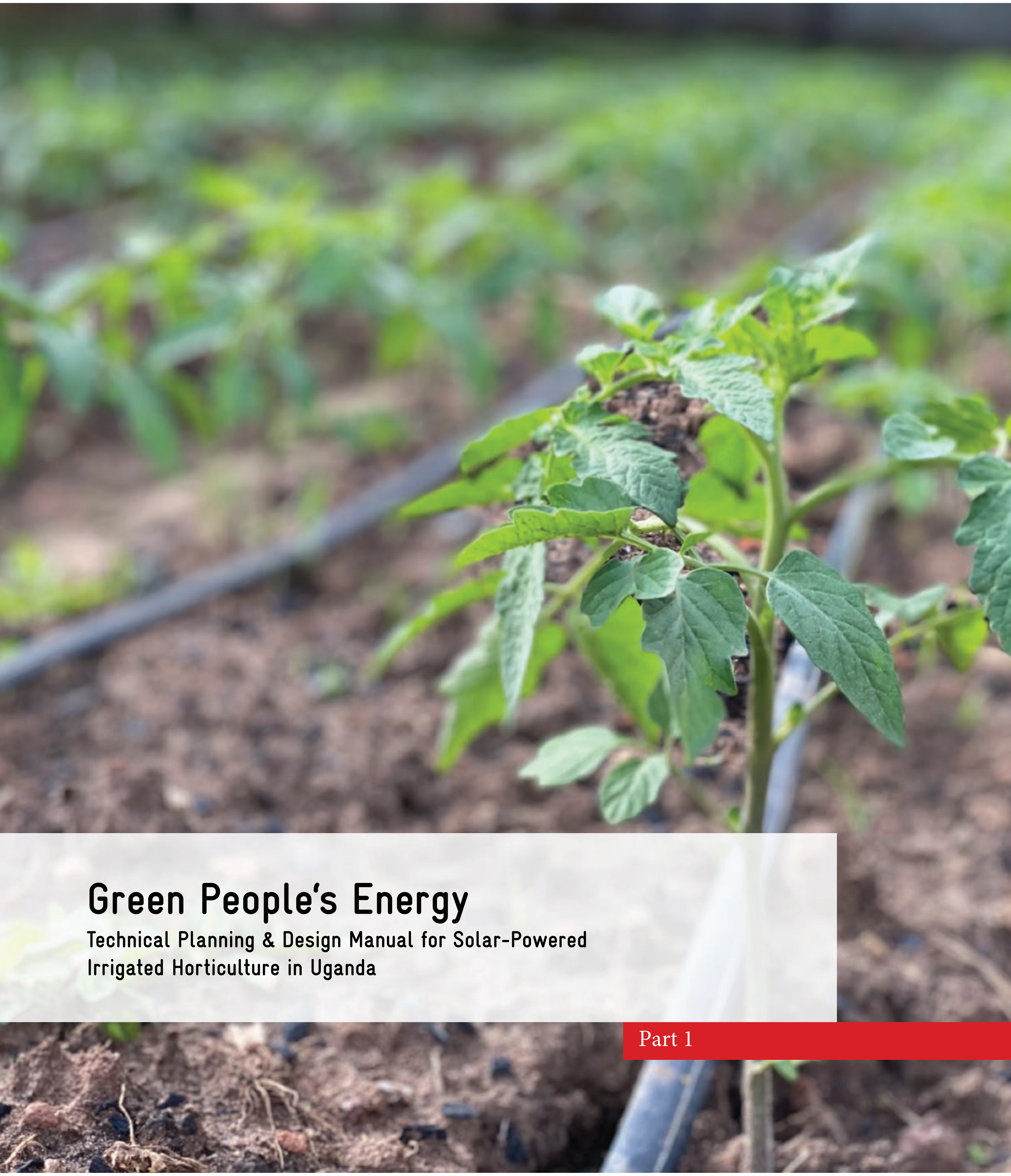

# Green People's Energy

## Technical Planning & Design Manual for Solar-Powered Irrigated Horticulture in Uganda

Part 1

german cooperation
DEUTSCHE ZUSAMMENARBEIT

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

# FOREWORD

Green People's Energy for Africa (GBE) is an initiative launched by the German Federal Minister for Economic Cooperation and Development, Dr. Gerd Müller, in June 2017 as part of the Marshal Plan with Africa. The initiative is implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH in nine focus countries in Sub-Saharan Africa.

In Uganda, the project aims to improve access to decentralized renewable energy (DRE) for farmers, enterprises, cooperatives and social institutions in rural areas. It is part of the Promotion of Renewable Energy and Energy Efficiency Programme (PREEEP) which supports the Ugandan Ministry of Energy and Mineral Development (MEMD) in its objectives for the promotion of renewable energy and energy efficiency.

Through its Technical Training and Skills Development project component, GBE Uganda develops trainings and curricula for DRE technologies and improves the capacities of technical teachers and users on the design, installation, and maintenance of technologies, such as solar-powered irrigation systems (SPIS).

While SPIS technology is ready in Uganda to be more widely adopted by rural farming communities, challenges - both, among system designers and technicians, as well as farm users - need to be overcome to ensure a greater uptake. These include:  the lack of sufficient skilled SPIS technicians and trainers, knowledge among users on the operation and maintenance of these systems and the risk of groundwater exploitation from unsustainable use of the SPIS.

To improve the capacity of farmers, designers, system installers, and technical teachers on sustainable solar powered irrigation systems, GBE Uganda partnered with Engineers without Borders - USA (EWB-USA) to fill the prevailing knowledge and technical gaps through training of trainers, technicians and users; as well as offering tailored advice for users who consider investing in solar-powered irrigated horticulture to improve their farming.

The Design Manual at hand therefore identifies technical steps in planning, designing, installing, operating and maintaining of a SPIS and provides practical examples of the application of design calculations, software, and phone apps for sustainable sizing of solar-powered irrigation systems for smallholder farmers in Uganda.

Hopefully, the knowledge provided may prove useful in contributing to increased sustainable application of SPIS and by all those active in the field of solar irrigation, especially technicians - from both private and public sector - trainers at vocational institutes and their trainees, and technical teams of development and humanitarian organizations.

**Dennis Barbian**
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Green People's Energy, Uganda
June 2021

# ACKNOWLEDGMENT


The preparation of this Technical Planning & Design Manual for Solar-Powered Irrigated Horticulture for Designers, Installers, and Trainers of Solar Powered Irrigation Systems is an initiative of the "Green People's Energy Project, GBE" in Uganda, funded by the German Federal Ministry for Economic Cooperation and Development (BMZ) and implemented by GIZ in cooperation with the Ministry of Energy and Mineral Development (MEMD).

The project was managed and coordinated by **Lukia Nabawanuka**, **Rolex Muceka** and **Santa Akanyo**, GBE Technical Advisors, and implemented by the consultant Engineers Without Boarders - USA.

Additional inputs by other GIZ technical staff; **Blumenthal Kilian**, Water and Energy for Food – Kenya, **Marty Forkkink**, PRUDEV – Uganda, **Karungi Acheles**, Energizing Development – Uganda, **Tabak Enoh**, GIZ Headquarters – Germany, to this SPIS Design Manual are appreciated.

Special thanks to **Valentin Hollain** for his support during the early stages of adapting the manual during his time as the GBE project coordinator in Uganda.

The preparation of the manual contents by EWB – USA as well as several drawings by the graphic designer is acknowledged.

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# ABBREVIATIONS

| | |
|---|---|
| BMZ | German Federal Ministry for Economic Cooperation and Development |
| EWB-USA | Engineers Without Borders - USA |
| GBE | Green People's Energy (Grüne Bürgerenergie) |
| GIZ | The German Development Agency (Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH) |
| IEC | International Electrotechnical Commission |
| MAAIF | Ministry of Agriculture, Animal Industry and Fisheries |
| MEMD | Ministry of Energy and Mineral Development |
| NGO | Non-Governmental Organization |
| PREEEP | Promotion of Renewable Energy and Energy Efficiency Programme |
| Solar PV | Solar Photovoltaic |
| SPIS | Solar Powered Irrigation Systems |
| TDH | Total Dynamic Head |
| TDS | Total Dissolved Solids |
| ToTs | Training of trainers |

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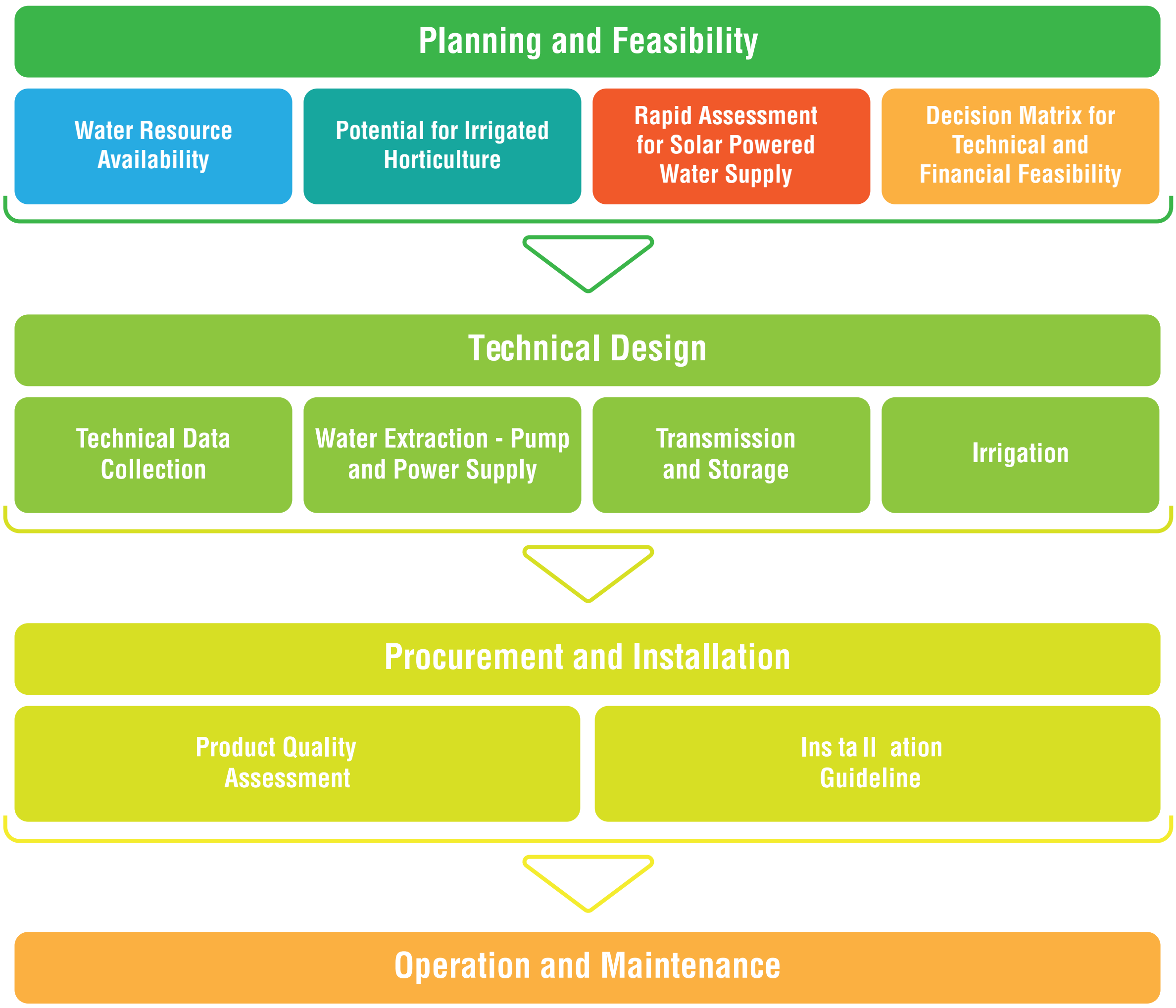
# EXECUTIVE SUMMARY

This manual was compiled by Engineers Without Borders USA (EWB-USA) in cooperation with Green People's Energy for Africa (Grüne Bürgerenergie für Afrika, GBE), as part of GBE's training activity on solar-powered irrigation in Uganda. The collaboration aims to improve the capacities of designers, installers, trainers, and users of solar-powered irrigation systems (SPIS) in Uganda. The practices and processes outlined throughout this document are related to the conditions and cultural context found in Uganda.

The solar-powered irrigation solutions for horticulture outlined in this manual describe systems in which water is extracted from its source and delivered, by solar-powered mechanized systems, into an overhead storage tank and then distributed via gravity to crops either with sprinkler or drip irrigation.

The manual will follow the process outlined below for planning and feasibility, technical assessment, design, in-stallation, technical operation and maintenance.

Note: This manual includes technical Operation and Maintenance, diagnostics and procedures. Operation and Maintenance activities for the user are addressed in a separate manual.



Assumptions

❖ **Intended Audience**

This design manual targets personnel performing SPIS evaluation, technical advisors leading SPIS projects, trainers, designers, installers of these systems who have technical background in general electrical engineering and plumbing including experience with SPIS.

Installation work will be done and/or overseen by a trained technician and electrician. This manual is not intended for use by people without experience in electrical installations and/or water systems

❖ **Farm Sizing**

In some cases, this manual will make a distinction between household, small-, medium-, and large-scale farms. These are distinguished as:

- Household: <0.5 acres
- Small-scale: 0.5–5 acres
- Medium-scale: 5–10 acres
- Large-scale: 10+ acres

According to Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), micro-scale irrigation farm-ing is that with a maximum irrigated area of 2.5 acres and usually with a water source that is not more than 700 m away from the irrigated land.

❖ **Water Source**

For the purposes of this manual, two principal types of water source will be considered:

1. Groundwater Supply – Borehole, shallow well
2. Surface Water Supply - Lakes, Springs, and Valley Dams

❖ **Irrigation Options**

Three principal types of irrigation will be discussed within this manual: drip, sprinkler, and drag hose. Other types of irrigation are not considered optimal for mechanized irrigated horticulture.

# 1. INTRODUCTION

## 1.1. What is Sustainable Agriculture?

Sustainable agriculture focusses on production of crops and livestock with minimal effects on the natural environment. Through resource conservation, crop rotation, and recycling of on-farm crop residue and animal waste, sustainable agriculture further strives to minimize new or unnecessary costs and energy into the farm system. The major aim of sustainable agriculture is to meet the current food and textile's need without compromising the ability of the future generation to meet their own needs. To practice agriculture sustainably in Uganda, a number of factors should be encouraged and practiced. These include:

- Natural resource conservation: As we gear towards the future, there is need to conserve the natural resources including use of land and care for its replenishment to achieve the most successful crop production. Encouraging crop rotation (rather than continuous mono-cropping where the same crop is grown every year) has significant benefits for soils as a primary agricultural resource. Use of water efficient irrigation methods such as drip irrigation instead of flood irrigation.

- Use of renewable resources: There is need to minimize the use of non-renewable inputs and petroleum-based products, and instead utilize renewable input products. Continuous use of non-renewable inputs such as fossil fuels would lead to depletion of these resources. Furthermore, their use has a snowballing effect of climate change thereby affecting the future generation. Therefore, it is highly encouraged to use renewable inputs such as solar energy that is free and abundant.

- A preference to focus on local people and their particular needs, knowledge, skills, and social-cultural and structural institutions.

- A need to ensure basic human nutritional requirements in the local production of food for both current and future generations.

- A need to reduce the vulnerability of the agricultural sector in its dependence on externalities such as climate, water, and soil conditions, and instead encourage the uptake of new technologies as well as tried-and-true methods that can reduce the impact of these externalities, i.e., the adoption of irrigation

## 1.2. Sustainable Agricultural Practices in Uganda

Agriculture is a core activity of the Ugandan economy, According to MAAIF, agriculture contributed 25% of the country's GDP in 2017. It is Uganda's largest employer, over 80% of which are women, making this sector their major employment category

Most crops in Uganda grown for export include coffee, tea, tobacco and cotton. These contribute to about 75% of the overall economy. A number of farmers are also involved in staple crop production, such as maize, sorghum, millet, cassava, sweet potatoes, rice, beans and soya beans, all of which are prevalent in large-scale farming operations.

Farmers in Uganda are encouraged to adopt sustainable agricultural practices to lessen harm to microorganisms within the ecosystem. Adopting sustainable agriculture contributes to the growth of nutritious and healthy food with high market potential which improves the standard of living of the practicing farmer, as well as the health of the environment at large.

## Some of the common sustainable practices in Uganda include:

- Rotating crops and embracing crop diversity. Here, farmers are encouraged to change crops in parts of their plots each growing season, and not stick to one crop every year, especially in the same section of soil while ensuring complementarity. This improves soil health and optimisation of soil nutrients. For example, rotating heavy nitrogen feeder crops such as maize with nitrogen fixing crops such as soya beans would leave a healthy balance of nutrients in the soil.
- Planting Cover crops. These are crops that are planted not to provide any commercial value but rather to protect the soil against erosion, pests and disease, weeds or to enrich the soil with nutrients especially when nitrogen fixing legumes are planted. Cover crops can be planted after harvesting or before planting. They promote beneficial biodiversity interaction within the agroecosystem.
- Reducing tillage. Tillage refers to the operations carried out between harvest and a following sowing/cultivation operation. Farmers are discouraged from this practice as it disrupts soil structure, and accelerates surface runoff and soil erosion, thus negatively affecting yields on crops to be planted in subsequent seasons.
- Integrated Pest Management (IPM). This is an effective approach used to manage pests using the most economical means, and with the least possible hazard to people, property, and the environment. This practice helps eliminate pests and diseases that destroy crops but does so more cost effectively and with less environmental impact than using chemical herbicides or pesticides. It involves use of multiple tactics such as cultural, physical, biological and chemical methods. Some examples of IPM tactics include growing crops that adapted to the field conditions, paying proper attention to crop water and nutritional needs, use of insect traps, use of predators.
- Integrating livestock with crop production. Grazing livestock on a cover crop before planting of new crops can improve soil fertility and structure, but also contributes to animal nourishment, health, and well-being, and can be more cost-effective overall.

However, a number of factors can be attributed to the slow-paced adoption of these sustainable practices in Uganda. These include:

- Inadequate training. Most small-scale farmers begin farming with no prior knowledge of agricultural best practices and limited information with which to improve season-to-season.
- High poverty rates. Most farmers start farming with no capital. This limits their ability to effectively scale up a sustainable practice.
- Climate change. With increasingly varied changes in seasonal rainfall and temperature, farmers are finding it more challenging to predict when they should plant their crops.

## 1.3. What is Horticulture?

Horticulture is a branch of plant agriculture generally concerned with production of food and ornamental crops in more controlled settings, such as vegetables, fruits and nuts, as well as other ornamental flowering plants and herbs grown for aesthetic or medicinal purposes[1].

Horticultural crops generally have a higher value than field crops, due to a wider range of local, regional, and international market viability. However, horticulture is currently practised in Uganda on a relatively small scale due to limiting factors such as climate variance and inconsistent water availability throughout the country.

But, if more farmers were able to adopt various irrigation techniques, horticultural practices could be on the rise in the country, as irrigation is often necessary for these higher-value crops to remain productive through dry periods and hotter temperatures.

## 1.4. What is Irrigated Horticulture?

Irrigation is defined as the planned application of water for the purpose of supplying moisture essential for plant growth. A broader, more inclusive definition is that irrigation is the application of water to the soil for the following purposes:

- To increase yields by irrigating crops during the dry season, thereby allowing for increased annual productivity
- To cool the soil and atmosphere, thereby making a more favourable environment for plant growth
- To wash out or dilute salts in the soil (Leaching)
- To apply fertilizers or soil amendments dissolved in irrigation water (Fertigation).

Irrigation typically generates more yield of an equivalent area compared to rain-fed production alone[2].

### Why do we need to irrigate our crops?

Practically speaking:

- To insure crops against drought resulting from unpredictable and poorly distributed seasonal rainfall patterns
- To meet increased food demand resulting from increased population necessitates an increase in production through irrigation.
- To increase farmer incomes with off-season cultivation by taking advantage of higher off-season produce prices
- To meet year-round market demand without compromising quality.

Irrigation is considered essential for the most successful horticultural production due to those crops having an increased water requirement, as well as its improved control over crop water requirement at the various stages of plant root and leaf growth, fruiting, and maturation.

1 https://horticulture.ucdavis.edu/.

2 https://news.unl.edu/newsrooms/today/article/gap-growing-between-irrigated-rain-fed-crop-yields

# 2. PLANNING AND FEASIBILITY

## 2.1. Irrigated Horticulture

This section outlines the process and considerations for planning irrigation systems and analysing the feasibility of the system being considered.

### 2.1.1. Forms of Irrigation

Irrigation can be done by hand, with watering cans or backpacks with water sprayers, or through mechanized options including drip irrigation, sprinkler irrigation, drag hose, or flood irrigation. In this manual, we focus on the mechanised options connected to a solar powered water pumping system from a reliable water source to form what we call a solar powered irrigation system.

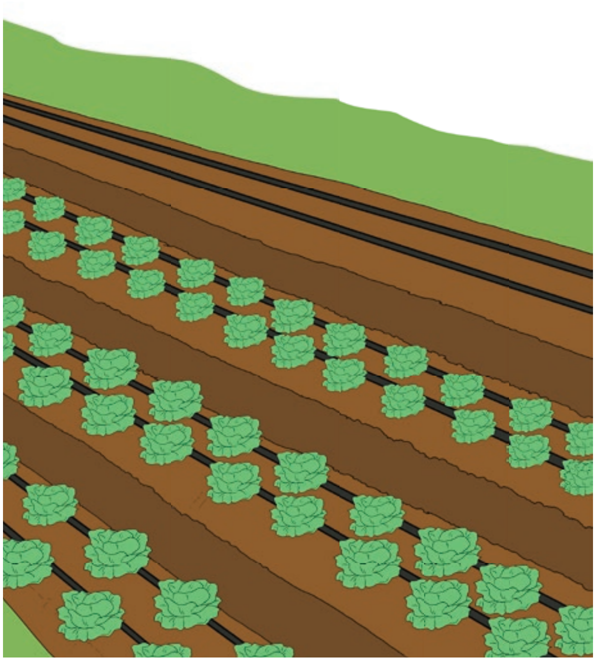


Figure 1: Drip Irrigation

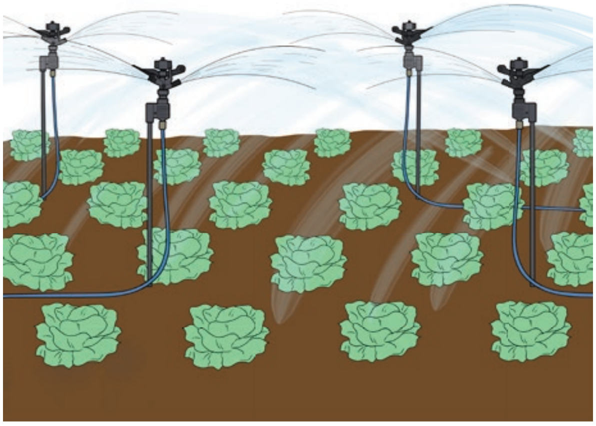


Figure 2: Sprinkler Irrigation

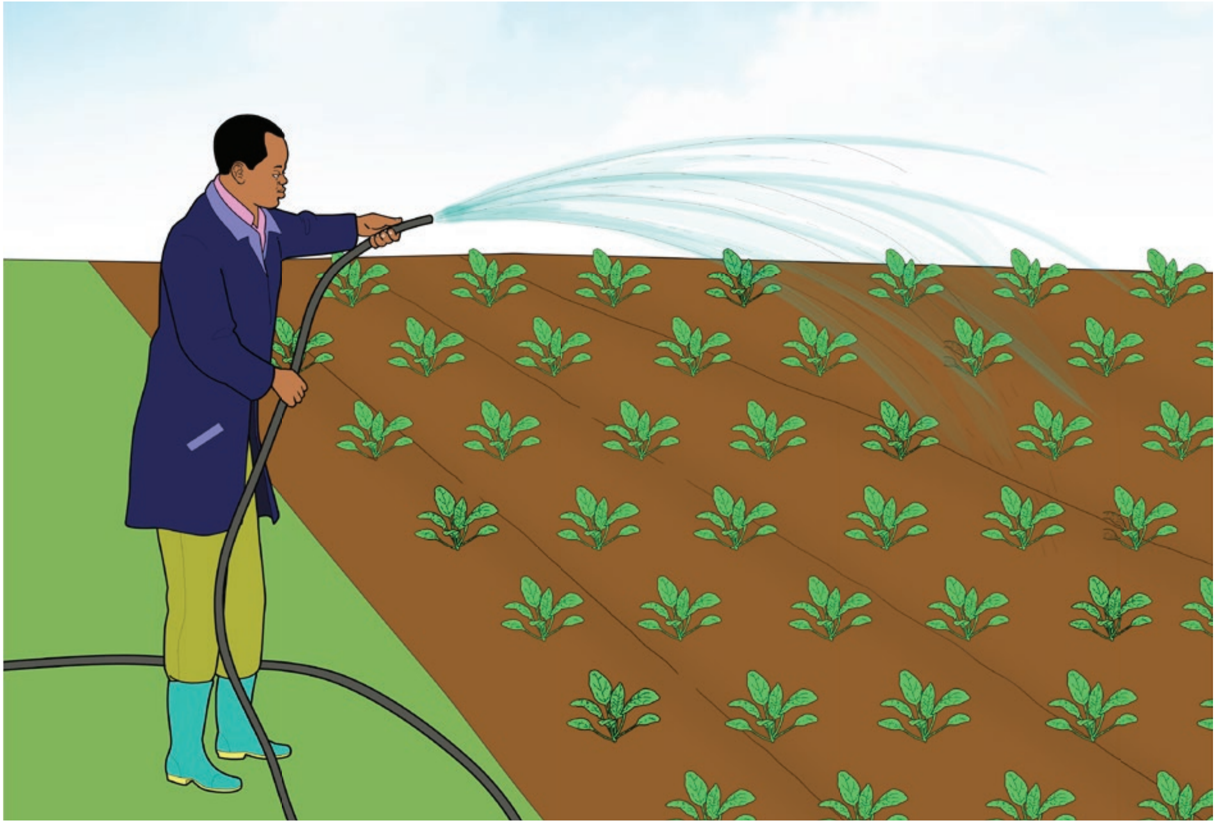


Figure 3: Drag hose Irrigation[3]

### 2.1.2. Irrigated horticultural crops in Uganda

Irrigation produces the best results in these higher-value crops. The following table shows examples of common irrigated crops in Uganda.

Table 1: Common Horticulture Crops in Uganda[3]

| Vegetables | Fruits | Flowers | Spices |
|---|---|---|---|
| Cabbage | Passion fruit | Rose | Vanilla |
| Tomato | Pawpaw | Chrysanthemum cuttings | Ginger |
| Onion | Jackfruit | Celosia/Poinsettia cuttings | pepper |
| Egg Plant | Citrus | Gerberas | Turmeric |
| Amaranths | Pineapple | Summer flowers | Chilies |
| Green pepper | Mango | Foliage plants | Arogana |
| Sweet pepper | Avocado | Ornamental | mints |
| Cauliflower | Banana | | Thyme |
| Kale | Water melon | | Rosemary |
| Cucumber | Guava | | Lavender |
| Garlic | Grape | | Thyme |

3 Source: Ssebuliba *et al.*, 2001, IDEA Project UFEA, 2002

| Vegetables | Fruits | Flowers | Spices |
|---|---|---|---|
| leek | Strawberry | | Lemon grass |
| Hot Pepper/Chili | Melon | | |
| Lettuce | Tree tomato | | |
| Spinach | | | |
| French beans | | | |
| Green beans | | | |
| Cow peas | | | |
| Pumpkin | | | |
| Field Peas | | | |
| Egg plant/garden eggs | | | |
| Okra/Gombo | | | |
| Malakwang (Hibiscus) | | | |
| Ntula (Solanum spp) | | | |
| Nakaati (Solanum spp) | | | |
| Jobyo (Gynandra spp) | | | |

## 2.2. Principal Considerations for Irrigated Horticulture

Below are some factors to consider before embarking on a horticultural enterprise. These factors are explicitly expounded in the next sections.

### Table 2: Considerations for Irrigated Horticulture

| FACTORS | CONSIDERATIONS | NOTES |
|---|---|---|
| Water supply | Type of water source i.e., borehole, river, swamp, lake etc. | The quantity of water available among others determines the size of irrigated land and the type of irrigation |
| Plot characteristics | Look at the size of the plot, the soil characteristics, slope and topography | This shall help in determination of the irrigation method and the water demand. |
| Climate | The climatic condition of the area i.e. humid, windy or semi-arid etc. | Clearly understanding the climatic conditions shall help in determining the suitable crops, irrigation water demand and scheduling |

| FACTORS | CONSIDERATIONS | NOTES |
|---|---|---|
| Crop | Vegetables, fruit trees, ornaments and herbs | The adopted crop should clearly be noted so as to come up with right water requirements. Different crops have different water demands |
| Fertilization need | Different crops have got different nutrients they require. These may be obtained from organic or inorganic fertilizers. | For better yields, use of fertilisers is a necessity |
| Irrigation method | Drip, Sprinkler or drag horse irrigation | This is influenced by both technical and economic considerations. |
| Financial Feasibility | Costs Vs returns | The horticultural enterprise should be economically feasible. |

Important Note

Do not forget to inquire with the local government about local regulations that may apply to the use of land at the proposed farming site. Ministry of Water and Environment guidelines recommends that agricultural practices should not be carried out in protected areas such as swamps, forests, and National parks. The agricultural plot must be at least 200m from the edges of a scheduled lake, 100m from a non-scheduled lake, 100m a scheduled river and 30 m from non-scheduled river or wetland.

Some preliminary questions to get you thinking:

- ✓ Are there any city or regional planning regulations concerning the use of the proposed farming site?
- ✓ Does your site have access to water?
- ✓ What is the quantity and quality of the available water?
- ✓ Are the soil and site conditions suitable?
- ✓ What is the harvest period and the anticipated yield?
- ✓ Do you have access to labour for field activities?
- ✓ What are the production costs and what income can you expect?
- ✓ Do you have access to a viable market, and what price do you expect?

Do not rush into horticultural production, how you start is much more important than when you start.

The future success of a horticultural enterprise requires spending some good time researching and planning before starting production. This time is part of your investment in the business and can even be the significant difference between success and failure of the farming business.

### 2.2.1. Water Supply

The principal objectives of an irrigation system are to deliver the right amount of water, at the right time, to the right place, reliably, and without any losses.

In this section we will look at water supply, including questions of availability, distance to plot for irrigation, quantity and quality, and ownership. When water is readily available, larger areas can be irrigated, and mechanized irrigation can be put in place. Where water is scarce, irrigation is still an option, but opportunities for mechanization may be limited and expensive.

At the end of this section, you should be able to fill in the following Water Supply Data Collection table:

Table 3: Water Supply data collection

| Water Supply | Observation/finding | Notes |
|---|---|---|
| Water source type | | |
| Current status<br>Does water supply require development? | | |
| Is water supply year-round or seasonal? | | |
| Is water supply private or public? | | |
| Any other uses of the water source | | |
| Land ownership at water source location | | |
| Distance of water sources from plot (m) | | |
| Quantity of water available ($m^3$/hr or day) | | |
| Water quality | | |
| Depth of water level(m) | | |
| Any other water source available | | |

#### 2.2.1.1. Water Availability

The quantity and quality of water available will determine what crops to grow and how many to be planted. Water, in the form of soil moisture, determines the crop's growth rate, planting density, and its yields. Water also highly affects fruit and flower quality. Insufficient soil moisture (water) may lead to[4]:

4 FAO

- Aborted flowers
- Blossom end rot
- Fruit splitting
- Fruit drop
- Small fruit
- Insufficient leaf growth
- Sunburn of fruit directly exposed to strong sunlight
- Lower yields
- Hampered crop development

To realize an economically viable output, water availability is most important as it determines the four stages of crop growth i.e., the sprouting stage, crop development, mid-season, and late-season. Differing amounts of water are required for productive growth at every stage. Water shortages in different growth stages differently affect the crop development.

It is better to plant a small crop area and have excess water than it is to plant a larger area and risk having water-stressed crops due to inadequate water supply.

#### 2.2.1.2. Water Source

There are basically two ways a farmer can access irrigation water: surface water (rivers, lakes, ponds and springs, etc.); and ground water sources (boreholes, shallow wells). Other ways to access water are through rainwater harvesting into tanks or ponds, or reclamation of wastewater. These are not being considered for purposes of this manual as they are not viable water resources for mechanized irrigation.

If there is a need to develop the water source, i.e., drill a borehole or develop a valley tank, this should be done before making any other decisions. The resulting quantity of water will determine all other components of an irrigated system.

Water source potential:

- Borehole
- Stream
- Valley Dam

Seasonal water sources are not recommended for irrigation unless there is sufficient water to capture in storage to last through the dry season. An example of this might be a valley tank.

#### 2.2.1.3. Water Access

Is the water shared or private? Is the water source on the plot, nearby, or very far away? If the water source is shared, what options are there for developing an irrigation system? For example, is it possible to extract water from this source with a mechanized system, potentially reducing water access for others? Water is expensive to pump long distances. If the water is far away, are there security risks for the electrical system? Do you have a water abstraction permit? MWE offers abstraction permits for both surface and ground water to regulate how much water can be accessed from a given source. However, for small scale systems, one may not require to obtain an abstraction permit.

#### 2.2.1.4. Water Quantity

The amount of water you can access will determine the type of crop you can grow, and the area of crop you can plant. The amount of water required by a crop each day throughout the year will determine the area of crop you can plant using the available water. The quality and yield of the crops will be reduced if the crop water requirement is not met each day.

Water quantity is usually measured in $m^3$/hour or $m^3$/day.

#### 2.2.1.5. Water Quality

Water quality is an important step in confirming water availability. Water quality can determine the type of crops to grow, type of irrigation system, type of filtration system, as well as the style of irrigation management.

Water quality may not be known at the time of initial assessment for feasibility. However, local knowledge sources or users may be able to provide information from experience on the quality of water at the selected source.

Key irrigation water quality parameters include:

i. PH values: The alkalinity or acidity of the water may affect the irrigation equipment, plant growth and/or pesticide efficiency. The generally accepted pH for irrigation water is between 5.5 and 7.5.

ii. Iron: Soluble iron and iron-loving bacteria can cause blockages in pipes, drippers and sprinklers and can damage equipment such as pressure gauges. If water with high soluble iron is applied by spray, it can discolour leaves and reduce the efficiency of transpiration and photosynthesis

iii. Hardness: Water that contains high levels of dissolved calcium or magnesium salts, or both, is described as being 'hard'. Other cations such as iron, manganese, aluminium and zinc can also contribute to hardness. A high presence of these can indicate the nature of the water. Hard water can affect soil, stock and domestic water use, and pipes and equipment.

iv. Salinity: Salinity is the concentration of all soluble salts in water or in the soil. For most horticultural crops more than 2 dS/m will cause reductions in crop yield. In water, salinity is usually measured by its electrical conductivity (EC), which is a measure of the concentration of ions in water or in the soil solution. Salinity limits the ability of the plant to take up water thus stagnating growth.

v. Turbidity: The presence of suspended solids in water affects the level of filtration and irrigation method to use. Water with silts can easily clog irrigation system emitters.

vi. Sodium Adsorption ratio (SAR): this is the proportion of sodium to calcium and magnesium. SAR has a great effect on the soil water infiltration rate.

After the analysis of the water quality, the table below will be filled.

### Table 4: Water Quality parameters

| Water quality parameter | Level | Notes/Comment |
|---|---|---|
| Water pH | | |
| Salinity (EC) | | |
| Sodium Adsorption Ratio (SAR) | | |
| Turbidity | | |
| Hardness | | |
| Iron | | |

## 2.2.2. Plot Characteristics

The plot characteristics are very important considerations for irrigated horticultural farming. These determine the irrigation water requirement and irrigation scheduling.

At the end of this section, you should be able to fill in the following table.

### Table 5: Plot characteristics assessment

| Plot Characteristics | Observation/Results | Notes |
|---|---|---|
| Plot size | | |
| Ownership | | |
| Current usage | | |
| Terrain – flat/hilly, etc | | |
| Soil type | | |

### 2.2.2.1. Plot size

The size of the plot can be estimated by pacing (walking at a steady speed) or using a tape measure. To reliably use pacing, the person pacing is required to determine their pace factor. Pace factor can be determined by pacing an accurately measured distance say 100m. The pace factor is the ratio of the measured distance to the number of paces/steps. For any field measurement, the actual distance is determined by multiplying the number of paces by the pace factor. For more accurate results, a topographical survey can be done. Small plots are more suitable and economically viable for vegetables than fruit trees which typically require a larger area to grow. Additionally, a large area usually implies a higher total water requirement for irrigation.

Example:

Ongom is a technician and has visited the garden of Mr. Odel a famer in his neighbourhood to carry out a quick site survey for his anticipated SPIS. In his experience as a solar technician, Ongom has paced before a distance of 120 meters and attained 125 steps. His pace factor was then determined to be 120/125 =0.96. While at Mr. Odel's garden, he got 28 paces for the longest side and 18 paces for shortest side. The plot size of Mr. Ongom is therefore [(0.96x28) x (0.96x18)] =464.5 m$^2$

Tools/Resources For Field Surveys

- GIS
    - Field Area Measure (App)
    - GPS Essentials (App)
    - Map Coordinates (App)

And many others

### ❖ Ownership of the plot and current usage

Is it rented/hired or privately owned? How is the plot used currently? For example, if it is, or has been, used domestically there are more likely to be contaminants in the soil. If it is used for farming, which crops are currently being grown on the plot? Is there a known or visible need to shift to a different crop?

### ❖ Land Tenure Systems in Uganda

There are basically four legal tenure systems in Uganda.

- Freehold: This grants full ownership of the land
- Mailo: Allows for separation of ownership (mailo owner) from development by registered occupants (bibanja) and unregistered occupants (Bona Fide).
- Customary: Ownership originates from local customary norms and practices. It may be oral or documented
- Leasehold: Created by law or contract. Only tenure available for both citizens and non-citizens.

Land tenure and property rights affects the adoption of technology and development of agricultural land. It is natural that with unsecured property rights farmers do not feel emotional attachment to the land they cultivate, do not invest in land development and will not use inputs efficiently.

It is important to set an irrigation system on a land that the farmer has ownership or access to for a minimum of 12 months.

### ❖ Terrain

Is the plot flat, on a hill, rocky, etc.? The terrain affects the rate of soil erosion and ease of developing horticultural crops. The slope of the field has an impact on the hydraulic flow of the irrigation water in the field, affecting the layout of the irrigation system.

### ❖ Soil Type

Soils can either retain or expel water. Soil type affects the irrigation schedule, crop selection.

Note:

Soil type does not necessarily affect the quantity of the crop water requirement but rather affects the irrigation schedule by either increasing or reducing the frequency of application. For example, if the crop water requirement of a tomato in Unyama is 2 litres per day. On a clay soil, the farmer can decide to apply 1 litre per application twice a day (morning and evening). However, for sandy soils with low water holding capacity, the farmer can apply 0.5 litres per application four times a day.

Soil sampling methods to identify soil type

Soil type can be quickly and easily determined using the do-it-by yourself procedure described as follows.

- Take a handful of moist (but not wet) soil from your garden,
- Squeeze the soil firmly between your hands,
- Then, open your hand.

The following table then identifies the soil type depending on its reaction to this action in the procedures above.

### Table 6: Soil Properties

| Soil Type | Properties | Good for: | Water application |
|---|---|---|---|
| Sand | Does not hold its shape. | Drip irrigation or Sprinkler irrigation | Needs frequent but small irrigation applications |
| Loam | Holds its shape and crumbles when you poke it lightly | Drip, Sprinkler and Surface irrigation | Average irrigation application |
| Clay | Holds its shape and does not easily break when poked | Surface, Sprinkler and Drip | Needs high irrigation applications but less frequent. Due to low infiltration rates, application period is longer. |

The above method gives a rough clue if the soil is loamy, clay or sandy. For more precise results such as silty loam, sandy loam, etc, a laboratory soil analysis is required. Below are some major soil classifications.

<u>Sand</u> is loose and single-grained. The individual grains can be seen or readily felt. Squeezed in the hand when dry, sand falls apart when pressure is released. Squeezed when moist, it forms a cast but crumbles when touched.

<u>Sandy Loam</u> is soil containing a high percentage of sand but having enough silt and clay to make it somewhat coherent. The individual sand grains can be readily seen and felt. Squeezed when dry, a sandy loam forms a cast that falls apart readily. If squeezed when moist, a cast can be formed that bears careful handling without breaking.

<u>Loam</u> is soil having a relatively even mixture of different grades of sand, silt and clay. It is mellow with a somewhat gritty feel but is fairly smooth and slightly plastic. Squeezed when dry, it forms a cast that bears careful handling, and the cast formed by squeezing the moist soil can be handled freely without breaking.

<u>Silt Loam</u> is soil having a moderate amount of fine sand and only a small amount of clay; over half of the particles are of the size called silt. When dry, a silt loam appears cloddy, but the lumps can be broken readily; when pulverized, it feels soft and floury. When wet, the soil runs together readily and puddles. Either dry or moist, silt loam forms a cast that can be handled freely without breaking; when moistened and squeezed between thumb and finger, it does not ribbon but has a broken appearance.

<u>Clay Loam</u> is a moderately fine-textured soil that usually breaks into clods or lumps that are hard when dry. When the moist soil is pinched between the thumb and finger, it forms a thin ribbon that breaks readily, barely sustaining its own weight. The moist soil is plastic and forms a cast that bears much handling. When kneaded in the hand, clay loam does not crumble readily but works into a heavy compact mass.

Clay is fine-textured soil that usually forms very hard lumps or clods when dry and is very plastic and usually sticky when wet. When the moist soil is pinched out between the thumb and finger, it forms a long flexible ribbon. Some clays that are very high in colloids are friable and lack plasticity at all conditions of moisture.

Soil nutrients

Knowing the nutrient status of the soil is important to crop production, specifically helping to determine what crops could do well in that particular soil. Soil analysis is also vital for effective fertility management. For example, soil pH varies, especially with continuous use of fertilizers. The acidity or alkalinity of the soil can interfere with crop growth as pH affects its nutrient uptake from the soil, but, different crops can grow better depending on soil pH (acidic or alkaline).

Soil sampling methods to identify nutrients present in soil

Soil sampling and testing serves as a basis for crop selection. But it can also guide recommendations for addition of nutrients in particular soils on an individual farm, since soil fertility varies within fields and from year to year. Soil sampling requires analysis by a laboratory and is only recommended when concerns are raised regarding the quality of the soil.

Benchmark sampling involves identifying unique areas in the field and sampling each area.

Grid sampling is an accurate but expensive method that helps to develop a nutrient map useful for precision farming. The field is divided into grids for sampling.

Random sampling includes arbitrary samples from the field without any pattern.

Topographic sampling takes samples from each unique topographic area within the field.

Once soil samples have been obtained, they can be sent to any available soil fertility laboratory for analysis. In cases where the farmer may not afford soil testing, preliminary soil texture properties of the area can be obtained from the District Agricultural officer (DAO). The DAO has a soil textural map for the district.

### ❖ Pests and Soil Diseases

Another major management issue that influences crop production is pests and plant diseases within an area. These pests can be fungi and bacteria diseases. These include:

- Bacterial speck, bacterial disease and results in small, black spots on leaves, stems and fruits of tomatoes, at all stages of growth.
- Clubroot, fungus disease that only affects Brassicas (the broccoli family). Plants are yellowish and stunted, with large malformed 'clubbed' roots.
- Leaf spot diseases, type of diseases that can affect beetroot, broad beans, carrots celery, peas, potatoes (early blight) silver beet, and tomatoes (target spot).
- Damping off, fungal disease such as Pythium may kill small seedlings of most vegetables. Seedlings die before they emerge or soon after emergence, which results in plant collapse. Damage may occur all year, mainly in wet conditions. Do not over-water and ensure that plants are not too crowded.
- Powdery Mildew, a fungal disease in warm, moist conditions, white patches occur on the surfaces of older leaves and leaves turn brown and shrivel.
- White mold, a fungal disease that can attack most vegetables, especially beans, celery, lettuce and the broccoli family.

- Wilt diseases, fungal disease such as fusarium, rhizoctonia and verticillium can cause wilting and death of most vegetables, by attacking roots and basal stems.

This is not common, and the following outlined procedures should only be conducted if pests and/or diseases are suspected.

Some pests and diseases may be soil-borne. These diseases can be checked by a scientific system known as the Elisa test or with specific observations based on farming experience. In the Elisa test, soil samples or mashed plant matter are mixed with different chemicals that react with specific pathogens.

Pests can also be identified through pest scouting. Pest scouting is the process of assessing pest pressures through the direct observation of insects and crop performance itself. It can evaluate potential economic risks from the pest infestations and diseases and can also help determine the effectiveness of a chosen pest and/or disease intervention.

There are a number of pests that have emerged especially due to climate change. The farmer may not be in position to identify all pests and diseases even with experience. It is important to always look at to the government agricultural officers for help. These agronomists will advise on the control and prevention methods to apply.

### 2.2.3. Climate

Climate – temperature, humidity, etc. Climate is a determining factor in crop selection, crop water requirement, and irrigation scheduling.

By the end of this section, you should be able to fill in this table.

#### Table 7: Climate assessment

| CLIMATE | Observation/Results | Notes |
|---|---|---|
| Altitude | | |
| Climatic zone | | |

Altitude Influence on Crop Water Requirement and Crop Selection

Altitude, or land elevation, affects the amount and type of sunlight received by crops, potential crop water uptake, and sometimes the nutrient availability in the soil. As such, certain crops can grow well in higher elevations while others can only grow in lower elevations. For example, the main requirement for successful onion production is sunlight hours. A high elevation will then significantly reduce their yield.

A rule of thumb is that the higher you go, the cooler it becomes. As a result, higher altitudes are generally associated with lower plant evapotranspiration rates and therefore lower overall water requirements. Topography (or change in elevation) affects the rate of soil erosion. Some low altitudes are known as sediment deposition zones due to soil erosion from above and water flows over time. Therefore, they are considered to be more fertile and suitable for crop production.

### 2.2.3.1. Temperature

Temperature is important to horticultural production as it affects both the crop water requirement and other processes such as plant respiration and photosynthesis. Plant respiration is the process by which plants take in oxygen and give out Carbon Dioxide, just as we humans do, it is essential to balance the process of photosynthesis during which the plants are taking in the $CO_2$ and releasing the $O_2$ – a process that is unique to plants and essential for the health of the air we breathe.

The optimum growing temperature for most crops is 25⁰C. However, research studies show that some crops' productivity increases with higher temperatures, but generally not exceeding 30⁰C. For example, tomatoes require both higher temperatures and higher water consumption, explaining why most tomatoes do well during the off-season. In general, temperatures below 25⁰C are considered low and those above 29⁰C are considered high. However, temperature needs vary according to crop types and specific variety.

Temperature data can be accessed from a nearby weather station or Uganda National Meteorological Authority (UNMA). The average temperature is obtained by summing the daily maximum and minimum temperatures for every day in that period and then dividing by the total number of days. Alternatively, using FAO CLIMWAT model, the average monthly temperature data of the area can be obtained.

### 2.2.3.2. Humidity

Humidity is the amount of water vapour in the air. The optimum relative humidity for crop production is 50%-70%.

Climate and Weather influence on water requirements and crop selection

Irrigation systems are designed to reliably provide enough water for crops during peak demand periods. Peak daily water requirements occur during the driest months of the year or in the driest areas of the country.

Crops have different water requirements under different weather conditions and growth stages. Sunny and hot weather requires more water per day than cool and cloudy weather.

Table 8: Effect of major weather factors on crop water requirement

| Weather Factor | Crop Water Requirement | |
|---|---|---|
| | High | Low |
| Temperature | Hot | Cool |
| Wind Speed | Windy | Low Wind |
| Humidity | Dry (low) | Humid (high) |
| Sunshine | Sunny (no clouds) | No Sun (cloudy) |

### Table 9: Climatic Zone Characterization[5]

| Climatic zone | Annual Rainfall (mm) | Wet season (months) |
|---|---|---|
| Desert | < 100 | 0-1 |
| Arid | 100-400 | 1-3 |
| Semi-arid | 400-600 | 3-4 |
| Semi-humid | 600-1200 | 4-6 |
| Moist sub-Humid | 1200-1500 | 6-9 |
| Humid | >1500 | 9-12 |

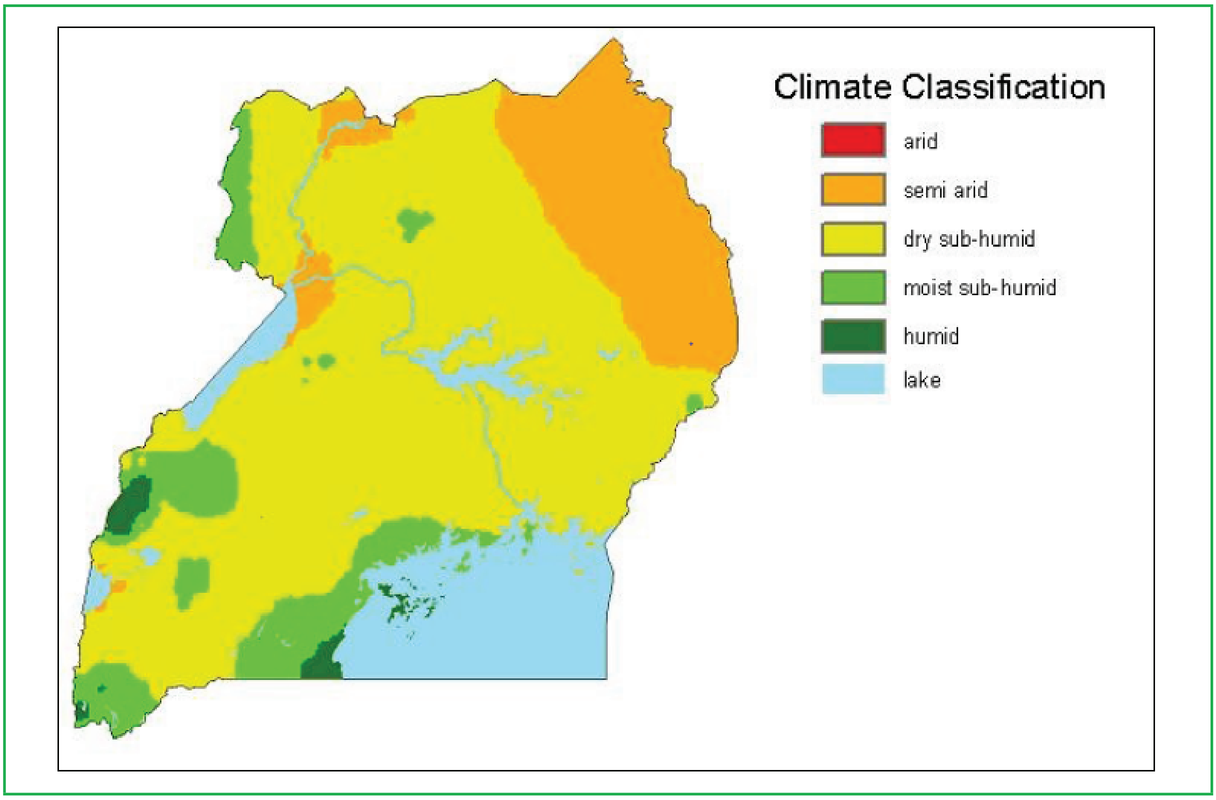



Figure 4: Uganda Climatic Zones[6]

In general, climate data of the nearby weather station for an area can be easily obtained from the FAO ClimWAT for CROPWAT software. ClimWAT is an open-source software that offers climatic data for all weather stations in the world. It can be downloaded from http://www.fao.org/fileadmin/user_upload/faowater/Applications/CLIMWAT2.zip

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### 2.2.4. Considerations for Crop Selection

Crop selection considers water requirement, marketability, and market availability.

You should be able to fill in the below table after this section.

Table 10: Crop Selection

| Crop Selection | Observation/Findings | Notes |
|---|---|---|
| Crop type | | |
| Production time | | |
| Expected yield | | |
| Market value/harvest | | |
| Number of harvests per year | | |
| Water required | | |
| Crop Rotation? | | |

Initial Steps

- ✓ Research the most suitable crop varieties that may present a viable financial opportunity in your selected market.
- ✓ Obtain relevant data on production timing, expected yields, required fertilizers, and quality indicators.
- ✓ Identify potential risks including pest and disease hazards (soil types and location are important contributing factors here).
- ✓ Be familiar with the various farming practices such as the organic method where no synthetic pesticides or fertilizers are used, as well as more conventional techniques where the use of synthetic pesticides and other additives are used to enhance plant growth. Select a production method (organic or conventional) suitable to local conditions, budget, and market demand.
- ✓ Evaluate whether the proposed horticultural enterprise will be profitable.
- ✓ Make an informed decision.

#### 2.2.4.1. Marketability

Crop selection will first depend on what is in demand, i.e. crop marketability, in the local market, regional market, or even global markets. Access to an identified market must be reliable for highest volume of sales. Market availability is therefore critical to crop selection. If crops can be sold at an acceptable or higher profit, and are suitable for the local environment, then they should be a good option. It is advisable to always consult the local government agricultural or commercial officers for market insights before deciding on the crop enterprise to embark on.

### 2.2.4.2. Market Availability

Is your identified market readily accessible, say nearby, or easy to get to? Is transport available? How often does the market occur? Access to the market points, vendors and final consumers should be clearly identified. Approach with the support through the district commercial officers, vendor associations, market associations can be utilised to availability of market.

### 2.2.4.3. Cash crops

These are crops that are produced primarily for their commercial value, or income potential to the farmer, rather than for their value as farm inputs, livestock feed, or home consumption. They are also known as marketed crops. The economic viability of the overall farm enterprise is evaluated before growing such crops.

- **Production time**

This is the number of days, weeks, or months it takes for a plant to grow from seed to its intended harvest. Variations in production times typically stated by input suppliers can be dependent on specific cultivar, seasonal weather, climatic zone, among other factors such as microclimates specific to an individual plot of land. For example, tomatoes may take about 60-80 days[7] from transplanting period while rice may take a minimum of 100-160 days[8] from time of transplanting to harvest time

- **Expected Yield**

Crop yield determines the viability of the horticultural enterprise. It is important to estimate the expected yield per season. Yield can be estimated either using the area of the plot or, more specifically the number of plants grown within that area.

- **Crops (Harvests) per year**

It is important to note that soil needs some time to rest as well otherwise it will become depleted of nutrients and crops will not grow satisfactorily. In line with sustainable practices, farmers are encouraged to carryout rotational crop cultivation so as to boast the soil fertility and nutrient build up for higher yields.  For example, include legumes in the rotation that increase fertility by adding nitrogen into the soil or cover crops that conserve the soil.

- **Market value**

Estimate the potential annual return from a 200 $m^2$ plot. For example, tomatoes are worth 2000 Ugx/kg and you expect 800kgs per harvest and will harvest twice per season.

2000 x 800 x 2 = 3,200,000 Ugx/season

- **Water Requirement**

What is the water requirement for the selected crop? Given the water availability assessed earlier, is this a feasible selection? An example of water requirements for selected crops is given below. It is good enough for an assessment for crop selection to identify the crop of choice as requiring low, medium or high quantities of water.

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7 https://harvesttotable.com/ http://
8 www.knowledgebank.irri.org/

Table 11: Indicative crop water requirements for some crops[9]

| Crop | Crop water need (mm/total growing period) | Sensitivity to drought |
|---|---|---|
| Banana | 1200-2200 | High |
| Cabbage | 350-500 | medium-high |
| Citrus | 900-1200 | low-medium |
| Maize | 500-800 | medium-high |
| Melon | 400-600 | medium-high |
| Onion | 350-550 | medium-high |
| Peanut | 500-700 | low-medium |
| Pea | 350-500 | medium-high |
| Pepper | 600-900 | medium-high |
| Potato | 500-700 | High |
| Soybean | 450-700 | low-medium |
| Sunflower | 600-1000 | low-medium |
| Tomato | 400-800 | medium-high |

### 2.2.5. Fertilization

Does the selected crop require fertilization? How does the fertilizer affect the water requirement or irrigation solu-tion? Is organic or conventional farming a preference?

The fertilizer type affects the irrigation method to be used. For example, a farmer would prefer drip irrigation when using liquid fertilizer since, drip allows it to be directly applied into the root zone. On the other hand, a farmer applying solid fertilizer as top dressing would prefer a sprinkler system.

Organic or conventional farming

The difference between organic and conventional farming is that conventional farming relies on chemical intervention to fight pests, weeds and to provide plant nutrition whereas Organic farming relies on natural principles like biodiversity and composting to produce healthy food. It emphasises the use of manures and composts and excludes the use of artificial/synthetic additives such pesticides on soil and plants.

Table 12: Fertilizer need assessment

| Fertilization Parameter | Observation/findings | Notes |
|---|---|---|
| Amount of fertilizer required? | | |
| Type of fertilizer | Organic/inorganic?<br>Liquid/granular? | |

9 FAO