MAKERERE UNIVERSITY

COLLEGE OF ENGINEERING DESIGN ART AND TECHNOLOGY

SCHOOL OF ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

DESIGN OF A COMMUNITY IRRIGATION SCHEME TO SERVE FIVE SMALL HOLDER FARMERS

By

BIGIRWAMUKAMA HENRY

Reg No. 14/U/4069/PSA

Students No. 214003925

A final year project report submitted to the College of Engineering Design Art and Technology, School of Engineering in partial fulfillment of the requirements for the award of the Degree of Bachelor of science in Mechanical Engineering

MAY 2018
STATEMENT OF AUTHOR

I hereby certify that this report is my original work and all the sources of materials used for the report have been duly acknowledged. This has been submitted in partial fulfillment of the requirements of Bsc. in Mechanical Engineering at Makerere University. I solemnly declare that this report is not submitted to any other institution, elsewhere for the award of any academic degree, diploma or certificate.

Name ............

Signature ............

Date .........

21ST May 2018
APPROVAL

I hereby approve that this report was written by Bigirwanukama Henry and also to the best of his knowledge and experience. It is authentic and has never been published or delivered to any academic institution. It clearly relates to the project entitled:

DESIGN OF A COMMUNITY IRRIGATION SCHEME TO SERVE FIVE SMALL HOLDER FARMERS.

Academic supervisor: Prof. Joseph Byaruhanga

Signature: Byaruhanga

Date: 12/06/2018

Academic co-supervisor: Prof. John Baptist Kirabira

Signature: ........................................

Date: ........................................
ACKNOWLEDGEMENT

I would like to thank the Almighty God for giving me life and making this whole process possible.

I wish to pass a vote of thanx to Makerere University for this opportunity to students to pursue their final year projects. I also appreciate the organization of the Mechanical Engineering department under college of Engineering, Design Art and Technology.

I acknowledge the support and guidance rendered by my supervisor Prof. Joseph Byaruhanga who gave me insights on how to pursue the project as well as the financial support to purchase the equipment for the project. I am also grateful to Eng. Wangi Mario who helped me out while in the field.

I finally thank my parents for the additional financial support.

May God bless you abundantly.
ABSTRACT

There is unreliability of food security in Uganda caused by over reliance on rain fed agriculture by the biggest percentage (97%) of households in Uganda. Prolonged droughts always lead to food scarcity in the country. Irrigation is the solution to this problem. However, farmers have not engaged in irrigation majorly because of the financial requirements. The major aim of this project therefore, was to design a community irrigation scheme to serve small holder farmers. A case study area was chosen to be Galiraya in Kayunga district where five farmers were growing upland rice on 4 acres of land each, totaling to 20 acres. Information on the climate, soil, topology, water availability, solar irradiance and wind was collected to aid in the design. Measurements of head, area, distance from the water source as well as coordinates of the place were also taken. Considerations were made on different types of irrigation and the manual hose pipe type was found most eligible because of its low costs involved. The irrigation water requirement for the rice was calculated by subtracting the total effective rainfall from the total rice water requirement and this was found to be 26.7 m$^3$/day. Total head(26m) was calculated by summing up the head of the area(16m) as measured by a hand held GPS, the head loss in the pipes(5m) and the dynamic head required by the nozzle(5m). A tank was designed to accommodate 30,000 litres a day. The main pipe was also designed with diameter of 1.5 inc, total length of 600m and was of flexible PVC material. The pump was designed by calculating the pump power from the flow rate and total head required. A suitable pump was chosen from available pumps and it had 550 watts, maximum head of 52m and maximum discharge of 4 m$^3$/hr. the number of solar panels for the pump was determined from the pump power required and these were 6 in number. With this design, a topomap was created from the coordinates showing the design. A prototype was then set up in the area. Analysis was done to see the financial benefits of this system and it was discovered that through this, every farmer earns Shs 5,400,000 more per season with this system than when without it. It was concluded that setting up these kinds of irrigation schemes would increase food availability as well as increase the financial benefits of the farmers.
LIST OF FIGURES

Figure 1 A graph showing Average high and low temperature of the area ........................................... 25
Figure 2 A graph showing Average monthly Rainfall ................................................................. 26
Figure 3 A graph showing Average daily Incident shortwave solar Energy ........................................ 27
Figure 4 laying the main inlet pipe ............................................................................................... 16
Figure 5 connecting two pipes together ...................................................................................... 17
Figure 6 water well ......................................................................................................................... 18
Figure 7 pump house .................................................................................................................... 18
Figure 8 no return valve .............................................................................................................. 19
Figure 9 pump submersed in the well .......................................................................................... 20
Figure 10 voltage regulator ......................................................................................................... 21
Figure 11 solar modules ............................................................................................................... 21
Figure 12 water delivered to highest point .................................................................................. 22
Figure 13 water fills the tank ....................................................................................................... 23
Figure 14 main distribution line ................................................................................................. 24
LIST OF TABLES

Table 1 Crops grown in Uganda ................................................................. 6
Table 2 System components ........................................................................ 29
Table 3 Bill of materials for community project ........................................ 36
Table 4 Bill of materials for individual project ............................................ 37
Table 5 Comparison of the yields from irrigation and rainfed agriculture ....... 38
# Table of Contents

STATEMENT OF AUTHOR ............................................................... Error! Bookmark not defined.

APPROVAL ....................................................................................... Error! Bookmark not defined.

ACKNOWLEDGEMENT ..................................................................... iii

ABSTRACT ....................................................................................... iv

LIST OF FIGURES ............................................................................... v

LIST OF TABLES ................................................................................ vi

LIST OF ACRONYMS ......................................................................... 1

CHAPTER ONE: GENERAL INTRODUCTION .............................................. 2

1.1 Background .................................................................................. 2

1.2 Problem statement ....................................................................... 3

1.3 Objectives ................................................................................... 3

1.3.1 Major objective ....................................................................... 3

1.3.1 Specific objectives .................................................................. 3

1.4 Justification .................................................................................. 4

1.5 Statement of scope ...................................................................... 4

CHAPTER TWO: LITERATURE REVIEW ..................................................... 5

2.1 Introduction .................................................................................. 5

2.2 Major crops grown in Uganda ...................................................... 6

2.3 Crop water requirements .............................................................. 6

2.3.1 FAO Penman-Monteith method .............................................. 7

2.3.2 Pan Evaporation method ....................................................... 7

2.3.3 Blaney criddle method .......................................................... 8

2.4 Methods of irrigation ................................................................... 8

2.4.1 Surface irrigation ................................................................... 8

2.4.2 Sprinkler irrigation systems .................................................. 9

2.4.3 Localized irrigation systems .................................................. 10

2.4.4 Manual irrigation systems .................................................... 11

2.5 Choosing an irrigation method ..................................................... 11

2.5.1 Natural conditions .................................................................. 12

2.5.2 Type of crop .......................................................................... 12

2.5.3 Type of technology ............................................................... 13
2.5.4 Required labour inputs ................................................................. 13
2.5.5 Costs and benefits ........................................................................ 13
2.5.6 Conclusion ..................................................................................... 13

CHAPTER THREE; METHODOLOGY ..................................................... 14

3.0 Introduction ....................................................................................... 14
3.1 Reviewing literature ........................................................................ 14
3.2 Choosing and studying the case study area ...................................... 14
  3.2.1 Measuring head ........................................................................... 14
  3.2.2 Measuring length and Area .......................................................... 14
3.3 Choosing the type of irrigation ....................................................... 14
3.4 Determining the water requirements ............................................... 15
3.5 Designing of system components .................................................... 15
3.6 Drawing a topomap of the area with the design. ............................. 15
3.7 Developing a prototype of the design in the case study area .......... 15
  3.7.1 Laying the main inlet pipe ............................................................. 15
  3.7.2 Digging a well and building a pump house .................................. 17
  3.7.3 Connecting the no return valve ................................................... 19
  3.7.4 Connecting the pump, regulator and solar modules .................... 19
  3.7.5 Testing of the pump ................................................................... 22
  3.7.6 Placing the tank stand and the tank ............................................ 22
  3.7.7 Connecting the main distribution line from the tank ................... 24

CHAPTER FOUR: RESULTS ANALYSIS AND DISCUSSION ..................... 25

4.1 Case study area ................................................................................ 25
  4.1.1 Climate ...................................................................................... 25
  4.1.2 Solar energy .............................................................................. 26
  4.1.3 Topography ............................................................................... 27
  4.1.4 Water availability ..................................................................... 27
  4.1.5 Head and Area .......................................................................... 27
4.2 Irrigation type.................................................................................... 27
4.3 Crops and water requirement .......................................................... 28
4.4 Design of system components......................................................... 29
  4.4.1 Embodiment design .................................................................. 29
4.4.2 Detailed design .............................................................................................................. 30
Solar panel sizing for the pump .................................................................................................. 32
4.5 Topomap of the area .............................................................................................................. 34
4.6 Technical analysis ................................................................................................................. 35
4.7 Cost analysis ......................................................................................................................... 36
4.8 Economic benefit ..................................................................................................................... 37

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION .................................................. 39
5.1 Conclusion .............................................................................................................................. 39
5.2 Recommendations .................................................................................................................. 39
LIST OF ACRONYMS

AE.............................Application Efficiency

BP..............................Back flow preventer

CAD..............................computer aided drawing

CWR..............................crop water requirements

FAO..............................food and Agriculture organization

GDP..............................Gross domestic product

UCA..............................Uganda census of Agriculture

ET..............................Evapotranspiration

GIR..............................Gross Irrigation requirement

NIR..............................Net irrigation requirement

PVC..............................Polyvinyl chloride.

NEMA.............................National Environmental Management Authority
CHAPTER ONE: GENERAL INTRODUCTION

1.1 Background

The agricultural sector dominates Uganda’s economy. It accounts for over 24% of GDP, 69% of export earning, 73% of employment and provides most of the raw materials to the mainly agro-based industrial sector. Food crop production predominates the sector, contributing 62% of the agricultural GDP and most of this production is from the country’s estimated 3.95 million small holder farmers[1]. Agricultural production is carried out on small plots whose national average form size is 2.2 ha [2].

Uganda is found in the equatorial region. The soils and associated agro-climatic conditions are favourable for the successful cultivation of large variety of crops virtually throughout the year. The main climatic variable affecting agriculture is rainfall, about 70% of the country receives bimodal rainfall allowing two cropping seasons per year. The total annual rainfall ranges from 750 mm in the parts of the eastern karamoja plateau to about 2100 mm in the sese islands of kalangala district in Lake Victoria [3]. However, of concern is the recent trend relating to the timing and duration of rainfall, prolonged dry spells as well as floods during rainy seasons. As a result, farm level productivity is far below the attainable potential for most crops. This creates the need to devise other means of providing water for the plants without relying entirely on the rainfall.

Water for production is one of the seven pillars of the plan for the modernization of agriculture which was assented to by the government of Uganda in December 2001 as the main instrument for operationalizing the poverty eradication action plan.[4]. 4400 km² of the 242,000 km² of land in Uganda are covered by water bodies. The Uganda territory is situated entirely within the Nile basin and is for operational purposes divided into total of eight sub-basins. However, only a fraction of these extensive water resources has been tapped for irrigation despite a monomodal rainfall pattern in the north-eastern part of the country. Use of this water to supplement rainfall during moisture-deficit periods is considered an integral part of the strategy to intensify agricultural production in the areas where horizontal expansion is constrained [4].

The potential irrigation area is estimated at 202,000 ha of which less than 14,418 ha are currently under formal irrigation and 67,000 ha are under informal irrigation particularly for rice production. Water use for small-scale irrigation scheme is estimated at 10,000 m³/ha/year. This reveals that the country has not reached anywhere its irrigation potential of 202,000 ha which is equivalent to...
2.02 billion m$^3$ of water per year with a water application rate of 10,000 m$^3$/ha. Consequently this is far below the annually renewable water resource of 40 billion m$^3$.[4]

Therefore, there is need to set up multiple community irrigation schemes so as to increase on the agricultural productivity of the small holder farmers and in turn boost the country’s economy.

1.2 Problem statement
Food security in Uganda is unreliable and this is because of over reliance on rain fed agriculture. Recent changes in the climatic conditions for example prolonged dry spells have made agricultural productivity very low and unreliable. According to UCA report 2008/2009, 2 million out of 3.6 million households asked, ran out of food at some point in the year and 1.8 million households identified drought as the major cause of the food shortage[5].

Uganda has 41028 km$^2$ of the 241551 km$^2$ of land covered by water bodies. In addition, the country lies in the equatorial region where 70% of the country receives bimodal rainfall. The total annual rainfall ranges from 750 mm in the parts of the eastern karamoja plateau to about 2100 mm in the sese islands of kalangala district in Lake Victoria. This gives Uganda a high irrigation potential of 202000 ha of irrigable land of which only 14418 ha have been utilized.

Small holder farmers in Uganda have not adopted to irrigation citing the high costs involved in setting up individual irrigation systems. Most irrigation systems in Uganda are owned by large scale farmers. About 0.9% of small household farmers practice any form of irrigation.

Therefore, there is need to set up multiple community irrigation schemes which can ensure constant supply of water and also be cost friendly to the farmers.

1.3 Objectives
These were the objectives for this project.

1.3.1 Major objective
To design a community irrigation scheme to avail water for irrigation to five small holder farmers.

1.3.1 Specific objectives
- To identify different crops that are to be planted under these irrigation schemes and their water requirements for proper growth
- To design and choose an appropriate pump to run the system.
• To develop and test a prototype in a chosen case study area.

1.4 Justification

Food crops production throughout the year is a step towards hunger reduction as it ensures proper nutrition and efficient working of the body system. It is only then that the community will be able to carry out their tasks effectively so as to achieve sustainable development goals that focus on seeing each individual living above the poverty line. Shortage of food for example in Isingiro in 2016, causes a major setback in achieving these goals.

The Community irrigation that serves five small holder farmers would ensure crop production throughout the year regardless of rainfall patterns. This would ensure food security in the country and would as well create surplus produce that would be exported and earn the country revenue.

The small holder farmers would benefit economically since the cost of major equipment would be shared amongst five farmers. This would increase their annual produce and hence their income.

Through rain water management systems, the community would be assured of water availability throughout the year and by using this water for irrigation, there will be constant supply of food crops.

1.5 Statement of scope

The project intends to cover design of a community irrigation system to include:

• Review on materials to ascertain the development of the community irrigation system
• Identification of design parameters like soil type, topography and climatic conditions of the area to allow estimation of crop water requirements.
• Determining parameters that would allow proper presentation of system layout.
• Designing of a community irrigation system including pipeline hydraulics for main pipe, sub mains, distribution line, laterals and emitters.
CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction
Irrigation can be defined as the process of slow application of water either on the surface of the soil or sub-surface. Many irrigation systems exist that have been exploited and that have been adopted for various places depending on certain conditions[6]

Water is naturally supplied to plants through rains, however the total rainfall in a particular area maybe be either insufficient or ill-timed. In order to get maximum yield, it is essential to supply optimum quantity of water and maintain correct timing of water[7].

Much research has been done in the area of irrigation and many methods have been explored including surface irrigation, pressurised systems and manual systems. All these methods have been setup in different areas in the world and all have proved efficient.[8]

There are many factors considered when selecting a particular irrigation system. These include availability of water resources, soil requirements, topography, climate, types of crops to be grown, availability and cost of capital and labor, type and appropriateness of a particular irrigation technology to farmers and its associated energy requirements, water use efficiencies as well as socio-economic, health and environmental aspects. Using a single criterion for selection purposes in not wise however, in some instances, one criterion can weigh heavily in favor of a particular irrigation system[9].

The success of a project is largely determined by the socio-economic impact of the irrigation system chosen. The socio-economic benefits are derived not only by the government but also more importantly, by the communities in which the project is located.

Health and environmental impact of the irrigation system is an important factor to consider. The introduction of an irrigation scheme in a particular area can improve health however; it can as well introduce health hazards if mitigation measures are not adequately addressed during the scheme design, implementation, operation and management. Irrigation may also introduce environmental risks such as salinization and the deterioration of biodiversity.[10]

It is therefore necessary to obtain all available information and data and to carry out an analysis of all the factors before possibly ranking the criteria for purposes of selecting an irrigation system. In order for a project to be sustainable, all technical, socio-economic, health and environmental
information should be analyzed in such a way that the system chosen is technically feasible, economically viable, socially acceptable and environmentally sound.

2.2 Major crops grown in Uganda

Maize, beans cassava banana and sweet potatoes are the most grown crops by households with each being grown by over a million households[11][12][13]

Table of households growing different crops in Uganda

Table 1 Crops grown in Uganda

<table>
<thead>
<tr>
<th>Crop</th>
<th>households</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>1743016</td>
<td>17.7</td>
</tr>
<tr>
<td>finger millet</td>
<td>409740</td>
<td>4.1</td>
</tr>
<tr>
<td>Sorghum</td>
<td>606266</td>
<td>6.1</td>
</tr>
<tr>
<td>Rice</td>
<td>103570</td>
<td>1</td>
</tr>
<tr>
<td>Beans</td>
<td>1664756</td>
<td>16.9</td>
</tr>
<tr>
<td>Peas</td>
<td>260126</td>
<td>2.6</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>653793</td>
<td>6.6</td>
</tr>
<tr>
<td>Simsim</td>
<td>322313</td>
<td>3.3</td>
</tr>
<tr>
<td>soya beans</td>
<td>66718</td>
<td>0.7</td>
</tr>
<tr>
<td>Banana</td>
<td>1622813</td>
<td>16.4</td>
</tr>
<tr>
<td>Cassava</td>
<td>1125337</td>
<td>11.4</td>
</tr>
<tr>
<td>sweet potatoes</td>
<td>1145763</td>
<td>11.6</td>
</tr>
<tr>
<td>irish potatoes</td>
<td>150296</td>
<td>1.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>9874507</td>
<td>100</td>
</tr>
</tbody>
</table>

2.3 Crop water requirements

Every crop has its own water requirement for successful yield. This requirement can be estimated by determining the crop evapotranspiration (ET₀).[14] A number of formulae have been developed from which crop evapotranspiration can be estimated.[9]
2.3.1 FAO Penman-Monteith method

This method defines the reference surface as a hypothetical reference crop with an assumed crop height of 0.12m, fixed surface resistance of 70s/m. Its expression is derived from measurement of standard climatological data entailing sunshine, temperature, humidity and wind speed. The equation is as below.[15]

\[
ET_0 = \frac{0.408\Delta(R_n - G) + \frac{900}{T+273}U_2(e_s - e_a)}{\Delta + \gamma(1+0.34U_2)}
\]

Where \( R_n \) = net radiation at crop surface (MJ/m\(^2\))

\( G \) = soil heat flux density (MJ/m\(^2\))

\( T \) = mean daily air temperature at 2m height (°C)

\( U_2 \) = wind speed at 2m height (m/s)

\( e_s \) = saturation vapour pressure (kpa)

\( e_a \) = actual vapour pressure (kpa)

\( e_s - e_a \) = saturation vapour pressure deficit (kpa)

\( \Delta \) = slope of vapour pressure curve (kpa°C)

\( \gamma \) = psychometric constant (kpa°C-1)

2.3.2 Pan Evaporation method

This is employed because of its simplicity and practicality.

The evaporation rate from pans filled with water can easily be determined. In the absence of rainfall, the amount of water evaporated during a given period corresponds to the decrease in water depth in the pan during the given period. Pans provide a measurement of the combined effect of radiation, wind, temperature and humidity on an open water surface.

The pan responds in a similar manner to the same climatic factors affecting crop transpiration, however several factors produce difference in the loss of water from a water surface and from a cropped surface[16].
Despite the difference between pan evaporation and reference crop evapotranspiration, the use of pans to predict ET$_0$ for periods of 10 days or longer is still practiced.

The measured evaporation from a pan is related to the reference crop evapotranspiration (ET$_0$) though an empirically derived pan coefficient (Kp) as given in the following equation from FAO (1998a):

\[ ET_0 = Kp \times Epan \]

Where;

- ET$_0$ = Reference crop evapotranspiration (mm/day)
- Kp = Pan coefficient
- Epan = pan evaporation (mm/day)

### 2.3.3 Blaney Criddle Method

This takes into consideration temperature as the only parameter to be measured and therefore results either into overestimation in certain conditions. It is an inaccurate method especially in windy, dry and sunny areas.[17]

\[ ET_0 = p(0.46T_{mean} + 8) \]

Where;

- ET$_0$ = the reference crop evapotranspiration in mm/day for the month considered
- T = mean daily temperature in °C over the month considered.
- P = is mean daily percentage of total annual daytime hours obtained for a given month and latitude.

### 2.4 Methods of irrigation

Different types of irrigation systems are in existence and these include; surface irrigation, sprinkler, drip and manual irrigation systems.

#### 2.4.1 Surface irrigation

This is the oldest method of irrigation that has been in existence since irrigation was discovered. It involves application of water by gravity across the soil surface by flooding or using small
These channels include; basins, bourders, paddies, furrows, rills and corrugation. It accounts to about 95% of irrigations systems installed in the world.

Advantages include;

- Easy to operate and maintain
- They are not affected by windy conditions
- With the exception of furrow irrigation, they are good for the leaching of the salts from the root zone
- They are generally associated with low energy costs

Disadvantages include;

- It requires uniformly graded and shaped land so as to attain high efficiencies
- A high degree of management and water control is required.

2.4.2 Sprinkler irrigation systems

It consists of a pipe network, through which water moves under pressure before being delivered to the crop through sprinkler nozzles. The system basically simulates rainfall in that water is applied through overhead spraying hence method is also called overhead irrigation system.[19]

These systems are suitable for most crops. They are generally suitable for light, frequent irrigations, unlike most surface irrigation systems.

Sprinkler irrigation systems are sub-divided into two groups. i.e

- Movable and continuous move systems which operate which operate while moving and these include (centre pivot, linear move systems, travel gun systems)
- Set systems (risers) which operate with the sprinklers in a fixed position[20]

Advantages;

- This technique enables judicious utilization of even small water flows and permits efficient irrigation of undulated lands, and soils with shallow depths
- It saves 10 to 16% land that is used in construction of channels and ridges in other methods.
- Highly permeable as well as relatively less permeable soils can be easily irrigated by sprinkler method without any risk of run-off and erosion, inundation and seepage losses.
- Fertilizers, pesticides and weedicides can be applied with water spray thus saving extra labour.

Disadvantages:
- High initial cost of equipment
- Operating costs are generally higher than the irrigation by surface methods
- Wind disturb the sprinkler pattern giving uneven distribution of the irrigation water
- Sprinkling with water containing an appreciable amount of salts may result in bum or death of the plants

2.4.3 Localized irrigation systems
This is a system for supplying filtered water (and fertilizer) directly into the soil. The water is distributed under low pressure through a pipe network in a predetermined pattern and applied as a small discharge to each plant or adjacent to it. There are three major categories of localized irrigation[21]

- Drip irrigation; where drip emmitters are used to apply water slowly to the soil surface
- Spray irrigation; where water is sprayed to the soil near individual trees
- Bubbler irrigation; where a small stream is applied to flood small basins or the soil adjacent to individual tree.

The basic localized irrigation system consists of the head of the system that filters and controls the supply of water and fertilizers to the network, the plastic buried pipes that supply the water to the laterals, the polyethylene laterals that supply the water to the emmitters and the emmitters that discharge the water to the pre-determined points and at predetermined flows.[22]

Advantages
- Fertilizers and nutrient loss is minimized due to localized application and reduced leaching
- Water application efficiency is high if managed correctly
- Field levelling is not necessary
- Fields with irregular shapes are easily accommodated
- Recycled non-potable water can be safely used.
- Moisture within the root zone can be maintained at field capacity
• Soil type plays less important role in frequency of irrigation
• Soil erosion is lessened.
• Weed growth is lessened

Disadvantages

• Clogging of emitters which calls for good maintenance through flushing probably once a month
• High initial cost of equipment.

2.4.4 Manual irrigation systems

Manual irrigation systems are very simple, but effective methods for making water available to crops. Manual irrigation systems are easy to handle and there is no need for technical equipment. But it is important that they are constructed correctly to avoid water loss and crop shortfall. The systems allow for high self-help compatibility and have low initial capital costs. They can be used in almost every area, but they are especially adapted for arid areas where evaporation rates are high.[23]

Advantages

• Improved water-use efficiency (reduced loss through evaporation)
• Well directed, selective and targeted irrigation
• Can be constructed with locally available material
• Low investment costs

Disadvantages

• Labour intensive
• Non uniform water distribution

2.5 Choosing an irrigation method

To choose an irrigation method, the farmer is supposed to know the advantages and disadvantages of the various methods. The method chosen must suit best the local conditions. Unfortunately, in many cases there is no single best solution. All methods have their advantages and disadvantages. Testing of the various methods under the prevailing local conditions provides the best basis for a sound choice of irrigation method[9]. The suitability of the various irrigation methods depends
mainly on the following factors: natural conditions, type of crop, type of technology, required labour inputs and most importantly costs and benefits.[24]

2.5.1 Natural conditions
These include; soil type, slope, climate, water quality and availability

a) **Soil type**: Sandy soils have a high infiltration rate and a low water storage capacity. This necessitates frequent irrigation application. Drip and sprinkler irrigation are more suitable than surface and manual irrigation for this kind of soil. For areas with clay or loam soils all three irrigation methods can be used. Clay soils have low infiltration rates and thus are suited to surface irrigation. If different soil types are found within one irrigation area, drip or sprinkler irrigation are suitable since they ensure an even water distribution.[25]

b) **Slope**: unevenly sloping and steep areas are suited by drip or sprinkler or manual irrigation since no land levelling is required for the three methods unlike surface irrigation.

c) **Climate**: sprinklers are affected by strong wind and thus drip, manual or surface irrigation methods are preferred. In areas of supplementary irrigation, sprinkler or drip irrigation may be more suitable than surface irrigation because of their flexibility and adaptability to varying irrigation demands on the farm[9].

d) **Water availability**: In short water supply areas, drip and sprinkler irrigation methods are preferred due to their water saving advantage.

e) **Water quality**: sediments containing water is suited by surface irrigation since the sediments might clog the drippers or sprinklers. Drip irrigation is suitable for areas with water that contains salts since less water is applied to the soil.[26]

2.5.2 Type of crop
Surface irrigation can be used for all types of crops. Drip and sprinkler irrigation methods require high capital investments per hectare and thus are used for high value cash crops such as fruits and vegetables. They are seldom used for the lower value staple crops. Drip irrigation is suitable for irrigating individual plants or trees or row crops such as vegetables and sugarcane. It is not suitable for close growing crops (e.g. rice).

Manual irrigation can be applied on every crop.
2.5.3 Type of technology
Drip and sprinkler irrigation methods are more complicated than manual and surface irrigation methods. Maintaining their equipment requires a high level of “know how.” A regular supply of fuel and spare parts is also necessary. Surface and manual irrigation systems on the other hand require less sophisticated equipment for their construction as well as their maintenance.

2.5.4 Required labour inputs
The construction, operation and maintenance of surface irrigation schemes require much labour input relative to sprinkler and drip irrigation. Furthermore, surface irrigation schemes require accurate levelling of land as compared to drip and sprinkler irrigation systems. Manual irrigation requires the most operation labour input.

2.5.5 Costs and benefits
Farmers are only interested in implementing a particular irrigation method if it is economically attractive. The cost of installation, construction, operation and maintenance when compared with expected benefits should be way less for the farmer to economically benefit from the project. Manual irrigation is the most cost effective way of irrigation since it requires very low costs for their set up and operation.

2.5.6 Conclusion
Surface irrigation should be used when there are mild and steel slopes, soil type with medium to low infiltration and a sufficient supply of water. Sprinkler and drip irrigation methods are suitable when there are steep or irregular slopes, soils with a very high infiltration rate or scarcity of water.

However, for small holder farmers who have little capital, manual irrigation is the best form of irrigation. The economic benefit of the irrigation system is the core consideration when choosing a type of irrigation system.
CHAPTER THREE; METHODOLOGY

3.0 Introduction
This project was done and objectives achieved through the following ways.

3.1 Reviewing literature.
Different manuals and articles published in the field of agriculture as well as irrigation were read and statistical data as well as knowledge in the field of irrigation and related fields were acquired.

The crops grown in Uganda, the crop water requirement determination methods and different methods of irrigation systems were analyzed critically in the literature review. This helped at later stages in the design of the community irrigation scheme.

3.2 Choosing and studying the case study area
Different communities have different conditions. That is why there was need to choose a case study area. Different factors were considered to choose a community of five farmers to be used for this project

3.2.1 Measuring head
A hand held GPS machine was used to measure the height above sea level for both the lowest point and the highest point of the area. The difference between the altitudes was got and this was the head for the area.

3.2.2 Measuring length and Area
A measuring tape was used to measure the total distance from the water source to the highest point of the fields.

The different edges of the fields were also measured and their respective areas calculated for proper designs

3.3 Choosing the type of irrigation
Different types of irrigation types were considered according to factors like, cost benefits, topology, operation, maintenance, and nature of the area.

In this case cost requirements overweighed the rest of the factors.
3.4 Determining the water requirements

Upland rice is the crop to be planted on 20 acres of land with black loam soils. Different manuals were revised to know the total water requirement of upland rice and the irrigation water requirement was calculated.

3.5 Designing of system components

Each component was designed according to the requirements of the fields. Their size, length and material were designed accordingly.

3.6 Drawing a topomap of the area with the design.

Autocad software was used to come up with the topomap of the area with the design components.

3.7 Developing a prototype of the design in the case study area

Equipment were purchased and taken to the case study area. The community was involved to dig a well which was to collect water from the swamp. Pipes were laid and interconnected using pvc connectors. A no return valve was connected about 5m from the pump. The tank was placed in place on top of the tank stand. A house was built at well to accommodate solar panels and the voltage regulator. The system was tested for functionality.

3.7.1 laying the main inlet pipe

A path 1ft deep was created from the water source to the highest point where the tank was to be placed. This path was created for the 1.5inch main pipe that was to carry water from the water source to the tank. Six 1.5-inch diameter PVC pipes of 100m length each were interconnected by Plastic connectors and laid into the path.
Figure 1 laying the main inlet pipe
3.7.2 digging a well and building a pump house.

The community was involved to setup a well to collect relatively clear water (water free from grass and other particles that hinder its flow. This well was to be 5ft deep with stones placed under it and cemented on its sides to avoid eroded soil from contaminating the water.

On top of this well, a small house was built to ensure safety of the regulator and the pump as well as accommodate the solar modules on its roof.
3.7.3 Connecting the no return valve.
This valve was placed 5m away from the pump and its major purpose was to prevent the back flow of the water which would be dangerous to the pump.

![Figure 5 no return valve](image)

3.7.4 Connecting the pump, regulator and solar modules
The pump was connected to the main inlet pipe and then powered by six solar panels that were connected in parallel. A voltage regulator was placed between the solar panels and the pump to ensure safety of the pump. The was then dipped into the well
Figure 6 pump submersed in the well
Figure 7 voltage regulator

Figure 8 solar modules
3.7.5 Testing of the pump
The switch was turned on and the pump checked to see if it delivers water. Water was delivered to the end of the pipeline which is 600m away and it had enough dynamic head to enter the tank.

3.7.6 Placing the tank stand and the tank
A tank stand 3m high was then fixed in the ground and a 5,000L tank was placed on top of it and the main inlet line was connected to the tank. The switch was turned back on and the tank filled with water.
Figure 10 water fills the tank
3.7.7 connecting the main distribution line from the tank

A 1.5-inch diameter PVC pipe was connected from the bottom of the tank to the fields.

Figure 11 main distribution line
CHAPTER FOUR: RESULTS ANALYSIS AND DISCUSSION

4.1 Case study area

4.1.1 Climate

Temperature

Kayunga’s climate is warm, muggy and overcast. The temperature varies from 61°F to 87°F. The clearer part of the year in kayunga begins around June 12 and lasts for 3.7 months.[27]

Rainfall

Kayunga experiences extreme seasonal variation in monthly rainfall. Rain falls throughout the year in the area. The most rain falls during the 31 days centered around April 17, with an average total accumulation of 8.1 inches. The least rain falls around January 27, with an average total accumulation of 2 inches.
4.1.2 Solar energy

The average daily incident shortwave solar energy experiences some seasonal variation over the course of the year. The brighter period of the year lasts for 2.3 months, from January 5 to March 13 with an average daily incident short wave energy of 6.3kwh per square meter. The darker period of the year lasts for 1.3 months, from April 19 to May 29 with an average daily incident short wave energy of 5.1kwh per square meter.
4.1.3 Topography
The geographical coordinates of the area are 0.702°S latitude, 32.889°E longitude. The elevation change of the area is 16m with highest point at 1044m.a.s.l and lowest point at 1028m.a.s.l. The total area to be cultivated is 20 acres.

4.1.4 Water availability
The piece of land has the Victoria Nile in the neighborhood. The distance from the water source to the highest point of the fields is about 600m.

4.1.5 Head and Area
Water source altitude = 1033m.a.s.l
Highest point altitude = 1051m.a.s.l
Head required = 1051-1033
= 18m

4.2 Irrigation type
Due to the economic condition of small holders, the most affordable type of irrigation had to be chosen. A manual irrigation system using garden hose pipes with nozzles is used. Each farm was to have its own hose and it was to be placed at the center of the farm for easy distribution.
4.3 Crops and water requirement.
The farmers were previously planting maize on part of the piece of land. Their plan is to plant upland rice on a total of 20 acres of land.

Upland rice requires 400mm of water per unit area in its base period. Taking a growing season of September to December,[28]

Total rainfall received = (5+6+5+3) inches

= 19 inches

= 19 x 25.4 mm

= 482.6 mm

Effective rainfall = 0.75 x 483.6

= 362.7 mm

Net irrigation requirement = total water requirement – effective rainfall[29]

= WR – ER

= 400 – 362.7

= 37.3 mm

Considering 10% water losses due to evaporation, leaching and runoff

Irrigation Efficiency = 90%

Gross irrigation water requirement = NIR / irrigation efficiency

= 37.3/0.9

= 41.4 mm

Total Irrigation water depth required = 41.4 mm

Daily irrigation water required per unit area = 41.4/126

Daily depth of irrigation = 0.33 mm/day

For 20 acres of land
Daily irrigation water requirement = 0.33 x 4046 x20
= 26.7m$^3$/day

Required application rate = 26.7m$^3$/ 8hrs
= 3.34m$^3$/hr

4.4 Design of system components.
4.4.1 Embodiment design
The system required the following components

Table 2 System components

<table>
<thead>
<tr>
<th>Component</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nozzles</td>
<td>5</td>
</tr>
<tr>
<td>Garden hoses</td>
<td>5</td>
</tr>
<tr>
<td>Risers</td>
<td>5</td>
</tr>
<tr>
<td>Laterals</td>
<td>5</td>
</tr>
<tr>
<td>Main distribution pipe</td>
<td>1</td>
</tr>
<tr>
<td>Tank</td>
<td>1</td>
</tr>
<tr>
<td>Main inlet pipe</td>
<td>1</td>
</tr>
<tr>
<td>No return valve</td>
<td>1</td>
</tr>
<tr>
<td>Pump</td>
<td>1</td>
</tr>
<tr>
<td>Solar panels</td>
<td>6</td>
</tr>
<tr>
<td>Voltage regulator</td>
<td>1</td>
</tr>
<tr>
<td>Pipe connectors</td>
<td>16</td>
</tr>
<tr>
<td>Electrical cables</td>
<td></td>
</tr>
</tbody>
</table>
4.4.2 Detailed design

**Hose pipes**;

Material: synthetic rubber

Diameter: ¾ inches

Total length: 50m

Nozzle type: orbit mini hose nozzle

Max Spray distance: 50m

**Risers**

Material: steel

Diameter: 1 inch

Length: 1m

**Laterals**

Material: flexible PVC

Diameter: 1 inch

Length: 90m

Number: 5

**Main distribution pipe**

Material: flexible PVC

Diameter: 1.5 inches

Length: 500m

**Reservoir tank**

Capacity: 30,000 ltrs

Material: un plasticized PVC

Tank stand height: 3m
Main inlet pipe

Material: flexible PVC due to its resistance to corrosion, durability and affordability

Diameter. For a flow rate of $4\text{m}^3/\text{hr}$ and velocity of $1\text{m/s}$

$$Q = 4\text{m}^3/\text{hr} = 0.0011\text{m}^3/\text{s}$$

$$Q = A\times V$$

$$A = \frac{Q}{V}$$

$$= 4\text{m}^2$$

$$A = \pi D^2/4$$

$$D = \left(\frac{4\times 0.0011}{\pi}\right)^{0.5}$$

$$D = 0.037\text{m}$$

$$D = 1.43\text{inches}$$

Take diameter as 1.5inches

Length: 600m

Water Pump

Total Head required = measured head + head losses + height of the stand and tank

Head losses

$$= \frac{LFV^2}{2gD}[30]$$

$$= 600 \times 0.003 \times 1/2 \times 9.81 \times 0.0381$$

$$= 2.6\text{m}$$

Total head required = $18 + 2.6 + 4.5$

$$= 25.1\text{m}$$

Flow rate required = $3.34\text{m}^3/\text{hr}$

$$= 0.0012\text{m}^3/\text{s}$$

Pump power = $\text{eff} \times QgH$
A solar water pump was chosen from existing pumps and it has the following specifications:

- **Model:** SL4SP2-8
- **Type:** submersible
- **Power:** 550w
- **Flow rate:** 4m$^3$/hr
- **Max head:** 52m
- **Voltage:** 43V/DC

**Solar panel sizing for the pump**

Pump power requirement = 550w/0.65

= 846.1w

Solinic solar module was chosen for this purpose and it has the following specifications at STC:

- **Maximum power output:** 200wp
- **Open circuit voltage:** 43.2V DC
- **Short circuit current:** 6.5A DC
- **Power rating of the module:** 200w
- **Module guaranteed power at STC:** 0.9x200

= 180w

Module operating output at operating temperatures = 0.9x 180

= 162w

Number of modules required = pump power requirement/output of each module[31]

= 846.1/162
= 5.2

= hence 6 solar panels

Number of panels connected in series = pump voltage requirement/solar panel voltage

= \frac{48}{43}

=1.1 this approximates to 1

To ensure the safety of the pump, a voltage regulator was introduced between the solar modules and the pump.

A no return valve was also put 5m from the pump to prevent backflow.
4.5 Topomap of the area

**TOPOMAP OF KAYUNGA GALIRAYA SHOWING IRRIGATION SYSTEM LAYOUT**

<table>
<thead>
<tr>
<th>KEY</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>MAIN INLET PIPE</td>
</tr>
<tr>
<td>-</td>
<td>MAIN DISTRIBUTION LINE</td>
</tr>
<tr>
<td>○</td>
<td>HOSE PIPE ROLL</td>
</tr>
<tr>
<td>-</td>
<td>LATERALS</td>
</tr>
<tr>
<td>△</td>
<td>TRRRS</td>
</tr>
<tr>
<td>△</td>
<td>SWAMP</td>
</tr>
<tr>
<td>△</td>
<td>VICTORIA MILE</td>
</tr>
<tr>
<td>△</td>
<td>BUILDINGS</td>
</tr>
<tr>
<td>△</td>
<td>NO RETURN VALVE</td>
</tr>
</tbody>
</table>
4.6 Technical analysis.

The system was started and time to fill the tank was recorded.

Tank capacity = 10,000 ltrs

Time to fill the tank = 2hrs; 51 mints

= 2.85 hrs

Quantity of water delivered to the tank in 1 hr = \( \frac{10,000}{2.85} \)

= 3508 ltrs/hr

Quantity of water expected in 1 hr = 4000 ltrs

Efficiency of the water delivery = \( \frac{\text{quantity of water collected in 1 hr}}{\text{quantity of water expected in 1 hr}} \)

= \( \frac{3508}{4000} \)*100

= 87.7%
4.7 Cost analysis
Bill of materials

Table 3 Bill of materials for community project

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Unit cost (shs)</th>
<th>Total cost (shs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar pump.</td>
<td>1</td>
<td>1,800,000</td>
<td>1,800,000</td>
</tr>
<tr>
<td>Solar panels</td>
<td>6</td>
<td>600,000</td>
<td>3,600,000</td>
</tr>
<tr>
<td>Solar Panel stand</td>
<td>1</td>
<td>300,000</td>
<td>300,000</td>
</tr>
<tr>
<td>Garden hoses</td>
<td>5</td>
<td>100,000</td>
<td>500,000</td>
</tr>
<tr>
<td>Nozzles</td>
<td>5</td>
<td>50,000</td>
<td>250,000</td>
</tr>
<tr>
<td>Storage tank</td>
<td></td>
<td>3,000,000</td>
<td>3,000,000</td>
</tr>
<tr>
<td>Electrical wires</td>
<td></td>
<td></td>
<td>50,000</td>
</tr>
<tr>
<td>Main inlet pipe (1.5inch)</td>
<td>600m</td>
<td></td>
<td>3,000,000</td>
</tr>
<tr>
<td>Main distribution pipe</td>
<td>500m</td>
<td></td>
<td>2,500,000</td>
</tr>
<tr>
<td>Lateral pipes (3/4inch)</td>
<td>450m</td>
<td></td>
<td>1,250,000</td>
</tr>
<tr>
<td>Pipe fittings</td>
<td></td>
<td></td>
<td>200,000</td>
</tr>
<tr>
<td>Valves</td>
<td></td>
<td></td>
<td>200,000</td>
</tr>
<tr>
<td>Well and pump house</td>
<td>1</td>
<td></td>
<td>1,500,000</td>
</tr>
<tr>
<td>Material transportation</td>
<td>3trips</td>
<td>250,000</td>
<td>750,000</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td></td>
<td></td>
<td>500,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>19,500,000</strong></td>
</tr>
</tbody>
</table>

Total cost of the project is shs 19,500,000 for five farmers

Contribution by each farmer = 19,500,000/5

  = shs 3,900,000
If each farmer was to set up individual systems, he would incur the following costs

Table 4 Bill of materials for individual project

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Unit cost (shs)</th>
<th>Total cost (shs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump</td>
<td>1</td>
<td>1,200,000</td>
<td>1,200,000</td>
</tr>
<tr>
<td>Solar panels</td>
<td>4</td>
<td>600,000</td>
<td>2,400,000</td>
</tr>
<tr>
<td>Solar panel stand</td>
<td>1</td>
<td>250,000</td>
<td>250,000</td>
</tr>
<tr>
<td>Garden hose</td>
<td>1</td>
<td>100,000</td>
<td>100,000</td>
</tr>
<tr>
<td>Nozzle</td>
<td>1</td>
<td>50,000</td>
<td>50,000</td>
</tr>
<tr>
<td>Storage tank</td>
<td>1</td>
<td>1,000,000</td>
<td>1,000,000</td>
</tr>
<tr>
<td>Electrical wires</td>
<td></td>
<td></td>
<td>40,000</td>
</tr>
<tr>
<td>Main inlet pipe</td>
<td>600m</td>
<td></td>
<td>1,800,000</td>
</tr>
<tr>
<td>Main distribution line</td>
<td>200m</td>
<td></td>
<td>600,000</td>
</tr>
<tr>
<td>Lateral</td>
<td>90m</td>
<td></td>
<td>250,000</td>
</tr>
<tr>
<td>Pipe fittings</td>
<td></td>
<td></td>
<td>100,000</td>
</tr>
<tr>
<td>Valves</td>
<td></td>
<td></td>
<td>80,000</td>
</tr>
<tr>
<td>Well and pump house</td>
<td></td>
<td></td>
<td>1,000,000</td>
</tr>
<tr>
<td>Material transportation</td>
<td></td>
<td></td>
<td>400,000</td>
</tr>
<tr>
<td>miscellaneous</td>
<td></td>
<td></td>
<td>200,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>9,470,000</strong></td>
</tr>
</tbody>
</table>

Community project cost per farmer = shs 3,900,000

Individual project cost = shs 9,470,000

Difference = shs 5,570,000

Comparing the two situations, a farmer would save shs 5,570,000 shs by joining hands with four other farmers compared to when he is alone.

4.8 Economic benefit

According to FAO, irrigation of upland rice fields increases the yields from 1t/ha of rain fed to 3t/ha[11]
Rainfed yields = 1t/ha

Irrigation yields = 3t/ha

Taking a common farmers’ price of 2000 per kg

**Table 5 Comparison of the yields from irrigation and rainfed agriculture**

<table>
<thead>
<tr>
<th></th>
<th>Rain fed farming</th>
<th>Irrigated farming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yields</td>
<td>1t/ha</td>
<td>3t/ha</td>
</tr>
<tr>
<td>Yealds per farmer</td>
<td>1.62t</td>
<td>4.86t</td>
</tr>
<tr>
<td>Price / kg</td>
<td>2000</td>
<td>2000</td>
</tr>
<tr>
<td>Sales</td>
<td>3,240,000</td>
<td>9,640,000</td>
</tr>
</tbody>
</table>

Difference between the sales = shs 5,400,000

Each farmer earns 5,400,000 more in sales when they have the system installed compared to when they rely on rainfall.
CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1 Conclusion
To conclude, it is evident that setting up a community irrigation scheme serving five small holder farmers increases food availability in the country by increasing yield from 1t/ha to 3t/ha of upland rice. The scheme also ensures that each farmer gets 5,400,000 more than they would get if they were to rely on rainfall. Being part of the community scheme, saves the farmer shs 5,570,000 compared to each of them establishing their individual systems.

Generally, setting up community irrigation schemes each serving five small holder farmers is a very effective way of solving the problem of food insecurity in the country and financial constraints of irrigation.

5.2 Recommendations
Before any scheme is setup, proper design for every component should be made so that establishment of the project is done following the design.

For cases of no nearby water source, a reservoir can be created downhill to collet rain water during rainy seasons so that it can be used later on in the dry seasons.

Critical attention should be put on the water requirements of the crops grown because too much water would spoil some crops and less water would make the scheme ineffective.

Similar schemes should be established all over the country so as to increase on agricultural produce and economic growth of the country given the fact that Agriculture is the back born of the country.
References


