KP10
Knowledge Product 10

CCARDESA
Centre for Coordination of Agricultural Research and Development for Southern Africa

DECISION TOOL:

Climate Smart Water Management Options for Maize & Sorghum

CLIMATE SMART AGRICULTURE
KNOWLEDGE PRODUCTS FOR EXTENSION WORKERS
Customised Information Tools for Agricultural Professionals

Audience: Local Level Extension Staff (Government, NGO/Civil Society, Private Sector)

Maize | Sorghum | Decision Point | Gender | Youth | Climate Smart | Practice | Technology

Pivot Irrigation. Stock Image

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Implemented by:
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KP10

WHAT IS CLIMATE SMART AGRICULTURE (CSA)?

CSA comprises three interlinked pillars, which need to be addressed to achieve the overall goals of food security and sustainable development:

1. **Productivity:** Sustainably increase productivity and incomes from agriculture, without negative impacts on the environment
2. **Adaptation:** Reduce exposure of farmers to short- term risks, while building capacity to adapt and prosper in the face of shocks and longer-term stresses (resilience). Attention is given to protecting ecosystem services, maintaining productivity and our ability to adapt to climate changes
3. **Mitigation:** Wherever and whenever possible, CSA should help to reduce and/or remove greenhouse gas (GHG) emissions. This implies that we reduce emissions for each unit of agricultural product (e.g., through decreasing use of fossil fuel, improving agricultural productivity and increasing vegetation cover).

CSA = Sustainable Agriculture + Resilience – Emissions.

How is CSA Different?

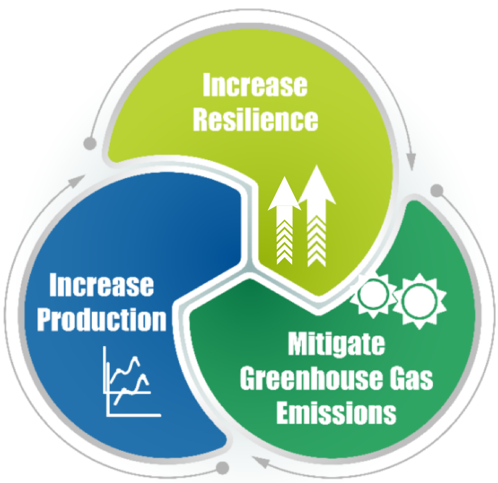
1. CSA places greater emphasis on **hazard and vulnerability assessments** and **emphasises weather forecasting** (short term) and **climate scenario modelling** (long term) in the decision-making process for new agricultural interventions
2. CSA promotes the scaling up of approaches that achieve **triple wins** (increase **production**, increase **resilience** and [if possible] **mitigate GHG emissions**), while at the same time **reducing poverty** and **enhancing ecosystem services**
3. CSA promotes a systematic approach to:
   a. Identifying **best bet** opportunities for agricultural investment
   b. Contextualising **best bet** options to make them **best fit** their specific context through learning and feedback loops
   c. Ensuring the **enabling environment** is in place so that farmers (and other stakeholders) can invest in CSA practices and technologies to catalyse adoption.

Key Messages:

1. Climate smart management of available water resources can greatly increase resilience of maize and sorghum to ever changing rainfall patterns
2. To make climate smart decisions on which water management option for maize/sorghum best suits your farmers, you need to understand:
   a. Crop water requirements
   b. Probable rainfall
   c. The current status of the soil
   d. Farmers' priorities
   e. Gender dynamics
3. Climate smart water management options for maize and sorghum include:
   a. Variety/crop selection
   b. Solar irrigation
   c. Deficit irrigation
   d. In-field water harvesting
   e. Rainwater harvesting.

Entry Points for CSA

- CSA practices and technologies
- CSA systems approaches
- Enabling environments for CSA approaches.



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CLIMATE SMART WATER MANAGEMENT OPTIONS FOR MAIZE & SORGHUM

This Decision Tool aims to help field-level extension staff make climate smart decisions on which water management option best suits their farmers' context. This tool is not designed as a technical guide to implementation. It is designed to assist extension staff in making climate smart decisions on improvements to their farming systems with their clients/farmers. Reference to technical guides relevant to the practices/technologies outlined are included at the end of the tool. The tool focuses on some of the Best Bet Climate Smart Water Management Options for maize and sorghum production in the Southern African Development Community (SADC) region. These are just some of the many options available. In many cases, multiple options might be selected. They are listed in no particular order and have been selected as best bet because:

- They are climate smart (see Table 1)
- They are applicable in multiple agro-ecological zones across the region
- They have high potential to address major constraints (water stress) to maize and sorghum production in the region (Table 1).

These are best bet options. An understanding of the local context and farmers' priorities is required in order to make these options **Best Fit** to individual farmer's needs.

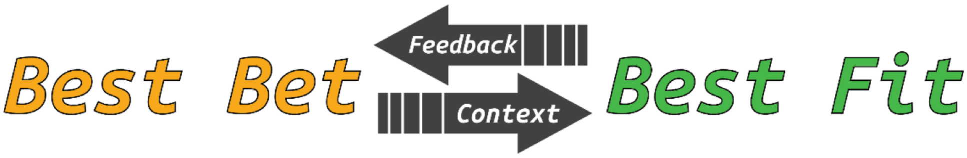


Table 1: Best Bet Climate Smart Water Management Options for Maize & Sorghum that have potential to address climate risks across the SADC region.

Climate Smart Water Management Practice Option	What is it?	3 Pillars of CSA		
		Increase Production	Increase Resilience	Mitigate GHG Emissions if possible
Variety/Crop selection	Selecting early maturing, drought-tolerant varieties Or, selecting more drought tolerant crops (e.g., sorghum instead of maize)	Varieties specifically bred for yield potential at lower water availability	More predictable yields	N/A
Solar Irrigation	Using solar technology to irrigate crops from either surface or sub-surface water sources	Plants get enough water Potential for two or more cropping seasons per year	Predictable yields. Higher production equals increased food security/income and resilience	Significant reductions in CO_2 emissions compared to grid and diesel-fuelled systems
Deficit Irrigation	Used when there is not enough water. Water is applied only during the most critical growth stages	Stabilises yield	Adapts to real time rainfall conditions	Depends on irrigation system used
In-field Water Harvesting	Practices to increase water infiltration and moisture retention in the soil (e.g., zai pits, contour bunds, Integrated Soil Fertility Management, etc.)	Water is available to plants when it is needed Reduced nutrient leaching	Mitigate dry spells	Can lock more carbon in the soil More efficient use of fertilisers
Rainwater Harvesting	The collection and storage of rainwater to reuse rather than letting it run off	More water available to plants when it is needed	Mitigate dry spells	N/A

WHICH CLIMATE SMART WATER MANAGEMENT OPTION IS BEST SUITED TO YOUR FARMERS?

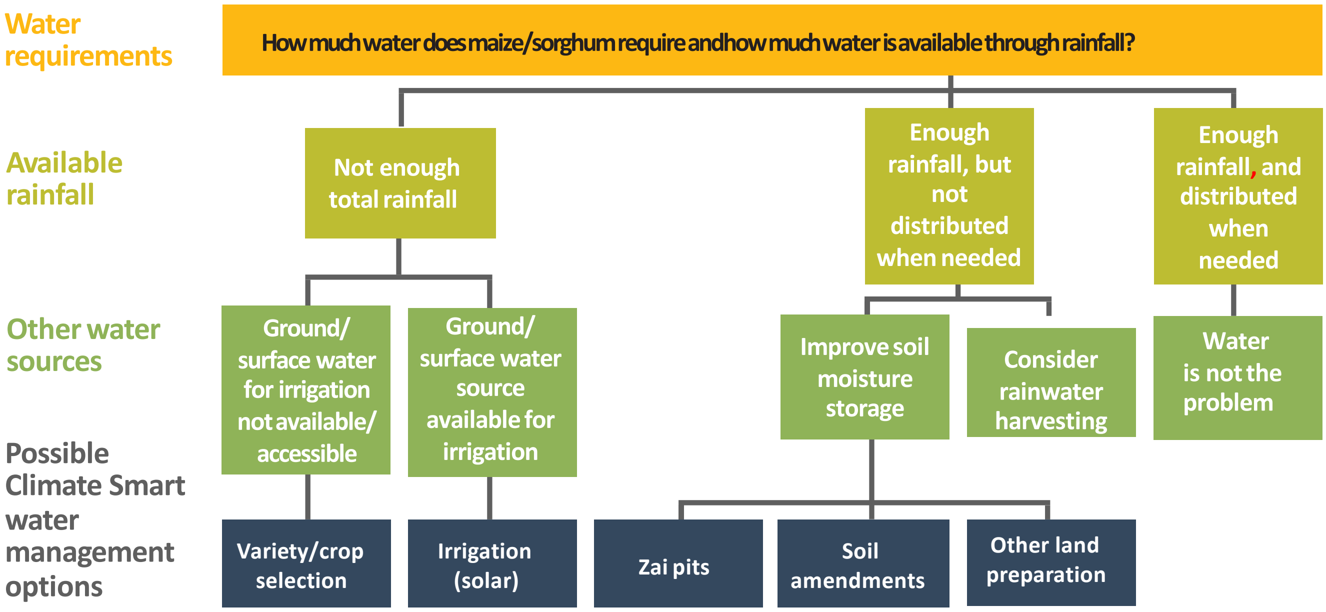
To make **climate smart decisions** on the land preparation options best suited to your farmer(s), it is key to understand the local context:

- Crop water requirements
- Available (probable) rainfall
- What other sources of water are available, if any.

The Decision Point figure illustrates the decision making process based on these three core criteria. Each one is then discussed in more detail below.

To make climate smart decisions on water management options for maize and sorghum, an understanding of crop water requirements, expected rainfall and other potential sources of water is required.

DECISION POINT



CROP WATER REQUIREMENTS

The first step is to know the crop water requirements. To make climate smart decisions, it is important to know not just **how much water** is needed, but **when** it is needed.

Existing drought tolerant varieties are being identified and new varieties developed. With different varieties, the ranges indicated below may change.

Table 2: Water requirements and critical growth stages for water stress in maize and sorghum.

	Normal range (mm/total growing period)	Critical growth stages for water stress
Maize	500–1,200	Flowering to late grain filling phase, with a peak during the tasselling and silking phases
Sorghum	400–900	Reproductive stages, especially flowering.

Figures 1 and 2 illustrate the daily water requirement (in mm) at the different growth stages of maize and sorghum (respectively) in different agro-ecological zones in the SADC region. The charts illustrate how humidity and temperature Impact on water stress. Sorghum and maize grown in areas with high temperatures and low humidity will require significantly more water than those in humid areas with medium temperatures.

Figure 1: Maize water requirements by growth stage in the tropics and sub-tropics.

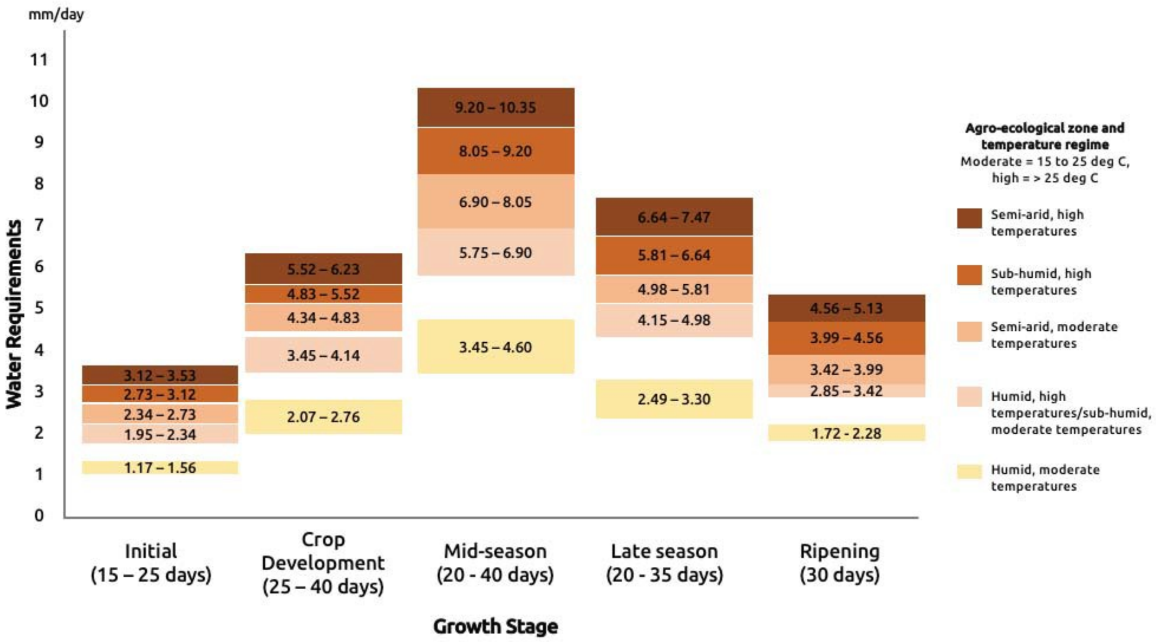
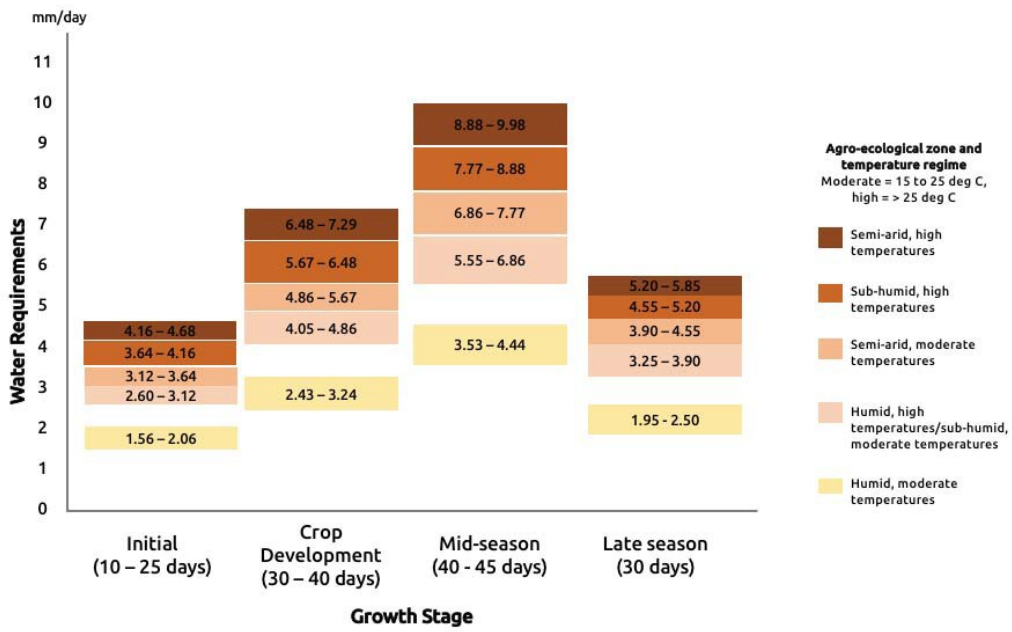


Figure 2: Sorghum water requirements by growth stage in the tropics and sub-tropics.



Source: ASHC.

AVAILABLE (PROBABLE) RAINFALL

The next step is to understand local rainfall:

- Do your farmers think that there will be enough rain in the next season?
- What information are they using to make these assumptions?

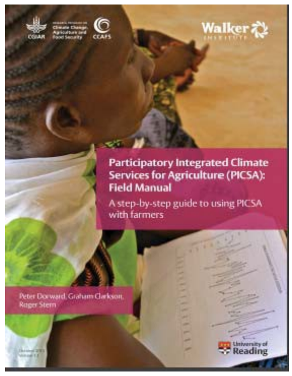
The Participatory Integrated Climate Services for Agriculture (PICSA) field manual is an excellent resource to help you work with your farmers to estimate the probability of certain levels of rainfall in your area over the coming season, using the most locally available data. PICSA helps you in supporting farmers to make more informed decisions based on accurate, location-specific climate and weather information as well as crop, livestock and livelihood options.

Your local Met Office should be able to provide you with some basic information to help your farmers make more informed and climate smart decisions. In any case, ask farmers about their past observations on rainfall, seasons, access to water and extreme events.

You can consider collecting rainfall data with your farmers, especially documenting dates on which it rained, and the duration and intensity.

If you have access to a rain gauge, this will be even more accurate. Over time, you can build up a picture of the trends locally. This will help you and your farmers in climate smart decision making.

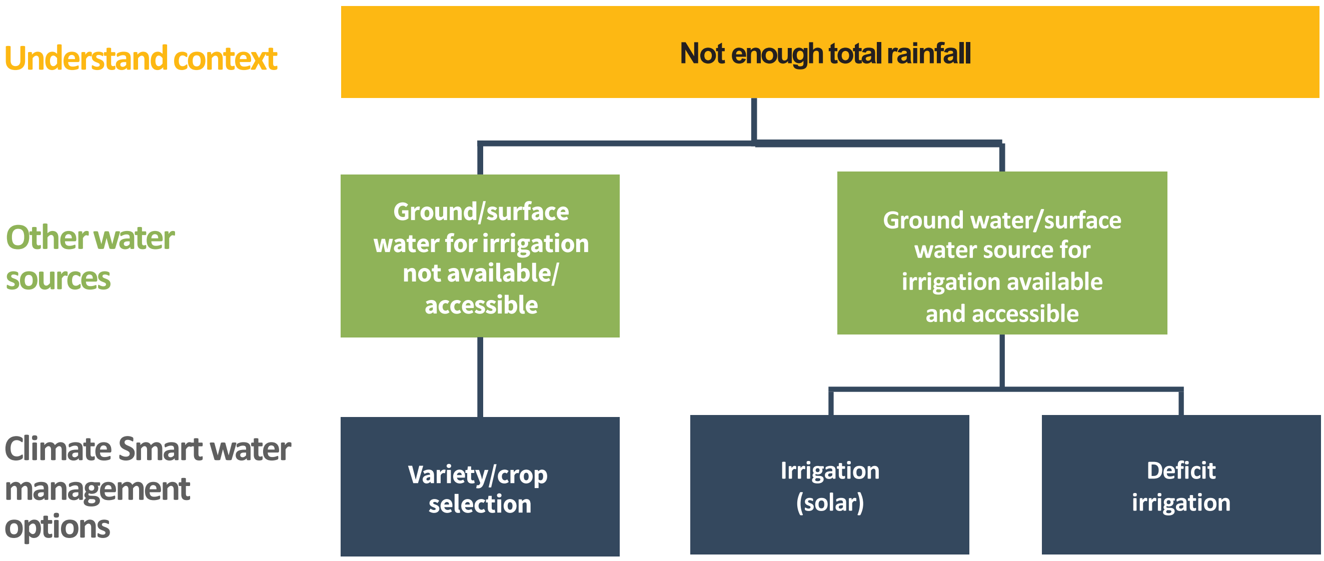
Once you know the water requirements for maize and sorghum and have estimated probable rainfall, you will be able to make decisions on whether or not it is likely that there will be enough rainfall to meet the crops' needs in the coming season.



The Decision Point below illustrates a decision tree where other water sources are both available and unavailable.

Climate smart decisions on water management options for maize and sorghum should factor in what other water sources might be available to supplement rainfall, if it is not expected to be enough to meet crop requirements.

DECISION POINT



If the area does not receive enough total rainfall during the growing cycle, then the farmers' options are limited. Irrigation may or may not be an option depending on a range of factors including:

- **Availability** of ground or surface water sources
- **Cost** of accessing these sources
  - Distance to field
  - Depth of water table
  - Cost of pumping equipment required
- **Access to credit**
- **Individual vs group** schemes
- Availability of **labour**
  - Canals and distribution channels may need to be dug
  - Does the household have access to the labour required to do this?
  - Is labour availability the same for men and women farmers?
- **Land ownership** – owned vs rented
- **Gender and age** also need to be assessed
  - Women may not have the same access to credit and labour as men
  - Older farmers may be less interested in investing in something that will take several years to pay back
  - Young farmers might lack the finance to invest
- **Cost benefit analysis** – will the potential increase in yield offset the costs involved, and over what time period?
- Does the farmer **plan to grow for sale** or **grow** for **consumption**?
  - If growing for **consumption**, it may be difficult to repay investment costs
- What effect will use of this water have on other users within the catchment?

BEST BET!

BEST BET WATER MANAGEMENT OPTIONS FOR ADDRESSING CLIMATE RISKS IN MAIZE/SORGHUM PRODUCTION

Below are five climate smart water management options for sorghum and maize. They are listed in no particular order. All are broadly applicable across the SADC region. In many instances a combination of these options will give optimum results in terms of water management. While these are best bet options, they are not universally applicable. CSA is context specific, and each of these options will need to be tested under local conditions and adapted to make it **Best Fit** the local context.

VARIETY/CROP SELECTION

If rainfall is not sufficient and irrigation is not an option, then you need to work with your farmer to assess if it is viable to grow maize or sorghum at all:

- Are new short-season, drought-tolerant varieties available locally, and are these accessible/affordable?
  - Early-maturing varieties tend to have lower yield potential than later-maturing varieties
- Is there potential to switch to sorghum instead of maize, as sorghum requires less water?
  - Is the crop for own consumption or sale?
  - Is sorghum an acceptable food locally, and can it be sold on the market?
  - Is there local knowledge on how to grow sorghum, or is it a new crop to the farmers?

For more information on how to make climate smart decisions on which crop and variety to plant, please see **KP09 – Climate Smart Seed Selection**.

SOLAR IRRIGATION

There are many different potential types of irrigation, depending on the source of water to be used. **Gravity fed systems**, where water is diverted and collected at a higher level than the field to be irrigated, and channelled either through pipes or canals to the field, require the least amount of energy – and are a very climate smart option. All options should be considered before selecting the best option for your location.

Solar irrigation uses solar energy to power irrigation systems that would otherwise use electricity from the national grid, or diesel-fuelled pumps. The benefits in terms of greenhouse gas (GHG) emissions from two different projects are illustrated in Table 3.

The cost of solar irrigation equipment is declining rapidly, with new solar products continually entering the market. You should regularly visit your local agri-supplier to see what is on the market, so that you can advise your farmers appropriately.

The essential components of solar irrigation systems are illustrated in Figure 3. They include the following:

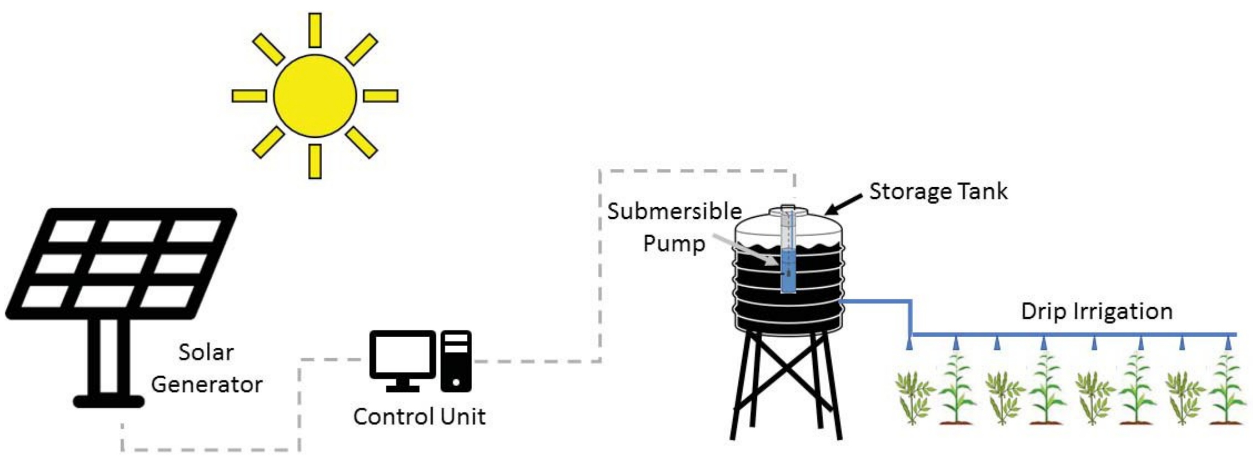
- **Solar generator,** i.e. a photovoltaic (PV) panel or array of panels to produce electricity
- A **mounting structure** for PV panels, fixed or equipped with a solar tracking system to maximise the solar energy yield
- A **pump controller**
- A surface or submersible **water pump** (usually integrated in one unit with an electric motor)
- A **distribution system** and/or storage tank for irrigation water.

Table 3: GHG emission reductions due to use of solar pumping equipment in two separate projects.

Project	Unit	Solar	Grid Electricity	Diesel
GIZ 2016	gCO2eq/kWh	16–32	600	1,000
POST 2011	gCO2eq/kWh	75–116	488–990	-

Source: GACSA, 2017

Figure 3: The essential components of a solar irrigation system.



Where can solar irrigation be practised?

Solar irrigation can be practised in any location where the following requirements are fulfilled:

- Sufficient solar irradiation – solar power received per unit area of land surface
- Land availability – sufficient unshaded land to support the PV panels, and accommodate water infrastructure such as storage tanks
- Water availability and legal permit/licence to abstract water – sufficient water to satisfy the pre-determined irrigation water requirement of the crop(s)
- Appropriate water quality – sufficiently low levels of salinity or heavy metal concentrations.

Factors to consider when deciding on the type of solar irrigation system

Availability and cost of the different systems are likely to be the most limiting factors in decision-making.

- Drip irrigation systems are highly efficient, but are more suited to high-value crop production on small land areas (e.g., vegetables), rather than for maize and sorghum
- Surface irrigation systems using earth channels are much less efficient, but require much lower investment costs.

The irrigation efficiency of different systems is outlined in Table 4. Relative costs as well as some key resources required for the three main types of irrigation systems are outlined in Table 5.

Table 4: Irrigation efficiency of different types of systems.

Application system	Irrigation efficiency
Drip systems	90%
Sprinkler systems	65%–80% (depending on type)
Surface irrigation systems (piped supply)	80%
Surface irrigation systems (earth channel supply)	60%

Table 5: Relative comparison between various factors that commonly influence decision making on irrigation systems.

Irrigation type	Initial costs	Land leveling	Efficiency	Adding of fertilisers	Labour requirements
Surface	Low	Required	Low	No	Intensive
Sprinkler	High	Not required	Middle	Economical	Low
Drip	High	Not required	High	Highly efficient	Low

Source: Energypedia

Solar irrigation systems do require significant up-front investment. It is important that you discuss with your farmers if this investment is justified. These systems may only be viable for higher-value crops, and may only be practical in group schemes rather than for individuals.

TIP

You should always calculate the total lifetime costs of the system, as well as the payback period.

Consider entering into a service contract with the supplier/ installer to ensure minimal downtime.

Source: www.omafra.gov.on.ca

DEFICIT IRRIGATION

Deficit Irrigation involves irrigating plants with less than the optimal amount of water, but applying this water during the most beneficial growth stages. This strategy can be applied using several types of irrigation systems. It is appropriate in the following contexts:

- Irrigation water is available, but is not sufficient to meet full crop needs
- Where it is more profitable for a farmer to maximise crop water productivity over harvest per unit area – saved water can be used to irrigate extra units of land or for other purposes, such as feeding livestock.

The aim of deficit irrigation is to **stabilise rather than maximise yields**.

The correct application of deficit irrigation requires a thorough understanding of the yield response to water – crop sensitivity to drought stress – and the economic impact of reductions in harvest. This climate smart option may become more important in the future in regions where rain-fed agriculture is important, and where lower and more variable rainfall is predicted.

Deficit Irrigation is a responsive practice, and cannot be scheduled in the same way as full irrigation. The best water delivery systems are those that can be used **on demand**; for instance, where farmers have access to wells, or nearby water sources.

To make the most of this option, it should be used in conjunction with localised, accurate weather forecasting. In many communities, the available water supply is inadequate to irrigate all of the available land. In such cases, farmers might consider the communal benefits of allowing sub-optimal yields on their individual fields, by practising deficit Irrigation, so that the water saved might be used to irrigate additional land in the community.

The Decision Point below illustrates how an understanding of farmers' priorities and the local context can influence decisions on which water management option might be most suitable.

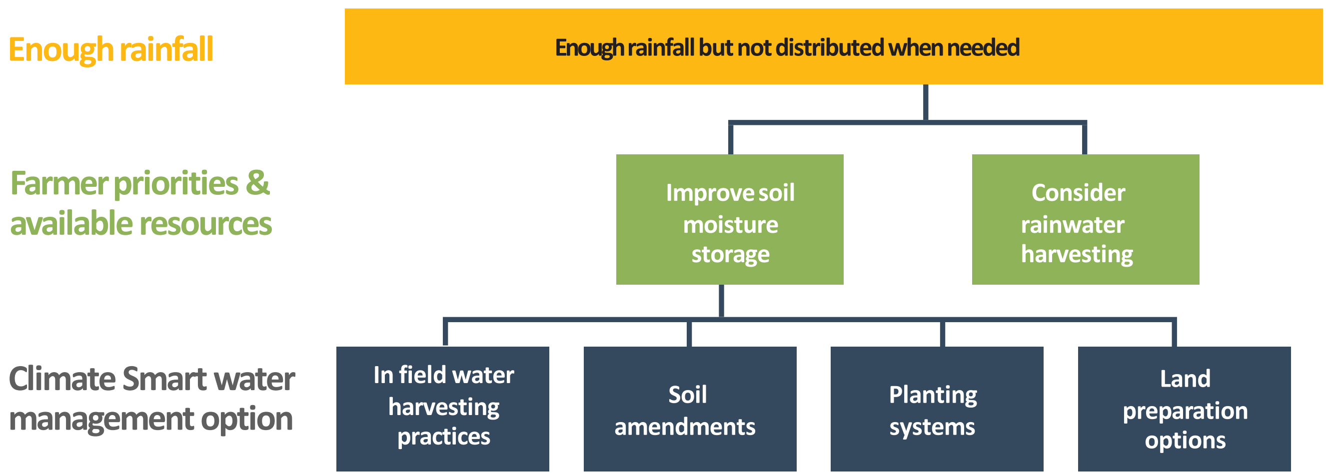
When there is enough rainfall, but it is not distributed evenly, farmers' priorities and available resources will influence decision making on climate smart water management options.

Improve Soil Moisture Storage

The two remaining climate smart options for water management in maize and sorghum fall under the umbrella of improving soil moisture storage. There are many climate smart options for increasing the potential of the soil to retain more moisture. These include soil amendments, cropping systems and land preparation options, all of which are covered in more detail in **other Knowledge Products (KPs 06, 07 and 08)**. These options are applicable where there is enough total rainfall, but the rainfall is not distributed evenly over the growing season.

DECISION POINT

Figure 4: Understanding how farmer priorities and local context can influence water management decisions.



IN-FIELD WATER HARVESTING

The focus of this section is on climate smart **in-field water harvesting practices** that aim to capture runoff water, and how to best choose the one most suited to your farmer(s).

- In-field water harvesting practices can be labour intensive and are best suited to arid and semi-arid regions where other options are limited
- Climate smart soil amendments, planting systems and land preparation options can all be implemented along with in-field water harvesting to maximise moisture retention.

A water harvesting scheme will only be sustainable if it fits into the socio-economic context of the area and fulfils a number of basic criteria. These include:

SLOPE: The ground slope is a key limiting factor to water harvesting. Water harvesting is not recommended for areas where slopes are greater than 5%, due to uneven distribution of runoff and the significant quantities of earthwork required.

SOILS: Should have the main attributes of soils suitable for irrigation:

- Deep soils
- Not saline or sodic
- Ideally possess inherent fertility
- Soils with a sandy texture are a serious limitation as the infiltration rate may be higher than the rainfall intensity – no runoff will occur.

COSTS: The quantities of earth and stonework involved in construction directly affects the cost of a scheme, and indicates how labour intensive its construction will be.

This short video illustrates how to test infiltration rates of soils in a simple way.

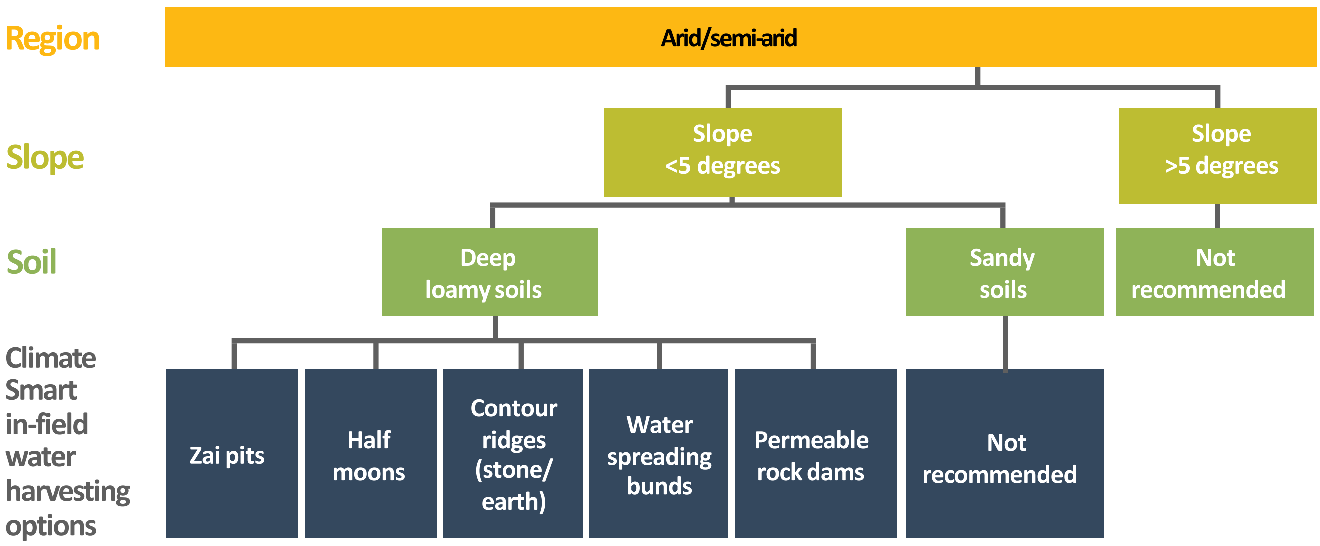
Water Infiltration in No-Till vs Conventional Soil

TAWC – Texas Aliance for Water Conservation

The Decision Point below illustrates a decision tree that focuses on climate smart in-field water harvesting options for small-scale maize and sorghum farmers. Other options are available for rangeland fodder and tree-based systems.

Figure 4: Decision tree for climate smart in-field water harvesting options suitable for small scale maize/sorghum farmers.

DECISION POINT



Assuming the soil texture is suitable, deciding on which climate smart in-field water harvesting option to implement will depend on several factors:

- **Floodwater or runoff systems**
  - Is it possible to divert floodwater (water spreading dams, permeable rock dams), or is it necessary to try to capture runoff (contour ridges, zai pits, half-moons)
- **Availability of labour**
  - Individuals might choose to do half-moons, or zai pits
  - Labour constrained farmers might choose other climate smart alternatives such as soil amendments, different field preparation practices, or choosing alternate crops/varieties
  - Groups may choose more labour-intensive options
- **Availability of stones**
  - Limited availability will rule out stone bunds, or permeable rock dams
- **Local topography** and catchment size
- **Cost benefit analysis.**

RAINWATER HARVESTING

If there is enough rainfall but distribution is variable, another option is rainwater collection from runoff into tanks/ponds. The collected rainwater can be used in conjunction with either gravity fed or pumped (solar) irrigation systems. There are many types of rainwater harvesting systems available across the SADC region.

There are various factors your farmers should consider when making a decision on which option might best suit them:

- Small systems often rely on water collected from roofs
  - Metal/slate roofs work best
  - These limit the volume of water that can be collected due to surface area, and because the tank must fit below the eaves (gutter) of the roof.

TIP

To maximise results of in-field water harvesting, it should always be implemented as part of a broader Integrated Soil Fertility Management approach.

Ultimately, the farmers themselves should make the decision on which (if any) climate smart in-field water harvesting practice they want to try out. To do this, they need to understand the lifetime costs of each option and not just the initial costs.

Annual maintenance costs in terms of labour and/or capital investment should be calculated and planned for.

If the benefits are not well understood, then a pilot site might help convince farmers of the benefits. Different practices can be piloted over a season, and farmers can then decide which are best.

TIP

Remember, when establishing farmer trials, keep all other variables (seed type, soil amendments added, time of planting, weeding, etc.) the exact same. The highest possible yield is not always the most profitable for the farmer. Gross Margins should always be calculated to assess the return on investment, so that the most profitable option is clear.

- Larger systems require significant investment in labour and/or money, and are generally only viable as group schemes
  - Technical experts will be required for larger systems
- When considering rainwater harvesting, it is always good to consider what else the water might be used for if it is made available. It is better to understand and plan for this at the start, rather than to find capacity is not enough because water is being drawn down for other uses such as for livestock or human consumption.

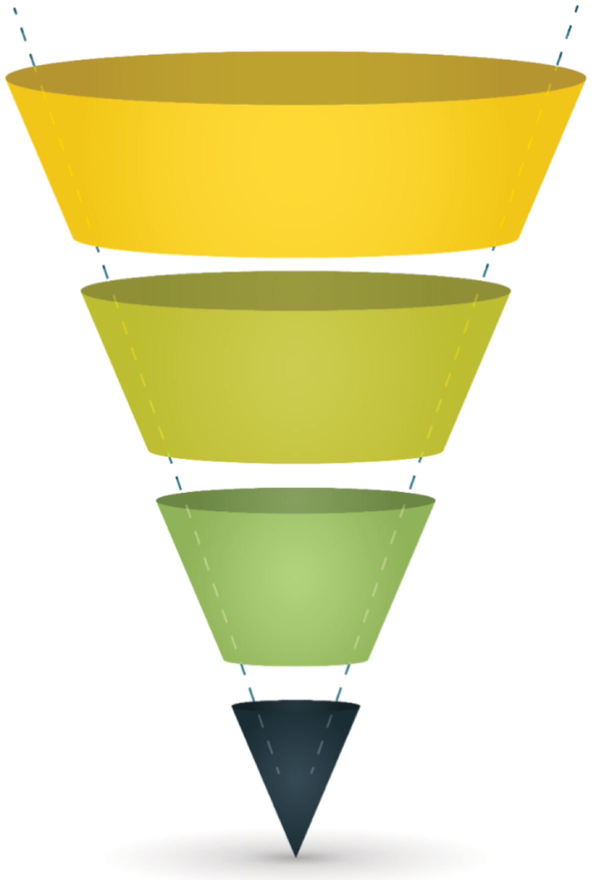
Table 6 details the main advantages and disadvantages of some common water harvesting technologies used across the SADC region.

Table 6: Advantages and disadvantages of different water harvesting technologies used across the SADC region.

Technology	Target Level	Advantages	Disadvantages	Suitability for Maize/ Sorghum
Plastic water tank (5 m³) 	• Individual	• Easy to install • Easy to move • No evaporation • No pump required	• High Initial Cost • Difficult to repair • Relatively short lifespan – 10 yrs	• Only suited to very small-scale production (e.g., home gardens)
Plastic water tank (1 m³ – 10 m³) with drip irrigation kit (100 m² –200 m²)	• Individual	• Easy to install • Easy to move • No evaporation • No pump required • Drip irrigation has 80%+ water-use efficiency compared to 35% with a watering can	• High cost • Difficult to repair • Relatively short lifespan – 10 yrs • Drip system requires constant maintenance and has a short lifespan • Sustainability of access to replacement parts for drip system	• Only suited to very small-scale production (e.g., home gardens)
Bamboo water tank (5 m³ –8 m³) 	• Individual	• Made from locally available materials • Easily repaired • 30-year lifespan • Low evaporation • No pump required	• Cannot be modified once installed • Requires skilled labour to construct (trained technician) • Takes a minimum of 3 weeks to construct • Limited maximum capacity	• Only feasible where bamboo is easily and cheaply available • Only suited to very small-scale production (e.g., home gardens)
Semi-underground tank (SUT) (6 m³ –10 m³) 	• Individual	• Low cost • Locally available materials • Does not require skilled labour • Volume can be increased after installation • Easy to repair (replace plastic liner or re-plaster) • Low evaporation	• Requires a pump to lift water (energy requirement) • Higher level of water impurities/germs than other solutions • Short lifespan of just 10 years • Sourcing the correct specification of plastic for the 10 m³ tanks is a challenge	• Only suited to very small-scale production (e.g., home gardens)

Technology	Target Level	Advantages	Disadvantages	Suitability for Maize/ Sorghum
Runoff water pond (between 250 m³ and 480 m³) 	• Groups	• Large capacity • Easy to construct • Locally available labour and materials • Potential for integration of small-scale fish production	• Requires pump to lift water • Too expensive for individual households • Requires a strong group/committee to maintain/manage • Requires a large piece of land • High levels of evaporation • Requires detailed feasibility studies	• Multiple ponds are required to irrigate a significant area of land • Requires detailed feasibility studies
Solar irrigation systems (1 – 5 ha) 	• Groups	• Can irrigate a large area of land for a long period • Minimum labour requirement once operational • Low running costs	• High initial cost (but coming down all the time) • Only suitable where groundwater can be accessed • Sustainability – requires a motivated committee to manage the system • High potential for theft of solar panels • Low output on cloudy days • Not replicable without external support	• High cost but also high impact if established effectively
Night storage reservoir (NSR) (700 m³)	• Groups	• Filling at night reduces conflict with downstream communities • High capacity • Easy to construct using local skills	• Requires regular maintenance to remove sediment • Limited applicability – must have perennial water source • Requires a committee to manage/maintain	• If the geography is right this can be a viable option, but downstream users must be consulted
Small earth dams 	• Groups	• Potentially very high volume • Construction costs can be kept down using local labour	• Evaporation losses • Requires an expert to conduct feasibility study and oversee construction • Siltation – catchment area may need to be rehabilitated as well • Only applicable in specific sites • Requires a large piece of land	• Potential to irrigate significant areas of land depending on local geography

TO SUMMARISE



STEP 1: Consider your crop water requirements

- Different varieties and crops require different amounts of water

STEP 2: Know what sources of water are available

- Enough/not enough
- Rainfall – probable
- Surface
- Sub surface

STEP 3: Consider the local context

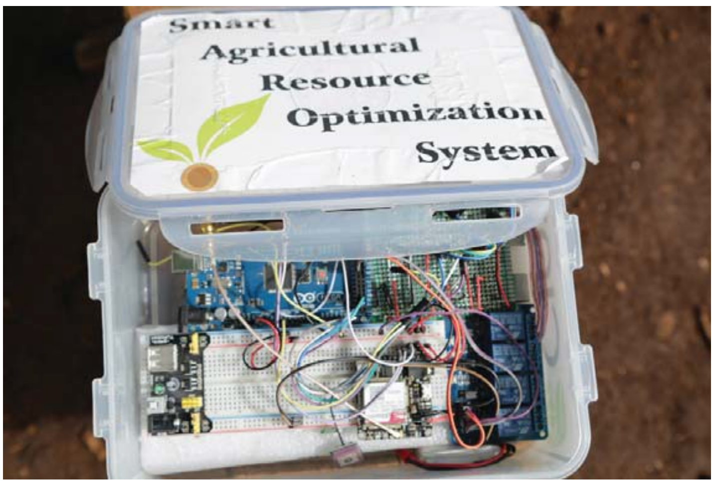
- Availability & accessibility of different varieties
- Geography/topography
- Farmers' needs/priorities

STEP 4: Cost benefit analysis

- Which option is financially viable
- Consider alternatives.

Climate smart soil water management is just one component of **Integrated Soil Fertility Management** (ISFM).

The benefits of adopting multiple climate smart practices are much greater and more sustainable than from adopting just one.



Irrigation Kit

Jonathan Odhong, ITA, 2017

WHERE CAN I FIND MORE INFORMATION?

The following resources, which were used as reference for the development of this Knowledge Product, provide valuable additional reading on this subject. Please also refer to the CCARDESA website (www.ccardesa.org), the full series of Knowledge Products, and associated Technical Briefs.

- See also **CCARDESA KPs 6, 7, 8, 9, 12, 16 & 19** for more detail on specific climate smart practices and technologies included within Integrated Soil Fertility Management.
- **ASHC** – Handbook For Integrated Soil Fertility Management
  - An excellent resource that every extension officer should have access to
- **ASHC** – Sorghum and Millet Nutrient Management
  - A very practical resource for anyone growing sorghum or millet
- **ASHC** – Maize-Legume Cropping Systems
  - A practical guide to growing maize and legumes. Excellent resource for extension staff in the field
- **CIAT** – Impact of Conservation Agriculture on Soil Health
  - Aimed more at policy level, but a useful overview of the climate smart credentials of solar irrigation
- **Energypedia** – Basics and SWOT Analysis of Solar Powered Irrigation Systems (SPIS):
  - A useful and comprehensive guide on SPIS
- **FAO** – Green manure cover crops and crop rotation in conservation agriculture on small farms: Integrated Crop management Vol 12, 2010
  - Focused on Paraguay and a bit scientific in places, but covers all the principles behind the practices
- **FAO** – Soil and water requirements:
  - Quite technical, but a useful guide on how to calculate/estimate the water requirements of different crops
- **GACSA Practice Brief** – Solar Powered Irrigation Systems: A clean energy, low-emission option for irrigation development and modernisation
  - A very useful infographic/poster that relates to soil health in general, not just conservation agriculture.

Addison, 2003

Citation: CCARDESA and GIZ 2019. Knowledge Product 10: Climate smart water management options for maize & sorghum. CCARDESA Secretariat, Gaborone, Botswana.