AOO82MUAT	Tomato	0.0352	24	795	0.91	724.00	22585
BOO82MATP	Tomato	0.0800	50	1656	0.91	1507.00	20700
" "	Pepper	0.0800	2BAGS	160	16.0	2560.00	2000
COO82MSUT	Tomato	0.3000	183	6061	0.91	5516.00	20203
DO182MMIT	Tomato	0.0583	40	1325	0.91	1206.00	22727
EO182MDHT	Tomato	0.1240	87	2881	0.91	2622.00	23234
F0182MNT	Tomato	0.0780	50	1656	0.91	1507.00	21231
G0182MUT	Tomato	0.0900	58	1921	1.21	2324.00	21344
HOO23MST	Tomato	0.0952	74	2451	1.06	2598.00	25746
IOO23MST	Tomato	0.0560	44	1457	1.06	1544.00	26018
JOO23MMBT	Tomato	0.1517	95	3146	1.06	3335.00	20738
KOO23MAW	Wheat	0.6500	6BAGS	600	6.60	3960.00	923
LOO73MT	Tomato	0.1080	70	2318	1.06	2457.00	21463
MOO73MDAT	Tomato	0.0450	33	1093	1.06	1159.00	24289
NOO75MTM	Tomato	0.3500	56	1855	1.06	1966.00	5300
" "	Maize	0.3500	2½BAGS	250	5.70	1425.00	714
POO85MDO	Okra	0.0675	23(SMALL)	178	2.58	460.00	2637
QOO85MMAO	Okra	0.2240	57(SMALL)	442	2.58	1140.00	1973