MODULE 2

Soil and Water

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1 INTRODUCTION

Training structure

In this module, you will learn about Climate-Smart Agriculture (CSA) and its impacts on agriculture and food security. The training will cover the basics of climate science as well as the connections between climate, agriculture, and food security. This training is designed so that extension practitioners get a clear understanding of:

- What are the natural resources?
- How are the natural resources effected by climate change?
- What adaptation and mitigation strategies can be put in place to deal with the impact of climate change?

Training objectives

After completion of the training module the extension practitioner should:

a. Be able to select and implement appropriate soil and water management practices for specific scenarios.
b. Know how to identify unproductive water losses (runoff & evaporation from the soil surface) and put strategies in place to minimize these water losses.
c. Be able to list and describe the of adaptation and mitigation strategies to deal with the impact of climate change.

Land (soil) and **water** are two of the most important natural resources, which are threatened by climate variability that is considered to be the main cause of both land degradation and water scarcity. **Climate variability** includes changing changes in rainfall patterns, increased frequency and intensity of drought and floods; rising temperatures, as well as profound ecological shifts. Arid and semi-arid regions are more prone to higher temperatures coupled with limited rainfall due to the interaction between land degradation and climate variability. Desertification is one of the most dire problems in these areas and is caused by climate and land degradation related changes. Climate-induced changes include changes in air temperature and moisture, while land degradation-induced changes include reductions in soil organic matter, above and below ground biomass and soil fertility. However, the occurrence of **extreme weather conditions** such as extreme drought or heavy rainfall can accelerate wind and water erosion that which in turn will con-tributes hugely towards biomass, and physical and chemical degradation of the land. Wind and water are the main driving forces for of soil erosion. Soil erosion adversely affects the productivity of agricultural land as it selectively removes the plant nutrients and organic matter in the surface

soil where the majority of crop roots are found. Furthermore, it promotes the removal of finer soil particles that leads to soil compaction. Soil ero-sion further promotes water runoff that causes a reduction in the availability of water to the crop. However, soil erosion depends on factors such as the type of soil, depth of soil, slope of land, soil organic matter content, cultivation practices, crop growth and duration and intensity of rainfall or wind.

One of the most affected economic sectors by the aforementioned conditions is agriculture, a sector considered imperative to both economic development and poverty reduction. Yet, it faces a serious challenge to meet the ever-increasing food demand and to improve productivity in both irrigated and rainfed areas. This suggests that there will be a greater need for water to produce food in the near future, though this will be dependent upon improvements in rainfed and irrigated agriculture.

Developing countries rely heavily on rain-fed agriculture to produce grain crops for most of their farmlands. Due to the ever-increasing **unfavourable climatic conditions** that result in inadequate and fluctuating water availability, the productivity and profitability of these lands are significantly decreased. Climate change is attributed to decreasing rainfall events. There is therefore an ever increasing need to use the limited water resources in food production more efficiently.

Research indicates that Climate-Smart Agricultural (CSA) technologies and management practices have demonstrated effectiveness in addressing the issue of water scarcity for food production in resource poor countries (Hensley et al., 2000) This practice is reported to have been long adopted, espe-cially in sub-Saharan Africa using indigenous knowledge systems. CSA technologies and management prac-tices are considered as an alternative option that will capture the concept that agricultural systems can be de-veloped and implemented to concurrently improve food security and rural livelihoods. It will achieve this through enabling **climate change adaptation** and offering mitigation benefits.

It should be noted that agricultural production varies widely from place to place, and climate change affects each area and each farm in a different way. CSA approaches are specific to site and context and there is no one solution, or even one set of solutions, that fits all situations. Nonetheless, we can define some general princi-ples to follow, and we can give examples that readers could adapt to suit their particular circumstances.

There is a serious skill gap between resource-poor rural farmers and using CSA technologies. Furthermore, it is also recognised that these farmers have the need for information and appropriate learning methods that are not being met, and this is especially the case in South Africa.

2 OVERVIEW OF NATURAL RESOURCES

Objectives

1. Understand the importance of water and soil as natural resources.
2. Describe soil texture and soil characteristics related to texture.
3. Explain how the choice of CSA technology will be influenced by the soil structure.

Natural resources are materials from the earth that are used to support life and meet people's needs. Any natural substance that humans use can be considered a natural resource. Oil, coal, natural gas, metals, stone, and sand are natural resources. Other natural resources are air, sunlight, soil, and water. For this manual the focus will only be on soil and water as they are the most important natural resources for the existence of life.

2.1 RAINFALL (WATER)

South Africa is generally semi-arid; its precipitation is highly variable, and farmers often face water shortages. The average annual rainfall for South Africa is about 464 mm (compared to a global average of 786 mm), but large and unpredictable variations are common. More than one-fifth of the country is arid and receives less than 200 mm of precipitation annually, while almost half is semi-arid and receives between 200 and 600 mm annually. Only about 6% of the country averages more than 1 000 mm per year.

The amount of precipitation gradually declines from east to west. Whereas the KwaZulu-Natal coast receives more than 1 000 mm annually and Kimberley approximately 400 mm, Alexander Bay on the west coast receives less than 50 mm.

About one third of the arable land in South Africa is of low potential for crop production, located mainly in semi-arid areas, with the main problem being water shortage due to a **low and erratic rainfall** pattern, high evaporation rates and often with soils having low water holding capacity and poor fertility.

The situation is aggravated further by the fact that most of the rainfall occurs in the form of high-intensity thunderstorms, resulting in high water losses due to runoff. Storms, as extreme weather events, are considered one of the effects of climate change. Suitable CSA technologies (e.g. Rainwater harvesting and conservation practices) are needed to adapt to the effects of climate change.

Since water is the most limiting natural resource, it needs to be utilised effectively for crop production. Some useful **tips** to as improve the **water use efficiency** are as follows:

- While fertilisers promote plant growth, it also increase water consumption. More water is lost through the process of transpiration form a lush vigorously cropping crop. By applying the minimum amount of fertiliser needed, smaller plants with a lower transpiration rate might be induces without compromising on crop yield.

- If production is done on small homestead garden level, then a garden fork can be used to aerate the garden periodically. Holes every 30 cm will allow water to reach the roots, rather than run off the surface.
- Plant drought resistant crops and cultivars. Drought tolerant crops (like maize, cowpeas, barley, sunflower and sorghum) require less water than others once they are established and continue to grow and produce even when rains fail.
- Apply a layer of mulch to minimize Es losses and discouraging weed growth.
- Construct manual rainwater harvesting structures in the homestead gardens or mechanized basins on a larger scale in croplands to collect and store water and prevent losses through runoff.
- Collect water from roof tops in tanks and drums to be used for supplemental irrigation during periods of drought and water stress.
- Irrigate your crops early in the morning or late in the evening when it is not so hot and evapotranspiration is low.
- Avoid watering when it is windy.
- Instead of irrigating the whole garden only irrigate around the plants where the most roots are growing.
- Add organic matter to your soil to improve the soil structure and water holding capacity.
- Avoid over-watering crops, as this can actually diminish plant health and cause yellowing of the leaves.
- Keep the garden / cropland free of weeds as it competes with the crop for the available water and nutrients.

2.2 SOIL

South Africa contains three major soil regions. East of approximately longitude 25° E, soils have formed under wet summer and dry winter conditions; the more-important soil types there are laterite (red, leached, iron-bearing soil), unleached subtropical soils, and gley like (i.e., bluish gray, sticky, and compact) podzolic soils (highly leached soils that are low in iron and lime). A second large region is in an area that receives year-round precipitation (Western Cape and Eastern Cape) and generally contains gray sand and sandy loam soils. In the rest of the country, which is generally arid, the characteristic soils consist of a sandy surface layer, often sandy loam, under which is a layer of lime or an accumulation of silica. With some exceptions, the soils of South Africa are not characterized by high fertility, and those that are - for example in the coastal region of KwaZulu-Natal - tend to be easily degraded..

Soil plays a very important role in agricultural production. It performs the following functions:

- Providing plants with essential minerals and nutrients
- Providing air for gas exchange between roots and atmosphere
- It stores water (moisture) and provides adequate aeration

Improper management of soil leads to soil and land degradation. As soon as the pristine land is used for agriculture, the quality of soil resources begins to deteriorate and the rate of deterioration depends on the skill of the land manager. Therefore, it is important that land and soil users learn to use the soil and land in a sustainable manner.

2.2.1 Soil texture

The inorganic material in soil is called mineral matter. Minerals were formed from rocks that have weathered into small particles. Most soils contain mineral particles of different sizes. These particles are called sand, silt, or clay, depending on their size, as shown in the examples in Figure 1.

- **Sand** is the largest of the mineral particles. Sand particles create large pore spaces that improve aeration. Water flows quickly through the large pore spaces. Soils with a high sand content are generally well drained. Sandy soils lack the ability to hold nutrients and are not fertile. Sandy soils also have a gritty feel. Sandy soils are light, dry, warm, and often acidic.
- **Silt** is the medium sized soil grain. Silt has good water-holding capacity and good fertility properties. It feels like flour when dry and smooth like velvet when moist.
- **Clay** is the smallest size soil particle. Clay has the ability to hold both nutrients and water that can be used by plants. It creates very small pore spaces, resulting in poor aeration and poor water drainage. Clay forms hard clumps when dry and is sticky when wet. It is wet and cold in winter and baked dry in summer.
- **Loams** are mixtures of clay, sand and silt that avoid the extremes of each type.

Soil texture describes the ratio of three sizes of soil particles and the fineness or coarseness of a soil. Soil texture can be determined in two ways.

The percentage of sand, silt and clay can be tested in the laboratory. After testing, the texture class of the soil can be determined using the texture triangle.

(a) (b) (c)

Figure 1 Examples of a clay (a), (b) loam and (c) sandy soil.

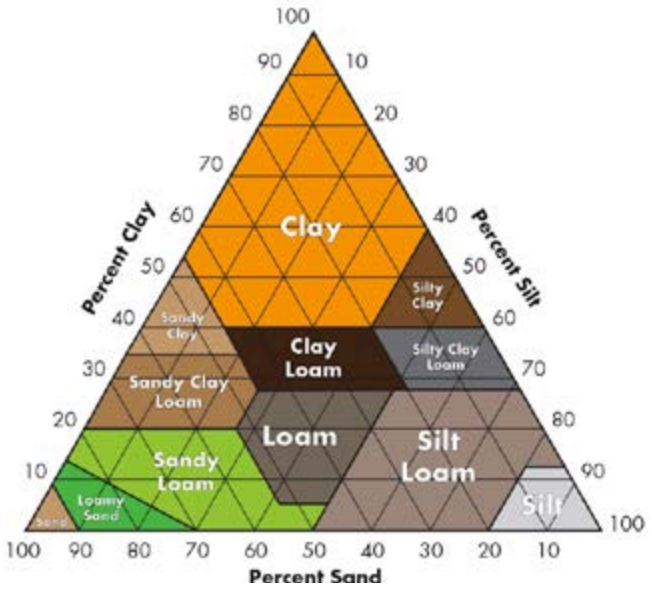


Figure 2 The textural triangle is used to classify soils.
Source: https://www.trugreen.com/lawn-care-101/learning-center/grass-basics/dig-deeper/soil-texture.

Soils with different percentages of sand, silt and clay are given different designations. A soil with 35% clay, 30% silt and 35% sand is called clay loam, as shown in the example in Figure 2.

The relative amounts of sand, silt, and clay may also be determined in the field by wetting a soil sample and rolling it into a sausage and then trying to form it into a circle. With a sandy soil the moistened ball cracks when compressed and falls apart, while with the cla y soil a full circle without cracks can be formed, as illustrated in Figure 3.

The texture of a soil is important because it determines the soil properties that affect plant growth. Three of these properties are the water-holding capacity, permeability, and workability of the soil. Water holding capacity is the ability of a soil to retain water. Most plants require a constant supply of water, and this is obtained from the soil. Plants do need water, but they also need air in the root zone. Permeability is the ease with which air and water can pass through the soil. Soil workability is the ease with which the soil can be worked and the timing of the working.

Sandy soils have low water-holding capacities and generally high infiltration rates. Clayey soils have high water-holding capacities and generally low infiltration rates. In addition, well-drained soils typically have good soil aeration meaning that the soil contains air that is similar to atmospheric air, which is conducive to healthy root growth, and thus a healthy crop (see Table 1).

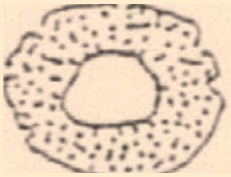
	**Sand** Moistened ball cracks when compressed; falls apart
	**Loamy sand** Cracks and does not allow a sausage to be rolled
	**Sandy loam** Ball or sausage can be rolled
	**Sandy clay loam** Can be rolled out thinly but cracks when bent
	**Clay loam** Cracks under attempts to form an “O”
	**Sandy clay** “O” can be formed with some cracking
	**Clay** “O” can be formed without cracking

Figure 3 Determination of soil texture classes.
Source: Ritchey et al., 2015.

Table 1 Characteristics of Sand, Silt and Clay.
Source: https://www.vaderstad.com/en/know-how/basic-agronomy/soil-basics/characteristics-of-different-soil-types.

Characteristics	Sand	Silt	Clay
Looseness	Good	Fair	Poor
Air space	Good	Fair to good	Poor
Drainage	Good	Fair to good	Poor
Tendency to form clods	Poor	Fair	Good
Ease of working	Good	Fair to good	Poor
Moisture holding ability	Poor	Fair to good	Good
Fertility	Poor	Fair to good	Fair to good

With climate change, rainfall is generally decreasing, meaning that less water is available for production. Production on a sandy and clay soil in the same area that receive in the same rainfall will be significantly different. Total crop failures might be experienced on the sandy soil due to the low water holding capacity, but acceptable yields might still be possible on the clay soil. Different soil and water management practices will be used for differing soil types to mitigate the effects of climate change.

2.2.2 Soil structure

Sand, silt, clay, and organic-matter particles in a soil combine with one another to form larger particles of various shapes and sizes. These larger particles, or clusters, are often referred to as aggregates. The arrangement of the soil particles into aggregates of various sizes and shapes is soil structure. Aggregates that occur naturally in the soil are called peds, whereas clumps of soil caused by tillage are called clods.

Ways in which aggregates are created include freezing and thawing, wetting and drying, fungal activity, tillage, and the surrounding of the soil by plant roots that separate the clumps. Weak aggregates are cemented to make them distinct and strong. Clay, iron oxides, and organic matter often act as cements. When soil micro-organisms break down plant residues, gums are produced that glue peds together.

The eight primary types of soil structure are blocky, crumb, columnar, granular, massive, platy, prismatic, and single grain. Granular is the most desirable structure type because it has the greatest proportion of large openings between the individual aggregates.

- **Blocky**: The units are block-like. They consist of six or more flat or slightly rounded surfaces.
- **Crumb**: The aggregates are small, porous, and weakly held together.
- **Columnar**: The units are similar to prisms and are bounded by flat or slightly rounded vertical faces. The tops of columns are very distinct and normally rounded.
- **Granular**: The units are approximately spherical or polyhedral. The aggregates are small, nonporous, and held strongly together.
- **Massive**: There is no apparent structure. Soil particles cling together in large uniform masses.

- **Platy**: The units are flat and plate-like. They are generally oriented horizontally. Plates overlap, usually causing slow permeability.
- **Prismatic**: The individual units are bounded by flat to rounded vertical faces. Units are distinctly longer vertically. The tops of the prisms are somewhat indistinct and normally flat.
- **Single grain**: There is no apparent structure. Soil particles exist as individuals and do not form aggregates.

Soil structure is important for several reasons. Soil structure affects water and air movement in a soil, nutrient availability for plants, root growth, and microorganism activity. The pore spaces created by peds are larger than those between individual particles of sand, silt, or clay. This allows for greater air and water movement and better root growth. The larger spaces make passageways for organisms. The aggregates are also better able to hold water and nutrients.

Soil structure can be destroyed. A major cause of damage is driving heavy equipment (like a tractor and im-plements) over wet soil. Damage is also caused by working soil when it is either too wet or too dry. Either condition leads to the clay particles clogging the pore spaces. The soil becomes compacted and very dense; and when it dries, it becomes very hard. It is extremely difficult for most plants to survive in a soil whose structure has been destroyed.

With climate change, extreme weather conditions, like floods and prolonged droughts are common. Timing of cultivating fields is therefore important so that it does not coincide with periods of flooding and droughts when soils are highly susceptible to structural damage.

2.2.3 Summary

Most soils have different sizes of mineral particles called sand, silt, and clay. Sand is the largest of the mineral particles. Silt is the mid-size soil particle. Clay is the smallest size soil particle. Soil texture describes the proportion of the soil particles and the fineness or coarseness of a soil.

The texture of a soil determines soil characteristics that affect plant growth. Three of these characteristics are water-holding capacity, permeability, and soil workability.

Sand, silt, clay, and organic-matter particles in a soil combine with one another to form larger particles of various shapes and sizes. Soil structure is the arrangement of the soil particles into aggregates. The eight primary types of soil structure are blocky, crumb, columnar, granular, massive, platy, prismatic, and single grain.

Soil structure affects water and air movement in a soil, nutrient availability for plants, root growth, and micro-organism activity.

Checking your knowledge:

1. How do sand, silt, and clay differ?
2. What is soil texture?
3. How is soil texture determined?
4. Why is soil structure important?

Expanding Your Knowledge:

Explore the soil around your homestead garden. Dig up some soil and squeeze it, crumble it, and feel it.

- Is the texture gritty or smooth?
- Does the soil form a ball that easily crumbles?

See if you can determine the texture and the type of soil structure.

Practical activity 1

1. A simple activity can be performed to determine the soil texture of a given sample. Extension practitioners can be supplied samples of three soils. In their activity groups they need to work together to determine the soil texture of the given samples by making use of the touch and feel method.

2. In order to get a better understanding of the impact of soil texture on infiltration rate and water holding capacity a simple group activity can be performed. Take three transparent plastic cups and make equal amounts of holes in the bottom of each cup using a needle. Fill each cup halve full with a sand, loam a clay soil, respectively. Each cup is then placed again into a larger cup. In their groups, extension officers are then requested to pour an equal volume of water (e.g. 150 ml) into each cup with the soil. They are then requested to observe the infiltration rate and the volume of water that have drained out into the larger cup.

3 CLIMATE AND CLIMATE CHANGE

Objectives

1. Understand the meaning of "climate change".
2. Understand how production is influenced by the impact of climate change.

3.1 IMPORTANCE OF CLIMATE FOR CROP PRODUCTION

Nearly 50% of crop yield is attributed to the influence of climatic factors. The following are the atmospheric weather variables which influences the crop production:

- Precipitation
- Temperature
- Atmospheric humidity
- Solar radiation
- Wind velocity
- Atmospheric gases

Precipitation

Precipitation includes all water which falls from atmosphere such as rainfall, snow, hail, fog and dew. Rainfall is one of the most important factors that influences the vegetation of a place. The total precipitation amount and distribution greatly affects the choice of a cultivated species in a place. Low and uneven distribution of rainfall is common in dryland farming where drought resistance crops like pearl millet, sorghum and minor millets are grown. In desert areas grasses and shrubs are common where hot desert climate exists. Though the rainfall has major influence on yield of crops, yields are not always directly proportional to the amount of precipitation as excess above optimum reduces the yields. The distribution of rainfall is often more important than the total rainfall to have a longer growing period, especially in drylands.

Temperature

Temperature is a measure of intensity of heat energy. The range of temperature for maximum growth of most of the agricultural plants is between 15 and 40oC. The temperature of a place is largely determined by its distance from the equator (latitude) and altitude. It influences distribution of crop plants and vegetation. Germination, growth and development of crops are highly influenced by temperature. It affects leaf production, expansion and flowering. Physical and chemical processes within the plants are governed by air temperature. Diffusion rates of gases and liquids changes with temperature. Solubility of different substances in plant is dependent on temperature. The minimum, maximum (above which crop growth ceases) and optimum temperature for specific crops are of importance for crop production.

Atmospheric Humidity (Relative Humidity)

Water is present in the atmosphere in the form of invisible water vapour, normally known as humidity. Relative humidity is the ratio between the amount of moisture present in the air to the saturation capacity of the air at a particular temperature. If relative humidity is 100% it means that the entire space is filled with water and there is no soil evaporation and plant transpiration. Relative humidity influences the water requirement of crops. Relative humidity of 40-60% is suitable for most of the crop plants. Very few crops can perform well when relative humidity is 80% and above. When relative humidity is high there is chance for the outbreak of pest and disease.

Solar radiation

From germination to harvest and even post-harvest crops are affected by solar radiation. Biomass production by photosynthetic processes requires light. All physical process taking place in the soil, plant and environment are dependent on light. Solar radiation controls distribution of temperature and thereby distribution of crops in a region. Visible radiation is very important in photosynthetic mechanism of plants. Photosynthetic Active Radiation (PAR - 0.4 – 0.7µ) is essential for production of carbohydrates and ultimately biomass.

Wind velocity

The basic function of wind is to carry moisture (precipitation) and heat. The moving wind not only supplies moisture and heat, also supplies fresh CO_2 for the photosynthesis. Wind movement for 4 – 6 km/hour is suitable for most crops. When wind speed is enormous then there is mechanical damage of the crops (i.e. it removes leaves and twigs and damages crops like banana, sugarcane). Wind dispersal of pollen and seeds is natural and necessary for certain crops. Wind can causes soil erosion, increases evaporation and spread certain pests and diseases.

Atmospheric gases

CO_2 is important for photosynthesis. CO_2 is taken by the plants by diffusion process from leaves through stomata. CO_2 is returned to atmosphere during decomposition of organic materials, all farm wastes and by respiration. O_2 is important for respiration of both plants and animals, while it is released by plants during photosynthesis. Nitrogen is one of the important major plant nutrients. Atmospheric nitrogen is fixed in the soil by lightning, rainfall and nitrogen fixing microbes that lives on legume crops and then made available to plants. Certain gases like SO_2, CO, CH_4 and HF released to atmosphere are toxic to plants.

3.2 CLIMATE OF SOUTH AFRICA

The climate of South Africa is determined by South Africa's situation between 22°S and 35°S, in the Southern Hemisphere's subtropical zone, and its location between two oceans, Atlantic and the Indian.

It has a wider variety of climates than most other countries in sub-Saharan Africa, and it has lower average temperatures than other countries within this range of latitude, like Australia, because much of the interior (central plateau or Highveld, including Johannesburg) of South Africa is at a higher elevation.

Winter temperatures may reach the freezing point at high altitude, but are at their most mild in coastal regions, particularly KwaZulu-Natal Province and perhaps the Eastern Cape. Cold and warm coastal currents running north-west and north-east respectively account for the difference in climates between west and east coasts. The weather is also influenced by the El Niño - Southern Oscillation.

South Africa experiences a high degree of sunshine with rainfall about half of the global average, increasing from west to east, and with semi-desert regions in the north-west. While the Western Cape has a Mediterranean climate with winter rainfall, most of the country experiences summer rain.

3.2.1 Temperature

South Africa has typical weather for the Southern Hemisphere, with the coldest days in June - August. On the central plateau, which includes the Free State and Gauteng provinces, the altitude keeps the average temperatures below 20°C; Johannesburg, for example, lies

at 1 753 metres, as shown in Table 2. In winter temperatures can drop below freezing, also due to altitude. During winter it is warmest in the coastal regions, especially on the eastern Indian Ocean coast.

Warm season weather is influenced by the El Niño - Southern Oscillation. South Africa experiences hotter and drier weather during the El Niño phase, while La Niña brings cooler and wetter conditions.

3.2.2 Precipitation

South Africa is a sunny country, averaging 8 - 10 daily sunshine hours in most regions. In South Africa, annual rainfall averages 464 mm (compared to a global average of 786 mm), but large and unpredictable variations are common. There are some semi-desert areas along South Africa's western edge which, on average, receive the most rainfall. In general, rainfall is greatest in the east and gradually drops westward. For most of the country, rain falls mainly in the summer months with brief afternoon thunderstorms. Cape Town and the Western Cape are exceptions as their climate is Mediterranean and they experience more rain in the winter. During the winter months, snow accumulates on the high mountains of the Cape and the Drakensberg.

Table 2 Average temperatures (°C) in South Africa per locality.
Source: https://en.wikipedia.org/wiki/Climate_of_South_Africa.

City	Summer (January)		Winter (July)	
	Max	Min	Max	Min
Johannesburg	26	15	17	4
Pretoria	29	18	18	5
Polokwane	28	17	20	4
Musina	34	21	25	
Thohoyandou	31	20	24	10
Nelspruit	29	19	23	6
Bloemfontein	29	15	15	-2
Kimberley	33	18	19	3
Upington	36	20	21	4
East London	26	18	19	10
Mthatha	27	16	21	4
Cape Town	26	16	16	7
Durban	28	21	23	11
Pietermaritzburg	28	18	23	3

3.3 CLIMATE CHANGE

Climate change is any significant long-term change in the expected pattern of the average weather of a region (or the entire earth) over a significant period of time. Climate change is about abnormal variations in climate and the effects of these variations on other parts of the earth.

Climate change has had a major impact on South Africa, primarily due to increased temperatures and precipitation variability. Extreme weather events are becoming more frequent due to climate change. This is of critical importance to South Africans as climate change will affect the overall health and well-being of the country, for example in terms of water resources. As in many other parts of the world, climate research has shown that the real challenge in South Africa has more to do with environmental issues than development issues. The most serious impact will be on water supply, which has huge implications for the agricultural sector. Rapid environmental changes have significant impacts on the community and the environment in a number of ways, from air quality, temperature and weather patterns to food security and disease burden. The various impacts of climate change on rural communities include: Drought, depletion of water resources and biodiversity, soil erosion, decline in subsistence agriculture and cessation of cultural activities. Africa is currently suffering from significant heat waves and will continue to do so in the future as the continent is in the midst of the current environmental crisis. South Africa contributes to significant CO_2 emissions and is the 14th largest CO_2 emitter. Above the global average, South Africa emitted 9.5 tons of CO_2 per capita in 2015. This is largely due to its energy system, which relies heavily on coal and oil. As part of its international commitments, South Africa has pledged to reduce emissions between 2020 and 2025.

3.3.1 Impacts of climate change

Farmers are challenged by the impacts of climate change illustrated in Figure 4.

Figure 4 Some effects of climate change.

Rainfall: Climate change will result in a shift in the rainfall pattern. There will likely be more intense periods of heavy rain and longer dry spells.

Temperature: Temperature patterns are also affected by climate change. Rising average temperatures, more extreme heat throughout the year, fewer sufficiently cool days in winter, and more frequent thaws in the cold season will likely impact farmers in all areas.

Floods: Many agricultural regions of the country are experiencing increased flooding. Rising sea levels are also increasing the frequency and intensity of flooding on farms in coastal regions. Floods destroy crops and livestock, accelerate soil erosion, pollute water, and damage roads, bridges, and other infrastructure.

Droughts: Too little water can be just as damaging as too much. Severe droughts have taken a heavy toll on crops, livestock, and farmers in many parts of the country. Rising temperatures will likely make droughts even worse, depleting water supplies and, in some cases, spurring destructive wildfires.

Changes in crop and livestock viability: Farmers choose crop varieties and animal breeds that are well suited to local conditions. As those conditions shift rapidly over the coming decades, many farmers will be forced to rethink some of their choices—which can mean making new capital investments, finding new markets, and learning new practices.

New pests, pathogens, and weed problems: Just as farmers will need to find new crops, livestock, and practices, they will have to cope with new threats. An insect or weed that could not thrive in decades past may find the new conditions due to climate change suitable - and farmers will have to adapt.

Degraded soils: Typical monoculture cropping systems leave soil bare for much of the year, rely on inorganic fertiliser, and cultivate fields regularly. These practices leave soils low in organic matter and prevent formation of deep, complex root systems. Among the results: reduced water-holding capacity (which worsens drought impacts), and increased vulnerability to erosion and water pollution (which worsens flood impacts).

Simplified landscapes: Industrial agriculture treats the farm as a crop factory rather than a managed ecosystem, with minimal biodiversity over wide areas of land. This lack of diversity in farming operations exposes farmers to greater risk and amplifies climate impacts such as changes in crop viability and encroaching pests.

Intensive inputs: The industrial farm's heavy reliance on fertilisers and pesticides may become even more costly to struggling farmers as climate impacts accelerate soil erosion and increase pest problems. Heavy use of such chemicals will also increase the pollution burden faced by downstream communities as flooding increases. Farmers may also increase irrigation in response to rising temperature extremes and drought, further depleting precious water supplies.

Climate change impacts affect people (farmers, residents of rural communities, and all of us who rely on the food farmers produce) in various ways. As summer heat intensifies, farmers and farm workers will face increasingly gruelling and potentially unsafe working conditions. Accelerating crop failures and livestock losses will make farmers with access to insurance or disaster relief programs more reliant on those taxpayer-funded supports, while those without sufficient safety nets will face additional challenges. Failing farms and stagnating farm profits will also increase

suffering in many rural communities. Farming communities will be among the first to feel the ways extreme weather exacerbates agriculture's impacts on water resources - with nearby water supplies polluted or depleted before the damage extends to drinking water and fisheries far downstream. Nationwide, reductions to agricultural productivity or sudden losses of crops or livestock will likely have ripple effects, including increased food prices and greater food insecurity.

Practical activity 2

1. Extension practitioners need to get the long-term (20 years or more) monthly climate data for the areas where they are working. They then need to compare it to the monthly averages of the past 5 years to determine whether there has been a shift in the climate pattern due to climate change.

2. Extension practitioners need to put up a manual rain gauge at their offices to keep daily rainfall records.

4 SOIL AND WATER MANAGEMENT PRACTICES IN RELATION TO CSA

Objectives

1. Understand the concept of "climate smart agricultural".
2. Understand how CSA technologies can be used as climate change adaptation and mitigation strategies.
3 Identify applicable soil- and water management strategies for various production scenarios.

Climate-Smart Agriculture (CSA) refers to agricultural strategies that boost production and system resilience while lowering greenhouse gas emissions in a sustainable way. CSA aids in the direct integration of climate change adaptation and mitigation into agricultural development planning and investment plans. Sustainable agriculture, in our opinion, is based on landscape-scale integrated management of water, land, and ecosystems.

CSA is widely promoted as the future agriculture and as a viable answer to climate change. CSA has the potential to boost productivity and resilience while reducing the vulnerability of millions of smallholder farmers in Africa, as agriculture remains critical to development. Smallholder farmers can profit directly from CSA by boosting the efficiency of valuable inputs like labor, seeds, and fertilisers, as well as increasing food security and money generation options. CSA contributes to the preservation of natural resources for future generations by conserving ecosystems and landscapes.

4.1 SOIL MANAGEMENT STRATEGIES

Soil is an essential, but frequently overlooked, component of the climate system. After the oceans, it is the second greatest carbon store, or 'sink.' Climate change may result in more carbon being stored in plants and soil due to vegetation growth, or more carbon being released into the atmosphere, depending on the region. Land restoration and sustainable land use in urban and rural regions can assist us in mitigating and adapting to climate change.

Climate change is an unavoidable reality, and adaptation techniques are needed to address the consequences of climate change on agricultural production. Agricultural production is already being impacted by climate change. Drought is the most visible factor, as it reduces production by making many locations too dry for crops to flourish. Many crops grow faster as a result of increased temperatures, but this means that they do not develop as fully as they grow. In other words, the crops mature before they are fully matured. This translates to a reduced overall yield. Pests, primarily insects, are expanding into previously uninhabitable

areas. Many pests are eliminated each year by a single frost and so cannot survive in colder climates. Pests move in and kill crops when these locations warm and no longer have frost.

There were "age-old" agronomic approaches advocated for soil and water conservation and establishing drought resistant, weather robust agricultural systems before "climate change adaptation" became a trendy word. Conservation tillage, mulching, increasing crop diversity in a crop rotation (especially including perennial forage crops in a rotation), use of drought and heat tolerant crop cultivars, changes in cropping pattern and planting calendar, soil fertility improvement techniques, and soil moisture conservation practices are some agricultural adaptation strategies that farmers can use. In places where the new climatic conditions are not favorable for some crops, some suggestions could be to change to other crops that maintain forest cover and diversity, diversify the agricultural areas implementing more crops, or change the cropping pattern in warm regions shifting towards patterns used in hotter regions.

Human capital development through training, outreach strategies, and extension services at various levels will improve climate change adaptation capacity, particularly in developing nations.

To deal with the effects of climate change, many CSA technologies can be used. A climate smart agricultural technology, according to Sullivan et al. (2012), is described as agricultural methods that boost production and system reliance while lowering greenhouse gas emissions.

To avoid erosion, save soil moisture, and maintain and improve soil fertility, three main soil and water conservation techniques are used:

- Terraces, bunds, contour ditches, check dams, reservoirs, grassed waterways, diversion drains, and other **physical solutions** to discourage erosion and enhance water infiltration include terraces, bunds, contour ditches, check dams, reservoirs, grassed waterways, diversion drains, and others.
- Reforestation, hedgerows, and vegetative strips are examples of **biological techniques** that use trees and grass to prevent erosion.
- Leguminous plants and crops fix nitrogen in the soil, which is beneficial to soil health.
- Contour planting, strip cropping, intercropping, mixed cropping, fallowing, mulching, grazing management, and agroforestry are **agronomic measures** that entail managing the crop itself.

Why is it climate smart?

- Preventing erosion reduces the amount of carbon released into the air.
- Conserving soil fertility reduces the need for artificial fertilisers.
- Boosting the amount of organic matter in the soil reduces the amount of CO_2 in the air.
- Trees, grass, hedgerows and vegetative strips produce forage that can be used to feed live-stock, as well as preventing soil erosion by wind and water.

Currently, our natural resources (land, water, forests, and soils) are used for production with little regard for their long-term viability. Climate-Smart Agriculture focuses on natural resource restoration, conservation, and long-term use.

Conservation agriculture (CA) Conservation agriculture (CA) strives to increase agricultural yields while lowering production costs, preserving soil fertility, and saving water. It's a means to create sustainable agriculture while also improving people's lives. By establishing a permanent soil cover and reducing soil disturbance, CA improves soil structure and protects the soil against erosion and nutrient losses. CA is a three-principle approach to agricultural management (see Figure 5):

- Minimum soil disturbance: no till or minimum tillage.
- Keeping the soil surface covered with mulch or cover crops.
- Use of crop rotations.

Disturb the soil as little as possible
Farmers plough and hoe to enhance soil structure and control weeds in conventional farming, but in the long run, they degrade the soil structure and contribute to deteriorating soil fertility. Tillage in conservation agriculture is limited to ripping planting lines or hoeing holes for planting. Planting directly into the soil without ploughing is preferable.

Keep the soil covered as much as possible
Farmers in traditional farming remove or burn crop waste, or plough or hoe them into the soil. The earth is kept bare so that rain may readily wash it away or the wind can blow it away.

Crop leftovers left on the field, mulch, and specific cover crops are used in conservation agriculture to protect the soil against erosion and weed growth throughout the year.

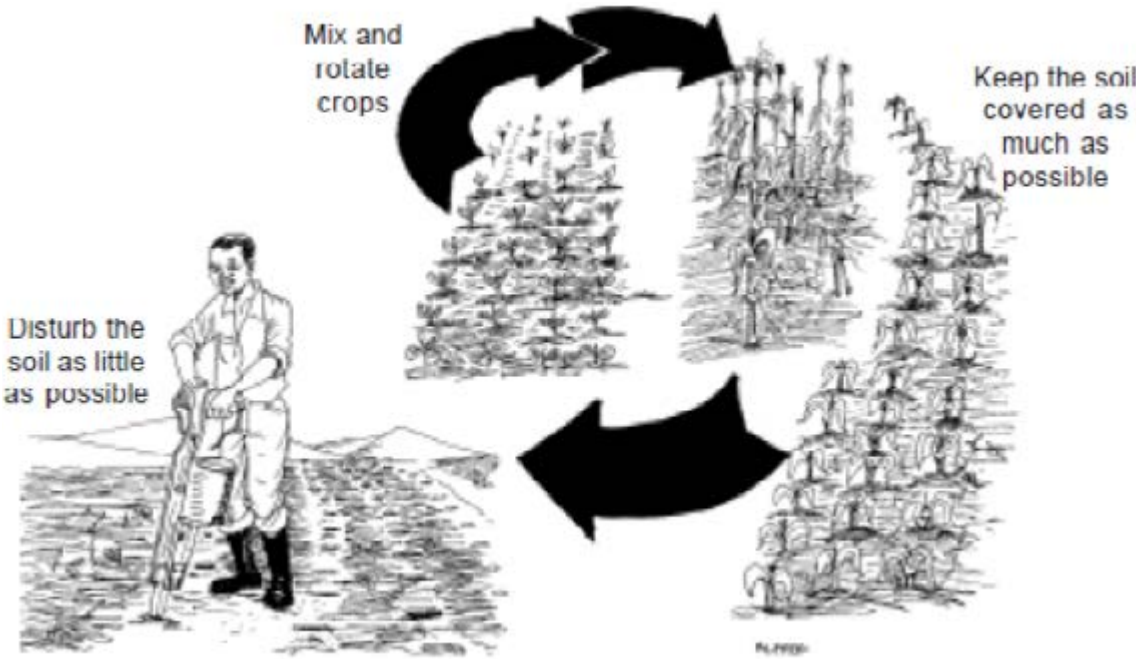


Figure 5 The three principles of conservation agriculture.

Mix and rotate crops
The same crop is sometimes sown each season in conventional farming. Certain pests, illnesses, and weeds are able to thrive and multiply as a result, resulting in decreased yields.

This is minimised in conservation agriculture by planting the proper mix of crops in the same land and rotating crops season to season. This also aids in the preservation of soil fertility.

All three principles must be used together to reap the full benefits of conservation agriculture. Although this ideal is not achievable everywhere, farmers should strive to achieve it as much as feasible. Because each farmer's position is unique, this could indicate a variety of things. It may be preferable for some farmers to plant a cover crop first. Others might benefit from decreasing their tillage to “ripping” (creating a short furrow without turning the soil over) or “pitting” (digging planting holes with a hoe) as a first step toward conservation agriculture. These farmers can then leave crop residues in the field and begin planting cover crops as a second step. Conservation agriculture can be difficult to implement. It entails a distinct approach to farming. Farmers may be hesitant to change, and they may have to learn new skills. It also necessitates a shift in mindset: for example, they must learn that while a "clean" field is preferable, the benefits are substantial. Farmers quickly discover that by implementing these principles, they may save time, money, and improve the fertility and water-holding capacity of their soil. This translates to better crop yields.

Why is conservation agriculture climate-smart?
Conservation agriculture is climate-smart for a number of reasons.

- Reduce carbon losses caused by ploughing
- Add to the organic matter in the soil
- Reduce erosion
- Avoiding plowing saves fuel, which reduces the usage of fossil fuels

Conservation agriculture can provide a number of advantages, including stable yields, drought mitigation, lower field preparation costs, reduced soil erosion, and contributions to climate change mitigation and adaptation.

Table 3 Comparing current farming and conservation agriculture.
Source: FAO, 2018.

	Current farming	Conservation agriculture
Soil structure	Ploughing and disc-harrowing on a regular basis depletes soil organic matter and destroys soil structure. As a result, very fine, unstable particles are produced. At ploughing depth, a hardpan – a hard layer through which water cannot pass – forms.	To break up a hardpan, deep ripping may be required. Deep-rooted plants can also help to break it up. Because the soil is only lightly disturbed, its structure remains intact. Because crop residues and cover crops remain on the soil, organic matter accumulates.
Soil moisture	Ploughing turns the soil over, allowing much of the moisture in the air to evaporate. Water pools on the surface of flat land or becomes trapped above the hardpan, causing waterlogging and crop death. It also destroys many of the soil's pores and cracks, making it difficult for water to penetrate. Because of the slope, much of the rain runs off and is lost, rather than being stored in the soil or replenishing the water table.	In a well-structured soil, water can soak into the soil easily through pores. It is stored in the soil, so is available for crops if there are active roots. There is no hardpan, so water can percolate deep into the ground and recharge the water table. Mulch and cover crops shade the soil surface, so less water evaporates.
Erosion	Heavy rains pound the soil, breaking up lumps of soil into fine particles and forming a crust that seals the surface and prevents water from penetrating. Water runs downhill on slopes, carrying valuable topsoil with it. Rills form and grow into gullies, which carry soil into rivers. When the next rains come, the silt clogs reservoirs and irrigation canals, causing flooding.	Cover crops and mulch shield the soil surface from heavy rains and impede erosive overland flow. Roots bind the soil together, making it less prone to erosion. Because less water runs off, there is less water loss.

Soil fertility	Ploughing exposes the soil to the sun and rain while burying organic matter. It disintegrates organic matter into smaller fragments that can be easily washed away. Crop residue removal or burning depletes soil fertility. Planting the same crop year after year depletes the soil of valuable nutrients. A healthy soil requires a small number of earthworms, burrowing beetles, microbes, and other soil life.	Crop residues and cover crops remain on the soil and contribute to organic matter. Adding compost, manure, or mulch from other sources improves fertility even more. There are numerous earthworms and other soil life forms. By fixing nitrogen, legumes improve fertility.
Weeds and pests	Weeds can grow unchecked when the earth is left bare. Planting the same crop year after year helps weeds, pests, and illnesses thrive.	Weeds are smothered and prevented from growing quickly by the cover crop or mulch. Weeds can also be controlled with careful application of herbicides. Companion planting and mixed cropping can help to discourage weeds and pests. Crop rotation disrupts the life cycle of pests and disease organisms. A healthy soil aids in the control of pests and diseases.
Costs and labour	Ploughing and weeding are difficult tasks that take a long time and are costly if hired labor is required. Fuel prices are considerable, and expensive equipment is subjected to a lot of wear and tear. Herbicides might save time and effort, but they can also be harmful to the environment, especially if the amount and timing are incorrect. Many herbicides and pesticides are harmful to humans and the environment.	Plowing isn't required, thus there's no need to spend money on expensive mouldboardm ploughs, disks, or harrows, though farmers may need to invest in new planters. Planting basins, which are employed in one sort of conservation agriculture, require a lot of work in the first year but require less work in subsequent years. Planting basins assist with seed and fertiliser dosing, lowering costs. Fuel expenditures and the cost of employing animal traction are lower, and equipment wear is reduced.

4.1.1 No / minimum tillage

No-till and minimum tillage are conservation techniques that use crop remains on the soil surface to decrease the detrimental impact of rainfall on the soil (see Figure 6). These approaches are classified as rainwater harvesting since they result in decreased runoff and improved infiltration of precipitation. Tillage that minimizes mechanical soil disturbance and so conserves water in the soil profile is known as minimum tillage. Rips on the row with regulated traffic to only one major tillage/cultivation followed by chemical weed and disease management are all examples of minimum tillage. Croplands are not tilled at all with no-till.

Because the soil is not tilled and exposed to the evaporative components of the atmosphere, no-till (NT) conserves water in the soil profile. The moisture is retained within the soil profile. In most cases, the new crop is planted straight into the preceding year's stubble. A specifically built planter penetrates through the crop wastes and into the undisturbed soil underneath to plant. NT promotes soil carbon sequestration and improves soil characteristics as well as biological soil diversity. Weeds are controlled with herbicides, which eliminates the need to till the land.

4.1.2 Mulching

Mulch is a layer of material applied to the surface of the soil (see Figure 7). It is used to conserve soil moisture, regulate soil temperature, improve soil fertility and health, reduce weed growth, and improve the aesthetic appeal of the area. It's usually organic, and it can be used on bare soil or around existing plants. Mulches are naturally integrated into the soil as a result of the action of worms and other organisms. It's utilised in both commercial crop production and gardening, and when used correctly, it can boost soil productivity substantially. Depending on the purpose, it is used at different periods of the year. Mulches help to warm the soil at the start of the growth season by allowing it to retain heat that is lost during the night. Certain crops can be seeded and transplanted earlier, resulting in rapid growth. Mulch regulates soil temperature and moisture as the season progresses, preventing weed seedlings from germinating.

Figure 6 Rip on the planting row where minimum tillage is used.
Source: Botha et al., 2014.

Figure 7 Application of mulches using various materials.

Mulch can be made from organic materials including grass clippings, leaves, straw, reeds, kitchen wastes, comfrey, shredded bark, entire bark nuggets, sawdust, shells, woodchips, shredded newspaper, cardboard, wool, and animal manure. Stones and gravel, for example, are inorganic materials that can be employed.

The **advantages** of mulching are:

- Increases water infiltration
- Reduces evaporation from the soil surface (Es)
- Weeds do not grow well because the sunlight is blocked out
- Soil does not spatter on leaves during watering and rainfall events
- Keeps roots and bulbs cool in summer and warm in winter
- Provides food for the micro-organisms in the soil and for the plants
- Reduces greening of roots and bulbs
- Reduces soil erosion

Unfortunately, mulches also have some **disadvantages** such as:

- Over-mulching can bury and suffocate plants
- May prevent seeds from germinating if it is placed too soon
- Impermeable mulches, like a black plastic, do not let air or water in
- Mulch provides a convenient hiding place for pests
- Some organic mulches or crop residues can be toxic to other crops (allelopathic)

Botha et al. (2003) validated the benefits of effective mulching in mitigating the negative effects of climate change in their research. They have conducted a study where mulch was placed on the soil surface and temperature was recorded at a depth of 25 and 75 mm below the soil surface. On a Bonheim soil form, the water content of the soil in the first 300 mm of the soil profile was also measured. They used a bare dirt surface as a control. Mulch treatments included organic reeds covering 50% and 100% of the soil surface, as well as stones covering 50% of the soil surface. Temperature changes under the 100% mulch were the fewest when compared to bare soil, eliminating temperature extremes. The insulating effect of the mulch would definitely help plant growth, particularly germination.

During the summer, the 100 percent reed mulch provided the coolest soil, followed by increasing temperatures beneath the 50 percent (reed

and stone) and bare soil, respectively. During the winter, the beneficial effect of mulch was proved by creating a warmer soil in extremely cold temperatures.

Soil water storage was greatest under 100 percent reed mulch, followed by 50 percent reed and stone mulches (nearly identical), and bare soil had the lowest values. Both the summer and winter measuring periods revealed the same storage trends. As a result, both stone mulch and organic mulch are equally effective at lowering Es and increasing crop yields. If there are sufficient crop residues available, a 100 percent residue cover is recommended to increase soil water storage, decrease Es, and beneficially modify soil temperature to improve crop growth and yield. Because of the scarcity of crop residues and the critical need for animal feed during the winter, a 50 percent stone mulch will most likely be the best practice to recommend in rural areas. Because of the biological degradation of organic mulch, stone mulch is superior to it in terms of sustainability.

4.1.3 Cover crops

Cover crops are plants (grasses or legumes) that are planted in between or alongside regular crops to protect and improve the soil. Cover crops are primarily used to prevent soil erosion, improve soil health, increase water availability, smother weeds, attract pollinators, control pests and diseases, increase biodiversity, serve as mulch and a source of green manure and organic matter, and are used for grazing or forage. Depending on the type of cover crop, they either add or absorb nitrogen.

Grass, legumes, and broadleaf non-legumes are the three main cover crop categories, based on their properties and application options. In most cases, they serve multiple functions at once, such as preventing erosion, improving soil quality, and providing grazing, among others.

Grasses are annual cereals that include buckwheat, rye, wheat, corn, barley, oats, and others. They grow quickly and leave easily manageable residues. Their fibrous threadlike root systems are robust and resistant to erosion. In terms of nutrients, they accumulate soil nitrogen from Azospirillum symbiosis but lack the ability to fix atmospheric nitrogen.

As nitrogen-fixing cover crops, legumes are well-known for nitrogen enrichment. When plants grow large, their robust taproot system aids in the control of undesirable undersurface compaction. Furthermore, the larger the plant, the more nitrogen it can fix. Figure 8 shows examples of legumes such as crimson and white clover, cowpeas, alfalfa, hairy vetch, and fava beans.

Broadleaf non-legumes absorb nitrogen from the soil, hold it in place, and produce green manure. They usually die in the harsh winter weather and do not necessitate any additional termination. Non-legumes used as fall cover crops, on the other hand, should be treated before seeding for weed control.

Lucerne Cowpea Clover

Figure 8 Examples of crops that can be as a cover crop.

Specific **advantages** of cover crops are:

- Cover crop roots help to prevent erosion from water and wind, especially on erodible soils on steep slopes
- Adds organic matter to the soil
- Improves the texture and structure of the soil
- Improves infiltration by reducing runoff
- They absorb excess water after winter rains, improving water infiltration (as well as soil aeration) via their roots and retaining moisture for the following cash plants
- Nitrogen fixation (provided that the selected cover crop is a legume)
- Can be cut and applied as mulch
- Cuttings can be used as fodder for animals

Cover crops have a number of **disadvantages**, including:

- There is fierce competition for limited water and nutrients with the cash crop if it is not adequately managed (frequent trimming)
- Competes with the cash crop for sunlight, especially after emergence
- Management of cover crop requires a high level of knowledge and skill

In crop rotation, no-till, and organic farming, cover cropping is highly recommended. Cover crops are usually only suggested in locations where there is enough rainfall to sustain two crops or where irrigation water is available.

4.2 WATER MANAGEMENT STRATEGIES

4.2.1 Rainwater harvesting

More and more marginal regions are being used for agriculture as the population grows and less land becomes available. However, much of this land is in arid or semi-arid regions with low and unpredictable rainfall, and much of the valuable water is lost as surface runoff and Es. Droughts in recent years have highlighted the dangers that humans and cattle face when rains falter or fail. While irrigation is the most obvious remedy to drought, it has proven to be expensive and only benefits a select number." Rainwater harvesting", a low-cost alternative, is becoming increasingly popular.

The collection of runoff for productive uses is known as rainwater harvesting. Instead of allowing runoff to cause erosion, it is collected and used. Water harvesting is a directly productive technique of soil and water conservation in semi-arid drought-prone locations where it is already practiced. With this technology, both yields and production dependability can be greatly increased. Rainwater harvesting (RWH) can be thought of as a very basic kind of irrigation. The main difference is that the farmer has no control over the time with RWH.

Only when it rains can runoff be gathered. In areas where crops are totally rainfed, a 50% decrease in seasonal rainfall, for example, could result in crop failure. However, reasonable yields can still be obtained if the available rain can be concentrated on a smaller area. However, there may be little runoff to collect in a year of extreme drought, but in the majority of years, an efficient water harvesting system will boost plant development. As a result, adopting appropriate RWH&C techniques on domestic gardens, croplands, and rangelands in selected rural villages in South Africa could empower villagers to more productively produce their own crops utilizing arable land and increase livestock output using RWH&C techniques. As a result, using appropriate RWH&C techniques on homestead gardens, croplands, and rangelands in selected rural villages in South Africa could empower villagers to more productively produce their own crops on arable land and increase livestock production on rangelands, reducing household food insecurity.

The capture of rainfall at or near the point of fall is a simple solution to the problem of water access that has been practiced for thousands of years. Rainwater harvesting (RWH) has a number of clear advantages for home and agricultural water supply:

- water on the spot, where the household or crops and/or plants or animals need it;
- water under individual household control rather than a communally managed system; and
- capturing considerable amounts of water is possible in all but the driest areas

However, there are certain disadvantages. Roof water harvesting for residential water supply is costly, with the storage facilities required to transport customers through dry times accounting for the majority of the expense. RWH faces clear challenges during long dry seasons, and it may not be able to provide a year-round water supply.

Water harvesting is especially useful for making the best use of rainwater in the following situations:

- In dry climates, where rainfall is scarce and unevenly distributed, agricultural production is nearly impossible. Water harvesting can make farming practicable in the absence of other water resources if other production parameters such as soils and crops are favorable
- Crops can be grown in rainfed locations, but yields are low and there is a high danger of failure. Water harvesting systems can supplement rainfall in this area, allowing production to expand and stabilise
- In areas where there is insufficient water supply for domestic and animal production. Water harvesting can meet these requirements
- In desertification-affected arid land, where the potential for production is dwindling due to a lack of proper management. Water harvesting can help improve the vegetative cover on these lands and help to halt environmental degradation

In many cases, even if total rainfall appears to be adequate for the production of specific crops, the intensity and distribution of the rainfall are such that the water available during the crop growth cycle is insufficient to support a good harvest. Rainfed agriculture in semi-arid regions must also contend with low potential soils. The problem of insufficient soil water is exacerbated not only by low and unfavorable rainfall distribution, but also by high unproductive water losses through Es, runoff, and deep drainage. These losses impede the efficient use of available water for crop production and must be reduced to maximize rainwater productivity. Es and runoff are the two most significant losses. A concerted effort must be made to reduce these wasteful water losses, which can be accomplished through a variety of water harvesting techniques.

Table 4 Classification of rainwater harvesting systems.
Source: Botha et al., 2014.

Macro-catchment	Micro-catchment	Roof-top Micro-catchment
• Ex-field rainwater harvesting • Outside the farm/field/ land boundary	• In-field rainwater harvesting • Inside/within the farm/ field/land boundary)	• Non-field rainwater harvesting • Artificial/man-made runoff area
Characteristics		
		
• Overland flow harvested from catchment areas outside the farm/field/ land boundary • Runoff stored in soil profile/ below-surface reservoir • Provision for overflow of excess water • Can be practised in arid and semi-arid areas below 450 mm annual rainfall	• Overland flow harvested from short catchment lengths within the farm/ field/land boundary • Runoff stored directly in the soil profile • No provision for overflow of excess water most of the time • Can be practised in semi-arid areas with rainfall between 450 - 700 mm1	• Generally smaller catchment area compared to ex-field • Runoff stored in reservoir above/below ground surface • Tap / outlet normally attached to reservoir to access water • Can be practised in arid and semi-arid areas with annual rainfall of less than 450 mm

Advantages		
• Makes crop production possible in arid / semi-arid areas • Reduces risk of crop failure • Harvested water can be used for supplementary irrigation • Recharges aquifers	• Increases crop production in semi-arid areas • No ex-field runoff from the field • No erosion from the field • Low maintenance • Only dependent on rainwater from own field • Can be practised on small or large areas • Low implementation cost • No high-tech structures needed	• Used to obtain water for irrigation purposes as well as domestic purposes • Has potential to supply drinking water when no water is available • Reduces risk of crop failure
Examples		
• Jessours • Contour stone bunds • Stone dams	• Small pits • Small runoff basins • Runoff strips inter row system • In-field rainwater harvesting	• Rooftop water harvesting
		

Rainwater harvesting is the process of collecting runoff from roofs, roads, surrounding hills, or a compacted soil surface in a home garden or land during a rainstorm so that it can be used more effectively for food production and other domestic uses. We can categorise rainwater harvesting as ex-field, in-field, or non-field based on the extent of the water harvesting (as in Table 4).

Ex-field rainwater harvesting, for example, is the collection of run-off water from hills and its conveyance to a storage dam, from which the water can later be used, for example, to water vegetable gardens in a rural settlement. As a result, run-off water is used outside of the catchment area.

The run-off water is used within the catchment area with in-field rainwater harvesting (IRWH). This is common in home gardens and crop production land, where run-off water is collected during a rainstorm from a 2 m wide no-till strip between alternative crop rows and stored in basins. Because no-till is used on the runoff area, a crust forms, which improves runoff. If properly implemented, this innovative technique has the potential to significantly reduce overall runoff as well as Es. Mulch on the run-off area can help to reduce Es losses while also preventing erosion and soil movement.

Non-field rainwater harvesting would be, for example, collecting rainwater from a house's roof and storing it in a tank. The tank's water can then be used for domestic purposes (drinking, cooking, and washing) or as supplemental irrigation for crop production. When used in conjunction with IRWH, a person in a rural settlement, for example, can produce food for his family all year.

Efficient water harvesting and conservation techniques for smallholder crop production can aid in alleviating poverty and helping farmers to become self-sufficient. The lack of such techniques is a pressing problem for agriculture in semi-arid areas. Water harvesting can aid the smallholder crop farmers in utilizing their low and erratic rainfall in order to grow a sufficient crop to sustain their livelihoods.

Rainwater harvesting is a climate-smart practice for a variety of reasons. Much water runs off and is wasted, especially during heavy rain. Excess water can cause erosion and flooding. Slowing the flow so that the water percolates through the soil and recharges the water table, as well as collecting in reservoirs of any type, means less flooding downstream. Capturing water for later use reduces the risk of dehydrated populations, animals, and crops during dry seasons and drought. Furthermore, conserving surface water and replenishing soil moisture and the water table reduces the need to pump water from an underlying aquifer, a practice that frequently necessitates the use of fossil fuels.

Extensive research has been conducted in South Africa to develop a water harvesting system for growing crops in homestead gardens, but the emphasis is now shifting to implementing water harvesting in croplands on a much larger scale.

4.2.1.1 Rainwater harvesting for homestead gardens

Homegrown or small-scale food production is a viable contributor to rural poor food and nutrition security. Water scarcity continues to be a major threat to poverty alleviation, hunger alleviation, and sustainable development. RWH and other innovative water technologies have the potential to improve rural water supply. RWH can also contribute to South Africa's food security by increasing dryland agriculture's water productivity and enabling homestead gardening. Despite being used in South Africa for decades, RWH is still far from being used to its full potential due to unresolved issues that prevent widespread adoption. The current water-related legislation, insufficient financial support, and a lack of national coordination are major obstacles to the nationwide expansion of RWH. Based on the available literature, various RWH&C practices can be implemented in homestead gardens. Only those with the potential to be used in homestead gardens in South Africa's semi-arid regions are described in greater depth below.

- ***Trench bed gardening***

Trench bed gardening involves removing soil from a bed that is typically 1 m wide, 2 m to 3 m long, and 1 m deep. The topsoil is separated from the subsoil and mixed with compost or manure. The material is placed in a thick layer at the bottom of the trench, and the soil is returned, topped by manure-rich topsoil mounded above ground level. Trench bed gardening is typically combined with two other RWH methods. The first is the diversion of water from adjacent garden surfaces into the beds via small cut-off channels. The second step is to build small storage reservoirs (30,000 litres) to collect water from roofs and the ground, which will be supplemented by grey water (Denison & Wotshela, 2009).

- ***Roof top systems***

Rainwater can be collected from roofs of houses and other buildings, as shown in Figure 9, as well as other impermeable surfaces such as courtyards or roads, and stored in a tank. These systems provide a low-cost source of water for humans and animals. Although primarily used for domestic purposes, unfit for drinking water may be used for supplemental irrigation.

Water collection from roofs for household and garden use is a common practice in South Africa. Tanks and containers of all sizes are common in rural areas, ranging from large brick reservoirs to makeshift drums and buckets.

Advantages of collecting rainwater from roofs are the following:

- Roofs are physically in place, and runoff is readily available
- Roofwater is much cleaner than runoff from the ground
- Because there is little absorption or infiltration on the roof surface, most of the rainwater that falls on it can be collected

Roof water harvesting consists of three major components: the roof, the gutter, and the storage tank.

Figure 9 Example of roof water harvesting in a rural community.
Botha et al., 2012.

- ***Homestead ponds***

Homestead ponds are more associated with cultivation, conservation, and irrigation (Denison & Wotshela, 2009). The system of homestead ponds, according to Denison and Wotshela (2009), aimed to bring and concentrate water resources around homesteads and occasionally on agricultural land. Despite the fact that their construction was simple, it required a lot of hard work. Homestead ponds were mostly hand dug pits built with picks, hoes, and shovels. They varied in depth and diameter, but on average were about 2 m deep and 5 m in diameter. During excessive flows, some households erected stonework to support the walls and bottom base against erosion. Water stored in the homestead ponds is used for supplemental irrigation of homestead crops as well as drinking water for animals. Only a few of them remain in use in Thaba Nchu (Free State) and Tyhume Valley (EC), owing to their uncovered nature, which made them dangerous to young children and small livestock, and the tragedy of children drowning, which led to homestead ponds being abandoned (Denison & Wotshela, 2009).

- ***In-field rainwater harvesting***

Hensley et al. (2000) first proposed the IRWH technique in South Africa as an alternative to conventional crop production in Figure 10.

On high drought risk clay and duplex soils, IRWH combines the benefits of water harvesting, no-till, basin tillage, and mulching. This novel water conservation technique has the potential to significantly reduce total runoff and surface evaporation (Es). This increases plant available water and, as a result, yields.

The specific principles of IRWH are thought to result in the following advantages:

- Basin tillage minimizes runoff from the land
- Water collected from the untilled, crusted soil on the 2-m wide intercrop row area is used to concentrate runoff water in the basins. This encourages water infiltration beyond the surface evaporation zone, reducing Es losses.
- Applied mulch on the runoff area minimizes Es losses and prevents erosion or soil movement

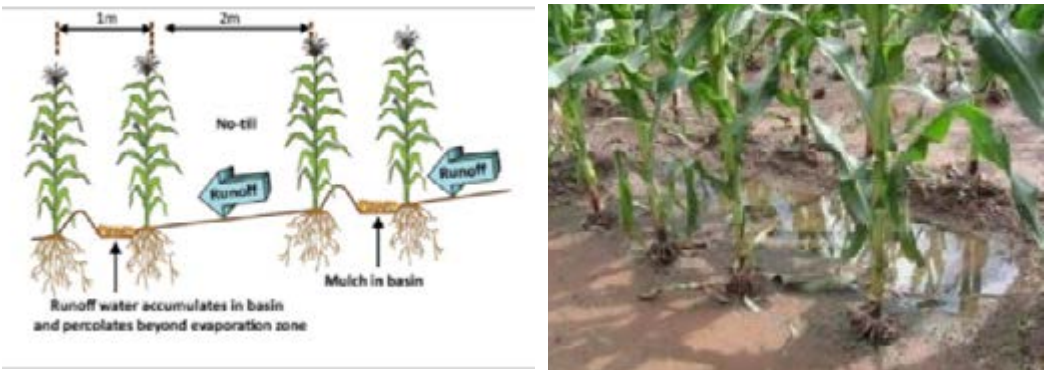


Figure 10 Diagrammatic representation of the in-field rainwater harvesting technique.
Source: Botha et al., 2014.

The IRWH technique promotes rainfall runoff on a 2-m wide strip between alternate crop rows and stores the runoff water in the basins. Water collected in the basin can infiltrate deep into the soil beyond the evaporation zone at the surface. After the basins have been built, the land is subjected to no-till farming. Because there is no cultivation in the runoff area, a crust forms, which improves runoff.

In other words, IRWH is a risk-free, socially acceptable technique that combines rainwater harvesting and conservation techniques to increase crop yields while remaining economically viable and preserving our limited natural resources.

The **requirements** for the application of IRWH are as follows:

- The slope should not exceed 8% on non-erodible soils
- The effective soil depth should be at least 700 mm
- The annual rainfall must be between 450 – 700 mm
- Preferably clay (more than 10%) or duplex soils
- Avoid sandy soils

Botha et al. (2003) found that the soil water content of the IRWH treatment was significantly higher than that of conventional tillage throughout the growing and fallow periods (CON). This is a significant discovery that can be used to mitigate the effects of climate change caused by less rainfall. In a warmer, drier climate, it is critical that the limited available rainfall be used as efficiently as possible. The IRWH technique increases effective rainfall by concentrating runoff where crops are grown. Botha et al. (2003) discovered that the higher soil water content of the IRWH plots contributed to more vigorous maize plant growth compared to the CON plots. As a result, plant heights on the IRWH plots were significantly higher than on the CON plots. The seed yield of maize plants on the IRWH treatment was 83% higher than that of the CON treatment. The IRWH's biomass was also 70% greater than the CON's. In addition, the CON treatment lost 16 mm of rainwater to runoff when compared to the total runoff stoppage from the IRWH treatment.

Botha et al. (2003) recommended that farmers apply mulch in the basins of the IRWH technique and, if enough is available, on the runoff area as well. Organic mulch in the basins and stone mulch on the runoff area produced the highest maize yields. The latter also aided in preventing soil movement from the runoff area into the basins.

The conclusion was that IRWH outperformed CON tillage in the following areas:

- better soil water storage due to less water losses through runoff and Es;
- improved water and production efficiencies; and
- higher biomass and seed yield.

IRWH should be recommended as a “best practice” technology for resource-constrained farmers working on clay soils in semi-arid areas.

IRWH structures are commonly used in homestead gardens to grow a variety of vegetable crops. Basins are created by hand using a spade and a rake. As shown in Figure 11, IRWH can also be used on a larger scale to produce cash crops such as maize and sunflower. The mechanized IRWH structures in this case are built with a furrow plough and a basin plough. The furrow plough creates a 20-centimeter-high contour ridge with a slope that strives to be zero. Every 1.5 m along the ploughed contour, the basin plough creates a 10 cm deep and 1 m wide basin.

Figure 11 Construction of in-field rainwater harvesting basins on a semi-commercial scale.
Source: Botha et al., 2014.

4.2.1.2 Rainwater harvesting for croplands

A large proportion of the population lives in rural areas, where their livelihood is dependent on agriculture, either directly or indirectly. Land and water issues; old cultivation techniques; a lack of marketing information; poverty; degradation of natural resources and environmental issues; population growth; insufficient support services; framework and institutional constraints; and a lack of agricultural and rural development policies are among the prominent challenges in these areas.

Most croplands in South African rural villages have been idle for more than 20 years. Poor yields, a lack of implements, and a lack of fencing have resulted in the abandonment of most croplands in the former homeland states. A small number of rural villagers continue to use traditional methods to produce maize, their main source of food. However, high water losses due to R and Es occur under these conditions, resulting in less water available for crop production. As a result of climate change, the situation is exacerbated by low and erratic rainfall and higher temperatures.

Smallholder farmers will be able to alleviate poverty in their communities and become self-sufficient by employing efficient RWH&C techniques in communal croplands. The lack of such techniques, however, is a pressing issue for agriculture in semi-arid areas. Various cropland application techniques are available in the literature, but only those deemed appropriate for use in rural communities in South Africa's semi-arid areas are discussed in greater detail below.

- ***Contour ridging***

Contour bunds are a streamlined version of micro-catchments. Construction can be mechanized, making the technique suitable for larger-scale implementation. The bunds, as the name implies, follow the contour at close intervals, and the system is divided into individual micro-catchments via the use of small earth ties. Contour bunds allow for crop or fodder cultivation between the bunds. The runoff is high, as with other forms of micro-catchment water harvesting techniques, and when designed correctly, there is no loss of runoff out of the system. Bunds or ridges are

built along the contour line, on slopes ranging from 1 to 50%, and are typically placed at 5 to 20 m intervals. The first 1-2 meters above the crest are used for agriculture, while the rest is used as a catchment area. The ridge's height ranges between 0.3 and 1 m, depending on the slope grade and projected runoff storage capacity. On sandy soils that are prone to erosion, ridges can be strengthened with stones. Farmers can use animal- or tractor-drawn implements to accomplish the strategy. It's critical to build ridges along the contour precisely to avoid water flowing down it and pooling at the lowest point. Alternatively, cross-bunds or tied ridges can be added at appropriate intervals along the ridge. The contour ridge technique is the most important technique for supporting forages, grasses, and hardy trees on gentle to steep slopes in low rainfall areas, while it is used for arable crops such as sorghum and cowpeas in the semi-arid tropics.

The ability to locate the ridge as precisely as possible along the contour line is required for successful application of this technique. If this is not accomplished, water will flow along the ridge and accumulate at the lowest point, threatening to destroy the entire down slope system. Stone bunds can be built on gentle slopes if large stones are found in the area. Stone bunds are permeable, slowing sheet flow and encouraging infiltration. Excavated soil can be added to the upstream side of the bund to form an impermeable contour ridge. Surveying instruments, an A-frame, or hand tools can be used to delineate the contour, but these methods are too expensive, sophisticated, and time-consuming for the average small-scale farmer.

- ***Tied-ridging***

Tied-ridging occurs when the ridges along the contour are joined by a shorter ridge. Box-riding is the practice of making shorter ridges at shorter intervals rather than just at the end of each ridge. This produces a box effect, with the boxes acting as basins to keep the water in. Tied-ridging is regarded as a very reliable method of increasing crop yield and conserving water, despite the fact that it has a high labor constraint. Farmers have a negative outlook on this practice because of the decrease in the use of animal draught power and labor constraints among small-scale farmers, which poses a significant barrier to its adoption and use by farmers.

- ***Tied furrows***

Tied furrows, like tied-ridging, allow for the concentration and conservation of water, resulting in high crop yields. This system is more effective on soils with a high clay content, but such positive results do not occur on sandy soils, which have low fertility and water holding capacity. When planting sorghum and maize on the tied furrow system, row spacing of 1.0 m, additional fertiliser, and top-dressing are the best compromise for these sandy soils.

- ***Contour strip cropping***

Contour strip cropping is the practice of alternating crop strips with grass or cover crops. The planted strips are used for farming. The uncultivated strips allow runoff to enter the cultivated crop strips, increasing soil water content in the area surrounding the cultivated crops. The system has a dual benefit in that the cover crops can be used to produce fodder. The system is used on gentle slopes up to 2%. The width of the strip can be adjusted to suit the slope's gradient. With a catchment area to crop basin area ratio of less than 2:1, the system is successful. The system is suitable for most crops and is simple to automate.

- ***Runoff strips***

The cropping area is divided into strips along a contour in the runoff strip technique. As a result, the technique is best suited for gentle slopes. The catchment is formed by the upslope strip, while the crop is supported by the downslope strip. The width of the downslope strip should ideally be between 1 and 3 m. The amount of water required will determine the size of the upslope strip. Runoff strips can be fully mechanized, so labor input is minimal, though weeding and compaction may be required to improve runoff. Strip management and continuous cultivation can increase soil fertility and improve soil structure. If the slope is gentle and the cropped strip is too wide, the water distribution may be uneven. Uneven moisture distribution can also occur if a ridge forms along the cropped strip's upstream edge during cultivation. To avoid this, the cropping strip should not be wider than 2 m. Hensley et al. (2000) modified the runoff strip system in South Africa to include basins for runoff water storage in their IRWH technique.

- ***Inter-row system***

The inter-row system consists of bunds with heights ranging from 0.40-1 m that are built at 2-10 m intervals depending on the crop's water requirement. These triangular cross-sectional bunds are built along the land's main slope and are possibly the best technique for flat lands. To encourage more runoff, the bunds can be compacted, treated with a water repellent, or covered with plastic sheets. Between the ridges, runoff is collected and either directed to a reservoir at the end of a feed canal or to a crop grown between the ridges. To maintain a high runoff output, the catchment area must be well-maintained.

- ***Contour-bench terracing***

The contour-bench terrace technique is excellent for soil conservation and water harvesting, and it can be built on very steep slopes. Cropping terraces are typically built level and supported by stone walls to slow water flow and erosion. Steeper, uncropped areas between the terraces provide more runoff water. Drains are used to safely remove excess water. This technique is mostly used for trees and bushes, and it is only rarely used for field crops. The cost of building and maintaining such a system is prohibitively expensive for farmers in low-rainfall areas.

Stone terracing

Stone terracing, according to Denison and Wotshela (2009), is a simple rainwater harvesting and management technique that is labor intensive and used by only a few communities in the Eastern Cape and Limpopo Provinces. It entails stacking stones at the bottom of low-lying croplands. Stonewalls are stacked high at the base of slopes or downhill areas. These stone enclosures trap sediment that accumulates over time and contributes to the formation of new layers of soil. The method is used to plant a variety of crops and trees.

- ***Bund systems***

The bunds system is made up of semi-circular earthen bunds that face upslope. Bunds are typically arranged in staggered rows. They can also be shaped like a trapezoid or a crescent. They are built at such a distance apart that there is enough catchment to provide the necessary runoff water, which accumulates in front of the bund. This area can then be used to grow plants. The distance between the two ends of each bund ranges from 1 to 8 m, and the bunds are

0.30 to 0.50 m high. When building the bund, a slight depression is formed where runoff is intercepted and stored in the root zone. The technique can be used on a flat surface up to a 15% slope. Bunds can be used to rehabilitate rangeland, produce fodder, shrubs, and, in some cases, field crops and vegetables such as sorghum and watermelons.

- ***Pot-holing***

Close to the planting stations or in between the planting stations, holes known as potholes are dug. Rainwater is collected in these holes, which then raises the soil water content near the planting station. The problem is that potholes fill up during the season, necessitating the digging of new ones at the start of each season. Due to the decrease in the usage of animal draught power and the acute labor constraints faced by small-scale farmers, this technique, like tie-ridging, has a high labor constraint, and farmers have a negative attitude on these techniques. This is a significant barrier for farmers to embrace and apply these strategies.

- ***Deep pits and pits***

Pits is a trenching system used on soils with very low infiltration rates. The size and crop are what distinguishes deep pits from pits. To ensure a high infiltration rate, trenches are dug across the slope and then filled to the original level with local fractured rock, river sand, or organic material. These trenches collect rainwater, intercept runoff, and store it in the surrounding area. The combination of pits and bunds is ideal for agricultural land rehabilitation. Pits typically have a diameter of 0.3-2 m. Because the plant residues are thrown into the pits, the system maintains soil fertility. Deep pitting is used for deep-rooted perennial crops such as trees, whereas pitting is primarily used for annual crops such as millet, maize, and sorghum. There is a high demand for labor, particularly in the first few years. The pits must be restored after tillage. When the terrain is flat, pits are used for in-situ moisture conservation rather than water harvesting.

- ***Small runoff basins***

The small runoff basin technique consist of small diamond- or rectangular-shaped structures surrounded by low earthen bunds. The diamond or rectangle's long diagonal lies parallel to the slope, allowing R to flow to the lowest corner, where planting takes place. The negarim, with a width of 0.05-0.10 m and a length of 0.10-0.25 m, is suitable for even ground, though it may be used on practically any slope less than 5%. Slopes more than 5% may induce soil erosion, hence the bund height should be raised. Small runoff basins are ideal for growing tree crops, but the soil must be deep enough to hold adequate water throughout the dry season. Negarims have a favorable impact on soil conservation and require little maintenance.

- ***Swales***

Swales are long, level excavations that range in width and treatment from modest ridges in gardens to rock piles across the slope to intentionally excavated hollows in flatlands and low-slope landscapes. The crest of the swale is frequently vegetated, with trees or reeds planted on the crest. The swale's effect is to trap water that falls on the area above the swale and slow it down, allowing for maximum infiltration. In the event of heavy rain, which causes runoff flow to overtop the swale, the vegetation on the crest holds the swale's soil. In the furrow above the swale wall, the swale also generates a moist microclimate. Because plant-available moisture is substantially higher in this area, it is often quite productive. Swales are not the same as the contour bunds that are widely used in soil

conservation projects. Swales enhance water infiltration while soil conservation tries to drain water from the area without causing damage to the soil.

- ***In-field rainwater harvesting***

Manual IRWH was developed by the ARC-SCW team at Glen, near Bloemfontein in the central Free State, as detailed by Hensley et al. (2000). Because of the absolute stopping of ex-field runoff and the minimisation of Es, the approach proved to be sustainable and outperformed CON. It not only increases agricultural output but also prevents erosion by better utilizing rainfall and boosting rainwater productivity.

The mechanical IRWH constructions are built with a furrow and basin plough. The furrow plough provides a 20-centimeter-high contour ridge with a slope of zero. As seen in Figure 12, the basin plough creates a 10 cm deep and 1 m wide basin every 1.5 m along the ploughed contour.

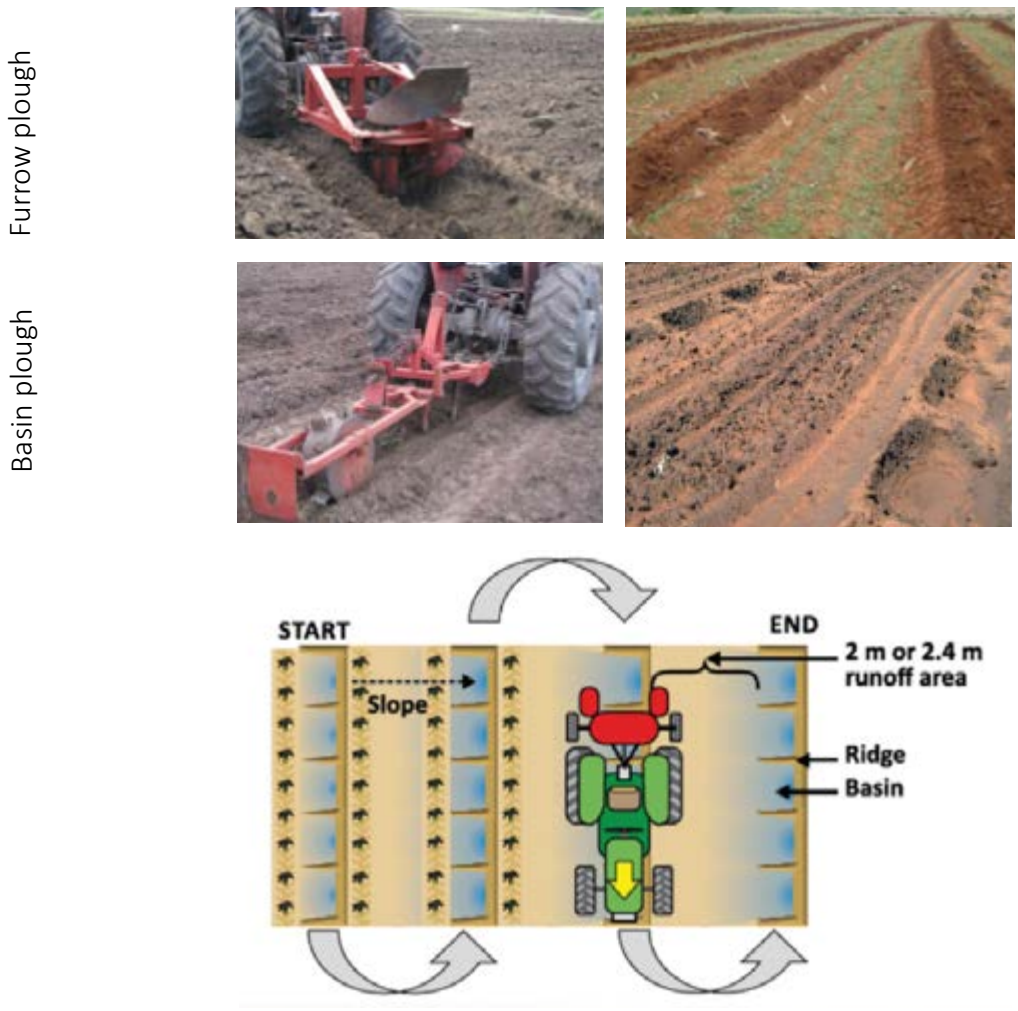


Figure 12 Diagrammatic representation of the construction of in-field rainwater harvesting basins in croplands.
Source: Botha et al., 2014.

- ***Mechanised basins***

Figure 13 depicts a mechanized basin that was originally designed to create basins to rehabilitate deteriorated veld. Ripping, ridging, and tying has proven to be a viable alternative to ploughing and harrowing for seedbed preparation, as well as a considerably more efficient water saving approach.

Small basins in a row collect rainfall, which can then sink deeper into the soil, below the evaporation layer, to conserve it. The mechanized basin method does not allow for the collection of additional runoff water.

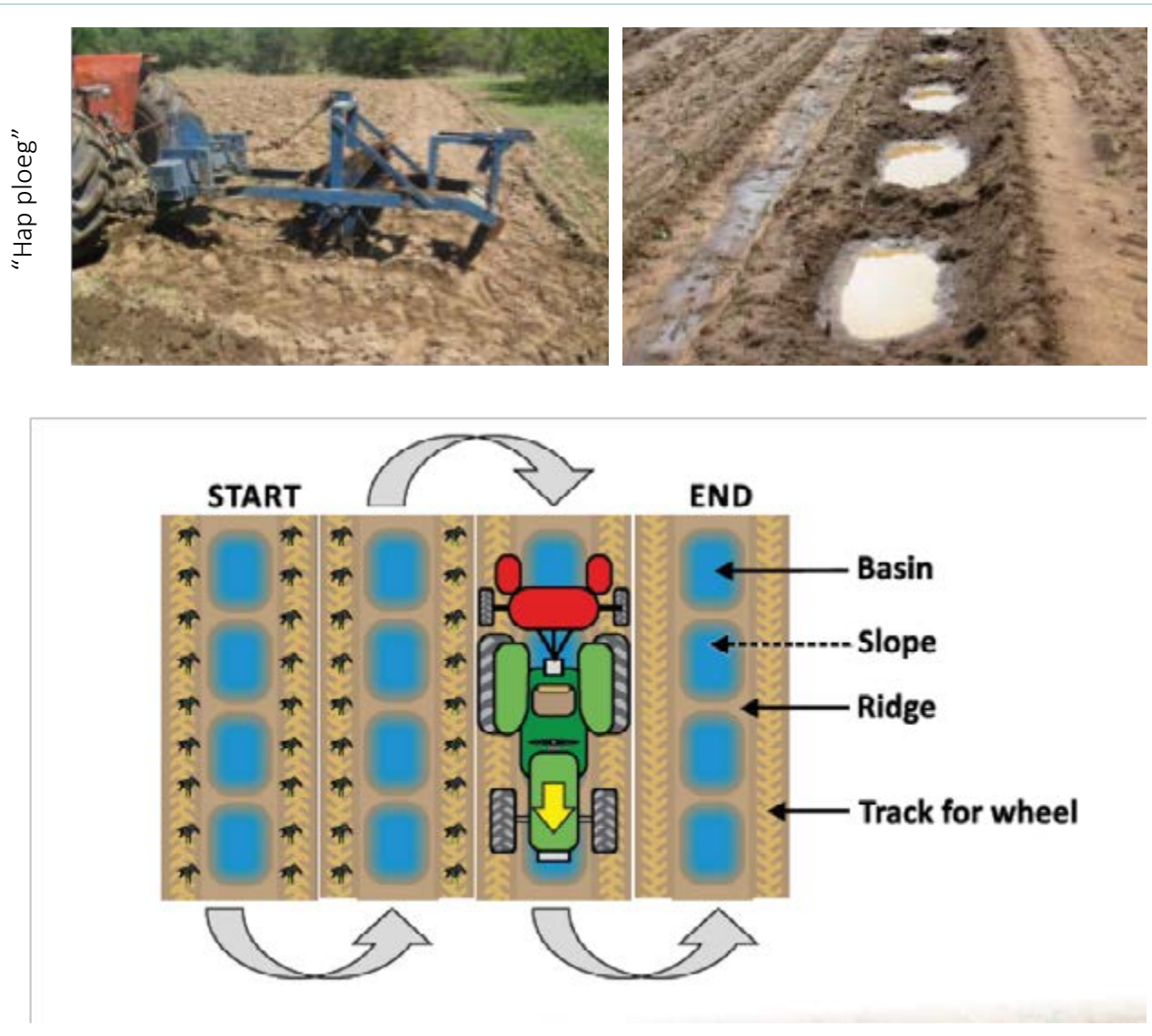


Figure 13 Diagrammatic representation of the construction of mechanized basins.
Source: Botha et al., 2014.

The mechanized basin plough has a basin attachment (small sharp scraper blade), which pivots on the rear of a three-point hitched ripper. The ripper tine operates directly in front of the attachment to break up compacted soil. The scraper at the rear of the attachment creates the basins. The diamond shaped wheel controls the movement of the scraper blade, resulting in a row of basins being created. The distance between the basin rows is versatile and depends on the planter, application and maintenance actions. A 1 m spacing is recommended. With a tractor wheel of 480 mm it implies that during implementation the tractor returns on its tracks when implementing a new row, but the return trip must start about 50 mm away from the initial wheel tracks.

- ***Daling plough***

The Daling plough generates a 1.8-meter-wide runoff area with a relatively wide and shallow basin. A chisel plough in front is followed by a large V-shaped scraper blade with an off-center wheel on the Daling plough. The chisel plough is directly connected to the tractor's three-point linkage. The chisel plough is trailed by a large V-shaped scraper blade. The chisel plough loosens the soil before constructing long V-shaped or chevron-shaped basins. The off-center rotating wheel lifts the scraper over the soil in front of it, leaving a ridge as shown in Figure 14.

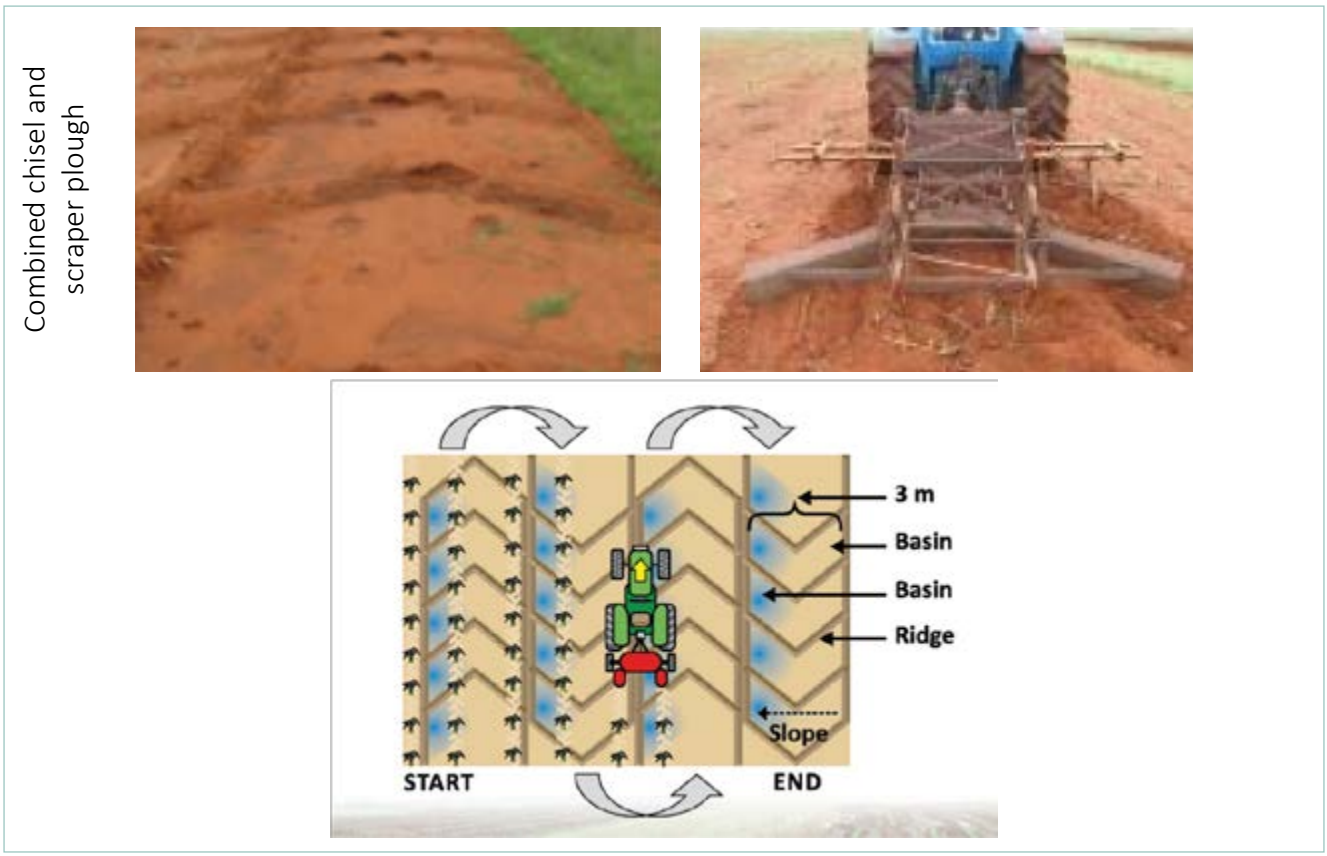


Figure 14 Diagrammatic representation of the construction of water harvesting structures using a Daling plough.
Source: Botha et al., 2014.

The Daling plough works on the same principles as the IRWH technique, but no sunken basins are created. The Daling plough scrapes the top layer of soil without disturbing the natural slope and with large ridges on both sides of the large scraper blade. Basins with V shapes are formed. The chisel plough creates a fine seedbed, while the scraper blade directs runoff toward the basin's lower end.

4.2.2 Use of grey water

The amount of water received following the rainfall event can be classified into three types: green, white, and blue water. Green water is water that infiltrates the soil and is taken up by plant roots for physiological processes, whereas white water is water that is intercepted and directly evaporated from the plant canopy, as well as evaporation from the ground surface. Blue water, on the other hand, refers to water derived from runoff into river basins. This water is also susceptible to deep percolation into aquifers, where it eventually finds its way to rivers. Green water is the most important component of rainfall in a dryland agricultural system. In addition to the three previously mentioned categories of water for dryland agriculture, there is grey water (as illustrated in Figure 15). This category of water includes any type of feces-free household water. This includes, among other things, water from the kitchen, kitchen sinks, bathrooms, and washing machines. This water can be used to water the homestead gardens' plants. Water containing urine and feces is referred to as black water. Black water must be thoroughly treated before it can be used to irrigate crops.

4.2.3 Drip irrigation and irrigation scheduling

Drip irrigation, also known as trickle irrigation, involves dripping water onto the soil at very low rates (2-20 litres/hour) through a network of small diameter plastic pipes fitted with emitters or drippers. Drip irrigation (as shown in Figure 16) is a type of micro-irrigation system that has the potential to save water and nutrients by allowing water to drip slowly to plant roots, either above or below the soil surface. The goal is to direct water into the root zone while minimizing evaporation. This climate smart agricultural technology entails making efficient use of irrigation water in order to save more water for other environmental purposes. It ensures that crops are irrigated at the appropriate time and with the appropriate amount of water based on crop requirements. In this regard, it increases yields and, as a result, household food security.

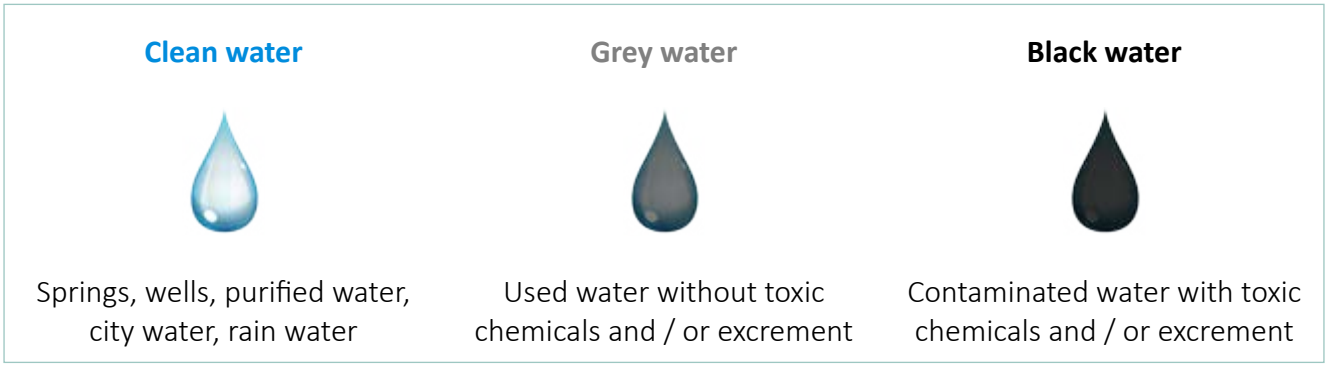


Figure 15 Classification of water according to source of origin.

It is appropriate for arid and semi-arid regions with limited access to water but irrigation facilities. Farmers can manage the amount of water used by the crop while also saving water for future climatic disasters in this manner.

Drip irrigation can aid in the efficient use of water. A well-designed drip irrigation system wastes almost no water due to runoff, deep percolation, or evaporation.

Drip irrigation reduces the amount of water that comes into contact with crop leaves, stems, and fruit.

Figure 16 Use of drip irrigation to improve water use efficiency.
Source: https://www.atsirrigation.com/do-you-know-the-6-major-parts-of-a-drip-irrigation-system.

5 CONCLUSION

Climate change is already a measurable reality that poses significant social, economic, and environmental risks and challenges around the world. As a result, South Africa must strike a balance between accelerating economic growth and transformation and conserving natural resources and responding to climate change.

In South Africa, water is the primary medium through which the effects of climate change are felt. Changes in rainfall patterns, with more intense storms, floods, and droughts; changes in soil moisture and runoff; and the effects of increasing evaporation and changing temperatures on aquatic systems are all having an impact on water quality and availability.

Climate change awareness is important because it helps people understand and address the impact of global warming. It increases "climate literacy" among extension practitioners and small-holder farmers, encourages changes in their attitudes and behavior, and assists them in adapting to climate change-related trends. By focusing on local or regional impacts, climate change awareness can be increased. Changes that extension practitioners and small-holder farmers have already noticed, such as a decrease in rainfall and increased temperatures, were highlighted. Because the effects of climate change vary, extension practitioners and small-holder farmers must be on the lookout for climate change impacts in their specific region. A variety of CSA technologies were showcased. This provides farmers with a variety of options from which to select technology that will meet their specific needs. It was discovered from these technologies that various CSA technologies can be successfully used to improve crop yields and rainwater productivity in homestead gardens and croplands when compared to conventional tillage / farmer practices. This is especially important in semi-arid environments, where every drop of rainwater must be used to produce food as efficiently as possible.

A variety of CSA technologies can be used in homestead gardens and cropland. Certain technologies, such as IRWH, are very effective at reducing unproductive water losses from the soil surface, such as runoff and evaporation. Unproductive water losses can be reduced even further when these water management strategies are used in conjunction with sound soil management practices such as mulching. The CSA technologies offer the farmer a variety of options from which to choose based on his specific needs and farming enterprise. With CSA technologies, communities are no longer limited to homestead garden production, but can also expand to semi-commercial or commercial croplands. A variety of implements for the construction of rainwater harvesting structures are available for this purpose. According to available literature, the Daling plough performed better on soils with clay contents of less than 29%; mechanized basins performed better on soils with clay contents between 29% and 36%; and IRWH works best on soils with clay contents greater than 36%. It is thus critical to understand the texture of the soil in order to apply the most appropriate climate smart technology.

Practical activity 3

A simple group activity can be performed to help extension practitioners understand the role that mulches can play in reducing evaporation losses from the soil surface. Fill four containers with soil of equal weight (for example, 2 kg) (e.g. 2 litre empty ice cream container). The soil in all four containers is the same. In one of the containers, the soil surface is left bare, while mulch is placed on the soil surface in the other containers. In one treatment, stones covering 50% of the soil surface can be used, while grass mulch covering 50% and 100% of the soil surface can be used in the other two treatments.

Extension practitioners are then requested to evenly distribute the same volume of water (e.g. 250 ml) over the soil in each container. Each container is then weighed and the weight recorded. All four containers are then place outside in a sunny spot for two days. After the two days the each container with its soil and much is weighed again. Extension officers then need to calculate the percentage water loss for each treatment.



Provide an example of a typical farming enterprise scenario in the area where the extension practitioners work. Examples of such a scenario include:

In the Eastern Cape, a small-holder farmer is staying in a rural village near the town of Alice. The area receives approximately 450 mm of rainfall per year, with approximately 320 mm falling between October and April. The majority of the rainfall falls in the form of heavy thundershowers, resulting in a large amount of runoff. Summers are extremely hot, with temperatures exceeding 33°C not uncommon in December and January. The famer is staying in a four-bedroom house with a corrugated zinc roof, gutters, and a JoJo tank. Because the village's taps frequently run dry for long periods of time, the water collected in the tank is primarily used for domestic purposes. Despite not having access to a tractor or implements, the farmer manages to cultivate an area of about 3 hectares for maize production using animal traction. He also grows vegetables in his homestead gardens, primarily for household consumption. The texture of the soil at his homestead garden is unknown, and some patches of soil in his garden are only 500 mm deep. He has a few cattle that roam freely in the communal rangelands during the day and are kraaled at night at his homestead. His cropland is on the outskirts of the village where he is staying, at the foot of the mountains. The cropland slopes at about 4%, and the effective soil depth is 800 mm, with a clay content of about 35%. Cattle are normally allowed to enter croplands after harvesting to use maize stalks as fodder. The farmer has noticed a change in the rainfall pattern; normally, the area receives good spring rains in October, but in recent years, good rains have only begun around mid-November. The farmer has a handheld rain gauge and has recorded that the total rainfall is also slightly less than it was a few years ago.

What recommendations do you have for the farmer in terms of CSA technologies and management practices to ensure continued sustainable production?

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Other useful locally developed manuals that can be used for training on CSA technologies for use in homestead gardens, croplands and rangelands are as follows:

Chitja J & Botha JJ (2020). Guidelines on best management practices and scaling-up approaches for entering food value chains for homestead-, community- and school gardens. WRC Project No. K5/2555/4. Water Research Commission of South Africa, Pretoria.

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