Implemented by:

MANUAL ON MICRO & SMALL SCALE IRRIGATION TECHNOLOGIES

FOR FARMERS IN ACHOLI & LANGO SUB-REGION

IMPRINT

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‘Promoting Rural Development in Northern Uganda‘
Plot 19, Nakasero road
GIZ office or address line 1
Address line 2
Phone +256 (0)417 888 500
giz_prudev@giz.de
www.giz.de/en/worldwide/59817.html

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Design
AFC Agriculture and Finance Consultants GmbH.
Text
Med-6 Agrotech Ltd
On behalf of the
AFC Agriculture and Finance Consultants GmbH
Baunscheidtstr. 17 | 53113
Bonn | Germany.

FOREWORD

Farming is the backbone of Uganda's economy employing about 80% of the country's population. However, the recent change in weather patterns, for example unpredictability of the rainy season has put farmers in a state of uncertainty. To address this challenge, the Government, through Ministry of Water and Environment (MWE) and Ministry of Agriculture (MAAIF) is spear-heading nationwide establishment of Water for Production facilities to mitigate the unpredictable rain patterns. In doing this, the Government is working with development partners like GIZ to promote adoption of water for production technologies in regions highly affected by prolonged dry spells.

Against this background GIZ Uganda under its Promoting Rural Development (PRUDEV) is championing the Water for Production project in northern Uganda. The project aims to train at least 800 farmers in water resource management and small-scale irrigated vegetable production. The project covers nine districts in the Acholi and Lango sub regions namely Agago, Gulu, Kitgum, Pader, Lira, Oyam, Otuke, Dokolo and Amolatar districts. Agriculture and Finance Consultants (AFC), a German consulting firm is implementing the project on behalf of PRUDEV.

As part of the project implementation, AFC hired MED-6 Agrotech Ltd, an irrigation and agronomy firm, to design an irrigation training manual for Community Based Trainers (CBTs) in Acholi and Lango regions. The manual is intended to serve as a reference guide for CBTs while training farmer groups assigned to them. However, it can also be used by other technical staff with basic knowledge in the various irrigation systems. With the manual providing designs and costing of small-scale irrigation systems, it's a practical guide to promote and spread small scale irrigation to other interested individual farmers and farmer's groups that want to start irrigation as a way of adapting to climate change.

This manual consists of three modules, covering the most critical areas needed to ensure that the CBTs are well equipped with the relevant basic knowledge in the field of irrigation.

Module I cover integrated water resource management focusing on rainwater harvesting and related costs and irrigation water sources available in Acholi and Lango. It also covers water resources protection and puts emphasis on water extraction permits.

Module II covers irrigation techniques, operations and maintenance. This module explains the different and feasible irrigation techniques of drip, sprinkler and surface irrigation. It also elaborates how the watering-can technique is used efficiently. Furthermore, the module looks at how to operate and carryout maintenance for the different irrigation techniques. In maintenance, emphasis is put on how to carryout maintenance on the different energy sources of solar, manual and engine pumps.

Module III covers improved water efficiency. It explains irrigation scheduling and examines the water needs of each crop per day per region.

ACKNOWLEDGEMENT

With great pleasure, the MED-6 team would like to acknowledge the contribution of various members towards the design of this irrigation manual for use in Lango and Acholi regions.

To begin with, we appreciate the efforts of the AFC technical team, National Advisor irrigation and National Advisor water resource management for their close and timely advice on the content of the manual.

In a special way, we would also like to appreciate our colleagues in the irrigation engineering fraternity for the technical guidance offered throughout the design of the manual with special appreciation going to Eng. James Kabunga, Eng. David Ssentongo and Eng. Ruben Musanyana.

Finally, and importantly, we send our heart-felt appreciation to Marty Fokkink, the team leader AFC for his timely, detailed, unconditional and professional guidance throughout the design of the manual.

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LIST OF ABBREVIATIONS

AFC	Agriculture and Finance Consultants
CBT	Community Based Trainer
DWRM	Directorate of Water Resources Management
HDPE	High-Density polyethylene
MAAIF	Ministry of Agriculture Animal Industry and Fisheries
MWE	Ministry of Water and Environment
NEMA	National Environment Management Authority
PRUDEV	Promoting Rural Development
PVC	Polyvinyl Chloride

MODULE 1: INTEGRATED WATER RESOURCE MANAGEMENT

Rainwater harvesting and Irrigation water sources

1.1: Introduction to rainwater harvesting.

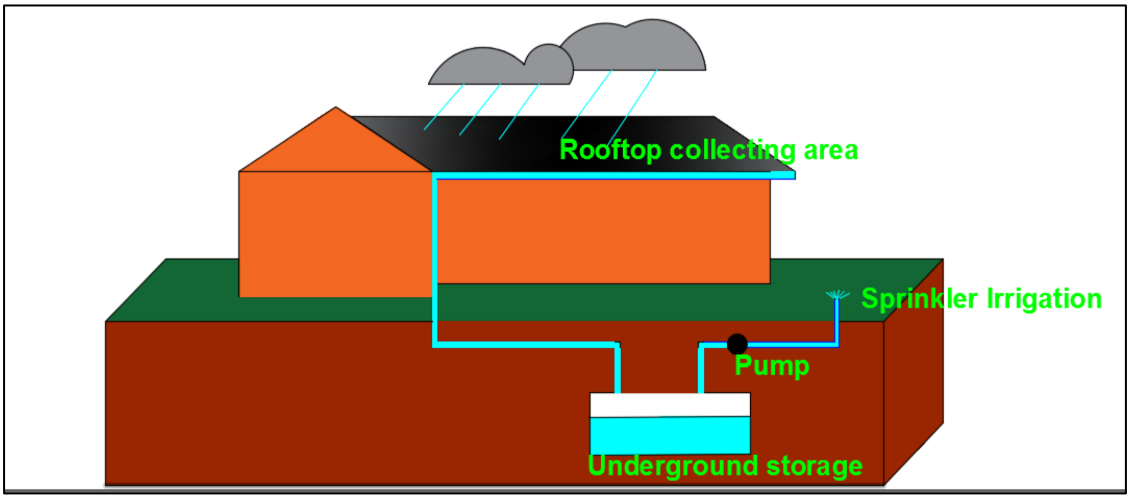
This is the process of collecting and storing of rainwater from rooftops or any surface as runoff to be used in times of water scarcity. Rainwater is harvested for different uses such as:

1. Irrigation
2. Domestic use
3. Construction
4. Commercial use

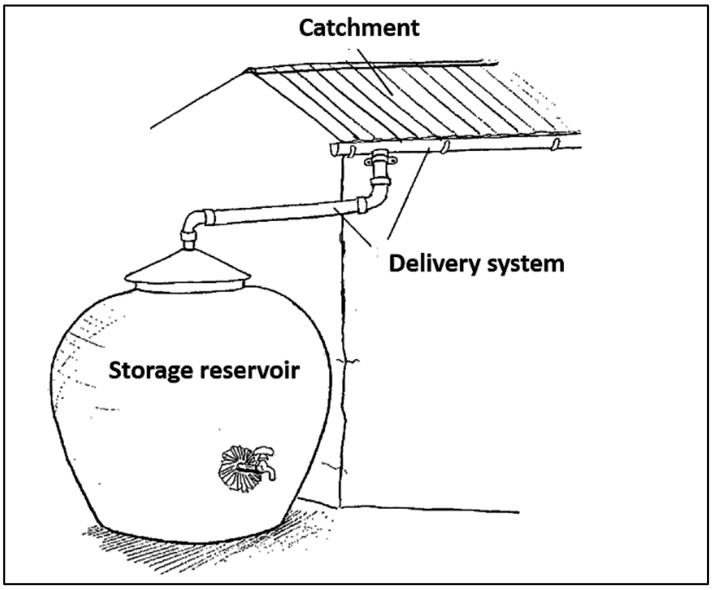
Rainwater is basically harvested in two common ways in rural areas. These are:

a) Rooftop rainwater harvesting

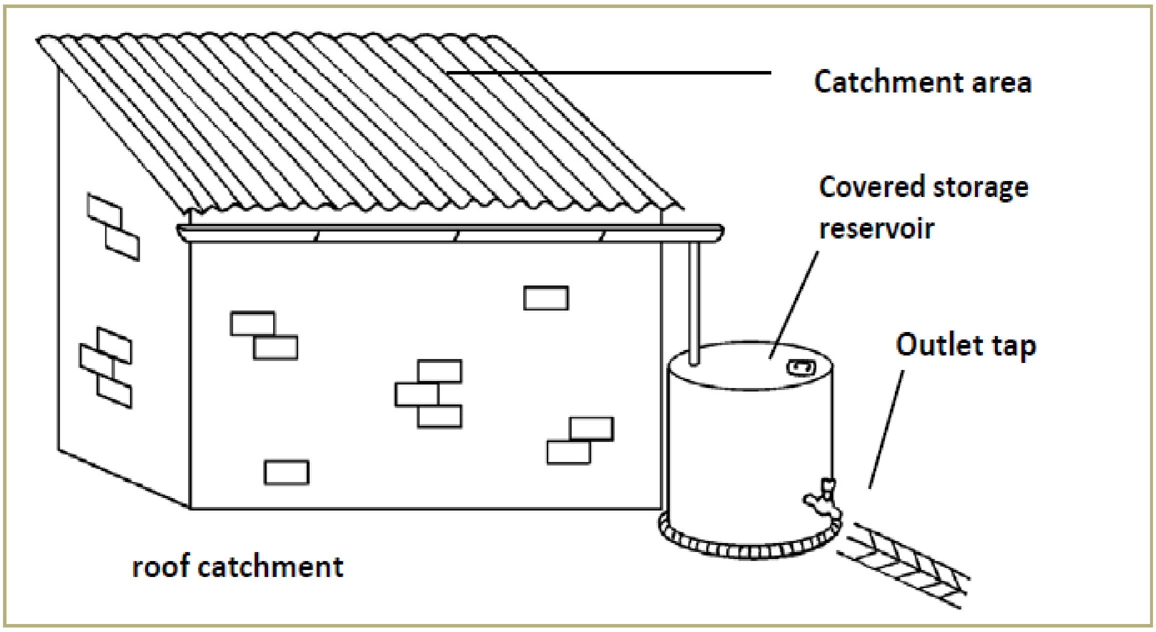
This type of harvesting depends on the type and size of the house roof /collecting area, the larger the roof area, the more rainwater is collected. Therefore, the size of the reservoir should also be large enough for the large volumes of water collected. Water is collected from the roof direct to a storage tank. The storage tanks are either over-head or underground tanks.



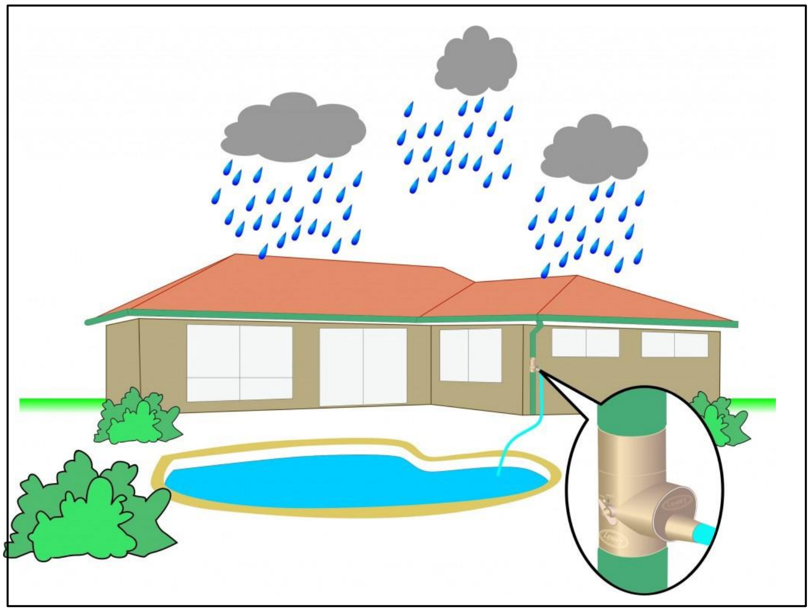
The roof as a collecting area for underground storage (source: www. med6agrotech.com)



Roof as collecting area (catchment area) for over-ground tank storage (source: sswm. infor/simple rain water harvesting)



Small rooftop collecting area, hence less water collected (source: www.quora.com/how-can - we- harvest- rain-water-in-low cost)



Large rooftop collecting area, hence more water collected (source: www.quora.com)

Basic materials used in rooftop rainwater harvesting

Particular	**Usage**
Gutter	Placed along the iron-sheet edges
Gutter clips	Holding the gutter, spaced at around 1m from each other.
Gutter outlet	Directs the water from gutters downwards.
Down pour pipe	Takes the water from the gutter to the pond.
Glue	It’s used for sealing pipes together.
Nails	Holds gutter clips firm.
Gutter endcaps	Closes the ends of the gutters to allow water go down.
Gutter elbow	Enable gutters to be connected at corners around the house.

b) Surface runoff rainwater harvesting

This type of rainwater harvesting has various surfaces as the collecting area, like roads, rocky hills and some playgrounds. Most times, it is directed through road channels and diverted into storage reservoirs.

The volume of water collected will also depend on the catchment area being used. Most times due to the problem of rubbish and soil erosion that comes with the running water, a wire mesh has to be put at the inlet and a small pond (soil trap) dug before the inlet to trap the soil carried in water. If the water is a lot and coming from far, two to three small ponds should be dug along the channel to the main reservoir to allow trapping of the soil coming with the runoff water.

small soil collecting pond.

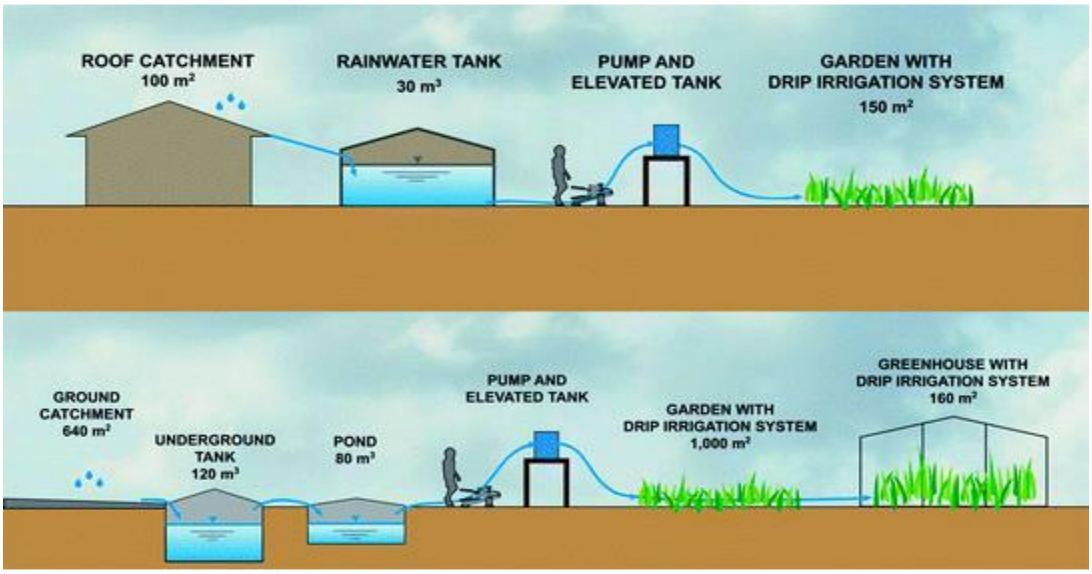
A rain runoff pond with a small soil collecting pond before the main water pond (source: www.med6agrotech.com)

Ground surface runoff harvesting, into a valley tank (source: www.med6agrotech.com)

1.2: Benefits of rainwater harvesting

- It's a free source of water
- Basic maintenance can be done easily by a trained person
- Reduces soil erosion from runoff
- Reduces poor drainage problems like flooding
- It's good for irrigation since does not contain harmful chemicals

- Collection systems are easy to setup and relocate when need arises
- They can be setup in any place that receives rain
- It's a good back up to other water sources
- Promotes conservation of other natural water sources like spring wells through reduced usage of those wells



Rainwater used directly on plants, no need to treat water (source: www.quora.com)

1.3: Determining the volume of rainfall water collected from a rooftop

Rainfall received in an area is recorded in millimeter (mm). To determine the volume of water that can be harvested from a given roof when it rains, one should multiply the rainfall amount (convert from mm to metre) by the area of the roof in squared meter.

Table showing average rainwater harvested on a large roof area in a month.

		ACHOLI SUB-REGION				
		Roof dimension				
	Rainfall (m)	L (m)	W (m)	A (m^2)	V_1 (m^3)	V_2 (Ls)
Low rainfall	**0.068**	**18**	**9**	**162**	**11.1**	**11,100**
High rainfall	**0.200**	**18**	**9**	**162**	**32.4**	**32,400**
		LANGO SUB-REGION				
		Roof dimension				
	Rainfall (m)	L (m)	W (m)	A (m^2)	V_1 (m^3)	V_2 (Ls)
Low rainfall	**0.098**	**18**	**9**	**162**	**15.9**	**15,900**
High rainfall	**0.170**	**18**	**9**	**162**	**27.5**	**27,500**

Legend:

L – rooftop length.
W – rooftop width.
A – rooftop area.
V_1 – harvested rainwater in cubic metre.
V_2 – harvested rainwater in litres.
Ls – litres.
m – metre.

From the table above, in Acholi sub-region, during months of low rainfall, this size of roof (162 m^2) can collect 11,100 liters of rainwater per month. During months of high rainfall, the same roof can collect 32,400 liters of rainwater per month.

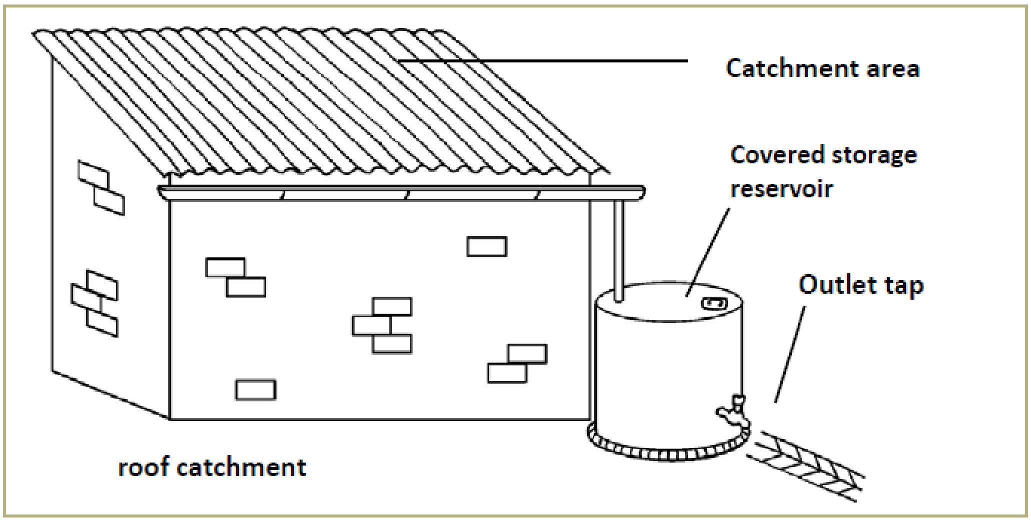
Table showing average rainwater harvested on a small roof area in a month.

		ACHOLI SUB-REGION				
		Roof dimension				
	Rainfall (m)	L (m)	W (m)	A (m^2)	V_1 (m^3)	V_2 (Ls)
Low rainfall	**0.068**	**12**	**3**	**36**	**2.5**	**2,500**
High rainfall	**0.200**	**12**	**3**	**36**	**7.2**	**7,200**
		LANGO SUB-REGION				
		Roof dimension				
	Rainfall (m)	L (m)	W (m)	A (m^2)	V_1 (m^3)	V_2 (Ls)
Low rainfall	**0.098**	**12**	**3**	**36**	**3.5**	**3,500**
High rainfall	**0.170**	**12**	**3**	**36**	**6.1**	**6,100**

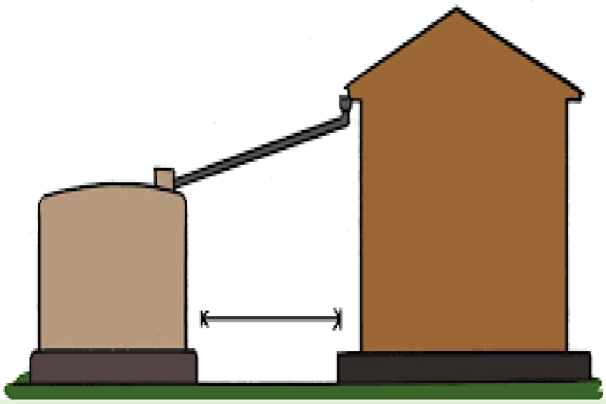
From the table above, in Lango sub-region, during months of low rainfall, small roof area (36 m^2) can collect 3,500 liters of rainwater per month. During months of high rainfall, the same roof area can collect 6,100 liters of rainwater per month.

Installation of rooftop harvesting system.

- Connect the gutters along the roof to collect all the water from the roof.
- The cutters are connected sloping towards where the water is to be delivered.



- Ensure the tank height is lower than the roof height to enable flow of water in to the tank by gravity.



- The recommended minimum distance between the tank and house should be 1.5m and maximum distance 3m to reduce pipe costs.
- From the gutters, connect drainage pipes to direct the water to the tank.

1.4: Surface runoff to underground reservoirs

This is where rainwater from roads, bare grounds and rocky surfaces is trapped and channeled to a specific underground storage structure. Runoff that occurs on surfaces before reaching a channel is also called overland flow. Under this technique, a normal reservoir is excavated in the earth. Both tarpaulin and dam-liner can be placed inside a pond whereas for a valley tank only a dam-liner can be placed. This will help to prevent water losses into the soil.

In this case the reservoirs are classified as:

1) Water ponds

2) Valley tanks

The water ponds and valley tanks differ mainly in size of the storage structure: water ponds are most times dug manually whereas a valley tank is made using an excavator. It stops or restricts the flow of water or underground streams. They have different designs depending on the water use.

Simple runoff water pond

However, in hilly areas with large rocky surface hills and valleys, valley dams can also be constructed across the flow of huge water from up the rocky hills. This will create storage for water in the dam which can be used for irrigation.

Picture showing a valley tank (source: www.med6agrotech.com)

1.5: Construction procedure of surface runoff water harvesting

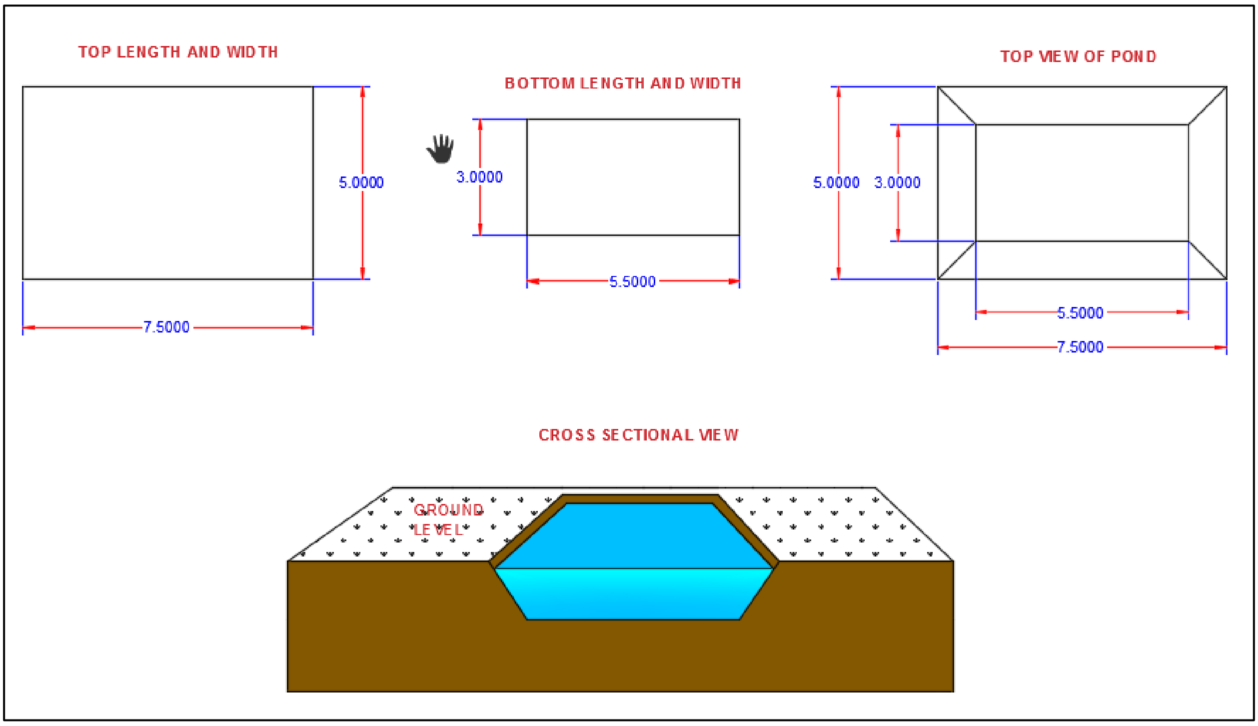
- Select a suitable site/ position for the reservoir.
- The reservoir should be positioned downstream or along the flow line of surface run-off.
- Considering water need, dimension the reservoir to be used, either a pond or valley tank to attain desired capacity.
- Considering the soil type and its permeability, choose which material to lay on the surface of the pond (dam liner) to prevent water loss into the soil. For example: tarpaulin and cementing the pond.
- Clear the passage for water into the reservoir.
- Ensure there is an overlap of the material used in the pond of about 50 cm beyond the outer perimeter.
- Dig a minimum of two small pits (sumps) along the water channel. These will help trap the soil that is carried along the running water before entering the main water ponds.

Dimensions of simple water harvesting ponds

These ponds are constructed in a shape of a trough to ensure the walls don't collapse. Their sizes will depend on the water need, affordability and availability of material to be used.

Volume of pond (Ltr)	Bottom length (m)	Bottom width (m)	Pond depth (m)	Top length (m)	Top width (m)
40,000	5.5	3.0	1.5	7.5	5.0
21,000	4.0	2.0	1.5	6.0	4.0
11,000	4.0	2.0	1.0	5.0	3.0

Technical design of a pond of 40,000 litre capacity.



Material requirement and estimated cost for ponds

	MASONRY POND								
	40,000 litres			**21,000 litres**			**11,000 litres**		
Materials	**unit**	**quantity**	**cost**	**Unit**	**quantity**	**cost**	**unit**	**quantity**	**cost**
Chicken wire mesh	roll	1	120,00 0	Roll	1.25	90,000	roll	1	60,000
Nails	kg	2	14,000	Kg	2	14,000	kg	2	14,000
Sand	trip	1	80,000	Trip	1	80,000	trip	1	80,000
Cement	bag	5	150,00	Bag	4	120,00	bag	3	90,000

			0			0			
Bricks	trip	0.5	125,000	Pc	350	52,000	pc	250	37,500
Waterproof cement	tin	6	30,000	Tin	4	20,000	tin	3	15,000
Binding wire	kg	5	25,000	Kg	3	15,000	kg	3	15,000
TOTAL			**944,000**			**721,000**			**561,000**
	TARPAULIN POND								
	40,000 litres			**21,000 litres**			**11,000 litres**		
Materials	**unit**	**quantity**	**cost**	**Unit**	**quantity**	**cost**	**unit**	**quantity**	**cost**
Tarpaulin	sqm	55	260,000	Sqm	35	170000	sqm	23	110,000
Sand	trip	1	80,000	Trip	1	80,000	trip	1	80,000
Cement	bag	3	90,000	Bag	2	60,000	bag	2	60,000
Bricks	trip	0.5	125,000	Pc	350	52,000	pc	250	37,500
TOTAL			**555,000**			**362,000**			**287,000**

When constructing a reservoir with dam-liner as the water proof material, the square meters of dam-liner needed for a given dam, for example 40,000 litres capacity will be 55 sqm as above for tarpaulin. Bricks, cement and sand will also be the other material one will use when constructing using dam-liner. The costs of a square metre of dam-liner range between UGX 16,000 to 27,000 depending on the thickness of the dam-liner.

The cost of using tarpaulin is less by almost half of cost of masonry, however the biggest disadvantage of tarpaulin is the short life span and easily damaged by foreign bodies when dropped in the pond.

Small pit constructed before main reservoir

1.6: Introduction to irrigation water sources

Irrigation water sources refer to the various natural and man-made sources where one can get water in quantities and quality suitable for irrigation. Some of the water sources like rivers may require construction of valley dams to make the water readily available and easy to use for irrigation. The irrigation water sources include:

a) Streams

A stream is a small and shallow naturally flowing waterbody. Stream flow is generally the most common source of water for irrigation. Besides being common in rural areas, some streams are seasonal and have small volumes of water.

A flowing stream of water in Northern Uganda. (source: www.med6agrotech.com))

b) Rivers

A river is a large and deep naturally flowing waterbody that follows a well-defined, permanent path, usually within a valley. According to the National Environment Regulations of Uganda, for non-scheduled rivers there should be no development within 30m from the riverbank for small rivers and 100m for big rivers. Rivers can be reliable sources of irrigation water.

River Achwa in Northern Uganda.

River Pager Kitgum, Uganda. (source: www.med6agrotech.com)

c) Over-head reservoir

An over-head reservoir is an artificial lake. It can be formed by building a dam across a valley. The structure simply provides storage to water above the normal ground level. The dam constructed creates a reservoir for the water above the ground which is then used for irrigation.

Reservoir formed by constructing a dam across a gully or small valley that enters the stream

If the dam cannot create a reservoir large enough to contain the required irrigation water, additional water can be pumped from the stream into another reservoir during the rainy season when flow is plentiful, thus supplying irrigation water later during the peak of the dry season, as shown below.

Over-head water tank reservoir. (source: www.med6agrotech.com)

Over-head water tank showing water flowing in. (source: www.med6agrotech.com)

d) Lake

Lakes are natural depressions of the land, which are filled up with water. Lakes are supplied with water by rainfall that falls directly on the surface of the lake, by water run-off from the adjacent land and small streams, or by groundwater that seeps through the soil to the lowest point which is the lake. In Uganda, the environmental regulations state that there should be no development or works within 200m of the edges of lakes (Kyoga and Kwania, amongst others) without a permit. For non-scheduled lakes, there should be no development within 100m. From the National Environment Act Cap 153 under the National Environment (Wetlands, Riverbanks and Lake Shore Management) Regulations, 2000; water bodies are classified and listed under categories called schedules. Lakes fall under schedule 7 however not all lakes that are known are listed mostly depending on the size, so those not listed are non-scheduled.

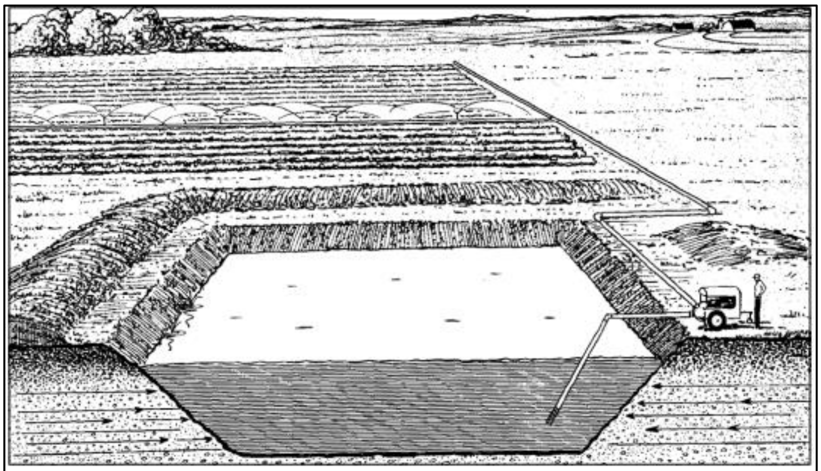
Lake Kyoga in Northern Uganda. (source: www.med6.com)

Lake Kwania in northern Uganda. (source: Pinterest)

e) Ponds

A pond is an area filled with water, either natural or artificial, that is smaller than a lake. Ponds are frequently man-made, where a storage area is artificially excavated in the ground and the depths and diameter can be varied to attain the target volume.

Water pond with dam-liner.



Dugout pond

f) Wells

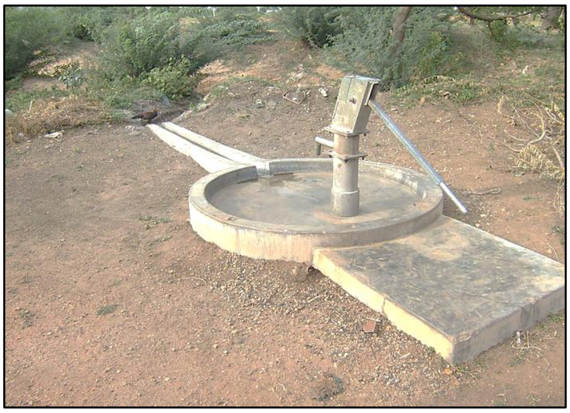
A well consists of a hole, with or without a supporting casing, extending down into where underground water is found. Wells are dug, driven or drilled depending on the soils, rock and the depth at which water is found. Wells are mainly classified as shallow wells and deep wells.

Shallow wells range from 0 to 30m depth and deep wells range from 30m to 100m plus. Most times shallow wells are hand dug without casing while deep wells are drilled with machines and borehole casing installed.

Shallow wells are locally sited, through looking at the closeness of the water table and looking at some local tree species that flourish near water. Deep wells are sited with electric hydrological gadgets.

Shallow well

Deep well



Hand Borehole

Water resources protection.

1.7: Introduction

Water resource protection in Uganda refers to the process through which the underground and surface water sources are safely guarded to ensure sustainable quality and quantity of the water source. This is done by the Ministry of Water and Environment (MWE) and its partner agencies like National Environment Management Authority (NEMA) and District water and environment offices. The MWE together with its support agencies developed a water source protection guideline policy in 2013 which is strictly used to ensure that water sources are not depleted and their quality is also maintained.

MWE and NEMA implements the water sources protection policies at the national and regional level. At district level, the water source protection policy is implemented by the district water office and the district environment office.

We shall look at the regulations governing the water source catchment areas that feed the ground and surface water sources. We shall also look at when one requires water abstraction permits. Under this section we shall also look at the main causes of pollution to the water source.

1.8: Environmental regulations.

Wetlands

Wetlands are areas permanently or seasonally flooded by water where plants and animals have become adapted. They include swamps, areas of marsh and banks of rivers. Swamps act as filtering units for surface runoff getting into the lakes. Within the MWE, wetlands are managed by the Directorate of Environmental Affairs with a Regional Wetland officer. At local government level within the northern region, some districts have come-up with ordinances that protect wetlands and restrict communities from farming in them. At district level, policies are implemented and monitored by the district water and environment office. Each district has a district environment committee and local environment committee at all sub-county levels.

When a user abstracts water from a water source using a motorized energy source (solar power pump, fuel pump), a water abstraction permit is needed. This document is issued by the Directorate of Water Resources Management (DWRM) at MWE giving permission to a person to use a given water source for a specified use. However, the following traditional uses of wetland resources shall not be subject to the application of water permit:

a) harvesting of papyrus, medicinal plants, trees and reeds.
b) Fishing using traps, spears and baskets.
c) Collection of water for domestic use.

Riverbanks

Riverbank is the land along the river all through to where the river pours its water. The riverbank is estimated to cover all the land 100m from where the river width stops. Every land owner or user in whose land a river bank is situated shall have a duty to prevent and repair damaged river banks through the following or any other measures:

a) agro-forestry
b) mulching
c) ridging (creating bands to control erosion)
d) grassing
e) control of livestock grazing
f) terracing.

- The major rivers shall have a protection zone of one hundred meters (100m) from the highest watermark of the river (like river Aswa).
- Minor rivers shall have a protected zone of thirty meters (30m) from highest watermark of the river.
- No activity shall be allowed within protected zones without the written authority from the DWRM of MWE or from the district water officer or district environment officer.

Lakeshore

Lakeshore means the land not more than 100 metres adjacent to or bordering a lake. Every landowner or user in whose land a lakeshore is situated shall have a duty to prevent and repair degraded lakeshores through any of the following:

a) agro-forestry
b) mulching
c) grassing
d) control of livestock grazing
e) terracing.

- All shores of big lakes (major lakes) shall have a protected zone of two hundred meters (200m) measured from the low water mark.
- All shores of small lakes (minor lakes) shall have a protected zone of one hundred meters (100m) from the low water mark.
- No activity shall be permitted within protected zones without the written authority from the district environment officer. A farmer should always approach the district environment officer with the written protected land usage plan.

The local governments have strongly condemned farmers from carrying out farming in wetland and lake shores. At district levels, ordinances have been formed to protect the wetlands and most farmers have been encouraged to grow trees. Most districts as a way of protecting the environment have seasonally given many farmers free tree seedlings to plant at sub-county level to help protect the environment.

1.9: Water abstraction permit application procedure in Uganda

In Uganda, the Directorate of Water Resources Management under MWE is the body responsible of issuing water abstraction permits to private companies, individuals and NGOs that intend to draw water mainly from lakes and rivers. This is required in cases when a farmer or individual intends to use a motorised of solar powered pump to draw water for use. For irrigation purposes, there are two categories of water abstraction permits from which a farmer can apply, either for only one or both, depending on the nature of water source(s). During the process of applying, the farmer becomes the applicant. The two categories include:

1. **Surface water permit.**

   This is given to a farmer getting water from a surface water body for example lakes, rivers, streams etc.

Lake.

2. **Ground water permit.**

   This is for water found underground for example wells.

Ground water deep well

When going to apply for a permit, a farmer is required to know the address of the location of the water source, list and quantify all the likely water demands during peak operations. They are also required to specify the energy source that the system will use and the amount of water it draws in an hour. This information is required to be entered into the application form.

Water abstraction permit application procedure

1. Pick the water permit abstraction application form from the district environmental office or Ministry of Water and Environment (MWE) regional office in Lira.
2. The permit application form is filled and three copies of the form are made for submission in triplicate.
3. The applicant is issued with a bank payment form. A given fee is assigned depending on water source and planned usage, the money is paid in the bank. The farmer must have a TIN (tax identification number) or at least specify the name of the district, county, sub-county and village.
4. After payment in the bank, the applicant can submit receipts of payment and the permit application form.
5. The applicant can then keep in close communication with the authority or district officer in-charge of processing the water abstraction permit.

1.10: Water pollution

Water pollution is the contamination of water bodies (like oceans, seas, lakes, rivers, aquifers, and groundwater) usually caused by human activities. Water pollution is any change in the physical, chemical or biological properties of water that will have harmful impact on any living organism in water and those that use that water.

Causes of water pollution

Here we are going to look at things that contaminate the water leading to the state as defined above. The major contaminants include:

1. **Trash or garbage**

   This includes paper, plastic, or food waste discarded by people on the ground, along with accidental or intentional dumping of rubbish, that are washed by rainfall into storm drains and eventually discharged into surface waters.

Trash and garbage disposed in a water stream. (source: www.med6agrotech.com)

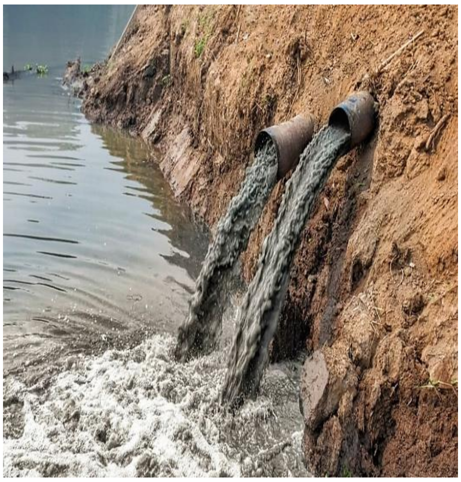
2. **Animal waste**

This includes faeces (direct or in sewerage form), animal excreta, bird droppings, etc. These elements contain numerous infectious agents (bacteria, viruses, and parasites) that contaminate the water.

Water contamination by animals and humans and its effects downstream.

3. **Chemical substances**

These chemicals can be either organic - pesticides, plastic, oil, detergents, etc.



4. **Sediments in the soil (silt) following soil erosion, construction activities, etc.**

When soil erosion occurs and water is drained in lakes, rivers, dam etc. This run-off water carries along soil sediments which it deposits as silt in the lakes, rivers and dams. As a result, the silt deposited displaces water in the dams, causes it to over-flow hence causing a lot of flooding in the surrounding area.

Mitigation of water pollution

1. Households or businesses not served by a municipal treatment plant may have an individual septic tank, which pre-treats the wastewater on site and infiltrates it into the soil.
2. Farmers may utilize erosion controls to reduce runoff flows and retain soil on their fields. Common techniques include contour ploughing, crop mulching, crop rotation or planting perennial crops.
3. Farmers can promote use of organic fertilizers and less of the synthetic fertilizer which normally has long term side effects on the quality of ground water when it gets deep in the ground water. More use of organic fertilizer will reduce the potential for nutrient pollution.
4. To minimize pesticide impacts, farmers may use Integrated Pest Management (IPM) techniques (which can include biological pest control) to maintain control over pests, reduce reliance on chemical pesticides, and protect water quality.
5. Sediment from construction sites is managed by installation of erosion controls, such as mulching, and sediment controls, such as sediment basins.
6. Proper waste management, disposal of wastes should be in right places that do not allow the waste to get into the water system.

Sediment and Erosion control measures.

1.11: Soil erosion

In agriculture, soil erosion refers to the washing away of a field's topsoil by running water and wind due to lack of soil cover like crops, grass, fallen plant leaves etc.

1.12: Major agents of soil erosion

Soil erosion by wind

Very fine soil particles are carried high into the air by the wind and transported great distances because of lack of soil cover. Fine-to-medium size soil particles are lifted into the air, translocated and deposited to the soil surface. Larger-sized soil particles that are too large to be lifted off the ground are moved by the wind and roll along the soil surface. The constant scratching of large particles with the ground results from windblown particles breaks down stable surface aggregates and further increases the soil erosion.

Wind causing soil erosion in a dry area with sandy soil.

Soil erosion by water

This is the washing away of topsoil by running water. Most times this is seen a lot when the ground is not covered. It is also very high along bare steep slopes of hills and sloping land. The process may be natural or accelerated by human activity. The common forms are shown below and the main causes of soil erosion are also shown and explained.

1.13: Common forms of soil erosion

Sheet erosion

This is the uniform removal of soil from the ground surface.

Rill erosion

This occurs when runoff water forms small channels as it concentrates down a slope. The channels can be up to 0.3m (1 foot) deep.

Gully erosion

This occurs when concentrated runoff cuts deep and wide channels into the soil. These channels are normally more than 0.3m (1foot) deep.

1.14: Factors that cause soil erosion

Heavy rainfall

The impact of raindrops on the soil surface can break down big soils and scatters the soil particles far apart. Lighter soil materials such as very fine sand, silt, clay and organic matter are easily removed by the raindrop splash and runoff water; greater raindrop energy or runoff amounts are required to move larger sand and gravel particles.

Runoff

Surface water runoff occurs whenever there is excess water on a slope that cannot be absorbed into the soil or is trapped on the surface as a result of reduced infiltration.

Weak soil type

Sand, sandy loam and loam-textured soils tend to be less erodible than silt, very fine sand and certain clay-textured soils. Generally, soils with faster infiltration rates, higher levels of organic matter and improved soil structure have a greater resistance to erosion.

Poor tillage and cropping practices

Reduced soil organic matter levels cause poor soil structure, or result in soil compaction, contribute to increases in soil erosion. As an example, compacted surface soils can decrease infiltration and thus increase runoff.

Steep and long slope

The steeper and longer the slope of a field, the higher the risk for erosion. Soil erosion is worse for higher slope lengths due to the increased velocity of water, which causes more erosion damage.

Lack of cropping and vegetation cover

The potential for soil erosion increases if the soil has no or very little vegetative cover of plants and/or crop residues. Plant and residue cover protect the soil from raindrop impact and splash, tends to slow down the movement of runoff water and allows excess surface water to infiltrate.

Poor farming practices

The depth, direction and timing of ploughing affects the degree of soil erosion. Also, the type of equipment used, and the number of times used on the soil affects the soil's ability to resist soil erosion.

1.15: Effects of soil erosion

- Reduced crop yields because of loss of fertile soil.
- Reduced ability of the soil to store water and nutrients.
- Loss of newly planted crops as a result of soil being washed away around them.
- Deposits of silt in low-lying areas which leads to burying of plants and as well water life. It also sends soil-laden water downstream, which can create heavy layers of sediment that prevent streams and rivers from flowing smoothly and can eventually lead to flooding.
- Siltation of watercourses and water storages
- Reduction in water quality of streams, rivers and some lakes.

1.16: Prevention of soil erosion

The most effective known method for erosion prevention is to increase vegetative cover on the land, which helps prevent both wind and water erosion. There is a higher potential for erosion when producing crops with less vegetative cover.

Terracing

This is an extremely effective mean of erosion control, which has been practiced for thousands of years by people all over the world, in hilly or mountainous areas.

Windbreaks

These are rows of trees and shrubs that are planted along the edges of agricultural fields, to shield the fields against winds. In addition to significantly reducing wind erosion, windbreaks provide many other benefits such as improved microclimates for crops.

Traditional planting methods

Mixed-cropping (instead of mono-cropping) and crop rotation have also been shown to significantly reduce erosion rates.

Mixed cropping, Sunflower and cassava, maize and beans

Mulching

Mulching plays a role in the mitigation of erosion because it reduces the impact of raindrops breaking up the soil particles.

Modern farming practice of mulching

MODULE 2: IRRIGATION TECHNIQUES, OPERATIONS AND MAINTENANCE

Irrigation techniques (watering cans, surface irrigation, sprinkler, and drip irrigation)

2.1: Introduction to Irrigation techniques

Irrigation refers to the controlled application of water to crops, at the right time, in the right quantity, quality and in a given interval and with a specified rate. The most common irrigation techniques that are practiced in Uganda by Micro and small-scale irrigation farmers include:

- Drip irrigation.
- Surface irrigation.
- Over-head irrigation.
- Use of a watering can.

Although the use of watering cans is the most common and rudimentary method used as an affordable way of watering small vegetable gardens by rural farmers, technically it is not considered an irrigation technique.

Surface irrigation

Drip irrigation

Over-head irrigation

Watering can method

2.2: Drip irrigation system.

Drip irrigation is an irrigation technique which emits small drops of water directly to the root zone. It is classified as:

- On-line drip irrigation system.
- In-line drip irrigation system.

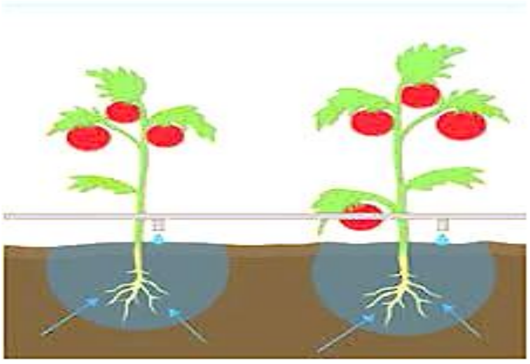
On-line drip irrigation where button drippers are placed on the lateral lines/drip pipe. This is common for wide plants like fruits trees, coffee and bananas. The spacing depends on the plants spacing.

In-line drip irrigation where the dripline/drip pipe is supplied with pre-punched holes at a given spacing. This is common for horticultural farming with crop spacing ranging from 20cm, 30cm, 45cm, 50cm, 60cm and 100cm.

Table showing the row and crop spacing of selected crops.

CROP	**ROW X CROP SPACING**
Cabbage	60cm x 60cm
Tomato	100cm x 40cm determinate 75cm x 50cm indeterminate
Green Pepper	100cm x 40cm
Onions	30cm x 10cm
Eggplants	100cm x 50cm

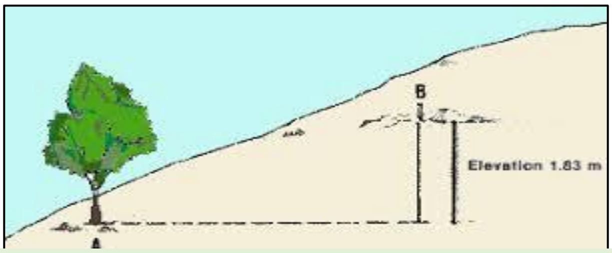
Drip irrigation is the most water efficient way of irrigation, with some 80 to 90% of efficient water use. The principle of the system remains the same, irrespective of the size of the land being irrigated. The laterals/drip pipes receive water from sub-main lines and sometimes directly from the main line depending on the acreage in the system design.



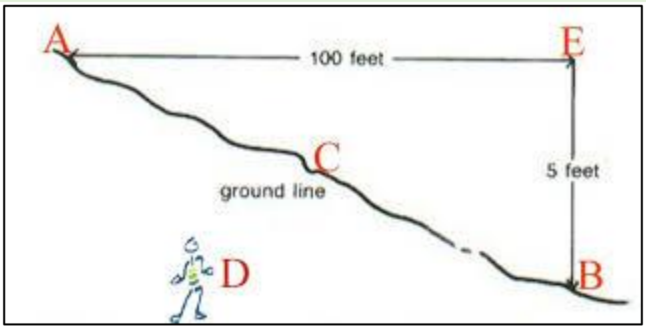
On-line drip *In-line drip*

On-line and In-line drip system layout

- Establish the size of the land in acreages using a measuring tape, simple smartphone or by simply counting walk yards around the land boundaries. This enables easy design and establishment of material required.
- Establish the main direction of the slope of the garden.



- Establish the highest point and lowest point on the garden.



A-Highest point, B-lowest point.

A-Highest point, B-lowest point.

- Select a position for the tank at the highest point on the garden.
- Measure the distance of the tank position from the water source.
- The driplines are laid across the slope.
- The sub-main lines are laid down the slope.

Source: *www.med6agrotech.com*

- The main line can either be across the slope or along the slope depending on the system design.

Mode of operation of drip irrigation system

- Fill the tank with water to full capacity.
- Open the main control valve/tap next to the filter.

Source: www.med6agrotech.com

- Open the sub plot valve/tap to irrigate at a given time.

Source: www.med6agrotech.com

- Repeat the same for other plots in case the field has many plots. Depending on the design capacity of the tank more than one tank can be opened at a time.

Drip irrigation advantages

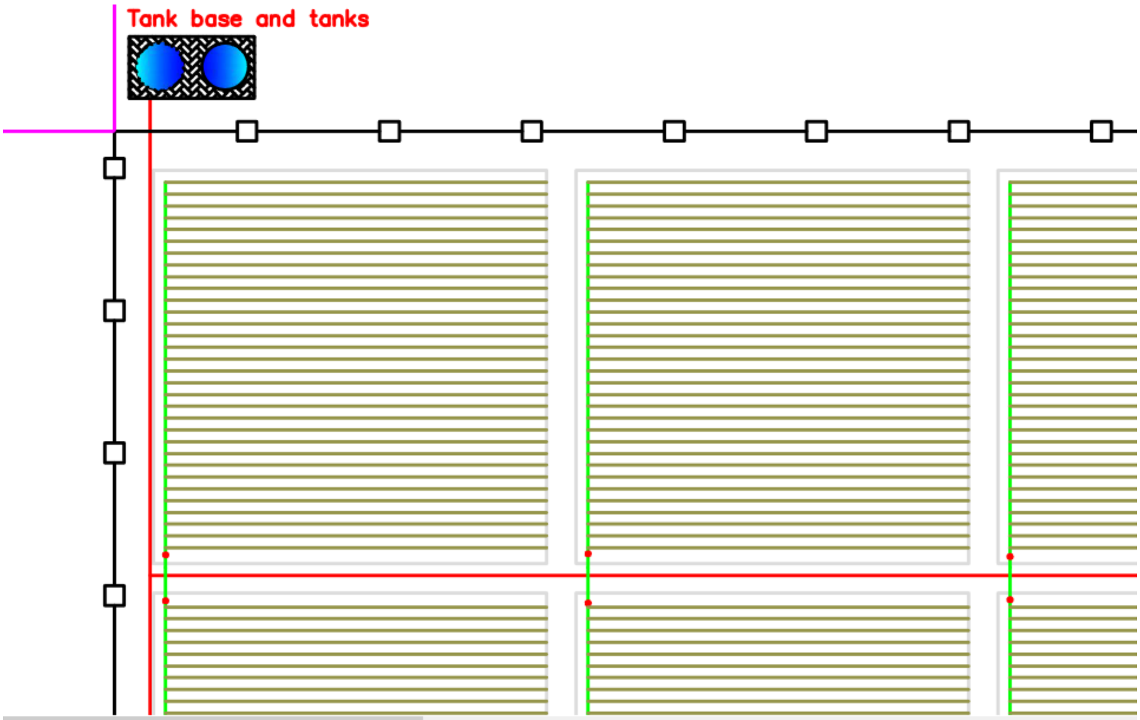
- Reduced water wastage. This is because water is only applied at crop root-zone.
- Prevent the spread of fungal diseases. The plant leaves don't have contact with water hence no moist conditions which favors fungal infections.

No contact with plant leaves

- Prevents soil erosion. This is because it drips slowly at a controlled rate.
- Reduces weeds. This is due to water being applied just within the plant root-zone.

Drip irrigation disadvantages

- Clogging of lateral holes/emitters.
- Requires serious installation planning.
- Requires frequent maintenance.



Drip system layout

Legend

	Main-line
	Submain-line
	Lateral line/ Drip line
	Submain control valve

2.3: Surface irrigation system

Surface irrigation is where water is applied and distributed over the soil surface by gravity. It is by far the most common form of irrigation that has been practiced for thousands of years. Surface irrigation is classified as: 1) Flood irrigation, 2) Furrow irrigation. Most common of the two types is the fact that both require large volumes of water. To date, this type of irrigation is still being practiced by large farming communities near lake shores and riverbanks.

Flood irrigation

Furrow irrigation

Principles of surface irrigation layout

- The water is distributed to the open fields through gravity flow.
- Controlled surface flooding is done for flood irrigation.
- Channels are designed and used to distribute water in furrow irrigation.
- Land levelling is also done.

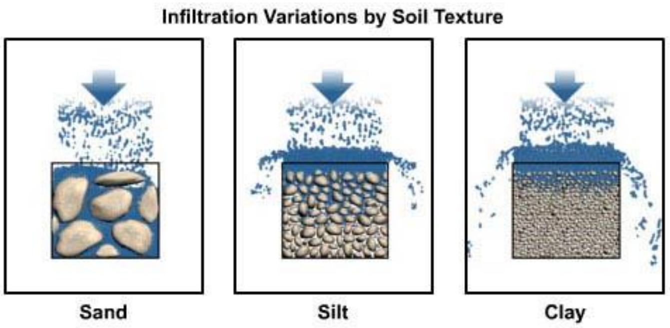
Source: www.med6agrotech.com

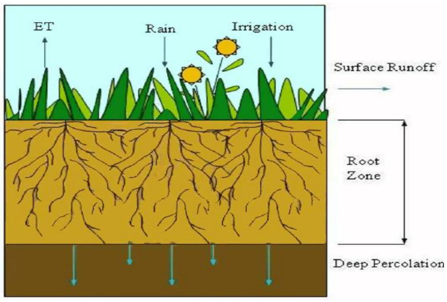
Advantages of surface irrigation

- Management is quite easy
- You do not need high financial support
- Good for short time water supplies
- No energy cost needed
- Works well with low infiltration rate soil

Disadvantages of surface irrigation.

- Levelling land requires high accuracy.
- It's not applicable to soils with high infiltration rates (sandy soils).





- Sometimes limited land gets more water than required.
- Not suitable for big fields.

2.4: Over-head irrigation (sprinkler irrigation)

This is the application of water to crops in a manner similar to natural rainfall. This type of irrigation operates with high pressures but of different pressure requirements. In rare cases these sprinklers, mainly mini sprinklers, are also designed and operated on gravity flow systems. This is however possible and common in hilly areas where the water source is on top of a hill and the head difference between the field and the water source is significant say about 2 bars (20m elevation) and above. The most practiced and common types of sprinkler irrigation, which are classified based on pressure required, rate of discharge and throw radius, are:

1) Micro sprinklers
2) Mini sprinklers
3) Rain-gun sprinklers

Advantages of sprinkler irrigation

- Suitable for all types of field condition except heavy clay soils.
- Uniform distribution of water.
- Less land loss provides more land for cultivation.
- Suitable for high cover crops like fodders.

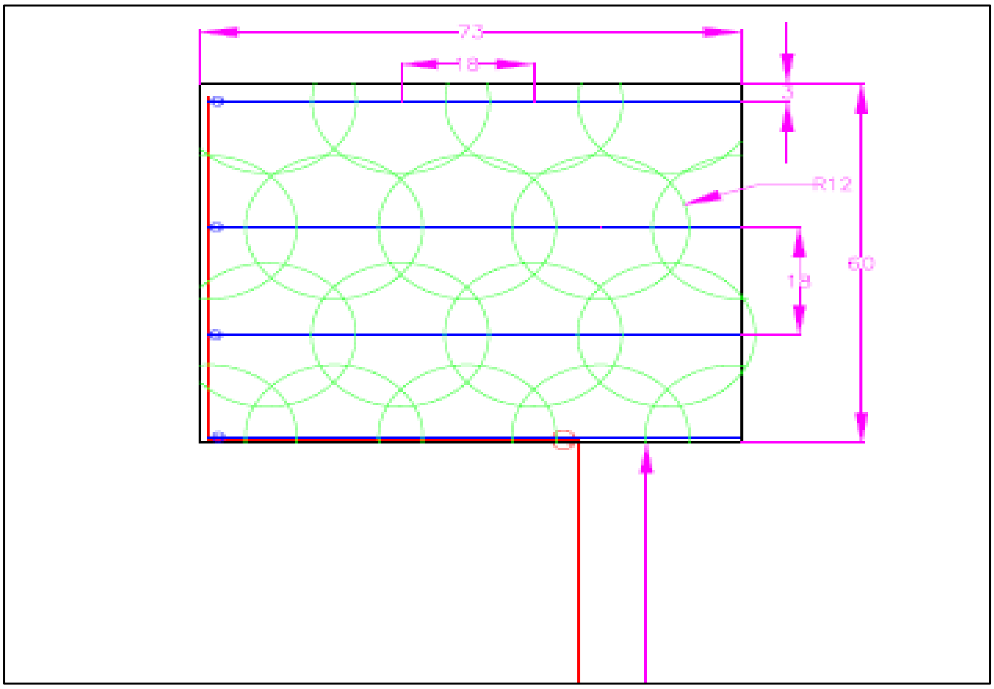
Disadvantages of sprinkler irrigation

- High operating costs
- Water wastage in windy conditions.
- Stable and large volumes of water needed.
- Promotes weed growth since water is scattered everywhere.

Source: www.med6agrotech.com

Principles of sprinkler system lay-out

- Measure and prepare the area of the sprinkler.
- Determine your water supply.
- Break-up the property into irrigation plots with separate valves.
- Pick your sprinkler heads.
- Design your sprinkler layouts.
- Measure and layout piping.
- Finishing up your plan.



Sprinkler system layout, Red line indicates the main-line, Blue line indicates the sub-main lines on which the sprinkler risers are set. The green circles and semi-circles indicate the throw radius of each sprinkler. Sprinklers are set in the middle of each circle and semi-circle.

Mode of operation of sprinkler irrigation

- Ensure the main line is connected to the pumping unit.
- Connect each irrigation plot to the main line with a control valve.
- Open each irrigation plot control valve at a given time to operate the sprinklers within the plot.
- Open the control valves for a given time for each irrigation plot.

This is the most common concept in both the rural and urban setting as an understanding of irrigation. The watering can method requires uniform manual application which is only achieved through the person applying the water moving uniformly across the place being watered. The amount applied to a given area is determined from the volume of the can being used and the uniformity of distribution to the area covered.

The use of the watering can method is preferably advisable - under ridge method of planting to achieve uniformity in watering with ease.

Watering tomatoes in Aromo, Lira, Uganda (Source: www.med6agrotech.com)

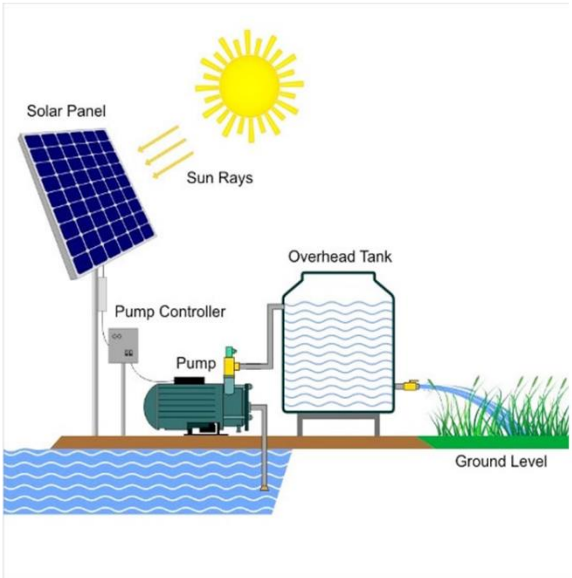
Maintenance and small reparation of energy sources (solar power pumps, engine pumps, and treadle pumps)

2.6: Introduction to maintenance and small reparation of energy sources

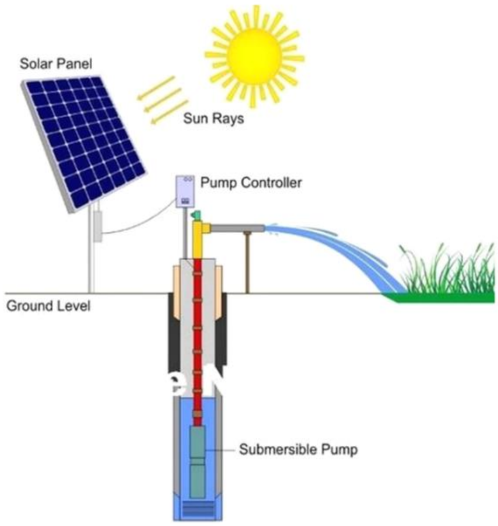
Maintenance and repair are important since it makes the pumps last longer. Maintenance and reparation of the energy source is important or even more important for sustainability to make the system profitable and also offer value for money invested. Maintenance and small reparation through timely component replacements or even repairs of components, makes farming consistent and sustainable. One should be knowledgeable about what to change/replace, how to change/replace and what to use to change/replace. Where he/ she cannot, a technical person should be hired.

2.

A solar pump operates when there is sunshine and most times for 8 hours a day. The solar pumps are either *submersible* or *surface* pumps.



Surface pump operating



Submersible pump operating

Submersible pump

Surface pump

Submersible pumps work in both shallow-wells and deep-wells; they are commonly used in boreholes to replace manual borehole hand pumps. Surface pumps are commonly used in open surface water sources like lakes and rivers where the water table is not below 6 meters. They can also be used in hand dug shallow wells with a water table not below 6 meters.

It's important to be able to tell the pump has stopped working and realize that the panels have a problem.

Table indicating potential problems, symptoms and causes of solar powered pumps

Component	**Problems**	**Symptoms**	**Causes**
Solar panel & connection	• Performance decline. • Low water pressure.	• Reduced flow rate. • Burnt wires.	• Loose wiring. • Dirty or damaged panels. • System over-heating.
Piping	• Low water volume.	• Water leakages. • Reduced flow rate.	• Loose connection.
Submersible pump	• Pump not working.	• Pump will not start.	• Blown fuses. • Fried motor.
Surface pump	• Pump not working. • No suction effect.	• Pump will not start. • Water not moving.	• Blown fuses. • Fried motor. • Loose suction.

Table indicating basic repairs or replacements to be done for solar powered pumps

Component	Repair	Replace	Reason
Solar panels		Yes	Damaged panels should all be replaced for efficiency. Cleaning can be done to those with dirt.
Wiring		Yes	Worn out wires should be replaced.
Piping	Yes		The broken section can be repaired depending on the type of pipe.
Pumps	Yes	Yes	They can be repaired by a technician depending on the damage or replaced.

Surface solar pump with garden hose pipe

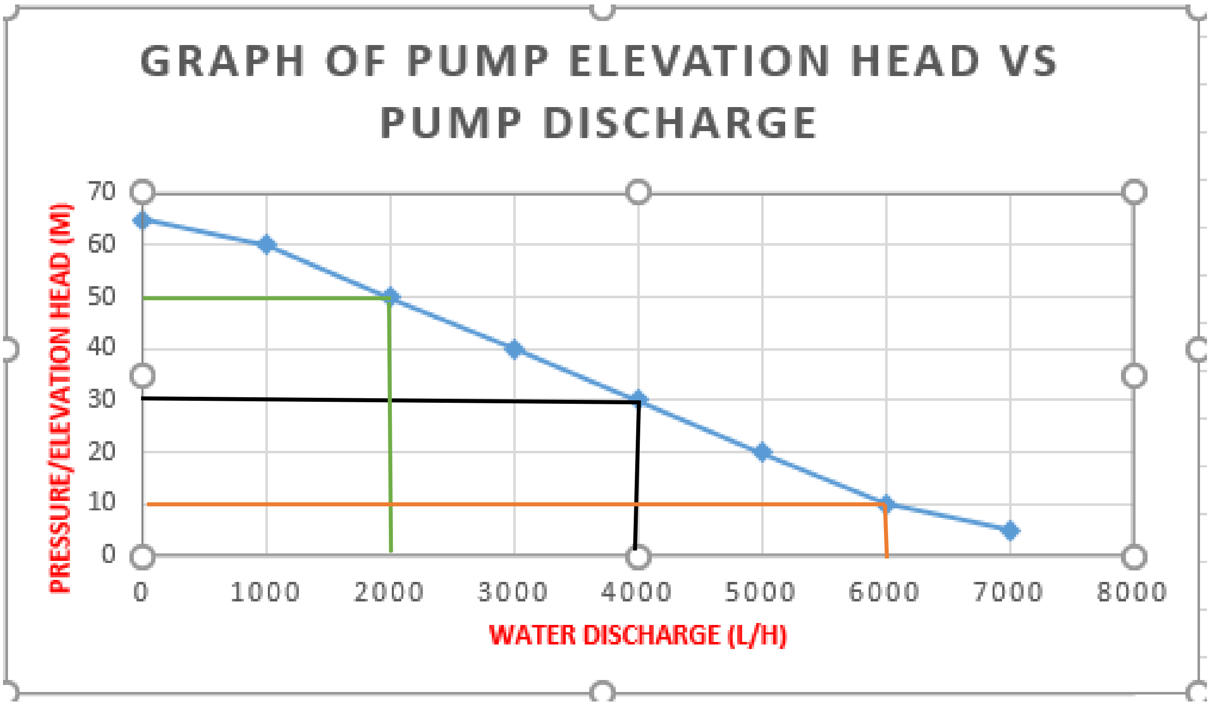
Submersible pump with micro sprinklers

Consider the following to be done on a regular basis:

- Proper cleaning of the panels with clean water and soap to get rid of dust.
- Check electrical wires to ensure no wire burnout
- Timely checks on the valves to ensure no leakages
- Take water meter readings for solar pump connections that might have
- Keep check on changes of the sound produced by the pump while operating

2.8: Specifications of solar pumping system

Relationship between pump pressure and pump discharge

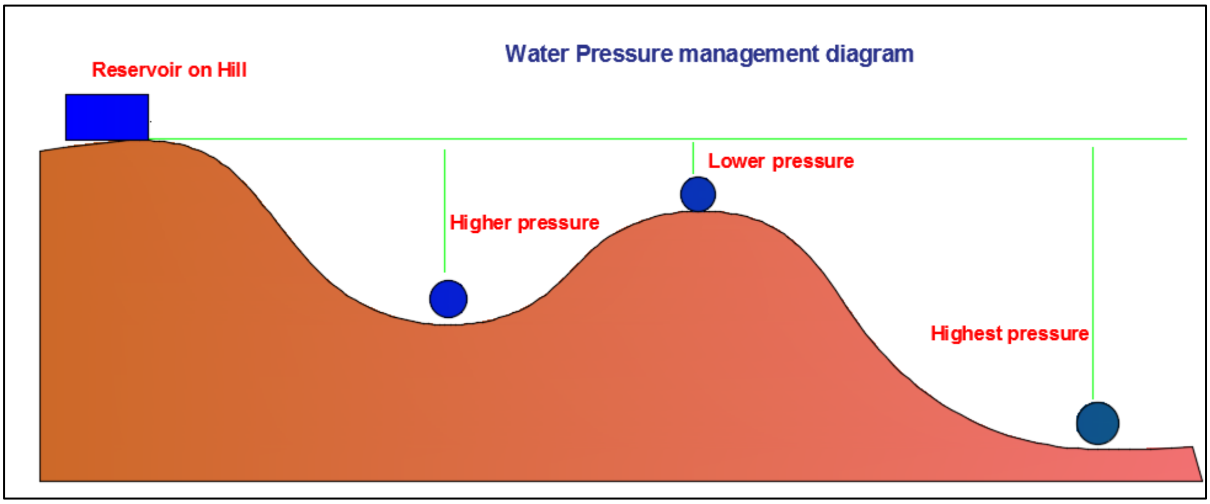


The blue line in the graph above represents the performance of the pump chosen.

When the pump pushes water to 50m height (elevation head), it gives 2000 litres. When the pump pushes water to 30m height, it gives 4000 litres. When the pump pushes water to 10m height, it gives 6000 litres.

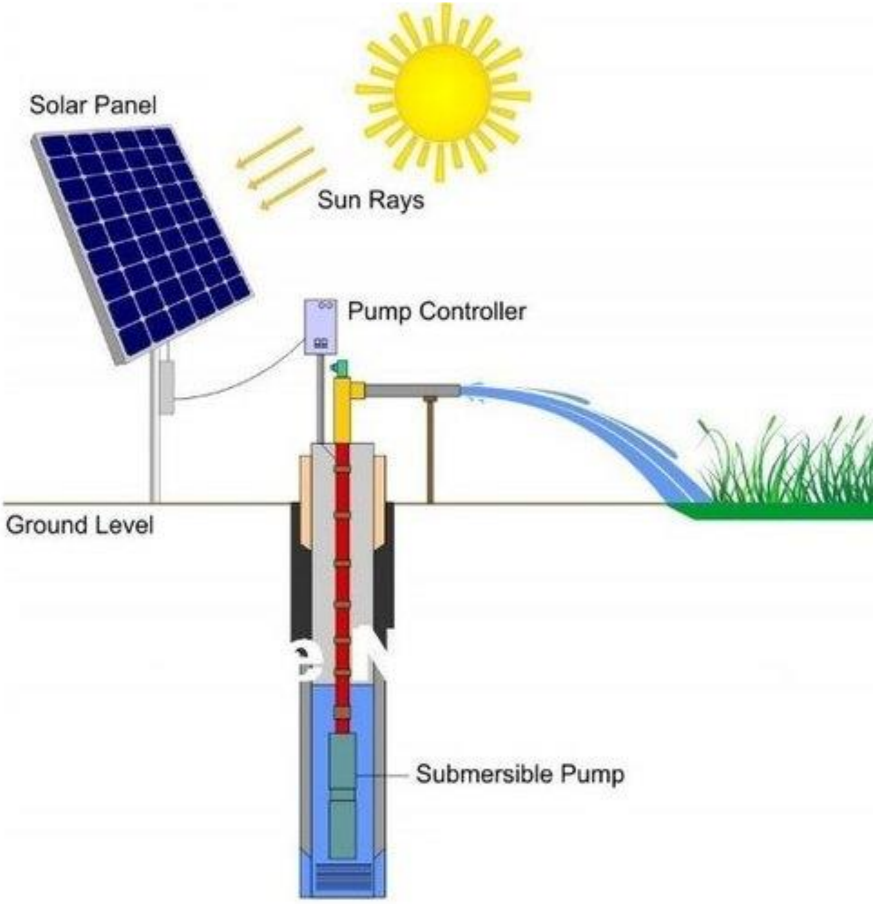
In conclusion, the more height to which the pump pushes water, the less amount of water the pump will give.

Variations in water pressure with elevation in gravity flow systems



When a water tank is placed on top of a hill, the house closest to the tank will have the lowest pressure, while the house furthest down the hill will have the highest pressure due to the big difference in height with the tank.

Technical features/ considerations for common submersible solar pumps

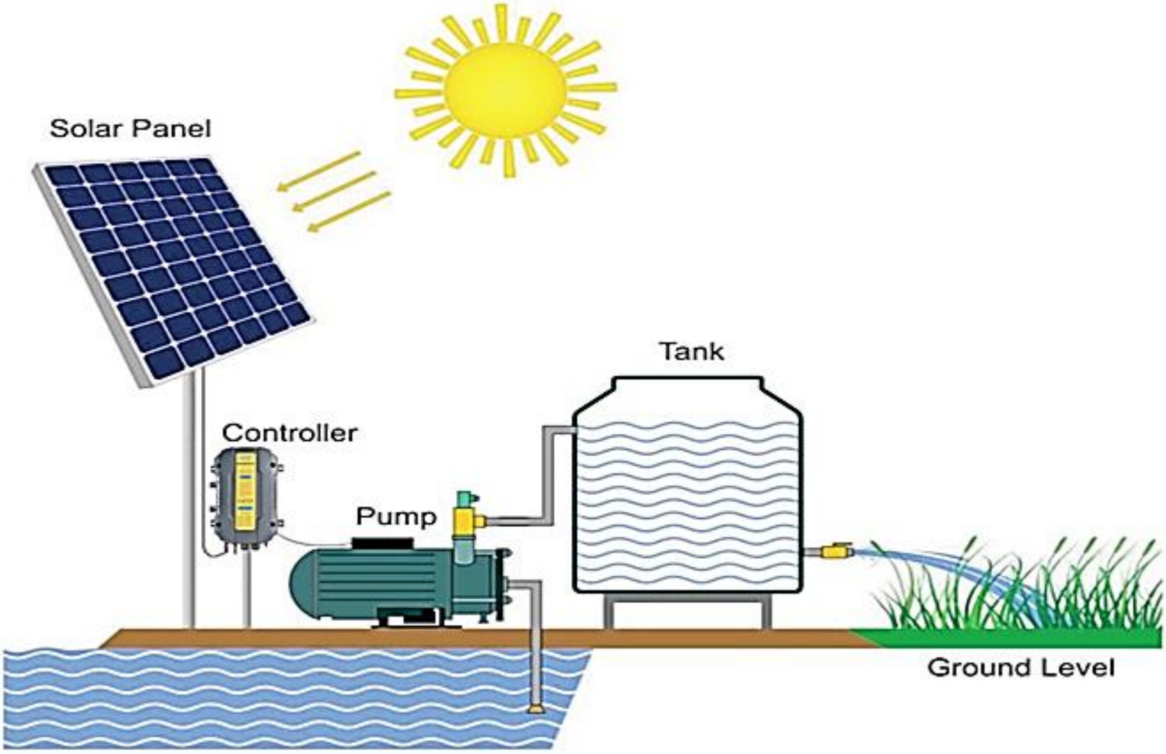


Schematic drawing of submersible pump

- Pressure ranges from 4 bars to 12 bars equivalent to 40m – 120m of elevation.
- Water volume pumped ranges 1000 litres per hour to 13,000 litres per hour.
- Number of panels used depend on pump power required and water amount required.
- Delivery pipe diameter sizes range from 32mm to 40mm.
- Controllers depend on pump make.

Technical features/ considerations for common surface solar pumps

- Pressure ranges from 1.5 bars to 4 bars equivalent to (15m – 40m) of elevation.
- Suction depth ranges from (0.5m – 10m).
- Water discharge ranges from 700 litres per hour to 6000 litres per hour.
- Delivery pipe diameter sizes range from 25mm to 40mm.



Schematic drawing of a surface solar pumping system

Photo of a surface solar pump with 6m suction pipe.

Advantages and disadvantages of solar pumps

Advantages

- They operate with free energy from the sun
- No environmental pollution
- Less costly to operate

Disadvantages

- They don't operate in rainy weather
- They don't pump at night
- Maintenance costs are high when using with Battery and Inverter.

Cost estimates for solar pumps

PUMP CATEGORY	SPECIFICATIONS	COST (UGX)
Submersible	Q=1,800 l/h and H=40m	4,500,000
Submersible	Q=3,000 l/h and H=60m	8,000,000
Submersible	Q= 6,000 l/h and H=70m	13,000,000
Submersible	Q=12,000 l/h and H=110m	18,000,000
Surface	Q=700 l/h and H=20m	2,600,000
Surface	Q=3,400 l/h and H=40m	4,300,000

Legend:

Q – Amount of water in litres per hour.

H – Height that needs to be pumped in metres.

2.9: Operation and maintenance of engine pumps

Fuel pumps happen to be the most available energy source and perhaps most familiar type to the ordinary farmers. Due to its comparativeness to ordinary generators, this simply means they use diesel or petrol to operate. These engine pumps are available in most business cities within the country.

Basic diesel pump operation steps

1) Pour water in suction pipe before starting.
2) Open the fuel line.
3) Put the engine speed knob in the center position.
4) Hold the starting handle loosely.
5) Pull the starting handle slowly, until you feel resistance then return it slowly.
6) Push the starting handle level down and release.
7) Pull the rope hard and fast, pull it all the way out. Use two hands if necessary.

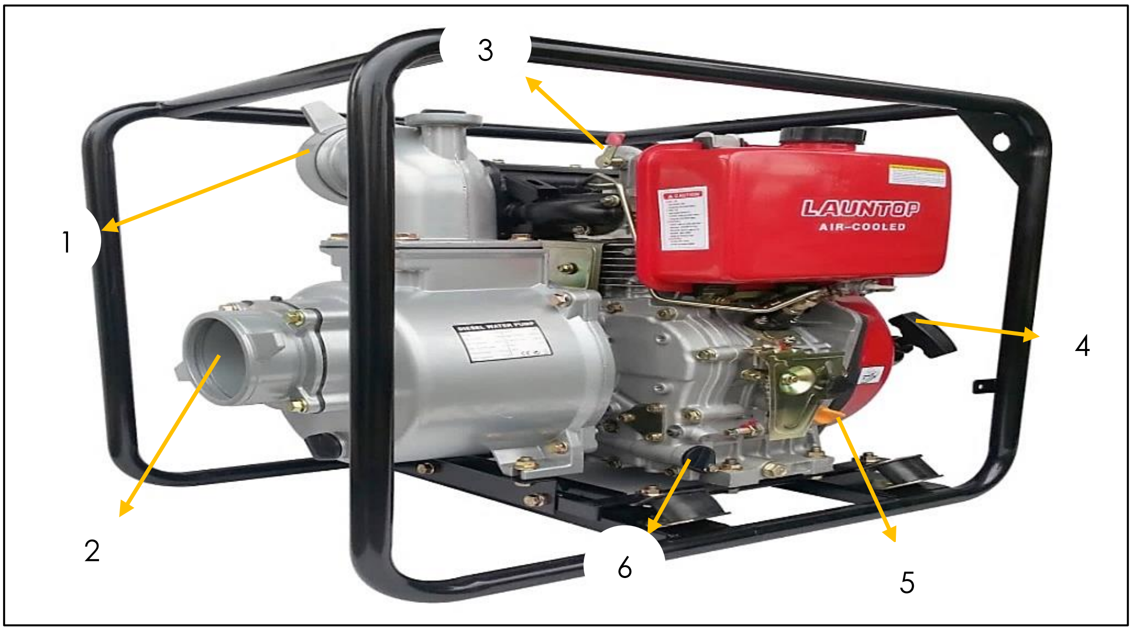


Photo showing a Diesel pump set for operation

<u>Legend</u>
1 – Outlet
2 – Inlet
3 – Starting knob
4 - Starter coil
5 - Oil inlet
6 – Oil drain plug

Maintenance and repair of diesel pumps:

- Check and fill the engine oil when need arises
- Check and tighten the nut and screw
- Do pump bleeding/ releasing air when the pump sucks air when fuel abruptly is done
- Check oil leakage
- Clean fuel tank
- Clean or change fuel filter

Advantages and disadvantages of diesel pumps.

Advantages

- Most can discharge large volumes of water and operate constantly well for many hours per day
- They are operated at any time when needed and fueled

Disadvantages

- They are expensive to buy

- Daily fuel costs make operation costs high
- They require skilled person to repair

Cost estimates for diesel pumps

PUMP SPECIFICATIONS	COST (UGX)
Q=48,000 l/hr. and H=68m head (pressure)	4,600,000
Q=35,000 l/hr. and H=65m head	3,800,000
Q=30,000 l/hr. and H=70m head	4,200,000

Legend:

Q – Amount of water in litres per hour.

H – Height that needs to be pumped in metres.

Basic operation steps of petrol engine pumps

1) Check the engine oil and ensure it's at the right level
2) Pour water in the pumping chamber from the top before starting
3) Ensure the suction foot valve is under the water surface and not touching the ground below water
4) Ensure the delivery hose is straight without bends
5) Start engine by pulling starter rope
6) Suction lift pipe should be made as short as possible to operate well
7) Ensure the delivery head is as per pump specification

Photo showing a petrol pump connected to the suction pipe operating.

Basic maintenance considerations of petrol engine pumps

- Check the engine oil daily and refill if low

- Check the air cleaner every 3 months, clean by blowing away accumulated dust and soaking in kerosene
- Check spark plug; if with blackish head, clean with sandpaper if still not working replace new one
- Remove water from pumping chamber after use by releasing the drain plug to avoid rust when not in use

Advantages and Disadvantages of petrol pumps

Advantages

- They are affordable to buy
- They can operate at any hour of the day when needed
- They are easy to repair
- They are easily available

Disadvantages

- Constant running costs of fuel is high
- They easily get frequent mechanical break downs
- They require skilled person to repair

Cost estimates for petrol pumps

PUMP SPECIFICATIONS	COST (UGX)
Q=35,000 litres /hr. and H=28m head	550,000
Q=28,000 litres/hr. and H= 50m head	1,200,000
Q=18,000 litres/hr. and H=72m head	1,100,000

2.10: Repair and maintenance of treadle pumps.

Thanks to its affordability, most rural farmers with open water sources and those with shallow well not below 4m water table have adopted it as the most affordable energy source in the rural setting. They deliver water to a height of 12m and on a flat ground they deliver to 200m. They get water from maximum of 6m depth.

Assembling and maintenance of a treadle pump.

Basic mode of operation of treadle pumps as per technical requirement

- Assemble the pump components, connecting the handle, connecting the peddles, connecting the peddle-pulley system and connecting the piston rubber cups
- Connect the filter to the rigid suction pipe of not more than 6m length. Though depending on the water source the shorter the suction pipes the higher the system pressure
- Ensure that the suction pipe is connected tightly to the inlet connection with no air escape
- Ensure the pressure delivery hose is also connected tightly to the outlet connection line
- Connect the rubber caps on each piston in the two separate cylinders and eventually attach the chain system to the peddles and finally to the pistons in each cylinder
- Pour water in the two cylinders before peddling, to enhance suction and reduce rate of damage of rubber caps

Basic maintenance of the treadle pumps as a source of energy for irrigation

Treadle pumps are the most convenient manual pumps to operate and maintain for an ordinary rural farmer with less technical experience in the field of pumps.

- Ensure water is poured in the two cylinders before usage
- Ensure timely greasing of the moveable parts
- Ensure timely replacement of the chains connections due to damage from peddling
- Ensure timely replacement of the rubber caps in each cylinder

Handling and maintenance of irrigation equipment (filters, driplines, sprinklers etc. and basic plumbing skills)

2.11: Introduction to handling and maintenance of Irrigation Equipment.

It is important to understand basic considerations in handling the different irrigation equipment and how the basic maintenance is done. The equipment will vary and some will be specific to a given type of irrigation technique. Most common practiced techniques of irrigation by individual or group farmers are drip irrigation, over-head sprinkler and surface irrigation which covers both furrow and flood irrigation. This is limited to farmers that have access to large water sources like, rivers, lakes and permanent flowing water streams.

2.12: Irrigation equipment components handling & maintenance

- **Filters:** These are a very important component of drip irrigation. Their main purpose is to remove any dirt or soil particles that come from the water source before getting into the drip lines. The filters prevent dirt or soil particles from blocking the dripline emitters (drippers). Maintenance is mainly done through cleaning the inside discs and screens with clean water. It is done periodically depending on workload. Filters for small scale irrigation are mainly disc filters or screen filters.

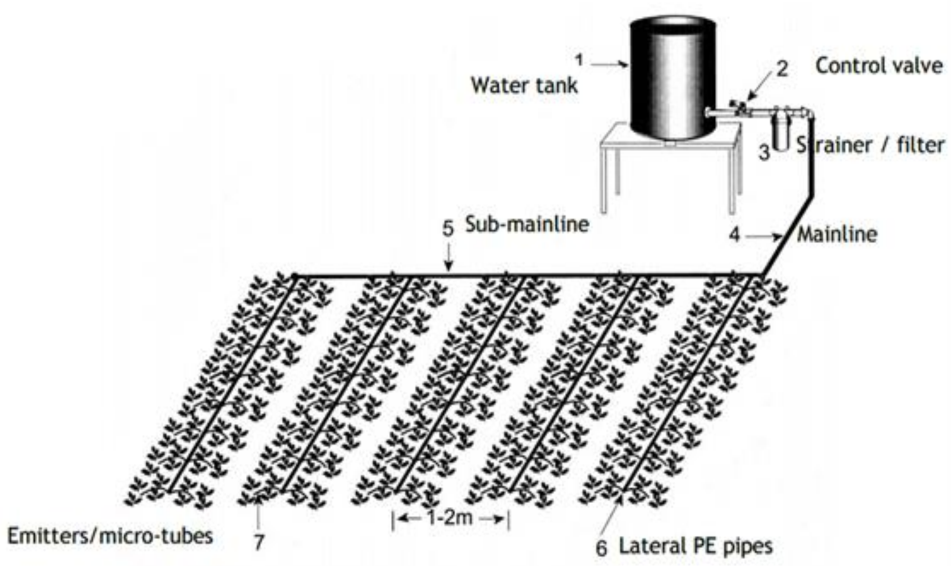
Screen filter *Disc filters*

Connection of filters to drip system

- Check the screen or disc filter and fit it well inside the filter casing.
- Check the direction of water flow from the tank and set the filter as per screen or disk filter.
- Connect the filter after the main valve.
- Then connect the main line to the filter.

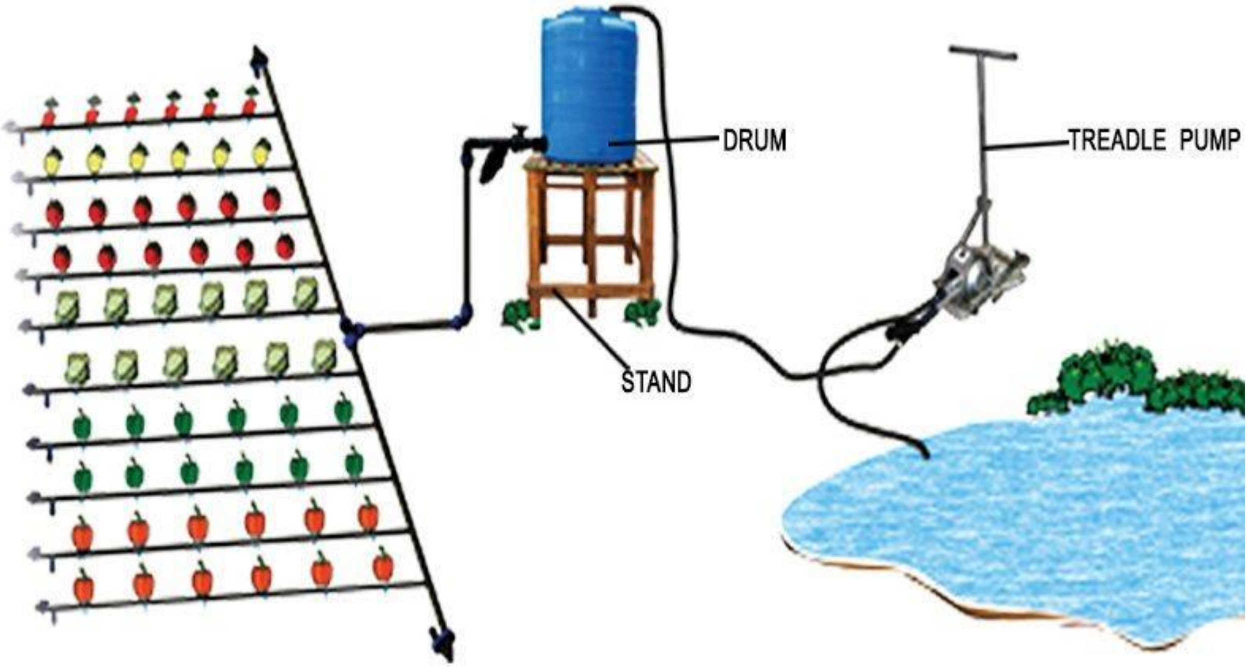
- **Driplines:** These are the most important components of drip irrigation; they need proper handling through good storage when not in use and also during usage they should be installed in a manner that reduces them from having direct contact with sunshine.
  They are either tape or round in physical appearance. They are always installed running across the slope of the plot picking water from the sub-main line which run down the slope of the plot. They are available in sizes of 9mm, 12mm and 16mm. The most used and common size is the 16mm. Driplines used in horticulture come with pre-punched drippers (emitters) with different spacing depending on the crop, ranging from, 20cm, 30cm, 45cm, 60cm and lastly 100cm though not common. Each crop has a preferable emitter spacing.

The driplines also have different discharge rates per hour depending on the manufacturer. Most common discharge for 16mm driplines are: 1.8 l/hr, 2.6 l/hr and 4 l/hr. Driplines are sold in roles of 300m -1500m. The cost of the driplines is per metre and it ranges from 400shs to 2200shs per meter depending on manufacturer and quality.

Schematic design of a low-cost drip irrigation system (Source: RCSD, 2008)

Drip system connected to a water tank



Simple drip-drum kit assembly

Photo showing drip system installed in Minakulu, Uganda 2020

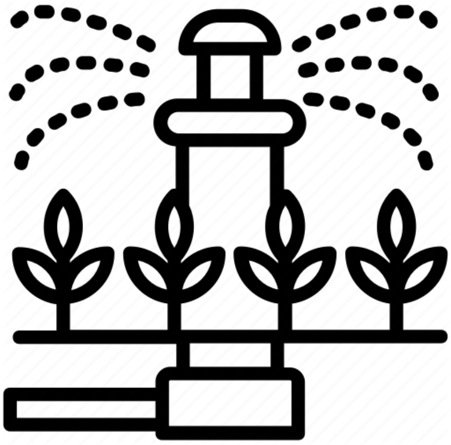
Connection of dripline to drip system

- Drill a hole in the sub-main line.
- Connect a starter rubber to the sub-main line.
- Insert a starter in the rubber.
- Connect the dripline to the starter.
- In case of underground sub-main line, connect a 70cm,16mm PE pipe to the starter first.
- Then connect a straight connector to it and then now connect the dripline.
- The end of every dripline is closed with an endcap.

- **Sprinklers:** These come in either plastic or metallic form, most commonly used in micro and small scale irrigation range from micro, mini to rain-gun sprinklers. The most critical part for maintenance are their nozzle openings that allow out water, they easily block with soil (mainly clay soil) and sometimes small stones and require cleaning and removing to allow efficient operation. The common brands on market discharge water in volumes ranging from 50 litres per hour to 13,000 litres per hour. They have pressure ratings ranging from 1 bar to 2 bars on average hence (10m to 20m). This means they require high pressure pumps in most cases.

  The prices per sprinkler range between 15,000shs per head to 120,000shs and for the case of rain-gun sprinklers they range from 150,000shs to 1,500,000shs.

Sprinkler spray nozzle in Kitgum, Uganda



Sprinkler irrigation spray heads on sub-main lines

Rain-gun sprinkler irrigation system in Lira, Uganda.

Connection of sprinkler heads to a sprinkler system

- Connect sub-main lines to the main line.
- Connect riser pipes to the sub-main lines.
- Connect sprinklers to the risers.
- Connect the pumping unit to the system.

- **Control Valves:** These are commonly used across all systems and are a very important component which can easily be damaged at the handle if poorly handled when in operation. Its basic maintenance is basically greasing the handle for the metallic type and replacement of rubbers for the flange types.

- **Pressure Gauge:** This is used to determine the pressure at which the system is operating as well as pressure losses down the system. In drip irrigation it is placed before the filter and after the filter incase two are available to be used to know the pressure loss after the filter. They are always connected along the sub-main line in sprinkler or on the riser stands of rain gun sprinkler system.

- **Foot-valve:** This is mainly used in the suction component of all engine pumps; it allows for pouring of water in the suction pipe before the system is started. This is because it allows water through and not back. It also acts as a primary filter of the pump. In case it's not there, the pump can easily suck in rubbish during operation.

Photo showing foot valve used in sprinkler

2.13: Basic plumbing equipment and tasks for irrigation equipment

Some of the basic plumbing tasks in irrigation works and what tools to use are:

- Drill inlet and outlet holes on tanks using a given red-hot long screw.

- Use pipe wrenches for most of the tightening work depending on the pipe size.

- Use both plastic and metallic pipe wrenches for tightening PE connections.

- For the case of threaded connections, apply thread tape at all male threads to prevent leakages.

- For the case of PVC pipes, connections should be done with PVC cement/Solvent glue.

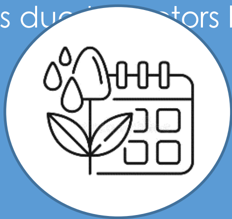
- Tape measure, pliers, hack saws, screw drivers, drip drill and drip punch are a must have for basic irrigation plumbing.

MODULE 3: IMPROVED WATER EFFICIENCY

Irrigation Scheduling and Crop Water Requirements

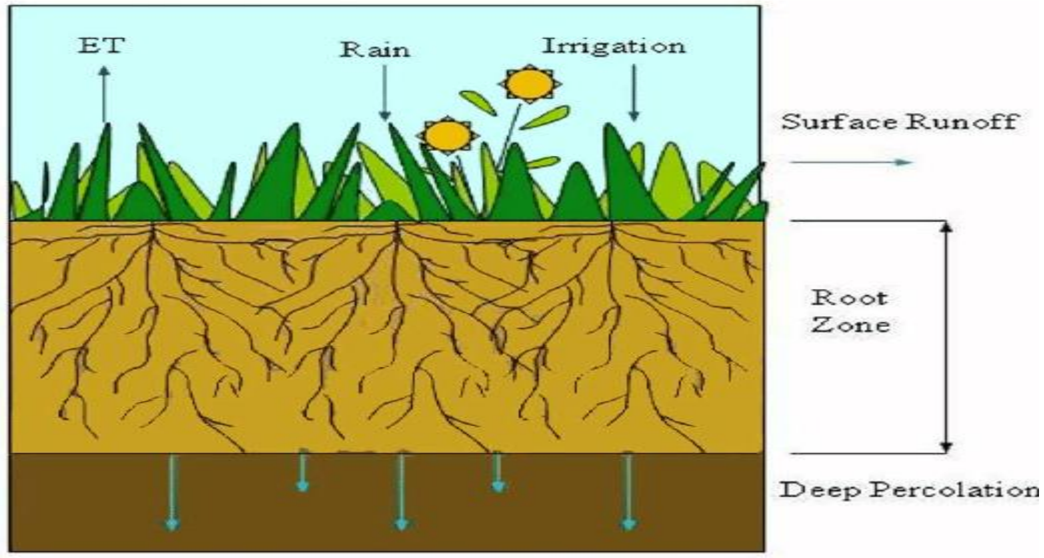
3.1: Introduction to Irrigation Scheduling and Crop Water Requirements.

Irrigation scheduling refers to the process through which a farmer operating an irrigation system is able to determine after how long to irrigate (time interval) and for how many hours to irrigate. Crop water requirement refers to the amount of water needed by a given crop at a given stage of growth to promote proper and timely crop growth. The different crops cabbage, tomatoes, eggplants, green pepper and onions all have different water requirements. For the selected districts in Northern Uganda, the crop water requirement varies due to factors like soil, and prevailing weather conditions



From left, insufficient water, over irrigated and well irrigated.

Farmers should be able to irrigate the right quantity of water within the specified duration depending on the crop.



The root zone indicates the volume of available water for plants

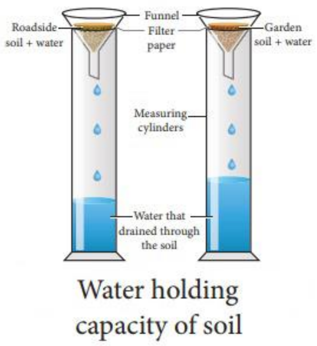
Water stress

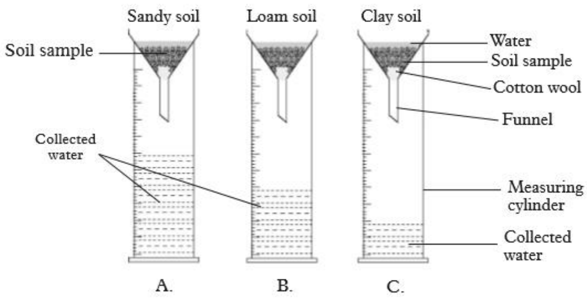
Bacterial wilt

3.2: Factors affecting the crop water requirement and Irrigation scheduling

Crops have different crop water requirements, which are influenced by different factors like:

- **Type of soil.**
  In sandy soil water infiltrates faster beyond the root-zone, so more water is required. Less water is required in loamy soils and least water is required in clay soils.





- **Sunshine.**

When it's highly sunny with no clouds, the crops will need more water due to high evapotranspiration. When it's not sunny hence cloudy, the crops will need less water.

- **Humidity.**

When the weather is very chilly, hence high humidity, the crops will need less water and when humidity is low, the crops will need more water.

- **Wind speed.**

When weather is very windy, crops will need more water and when it's less windy the crops will also need less water.

- **Crop cover.**

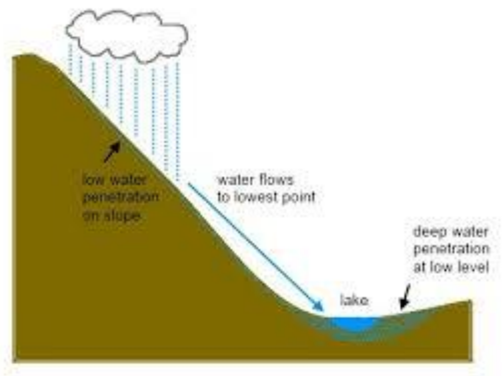
Crops that give a wide canopy cover to the soil will need less water since they promote less evaporation from the soil, crops with less crop cover will need more water.

Dense crop covers

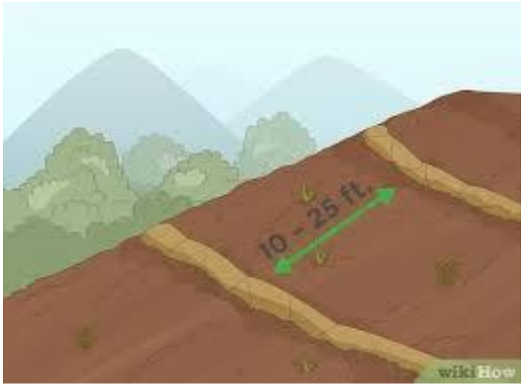
Poor crop cover

- **Ground slope.**

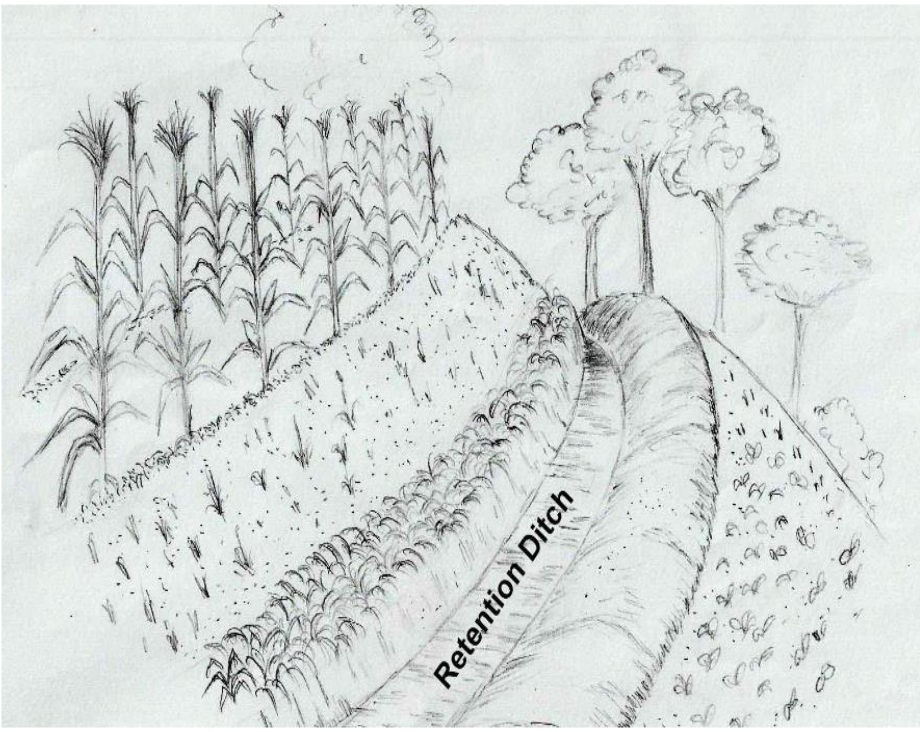
If the slope of the ground is steep the water requirement will be more due to less absorption time for the soil. If the ground is flat or gently sloping less water will be needed by the crops since the soil has enough time to absorb the water.



Steep slope



Trenches to trap run-off water



Layout of a retention ditch along a sloping field (Source: https://qcat.wocat.net/en/wocat/technologies/view/permalink/124

- **Method of ploughing.**

  In deep ploughing less water is required since water infiltrates easily and well. If the soils are not ploughed well water will not infiltrate well to the root-zone hence more water will be needed.

Deep ploughing with oxen

3.3: Crop water requirement and irrigation scheduling for Irrigation for in Acholi and Lango region for cabbage, tomatoes, green pepper, onions and eggplants.

- Consider the three critical stages of growth: early, development and late stage
- Establish the rooting depth
- Establish the row and crop spacing
- Establish the percentage wetted area

Tables showing the determination of crop water requirement and frequency of the different selected crops in Acholi and Lango Sub-region.

ACHOLI REGION				
	Growth stage	**Net irrigation requirement (litre/day)**	**Irrigation frequency (days)**	**Total water per irrigation (litres)**
Cabbage	Early stage	0.5	3	1.5
	Development stage	0.8	3	2.4
	Late stage	0.7	3	2.1
Tomato	Early stage	0.5	3	1.5
	Development stage	1.0	3	3.0
	Late stage	0.7	3	2.1
Egg plant	Early stage	0.7	3	2.1
	Development stage	1.1	3	3.3
	Late stage	1.0	3	3.0
Green pepper	Early stage	0.5	3	1.5
	Development stage	0.9	3	2.7
	Late stage	0.8	3	2.4
Onion	Early stage	0.1	3	0.3
	Development stage	0.2	3	0.6
	Late stage	0.1	3	0.3

LANGO REGION				
	Growth stage	**Net irrigation requirement (litre/day)**	**Irrigation frequency (days)**	**Total water per irrigation (litres)**
Cabbage	Early stage	0.7	3	2.1
	Development stage	1.1	3	3.3
	Late stage	1.0	3	3.0
Tomato	Early stage	0.5	3	1.5
	Development stage	0.9	3	2.7
	Late stage	0.6	3	1.8
Egg plant	Early stage	0.7	3	2.1
	Development stage	1.0	3	3.0
	Late stage	0.9	3	2.7
Green pepper	Early stage	0.5	3	1.5
	Development stage	0.8	3	2.4
	Late stage	0.7	3	2.1
Onion	Early stage	0.1	3	0.3
	Development stage	0.2	3	0.6
	Late stage	0.1	3	0.3

The crop will require different amounts of water at the three important stages of growth, at the early stage the crop requires fairly less water, at the development stage it requires the most water and at the late stage the water requirement reduces to amounts less than the development stage.

The irrigation frequency shows the number of days a farmer should spend before they can irrigate again. In this case, after irrigating, a farmer should spend three days with no irrigation. However, the three days counted include the day the farmer has irrigated. This means if a farmer irrigates on a Monday, they should irrigate again on Thursday and the pattern continues.

However, in case it rains after irrigation, the farmer should extend the day for the next irrigation by some days depending on the intensity of rain.

When a farmer is to irrigate on a Monday and then irrigate after three days, the farmer would therefore irrigate on a Thursday as stated above. In such a situation, the farmer should irrigate an amount of water that is equal to three times of what each crop needs per day. This is shown in the table as “Total water per irrigation”.

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For More Information, contact:

Promoting Rural Development in Northern Uganda

c/o Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices Bonn and Eschborn, Germany

giz_prudev@giz.de

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