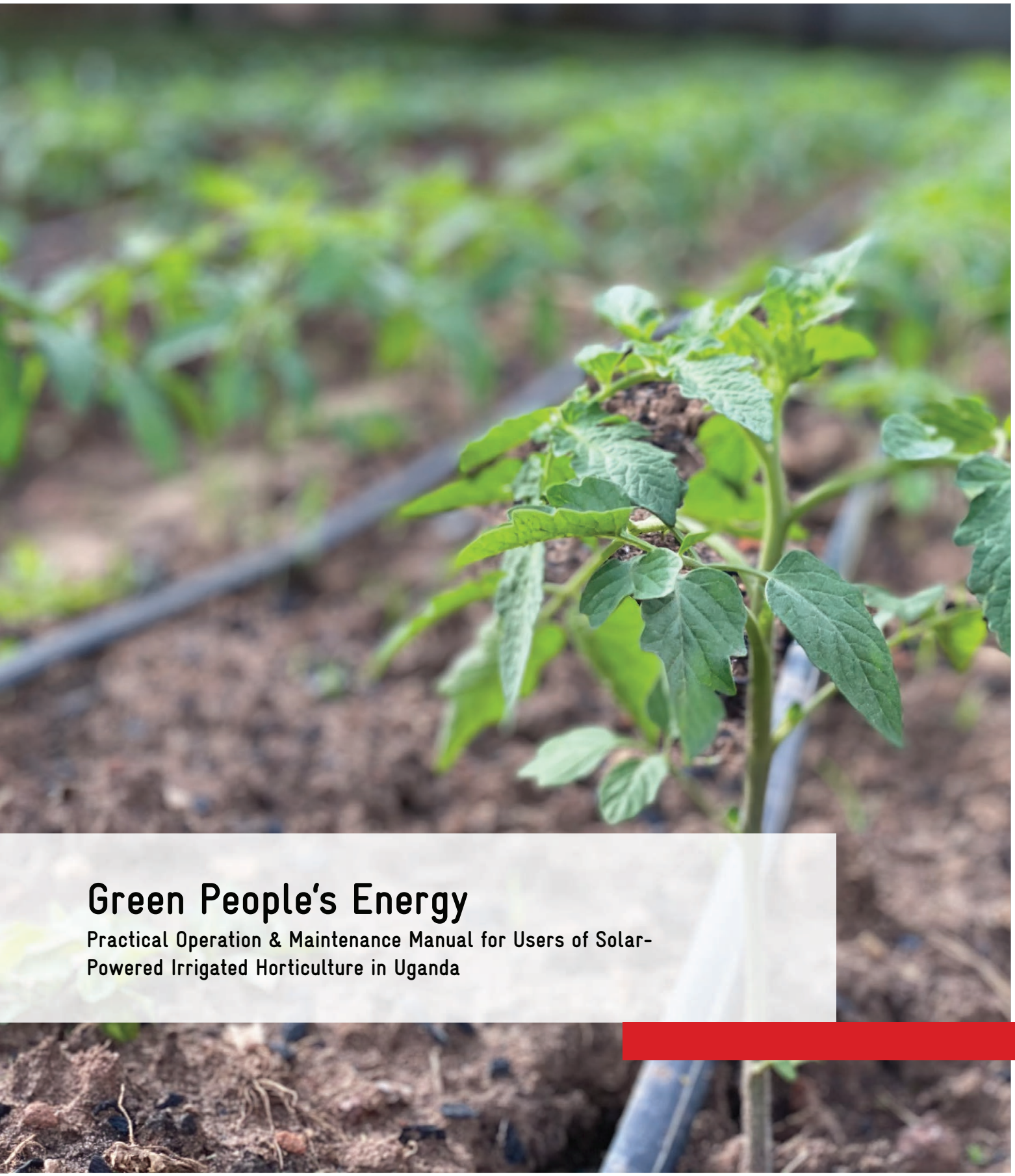

Green People's Energy

Practical Operation & Maintenance Manual for Users of Solar-Powered Irrigated Horticulture in Uganda

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 User Manual at hand, therefore, presents an introduction to solar-powered irrigation systems, safety for solar-powered irrigation systems, and operation and maintenance activities of the system operator. It identifies system components and Dos' and Don'ts expected by the user.

The manual blends the solar water pumping knowledge adapted from the *Solar-Powered Water Supply Practical Design Manual* adopted by the Ugandan Ministry of Water and Environment (MWE), with key critical topics of solar irrigation, best practices of solar-powered irrigation, and good agronomic practices that make investing in a solar-powered irrigation system profitable for horticulture farmers. It hence provides comprehensive Operation and Maintenance guidelines for SPIS Users.

Hopefully, the knowledge provided may prove useful in contributing to increased sustainable uptake of the technology and growth in solar-irrigated commercial horticulture.

Dennis Barbian

Project Coordinator
Green People's Energy, Uganda
June 2021

Acknowledgment

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The project was managed and coordinated by **Lukia Nabawanuka, Santa Akanyo and Muceka Rolex,** GBE Technical Advisors, and implemented by the consultant Engineers Without Borders - 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 User Manual are appreciated.

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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

AC	Alternating Current
BMZ	German Federal Ministry for Economic Cooperation and Development
CWR	Crop Water Requirement
DC	Direct Current
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
MEMD	Ministry of Energy and Mineral Development
NGO	Non-Governmental Organization
NPSH	Net Positive Suction Head
O&M	Operation and Maintenance
PREEEP	Promotion of Renewable Energy and Energy Efficiency Programme
PRUDEV	Promotion for Rural Development in Northern Uganda
PV	Photovoltaic
SPIS	Solar Powered Irrigation System

BACKGROUND AND STRUCTURE OF THIS MANUAL

One of the key challenges that affect the adoption of SPIS usually revolve around the poor operation and maintenance of the systems for their sustainable use. The SPIS is a relatively recent technology of which uptake is on the rise mainly attributed to its low O&M requirements. The systems are operated and maintained by *operators* and *technicians* with varying levels of qualification and experience. In the case of small SPIS, the operator is the farmer or farmer group.

The manual is divided into three sections:

The **Solar-Powered Water Pumping for Irrigation** section gives a general introduction to solar pumping for irrigation, the equipment one will find and some general rule of thumb considerations. It further looks at the pros and cons of solar water irrigation.

Important Safety Considerations discusses safety measures needed to protect maintenance personnel and system users from site electrical, mechanical and hydraulic hazards.

The **Operation and Maintenance** section aims at providing practical information for the operators in charge of routine operation and basic preventive maintenance. It further provides installation guidelines and steps for an irrigation system, irrigation scheduling, care and maintenance of crops so as to achieve high yields. It outlines when and how to complete typical monitoring tasks. It also provides basic assessment procedures to determine if technicians need to be contacted to complete more complicated system repairs.

Following this manual will provide quality support and safety for the SPIS in place while minimizing operation and maintenance costs.

Audience and User Information

This manual is intended for use by the farmer or technician in charge of day-to-day upkeep of the irrigation system including preventative maintenance of the solar equipment and maintenance of the irrigation solutions.

1. INTRODUCTION TO SOLAR POWERED IRRIGATION SYSTEMS

It is common knowledge today that the primary source of energy supporting all forms of life is the sun. With the ever-increasing concern about the environmental impact of some sources of energy including petroleum, gas and coal, harnessing solar energy is a logical alternative. Photovoltaics are an excellent alternate energy source for water pumping systems.

A Solar Powered Irrigation System (SPIS) is like any other irrigation system, except its power source is solar energy. In SPIS, we can divide the system into two: the water pumping side and the irrigation side. Water from a source like groundwater or surface water is pumped through a pressured line. The suction force (energy) is powered by the solar panels. The water is then stored in an elevated tank. For economical use, since batteries are not used to store energy, energy is stored in the form of water in the elevated tank. Based on the preferred method of irrigation, water is then spread out to the farmlands or field by gravity flow. The system is sized in a way that water reaches the furthest end of the irrigated area.

Solar pumping technology covers the entire energy conversion process, from sunlight, to electrical energy, to mechanical energy, to stored energy.[1] The solar irradiation is captured by the solar panels, which then converts the sunlight into electricity. Through a control/combiner box, whose major function is to condition the electricity from the panels, the pump motor is powered, and this drives the pump to pump the water into the reservoir. Water from the reservoir is then supplied to the irrigated area. The Figure 1 below (p.13) illustrates major components and the basic functional principle of a Solar Powered Irrigation System.

1.1. Appropriate application of solar energy in water supply

- Small scale irrigation
- Portable water supply for institutions
- Community scale water supply schemes for gravity-fed and stand-alone solar powered water systems
- Large systems serving rural growth centres (with or without the use of a solar-hybrid power combination to cover the full scope of the demand)
- Large scale water supply schemes using a solar-hybrid power combination to cover the full scope of the demand
- Livestock water supply

1 World Bank. 2018. "Solar Pumping: The Basics." World Bank, Washington, DC.

1.2. Advantages of use of solar solutions

- Low Operation and Maintenance costs
- Zero Pollution
- Year-round supply increases outputs/income
- Can be installed anywhere
- Highly reliable technology
- Increasingly more affordable

1.3. Risks and challenges with uptake of solar solutions

- High Capital Cost
- Need for innovative financing models or subsidies
- Limited Servicing Infrastructure
- Pumping limited to hours of solar radiation
- Water output determined by initial system design
- Need for increased capacity of local technicians and preventative maintenance for users at time of installation and operation

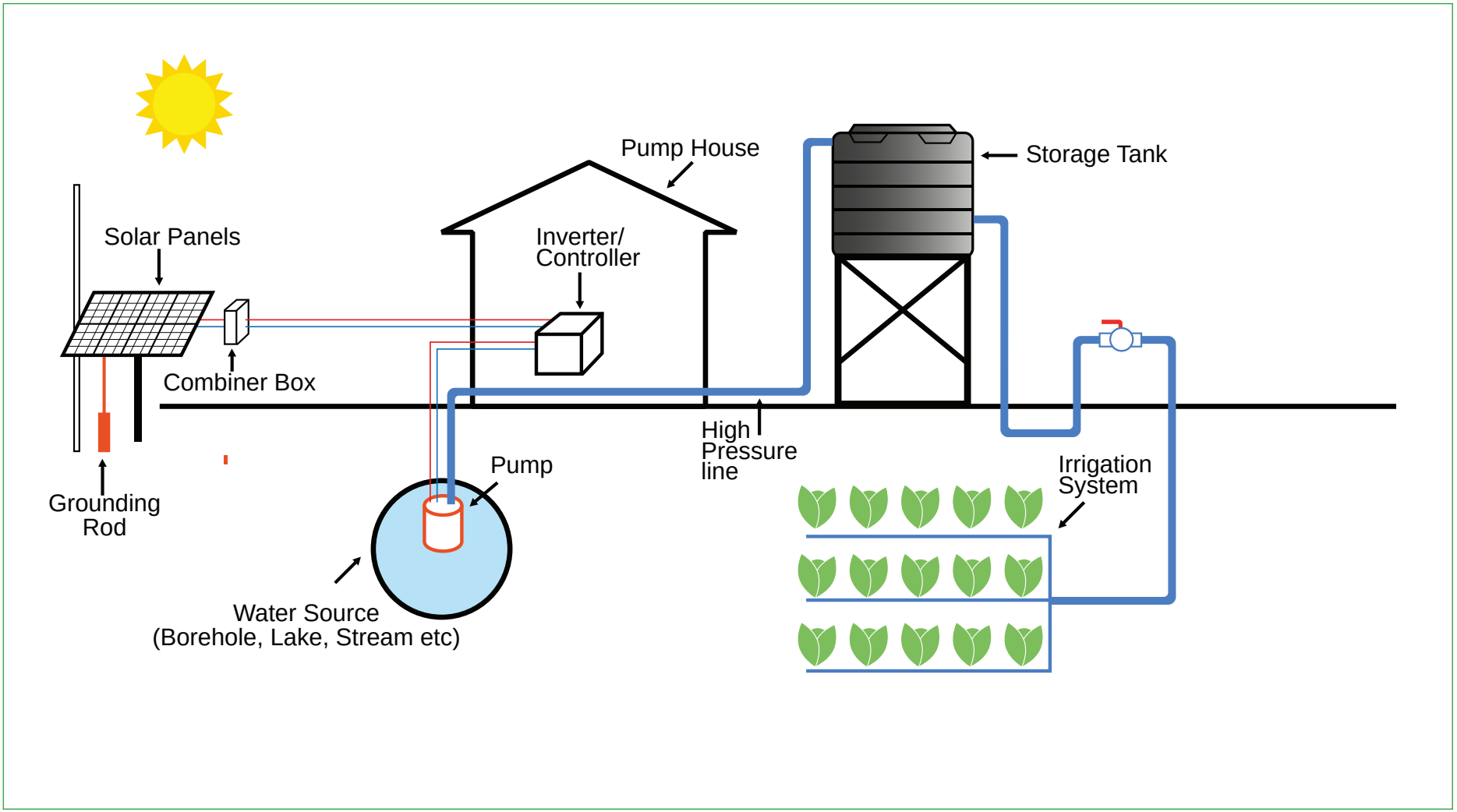

Figure 1: Illustration of a typical water pumping and irrigation system

1.4. Components of Solar Powered Irrigation Systems

The main difference between Solar Powered Irrigation Systems and pumping with grid or generator power is the source of energy. SPIS usually comprise the following components as shown in Figure 1 above and Figure 2 below.

The system can be separated into a Solar Pumping system which includes the power source, the pump and motor, the well, the high-pressure line to the storage tank and the irrigation system which includes the sub mains, the lateral lines and emitters (drippers or sprinkler heads) as per the irrigation method. Figure 2 below is an example of the components of the SPIS with the component locations. These two systems i.e., the pumping side and the irrigation side are joined at the water storage tank but operate independently and are maintained with different types of skills. The operator monitors both systems and implements most repairs of the irrigation system.

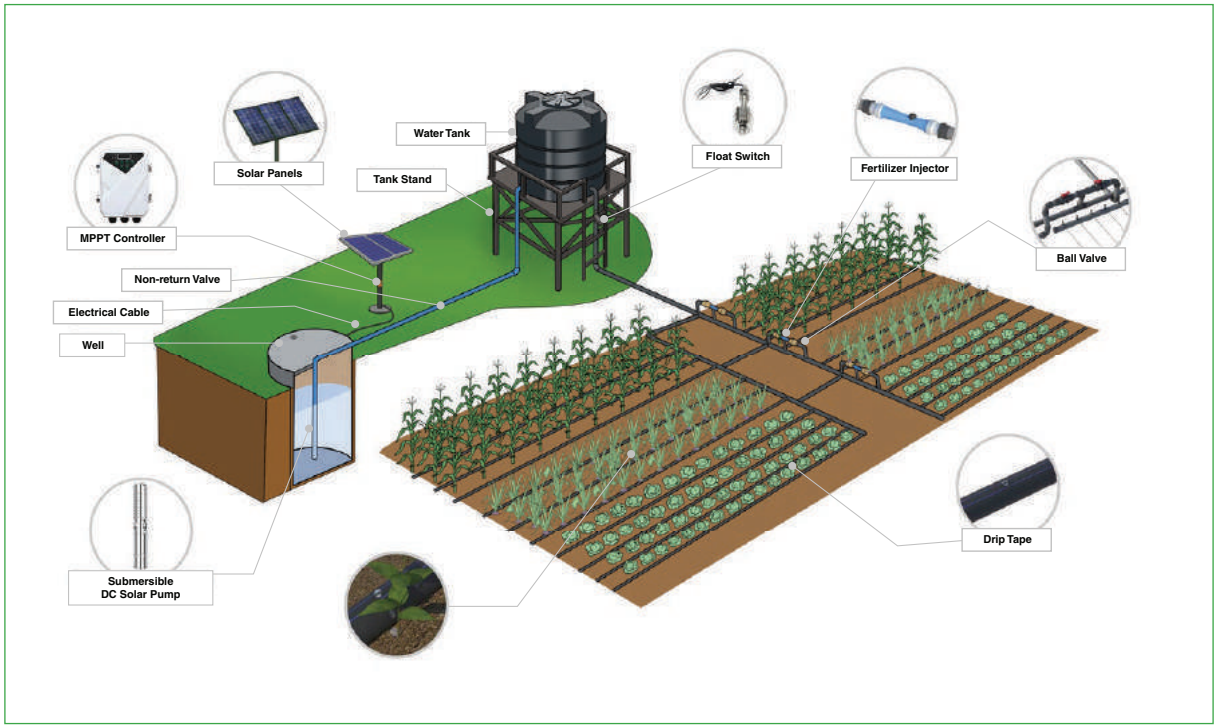

Figure 2: Illustration of the components of a typical SPIS[2]

1.5. Common Irrigation Methods

There are three common types of irrigation practiced in Uganda. Namely, drip, sprinkler and flood irrigation. Other irrigation types/methods like drop hose and hand watering are considered small scale and only practiced when conditions for their use are favourable. The common types of irrigation are elaborately discussed below.

1.5.1. Drip irrigation

This is a localized mechanism of irrigation where water is applied slowly to the soil through mechanical devices called emitters. Drip irrigation is the most water efficient method of irrigation though it is considered expensive. It has a water efficiency range between 90%-95%of water use.[1] In this type of irrigation, there is minimum wastage of water because water is applied directly to the plant roots.

2 engineeringforchange.org

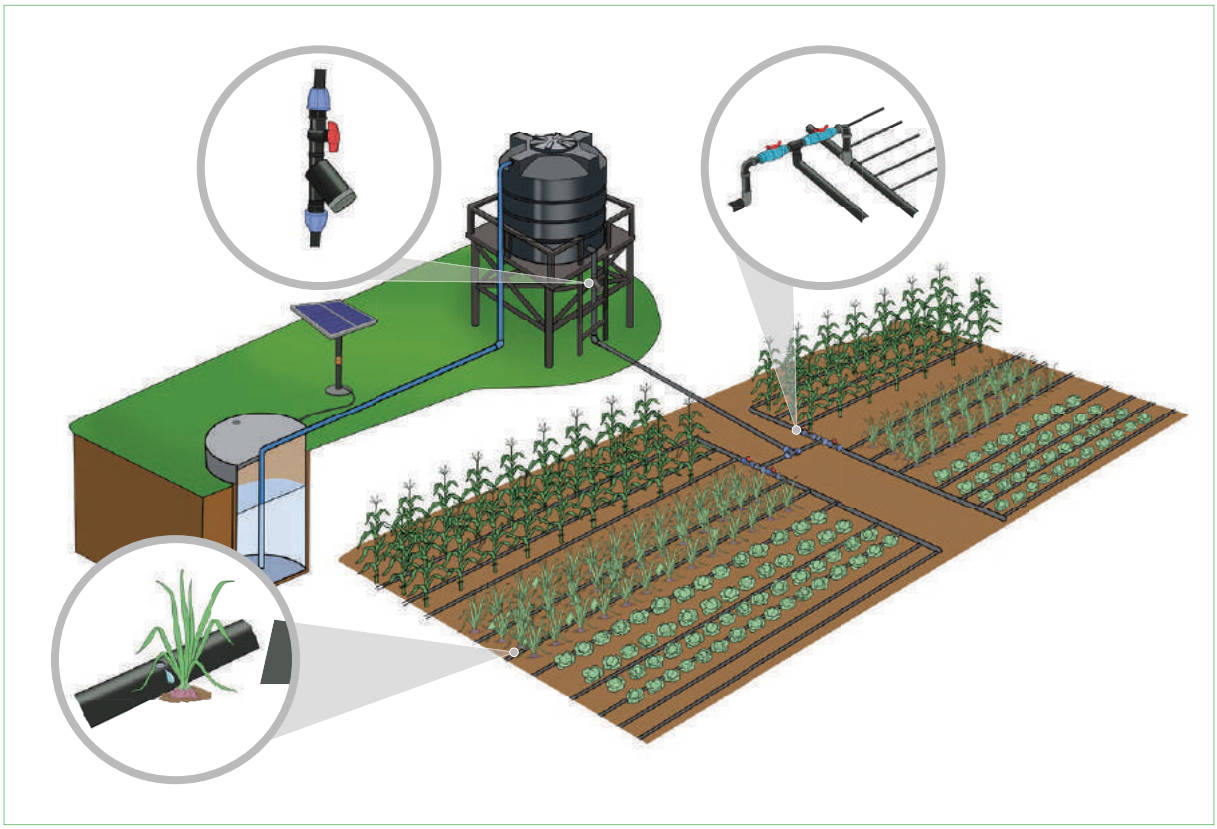

Figure 3: Illustration of a layout and components of a drip irrigation system

The components of the drip irrigation can be illustrated as shown and described below:

a. Water pumping System

The water pumping system comprises solar panels, a pump and a delivery pipeline into an elevated tank. A number of fittings are usually placed along this system for example to monitor the amount of water being drawn, for back washing and other purposes based on the system design.

b. Water Filters

Water filters are an essential part of every system to prevent silt and other debris from entering the system to prevent clogging of the emitters.

Drip irrigation equipment distributors supply various types of in-line filters to fit the different setups including media, screen, and disk filters, as well as sand separators. Each is designed for use based on different water sources.

c. Valves and Gauges

There are a number of valves and gauges used with drip irrigation systems, especially those designed to water multiple areas from the same water source.

Manual and automatic gate, ball, solenoid, and anti-siphon valves are used to control the flow of water to the different areas.

Water meter gauges measure the flow of water passing through different parts of the line.

Air release valve especially along the high-pressure line to curb and release any air generated during the suction process along the line.

Non-return valves prevent the backflow of water into the water source in case the system is closed or during maintenance.

d. Chemical Injectors

Drip systems usually facilitate the delivery of fertilisers and pesticides to the plants as anti-clogging agents to the drip nozzles.

Chemical injector devices placed inline send these chemicals through the water feed at a programmed rate to mix with the water flowing through the lines and to the plants.

e. System Controller

The last part of any drip system is the programmable controller that regulates the amount of time the water is passing through the delivery lines and to the fields. These are available as manually programmed types that simply turn on and off as programmed.

There are also computerized models that can detect soil conditions and turn on and off as required to keep plants appropriately watered.

1.5.2. Sprinkler Irrigation

Sprinkler irrigation is a method of applying irrigation water which is similar to natural rainfall. Water is distributed through a pressurized line to an elevated storage tank. and then sprayed into the air through sprinklers so that it breaks up into small water drops which fall to the ground.

Sprinkler irrigation is suited for most row, field and tree crops and water can be sprayed over or under the crop canopy.

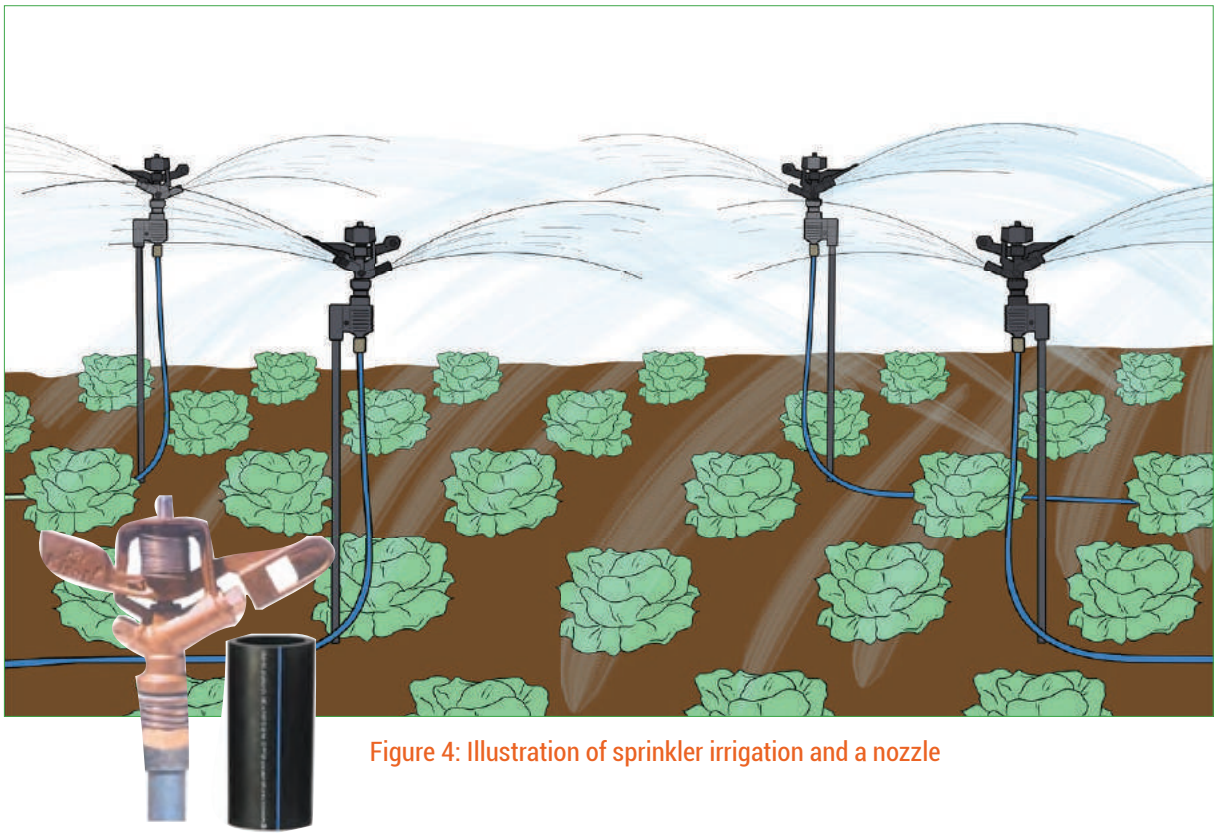

Figure 4: Illustration of sprinkler irrigation and a nozzle

A sprinkler system consists of the following components:

- A pump unit
- Tubing-main/sub mains and laterals
- Couplers
- Sprinkler Head
- Other accessories such as valves, bends, Plugs and risers

a. Pumping Unit:

Sprinkler irrigation systems distribute water by spraying it over the fields. The water is pumped under pressure to the fields. The pressure forces the water through sprinklers or through perforations or nozzles in pipelines and then forms a spray. A high speed centrifugal or turbine pump can be used for operating sprinkler irrigation for individual fields. Centrifugal pump is used when the distance from the pump inlet to the water surface is less than eight meters. For pumping water from deep wells or more than eight meters, a turbine pump is suggested. The driving unit may be either an electric motor or an internal combustion engine.

b. Tubing: Mains/sub mains and laterals:

The tubing consists of mainline, sub mains and laterals. Main line conveys water from the source and distributes it to the sub mains. The sub mains convey water to the laterals which in turn supply water to the sprinklers. Aluminium or PVC pipes are generally used for portable systems, while steel pipes are usually used for centre-pivot laterals. Asbestos, cement, PVC and wrapped steel are usually used for buried laterals and main lines.

c. Couplers:

Couplers are used for connecting two pipes and uncoupling quickly and easily. Essentially a coupler should provide;

- ✓ A reuse and flexible connection
- ✓ Not leak at the joint
- ✓ Be simple and easy to couple and uncouple
- ✓ Be light, non-corrosive, durable.

d. Sprinkler Head:

Sprinkler head distribute water uniformly over the field without runoff or excessive loss due to deep percolation. Different types of sprinklers are available. They are either rotating or fixed type. The rotating type can be adapted for a wide range of application rates and spacing. They are effective with pressure of about 10 to 70 m head at the sprinkler. Pressures ranging from 16 to 40 m head are considered the most practical for most farmers. Perforated lateral lines are sometimes used as sprinklers. They require less pressure than rotating sprinklers. They release more water per unit area than rotating sprinklers. Hence fixed head sprinklers are adaptable for soils with high intake rate.

e. Fittings and accessories:

The following are some of the important fittings and accessories used in sprin-kler system.

- ✓ Water meters: It is used to measure the volume of water delivered. This is necessary to operate the system to give the required quantity of water.
- ✓ Flange, couplings and nipple used for proper connection to the pump, suction and delivery.
- ✓ Pressure gauge: It is necessary to know whether the sprinkler system is working with desired pressure to ensure application uniformity.
- ✓ Bend, tees, reducers, elbows, hydrants, butterfly valve and plugs.

- ✓ Fertilizer applicator: Soluble chemical fertilizers can be injected into the sprinkler system and applied to the crop. The equipment for fertiliser application is relatively cheap and simple and can be fabricated locally. The fertilizer applicator consists of a sealed fertilizer tank with necessary tubing and connections. A venturi injector can be arranged in the main line, which creates the differential pressure suction and allows the fertilizer solution to flow in the main water line.

1.5.3. Drag hose irrigation system

This is a low-cost irrigation technique where a hose pipe is connected either directly to the main line or to a raised tank and dragged around the field by the farmer. It is a very tedious and time-consuming method. It is also mostly associated with lack of knowledge on the amount of water applied and less irrigation uniformity. However, it is simple and inexpensive since even a small pump can run it. More so it can be a starting point for farmers who are just adopting irrigation.

Figure 5: Illustration of a drag hose method of irrigation

The components of a drag hose are limited as compared to the drip and sprinkler that have a number of the components for its complete installation. These include:

1. Pipe line

These consist of any pipe material which could be uPVC, HDPE or lay flats that serve as manifold with hydrants to which the laterals are connected.

Other fittings and accessories such as filters, couplers could be connected to the system. In most cases a sand filter is the inlet pipe of the main line. Water is then oozed out from nozzles or directly through the pipe outlet by dragging to the field land.

1.6. Operation and Maintenance

The operation and maintenance of solar-powered irrigation systems includes the care and preventative maintenance of the solar electrical and pressurized piping system and the repair of the irrigation system as needed.

1.6.1. Definitions and Terminology

"**Operation**" is ongoing, recurring day-to-day work involved in the running of a technical facility for the purpose of producing value for beneficiaries or users. Activities associated with operation include but are not limited to controlling system parameters, scheduling and conducting inspections as well as monitoring and overseeing of facilities and processes.

"Preventive Maintenance/Servicing" is the routine recurring work required to keep a facility or scheme in such condition that it may be continuously used at its original or designed capacity and efficiency for its intended purpose. Typically, it includes tasks such as adjusting, lubricating, cleaning, and replacing components.

Diagnostics and Testing are the procedures taken to ascertain the source of failure when it is not obvious.

"Corrective Maintenance/Repair" comprises repair activities necessary to re-establish proper functioning condition or service of equipment. It may be both planned and/or unplanned. Some equipment at the end of its service life may need overhaul.

"Overhaul" is the complete restoration of equipment returning it to useful condition via appropriate and recommended maintenance.

1.7. Irrigation Scheduling

Based on the design by the technical person, the operator should be able to understand the irrigation scheduling as instructed.

Irrigation scheduling indicates how much irrigation water must be given to the crop and how often i.e., when this water is given.

How much and how often water must be given depends on the irrigation water need. This is calculated by the technician with prior knowledge to the climate factors, soil types and the crop type.

As an operator, when to irrigate is a very crucial decision in scheduling for example, let's assume the irrigation water need of a certain crop is 6mm/day. Does this mean we have to apply 6mm of irrigation water every day?

In theory, yes. Water could be given on a daily at once, however in practice water can be supplied for even a longer period of time based on the soil as it can be stored in the root zone and gradually used by the crops/plants.

The irrigation interval has to be chosen in such a way that the crop will not suffer from water stress or even flooding. Thus, the operator should understand how often to irrigate in such a way as to prevent the plants from suffering from water stress and how much to irrigate keeping in mind the soil water holding capacity. An effective irrigation schedule helps to maximize profits while minimizing water and energy use.

1.7.1. Irrigation scheduling plan

The following factors are considered when developing a workable and efficient irrigation schedule:

- Soil properties (texture and structure)
- Type of crop and its sensitivity to drought stress (root depth, crop water requirement (CWR)).
- Stage of crop development
- Climatic factors such as rainfall and temperature
- Geographic locations and daylength
- Availability and reliability of a water source
- The presence of shade trees and overhead elements
- Seasons

However, the above factors can be hard to find for a farmer thus a rule of thumb can be applied.

Rule of the thumb: In absence of data during design of small irrigation systems for the Ugandan environment during the dry season, the following can be considered:

- For vegetables, an average of one (1) litre per plant per day, or approximately 4 litres of water per square meter per day.
- For young fruit tree plants, approximately 6 litres per plant per week
- For mature fruit tree plants, approximately 12 litres per plant per week.

For example, if the crop water requirement of a tomato in Unyama is 1 litre per day. On a clay soil, the farmer can decide to apply 0.5 litre per application twice a day (morning and evening). However, for sandy soils with low water holding capacity, the farmer can apply 0.25 litres per application four times a day. Thus, the rule of thumb shall greatly be dependent on the soil type.

In addition to the soil type, the crop growing stages are vital factors in terms of irrigation scheduling. The total growing seasons of an annual crop can be divided into four stages:

i. The initial stage- from sowing to 10% ground cover
ii. The crop development stage- from 10% to 70% ground cover
iii. The mid-season stage- includes flowering and yield formation
iv. The late season stage-including ripening and harvest

In general, it can be stated that of all the four stages, the mid-season stage is the most sensitive to water shortages. This is mainly because it is the period of highest crop water needs. If the water shortages occur during this season, the negative effect on the yield will be pronounced. The least sensitive to water shortages is the late season stage. This stage includes ripening and harvest. Water shortages in this stage have only a slight effect on the yield especially if harvested dry. Care should however be taken even during this stage with crops which are harvested fresh such as lettuce. Fresh harvested crops are sensitive to water shortages during the late season stage. The initial and crop development stages are between the mid-season and late season with respect to sensitivity to water shortages. Some crops react favourably to water shortages during the crop development stage, they react by developing a deeper root system which is helpful during the later stages. In general, crops grown for their fresh leaves or fruits are more sensitive to water shortages than those grown for their dry seeds and fruits.

Table 1: Table showing sensitivity of various field crops to water shortage (Dr. N. Sai Bhaskar Reddy,2016)

Sensitivity	Low	Low - Medium	Medium - High	High
Crops	Cotton	AlfaLfa	Beans	Banana
	Millet	Citrus	Cabbage	Fresh Green Vegetables
	Pigeon Pea	Grape	Maize	Potato
	Sorghum	Groundnuts	Onion	Gugar
		Soybean	Peas	
		Sugar Beet	Pepper	
		Sunflower	Tomato	
		Wheat		

By using careful management and sound irrigation scheduling practices, the farmer can realize the direct savings in water, fertilizer, pesticide, herbicide, and farm labour. In addition, many farms have seen improvement in quality and quantity of their yields.

1.7.2. Determination of the soil moisture

Farmers can be informed by practical methods and measures of the wetness of the soil i.e., soil moisture. The amount of water held in soil is an important component in irrigated farming. Soils typically contain a finite amount of water, which can be expressed as the soil moisture content. If the pore space is occupied entirely by air, the soil is completely dry. If all the pores are filled with water, the soil is saturated.

In outdoor environments, water is added to soil naturally through rainfall or deliberately with the irrigation of plants. As the pores in the soil become filled with water at the expense of air, the soil moisture increases. This can be known by a physical touch as you press the soil in between your palm or the hands. If the soils are sticky and wet, the grains/particles are held together into crystalline shapes however when dry, they scatter into finite particles. When all the pores are filled with water, the soil is saturated. If the soil at the surface is saturated, excess water will leach downward through pores into deeper soil. Thus, one can be informed on when to irrigate.

On the other hand, one can use their finger or a stick into the soil-depth, if the material used comes wet, then the soil has some moisture and if it's dry then this implies the moisture in the soil is drained up. This can help inform the farmer however the reliability of this method is not recommended.

A tensiometer can also be used to determine the soil moisture. A tensiometer is a sealed, airtight, water-filled tube (barrel) with a porous tip on one end and a vacuum gauge on the other as seen in Figure 6. A tensiometer measures soil water suction (negative pressure), which is usually expressed as tension. This suction is equivalent to the force or energy that a plant must exert to extract water from the soil. The instrument must be installed properly so that the porous tip is in good contact with the soil, ensuring that the soil-water suction is in equilibrium with the water suction in the tip. The suction force in the porous tip is transmitted through the water column inside the tube and displayed as a tension reading on the vacuum gauge.

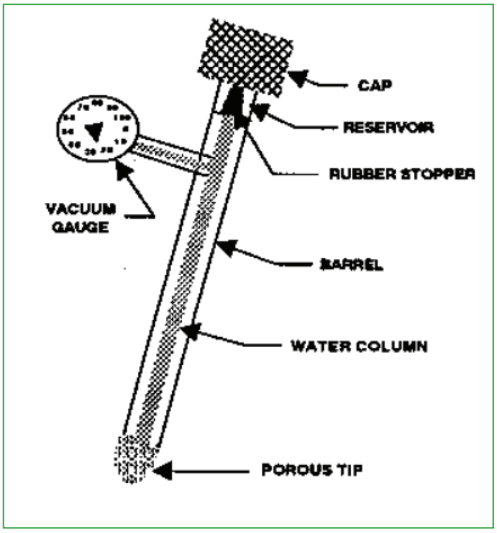

Figure 6: Diagram of a tensiometer[3]

3 Source : https://content.ces.ncsu.edu/measuring-soil-water-for-irrigation-scheduling

1.7.3. General care of crops

General care for crops refers to the actions taken to protect crops from nutrient deficiency, weather, or pests and diseases.

Farmers are encouraged to engage in the following practices so as to improve yields and produce:

- Thorough check of the soil moisture to always ensure that crops have sufficient water. i.e., the crops should not dry up.
- Mulching, application of organic mulches of compost, leaves, straw or well-rotted manure to keep weed growth minimal and continuously feed the plants as nutrients leach into the soil. This can also help in pest management.
- Frequent application of fertilizers, these boost the soil fertilizer and eventually better yields.
- Weed routinely: Weeds will compete for space, water and nutrients. Young seedlings are most at risk of suffering. To minimize the amount of weeding that is necessary, mulch. Care while using agrochemicals can be adopted. Agrochemicals should be adopted with care to ensure that those used pose no threat to human or environmental health since some of these are not accepted. This can be informed by data from UN.
- Check for insects and diseases: Watch out for unhealthy soil, diseased plants or an increase in insect activity. Spotted early, most problems can be easily overcome. Check plants routinely.
- Harvest in time: Many vegetables should be harvested as soon as they are mature, or they will go to seed (e.g., lettuce, broccoli, cabbage) or become tough and woody in texture (e.g., kohlrabi, turnips, beets). Other crops can be picked over a period of weeks; frequent picking actually encourages new growth and increases yields (e.g., peas, Swiss chard, beans, squash, cucumbers).

1.8. Record keeping

Record keeping for a farmer shall be a vital obligation in the O & M of the SPIS. A farm record is a document (in most cases a book) that is used to keep account of different activities, events, materials etc. regarding the farm operations. Farm records are different from farm accounts in the sense that farm accounts deal only with the financial aspects of all farm operations. Thus, a farmer should be able to take note of when he / she starts the season, i.e., land preparations until the final harvest season. In addition to this, the farmer should be able to tell the rainy and wet season within the area to better plan his/her cultivation period.

As any successful farmer should keep detailed and accurate farm records to lessen and smoothly carry out the operations within the fields. While taking note of the manure application, irrigation method or seed planting date, which might seem tedious and time-consuming in the short term, you'll be glad you did when the time comes to harvest your crops. Record-keeping will help your operation in many ways, some of which will be apparent immediately and others of which might have an impact five to 10 years down the line.

Below are seven charts that you can use for your field land.[4]

i. Soil conditioning chart

There is a need to know the nature or texture of soils that you shall be dealing with. These may require laboratory soil tests however on ground and simple experiments can be done to especially determine the texture of the soil, the soil moisture content and the nature by physical measures. A better understanding the soil's condition can help in improving the application of water, choice of enterprise of crops that can be cultivated. By recording this information, you can determine what amendments work for each crop and track the amount of amendment used for future purchasing decisions. Using this chart is equally important on a small plot as on a large plot.

4 https://www.hobbyfarms.com/

ii. **Seed starting chart**

This is especially important when the seeds are planted within the greenhouse or nursery bed until the time of transplanting to the field lands. Since not all seeds are started at the same time, it is helpful to keep seed-starting records if you're experimenting with new crop varieties or if you're managing a large amount of seeds. Not all planted seeds will germinate, so tracking germination rates will indicate how much seed you need to purchase for future plantings. It's also a good idea to record seed sources, but especially important if you're pursuing or maintaining organic application of fertilisers.

iii. **Planting chart**

Recording plot location and planting date will help you make future plot-rotation plans; plus, knowing the bloom or fruit date enables you to plan for harvests in subsequent periods and years. Be sure to take note of plant traits so you can determine what land-management actions to take, such as adding amendments or implementing pest control. As with seeds, you'll need to document sources of organic transplants.

iv. **Harvest chart**

This can be combined with the planting chart that indicates the harvest dates based on when these crops have been transplanted into the field's lands.

v. **Pest management chart**

By keeping these charts, whether for a small-scale or large-scale garden, you can identify the biggest pest threats to your produce and determine which management techniques are most effective.

vi. **Irrigation chart**

Watering is important to raise a crop successfully, and it is possible to both under- and over-water a plot. The information you log about the amount of water a plot receives and the method used to irrigate could come into play at a later date. This can be come up with during the irrigation scheduling with agronomist support in managing the varying rainy partners and seasons.

vii. **Equipment chart**

This shall entail all the equipment that is within the farm/field. From the electrical, mechanical components to the various irrigation accessories that are owned by the farmer.

2. SAFETY FOR SOLAR POWERED IRRIGATION SYSTEMS OPERATIONS

Personal safety is paramount and must come before the safety of the system.

You are responsible for your own safety. Always evaluate risks to your safety before proceeding with any work on the system. If conditions change, pause and re-evaluate risks. If you feel unsafe, STOP. Never proceed with any task that may be unsafe. If in doubt always call a technician.

This section is broken into the following categories:

i. Personal Protective Equipment
ii. Electrical Hazards
iii. Equipment Safety and Care
iv. Chemical Hazards
v. Fire Hazards
vi. Personal Safety

2.1. Personal Protective Equipment (PPE)

Personal Protective Equipment should be provided by the System Management and includes:

Hard Hats – to be used when climbing to heights above 2 m and when there is a danger of items falling from above. This shall be mainly for maintaining (cleaning purposes or during routine checks) the storage tank that is installed above the ground.

Respiratory protection – to be used when working with chemicals especially during mixing of pesticides and spraying periods during pests and disease management.

Gloves – to be used to protect the hands when working with chemicals.

Gumboots – These shall specifically be used as footwear for the farmers. These protect the farmer from bites especially from snakes and ease of movement especially in bushy areas and during daily cultivation practices.

2.2. Electrical Hazards

⚠ **Energized systems can be lethal when handled inappropriately, even if they appear to be unpowered. Always take extreme care and treat electrical systems with extreme caution.** ⚠

The operating voltages of Ugandan solar pumping systems, which are commonly at or above 600 volts direct current (DC), present a serious electrocution hazard, even with dry skin.

Proper maintenance and safety procedures protect both maintenance personnel and individuals collecting water from the system. A quality electrical design always takes electrical hazards into account from the beginning and implements safe practices to eliminate electrical exposures. Appropriate training of operators and technicians is essential to maintain these safety practices.

2.2.1. Damaged or Bare wires

- Wires with worn or degraded insulation which may have no visible damage
- Improperly specified or improperly installed wiring and equipment
- Partially connected electrical equipment
- Any operating equipment either powered ON or OFF
- Conducting material or standing water in contact with electrical equipment
- **All electrical equipment is potentially hazardous and should be treated with extreme caution even when power appears to be OFF!**

Safe wiring can become unsafe over time. Avoid creating a dangerous environment by ensuring wires are strung properly without damage to the wire.

Figure 7: Example of damaged insulation and bare wires. [5]

2.2.2. Solar Panels

⚠ **Solar panels have unique characteristics that make them difficult to work on safely. Adhering to safety guidelines is of utmost importance since solar panels are energized anytime the sun is up. Doing maintenance during night hours is not safe or practical.** ⚠

General Recommendations for Safety when working on Solar Panels

5 Liivet, A. (2019, April 19). Dangerous Wires. Retrieved from Flickr, Yahoo!: www.flickr.com/photos/23108377@N07/46729239405 Content available under Creative Commons (CC).

i. Do not work in bad weather.
ii. Do not sit on the solar module.
iii. Cover the solar modules while working on them.
iv. Do not wear metallic jewellery when working around electrical components.
v. Work with someone.
vi. Have a good ladder to reach the solar modules for cleaning and repairs in conditions when they are installed at heights not reachable while on the ground.
vii. Wear gloves when working with solar panels.

Grounding and Bonding

⚠ **Operators should never remove any electrical equipment covers. If removed covers or uninsulated wiring are found, do not touch these components. Immediately contact a certified Technician for support.** ⚠

A grounding and bonding system connects a grounding electrode to all metallic electrical enclosures which can contact electrical conductors in the event of insulation breakdown and is required by the IEC safety standards referenced in this report. A grounding electrode must be included in the system design and maintained in proper working order to protect personnel and users of the solar pumping system. This design creates a protective barrier around energized conductors and equipment.

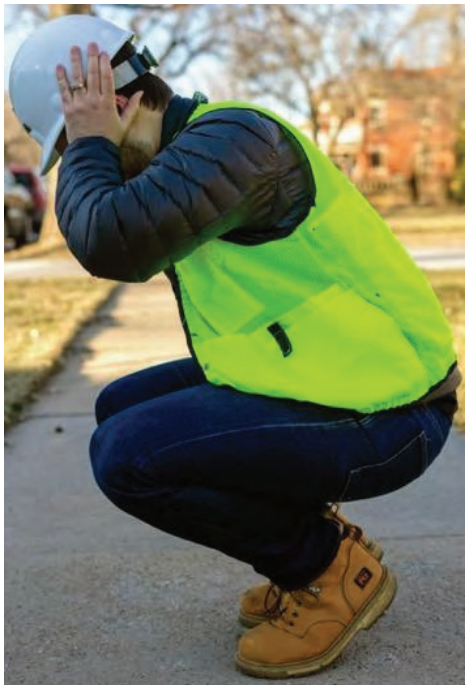

Figure 8: Illustration of how to do a Lightning couch[6]

Lightning Storms

⚠ **Never service a solar powered Irrigation system during a lightning storm.** ⚠

Due to the increased risk of shock, SPIS should never be serviced or actively managed during a lightning storm. Pumping system structure and components may attract direct lightning. Lightning rods are intended to ground the lightning strike and disperse it through the ground, this creates a physical danger zone around the entire area that receives a lightning strike.

During a storm, quickly move away from the system and lightning rod without delay. Always remain outside the fenced solar panel enclosure and pump house when lightning is a threat. Also ensure that no one enters the system premises during storms. If you are accidentally caught near the solar panel system during a storm, as a last resort protective measure only, put your feet together as closely as possible so that you can squat close to the ground without touching the ground (or concrete) with your hands. This is demonstrated in Figure 8.

2.2.3. Pump House / Pump Enclosure

The pump house provides protection for electrical controls and equipment. This should be well ventilated and properly aerated with a well-built roof. This ensures safety of the accessories within the pump house from theft and proper aeration for the inverter in case it is overheating.

In the pump house, do not allow water to pool on the floor. Water is an electrical conductor, and this can create a hazardous environment, particularly if damaged or bare wires are lying on the floor.

6 Source: Engineers Without Borders-USA

2.2.4. Pump Motor Controller

The pump controller should only be opened by the technician. The pump motor controller provides for conversion of the electricity coming from the solar panels through the combiner box. It provides protection and control requirements for the electrical motor of the pump. The controller has wires running from it to the storage tank to sense the water levels in the tank and well in order to turn off and on the pump motor in response to these inputs. Although the voltages on the sensing cables to these switches are normally below the voltages that can cause safety concerns, it is essential that grounding and surge protection be applied to the direct current from the solar panels and any alternate electrical sources to prevent damage to the pump controller.

2.2.5. Summary of Major Electrical Safety Rules

Table 2: summary of major electrical safety rules

⚠	**Energized systems can be lethal when handled inappropriately even if they appear to be unpowered. Always take extreme care and treat electrical systems with extreme caution!**
⚠	**Although proper grounding helps remove shock hazards, SOs and users of the Solar Powered Water System should never remove any electrical equipment covers. If removed covers or uninsulated wiring are found, do not touch these components. Immediately contact a certified ST for support!**
⚠	**Never service a Solar Powered Water System during a lightning storm!**
⚠	**Intrusion of any foreign material into the well may result in sickness or death of system users or severe harm to the system equipment!**
⚠	**Solar panels have unique characteristics that make them difficult to work on safely. Adhering to safety guidelines is of utmost important since solar panels are energized anytime the sun is up. Doing maintenance during night hours is not safe or practical!**
⚠	***Never* disconnect MC-connectors to break load or fault currents. Do not disconnect MC-4 connectors because they are not designed to interrupt any electrical current!**

2.3. Chemical Hazards

⚠ **Never climb a ladder with an open container of chemicals.** ⚠

Any injury, no matter how minor, should be reported and treated by a qualified professional. The content referenced in this manual should never be used in place of qualified medical advice.

Of primary concern is the handling of chemicals. Some fertilizers can contain chemicals, please be careful when handling.

Always use gloves, eyewear (in case of splash), and a respiratory mask when working with any inorganic matter such chemicals and pesticides.

If a chemical burn occurs, first aid should be administered immediately. Basic first aid measures are included below.

Chemicals should not be stored in the pump enclosure. Any chemical should be stored appropriately away from the well and system equipment. The pumphouse should be kept clear of clutter, waste, food, and other potential contaminants or invitations for pests to nest or reside inside the pumphouse, risking damage to the electrical equipment.

2.3.1. Burns

First-Degree Burns: First-degree burns involve the top layer of skin. Sunburn is a first-degree burn.

Signs:

- Red
- Painful to touch
- Skin will show mild swelling

Treatment:

- Apply cool, wet compresses, or immerse in cool, fresh water. Continue until pain subsides.
- Cover the burn with a sterile, non-adhesive bandage or clean cloth.
- Do not apply ointments or butter to burn; these may cause infection.
- Over-the-counter pain medications may be used to help relieve pain and reduce inflammation.
- First-degree burns usually heal without further treatment. However, if a first-degree burn covers a large area of the body, or the victim is an infant or elderly, seek emergency medical attention.

Second-Degree Burns: Second-degree burns involve the first two layers of skin.

Signs:

- Deep reddening of the skin
- Pain
- Blisters
- Glossy appearance from leaking fluid
- Possible loss of some skin

Treatment:

- Immerse in fresh, cool water, or apply cool compresses. Continue for 10 to 15 minutes.
- Dry with clean cloth and cover with sterile gauze.
- Do not break blisters.
- Do not apply ointments or butter to burns; these may cause infection
- Elevate burned arms or legs.
- Take steps to prevent shock: lay the victim flat, elevate the feet about 12 inches, and cover the victim with a coat or blanket. Do not place the victim in the shock position if a head, neck, back, or leg injury is suspected, or if it makes the victim uncomfortable.
- Further medical treatment is required. Do not attempt to treat serious burns unless you are a trained health professional.

Third-Degree Burns: A third-degree burn penetrates the entire thickness of the skin and permanently destroys tissue.

Signs:

- Loss of skin layers
- Often painless. (Pain may be caused by patches of first- and second-degree burns which often surround

third-degree burns)

- Skin is dry and leathery
- Skin may appear charred or have patches that appear white, brown or black.

Treatment:

- Cover burns lightly with sterile gauze or clean cloth. (Don't use material that can leave lint on the burn).
- Do not apply ointments or butter to burns; these may cause infection.
- Take steps to prevent shock: lay the victim flat, elevate the feet about 12 inches.
- Have a person sit up if face is burned. Watch closely for possible breathing problems.
- Elevate the burned area higher than the victim's head when possible. Keep the person warm and comfortable, and watch for signs of shock.
- Do not place a pillow under the victim's head if the person is lying down and there is an airway burn. This can close the airway.
- Immediate medical attention is required. Do not attempt to treat serious burns unless you are a trained health professional.

2.4. Ladder Safety

It is dangerous to climb to heights over 2 meters. Do not carry tools or containers when climbing the ladder to the tank. Ensure you always have three points of contact with the ladder when climbing. Wear suitable footwear and the necessary PPE. Always maintain a 4:1 ratio, where the distance from the floor to the roof is four times as long as the distance from the base of the wall to the base of the ladder. This is illustrated in Figure 9.

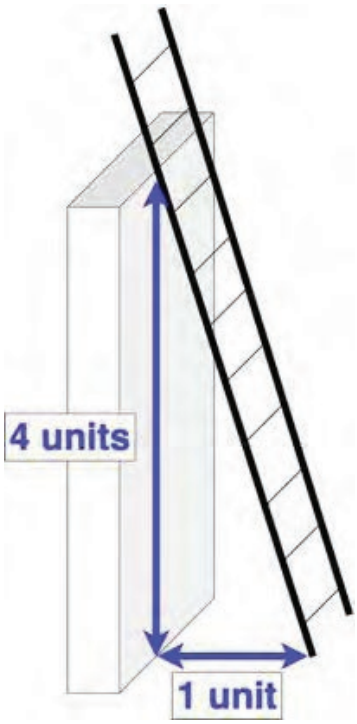

Figure 9: Illustration of the 4:1 ladder ratio[7]

7 Source: Engineers Without Borders – USA

2.5. Personal Safety

Personal safety is of great concern, particularly in remote areas. To ensure your safety and reduce risks to your person:

- The process of assuring personal safety is aided by planning the process to be followed by the personnel prior to starting the work:
    1. List of tasks to be completed
    2. Identification of specific risks of tasks
    3. Plan to reduce or eliminate each risk
    4. Communication with all personnel involved
- Ensure a clean environment clearing the area, including a radius around the fence, to reduce risk of insect, rodent, or snake infestation.
- Ensure the area is locked at all times, particularly at night.
- Post the necessary hazard signs around the compound to remind yourself and warn others of the danger.

3. OPERATION AND MAINTENANCE ACTIVITIES OF THE SYSTEM OPERATOR

3.1. General Guidance

The following section outlines the installation procedure, operations, and maintenance tasks for each component of a solar irrigation system. These tasks are typically performed by the operator who is responsible for the operation of the system and for basic preventive maintenance of system components. A table of these tasks follows at the end of this section as a printable guide to be kept in the pump house or with the system operator.

3.2. Installation guidelines

Upon design of a SPIS, the equipment both electrical and irrigation system should be installed to operate for the identified functionality. The electrical requirement i.e., the pump, solar panels and their accessories shall be installed by the distributor as per the manual with support by a technical staff.

The irrigation section can be installed by the technician and the user-operator based on provided instruction. Installation of irrigation systems vary based on the type of irrigation that has been adopted. The main items in the installation of irrigation systems include installation of the storage tank and the head assembly (control valve, filters, fertilization equipment). The other items of installation include connecting mains, sub-mains, and lying of drip lines and sprinkler heads. While installing the control head or the pipe network, the minimum number of accessories such as elbows, reducers etc should be used. This is required for proper maintenance of the system and to reduce unnecessary head loss in the system due to these connections.

3.2.1. Installation of portable pumping systems

For some portable systems, these can be assembled and installed based on the manufacturer's guide that usually comes along with the system. The procedure outlined below can be used as a guide in the installation of these portable pumps:

- Assemble all the components of the system in one place i.e., the solar panels and the pump
- Connect the hose pipe to the pump outlet and the other end to the elevated tank.
- You can now look for the position for the solar panels based on the radiations during the time you want to want to pump. Incline this to the best angle such that the radiations fall directly onto the solar panels.
- Connect the terminals of the panel to those of the motor of the pump as per the design or make.
- You can then prime your pump by putting some little water through the pump inlet and connecting the hose pipe to that point.

- Make sure the screen is placed rightly at the inlet of the hose pipe then you can place it in the water source.
- You can now start your pump by pressing the start button. Avoid any shading effects onto the solar panels. Once you are done pumping, put off the pump and de-assembly all the components.

Note: Remember to keep custody of the pumps, the hose pipes and all the accessories from direct sunlight, rainfall and theft. Always after use, store them in the pump house.

3.2.2. Installation of Filters and Fertigation Equipment

- A strong support in the form of hard base or concrete base along with the GI fittings should be used for the installation of the sand and hydro cyclone filters to avoid any vibrations due to load.
- The filter size should be in accordance with the capacity of the system. This should match with the pump discharge under size will lead to loss and over size will add cost.
- The delivery pipe of the pump should be connected directly to the hydro cyclone or the media or sand filter followed by the fertilizer equipment and the screen filter. All of these components should be installed in the main pipe.
- Once the sand/screen filter is an essential requirement. Suitable arrangements to collect and dispose of the bypass material should be made.
- In a pressurized irrigation system, the fertilizer injection unit is located between the sand filter (if required) and the screen filter. The general recommendation is that the fertilizer solution pass through at least two 90-degree turns to ensure adequate time for thorough mixing and for any precipitate to come out in front of the screen filter. It is necessary that a fertigation unit is installed at the upstream end of the screen filter so as to filter the under-solved matter present in the fertilizer solution.

3.2.3. Installation of Mains and Sub-mains

- Except for a fully portable system, both mains and sub mains if made out from PVC must be installed underground at a minimum depth of about 0.5m such that they are unaffected by cultivation or by heavy harvesting machinery. Even for systems, which have portable laterals that are removed at the end of each season, it is common practice to install permanent underground mains and sub mains. Generally, sub mains run across the direction of the rows.

The United States Soil Conservation Service has recommended the following minimum cover of earth over for various pipe sizes[8]:

Table 3: Minimum cover earth for pipes

Pipe size	Depth of earth cover
1.2 to 6 cm diameter	45 cm
6 to 10 cm diameter	60 cm
Over 60 cm diameter	75 cm

- If the mains and sub mains are made from materials other than PVC such as HDPE or GI, these may not be the need to install them below the ground surface; however, it is advisable to install them underground.
- It is important to remove mud and other impurities in the pipe before fitting of mains and sub-mains and gate valves. A ball valve is provided at the inlet end of the sub-main. After the ball valve, the air release valve is provided. A flush valve facing the slope of the sub-mains is provided at the end of each sub-main to facilitate sub-main flushing.

8 Fred Hamish, 1977

3.2.4. Laying of Laterals

- After the main and sub mains are installed, holes are drilled on the sub-main, according to the grommet take off (GTO)i.e., 11.9 mm diameter drill for 8 mm ID GTO and 16.5 mm drill for 13 mm ID GTO.
- Then the grommet is fixed in the drilled holes on the sub main and these take off (connectors) are fixed within the grommets.
- Once the grommet take offs are fixed on the sub-mains, lateral/polytube lying is done as per the design. Lateral is fixed to one end of the take off.
- Lateral placement is done according to row distance, with sufficient shrinking allowance and extra lateral length is provided at the end.
- The drippers are punched on the laterals as per the requirement.
- Generally, laterals are laid on the ground surface. Usually, laterals are placed along contours on sloping fields. Burying laterals underground might be necessary or at least have some advantages for some installations. Where this is done, the emission devices should be fixed above ground level except for the subsurface drip lateral.
- The downstream end of the lateral can be closed by simply folding back the pipe and closing it with a ring of larger diameter pipe, known as an end plug. This can be used during flushing by removing the end plug.

3.2.5. Punching of Laterals and Fixing of Emitters

- Punching of laterals should start from sub-main. Water should be allowed to flow through laterally to get bulging in pipe which makes easy punching.
- Punch the lateral sideways.
- The dripper position is fixed as per the spacing requirement.
- All the drippers should follow the same straight line.
- Do not fix the drippers on lateral until complete lateral is punched.
- Drippers are fixed on laterals as per the arrows marked (if having arrow marks) and it should be towards the sub-mains.
- While fixing the dripper, push it inside the lateral and pull it slightly. The end of the lateral should be closed with an end cap.

Once the system is completely installed, it needs to be tested by allowing water to flow into the system. Before allowing the water into the system, ensure that all the valves are open. After main, sub mains and laterals are flushed completely close the flushed completely close the flush valve and end caps. After closing of the valves and caps check the pressure at pressure gauges and ensure that the pressure at the selected points is as per the design pressure. It is also required to check the working of filters, air release valves and the fertigation unit. Once it is ensured that all the components are functioning properly and the required pressure exists in the system, the system is ready for use.

For sprinkler systems, the procedure for placing the mains, sub mains, laterals can be maintained as in the drip systems however, sprinkler nozzles instead of drip emitters are clamped between two laterals based on the designed spacing and coverage of the sprinkler nozzles. Sprinkler nozzles may vary in type and make.

3.3. Routine Operation and Care of Solar and Pumping Equipment

The following sections outline normal operations of the solar pumping system and should be followed as a general guideline supplemental to manufacturer's specific guidelines and management directions.

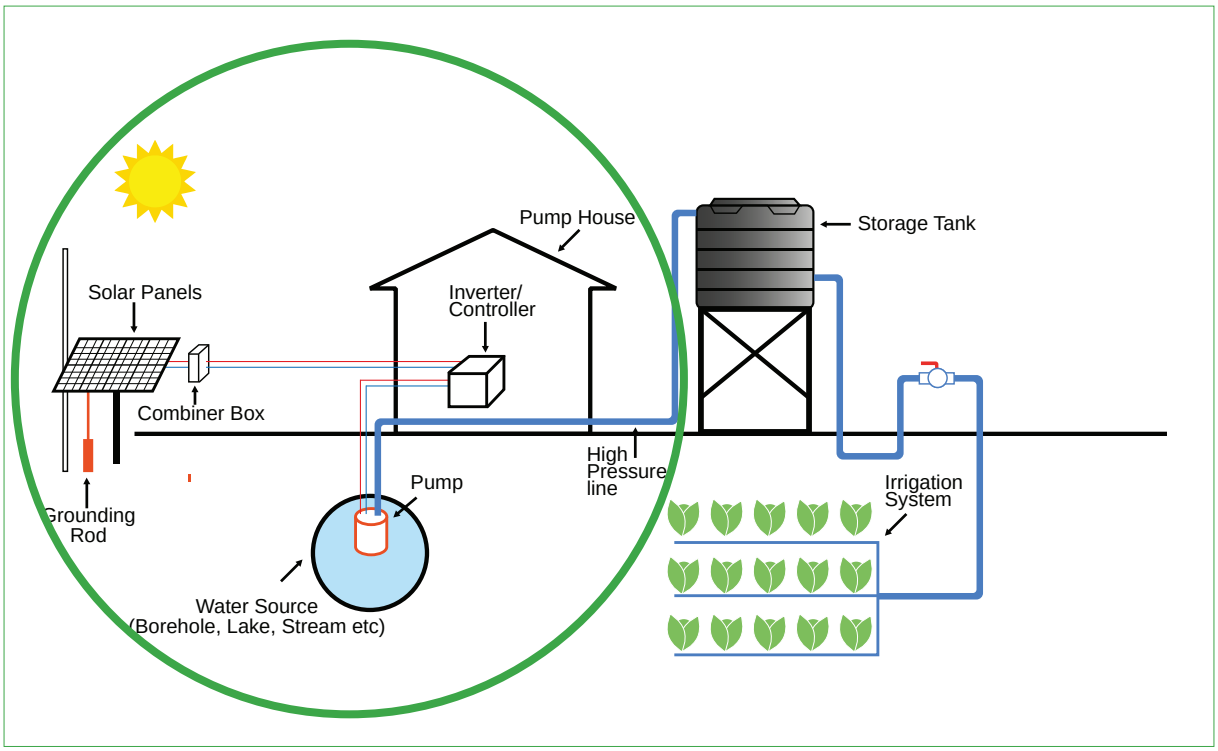

Figure 10: solar pumping equipment

IMPORTANT NOTE: How Shade affects the Solar Array

Shading of solar panels can be termed as introduction of a shadow to the solar panels. These can be a building, trees, uncleaned panels (filled with dust) or any object that can be about a shadow to the panels. Shading in solar panels reduces the power output from the panels to the controller unit and subsequently to the pump.

According to experts, solar panels can lose up to 40% of their potential output because of shading. Based on the panel installation, up to 100% of the solar efficiency can be reduced due to a shade. This is due to the way the solar cells in an array are connected within the system.

3.3.1. Solar Panels

These are the source of energy needed for the motor pump unit to pump water from the source. It is usually made up of a set of panels mounted on stand supports raised at and tilted angels. The solar panels are made up of solar cells that make use of the photovoltaic effect which converts sun radiations into electrical energy.

The solar panels are mounted in a way that they can receive the sun irradiance directly on the panel cells. This is highly dependent on the orientation and tilt of angle of the panels' surfaces. The solar panels should be tilted at 15 degrees and oriented towards the equator.

Lightning Rods and Grounding

For purposes of protection of the electrical component including the solar panels and the pumps, a lightning surge protector has to be installed within the array area. This provides protection from strikes of electric current that has not been neutralised. Thus, the excess electric charge concentrates around and causes harm. The lightning rod thus activates and diverts these electric charges into the ground to render them harmless.

This protects the equipment solar panels and pump and the people around from sudden fire breaks and other associated problems of high charge concentrations.

Solar Panel Care

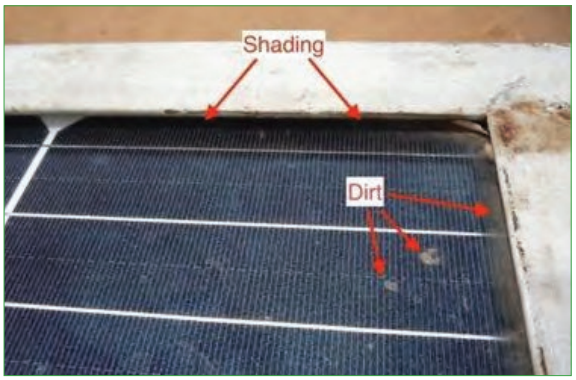

Figure 11 : Shaded panel by angle brackets and dirt[9]

Check to ensure nothing is shading the panels such as vegetation or structures.Visually inspect the area for possible sources of shade.

- Note that shading of even one panel will reduce power from all panels because of the electrical properties of the connections.
- Trim or remove any vegetation around the solar panels as well as any erection of structures that will block sunlight.Wash panels.
- Wash during early hours when it is not yet hot.
- Remember to remove jewellery, belts, etc. that may scratch the panels.
- Make sure the ladder you are using is in good repair.
- Use a soft sponge and water only. DO NOT USE SOAP.
- Squeegee dry the panels to ensure that water spotting does not occur during drying.

Figure 12: A squeegee for cleaning the solar panels[10]

Check if the panels are cracked.

- If yes, **contact the Technician** to request support.

Check if wiring is exposed, loose/sagging, or disconnected. Check if wires were damaged by rodents or animals.

- If yes, contact the Technician to request support.

Check if the panel mounting is strong and well attached. Check for cracks or any other sign of weakening.

- Check and tighten loose bolts.
- If signs of rust are showing, repaint the area with anti-corrosive paint to avoid further weakening from rust.
- If there are any visible areas of weakness, **contact the technician to request support.**

Check the area around solar panels for trash and debris, spider webs or any other insect nesting.

- Remove and dispose of trash and debris.
- Carefully remove spider webs and insect nests. Call a beekeeper or someone who can handle dangerous insects.

Lightening Rod and Grounding Care

Check to make sure the Lightning arrestor is secure, without risking to fall and damage the solar panels.

Figure 13: Earthing wire connected to a copper strip[11]

9,10,11 Source: Engineers Without Borders – USA

The image shows an earthing wire-usually green or yellow connected to a copper strip or rod. These strips can be made of copper, aluminium or galvanised iron

Check to ensure that the grounding rod/s are secure and have no signs of damage.

- If there are any visible signs of damage or disconnection, these could be costly or deadly, **contact the Technician to request support.**

3.3.2. Pump

Water pumps in SPIS systems can be surface pumps or submersible pumps. This can be dependent on the nature of the water source to be used. Surface pumps are often installed near the water source and suck water up on one side before pushing it away to the other side of the pump. They can pump water up to almost a maximum of 6 meters.

Submersible pumps are usually installed for ground water options however not limited to surface water options. They are usually installed at depths ranging from 10 up to 120 meters. These pumps push water up through a pressured line. Using control switches such as float meters; the submersible pumps can be operated in an automatic mode. This cannot be applied to the surface pumps as they require the attendance of the operator to do regular checks. They also require priming for their operation at most cases. Use of primary chambers and non-return valves can prevent loss of prime. Surface pumps are however cheaper, easier to install and maintain compared to submersible pumps.

Figure 14: Riser main pipe from the well[12]

12 Source: Engineer Without Borders – USA

Check if pump or discharge piping leaks.Visually inspect connections at wellhead for leaks.

- Due to the high pressure at the pump repairs to the discharge pipe require shutting the system down which should only be attended to by the Technician. **Contact Technician** to fix leaks.
- For surface pumps, ensure they are not placed in muddy areas or areas filled with a lot of sand as it will suck the sand and spoil the pump.
- For surface pumps especially that need priming, ensure this is done when starting the pump before its operation otherwise it will fail. Priming refers to the action taken to stimulate a process or action. Usually, water is added up to the hose pipe at the connection with the pump to enable it efficiently simultaneously while sucking water from the source.
- In case of cavitation (usually noticed by a noise, vibration and reduced performance of the pump)-forming of voids or bubbles within the pipeline brought about by pressure drops, the operator should check and ensure water from the source is sufficient and the well is not drying up otherwise contact the technician on how best to increase the net positive suction head. An inducer is installed at the end point of the inlet pipe from the source, minimization of losses i.e., not using very long and many pipes, avoiding bends within the connection and optimizing impeller design. These should be done and ensured by the technician.

3.3.3. Pump and Pump House/Enclosure Activities

Pump House Care

Record pump pressure when running.

In case of any abnormalities report to the technician

Check the area around the pump and remove and dispose of trash and debris.

- This is important to ensure that insects, rodents or snakes do not disturb regular operation or cause physical harm.

Check the enclosure for cracks and damage.

- Physically walk around the pump house inspecting the walls foundations and roof, entrances and exits of any piping looking for any sign of damage.
- Minor foundation, wall, or other concrete cracks or issues identified can usually be repaired with mortar.
- Roof damage may require replacement or repair of roofing material, depending on the problem.

3.3.4. Pump Controller (Inverter)

The controller is a link between the solar panels and the pump. It adjusts the fluctuation in the power outrage of the solar panels resulting from sun irradiance variations. The controller regulates the number of the revolutions of the motor and protects the pump against over and under voltage, reverse polarity, overload and over temperature.

Some controllers have incorporated inverters. Inverters convert direct current to the alternating current. Solar radiations produce DC power. It can however be noted that DC motors are usually of high efficiency than AC motors thus tend to be more preferred.

Inverter Care

Record electrical LED status, input and output, current and power if available on controller and/or inverter.

- Check for readings which differ significantly from normal recorded data. If the electrical discharge is not in the expected range**, contact the Technician.**

  Check for Alarms

- Most common alarms (red LED lights) will show one of the two following indicators:
- FAULT, or
- WELL DRY
- If the error reads "WELL DRY", call the Technician.
- If the error reads "FAULT", check to see if the pump is running*7. If the pump is running, the pressure shows in normal range and there are no unusual sounds, then it could be that the inverter has an internal error,

Contact the technician:

- If the pump is not running, the system may need to be re-started.
- To restart the system, will need to refer to the re-start procedure in the manufacturers operating manual to restart the specific equipment at their site.
- Inspect the wiring for potential failures, damage, or exposed wires.
- If any sign of damage to wiring, contact the technician to request support.
- If there appears to be a burnt fuse, or if there appears to be any blackened areas indicating an electrical burn, there may be a wiring fault. **Contact the technician to request support.**

Clean the inverter box.

- Remove dust and cobwebs
- Repair holes so that insects or rodents cannot enter and nest causing serious damage to the equipment.

3.4. Pressure Line and Water Storage

The pressure line is the pipe that carries the water from the pump to the storage tank, usually raised on a tank or over the garden storage shed. Because the pressure line is pressurized, most repairs will require a technician to restrict water flow at the pump house.

3.4.1. Pressure Line from Well to Storage Tank

Pressure Line Care

Physically walk the pressure line from the pump to the tank, while checking for the following problems:

Check if pipes or valves are leaking.

- Look for obvious signs of leakage, i.e., wet ground or puddles, as you walk the line for inspection.
- If yes, contact the technician to request support.

  Check if any pipes are exposed.

- If any pipes are exposed, re-bury the pipe by carefully re-digging the trench around and beneath the pipe, burying the pipe and covering it again with dirt.
- Ensure that the pipe has not been damaged while exposed by inspecting the area for visible signs of leakage or running the pump and watching the pipe for leakage.
- If the pipe has been damaged, contact the technician to request support.

3.4.2. Storage Tank

This is where water is stored. These are elevated to create a maximum pressure for irrigation throughout and through all corners of the fields.

Since output of solar radiations varies throughout the day and no batteries are recommended in this, the water tanks act as storage and can store water for use in such scenarios. Thus, the tanks serve as a battery in the form of stored water.

The elevation height creates the pressure for which the water is driven out to the fields. It is however important to always note that the mounting structures of the tank meet up with the static conditions preferable be designed by a structural engineer.

Within the tanks especially for the open ones, fertilisers can directly be batched before spreading out to the farm-lands.

Storage Tank Care

Check if the tank or connections are leaking.

- Conduct a visual inspection of the tank and its surrounding ground to look for visible signs of leakage.
- Ensure tank supports are firm and strong on the ground. This should be inspected and checked during its installation to ensure its safety during its operation.
- Quarterly cleaning / flushing of the tanks.
- If yes, contact the technician to request support.

Check for damage to the tank support structure.

- If yes, contact the technician to request support.

3.5. Irrigation System

A typical irrigation system layout can be noted from the elevated storage tank to the water application mechanism based on the method being applied – usually drip or sprinkler irrigation. The system can be looked at based on the irrigation head which usually varies based on the method of irrigation. It is indispensable in irrigation systems that operate under pressure such as sprinkler and drip irrigation.

3.5.1. Valves

These control the quantity of water flowing to the different sections of the irrigation system. Can be manual or automatic.

Check if the valves are operating, loose in connection or even fallen off.

- If yes, tighten the loose connection and immediately inform the technician for further diagnosis.

Check if the valve is releasing the right amount of water, undersized or oversized.

- Call the technician since the crops are either being over irrigated or under irrigated.

3.5.2. Filters

These remove particles/ debris or matter that could block drip emitters or sprinkler nozzles. These lead to failure of the emitters and in the due end poor performance of the system. Pressure difference across the filter is used as the indicator for deciding the timing of cleaning of the filter. In general, cleaning of these filters can be done on a weekly basis.

Check if the filters are filled with dirt thus clogging the system.

- Remove the filter and wash off the dirt when the system is not operating.
- Flush the nit of the filters with pure water.
- Replace the filter if the screens or discs are broken and are not doing the job of filtration of the water from to the fields.

Note: It is important to note that system should be flushed at the beginning of every season so as to ensure all the units i.e., main laterals, sub mains, filters and emitters are clean and not clogged with any debris that may allow uniformity in the flow of water during the irrigation process.

- The sub mains can be flushed by opening the flush valves to remove any matter/ debris.
- The laterals should be flushed by removing the end caps and allowing the water to pass through. Flushing can only be terminated once the water passing through is clean.

3.5.3. Fertigation System

The fertigation system is where fertilisers are injected in for an irrigation system i.e., addition of nutrients to the irrigation water. This brings about clogging of the system as a result of precipitation and accumulation of certain dissolved salts such carbonates, bi-carbonates, calcium, iron and manganese salts.

Check with the Fertigation unit is not cogged with chemicals.

- If yes, clean up the unit to allow easy mixing and flow of water for irrigation. This can be done by chemical treatment for example with application of chloride and acid with water. The frequency of chemical treatment is decided on the degree of clogging and quality of water. Chlorine treatment is required to remove organic and any physical materials and acid treatment is required to remove the salt and any chemical precipitates from the system. As a general rule, acid treatment is performed once in ten days and chlorine treatment once in fifteen days. It's important to done this should be done while the system is not in its operation thus during maintenance of the unit.
- Regular flushing of the unit with pure water.

3.5.4. Irrigation System-piping layout

For drip systems, there are manifold pipes, lateral pipes and the emitters. In sprinkler system, there are riser pipes that are used for wider coverage in terms of spraying by the nozzles. The sub mains and laterals usually have end caps at the end to restrain water from flowing through. Drip emitters and sprinkler nozzles are the final water outlet to the crops.

Conduct a physical walk of the lateral pipes, emitters and points of the sprinklers, while at the walk, the operator should check the following:

1. Leakages or any blockages along the lateral pipes.
2. Wash/flush the filters to remove any debris or any coated materials that have probably clogged the system.
3. Check within the bends of the laterals for any leakages and blockages.
4. Check the emitter to ensure none of them is blocked or broken.

Check if the emitters or the nozzle are not blocked or broken.

- If yes, replace the nozzle or change the lateral line for cases of drip systems. Conduct the technician for guidance.

Check if the manifold and lateral lines have no leakages and bursts.

- If yes, replace the line with a new one. This usually brings a break to the whole system.
- In case of a minor leakage, can thread it with thread tape and conduct the technician for guidance and support.

Check if the bends at the manifolds to the laterals are not busted or broken.

- Thread the section with tape to reduce the leakage.
- Use a coupler to re-join the burst between the two pipe sections.
- Avoid folding and twisting of the pipes to avoid breaking of the system pipes.

Check if the end caps are not broken or leaking

- Replace the end cap unit to resist wastage of water
- It should be noted that during cultivation or at the end of a season, the farmer should fold the laid pipes i.e., the laterals, sub mains to one side to avoid any inconvenience of cutting the pipes while digging.

PRINTABLE FORMS

0 Operations and maintenance guideline

Table 4: Regular Operation, Inspection and Preventative Care Activity Sheet

SYSTEM COMPONENT	INSPECTION DETAIL	ACTION/RESPONSE
General	Routine check of the proper operation of the system from the pumping section of the system to the end use through the drip emitters and the sprinklers heads. Normal operation will not require intervention of the operator, but failure of float switch may require the operator to operate the pump manually to avoid overflow.	In case of any failures beyond the operator, report to the technician.
Solar Array	Check if solar panels need to be washed.	Clean the solar panels.
	Check for debris on panel surfaces and any resulting damage.	Clean off the debris from the panels.
	Check for a source of shade on the panels such as vegetation or structures.	Cut down/trim any form vegetation that may bring about the shading.
	Are there any cracks in the panels?	If yes, report to the technician for support.
	Is there any exposed or loose or disconnected wiring? Check for any damage from rodents or animals.	If yes, report to the technician for support.
	Is the panel mounting strong and well attached? Are there cracks or any other sign of weakening?	If yes, report to the technician for support.
Pump	Record pump pressure when running.	In case of any abnormalities report to the technician.
	Check the area around the pump for debris for trash and debris.	Clean around the pump house.

SYSTEM COMPONENT	INSPECTION DETAIL	ACTION/RESPONSE
Controllers / Inverters, etc.	Check for any warning lights or alarms.	In case of any alarms, switch off system and contact the technician for support.
	Clean protective box.	In case of any broken wires, contact the technician.
Pump house	Check for any debris around the pump house.	Clean the pump house and keep it neat.
Pressure line	Are any pipes exposed?	Based on the kind of pump use, in case of submersible pumps that are not movable, bury the pipes, in case of surface pumps or pumps that shall be moved, ensure when pumping that it is aligned well.
	Are the filters/ screens free of debris or any foreign bodies?	Remove any debris from the filters/screens.
	Are any valves leaking?	Can tighten the valves with a tape and report to the technician.
	Are any pipes leaking?	Can tighten the pipe section leaking with a thread tape then report to the technician. Don't operate the system with a major leakage
	Are any connections leaking?	Tighten the connection with thread tape and report to the technician. For major connection leakages, close the system and contact the technician immediately.

SYSTEM COMPONENT	INSPECTION DETAIL	ACTION/RESPONSE
Tank / storage tank	Check for evidence of tank overflow (e.g., wet ground, erosion). Any cracks on the tank?	Contact technician in case of major leakages/cracks.
	Is the tank support structure well mounted and stable?	Contact technician.
	Check for any evidence of a dirty tank i.e., debris, dust coating on the tank walls.	Clean inside the tank.
Irrigation system	Are the lateral lines/pipes leaking?	Contact the technician.
	Are any connections leaking?	Contact the technician.
	Are any of the drip emitters or sprinkler heads leaking?	Contact the technician.
	Any blockages with the drip emitters or sprinkler heads?	Contact the technician.

0 Dos and don'ts of the farmer

The following are an outline of dos and don'ts that a farmer should be able to follow during their operation at the SPIS.

Dos of the user

- Regular checking and cleaning of the solar panels.
- Routine walk of the irrigation system checking out mains, sub mains and the laterals that are functional.
- Regular maintenance of the garden to keep away weeds and pests such as birds and animals.
- Minimize shading by trimming trees or grass surrounding the solar panels or where they shall be placed.
- Maintaining a tidy and clean pump house and surrounding area.
- Safe custody of pumping equipment especially for portable pumping systems.

Don'ts

- Repair on the pump in case it stops working.
- Repair on any of the electrical accessories of the pumping systems.

Daily Maintenance Activity Sheet

System Component	Daily Routine Activities
General	Follow the official pumping schedule for the operating mode of the scheme. Note: Normal operation will not require intervention of the technician, but failure of float switch may require the farmer to follow manual schedules determined for each site or contact the technician. Continuous check of the irrigation lines-drip lines and sprinkler heads for any leaks
Solar Array	Check if solar panels need to be washed. Check for debris on panel surface and any resulting damage.
Well / Wellhead	Record dynamic water level before starting pumping in the morning, when starting the system.
Pump	Record pumping times. Monitoring of the pump sound and noise.
Water meter	Record water meter reading at the beginning and end of each pumping cycle.
Controllers / Inverters, etc.	Maintenance and monitoring of the controller to overheating. Record electrical device LED status, input and output voltage, current and power if available on controller and/or inverter. Check and record any warning lights or alarms
Pump house	Always maintain a clean facility.
Tank / Distribution System	Check for evidence of tank overflow (e.g., wet ground, erosion). Check for tank level falling below normal operating conditions- this includes the stands and general condition of the tank.
Distribution System-Irrigation layouts	Continuous checks and monitoring of the drip lines, laterals, filters and screens, sprinkler heads and other irrigation system components. Flushing of the system lines to ensure no clogging, or debris along the distribution laterals. Walk within the system to ensure sufficient supply and distribution of water up to the last end of the system. Check for surface runoff to minimise water wastage.
General care of the field	Continuous weeding to pick out weeds. Mulching to enhance soil fertility and better yields. Use of scare crows, pesticides and insecticides to curb pets and diseases.

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