DESIGN OF SURFACE IRRIGATION FOR TOMATO PRODUCTION IN TUNGAN KAWO IRRIGATION, WUSHISHI, NIGER STATE

BY

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DECEMBER, 2010

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BEING A FINAL YEAR PROJECT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF A BACHELOR OF ENGINEERING (B. ENG) DEGREE IN AGRICULTURAL BIORESOURCES ENGINEERING,FEDERAL UNIVERSITY OF TECHNOLOGY,MINNA, NIGER STATE

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DECLARATION

I solemnly declare that this project work is a record of a research work that was carried out by me under the supervision of Mr. A Halilu and that it has not been presented for the award of any degree or diploma or certificate at any university or institution. Information derived from personal communications, published and unpublished work were duly referenced in the text.

14/12/2010

Njoku, Stanley Onye

Date

DEDICATION

This research project is dedicated to GOD ALMIGHTY

CERTIFICATION

This is to certify that the project entitled "Design of Surface Irrigation for Tomato Production in Tungan Kawo Irrigation, Wushishi, Niger State" by Njoku Stanley Onye, meets the regulations governing the award of the degree of Bachelor of Engineering (B. ENG.) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

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Supervisor

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ABSTRACT

This project study investigates the possibilities of incorporating an efficient and cost effective irrigation network for Tomato production at Tunga Kawo Wushishi.Based on the soil analysis and the topographical survey of the site as per its feasibility to dry spell farming some important parameters were used for the design of the project. The water holding capacity of the soil is 75mm/hr which is greater than the net depth of application (40mm/hr) which posses no water logging problem. The irrigation system which is gravity (Basin irrigation method).was adopted and designed based on computed gross water requirement.It is possible for the project to a very desired production level of about 8 tonns/ha.The economic analysis indicate the attractiveness of the investment with a cost-benefit ratio of 1:4.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Irrigation is an age old art. Historically, civilization has followed the development of irrigation. Civilization have risen on irrigated lands, they have also decayed and disintegrated in irrigated regions. Water is a scarce resource in the world and irrigation is the major user of water supplies, limiting agriculture development in many regions and countries of the world. Irrigation in the world today accounts for 70% of all freshwater withdrawals which are used to irrigate 17% of all cropped land; yielding 40% of the overall agricultural outputs worldwide (ICID Congress, 2005). Irrigation will play a greater and more dependable role in meeting future food demands than in the past. The goal shall be to "Grow More Food with less Drops". This will be feasible with advances in technology, modernization, better management of irrigation and where applicable, drainage systems. Poor irrigation management causes lower irrigation efficiencies and greater water losses. (ICID Congress, 2005).

The irrigation requirement of a crop is the total amount of water that must be supplied by irrigation to a disease free crop, growing in large field with adequate soil water and fertility, and achieving full production potential under the given growing environment (Doorenbos and Pruitt, 1977).

Surface irrigation systems are the most commonly used method for irrigating crops and pastures in Nigeria and around the world. In this method water is applied directly to the soil surface from a channel located at up-slope end of the field and allowed to cover the field by overland flow. The rate of coverage is dependent almost entirely on the quantitative differences between inlet discharge and the accumulating infiltration. Secondary factors include field slope and surface roughness, such as soil clods or vegetation that retard water flow. There are two features that distinguish a surface irrigation from other systems, The flow has a free surface responding to the gravitational gradient, and the on- field means of conveyance and distribution is the field surface itself. (Kanya, 2007).

Using the soil surface to convey water across the field results in a low capital cost but it introduces unique problems in. its design and management. Both design and management depend to a high degree on the soil properties such as infiltration rate and surface roughness. These properties can be difficult to measure or predict accurately, thus requiring a trial and error approach to develop proper design and management strategies (Hanson, 1994).

When the water is applied to the field, it advances across the surface until the water extends over the entire area and it is called advance phase .Then irrigation water either runs off the field or begins to pond on its surface. The interval between the end of the advance and when the inflow is cut-off is called the wetting or ponding .The volume of water on the surface begins to decline after the water is no longer being applied. It either drains from the surface (runoff) or infiltrates into the soil. (schwaki, 1994).

(FAO, (1989))reported that it is essential to use irrigation in improving agricultural production (for example tomato production) to cater to the needs of increasing world population. Crop yield from irrigated lands are higher and more consistent. It is estimated that although only 15-20% of the worldwide total cultivated area is irrigated, it contributes as much as 30-40% of the gross agricultural output.

1.2 Description of tomato

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important Vegetables worldwide. World tomato production in 2001 was about105 million tons of fresh fruit from an estimated 3.9 million ha. As it is a relatively short duration crop and gives a high yield, it is economically attractive and the area under cultivation is increasing daily. Tomato belongs to the *Solanaceae* family. This family also includes other well-known species, such as potato, tobacco, peppers and eggplant (aubergine).(Wikipedia, 2001).

1.2.1 Origin of tomato

Tomato has its origin in the South American Andes. The cultivated tomato was brought to Europe by the Spanish conquistadors in the sixteenth century and later introduced from Europe to southern and eastern Asia, Africa and the Middle East. More recently, wild tomato has been distributed into other parts of South America and Mexico. Common names for the tomato are: tomate (Spain, France), tomat (Indonesia),faan ke'e (China), tomati (West Africa), tomatl (Nahuatl),jitomate (Mexico), pomodoro (Italy), nyanya (Swahili).(Barbara, 2002).

1.2.2 Benefits of Tomato

Tomatoes are used as food in Nigeria and contribute to a healthy, well-balanced diet. They are rich in minerals, vitamins, essential amino acids, sugars and dietary fibers. Tomato contains much vitamin B and C, iron and phosphorus. Tomato fruits are consumed fresh in salads or cooked in sauces, soup and meat or fish dishes. They can be processed into purées, juices and ketchup. Canned and dried tomatoes are economically important processed products (Idah ,*et .al*.2010).Tomato is an annual plant, which can reach a height of over two meters (In South America, however, the same plants can be harvested for several years in succession. The first harvest is possible 45-55 days after flowering, or 90-120 days after sowing. The shape of the fruit differs per cultivar. The color ranges from yellow to red (Martin, 2005).

1.2.3 Tomato Production

In Nigeria, tomatoes production has received government support nationwide through construction of dams and canals upon the realization that vegetable crops are staple food coupled with the rapid growth in population and distinct economic and nutritional advantages. The world productivity of tomatoes has increased from 15.34 metric tons/ha in 19987 to 16metric tons/ha in 2002. This is an indication that farmers are now more aware of the importance of engaging in irrigation activities, especially by using modern farming inputs such as improved seeds, fertilizers and pesticides (Usman, 2006). According to Usman (2006), tomato is the most popular home garden and the second most consumed vegetable after potato in the world. Globally, world register of tomato tonnage has increased from 15.2 million tons in 1976 to 26.1million tons in 1987.This is an 84% increase in 13years, and corresponds to 4.2% annual growth rate. During this period, world population grew from 4 billion in 1976 to 5.2 billion in 1989, a 2% annual growth rate.

Nigeria's production of tomatoes is incomparable with other countries, although there is a kind of specialization in Niger and Benin for some vegetables. Production of tomatoes is specialized in the northern part of the country with particular reference to Kebbi, Sokoto, Kano, Jigawa and Bauchi states. The annual production of tomatoes for 1995/96 is estimated at 555.630 tons (FCPSAR, 1996). This estimate for Nigeria is for the states mentioned above, and the production level is expected to rise annually coupled with the rising population and increased farming activities (Agricultural Project Monitoring Evaluation Unit, Kaduna, 1996). Similarly, tomato production is carried out in the south of coastal countries (south of Benin, Niger and

Cameroun) for pluvial tomato, in the north of the same countries and in the south of Niger and Chad for out of season crops.(Abdullahi, 2009)

1.3 Statement of the Problem

Systematic, repeated simulation can lead to design parameters yielding optimum uniformity of infiltrated water and minimum deep percolation and run off from the end of the field. This informs the present study the design of surface irrigation for an all year round tomato production in Tunga kawo irrigation scheme, Wushishi, Niger state.

1.4 Justification of the Study

Considering the problem of water wastage on farm, it is imperative to redesign the various irrigation systems to enhance an all year round food production to meet the basic needs of our growing population. This of course will help improve the various farming activities, further reduce the time spent on farm and above all increase the quantity of farm produce. With the actual quantity of water known for the growth of a crop, projections can be made with respect to the number of times such crops should be irrigated while the remaining quantity of water can be delivered for other uses.

1.5 Objective of the Study

i, The principal objective of this study is to design an irrigation system that can provide water supply to farm lands in Tungan Kawo, Wushishi, Niger state.

ii. To test run the design irrigation system

iii. Determine the efficiency of the project in terms of its cost benefit ratio.

CHAPTER TWO

2.0 LITERATURE REVIEW

The efficiency of surface irrigation is a function of the field design, infiltration characteristic of the soil, and the irrigation management practice. However, the complexity of the interactions makes it difficult for irrigators to identify optimal design or management practices. While well designed and managed surface irrigation systems may have application efficiencies of up to 90% many commercial systems have been found to be operating with significantly lower and highly variable efficiencies (Anthony, 1995).

The infiltration characteristic of the soil is one of the dominant factors in determining the performance of surface irrigation applications and both spatial and temporal variations in the infiltration characteristic are a major physical constraint to achieving higher irrigation application (shafique, 1983).

A real time control system has the potential to overcome these spatial and temporal variations. Raine et al, (1997) have reported the significant improvements in irrigation performance are possible with optimization of individual irrigation events.Surface irrigation offers a number of important advantages at both the farm and project level. The gravity flow system is a highly flexible, relatively easily-managed method of irrigation. Because it is so widely utilized, local irrigators generally have at least minimal understanding of how to operate and maintain the system, In addition, surface systems are often more acceptable to agriculturalists who appreciate the effects of water shortage on crop yields since it appears easier to apply the depths required to refill the root zone. The second advantage of surface irrigation is that these systems can be developed at the farm level with minimal capital investment. The control and regulation structures are simple, durable and easily constructed with inexpensive and readily-available materials like wood, concrete, brick and mortar, etc. Further, the essential structural elements are located at the edges of the fields which facilitates operation and maintenance activities. Energy requirements for surface irrigation systems come from gravity. This is a significant advantage in today's economy. They are less affected by climatic and water quality characteristics. Like sediments & other debris reduce the effectiveness of trickle systems and wind affects the sprinkler systems. Salinity is less of a problem under surface irrigation than either of these pressurized systems. Surface systems are better able to utilize water supplies that are available less frequently, more uncertain, and more variable in rate and duration. (Wikipedia, 2009).

2.1 Surface Irrigation Techniques

Surface irrigation techniques can be broadly classified into uncontrolled flooding and controlled methods of; Border irrigation, Basin irrigation and furrow irrigation

2.1.1 Border irrigation

This method makes use of parallel ridges to guide a sheet of flowing water as it moves down the slope. The land is divided into a number of long parallel uniformly graded strips 10 to 100m wide and 200 to 1000m long, known as borders that are separated by low earth banks/ridges. It has no cross slope but uniform gentle slope in the direction of irrigation. The essential feature is to provide a surface such that water can flow down with a uniform depth. The precision of field topography is of critical consideration but the extended lengths permit better leveling through the use of farm machinery. Border irrigation has the following characteristics, It is suitable for most soils where depth and topography permit the required land leveling at a reasonable cost and without permanent reduction in soil productivity, it is more suitable to soils having low to moderate infiltration rates such as loamy soils but unsuitable to coarse sandy soils having infiltration rates, it is also not suited on soils having low infiltration rates and it is suitable to irrigate all close growing crops like wheat, barley, fodder crops and legumes. (Smith *et al*; 2005)

2.1.1.1 Development Costs

The two major development costs for borders are land leveling and border construction. Land leveling is more extensive than for furrows and less extensive than for basins, particularly if the field is leveled along the existing slope in the direction of flow. The border dikes do not have to be as high as for basins but do need to be maintained in order to prevent cross-flow into adjacent borders and care should be taken to intercept the flow that can occur in the dead furrow created by the diking equipment. Borders do not generally require as much labor as furrow irrigation but do require more than for basins since the time of cutoff has to be judged properly. In fact, furrow system cutoff times are usually after the completion of advance and for borders, they are typically shorter and before the completion of the advance phase. Consequently, achieving high efficiencies is more difficult in border irrigation than in furrow irrigation. Traditionally, free draining borders have about the same efficiency and uniformity as furrows thereby reducing the economic feasibility of borders that allow tailwater. However, borders can also be blocked to prevent runoff and achieve efficiencies as high as those for basins thereby becoming slightly more economical than basins. (Larry *et al*; 1998).

2.1.1.2 Field Geometry

Borders are usually long and rectangular in shape. Often referred to as "border strips", borders contain the flow within side dikes to direct the flow over the field. Borders can be furrowed where necessary for elevating a seed bed or compensating for micro-topography within the border. Borders can also be level or nearly level making them effectively the same as basins. Distinguishing borders from basins is often based on the rectangular shape rather than slope and in any event the differences are only semantic. (Burt, 2003)

2.1.1.3 Soil Characteristics

Borders do not generally have erosion problems except near outlets and tail water drains so they are somewhat more flexible irrigation systems than furrows. The slope aids advance and recession so border irrigation can be applied to the full range of soils so long as the flow per unit width is selected properly. However, as with basins, borders are better suited to the heavier soils and crusting soils may require special care such as furrowing. (Burt,2003)

2.1.1.4 Water Supply

Typical water applications under border irrigation are similar to basin systems and usually larger than furrows. In general border systems require 3-5 times as much flow per unit width as furrow systems and somewhat less than basins. For example, it would not be unusual to irrigate furrows on a spacing of at 2.5 feet with a 15 gpm flow (6 gpm/ft) and to irrigate a border with the same soil with a flow of 20 gpm/ft. The same water quality constraints noted for basins apply to borders as well. Consequently, water supplies for borders should be relatively high discharges for relatively short durations on relatively long intervals. (Yahaya, 1995)

2.1.1.5 Climate

Scalding is a more serious problem in blocked end borders than in basins because the end depths are greater and require longer to drain from the field. It is common practice to provide blocked end borders with surface drainage capability in case an error is made in the time of cutoff and too much water ponds at the end of the field. (Adam ,1999)

2.1.2 Basin irrigation

Basin irrigation is a common form of surface irrigation, particularly in regions with layouts of small fields. This is the simplest in principle of methods of irrigation, is claimed to give higher application efficiencies and there are many variations in its use, but all involve dividing the field into smaller units so that each has a nearly level surface. Bunds or ridges are constructed around the areas forming basins within which irrigation water can be controlled. The basins are filled to the desired depth and the water is retained until it infiltrates into the soil. When irrigating rice, or pondind water for leaching salts from the soil, the depth of water to continue to flow into the basins. This is similar to border irrigation except that here there is no longitudinal slope on the field and the length may be shorter (Smith *et a,l* 2005).

Basins may vary in size from 1 m^2 for growing vegetables (for example tomato) to as much as several hectares for the production of rice and other grain crops. Sandy soils require small basins and clayey soils allow large basins. The objective in selecting the basin is to enable flooding of the entire area in a reasonable length of time, so that the desired depth of water can be applied with a high degree of uniformity over the entire basin. Cotton, grain, maize, groundnuts, Lucerne(alfalfa), pasture and many other field crops which are sensitive to wet soil conditions around the stems (Smith et al, 2005).

2.1.2.1 Development Costs

Basin irrigation is generally the most expensive surface irrigation configuration to develop and maintain, but often the least expensive to operate and manage. Land leveling is the most costly development and maintenance requirement, although the perimeter diking can also be expensive to form and maintain. In areas where turnouts from the delivery system have relatively small discharges, development costs may also be increased by necessary changes in the irrigation system upstream of the basin. Since basins are typically designed to pond the water on their surfaces and prevent tail water, they are usually the most efficient surface irrigation configurations. In addition, management is almost always simpler. (Larry et al, 1998).

2.1.2.2 Field Geometry

In the absence of field slope to aid the movement of water on the field surface, the "run length", or distance the water has to advance over the field tends to be minimized. Many basins take on a square rather than a rectangular shape, but this depends entirely on the availability of sufficient flow rates and the intake characteristics of the soil. One of the major advantages of basins is their utility in irrigating fields with irregular shapes and small fields. (Burt, 2003).

2.1.2.3 Soil Characteristics

Basin irrigation systems usually operate at less frequent intervals than furrows or borders by applying a larger depth during irrigation. Consequently, medium to heavy soils with their high moisture holding capacity are better suited to basins than lighter soils. The efficiency and uniformity of basin irrigation depend on the relative magnitude of the field inflow and the soil intake. A soil with a relatively high intake characteristic will require a substantially higher flow rate to achieve the same uniformity and efficiency as for a heavier soil. Since the water may cover the entire basin surface, a soil that forms dense crusts upon drying may have detrimental impacts on seed germination and emergence. It is common practice to furrow soils of this nature to reduce crusting problems. On the other hand, basin irrigation is an effective means for reclamation and salt leaching. Many of the heavier soils will form cracks between irrigations which may be responsible for much of the water that infiltrates during irrigation. These soils are also susceptible to forming compacted layers (hard pans or plow pans) at the cultivation depth.

The impact of cracking in basin irrigation is an increased applied depth while the impact of a "plow pan" is to restrict it (Burt, 2003).

2.1.2.4 Water Supply

The water supply to an irrigated field has four important characteristics: its quality; its flow rate; its duration; and its frequency of delivery. The quality of the water added to the field will be reflected in the quality of the water throughout the root zone. Salinity is usually the most important quality parameter in surface irrigation and the higher the salinity in the irrigation water the higher will be the concentration of salts in the lower regions of the root zone. However, since basins do not apply water to the crop canopy as does sprinkle irrigation, water supplies with relatively high salinities can be used some water supplies also have poor quality due to toxic elements like Boron.(Yahaya, 1995) .

The most important factor in achieving high basin irrigation uniformity and efficiency while minimizing operational costs is the discharge applied to the field. In basin irrigation, the higher the available discharge the better, constrained only by having such a high flow that erosion occurs near the outlet. The duration of irrigation is dependent on the depth to be applied, the flow rate onto the field, and the efficiency of the irrigation. Basin irrigation's typically high discharges and high efficiencies mean that basin irrigations may require less total time than borders and furrows. This coupled with the fact that basins usually irrigate heavier soils and apply larger depths means that the irrigation of basin is typically less frequent than borders or furrows. The duration and frequency of basin irrigation impose different requirements on the water supply system than systems operated to service border and furrow systems. (Smith *et al* ; 2005)

2.1.2.5 Climate

Whenever water ponds on a cropped surface for an extended period of time the oxygen-carbon dioxide exchange between the atmosphere and the roots is disrupted. If the disruption is long enough, the crops will die. This process is sometimes called "scalding". Scalding is perceived as a serious risk in basin irrigation by irrigators in hot dry climates. Of course rice farming depends on this process for weed control. Another climate related impact of basin irrigation is the effect of water temperature on the crop at different stages of growth. Irrigation with cold water early in the spring can delay growth whereas in the hot periods of the summer it can cool the environment – both of which can be beneficial or detrimental in some cases. One important advantage of basins in many areas of high rainfall is that they can more effectively capture it than can borders or furrows. Thus basins enjoy the benefits of higher levels of effective precipitation and may actually require less irrigation delivery during rainy periods as long as the crops are not damaged by subsequent scalding or flooding. (Adams, 1999)

2.1.2.6 Cropping Patterns

With its full wetting and large applied depths, basin irrigation is most conducive to the irrigation of full-stand crops like alfalfa, grains, grass, and rice. Row crops can be and often are grown in basins as well. Widely spaced crops like fruit trees do not require as much of the total field soil volume to be wetted and thus basin irrigation in these instances is less useful. Although it should be noted that mini-basins formed around each tree and then irrigated in pass-through or cascade fashion are found in many orchard systems. Cascading systems are usually less efficient and have low uniformity due to poor water control. Basin irrigation is also more effective with deep rooted crops like alfalfa than with shallow rooted crops like vegetables. Crops which react adversely to crown-wetting do not favor basins. (Collins, 1996)

2.1.2.7 Cultural Factors

Because surface irrigation depends on the movement of water over the field surface, whose properties change from year to year and crop to crop as well as from irrigation to irrigation, surface irrigation management is a difficult task to do well and consistently. Basin irrigation reduces this burden by eliminating tailwater from the management process. However, where basin irrigation has not been practiced previously, the added costs and the uncertainty associated with a lack of experience are often substantial barriers to its adoption.(Humphrey, 1980)

2.1.2.8 Land Leveling

Land leveling operators varied in skill and experience. Today, the precision of land grading equipment is much greater and does not depend nearly as much on operator skill and experience.

It should come as no surprise that since the field surface must convey and distribute water any undulations will impact the flow and therefore the efficiency and uniformity. Basin irrigation is somewhat less dependent on precision field topography than either furrow or border systems because of high flows or the ponding, but many users of basin irrigation insist that the most important water management practice they have is " lasering "(bucks et al, 2001). Precision land leveling is an absolute prerequisite to high performance surface irrigation systems, including basins. This includes regular precision maintenance during field preparations (land smoothing).

2.1.3 Furrow irrigation

Furrow irrigation can be used to irrigate all crops planted in rows; including orchards. It is suitable for irrigating maize, sugarcane, tobacco, cotton, groundnut, potato and other vegetables. The amount of water per unit width on a furrow irrigated field may only be 20% of the water flowing over a similar width in a basin. (FAO 2002). It is suited to all soils except sandy due to high infiltration rates and has the following features; In this method water contacts only one half to one fifth of the land surface thus reducing crusting and evaporation losses, furrows provide better on farm water management flexibility under many surface irrigation conditions, and furrows provide the irrigators more opportunity to manage irrigations towards higher efficiencies as field conditions may change for each irrigation across field and throughout a season. (FAO, 2002).

2.1.3.1 Development Costs

Furrow irrigation systems are the least expensive surface irrigation systems to develop and maintain primarily because minimal land leveling is required to implement a furrow system and less precise land smoothing is necessary for maintenance. The furrow themselves can be formed with cultivation equipment at the time of planting. While less expensive to implement, furrow systems are substantially more labor intensive than basins. Variations in individual flows, slopes, roughness, and intake alter the advance rate of each furrow and there are often substantial differences in how long it takes the water to reach the end of the furrow. In addition, some furrows are compacted by the wheel traffic of planting and cultivation equipment and have substantially different characteristics than non-traffic furrows. Irrigators compensate by adjusting the furrow flows and thereby need to be at the field longer. Further, they also have to assess how long to allow the water to run off the field before shutting it off as opposed to shutting the flow off in a basin when the correct total volume has been added to the field. Because most furrow systems allow field tailwater, they are seldom as efficient as basin systems and thereby require more water per unit area. Measures such as the capture and reuse of tailwater can be employed to increase efficiency. Another alternative is a concept called cutback that involves reducing the furrow inflow after the flow has reached the end of the furrow. Surge flow and cablegation systems are examples of automated cutback systems. (Larry et al , 1998).

2.1.3.2 Field Geometry

Furrow irrigated fields generally have slopes in both the direction of the flow and the lateral direction. These slopes can vary within a field although the slope in the direction of flow should not vary significantly unless it is flattened at the end of the field to improve uniformity. One of the major advantages of furrow irrigation is that undulations in topography have less impact on efficiency and uniformity than they do in either basin or border irrigation.(Burt, 2003)

2.1.3.3 Soil Characteristics

Furrow irrigation can be practiced on nearly all soils but there are two important limitations. First, the risk of erosion is higher in furrow irrigation than in either basin or border irrigation because the flow is channeled and the flow velocities are greater. Secondly, since the furrow actually wets as little as 20% of the field surface (depending on furrow spacing), applying relatively large depths of irrigation water in the heavy soils can require extended periods of time and will result in low efficiencies. A four or six inch irrigation application is common in basin and border irrigation but would not be feasible with a furrow system on a particularly heavy soil. Furrow irrigation is more impacted by soil cracks than borders and basins since the cracks often convey flow across furrows. Furrows are probably less impacted by restrictive layers due to their inherent two-dimensional wetting patterns. (Burt, 2003)

2.1.3.4 Water Supply

Since the flow on the field is substantially less than in a basin or border system, a major advantage of furrow irrigation is that it can accommodate relatively small delivery discharges per unit area. As furrows typically apply smaller depths per irrigation, the availability of the delivery must be more frequent and for longer durations. More water on a volumetric basis is required for furrow irrigation because of its lower application efficiency in most cases.

Salts can accumulate between furrows and therefore the quality of irrigation water is more important in furrow systems than in basins or borders (Yahaya, 1995)

2.1.3.5 Climate

The climate over a surface irrigated field does not have significant impacts on the furrow irrigation. Scalding is seldom a problem even when the furrow ends are blocked. High winds can retard the furrow advance but this is rarely a problem. The effect of water temperature is less in furrows than in borders or basins because the wetted area is less. (Adams, 1999)

2.1.3.6 Cropping Patterns

Furrows are ideally suited for row crops of all kinds but are also used in solid plantings like alfalfa and grains. When the seed bed is between furrows and must be wetted, it is necessary to apply water to the furrows for extended periods and efficiencies of these emergent irrigations can be very low. The lateral movement of water or “subbing”, “wetting-across”, etc. is a relatively slow process so many irrigators of higher value crops like vegetables use portable sprinkle systems for the emergent irrigations. Special crops like rice are generally not irrigated with furrows because of the need for a uniform submergence to control weeds.(Collins ,1996)

2.1.3.7 Cultural Factors

Most of the cultural factors affecting furrow irrigation are the same as those noted previously for basin irrigation. The higher labor requirements require a resource in US agriculture that is becoming critically short. The lower efficiencies are problematic in an era of diminishing supplies, competition by urban needs, and the detrimental impact of salts and sediments on the quality of receiving waters when efficiencies are low. When polypipe is used to distribute water to the furrows an environmental concern with its disposal is raised. On the other hand, furrow irrigation is more flexible than either borders or basin as the configuration is easily changed by simply increasing or decreasing the number of furrows being irrigated simultaneously or by irrigating alternate furrows. (Humphrey, 1995)

2.1.3.8 Land Leveling

While precision land leveling is not as critical to furrow irrigation as it is to basin and border irrigation, an irrigator cannot expect to achieve high uniformities and efficiencies without it. Precision land leveling will reduce the furrow to furrow variations in advance times and will improve both uniformity and efficiency. Land leveling for furrow systems is also much less intrusive since field slopes can run in both field directions thereby reducing the volume of soil that has to be moved. Land smoothing, while not as important, is nevertheless a good practice on a regular basis.(Burt, 2003)

2.2 The Basic Design Process

The surface irrigation design process is a procedure to determine the most desirable frequency and depth of irrigation within the capacity and availability of the water supply. This process can be divided into a preliminary design stage and a detailed design stage.

2.2.1 The Preliminary Design

The operation of the system should offer enough flexibility to supply water to the crop in variable amounts and schedules and thereby allow the irrigator some scope to manage soil moisture for maximum yields as well as water, labor and energy conservation, and changes in cropping patterns. Water may be supplied on a continuous or a rotational basis in which the flow rate and duration may be relatively fixed. In those cases, the flexibility in scheduling irrigation is limited by water availability or to what each farmer or group of farmers can mutually agree upon within their command areas. On-demand systems should have more flexibility than continuous or rotational water schedules and are driven by crop demands. During preliminary design the limits of the water supply in satisfying an optimal irrigation schedule should be evaluated. It is particularly important that water measurement be an integral component of the water supply and that it is capable of providing the appropriate depth of water to the field (Davies, 2000)

The next step in the design process involves collecting and analyzing local climate, soil and cropping patterns to estimate the crop water demands. From this analysis the amoSunt of water the system should supply through the season can be estimated. Comparing the net crop demands with the capability of the water delivery system to supply water according to a variable schedule can produce a tentative schedule. Whichever criterion (crop demand or water availability) governs the operating policy at the farm level, the information provided at this stage will define the limitations of the timing and depth of irrigations during the growing season. (Baba, 1993)

The type of surface irrigation system selected for the farm should be carefully planned. Furrow systems are favored in conditions of relatively high bi-directional slope, row crops, and small farm flows and applications. Border and basin systems are favored in the flatter lands, large field discharges and larger depths of application. A great deal of management can be applied where flexibility in frequency and depth are possible. (Baba, 1993)

2.2.2 Detailed Design

The detailed design process involves determining the slope of the field, the furrow, border or basin inflow discharge and duration, the location and sizing of headland structures and miscellaneous facilities; and the provision of surface drainage facilities either to collect tailwater for reuse or for disposal. Land leveling can easily be the most expensive on-farm improvement made in preparation for irrigation. It is a prerequisite for the best performance of the surface system. Generally, the best land leveling strategy is to do as little as possible, i.e. to grade the field to a slope that involves minimum earth movement. Exceptions occur where other considerations dictate a change in the type of system, say, basin irrigation, and yield sufficient benefits to offset the added cost of land leveling. (Hardy, 1998)

If the field has a general slope in two directions, land leveling for a furrow irrigation system is usually based on a best-fit plane through the field elevations. This minimizes earth movement over the entire field, and unless the slopes in the direction normal to the expected water flow are very large, terracing and benching would not be necessary. A border must have a zero slope normal to the field water flow and thus will require terracing in all cases of cross slope. Thus, the border slope is usually the best-fit sub-plane or strip. Basins, of course, are level, i.e. no slope in either direction. Thus, terracing is required in both directions. When the basin is rectangular; its largest dimension should run along the field's smallest natural slope in order to minimize leveling costs. Field length becomes a design variable at this stage and again there is a philosophy the designer must consider. In mechanized farming long rectangular fields are preferable to short square ones. This notion is based on the time required for implement turning and realignment. The next step in detailed design is to reconcile the flows and times with the total flow and its duration allocated to the field from the water supply. On small fields, the total supply may provide a satisfactory coverage when used to irrigate the whole field simultaneously. However, the general situation is that fields must be broken into 'sets' and irrigated part by part, i.e. basin by basin, border-by-border, etc. These subdivisions or 'sets' must match the field and its water supply.(Dozie, 2002)

2.3 The Irrigation Requirement

The irrigation system is usually not expected to supply all of the moisture required for maximum crop production. To do so would ignore the valuable contribution of other water sources such as rain and thereby force the irrigation system to be larger and more expensive than necessary. It is also unrealistic that irrigation can or should be practiced without waste. Certainly, the fraction of that supplied which is beneficially used should be maximized, but this fraction or irrigation efficiency cannot be 100% without other serious problems developing.(FAO, 2001)

In arriving at the contribution an irrigation system will make to an irrigated area, particularly a surface irrigation system, four major factors require consideration? These are:. The concept of water balance in the region encompassing the plant environment, The body of soil supplying moisture, nutrient, and anchorage for the crop and the associated characteristics of this porous medium, the crop water requirements, including drainage for aeration and salt leaching, and the efficiency and uniformity of the irrigation system. (FAO, 2001)

2.3.1 Soil Characteristics

Soil characteristics of particular importance to irrigated agriculture include; the capacity of the soil to hold water and still be well drained; the flow characteristics of water in the soils;

the physical properties of the soil matrix, including the organic matter content, soil depth, soil texture, and soil structure; and soil chemical properties, including the translocation and concentration of soluble salts and nutrients due to the movement, use, and evaporation of the soil water. Knowledge of all these relationships and how they influence each other is critical to all who desire to improve irrigation practices and obtain the best, most efficient use of water. (Harrison, 1985)

2.3.2 Soil Moisture

If there is either excessive water (water logging) or insufficient water, crop growth will be retarded (Wikipedia 2001). As commonly defined, the available moisture for plant use is the range of soil moisture held at a negative apparent pressure of one-tenth to one-third bar (field capacity) and 15 bar (permanent wilting point). However, the soil moisture content within this pressure range will vary from 25 cm per meter of soil depth for some silty loams to as low as 6 cm per meter for some sandy soils.

2.3.3 Soil Physical Properties

The soil matrix serves several very valuable functions, not the least of which is serving as a foundation to hold the plants upright. It must also furnish nutrients and provide a good balance between aeration and available moisture content.

Soil texture and structure influence the intermolecular forces and "suction" of water in unsaturated soils. These forces can be quite substantial and include the capillary and attractive forces resulting from the close contact of soil particles. Soil texture, primarily soil structure, greatly influences the porosity and distribution of pore sizes, and thereby the permeability of soils to air, water, and roots, which is as important to crop growth as an adequate supply of nutrients. In fact, the entire soil-water-plant system is so interrelated that the failure or lack of one component can cancel the combined benefits of all the others. (Wikipedia, 2001)

2.3.4 Soil Chemical Properties

The chemical properties of soils can greatly influence how irrigable soils are by affecting the hydraulic characteristics and the suitability of the soil for crop production. Soils having an excess of soluble salts are designated as saline soils, and, if the soil has an excess of exchangeable sodium, it is termed a sodic soil. Sodic soils tend to have very poor soil structure, due to swelling or dispersion of soil particles.(Wikipedia, 2001)

Excess soil salinity will delay or prevent crop germination and can substantially reduce the amount and rate of plant growth because of the high osmotic pressures which develop between the soil-water solution and the plant. These pressures, which appear to be independent of the type of salts present, greatly impair the plant's ability to absorb water. In addition, some adverse effects due to salinity can include nutritional imbalances or toxicities caused by specific ions (e.g., boron, which is toxic in very small quantities). In sufficient concentrations, even beneficial salts (fertilizers such as potassium nitrate) can become toxic to plants. (Ben, 2003)

In addition to the soil chemical characteristics mentioned above, the soil must also have an adequate supply of available plant nutrients. Many chemical elements are essential for plant growth and are necessary to obtain large and satisfactory crop yields. These include calcium, carbon, hydrogen, iron, magnesium, nitrogen, oxygen, potassium, phosphorus, sulfur, and many other trace elements, depending on the type of crop. The availability of these nutrients to the plant depends to a large extent upon the moisture content of the soil.(Wikipedia, 2001)

2.4 Water Requirement for Tomato

Tomato is not resistant to drought. Yields decrease considerably after short periods of water deficiency. It is important to water the plants regularly, especially during flowering and fruit formation. The amount of water that is needed depends on the type of soil and on the weather (amount of rain, humidity and temperature). It is especially important to water regularly (e.g. 3 times a week) on sandy soils. Under good circumstances once a week should be enough. About 20 mm of water per week is needed under cool conditions, about 70 mm during hot and dry periods. Watering plays a major role in attaining uniform maturity and reducing the incidence of blossom end rot, a physiological disorder associated with irregular water supply and the resulting calcium deficiency in the fruit during its enlargement .There are several irrigation methods: which include surface irrigation, sprinkler irrigation and drip irrigation. Surface irrigation is the simplest method by pouring water into channels (furrow irrigation) or onto flat fields that are surrounded by small dykes (flood irrigation), ensuring that the water is evenly distributed. (Wikipedia, 2005)

2. 5 Factors Affecting Design of Irrigation Systems

The following are the factors that will be considered in this study;

2.5.1 Infiltration Rate

The property of soils, of great importance to irrigators, is the time rate at which water will percolate into the soil, or the infiltration.(Musa 2003). Infiltration can be defined as the path of liquid water into the soil. The rate of this process, relative to the rate of water application, determines how much water will enter the unsaturated soil zone, and how much, if any, will runoff. Munns (1999). Therefore this soil physical parameter is of paramount importance to the water economy of plant communities' surface runoff, deep percolation and plays a dominant role in the successful design and management of an irrigation system. (Hillel, 2000)

A cracked clay soil may absorb almost instantaneously 100 to 200mm of water but once the cracks have filled and closed as a result of the swelling of the soil, infiltration virtually stops. In compacted or otherwise densely structured soils, very little water is able to infiltrate, and rainfall easily results in ponding. Soils may also disperse under the impact of rainfall and clog the surface pores (surface sealing or capping of the soil). This happens particularly in many silty and fine sandy loam soils in the semi arid zones at the beginning of the rainy season when they are exposed to intense storms with little vegetative protection. As a result, much of the rainfall runs off the land. (Musa, 2003).

The infiltration rate is much higher at the beginning of irrigation event than it is several hours later. Moisture tension may be zero in the surface millimeters of the soil, shortly after wetting, and may be very high a few millimeters below, thus causing a large downward force (in addition to gravity) pulling water into the unsaturated soil. Several hours after wetting, these differences in tension may be very small, and gravity then becomes dominant force causing infiltration. The decrease of infiltration with time after wetting a soil is of importance in rainfall run off studies and irrigation management. Knowledge of spatial average value of this characteristic is required for design, evaluation and optimization of surface irrigation. Much is known about how water infiltrates the soil, yet we are unable to predict with reasonable certainty the rate that water will infiltrate the soil. This lack of predictive capability is largely a result of the magnitude of the temporal and spatial variability of infiltration and it has been considered as a major area of future research (USDA, 1998).

2.5.1.1 Factors influencing infiltration

A number of factors impact soil infiltration. Some of these are;

Compaction:

Compaction reduces infiltration; the most important source of compaction is by machinery. A compacted zone (plow pan) or an impervious layer close to the surface restricts the entry of water into the soil and tends to result in ponding on the surface. Ploughing agricultural lands produces soil compaction (Lindstorm 1984, Blackwell et al, 1985) reducing soil porosity through the partial expulsion of permeating fluids, air and water. Because the density of the largest soil pores is reduced by the compaction mechanism, the infiltration rate is also diminished (Hillel 1980).The use of compaction in furrows could be applied in some situations to improve the uniformity of advance and simplify irrigation management.(Allen, 1992).

Aggregates, structure and soil texture:

Infiltration is largely influenced through soil aggregates, structure and texture (Singer and Munns 1999). Soils that have stable strong aggregates as granular or blocky soil structure have a higher infiltration rate than soils that have weak, massive , or plate like structure. Soils that have similar structural size (having a less pore volume) have lower infiltration rates than soils that have a larger structural size.

Pores:

Pores are important considerations in studying water flow through unsaturated soil. They are channels for rapid movement of solutes and pollutants through soils. Volume of pores greatly influences the infiltration process. The bigger the volume of pores the higher will be the infiltration (Hillel 1980). Continuous pores that are connected to the surface are excellent conduits for the entry into the soil. Discontinuous pores may retard the flow of water because of entrapment of air bubbles. Pores (macro pores) have been defined by various authors (Allen and Musick, 1992) as having capillary potentials greater than -0.1 to -10.0kpa or equivalent diameters of 730 to 10000 microns. Organisms such as earthworms increase the amount of pores and also assist the processes of aggregation that enhances the process of water infiltration.(Wikipedia, 2002)

Crusting/ surface sealing

Soil seals and crusts reduce soil infiltration rates and increase soil strength. A crust on the soil surface can seal the pores and restrict the entry of water into the soil. The infiltration rate through a surface seal is much lower than the rest of the soil mass. Surface sealing in a furrow occurs when the velocity decreases below a certain value. The formation of surface seal is influenced by soil texture, aggregate stability, clay content and organic matter. The thickness of crust and type of crust is important (Fattah *et al;* 1998). Wet surface crusts have a lower initial infiltration than dry crusts because dry soils experience cracking which initially increases the infiltration.

Soil moisture content

The content or amount of water in the soil affects the infiltration rate of the soil. The infiltration rate is generally higher when the soil is initially dry and decreases as the soil becomes wet. Pores and cracks are open in dry soil and many of them are filled with water or swelled shut when the soil becomes wet. As they become wet the infiltration rate slows to the rate of permeability of the most restrictive layer. (Meddina *et al*; 1998).

Organic Matter

An increased amount of plant material, dead or alive, generally assists the process of infiltration. Organic matter increases the entry of water by protecting the soil aggregates from breaking down during the impact of rain drops, Particles broken from aggregates can clog pores and seal the surface causing decrease in infiltration. Other factors include water temperature and chemistry, positioning of stones in the soil and irrigation with low quality water. (Singh, 1997).

2.6 Determination of Infiltration Rate

Infiltration rate is therefore, described as the amount of water taken in by the soil over a period. This is known to have a unit of centimeter per hour 9 cm/hr). Infiltration rate can be determined with the use of a single or double infiltrometer. The diameter of the inner ring is 300mm while the diameter of the outermost ring is 600mm (Musa, 2003).

Cylinder Infiltrometer

This is a metal cylinder with the diameter of 300mm for the inner cylinder and 600mm for the outer in which both have a height 250mm was driven into the soil using a driving plate set on top of the infiltrometer and a heavy hammer to some heads so as to prevent the blow out of effects around the bottom of the cylinders. Water is ponded in the cylinders to some depth and at subsequent times (that is when the water level has dropped about one-half of the depth of the cylinder), water should be added to return the water surface to its initial point.(Haise et al, 1956)

2.6.1 Relative Humidity

Humidity is described as the amount of water vapour in the air at any given timSe while relative humidity is the water in air at any given time which is usually less than that required to saturate the air. The relative humidity is generally calculated in relation to saturated vapour density. (Clyma ,1993)

2.6.2 Evapotranspiration (ET)

The water requirement of a given crop is represented by its evapo-transpiration (ET) basically defined as the rate of transfer of water vapour from plant and soil surface to the atmosphere or is the sum of evaporation and plant transpiration. In evaporation, water is evaporated from the lake or pond surface and from rain droplets caught in the leaves of trees. Transpiration takes water out of the watershed by evaporation of water through the pores in leaves. The trees acquire water through the roots exclusively. This is the key element for the implementation of irrigation management strategies for crop production at both farm and irrigation scheme. (Martin et al, 1998)

Evapo-transpiration is a significant water loss from a watershed. Types of vegetation and land use significantly affect evapo-transpiration and therefore the amount of water leaving a watershed. Because water transpired through leaves comes from the roots, plants with deep reaching roots can more constantly transpire water. Thus herbaceous plants transpire less than wood plants because herbaceous plants lack a deep taproot. Also, woody, plants keep their structure over long winters while herbaceous plants must grow up from seed in the spring in seasonal climates, and will contribute almost nothing to evapo-transpiration in the spring. (Martin et al, 1998)

Evapo-transpiration cannot be measured directly. Pan evaporation data can be used to estimate lake evaporation but transpiration and evaporation of intercepted rain on vegetation are unknown. Evapo-transpiration is usually found by creating an equation of known or estimated inputs into a watershed, such as precipitation and outputs such as stream flow. If the other inputs and outputs are known, hydrologists can solve for evapo-transpiration. .(Clemmens, 1990)

Factors affecting evapo-transpiration include the plants growth stage or level of maturity, percentage of soil cover, solar radiation, temperature and wind. The following evapotranspiration equations will be considered; Hargreaves equation, Penman's equation, Hamon's equation and Blaney-Morin Nigeria.

2.6.3 Field Capacity

The soil is said to be at field capacity when after a good watering of the soil the deep percolation has virtually ceased while no significant evapo-transpirative soil moisture depletion has yet occurred. When the water table is at shallow depth (say <1-2m below the soil surface), the field capacity situation approaches the equilibrium soil moisture profile. When the water table is deep an equilibrium profile never becomes established in the field since considerable evapo(transpi)rative depletion has already occurred by the time the deep percolation process has ended. In such cases, field capacity refers to the situation where the water in the rapidly draining macro-pores in the upper soil layers (root zone) has percolated through. In a ready draining soil profile this situation reached within one day after rainfall or irrigation.(Clemmens, 1990)

2.6.4 Depth of Soil and Root Zone Depth

Depending on the thickness of the topsoil on which plants can be grown, soil can be classified as shallow, medium and deep. Usually deep soil having a medium texture and loose structure permits plants to root provides for the storage of a large volume of water in the root zone depth and can sustain the plant growth for a longer period in between two consecutive irrigations. Shallow soil requires more frequent irrigation resulting in a loss of water due to evaporation. Roots in shallow soil become stunted as a result of which the crop yield is decreased.(Williams, 2005)

The root zone depth is that depth of soil into which plant roots penetrate and extract moisture and nutrients for its growth. Whereas the depth of soil is fixed, the root zone depth with increase in the age of the plant.

The depth and frequency of irrigation is largely governed by the root zone depth .In early stages, when roots are short, the depth irrigation application should be small to provide moisture to the soil in the root zone depth only. But the number of irrigation application should be increased to replenish the desired moisture content as soon as the small depth of water gets depleted.(Williams, 2005)

CHAPTER THREE

METHODOLOGY AND MATERIALS

1 Description of Experimental Site

Tunga Kawo is an agricultural community located about 45 kilometres from the State apital located within Wushishi Local Government Area which has a total land mass of ,879km^2. Niger State is lying approximately on longitude of 6^0 34$'$ and 19 9^IE and latitude of ^{0} 36^I 52.03^{II}N. The site is bounded at Northwards by Kaduna and Kebbi States and the eastern ide by the Federal Capital Territory, Abuja and Kogi State and in from the southern zone she hares her boundary with River Niger. The entire State is drained by rivers Niger and Kaduna nd their tributaries.

.1.1 Soils of the Area

The major soil found in this area is the sandy loam type with a sparse distinction of the sandy – clay soil and sandy soils. This has so far encouraged the residents of major cities in Niger State to use the land for agricultural activities such as farming and grazing by the nomadic cattle rearers (Eze, 2000).

3.1.2 Vegetation and Land Use

Tungan Kawo falls within the semi-wood land or tree forest vegetation belt with derived dry grass or shrub land known as the southern guinea savannah (Fubara, 1986). This is also known as the transition belt, which lies between the savannah grass/shrub land of the north and the rain forest of the south. Due to intensive fallow type of agricultural practice and grazing of the land, the area is dominated by stunted shrubs; interspersed with moderate height tree and perennial foliage (Musa, 2003). Similarly, due to human activities and land use abuse which is characteristic of most expanding urban centre in Nigeria, the site is fast losing its remaining tree species to development. Along some of the seasonal river course and lowland areas, the vegetation is more wooded and resembles some forest affinities (Musa, 2003). The area is still being used as farm and grazing land by the residents of Minna and her environs.

3.1.3 Climate

3.1.3.1 Rainfall

Tunga Kawo, generally is known to experience rainfall similar to that experienced in Minna from the month of May to the month of October and on rear occasions, to November. It is known to reach its peak between the months of July and August. Towards the end of the rainfall season, around October, it is known to be accompanied by great thunder storms Tomatoes grow best in regions of moderate rainfall (50- 75cm per annum). If the rainfall is to heavy, fruit rotting tends to occur. (Sani, 1999).

3.1.3.2 Temperature

The maximum temperature period in this area is usually between the months of February, March and April which gives an average minimum temperature record of 33^0C and maximum temperature of 35^0C (Musa, 2003). During the rainfall periods, the temperature within the area drops to about 29^0C.

3.2 Land Grading Survey

This was done by using the field boundaries under consideration, following by establishment of a grid system over the field and set stake at the grid points. The grid spacing was taken to be 10 x 15m using fill stakes.

3.2.1 Dry Bulk Density Determination

Bulk density is a measure of the weight of the soil per unit volume (g/cc), usually given on an oven-dry (110° C). Variation in bulk density is attributable to the relative proportion and specific gravity of solid organic and inorganic particles and to the porosity of the soil. Most mineral soils have bulk densities between 1.0 and 2.0. Although bulk densities are seldom measured, they are important in quantitative soil studies, and measurement. According to Marshall and Holmes (1988), bulk density increases with the degree of compaction which may be due to the effect of cultivation practice and/or rainfall events on the top soil. A high bulk density would affect infiltration rates (Brady, 1984). Broadman *et al* (1990) noted that bulk density decrease is closely associated with an increase in infiltration capacity. Ahmed and Duru (1985) found a strong correlation between bulk density and infiltration rate of soil tested in Samaru, Kaduna State of Nigeria.

After all infiltration replicates had been completed in a given site, two of the spots where measurement had taken place were covered with a plastic sheet to prevent evaporation for about twenty-four hours. The field capacity was determined in the same way as the initial moisture content. The bulk density (BD) was calculated from the equation given below.

$$BD = \frac{(Weight\ of\ dry\ soil + can) - (Weight\ of\ empty\ can)}{(Volume\ of\ core\ sampler)} \qquad 3.0$$

3.2.2 Field Capacity Determination

Field capacity is the amount of soil water or water content held in soil after excess water has drained away and the rate of downward movement has materially decreased, which usually takes place within 2–3 days after a rain or irrigation in pervious soils of uniform structure and texture. The physical definition of field capacity (expressed symbolically as θ_{fc}) is the bulk water content retained in soil at −33 J/kg (or −0.33 bar) of hydraulic head or suction pressure.

This was determined by ponding water on the surface of the field under considered in an area of about 5sqm and was allowed to drained for three (3) days, while surface evaporation was prevented by covered up with polythene sheet. After three days sample was collected with aid of auger from the different soil depths and the moisture content was determined by the gravimetric method.

3.2.3 Permanent Wilting Percentage Determination

Permanent wilting point (PWP) or wilting point (WP) is defined as the minimal point of soil moisture the plant requires not to wilt. If moisture decreases to this or any lower point a plant wilts and can no longer recover its turgidity when placed in a saturated atmosphere for 12 hours. The physical definition of the wilting point (symbolically expressed as θ_{pwp} or θ_{wp}) is defined as the water content at −1500 J/kg (or −15 bars) of suction pressure, or negative hydraulic head. The most common method used to determining the Permanent wilting point was to grow indicator plant in containers, sun lower plant allowed to will and then placed in a chamber with approximately saturated atmosphere (usually 15 atmosphere) to test for permanent wilting.

3.2.4 Determination Of Crop Water Requirement (CWR)

This is obtained by using the following equation (Michael, 1999).reported by (Alfa, 2010)

$$CWR = IR + ER + S \tag{3.1}$$

Where CWR is the Crop Water Requirement, IR is the Irrigation water, ER = Effective rainfall and S is the soil profile contribution.

3.2.5 Determination of Evapo-transpiration (ET)

Blarney – Criddle method was used to obtained the Consumptive Use (CU) of water by crop for a given period where

U = seasonal consumptive use of water by crop for a given period, inches

u = monthly consumptive use

K = empirical seasonal consumptive use coefficient for the growing season

F = Sum of monthly consumptive use factor (f) for the growing season

K = empirical seasonal consumptive use coefficient for the month, u/f

$$f = \frac{t \, X \, p}{100} \tag{3.2}$$

t = mean monthly temperature, ^{0}C

p = monthly daylight hours expressed as percent of daylight hours of the year.

They have recommended the following relationships for f factor (expressed in mm/day) in Blaney – Criddle formula.

$$f = p(0.46t + 8.13) \tag{3.3}$$

(A.M. Michael 1999) pp 522

Where our t is measured in degree centigrade (Michael 1999). Net depth of irrigation for crop season is = 325mm

3.3 Infiltration Rate Determination

This was obtained by using double-ring infiltrometer which consist of two concentric rings. The diameters of the cylinders were 260mm and 400mm respectively. The value obtained for infiltration depth = 75 mm/hr. Using the method adopted by Larry (1958), cumulative infiltration depth was obtained using

$$F = et^f + g \qquad 3.4$$

Where

F = cumulative infiltration depth (mm);

t = time since infiltration began (min);

e, f, g = parameters from Appendix

t = 32min

$F = 0.6198\ (32)^{0.661} + 6.985$

(Larry G.J, 1958)Pp 344

3.4 Design Calculation

3.4.1 Estimating the Irrigation Schedule

A table is provided to estimate the irrigation schedule for the major field crops during the period of peak water demand; the schedules are given for three different soil types and different climates. The table is based on calculated crop water needs and an estimated root depth for each of the crops under consideration. The table assumes that with the irrigation method used the maximum possible net application depth is 75 mm.

Table 3.1 below gives a distinction between soil types and available water content

S/NO	SOIL TYPE	AMOUNT WATER OF WATER REQUIRED
1	Sandy soil	Little water can be stored, irrigation will have to take place frequently but little water is given per application
2	Loamy soil	In loamy soil more water can be stored than in a sandy or shallow soil, irrigation water is applied less frequently and more water is given per application
3	Clayey soil	In clayey soil even more water can be stored than in medium soil. Irrigation water is applied even less frequently and more water is given per application

(Cliff NJ 1987) Pp 386

Table 3.2 below gives a distinction between different climatic zone and its crop evapotranspiration.

S/N	CLIMATIC ZONE WITH DIFFERENT CROP EVAPOTRANSPIRATION mm/day	MEAN DAILY TEMPERATURE Low (less than 15°C)	 Medium (15-25°C)	 High (more than 25°C)
1	Desert/arid	4 – 6	7 – 8	9 – 10
2	Semi -arid	4 - 5	6 – 7	8 – 9
3	Sub- humid	3 – 4	5 - 6	7 – 8
4	Humid	1 – 2	3 – 4	5 – 6

(Hart W.E 1985)Pp 193

3.4.2 Determination of irrigation schedule

The simple calculation method to determine the irrigation schedule is based on the estimated depth (in mm) of the irrigation applications, and the calculated irrigation water need of the crop over the growing season. The simple calculation method is based on calculated irrigation water needs. Thus, the influence of the climate, i.e. temperature and rainfall, is more accurately taken into account. The result of the simple calculation method will therefore be more accurate than the result of the estimation method.

Table 3.3 below shows the simple calculation method to determine the irrigation schedule which involves the following steps that are explained in detail below:

STEPS TAKEN	IRRIGATION SCHEDULE
Step 1:	Estimate the net and gross irrigation depth (d) in mm.
Step 2	Calculate the irrigation water need (IN) in mm, over the total growing season
Step 3:	Calculate the number of irrigation applications over the total growing season.
Step 4:	Calculate the irrigation interval in days.

(BOUWER H 1978)Pp 97

Step 1: Estimate the net and gross irrigation depth (d) in mm

The net irrigation depth is best determined locally by checking how much water is given per irrigation application with the local irrigation method and practice. If no local data are easily available, Table 1 can be used to estimate the net irrigation depth (d net), in mm. As can be seen from the table, the net irrigation depth is assumed to depend only on the root depth of the crop and on the soil type. It must be noted that the d net values in the table are approximate values only. Also the root depth is best determined locally. If no data are available, Table 2 can be used which gives an indication of the root depth of the major field crops.

Table 3.4. Approximate Net Irrigation Depths, In mm

	Shallow rooting crops	**Medium rooting crops**	**Deep rooting crops**
Shallow and/or sandy soil	15	30	40
Loamy soil	20	40	60
Clayey soil	30	50	70

(Cliff NJ 1987) Pp 386

Table 3.5 Approximate Root Depth Of The Major Field Crops

DIFFERENT ROOT DEPTHS (cm)	**DIFFERENT FIELD CROPS**
Shallow rooting crops (30-60 cm):	Crucifers (cabbage, cauliflower, etc.), celery, lettuce, onions, pineapple, potatoes, spinach, other vegetables except beets, carrots, cucumber.
Medium rooting crops (50-100 cm):	Bananas, beans, beets, carrots, clover, cacao, cucumber, groundnuts, palm trees, peas, pepper, sisal, soybeans, sugarbeet, sunflower, tobacco, tomatoes.
Deep rooting crops (90-150 cm):	Alfalfa, barley, citrus, cotton, dates, deciduous orchards, flax, grapes, maize, melons, oats, olives, safflower, sorghum, sugarcane, sweet potatoes, wheat.

(Anderson .L 1980) Pp47

Not all water which is applied to the field can indeed be used by the plants. Part of the water is lost through deep percolation and runoff. To reflect this water loss, the field application efficiency (ea) is used. For The gross irrigation depth (d gross), in mm, takes into account the water loss during the irrigation application and is determined using the following formula:

$$d\ gross = \frac{100 \bullet d\ net}{ea}$$

d gross =gross irrigation depth in mm

d net =net irrigation depth in mm

ea = field application efficiency in percent

If reliable local data are available on the field application efficiency, these should be used. If such data are not available,

Table 3.6 shows the following values for the assumed field application efficiency:

DIFFERENT SURFACE IRRIGATION TECHNIQUE	ASSUMED FIELD APPLICATION EFFICIENCY IN %
Surface irrigation	ea = 60%
Sprinkler irrigation	ea = 75%
Drip irrigation	ea = 90%

(Eisenhaner, D. E. 1997)

Tomatoes are grown on a loamy soil, Tables 2.5 and 2.6 show that the estimated net irrigation depth is 40 mm. If basin irrigation is used, the field application efficiency is 60% and the gross irrigation depth is determined as follows:

$$d\ gross = \frac{100 \cdot 40}{60} = 67\ mm = rounded\ 65\ mm$$

Step 2: To calculate the irrigation water need (IN) in - over the total growing season

Assume that the irrigation water need (in mm/month) for tomatoes, planted 1 February and harvested 30 June,

Table 3.7 below shows as follows:

	Feb.	Mar.	Apr.	May	June
IN (mm/month)	67	110	166	195	180

The irrigation water need of tomatoes for the total growing season (Feb-June) is thus (67 + 110 + 166 + 195 + 180 =) 718 mm. This means that over the total growing season a net water layer of 718 mm has to be brought onto the field.

Step 3: To calculate the number of irrigation applications over the total growing season

The number of irrigation applications over the total growing season can be obtained by dividing the irrigation water need over the growing season (Step 2) by the net irrigation depth per application (Step 1). If the net depth of each irrigation application is 40 mm (d net = 40 mm; Step 1), and the irrigation water need over the growing season is 718 mm (Step 2), then a total of (718/40 =) 18 applications are required.

Step 4: To calculate the irrigation interval (INT) in days

Thus a total of 18 applications is required. The total growing season for tomatoes is 5 months (Feb-June) or 5 x 30 = 150 days. Eighteen applications in 150 days corresponds to one application every 150/18 = 8.3 days

In Summary:

The irrigation schedule for tomatoes, based on the total growing period is:

d net = 40 mm

d gross = 65

Interval = 8 days

3.4.3 Determination of Continuous Water Flow

D net =40mm

D gross =65mm

Interval = 8day

Area to be irrigated = 4ha

Conversion of mm/day into litres/sec.ha

8.64 mm/day = 1.0 litre/sec.hectare

65mm for every 8days = 65/8 =8.125mm/day

8.125/day corresponds to 0.93l/sec.ha

For an area of 4 ha the net continuous flow would be; $4 \times 0.93 = 3.72$ L/sec

3.5.2 Design of Basin Irrigation

Net water application = 325 mm

Infiltration rate = 75 mm/hr

Cumulative infiltration depth: F=40 mm/hr

Elapse time = 32 min

Stream size = 150 L/min

Intake family IF = 0.05

Area of basins = (50 x 50) m^2

3.5.3 Opportunity Time

According to La rry (1958), the opportunity time can be calculated for

$$= \left[\frac{Fn-C}{a}\right]^{1/b} = \left[\frac{325-7.0}{0.5334}\right]^{1/0.618} \quad = 16.3min \qquad 3.5$$

T_n = opportunity time or time of pounding

F_n = net water application

a, b, c = constant

3.5.4 Advance Time

This the time required for the unit flow rate to advance to the downstream end of the strip. This is obtained by the equation below:

$T_T = T_n X R_e = 16.3 \times 1.95 = 31.8\text{min}$ 3.6

Where

T_T = Advanced time

T_n = infiltration opportunity time

R_e = efficiency ratio

The efficiency is 60%. This ratio was obtained from Appendix

3.5.5 Inflow Time

According to Larry (1958), the time that water flow into basins, computed by the following relationship;

$$T_i = T_2 + \frac{(D)(A_S)}{KQ} \quad 3.7$$

$$= 31.8 + \frac{0.15 \times 2500}{60000 \times 0.15}$$

$$= 31.8\text{min}$$

Where T_i = inflow time (min);

T_a = time to advance across the basin (min);

D = desired depth of irrigation (mm);

A_B = area of basin (m^2, ft^2);

Q = stream size (I/min, m^3/s, ft^3/s);

K = unit constant (K = 60000 for D in mm, A in m^2, and Q in m^3/s).

3.5.6 Number of Basins Irrigated Per Set

Using the formula derived by Larry (1958), the number of basins irrigated per set was calculated for using the following formula

$$N_B = \frac{N_T T_i DDIR E_a}{144000D} \qquad 3.8$$

Where N_B = number of basins irrigated per set;

N_T = total number basins being irrigated

T_i = inflow time (min);

DDIR = design daily irrigation requirement (mm/day, in/day);

E_a = application efficiency (percent);

D = desired depth of irrigation (mm, in)

3.5.7 Maximum Depth of Flow

The maximum depth flow was calculated for using the formula described by Michael (1999), which is stated below as

$$DL = [0.168\,(n)]^{0.373} \text{ x } Q_u^{0.5623} \text{ x } T_i^{0.1875} \qquad 3.9$$

$$DL = [0.168\,(0.02)]^{0.375} \text{ x } (0.15)^{0.5625} \text{ x } 31.8^{0.1875}$$

$$= 0.08\text{m}$$

Where

DL =maximum depth of flow

Q_u = stream size,

T_i = inflow size

n = Manning's coefficient (0.02, for straight and uniform channel)

3.6 Design of Delivery System

3.6.1 Design of Canal Flows

The quantity of irrigation water was obtained by using the equation described by Micheal (1999);

$$Q = \frac{ad}{ct} \qquad 3.10$$

Where

Q = quantity of irrigation water m^3/s

A = area of the field

d = Net application dept

t = time required to irrigate the field

c = constant value, usually taken to be 100

The design efficiency was assumed to be 60%

The following assumptions were made;

i. Manning's coefficient, n = 0.02;

ii. Side slope 15:1;

iii. The bed slope gradient for the main canal was assumed to be 50%; that of the secondary canal was assumed to be 60% while that of the drains was 50%;

iv. Permissible velocity of between 0.4 - 1.0 m/s for non-scoring, non-silting condition and unlined earth canal;

v. The bottom width of the canal and the water depth ratio, were said to be $\frac{b}{d}$ = 2:1 for small irrigation canal up to 1.5m^3/s while for the drains of the field crop is said to be $\frac{b}{d}$ = 1:1I;

vi. Freeboard height of bank over water surface fro open canal with discharge up to 300mm

3.6.2 Design of Main Canal

From equation 3.6, we have that

$$Q = \frac{ad}{ct}$$

where d = Net application depth = 325mm = 3.25cm

Efficiency = 60%

Time of irrigation = 800min

Area = 4.0 ha

Area of the field to be served by main canal

$\frac{4.0}{2} = 2.0ha$

The stream size that carries the water from each main canal is given by

$$Q = \frac{ad}{ct} = \frac{2.0 \times 10^4 \times 0.325}{800 \times 60 \times 100} = 0.01\text{m}^3/\text{s}$$ 3.11

$$Q = \frac{0.01}{0.60} = 0.0166 \text{ m}^3/\text{s}$$

Design parameter for main canal

Q =0.0166 m^3/s

Bed slope = 0.5%

Side slope, m = 1.5

Roughness coefficient, n = 0.02

b was assumed to 0.35m and h to be 0.16m

Wetted Perimeter

$$P = b + 2h\sqrt{1 + m^2}$$ 3.12

$$P = 0.35 + 2(0.16)\sqrt{1 + (1.5)^2}$$

$$= 0.93\text{m}$$

The hydraulic radius is calculated

$$R = \frac{A}{P}$$ 3.13

$$= \frac{0.08}{0.93} = 0.086m$$

The velocity of flow is calculated from

$$V = \frac{R^{2/3} S^{1/2}}{n}$$ 3.14

$$= \frac{0.086^{2/3} X\, 0.5^{1/2}}{0.02}$$

$= 0.03$m/s

The rate of discharge (Q) of water from the canal is calculated for from

$$Q = AV \qquad 3.15$$

$=0.08 \times 0.03$

$= 0.0024\ m^3/s$

While the free board is calculated for from

$$F_b = d - h = \frac{20d}{100} \qquad 3.16$$

$100\ (d - h) = 20d$

$80d = 100h$

$$d = \frac{100h}{80}$$

$$= \frac{100\ X\ 1.6}{80}$$

$=0.2$m

Therefore, the Freeboard is calculated for as

$= d - h$

$= 0.2 - 0.16$

$= 0.04$m

The top width (T) of the canal is calculated for as

$$T = b + 2dh$$

$$= 0.35 + 2(0.2)(0.16)$$

$$= 0.41\text{m}$$

The top width of the water body passing through each of the canal is calculated for as

$$t = b + 2hm$$

$$= 0.35 + 2(0.16)(1.5)$$

$$= 0.83\text{m}$$

3.6.3 Design of Secondary Canals

Net application depth = 3.25cm

Time required to irrigate = 720min

Area of the field = 4.0ha

Area of the field to be served by each secondary canal

$$\frac{4.0}{5} = 0.8ha$$

The quantity of water to be conveyed by each secondary canal

$$Q = \frac{ad}{tc} = \frac{0.8 \, X \, 10^4 \, X \, 0.0325}{720 \, X \, 60 \, X 100} = \frac{260}{4320000}$$

$$= 0.0060 \text{ m}^3/\text{s}$$

$Q = \frac{0.060}{0.6} = 0.01\ m^3/s$

The design parameter for the secondary canal is shown below

Q (stream size for design) = $0.01\ m^3/s$

Bed slope = 0.6

Side slope, m = 1.5

Roughness coefficient, n = 0.02

Assuming the values of b and h are 0.6 and 0.8 respectively.

FIRST TRIAL

$$\text{Area} = hb + mh^2$$

$$= (0.8)(0.6) + (1.5)(0.8)^2$$

$$A = 1.44m^2$$

Wetted Perimeter

$$P = b + 2h\sqrt{1 + m^2} \qquad 3.17$$

$$P = 0.6 + 2(0.8)\sqrt{1 + (1.5)^2}$$

$$= 3.48m$$

Hydraulic Radius

$$R = \frac{A}{P} \qquad 3.18$$

$R = \frac{1.44}{3.48} = 0.41m$

Velocity of Flow

$$V = \frac{R^{2/3}S^{1/2}}{n} \qquad 3.19$$

$$= \frac{(0.41)^{2/3}(0.6)^{1/2}}{0.02}$$

$= 0.84m/s$

Discharge (Q)

$$Q = AV \qquad 3.20$$

$= 1.44 \times 0.84$

$= 0.21m^3/s$

Free board

$Fb = d - h = \frac{20d}{100}$

$100(d - h) = 20d$

$80d = 100h$

$d = \frac{100h}{80}$

$= \frac{100 X 0.8}{80}$

$= 1m$

$$\text{freeboard} = d - h$$

$$= 1 - 0.8$$

$$= 0.2\text{m}$$

Top Width (T)

$$T = b + 2dm \quad 3.21$$

$$= 0.6 + 2(1)(1.5)$$

$$= 3.6\text{m}$$

Water top width (t)

$$t = b + 2hm \quad 3.22$$

$$= 0.6 + 2(0.8)(1.5)$$

$$= 3\text{m}$$

3.12 Field Channels Design

D = Net application depth = 0.0325

Efficiency = 60%

Time of irrigation = 720min

Area of the field = 4 ha

The stream size

$$Q = \frac{ad}{tc}$$

$$= \frac{4\ X\ 10^4\ X\ 0.0325}{720\ X\ 60\ X\ 100}$$

$$= \frac{1300}{4320000}$$

$= 0.00030\text{m}^3/\text{s}$

$$Q = \frac{0.00030}{0.60}$$

$= 0.00005\ m^3/s$

Design parameter for field channels

Q (stream size for design) = $0.00005\text{m}^3/\text{s}$

Bed slope = 0.6

Side slope, m = 1.5

Roughness coefficient, n = 0.02

Assuming the values of b and h to be 0.06m and 0.04 respectively

Area

$$A = bh + mh^2 \qquad 3.23$$

$$= (0.06)(0.04) + (1.5)(0.04)^2$$

$$A = 0.0048\text{m}^2$$

Wetted Perimeter

$P = b + 2h\sqrt{m^2 + 1}$

$P = 0.06 + 2(0.04)\sqrt{(1.5)^2 + 1}$

$= 0.20\text{m}$

Hydraulic Radius (R)

$R = \frac{A}{P}$

$= \frac{0.0048}{0.20} = 0.024m$

Velocity of Flow (V)

$V = \frac{R^{2/3} S^{1/2}}{n}$

$= \frac{0.024^{2/3} X\, 0.6^{1/2}}{0.02}$

$= 0.03\text{m/s}$

Discharge (Q)

$Q = AV$

$= 0.0048 \times 0.03$

$= 0.00144\text{m}^3/\text{s}$

Free board

$F_b = d - h = \frac{20d}{100}$

$100(d - h) = 20d$

$80d = 100h$

$d = \frac{100h}{80} = \frac{100 X 0.04}{80}$

$= 0.05m$

Freeboard, $F_b = d - h$

$= 0.05 - 0.04$

$= 0.01m$

Top Width (T)

$T = b + 2dm$

$= 0.06 + 2(0.05)(1.5)$

$= 0.21m$

Water top width (t)

$t = b + 2hm$

$= 0.06 + 2 (0.04(1.5)$

$= 0.18m$

3.13 Design for Field Drains

Field drains area = 4.0 ha

Channel slope = 0.3%

Bed slope (m) = 1.5

Manning's coefficient = 0.02.

By trial and error, the value of b and h were assumed to be 0.5 and 0.3 respectively.

Area

$$A = bh + mh^2$$

$$= (0.5)(0.4) + (1.5)(0.3)^2$$

$$= 0.34\ m^2$$

Wetted Perimeter

$$P = b + 2h\sqrt{m^2 + 1}$$

$$P = 0.5 + 2(0.3)\sqrt{(1.5)^2 + 1}$$

$$= 1.6m$$

Hydraulic Radius (R)

$$R = \frac{A}{P}$$

$$= \frac{0.34}{1.6}$$

$$= 0.21m$$

Velocity of Flow (V)

$$V = \frac{R^{2/3}S^{1/2}}{n}$$

$$= \frac{0.21^{2/3} X\, 0.3^{1/2}}{0.02}$$

$= \quad 0.110\text{m/s}$

Discharge (Q)

$Q = VA$

$= \quad 0.110 \ \text{x}\ 0.34$

$= \quad 0.037\text{m}^3/\text{s}$

Free board

$F_b = d - h$

but

$$d = \frac{100h}{80}$$

$$= \frac{100\ X\ 0.3}{80} = 0.38\text{m}$$

Freeboard,

$F_b = d - h$

$= 0.38 - 0.3$

$= 0.08$

Top Width (T)

$T = b + 2dm$

= 0.5 + 2(0.38)(1.5)

= 1.64m

Water top width (t)

t = b + 2hm

= 0.5+ 2 (0.3) (1.5)

= 1.4m

3.14 Design of Pump Size

This is a function of expected discharge of the field channels.

The expected discharge, $Q = \frac{ad}{tc}$ 3.24

Where, Q = expected discharge; m^3/s

a = area to be irrigated m^2

d = Net application dept

c = 100 (constant)

t = 720 min, time required to application

Therefore $Q = \frac{4 X 10^4 X 0.00325}{720 X 60 X 100}$

= 0.31 m^3/s

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 RESULTS

4.1.1 Crop Water Requirement

The designed consumptive used was estimated to be 1.2mm for the crop growth period.

4.1.2 Laboratory experiments results

TABLE 4.1: Soil texture for various soil types

SOIL TEXTURE (%)	
SAND	31.5
CLAY	51.0
LOAMY + CLAY	45.0

The values contained in table 4. 1 were obtained using United State Department of Agriculture (USDA) method of soil classification.

TABLE 4.2: Different parameters gotten from the soil

S/NO.	FACTORS CONSIDERED	OBTAINED VALUES FROM STUDY AREA
1	Bulk density (Kg)	1.06
2	Permanent wilting percentage (%)	15.70
3	Field capacity (Using gravimetric method) (%)	30.50

TABLE 4.3: Water Distribution Network

	IRRIGATED AREA (ha)	MANNING'S COEFFICIENT	DESIGNED DISCHARGE(Q) (m^3/s)	BED SLOPE (%)	SIDE SLOPE (%)	FREE BOARD (m)	TOP WIDTH (m)	WATER TOP WIDTH(m)	DEPT (m)
MAIN CANAL	4.0000	0.0200	0.0166	0.5000	1.5000	0.0400	0.1000	0.9300	0.1600
SECONDARY CANAL	2.0000	0.0200	0.2100	0.6000	1.5000	0.2000	3.6000	3.0000	0.7000
FIELD CANAL	4.0000	0.0200	0.0014	0.6000	1.5000	0.0500	0.2100	0.1800	0.0300
DESIGNED FIELD DRAIN	4.0000	0.0200	0.0037	1.5000	0.3000	0.0800	1.6400	1.4000	-

4.1.3 Characteristics of Basin

Net water application : 325 min

Infiltration rate : 75 mm/hr

Accumulated infiltration depth : 20rnm/hr

Elapse time : 32 min

Opportunity time : 16.3 min

Advanced time : 31.8min

Inflow time : 31.8min

Number of basin per plot : 9

Irrigation interval : 8 days

4.1.4 Economic Analysis

The followings are the various costs required to implement the designed:

4.1.4.1 Fixed Cost

i.	Surveying of land 4 ha at ₦2, 000.00/ha	= ₦8, 000.00
ii.	Land development at ₦4, 000.00/ha	= ₦16, 000 00
iii.	Main distributing and field channel	= ₦80, 000.00
iv.	Drains	= ₦40, 000.00
v.	Pump	= ₦45, 000.00
vi	Total initial investments	= ₦189, 000.00
vii	Addition of 10% for contingency	= ₦18, 900.00
	Grand total	= ₦207, 900.00

4.1.4.2 Annuity

The life span of the project is 15 years by applying the formula below and the annual fixed cost of the project is calculated

$$A = \frac{P_i(1+i)n}{(1+i)n-1}$$

Where; A = Annual cost

P = Capital

n = life span of the project

i = Annual interest rate (5%)

$$A = \frac{207900\ X\ 0.05\ (1+0.05)\ X\ 15}{(1+0.05)\ 15-1}$$

$$= \frac{123{,}354}{14.7}$$

$$= N\ 11{,}137.5k$$

The annual cost in term of capital expenditure is ₦11, 137.5k

4.1.4.3. Variable Cost

i. Land preparation 4 ha at ₦2000/ha = ₦8, 000.00

ii. Seeds = ₦2, 500.00

iii. Weeding = ₦3, 500.00

iv. Labour for irrigation = ₦6, 000.00

v. Fertilizer application = ₦3, 500.00

Total = ₦23, 500.00

The annual cost of the project is the sum of fixed costs and variable costs.

Therefore

= ₦11, 137.5k + ₦ 23,500.00

= ₦34, 537.5k

4.1.4.4 Output

The seasonal expected yield per hectare is 8 tones.

Total yield for the area will be 8 x 4 = 32 tones

Cost of product per ton = ₦5, 000.00

Therefore, total expected per season = 32 x ₦5, 000.00

= ₦160, 000.00

4.1.4.5 Cost Benefit Ratio

Total annual cost of the project = ₦34, 537.5

Total annual benefit from the project t = ₦160, 000.00

Therefore, cost benefit ratio is 1:4

4.2 DISCUSSION OF RESULTS

As with other irrigation systems, the design of level-basin systems is an iterative process. It involves adjusting system layouts, inflow times, stream sizes, basin dimensions.

The importance of economic analysis is to determine the profitability of an investment or comparing the profitability of two or more alternative investments.

The life span of the project is 15 years, using the formula = $A = \frac{P_i(1+i)n}{(1+i)n-1}$

Where; A = Annual cost

P = Capital

n = life span of the project

i = Annual interest rate (5%)

The annual fixed cost of the project in term of capital expenditure (fixed cost) was calculated and the result is ₦*11,137.5K* while the variable cost is ₦ 23,500.00

Therefore, the annual cost of the project which is the sum of fixed costs and variable costs is ₦34, 537.5k

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

1. Based on the research and economic analysis carried out, it is concluded that the project is efficient with a cost-benefit ratio of 1:4.
2. This project proposes the development of an area for maximum productivity by providing efficient irrigation through surface irrigation system.
3. It is also concluded that the project has good potential return on investment.

5.2 Recommendations

Despite the constraint, the project is commendable, viable and should be developed. It should be put into practice to know if what was calculated theoretically actually conforms with what will be on the field.

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APPENDIX A

MONTHLY PERCENTAGE OF DAY TIME HOURS IN THE YEAR

MONTHS	%
FEBRUARY	7.85
MARCH	8.05
APRIL	7.08
MAY	7.39
JUNE	8.43

SOURCE: (ADAPTED FROM USDA, ARS TECH. BULL. NO. 1275, 1962)

APPENDIX B

SOIL INTAKE FAMILY AND THE CONSTANTS

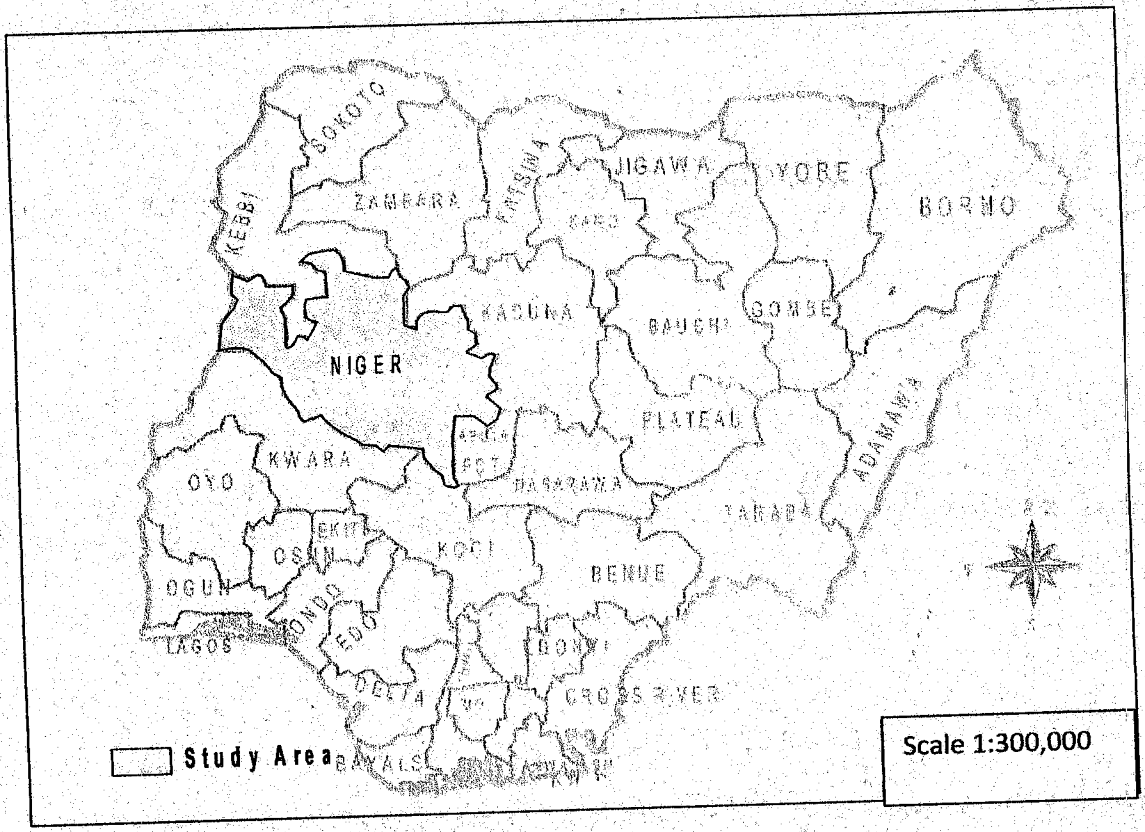
INTAKE FAMILY	CONSTANTS	
a	b	c
0.05	0.5334 0.618	7.0
0.10	0.6198 0.661	7.0
0.15	0.7110 0.683	7.0
0.25	0.7772 0.699	7.0
0.30	0.8534 0.711	7.0
0.35	0.9246 0.720	7.0

SOURCE: INTAKE FAMILIES (USDA, 1979) IN JENSEN M.E (1988)

DESIGN AND OPERATION OF FARM IRRIGATION SYSTEM

APPENDIX C

Map of Nigeria showing the location of Niger state.



Source: Niger state ministry of works

APPENDIX D

SOIL COMPOSITION OF THE FIELD UNDER STUDY

SAMPLES	1	2	3	4	5	6	7	8	9	10
PERCENTAGE OF SAND	30.0	29.5	28.0	31.0	30.5	33.5	25.9	31.5	33.0	29.9
PERCENTAGE OF SILT	19.4	21.0	22.9	23.1	24.5	20.5	23.5	24.5	30.0	29.8
PERCENTAGE OF CLAY	56.0	55.1	47.0	38.0	45.0	44.7	50.0	35.7	38.0	51.0
TEXTURAL CLASS	C	CL	C	SL	CL	C	L	L	S	CL

C = Clay
L = Loamy
S = Sandy

SOURCE: SOIL TEXTURAL CLASSES BASED ON USDA TEXTURAL TRIANGLE.

APPENDIX E

THE VALUES OF Cu CROP COEFFICIENT (K) FOR COMMON TIRRIGATED VEGETABLE

MONTHS	COEFFICIENT (K)
JAN.	0.50
FEB.	0.55
MAR.	0.60
APR.	0.65
MAY.	0.70
JUNE	0.75
JULY	0.80
AUG.	0.80
SEPT.	0.70
OCT.	0.60
NOV.	0.55
DEC.	0.50

SOURCE: (DANSTANE, 1972)

APPENDIX F

APPLICATION EFFICIENCY AND EFFICIENCY ADVANCE RATIO (Re)

APPLICATION EFFICIENCY AE%	EFFICIENCY ADVANCE RATIO (Re)
95	0.16
90	0.28
85	0.4
80	0.58
75	0.8
70	1.08
65	1.45
60	1.95
55	2.45
50	3.2

SOURCE: DESIGN AND OPERATION OF FARM IRRIGATION SYSTEM JENSEN
M. E. (1980)

APPENDIX G

MEAN MONTHLY TEMPERATURE IN °C FROM 1999 – 2009

Year	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1999	26.0	28.5	31.0	31.0	29.5	27.5	27.0	26.5	27.0	28.0	28.0	25.5
2000	26.5	26.5	30.0	31.5	29.5	27.5	26.5	26.5	27.0	28.0	27.5	24.5
2001	24.0	26.5	30.5	29.5	28.0	27.5	27.0	27.0	27.5	28.0	27.0	25.5
2002	29.1	33.2	35.1	33.7	30.3	27.7	26.6	26.6	27.6	29.4	29.4	27.0
2003	29.5	32.2	34.5	35.0	34.2	28.5	27.5	27.0	26.6	28.1	30.7	29.7
2004	29.0	31.3	34.3	35.2	31.4	27.9	27.0	26.0	30.7s	26.7	28.1	29.6
2005	28.0	32.9	35.9	32.1	29.6	26.2	27.0	27.3	29.9	28.4	27.7	27.3
2006	29.9	35.4	35.2	35.6	30.1	28.7	27.8	26.3	27.0	26.0	28.8	29.0
2007	28.5	32.2	34.3	34.0	28.3	27.3	25.9	26.4	27.7	30.1	35.4	28.3
2008	32.7	35.6	38.6	36.4	33.3	31.9	29.5	28.6	30.3	32.2	32.2	36.0
2009	35.7	37.2	35.2	33.9	31.8	30.9	29.8	30.5	31.5	34.6	33.7	30.0
Mean	25.75	28.0	30.4	31.4	29.5	27.0	27.2	26.6	27.8	27.9	27.3	25.5

Source: Nigerian Meteorological Station, Minna. (NIMET)

APPENDIX H

MEAN MONTHLY PERCENTAGE RELATIVE HUMIDITY FROM 1999-2009

Year	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1999	54	57	68	70	79	85	87	86	86	82	72	61
2000	65	36	45	66	73	86	87	87	86	82	72	45
2001	57	37	57	65	77	80	85	84	86	81	68	61
2002	25	28	39	60	62	76	86	88	88	82	56	41
2003	44	37	33	55	60	83	83	86	87	87	60	36
2004	24	24	32	62	79	84	86	86	87	82	62	41
2005	28	37	42	54	74	79	86	84	87	83	54	45
2006	50	42	38	46	78	79	85	89	86	89	50	37
2007	26	31	41	65	78	80	81	89	89	84	64	44
2008	30	29	39	56	77	81	87	90	90	84	60	50
2009	44	40	37	71	78	83	86	88	89	86	59	45
Mean	56	44	54	67	76	82	87	86	82	83	71	62

Source: Nigerian Meteorological Station, Minna. (NIMET)

APPENDIX I

MEAN MONTHLY RAINFALL (mm) FROM 1999- 2009

Year	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1999	0.00	7.90	0.00	35.70	102.80	164.20	243.90	254.70	237.10	212.20	0.00	0.00
2000	0.00	0.00		3.60	135.90	161.00	208.80	308.50	303.00	153.40	0.00	0.00
2001	0.00	0.00	15.70	21.80	122.50	171.20	213.40	279.00	321.10	179.90	46.60	0.00
2002	0.00	0.00	0.00	13.50	118.60	155.30	198.40	232.50	289.10	87.80	0.00	0.00
2003	0.00	12.20	13.60	28.70	65.50	142.20	162.10	212.40	268.70	144.20	0.00	0.00
2004	0.00	0.00	0.00	29.8	131.4	168.4	134.8	142.5	129.9	41.1	0.00	0.00
2005	0.00	0.00	0.00	28.9	52.8	142.6	115.2	91.2	139.8	304	0.00	0.00
2006	11.2	0.00	TR	0.00	100.6	60.7	213.9	154.0	310.0	310.5	60.7	0.00
2007	0.00	0.00	0.00	72.9	86.0	101.3	260.4	186.2	210.2	93.0	0.00	0.00
2008	0.00	0.00	0.00	17.8	118.8	99.6	175.9	128.4	191.1	60.4	0.00	0.00
2009	0.00	0.00	42.5	64.7	42	168.4	352.2	201.8	71.1	0.00	0.00	0.00
Mean	0.11	2.11	10.8	48.8	146.9	173.9	218.4	190.6	253.8	90.5	7.7	0.00

Source: Nigerian Meteorological Station, Minna. (NIMET)