MAAIF
Ministry of Agriculture,
Animal Industry and Fisheries

Sunflower Value Chain

A CLIMATE SMART AGRICULTURE APPROACH

AN EXTENSION WORKERS MANUAL

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MAAIF
Ministry of Agriculture, Animal Industry and Fisheries

CRAFT
Climate Resilient Agribusiness for Tomorrow

Ministry of Foreign Affairs of the Netherlands

SNV

WAGENINGEN UNIVERSITY & RESEARCH

CGIAR

AICCRA
Accelerating Impacts of CGIAR Climate Research for Africa

AGRI TERRA

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FOREWORD

MAAIF is implementing her sectoral objective of the NDPIII through the agroindustrialisation (AGI) program under the Parish Development Model Approach. The goal of NDPIII is to increase household incomes and improve the quality of life of Ugandans. The AGI program aims at increasing household incomes through promoting agro-enterprises.

Sunflower is one of the priority oil crop commodities which will contribute towards the attainment of the AGI goal. The commodity is mainly for the processing of oil but the by-products can be used as a component in the formulation of animal feed. Sunflower production in Uganda is predominantly small scale with estimated annual yields of 383,200MT from estimated production area of 265,000 Ha (UBOS, 2020). This gives an average of 0.981MT/Ha against the potential of the hybrid varieties of about 1.5MT.

This low production is attributed to a number of challenges including: high cost of quality inputs, inadequate extension services, declining soil fertility pest and diseases and price fluctuations. However, the recent climatic changes have exacerbated these existing challenges. In response to the climatic change and to address some of these challenges, a number of private seed companies in collaboration with NaSARRI have registered some hybrid varieties with good attributes including high yields.
One of the key objectives of the Uganda agricultural extension policy is: "To empower farmers and other value chain actors (including youth, women, and other vulnerable groups) to effectively participate and benefit equitably from agricultural extension processes and demand for services". To achieve the broader policy goals and strategic objectives, MAAIF in collaboration with SNV have developed a harmonised sunflower extension workers manual.

The objective of this manual is to sustainably transform sunflower value chain from a predominantly subsistence, low input, and low productivity, to a fully commercialised farming business, consequently improving household incomes of rural farmers who form most of the population in Uganda.

I wish to thank everyone who contributed to the development of this manual, particularly; MAAIF staff and stakeholders that provided input into the drafting and validation of this manual; team members for reviewing the document and steering the whole process, SNV CRAFT project for the collaboration in the development of the manual.

It is my hope that this manual will be resourceful and used adequately by extension service providers and other value chain actors to strengthen the sunflower value chain in Uganda.

FOR GOD AND MY COUNTRY

Maj. Gen. David Kasura-Kyomukama

Permanent Secretary

Ministry of Agriculture, Animal Industry and Fisheries.

EXECUTIVE SUMMARY

The manual is designed to assist the reader with information about sunflower value chain and its management in times of climate change. This manual takes the reader through a learning process on the importance, management, and benefits of sunflower crop. The different chapters describe the processes including production and post-harvest handling, marketing, challenges, and options for addressing the challenges to methods and practices for addressing and /or preventing effects of climate change and climate variability. The manual closes with a demonstration of potential economic gains from engaging in climate smart sunflower production.

Chapter one focuses on a description of the significance of sunflower at global, regional, and local levels including the world production of sunflower, currently being over 35 million tonnes and current production in Uganda for 2021 at 282 thousand tonnes. Such information develops trainees' appreciation of the importance of the crop and its value chain. While Chapter two introduces and describes the concept of climate change and also describes numerous technical processes that include climate smart field management processes and practices including pests and diseases and their management. This information is explained at length to enable readers appreciate and understand underlying reasons for specific practices and timing of activities.

The detailed information on climate smart practices will require the reader to identify practices that are applicable to the setting and situation of the user. However, it was deemed important to include a whole array of practices, knowing that production environments are different and dynamic. The manual is concluded with a section on potential financial benefits that can be realised through climate smart production of sunflower and a description of how these can be calculated. It is critical for the extension service providers and learners to appreciate the dynamism of this information and make provision for adjustments based on the prevailing settings.

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ABBREVIATIONS

AFSRT	Agency for Sustainable Rural Transformation
BC	Before Christ
CAGR	Compound annual growth rate
CDD	Consecutive dry days
CSA	Climate Smart Agriculture
CMIP5	Coupled Model Inter-comparison Project Phase 5
CRAFT	Climate Resilient Agribusiness for Tomorrow
CSA	Climate-Smart Agriculture
CWD	Consecutive wet days
DAP	Diammonium phosphate
DAOs	District Agricultural Officers
EIL	Economic Injury Level
ETL	Economic Threshold Level
FAO	Food and Agricultural Organisation
FAOSTAT	Food and Agriculture Organisation Corporate Statistical Database

FFS	Farmer Field Schools
GCM	Global Circulation Models
GHG	Greenhouse gas emissions
IFAD	International Fund for Agricultural Development
IPDM	Integrated Pest and Disease Management
MAAIF	Ministry of Agriculture, Animal Industry andFisheries
MAM	March, April, May
MTIC	Ministry of Trade, Industry and Cooperatives
NAADS	National Agricultural Advisory Services
NARO	National Agricultural Research Organisation
NaSARRI	National Semi Arid Resources Research Institute
NDSU	North Dokota State University
NGOs	Non-Government Organisations
NPK	“Nitrogen, phosphorus, and potassium”
NSAC	National Sunflower Association of Canada
OND	October, November, December

OWC	Operation Wealth Creation
PAN	Pannar
PSD	Production, Supply and Distribution
RCPs	Representative Concentration Pathways
SME	Small and medium sized enterprise
SMHI	Swedish Meteorological and Hydrographical Institute
SNV	Netherlands Development Organisation
SOC	Soil organic carbon
TBT	Technical Barriers to Trade
TNAU	Tamil Nadu Agricultural, University
UEPB	Uganda Export Promotion Board
UNBS	Uganda National Bureau of Standards
UOSP	Uganda Oilseed Producers and Processors Association
USDA	United States Department of Agriculture
VODP	Vegetable Oil Development Project
WRSI	Water Requirement Satisfaction Index

CHAPTER 1

BACKGROUND

1.1 Introduction: Sun flower crop and its development

Sunflower (Helianthus annuus L.) is an important global crop and consumption of the sunflower oil and seeds is on the increase. From 2014 to 2022 global consumption increased by 120% due in part to its perceived healthy characteristics as well as its popularity as a salty snack item. Sunflower grains are used both for extraction of oil and as seeds for snacking.

In Uganda the primary use of sunflower is for oil and the by-product (sunflower cake) being an important staple for the livestock industry. Similar growth in demand has been seen in East Africa including Uganda. However, production growth during this same period in Uganda has only increased by about 20%. Sunflower has become an attractive crop for smallholder farmers as it is a short-cycle cash crop that requires few external inputs. While Uganda is the third largest sunflower producer in Africa its yields per hectare are among the lowest. This is due in part to a lack of high yielding hybrid seeds, poor agricultural practices, and climate change. Uganda benefits from a climate that allows for two growing seasons in the year with the majority of sunflower being grown during the second season.

Climate change is projected to impact the sunflower growing region by reducing the predictability of the weather patterns and increasing severe wet and dry events. However, research by Wageningen University indicates that sunflower yields in the primary growing regions in the north is expected to increase under all modelled climate change scenarios with potential yield increases. To counter the increased variability of the climate it will be important that growers adopt climate smart practices, invest in irrigation and other infrastructure, and protect themselves with crop insurance where possible. Sunflower falls within the Uganda National Development Plan III (NDPIII) priority crops. Success in climate-smart sunflower production will only happen if the key agronomic principles are applied. The following key sunflower production parameters have to be known by farmers:

a) Sunflower production is best in warm to moderate semi-arid climatic regions.

b) The plant grows well within a temperature range of 20 - 25°C; temperatures above 25°C reduce yields and oil content of the seeds.
c) Plants are drought-tolerant but yields and oil content are reduced if they are exposed to extreme drought stress during the vegetative and flowering periods.
d) The optimal rainfall range is 500-750 mm for better yields.
e) Sunflower adapts to a wide variety of soils but performs best on sandy loam soils.
g) Sunflower growth depends on nitrogen more than any other nutrient. Due to its deep rooting system, it can use nitrogen from soil layers that are inaccessible to wheat, corn, or other field crops. The plant requires maximum 150 kg of nitrogen per hectare to produce three tonnes of yield per hectare. Over-fertilisation may lead to sunflower lodging. Phosphorous, potassium, boron, magnesium, and molybdenum are also needed to achieve the best yields.
h) The average fatty acid composition of oil from temperate sunflower crops is 55 - 75% linoleic acid and 15 - 25% oleic acid. Protein content is 15 - 20%.

i) Sunflower has one of the shortest growing seasons (80 – 120 days) of the major economically important crops of the world. Delayed harvesting results in poor oil quality, e.g., bad smell, change in colour, poor frying quality and reduced shelf life. The seeds are ready to harvest when the heads turn black or brown and the seed moisture content reaches 10 - 12%. Grain combiners are easily adapted for the harvesting of sunflower by the addition of a head snatcher.
j) Depending on climatic and cultivation conditions, yields can vary from as much as 600 – 3,000 kg/acre (1,500 – 7,500 kg/ha); irrigation is a key factor for obtaining high yields.
k) Sunflower does not tolerate waterlogged areas especially at planting stage

1.2 Social economic importance of Sunflower in Uganda

Uganda's sunflower sector has made significant contributions to the country's socioeconomic development. The sunflower oil seed industry is one of the most promising business sectors in Uganda for both local and export markets (Kamoga, 2011). Currently, about 265,000 hectares of land is under Sunflower production and continues to increase. There are many private companies, especially in Northern Uganda, promoting the growing of oil crops (especially sunflower). According to Word Bank (2021 – Trading Economics) report, 75 percent of Uganda's population lives in rural areas and roughly 25 percent (GoU 2021/22 – budget process) of them are unable to meet their basic needs for food, shelter, water, clothing, and medication. These rural dwellers basically practise subsistence farming. The promotion of oil seed industry, especially sunflower is seen as a cherished hope for them to reduce poverty and meet their basic needs. The interventions would improve the situation by increasing incomes and employment to farmers and other actors. Sunflower is mainly processed into four main products, namely, assorted oils, animal feeds, sunflower seeds and as a snack.

1.3 Geographical regions of sunflower production in Uganda

Sunflower is mostly grown in northern, eastern, and mid-western Uganda. In the Northern Region, sunflower production is concentrated mainly in Lango and Acholi sub-region, parts of Teso region, Elgon sub-region (Mbale, Sironko, Bulambuli, Kween) and mid-western (Masindi and Kiryadongo Districts in Bunyoro), Yumbe district in West Nile and parts of the Karamoja region. The breeding of sunflower varieties is done by the National Semi Arid Resources Research Institute (NaSARRI).

1.4. Marketing of sunflower and its uses.

1.4.1. Uses

Sunflower is used as an ornamental plant in many societies world over. Besides its use as an ornamental plant, parts of the plant are used in making dyes for the textile industry, body painting, and other decorations. Sunflower oil is used in salad dressings, for cooking and in the manufacturing of margarine and shortening (Kunduraci et al., 2010).

Sunflower is used in industry for making paints and cosmetics. In some countries the seed cake that is left after the oil extraction is used as livestock feed. The hulls are also used for manufacturing ethyl alcohol. The dried stems have also been used for fuel. The stems contain phosphorous and potassium which can be composted and returned to soil as fertiliser.

Sunflower meal is a potential source of protein for human consumption due to its high nutritional value and lack of anti-nutritional factors (Fozia et al., 2008). It also has potential for providing multiple ecosystem services in diverse cropping systems (Jones and Sieving, 2006; Franco et al., 2016). It is a crucial source of pollen and nectar in early summer for the activity of pollinators especially honeybees (Delaplane and Mayer, 2000).

CHAPTER 2

CLIMATE CHANGE AND SUNFLOWER PRODUCTION

2.1 Introduction: Climate and Climate Change

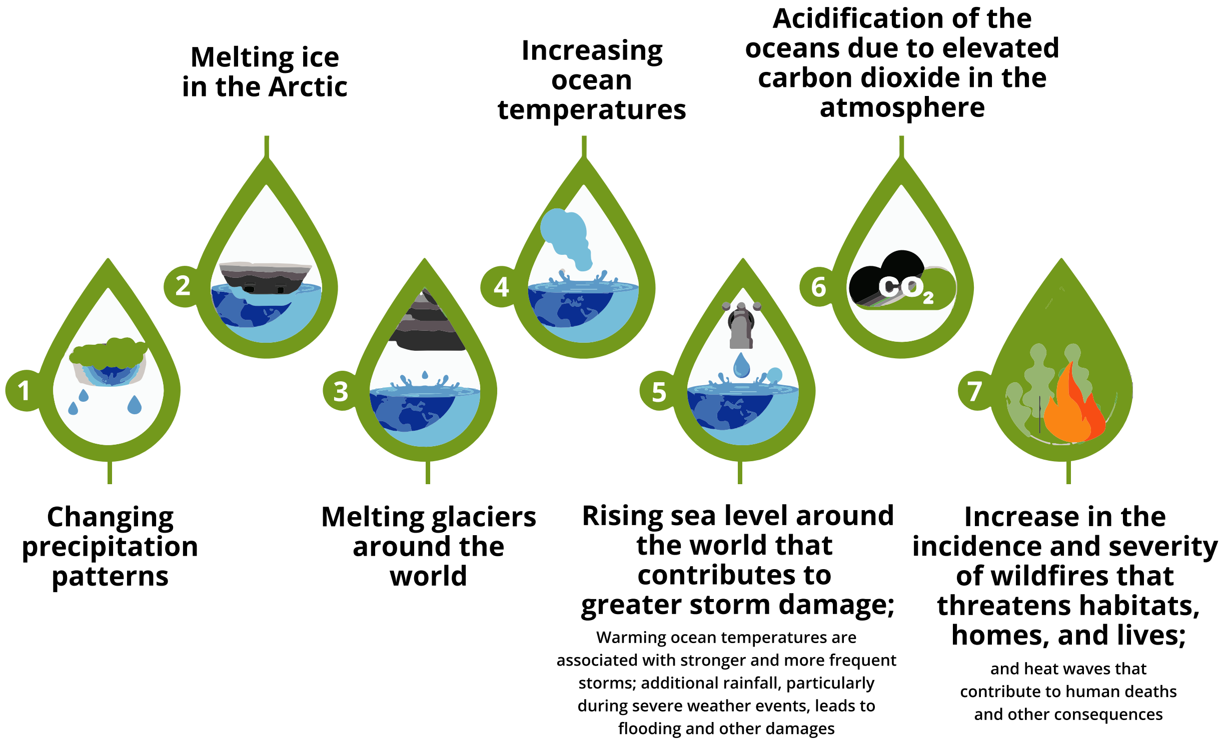
Climate is the average weather condition of a given geographical area recorded over a period of about 35 years. A description of climate includes information such as that for average temperature, rainfall, and sunshine. Major impacts of climate change are rising maximum temperatures: rising minimum temperatures, rising sea level, higher ocean temperatures, heavy rain and hail and melting of ice sheets across the globe

2.2 Causes of climate change

Major causes of climate change are (i) humanity's increased use of fossil fuels such as coal, oil, and gas to generate electricity, run cars and other forms of transport, and power manufacturing and industry (ii) deforestation (living trees absorb and store carbon dioxide), and increasingly intensive livestock farming, which leads to the emission of greenhouse gases such as methane and nitrous oxide (Online: WWF website). All these contribute to global warming through the greenhouse gas effect. Greenhouse gases are gases in the atmosphere such as carbon dioxide, methane and nitrous oxide that can absorb infrared radiation, and trapping heat in the atmosphere. This greenhouse effect means that emissions of greenhouse gases due to human activity causes global warming.

2.3 Impact of climate change

There are several effects of climate change. While some effects can be beneficial, particularly in the short term, current and future effects of climate change pose considerable risks to human health and welfare, and the environment. Even small increases in the earth's temperature caused by climate change can have severe effects. The evidence of climate change extends well beyond increases in global surface temperatures.



2.4 Climate change risks in Uganda

Major climate related extremes in Uganda are:

a) Prolonged dry spell and drought
b) Excessive or less rainfall
c) Seasonal changes
d) Increasing temperatures

2.5 Potential impacts of climate change to sunflower production

Climate change is expected to affect agriculture across Uganda; droughts will occur more often, and they will start earlier and last longer. Higher temperatures and lower rainfall, especially in the eastern and northern regions of Uganda are expected to reduce crop yields, while in other regions growing conditions may improve, allowing a greater range of crops to be grown, although more extreme weather conditions will likely increase instability in crop yields. The net effect will possibly lead to small average yield increases.

Although rainfall levels might decrease across eastern and northern regions of Uganda, this might result in more sunflower being grown as farmers are drawn to the drought tolerant nature of sunflower compared to other alternatives. Farmers may also look to adapt farming methods to combat drought conditions by choosing drought and heat tolerant crops such as sunflower.

There are many variables that affect disease development, all of which will be influenced by climate. It's likely that regions, where rainfall decreases and temperatures rise, will see a fall in diseases that require free water to facilitate their life cycle, such as downy mildew (Plasmopara halstedii), Sclerotinia rots, Phoma Black stem (Phoma macdonaldii) and Phomopsis stem canker (Diaporthe helianthi). Conversely, some diseases will develop under hotter and drier conditions such as Charcoal rot (Macrophomina phaseolina). Higher temperatures and reduced rainfall could also increase the incidence and spread of broomrape (Orobanche Cumana). It is thought that climate change may be involved in the recent development of Orobanche. On the other hand, if sunflower is grown in regions where sunflowers haven't been grown before, the lack of disease-causing inoculum may, at least initially, lead to less disease.

Sunflower relies heavily on insects to pollinate, especially honey and bumble bees, and there is evidence that pollination is already under threat from habitat loss, insecticides, pathogens, and alien species. Climate change could further affect pollination by changing the activity of pollinators, by reducing population sizes or by altering insect activity. On the other hand, multi-year evaluations of each hybrid for self-compatibility should be conducted so that the plant can pollinate itself, to counter the impact of reduced pollinator activity. It is important to note that hybrids are currently self-pollinating; nevertheless, production of hybrids by breeders still require the pollinators.

2.6 Climate change projections for Sunflower areas in Uganda

2.6.1 Temperature trends in Sunflower growing areas.

The temperature trend (from 1961-2005) for the first rainy season (March, April, May - MAM)) shows that temperature has been increasing by about 1°C in the sunflower growing areas. During the second rainy season (September, October, November and December - SOND), temperature in the sunflower growing areas of the country has been increasing for the past few decades by about 1.2°C - 1.4°C. During both the first and second rainy season, temperature in the sunflower growing areas of the country (MIDDLE) has increased by 1°C - 1.2°C. Temperature in the 2030s is expected to rise by about 1.8°C.

2.6.2 Rainfall

The seasonal mean rainfall in the first rainy season is projected to decrease in the sunflower growing areas of Uganda in both the 2030s and 2050s though a slight increase (5 - 10%) is expected in the northern growing regions by 2030s. However, the seasonal mean rainfall in the second rainy season is expected to increase (by about 20 - 40%) in the sunflower growing areas of the country especially in the 2050s. Likewise, the longest consecutive wet days (CWD) in the sunflower growing areas of Uganda is expected to decrease in both the 2030s and 2050s during the first rainy season. However, the length of the longest wet spells in the sunflower growing areas of the country is projected to increase slightly in the second rainy season especially in the 2050s.

2.6.3 Drought

The projection of the longest consecutive dry days (CDD) for both the second and first rains show that dry spells are expected to decline by 2 - 5 days in the sunflower growing areas by the 2030s and 2050s. The projected decline in the dry spell coupled with the expected increase in the seasonal mean rainfall accompanied by an increase in the number of consecutive wet days in the sunflower growing areas for the second rainy season could translate into enhanced extreme rainfall in the region.

2.6.4 Onset and length of growing spell

The onset, cessation, and length of the growing spell for the first rainy season (MAM) is estimated for the historical period (1961-2005) and the 2030s and 2050s. Climate projections shows that early onset (by about 2 - 5 days) of rainfall is expected in the first rainy season in the northern and central sunflower growing areas of the country. However, the seasonal rain is expected to be delayed (by about 4 - 8 days) in the north-western sunflower growing areas of Uganda. On the other hand, the length of the growing spell in the sunflower growing areas is projected to increase by about 4 - 8 days extending the season to June and subsequent months

2.7.Climate Smart Agriculture

Climate Smart Agriculture (CSA) is an approach to guide the needed changes of agricultural systems, given the necessity to jointly address food security and climate change (FAO, 2013). The principal goal of CSA is identified as food security, while productivity, adaptation, and mitigation are identified as the three interlinked pillars necessary for achieving this goal

- Productivity: CSA aims to sustainably increase agricultural productivity and incomes from crops, livestock and fish, without having a negative impact on the environment. This, in turn, will raise food and nutritional security. A key concept related to raising productivity is sustainable intensification.
- Adaptation: CSA aims to reduce the exposure of farmers to short-term risks, while also strengthening their resilience by building their capacity to cope and prosper in the face of shocks and longer-term stresses. Particular attention is given to protecting the services which ecosystems provide to farmers and others. These services are essential for maintaining productivity and our ability to adapt to climate changes.
- Mitigation: CSA helps to reduce and/or remove greenhouse gas (GHG) emissions. This implies that we reduce emissions for each calorie or kilo of food, fibre and fuel that we produce. That means we should avoid deforestation in agriculture; we should manage soils and trees in ways that maximise their potential to act as carbon sinks and absorb CO2 from the atmosphere..

2.7.1 Integrating many goals and managing options

Climate Smart Agriculture (CSA) produces great wins in (i) increased productivity, (ii) ability of production systems to withstand stress and (iii) reducing harmful gases being released into the environment. Most of the time it is difficult to achieve all these three and so in implementing CSA approaches, implementers should make decisions on the most important wins that will result in profit and leave others.

2.7.2 Maintaining environmental order

The surroundings of farmers provide them with numerous resources such as water, clean air and food. It is important that all CSA interventions do not destroy or reduce the quality of these resources but rather include them in their plans with the aim of preserving or even improving them.

2.7.3 Many entry points at different level

Climate Smart Agriculture (CSA) has many interventions at different points in entire production systems, e.g., interventions will be in the areas of farming, inputs, processing, marketing, knowledge, machinery, schools and training institutions, and others.

2.7.4 Specific to settings

What is climate smart in one place may not be climate smart in another, and no interventions are climate smart everywhere or every time. Implementers must take into account the results achieved when different aspects of production, the environment and their support entities interaction are altered by an intervention. An implementer will, therefore, aim at achieving the best possible results given the interactions of the mentioned aspects at that particular place. Because the nature of these aspects varies from place to place, it may sometimes be difficult to directly transfer entire sets of CSA practices from one location or setting to another.

2.7.5 Involvement of vgender response

To achieve food security goals and increase the ability of production systems to withstand climatic stress, CSA approaches must involve the poorest and most vulnerable groups. These groups often live on marginal lands which are most vulnerable to climate occurrences such as drought and floods. They are, thus, most likely to be affected by climate change. Gender is another central aspect of CSA. Women typically have less access and legal right to the land which they farm, or to other productive and economic resources which could help build their adaptive capacity to cope with events such as droughts and floods. Climate Smart Agriculture (CSA) strives to involve all local, regional and national stakeholders in decision making. Only by doing so, is it possible to identify the most appropriate interventions and form the partnerships and alliances needed to enable sustainable development.

CHAPTER 3

CLIMATE RESILIENT SUNFLOWER PRODUCTION

3.1. Introduction

The sunflower value chain will have to adjust to cope up with climatic change if it is to thrive in the agriculture sector. This calls for technological changes and more rigorous adoption and adaption to negate the effects. Climate resilient technologies must be identified across the value chain from site selection, and land preparations, sunflower production, sunflower nutrient requirements and soil fertility management practices..

3.2. Climate resilient agriculture; technologies, innovations, and management practices in Sunflower

Effects of climate change and variability can be minimised by using good management of sunflower production including:

a) Minimum soil disturbance techniques such as minimum tillage that harvest and store rainwater in-situ, e.g., planting furrows or planting holes.

b) Effective early weed control to reduce moisture loss.

c) Retaining disease-free or alternate crop organic residue as soil surface mulch.

d) Traditional farmer organic residue incorporation into planting ridges.

e) Use of farm manure in planting holes to create moisture retaining spongy effects around seedlings.

f) Integrated weed management could be proposed to limit the use of pesticides and mitigate crop damages.
Cover crops can be used for soil moisture retention

h) Intercropping sunflower with leguminous crops such as soybean is an option for maximising resource-use efficiency in low-input environments but wider spacing is recommended.

i) Sunflower yield can be maintained at good level in very low input cropping systems.

3.3. Site selection

Sunflower thrives best at medium to high elevations in the tropics. It is not suited for wet areas because it is a warm season crop. Avoid stony, waterlogged areas and continuous cropping with sunflower.

3.4. Land preparation

After selecting the field/site, clear the bush one month prior to the onset of rains, allow the grass to decompose (for manure) and carry out the first and second ploughing. Break the larger soil clods to fine texture to ensure maximum rainfall infiltration and to provide a suitable seedbed. All the stubbles of the previous crop should be removed, and all growing weeds should be destroyed and buried in the soils. Farmers are advised to plant at the onset of rainfall meaning land preparation has to be done before the rains start. Ridges, field waterways, terraces or contours and water harvesting basins should be constructed in locations where water run-off or erosion risk is high. Ridges and field water ways should be functional where irrigation is to be carried out. Avoid planting sunflower in waterlogged swampy areas; if a farmer prefers to do so, then proper drainage system must be done. At the planting time, farmers should ensure the soils are quite moist to ensure prompt germination..

Effective pre-emergence weed control using herbicides offers good control and eases post-emergence weed control. Apply a pre-emergency herbicide at 2.0l/ha before sowing and incorporate or apply as post-emergence spray on day five after sowing, followed by irrigation. The spray of these herbicides should be accomplished with backpack/knapsack/rocker sprayer fitted with a flat fan nozzle using 900 litres of water/ha (375 litres per acre) as spray fluid. It is essential that sunflower seeds be planted into a seedbed free of growing weeds. Weed control before planting can be accomplished with tillage, herbicides, or a combination of both. If tillage is the major method of weed control, implements such as field cultivator may be used before planting. Soil that is warm and dry on the surface, and moist below, encourages rapid sunflower development and may delay weed seed germination. The use of a nonselective herbicide is an alternative to pre-plant tillage for weed control. These foliar-applied herbicides can control seedling broadleaf weeds and grasses. In sunflower crops, where there are few herbicide options, alternative weed control techniques such as integrated weed management.

3.5. Ecological requirements for Sunflower production

3.5.1. Temperature

Sunflower is tolerant to both low and high temperatures. The crop is particularly sensitive to high soil temperature during emergence. Sunflower seeds will germinate at 5°C; however, temperatures of at least 14 - 21°C are required for satisfactory germination. Seeds are not affected by cold in the early germination stages. The optimum temperature for growth is 23 - 28°C however, a wider range of temperatures up to

34°C shows little effect on productivity. Extremely high temperatures have been shown to lower oil percentage, reduce seed fill and germination.

3.5.2. Rainfall

The rainfall requirement ranges from 500 - 1000 mm. Compared to other crops, sunflower performs well under drought conditions; this is probably the main reason for the crop's popularity in the marginal areas of Uganda. It has extensively branched taproot, penetrating to two meters, enables the plant to survive times of water stress. A critical time for water stress is the period 20 days before and 20 days after flowering. If stress is likely during this period, irrigation will increase yield, oil percentage and test weight.

3.5.3. Soil

Sunflower grow best on well drained, high water-holding capacity soils with a nearly neutral pH (pH 6.5 - 7.5). Sunflower will grow in a wide range of fertile soil types, sandy loam to clays. Sunflower has a low salt tolerance. Good soil drainage is required for sunflower production, but this crop does not differ substantially from other field crops in flooding tolerance. Soils with good water-holding capacity (clays) will be preferred under dry land conditions.

3.5.4. Altitude

Sunflower grows best at altitude below 1,500 metres above sea level, however, in the tropics it can also grow at heights of 2,600 metres above sea level.

3.6. Soil fertility Management

For high production and productivity, sunflower requires fertilisers. Fertiliser application should be made based on a soil testing outcome. This includes a sample for nitrate-nitrogen, sulphate-sulphur as well as phosphorus and potassium. Sunflower varieties respond well to both organic and inorganic fertilisers. Organic fertilisers such as compost and farmyard manure contain high percentage of nitrogen and potassium required for the growth of the crop and can be applied using band placement or broadcasting method preferably after the first weeding which is normally two weeks after planting or after the second weeding when the crop is at knee height.

Synthetic or inorganic fertilisers such as DAP, NPK and Urea can be applied. DAP can be applied during planting to enhance root establishment. Dig a planting hole, pour the fertiliser in crystal form; cover it and plant the seeds after. Starter applications should be placed away from the seed. When sunflower is seeded with row equipment, all phosphate and potassium should be side banded beside and below the seed during planting. Germinating sunflower seeds are very sensitive to fertilizers getting into contact with them and this should be avoided at all times. A dosage of NPK can be applied using ring placement or broadcast method; this can be done when the crops are at knee height.

Foliar application of urea can also be used. The crop specific blended fertilizer is available on market with the following ratios of NPK (24:17:10) applied at a rate of 50kg/acre.

Macro-nutrients: Sunflower normally reacts well to nitrogen and phosphorus fertilisation, where there is a shortage of these elements in the soil. It is therefore essential that any fertilisation programme for sunflower should be based on soil analysis. Soil analysis will not only lead to more appropriate fertilisation levels but can also significantly limit unnecessary fertilisation costs.

Nitrogen (N): When there is a shortage, the growth rate decreases dramatically, leaves turn to pale green and the lower leaves die off. Nitrogen is the nutrient of greatest accumulation in the above-ground portion of the sunflower crop. Nitrogen recommendations vary with yield expectations associated with soil (Table4), climate, soil moisture, cropping sequence, and residual nitrogen in the soil.

Fertiliser nitrogen rates should be lowered if legumes are grown in rotation before sunflowers. Since sunflowers are efficient in recovery of residual nitrogen, a soil test for available nitrogen in the profile is strongly encouraged. Profile nitrogen samples should be taken to a depth of at least two feet (60.9 cm). On deep, well drained soils, deeper sampling may be justified to four feet (121.9 cm). The use of excessive nitrogen rates is not advisable. If fertiliser is placed in contact with the seed, the starter material should contain no more than five kilograms of actual nitrogen plus potash per acre. The nitrogen and potash can cause germination damage because of their high salt index when placed with the seed. Much higher amounts can be applied in a two-by-two band (2 inches (5.08 cm) deep and 2 inches (5.08 cm) away from the seed) or applied by broadcasting without seedling damage. These fertiliser placement statements hold true regardless of the crop. Nitrogen source should be based on applied cost, availability, adaptability to your management system, and dealer services. Nitrogen application for sunflowers can be made pre-plant, side-dress, or a combination of these methods with equal results. Applications should be timed so that nitrogen is available for rapid plant growth and development.

Phosphorus: A shortage of phosphorus is characterised by retarded growth. In serious cases, necrosis can be detected on the tips of the lower leaves. There are factors which should be considered when planning a phosphorus fertilisation programme:

a) Attempts should be made to build up the phosphorus content of the soil over time. The optimum soil phosphorus level for sunflower is about 10 mg/kg. This means that phosphorus fertilisation is essential when the level of phosphorus in the soil is below 10 mg/kg. However, at a higher level, the crop will probably not respond to phosphorus fertilisation.

b) Phosphorus (P) application should be based on a soil test. Reliable sunflower response to phosphorus fertilisation has generally occurred on soils testing low or very low in available phosphorus where yield potential is not restricted by lack of moisture or other environmental factors. With medium-testing soils, yield responses have been unreliable and normally quite small. Phosphorus applications are recommended with medium and low soil tests for potential yield response and to maintain the soil in a highly productive condition.
c) Phosphorus should be applied pre-plant-broadcast, pre-plant-knifed, or banded at seeding. Starter applications are most efficient, particularly when small amounts are applied on soils low in available phosphorus. Phosphorus can be placed in direct contact with the seed or to the side or below the seed with no restrictions in economical rates. Pre-plant applications should be thoroughly incorporated because phosphorus does not move much in the soil.
d) Liquid and solid fertilisers, as well as varying chemical forms of phosphorus are available. Selection of a phosphorus source should be made based on cost, availability, and adaptability to the operation

Potassium: Like phosphorus, a soil test is the best guide to potassium (K) need. Although sunflower draws large quantities of potassium from the soil, potassium fertilisation is usually unnecessary, unless soil tests levels are low, which normally occurs in sandy soils.

Potassium should be applied pre-plant-broadcast or as a starter. Sunflowers are sensitive to fertiliser salts (N and K). When applying starter applications with the seed. Preferred fertiliser placement is two inches (5.08 cm) deep and two inches (5.08 cm) away from seed. Applications should be thoroughly incorporated to place the potassium in the root zone. The most common potassium source is muriate of potash (potassium chloride); however, potassium sulphate, potassium nitrate, potassium-magnesium sulphate, and mixed fertilisers are other sources. Little difference in potassium availability exists among these materials. Selection should be based on cost, availability, and adaptability to the farm operation. Lodging of sunflower at maturity has been a problem in some areas resulting in considerable harvest loss. However, research has shown that many factors such as weather stress, insect, and disease damage; hybrids, date and rate of planting; and nutrient imbalance can cause lodging. Adequate potassium is essential for strong stalks and may help reduce lodging on medium to low potassium test soils.

Liming: Lime recommendations are intended to maintain soils in a productive condition. Sunflower is not the most responsive crop to lime, but liming of acid soils should not be ignored. Lime is recommended for sunflowers on all soils with a pH of 6.0 or less. If sunflower is grown in a cropping system that includes legumes, liming to obtain a higher pH (6.2 - 6.5) should be maintained.

Other Elements: Because of the extensive root system, secondary and micronutrient deficiencies in field grown sunflower is rare. In fact, sunflower is often suggested as an alternative crop on severely iron-deficient soils. Likewise, there should be no problems with boron, copper, or manganese nutrition in sunflower.

Soil Fertility and Micronutrients: Iron availability decreases with increasing soil pH. However, sunflower is tolerant to low iron availability. Sunflower production is usually successful on soils that cause deficiencies on sensitive crops such as maize, sorghum, or potatoes. Severe iron deficiency of sunflowers in the seedling stage shows interveinal chlorosis on the youngest leaves with stunted plants. Zinc-deficient plants are stunted with distorted upper leaves. As the deficiency intensifies, leaves tend to wilt. Zinc deficiencies or responses to added zinc are not likely. Considerations must include individual management skills, soils, and average weather conditions. Adequate fertiliser nutrients must be provided as required for selected yield goals. The most limiting factor, however, for yield on dry land sites, is often stored soil water and effective rainfall.

3.7. Sunflower varieties, their sources, and preferences in different regions different regions

3.7.1. Sunflower varieties, their characteristics, and sources

Scientists in Uganda have embarked on production of hybrid varieties which they are encouraging farmers to grow. The most recently released is Sesun 1H which has features of uniform growth both at vegetative stage and after flowering. The head bends and forms a goose neck which is always hidden below the leaves thus avoiding flying birds. It matures between 89 - 100 days, oil content is 43% and the seed coat is black.

The other variety is Sesun 2H which is of medium maturity. It is very vigorous in growth with large leaves. It grows uniformly and with big heads which tend to twist and has the same maturity period with Sesun 1H, with oil content of 36% and it can yield up to 1,600 kilograms per acre (4,000 kg per hectare).

There is also the open pollinated variety namely, Sunfola, with yield capability of 600 kilograms per acre. These varieties are accessible at the National Semi Arid Resources Research Institute (NaSARRI) but, for farmers who are far, arrangements can be made for delivery to their respective places. Table 5 presents a summary of some sunflower varieties and their sources in Uganda

Table 5: Sunflower varieties, their characteristics, and sources in Uganda

Sunflower variety	Type	Source	Period to maturity	Oil Content (%)	Kg per acre
NEW SUNFOLA	Open pollinated variety	NaSARRI	100 – 110 days	40	600 - 720
AGSUN 8251	Hybrid	Ngetta Tropical Holdings (imported)	90 – 95 days	44	800 (without fertiliser) and 1,500 - 2,500 (with Fertiliser)
SESUN 1H	Hybrid	NaSARRI	89 – 100 days	43	
SESUN 2H	Hybrid	NaSARRI	89 – 100 days	36	1,600
PAN 7057	Hybrid	Mukwano industries, made by a company called PANNAR	130	43	
AGUARA4	Hybrid	ADVANTA Company	80 – 85 days	40-45	1,000 – 1,200
		(Europe)			
AGUARA 6	Hybrid	ADVANTA Company (Europe)	80 – 85 days	40-46	1,000 – 1,200
HYSUN 33	Hybrid	ADVANTA Company (Europe)	117 days	41	660 - 900

Sources: Online: National Crop Variety List for Uganda; Online: Ngetta Tropical Holdings; Daily Monitor 17 June 2020; PANNAR 2018; Anyanga W, NaSAARI; Ogwang Emmanuel, VODP; Sirajul et al., 2012; Ejaz et al., 2012; Online Novak; ARC 2014-15.

Hybrid recommendations: Choosing a suitable hybrid package is one of the most critical and challenging management decisions farmers make each year. It is important to choose proven performers based on:

- Data from multiple years and trials across a large homogeneous area, to rule out variation and improve performance forecasts.
- Yield, stability, and risk hedging all play an important role when selecting a hybrid.
- Hybrid's agronomic traits and disease risk profile: Select a hybrid package with a variety of growth classes to diversify risk, and phase in new hybrids gradually.

Sunflower variety preferences across the regions show that market availability is a predominant factor in the decision on the variety to plant. Cost effectiveness and yields are also other reasons for preferences. Because the market is so critical for the farmers, it is important that, much emphasis is placed on variety suitability for specific agro-ecological zones. All other relevant climate-smart practices should also be emphasised to counter any inferior characteristics that could be found in the marketable varieties.

3.8. Sunflower climate-smart field management practices

3.8.1. Challenge of imported seed

Some of the sunflower seed imported from other countries may lack germination viability due to delay in transportation and some end up being infested by diseases. There is limited follow back in case of crop failure. Ecological suitability if some varieties require some research work.

3.8.2. Ridging

Form ridges and furrows, six meters long, as shown in Figure 10 (this can be adopted by our local farmers using local resources such as oxen-pulled ploughs). The use of bund-former or ridge plough will economise and form irrigation channels across and ridges according to the topography of the field. This can be done with a tractor, oxen, or hoes.

Spray while facing towards where the wind is flowing to. Instructions on the chemical packaging should always be read, understood, and followed. Containers that contained the chemical should be disposed of far away from household utensils to avoid contamination of human food - dispose of the containers in pit latrines.

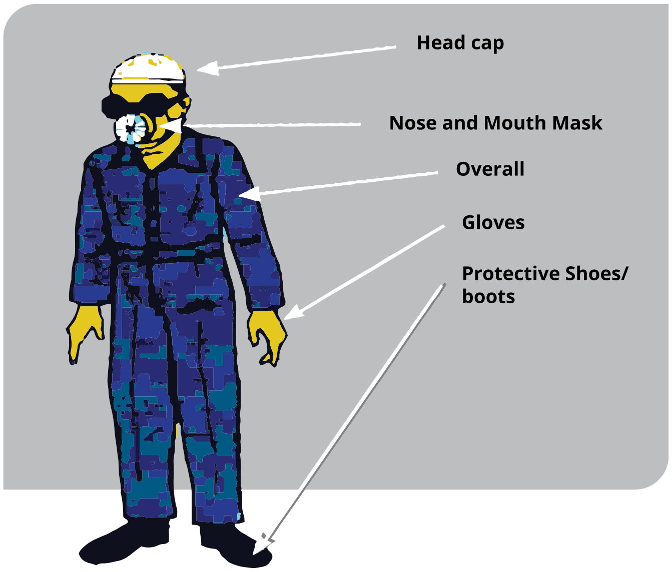


Figure 9: Protective wear that should be worn when applying chemicals to control weeds, pests, and diseases.

Figure 10: Forming ridges and furrows, *Source Tamil Nadu Agricultural, University, (TNAU Agritech Portal)*

3.8.3. Planting

Planting should be done within the first two weeks after the rains have started. In areas with longer rainy season, it is advisable that planting should be delayed to avoid ripening of the crop during the rainy season.

Planting depth: For good yield, proper crop spacing and planting depth are important. In the heavy soil, shallow planting is recommended, while in the lighter soil, deep planting is recommended. In heavy soils, the seed should not be planted deeper than 2.5 - 4.0 cm. In lighter soils, it may be planted up to 5.0 – 6.0 cm deep.

Seed rate and plant spacing: Seed rate and plant spacing are crucial for soil moisture and fertility utilisation and ultimately optimum crop yield. Additionally, the use of recommended spacing will facilitate good crop canopy that will cover the soil and reduce moisture loss. For the sunflower current varieties, seeding rate depends on:

a) type of variety.
b) soil and the climatic zone.
c) technology used for planting.
d) quality and germination vigour of seeds.

Planting should be on average 2 kg per acre with two seeds planted per hole, leaving one plant at thinning. Recommended spacing is 75 by 30 centimetres (Figure 13)..

3.8.4. Growth Stages

The total time required for development of a sunflower plant and the time between the various stages of development depends on the genetic background of the plant and the growing environment. The average development of many plants should be considered when determining the growth stage of a sunflower field. Later in the season, for stages R-7 through R-9 (refer to Table

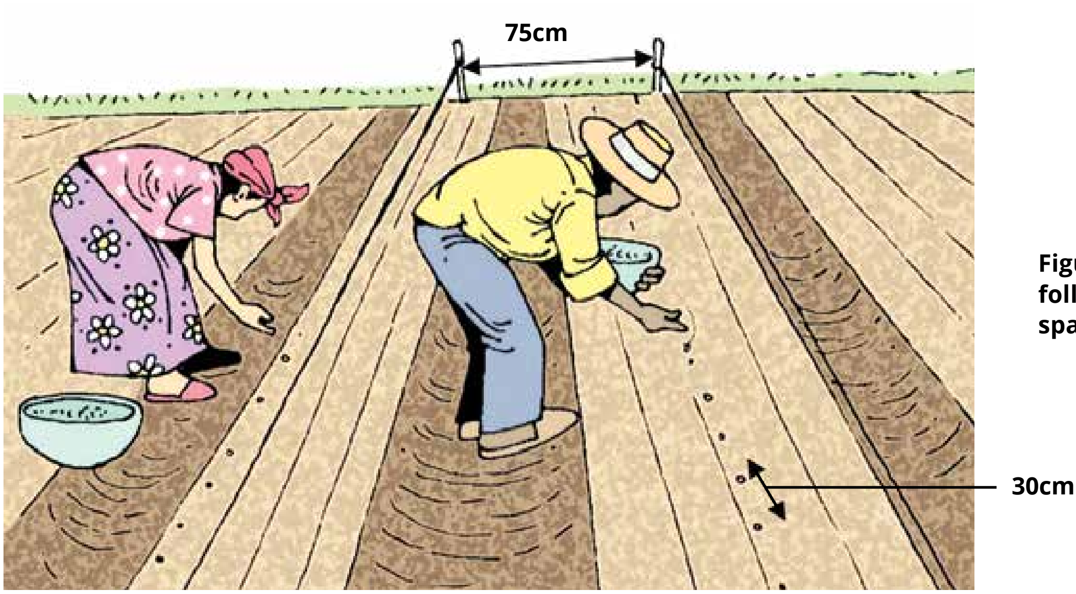


Figure 13: Planting sunflower following the recommended spacing.

6), use healthy, disease-free heads to determine plant development since some diseases can cause head discoloration. Maturity is typically reached 90 – 120 days after planting for early maturing varieties and 120 - 150 days for the other varieties.

Table 6: Sunflower growth stages and description

Stage	Description
Vegetative Emergence	Seedling has emerged and the first leaf beyond the cotyledons is less than four centimetres long.
Vegetative Stage (V-1 to V-4)	These are determined by counting the number of true leaves at least four centimetres in length beginning as V-1, V-2, V-3, V-4, etc. (See Figure 14). If senescence of the lower leaves has occurred, count leaf scars (excluding those where the cotyledons were attached) to determine the proper stage.
Reproductive stage (R -1 to R-9)	The terminal bud forms a miniature floral head rather than a cluster of leaves. When viewed from directly above, the immature bracts have a many-pointed star-like appearance. The immature bud elongates 0.5 to 2.0 cm above the nearest leaf attached to the stem. Disregard leaves attached directly to the back of the bud. The immature bud elongates more than two centimeters above the nearest leaf. The inflorescence begins to open. When viewed from directly above, immature ray flowers are visible. This stage is the beginning of flowering. The stage can be divided into sub-stages dependent upon the percent of the head area (disk flowers) that have completed or are in flowering. Flowering is complete and the ray flowers are wilting. The back of the head has started to turn pale yellow. The back of the head is yellow, but the bracts remain green. The bracts become yellow and brown. This stage is regarded as physiological maturity.

Schneiter, A.A., and J.F. Miller. 1981. Description of Sunflower Growth Stages. Crop Sci. 21:901-903

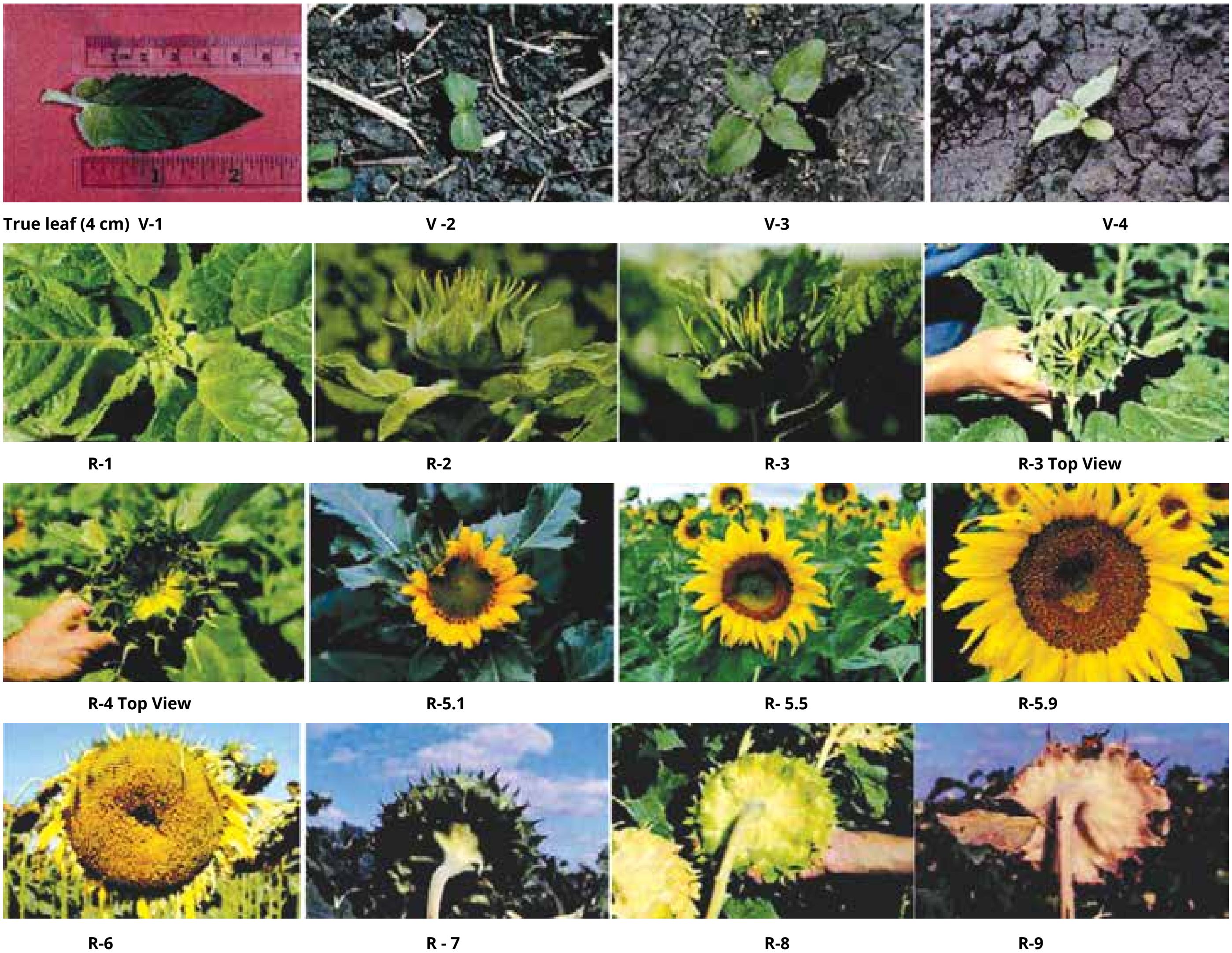


Figure 14: Stages of sunflower development. Source North Dakota State University, NDSU, Extension service, 1998

3.8.5. Pests and diseases management options

Although several insects and diseases may attack sunflower, the effects are usually not serious enough to hamper yield. Insects such as cutworms, dusty surface beetle and ground weevils may damage emerging seedlings; and birds usually feed on the seed when the plants are mature. The most serious diseases are caused by fungi, and they include: rust, Verticillium wilt, Sclerotinia root rot, phoma black stem, charcoal rot and leaf spot. They are common in virgin lands because they are soilborne diseases. They are mainly common in land where beans and cotton have been grown. Another common disease is Crinkle leaf which is a viral disease affecting leaves causing stunted growth.

Scouting/identification/management:
Field scouting involves walking into the field and assessing the overall health of the crop. Sunflower pests tend not to be distributed evenly throughout a field, so fields should be checked in several locations. Therefore, the fields should be monitored regularly for potential problems, to determine pest species present, and if populations are at economic threshold levels.The plant is a host to several pests and diseases

3.8.5.1 Sunflower Pests

African Boll Worm *(Helicoverpa armigera)*

The African bollworm attacks many crops, including cotton, sunflower, tobacco, tomato, maize, sorghum, and legumes, but also feeds on many different weeds, hence crop rotation patterns should take these into consideration. Adult moths are about two centimetres long in the resting position (Figure 15) and are dull brown with grey and yellow shades, with a characteristic dot pattern on their wings. Moths become active at dusk and females lay eggs (oviposit) on suitable plants mostly during the evening hours. Eggs are laid singly on fruiting and flowering parts of the plants, or on the leaves. The eggs are white yellow in colour when they are freshly laid, and tum yellow-brown as they develop. Because of this, older eggs are more difficult to see (Figure 16 and 17) because they are found against the generally dark plant surface. The egg is round, with a diameter of 0.45 - 0.5 mm. The distinct ridge structure and the raised micropyle on top can be seen in the field with a hand lens. A single female moth can lay a thousand or more eggs during its lifespan of approximately two weeks. In East Africa, the egg takes 4 - 6 days to hatch, depending on the temperature. When it hatches, the young caterpillar prefers to feed on the soft plant parts, which are rich in protein, particularly buds and flowers. Older caterpillars (Figure 18) are especially damaging, because they consume only a small part of a flower or fruit, and then move to the next, leaving a trail of damaged flowers or fruits (Figure 19) which will produce no harvest.

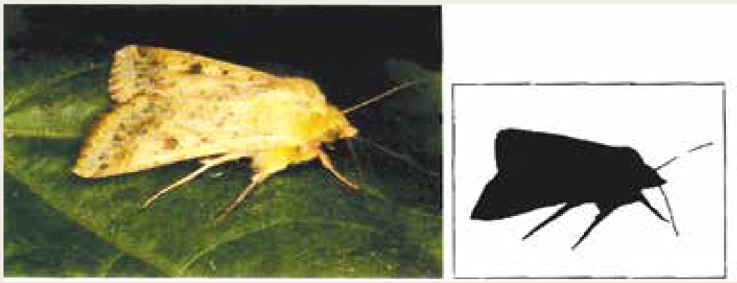


Figure 15: African Boll Worm moth

Figure 16: African Boll Worm egg

Figure 17: African Boll Worm egg on sunflower leaf

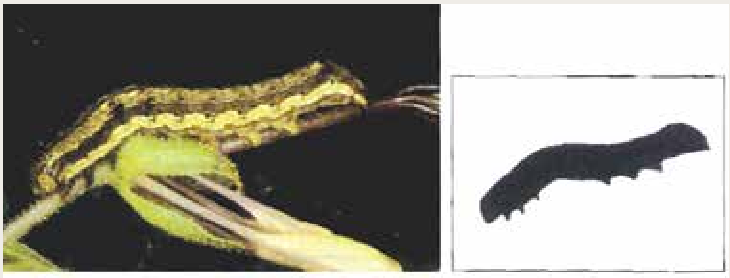


Figure 18: African boll worm caterpillar on a sunflower leaf

Figure 19: Damage to the sunflower by African | Boll worm caterpillar

Figure 20: Capitullum damaged by birds *(Source TNAU, Agritech Portal)*

Birds *- in Uganda, birds that damage sunflower crops include quelea birds, parrots, and guinea fowls. They attack the fields just after planting. Control: Control of loss due to birds includes practices such as scaring the birds, sending dogs into the gardens, banging empty tins, use of vuvuzelas, making noises that generate echos, making and using kites, ribbons, reflectors and providing alternative seeds in other areas which can distract the attention of the birds from the sunflower gardens.*

Bird scaring is mainly effective in the morning and evening which are the times of the day when birds are actively feeding.

Figure 21: Variegated Grasshopper

Variegated Grasshopper (Smelly grasshopper) - (Zonocerus variegatus), It feeds on the leaves and stems of both young and mature plants with a voracious appetite. It feeds on crops in aggregation during larger instar stages.

Control: Use of insecticides which should be sprayed in the early morning before the air temperature rises in consideration of the insect's habits of activity. Spray on both the crops and surrounding field (NUFLIP-GoU-JICA).

Figure 22: The semilooper

Semilooper - *Trichoplusia ni (Noctuidae: Lepidoptera)*

Damage symptoms: Leaves have holes and severe damage results in skeletonization and defoliation. Bionomics: Adult is a stout moth, head, and thorax grey in colour with basal tufts ferruginous, grey wavy forewings with a slender mark. Larva is slender, attenuated anteriorly and green in colour with light wavy lines and a broad lateral strip on either side.

3.8.5.2 Sunflower Diseases

Verticillium wilt, or more accurately called the leaf mottle, is caused by the soilborne fungus *Verticillium dahliae*. Verticillium leaf mottle typically causes necrosis between the main leaf veins with yellow margins. Host: The fungus has a wide host range and causes wilt of several other cultivated plants and weeds. Potato is the other important crop host of Verticillium.

Symptoms: Symptoms begin on the lower leaves and progress to upper leaves. Affected leaves rapidly become completely dry, but do not wilt to the same degree as with *Sclerotinia* wilt. Thus, the term leaf mottle may be more appropriate than *Verticillium* wilt. Symptoms usually are

Other Pests

Seedling and Root Feeders | Cutworms

Figure 23: Different Species of Cutworms

(Source: The National Sunflower Association of Canada (NSAC, 1996) and North Dokota State University, NDSU Department of Entomology)

Sunflower Beetle Cutworms

Figure 24: Larva and adult sunflower beetle

(Source: NSAC, 1996 NDSU, Department of Entomology)

Insects feeding on the Stem.

Sunflower Stem Weevil

Figure 25: Adult black sunflower stem weevil

(Source: NSAC, 1996 NDSU, Department of Entomology)

not observed until flowering, but under severe conditions, they may occur as early as the six-leaf stage. The vascular system of infected plants may be discoloured brown, visible as a brown ring in a cross-section of the stem. The pith of severely diseased plants is blackened with a layer of tiny black fruiting bodies (microsclerotia).

Damage: Sunflowers infected with *Verticillium* usually die before seeds are completely mature leading to yield losses; smaller head size, lighter test weight and reduced oil concentration. The stems of infected plants are weakened as the pith shrinks and are more prone to lodging.

Control: Verticillium leaf mottle is a serious disease on lighter soils with a history of sunflower cropping, and is seen less frequently on heavy, clay soils. This disease will cause some yield loss each time a susceptible crop is planted, as the fungus can persist for 5 - 10 years as microsclerotia. The disease could be controlled through seed dressing, crop rotation, and addition of organic matter to soil and planting of resistant varieties.

The recommended pesticides for the management of the disease include; hexaconazole, fluazinam, dimethomorph.

Figure 26: Interveinal necrosis with yellow margins
(Source: NDSU, 2007)

Alternaria leaf spot and stem spot is a common sunflower disease in Uganda. Alternaria leaf spot is a common disease in senescing leaves. Under warm and humid conditions, it can become a serious defoliating and yield reducing disease. Host: Sunflower, safflower (thorny plant mainly grown in India that was unofficially introduced in Uganda, but evaluation was not done).

Symptoms: Dark brown irregular spots with dark brown to purple borders and a grey centre develop on leaves (Fig.27). The spots on young plants may have a yellow halo. Leaf lesions may merge, causing leaves to wither. Stem lesions begin as dark flecks then enlarge to form long, narrow lesions. The stem lesions often join to form large, blackened areas which may result in stem breakage. The lesions are located randomly along the stem and not associated with a petiole.

Control: Management practices to minimise Alternaria include crop rotation and burying of infested crop refuse to hasten decomposition.

Figure 27: Leaf and stem lesions
(Source: NDSU, 2007).

The recommended pesticides for the control of the disease include; hexaconazole, fluazinam, dimethomorph, propamocarb

Septoria Leaf Spot is present in Uganda but is not a serious threat. Septoria leaf spot develops first on the lower leaves and spreads to the upper leaves. *Septoria* can be seedborne and can survive on infected sunflower crop refuse. *Septoria* leaf spot may appear anytime during the growing season and is favoured by moderately high temperatures and abundant rainfall.

Figure 28: Septoria leaf spot. Note small black pycnidia in the

Symptoms: The spots begin as water-soaked areas (greasy green in appearance). The spots become angular, with tan centres and brown margins (Fig.28). A narrow yellow halo often surrounds young spots. Mature leaf spots may contain tiny black specks, the fungal fruiting bodies (pycnidia), which are visible with a 5X - 10X hand lens. The presence of pycnidia is the best means of distinguishing leaf spots caused by *Septoria* from those caused by *Alternaria*.

Damage: Severe *Septoria* infection may cause some defoliation, but if this affects only the lower leaves on mature plants, the impact upon yield will be minimal.

Control: Crop rotation, incorporation of sunflower residue and clean seed are the best means of managing *Septoria* leaf spots.

The recommended pesticides for this disease include; hexaconazole, fluazinam, dimethomorph, propamocarb.

Figure 29: Sclerotinia wilt and Sclerotinia Basal rot lesion *(Source: NDSU, 2007)*

Stalk and root-infecting diseases

Sclerotinia Wilt and Basal Rot: Infected plants die rapidly, and if the plant dies prior to seed maturity it results in yield loss, lower test weight, and lower oil content.

The recommended pesticides for this disease include; dimethomorph

Host: Sclerotinia has a very wide host range of over 360 species, which includes sunflowers, dry beans, field peas, and potatoes.

Symptoms: Wilt can appear at any time between emergence and maturity, but it is more prevalent around flowering. Sudden wilt of the plant occurs when infected roots cannot uptake adequate water to meet the demands of the plant. Examination of the stem-root area will reveal a tan-brown, water-soaked lesion at the soil surface. The stalks and roots may become covered with white mycelia and hard sclerotia bodies develop under very wet soil conditions.

Control: Management of sclerotinia is difficult because of the wide host range, but rotation to cereals, such as maize is the most effective to minimise sclerotinia in the soil. Sunflower hybrids with some levels of resistance are available. The use of mycoparasites which feed on other fungi has proven efficient against Sclerotinia. One commercially available one is Coniothryium minitans (Contans); however, this is not available in Uganda. This mycoparasite can kill sclerotia in several months rather than years.

Figure 30: Sclerotinia mid-stalk rot lesion and Sclerotia bodies develop within the stem tissue or on the surface of the stem. *(Source, NDSU, 2007)*

Sclerotinia MidStalk Rot: Mid-stalk rot is the disease least often caused by Sclerotinia. Lodging can cause complete yield loss on a per plant basis.

Symptoms: Infection can occur anytime from seedling to maturity depending on the presence of infecting spores and favourable environmental conditions. Mid-stalk rot begins with infection of the leaf, and the fungus progresses internally through the petiole until it reaches the stem. The leaf lesions are not unique enough to identify the fungus, but the stem lesions are identical to those formed by root infection; they are tan coloured and water-soaked (Fig.30). The sclerotia can develop within the stem or on the exterior of the stem. Leaves above the lesion wilt, and the stalk eventually disintegrates becoming shredded as only vascular components of the stem remain.

Control: The control measures for Sclerotinia wilt also apply to mid-stalk rot management. Cultural practices to avoid high plant densities by reducing populations and high nitrogen fertilisation help lower the incidence of infection. Shallow or zero-tillage practices may aid in faster deterioration as sclerotia are left on the ground surface and subject to increased environmental deterioration. Resistance genes have been the most effective approach.

The recommended pesticides for this disease include; dimethomorph

Head rot and diseases of mature plants

Sclerotinia Head Rot: Head rot is considered the most important disease affecting sunflower production, causing yield and quality loss. Sclerotinia head rot (Fig.31) is quite variable, usually occurring late in the season and is influenced primarily by the amount of rainfall from flowering through to harvesting.

Figure 31: Sclerotinia Head Rot, and skeleton head filled with sclerotia *(Source, NDSU, 200*

Hosts: Sunflower, dry beans, field peas, potatoes.

Symptoms: The first symptoms of head rot usually are the appearance of water-soaked spots or bleached areas on the fleshy back of the head. The fungus can decay the entire head, with the seed layer falling away completely, leaving only a bleached, shredded vascular system interspersed with large sclerotia. The bleached, skeletonised heads resemble straw brooms and are obvious in the field even from a distance. Yield loss from head rot on an individual plant can range from minimal to total loss if the head disintegrates and drops all the seed to the ground prior to harvest. Intact but diseased heads will have light and fewer seeds, with lower oil content and will shatter during harvest.

Control: Fungicides may help reduce the incidence of head rot, with applications made preventively since several weeks lapse from infection to symptom development.

The recommended pesticides for this disease include; difenoconazole

Phoma Black Stem: Phoma is the most widespread stalk disease, but yield losses are considered minimal.

Figure 32: Phoma black stem lesion
(Source, NDSU, 2007)

Host: Cultivated sunflower.

Symptoms: Large, jet-black lesions develop on the stem (Fig. 32), sometimes reaching about 4 - 5 cm in length. The lesions are uniformly black and shiny with definite borders. Small circular fruiting bodies of the fungus are produced on the surface of the stem, but these require a hand lens to see. The fungus may also produce lesions on the back of the head, on the leaves, and at the base of the stalk. Stem lesions do not result in pith damage or lodging and are generally regarded as superficial lesions. If stem weevil larva tunnelling spreads Phoma spores within the pith, extensive pith degeneration can occur.

Control: Cultural practices to minimise Phoma include a four-year rotation to minimise the inoculum load in the soil, delayed planting and avoiding high plant populations and high nitrogen fertilisation. Control of stem weevils can help reduce transmission of the fungus, but insecticide application is rarely economically justified. Some hybrids are more tolerant than others, but none are immune to the disease.

The recommended pesticides for the control of the disease include; hexaconazole, fluazinam, dimethomorph, propamocarb

Charcoal Rot (Macrophomina phaseolina)

Figure 33: Charcoal rot effects:

(Right) Silver grey discoloration of lower stem; Charcoal rot affected stalk split apart reveals characteristic compression of pith into layers caused by charcoal rot compared with healthy green stalk (left); (Source NDSU, 2007)

Host: a fungus that attacks about 400 plant species, including sunflower, dry beans, hbean, maize and sorghum.

Symptoms: Silver-grey lesions appear on stalks near the soil line (Fig.33), which eventually decay the stem and tap root, leaving a shredded appearance. Stems are hollow and rotten, and lodge easily. Plants show poor seed fill and undersized heads. Seed yield, test weight and oil concentration are reduced. Numerous tiny black fungus bodies, called microsclerotia, form on the outside of the stalk and in the pith. Another unique characteristic of charcoal rot is the compressing of pith tissue into horizontal layers, like a stack of separated coins. This is a diagnostic characteristic of the disease.

Damage: Post-flowering stresses due to high plant population or drought coupled with heavy applications of nitrogen fertiliser, hail or insect damage promote disease development and accentuate the impact of charcoal rot. Yield losses can be significant if disease incidence is high, as infected plants die before seed set is complete.

Control: Crop rotation, balanced fertiliser programmes and practices to reduce moisture stress all help minimise the impact of charcoal rot. Certain hybrids offer some resistance, possibly through drought tolerance. Since the fungus also attacks maize, sorghum and soybeans, not growing sunflower and these crops in successive years on the same ground would be advisable if charcoal rot has been observed.

The recommended pesticides for the control of the disease include; dimethomorph, propamocarb

Sunflower Mosaic

Sunflower mosaic can be caused by three different viruses, namely Cucumber mosaic virus, Sunflower virus, and Tobacco mosaic virus. The most common virus causing sunflower mosaic is Cucumber mosaic virus. This virus can be mechanically- and aphid-transmitted and has a broad host range. Aphids can acquire and transmit Cucumber mosaic virus within 5 to 10 seconds of feeding.

Symptoms: Sunflower mosaic symptoms are most pronounced on leaves younger than 2 months old, appearing as yellow (chlorotic) rings or green to yellow mottling. Affected plants are stunted andhave narrow, light brown streaks on petioles and stems. Heads of infected plants are malformed and produce shrivelled seed. The disease is rarely an economic problem in the High Plains.

Control: There are no known biological control methods and cultural control is impractical as the disease is quite rare. All chemical control options must be used after consulting technical persons.

Other Diseases

Rust

Figure 35: Rust effects:

Rust occurs most commonly on leaves and after flowering characterised by cinnamon red pustules that produce spores; then later black pustules that also produce spores.

3.8.6. Weed Management

Young plants are highly sensitive to strong weed competition and cannot develop fast enough to form a full shade covering to suppress weed seedlings. For this reason, the first six weeks after planting are a critical period for the crop and farmers are expected to weed at this period. It is advisable to weed the farm twice but for those who prefer to use herbicides it is advisable to spray the field seven days before planting is effected. All the herbicide application is to be followed by one late hand weeding 30 - 35 days after sowing. Hoe and hand weed on the 15th and 30th day of sowing and remove the weeds. In case of irrigated land, allow the weeds to dry for 2 - 3 days before irrigation.

Weed control methods include hand pulling and placing weeds as mulch, shallow weeding using an ox-cultivator for young crop or hand hoe and legume cover cropping to smother the weeds. Post-emergence herbicides must be applied to seedlings less than 8 cm tall. Crop rotation is also important to manage the weeds. Intercropping with groundnuts, soybean, in controlled ratio with maize in sunflower also smothers weeds. The pre-emergence herbicides used in sunflower include; pendimethalin. Selective herbicide for post emergence application include;quizalafop and clethodim

Figure 36: Intercropping in sunflower to smother weeds *(Source TNAU, Agritech Portal)*

Figure 37: Weeding using oxen

Figure 37: Weeding using oxen

***Power weeders** can be used for weeding. A power weeder is a farm machine used for removing weeds, unwanted plants, and grass. Power weeders are also known as cultivators and consist of laterally adjustable discs to work between crop rows. The power weeder stirs the soil and breaks the soil lumps.*

3.8.7 Safe use and handling of agrochemicals.

It is critical that people applying these chemicals put on protective wear. These include an overall, boots and chemical resistant gloves as well as a nose mask and goggles to avoid inhaling the chemical droplets that could be blown towards the face by the wind.

CHAPTER 4

HARVESTING, POST-HARVESTING, STORAGE & MARKETING

4.1. Introduction

The chapter explains concepts of a resilient system and the three pillars of climate smart agriculture. It also describe the key characteristics of climate smart agriculture and the impact on gender dimensions. The section further explains the potato production requirements, soil water conservation practices including terracing and mulching and continues to highlight the potato production cycle from land preparation, variety selection, planting, sprouting, weed, pest and disease management.

4.2 Harvesting Sunflower

Sunflower harvesting should start as soon as 80% of the sunflower heads are ripe to minimise loss from birds and from shattering. Cut the capitula (flower heads) only. Harvesting is done by cutting off the head when it is not completely dry. The harvested sunflower should not be left to dry completely because it becomes a challenge to separate the seeds. Most sunflower plants take between 100 - 120 days to grow and it is important for farmers to observe this period.

Sunflower is ready for harvest when: The seeds come off easily once the flower head (disc) is brushed.. The yellow petals dry and fall off and moisture content of seeds reduces to about 12% (can be checked using a moisture metre).

a) The best harvesting stage is when the backs of the heads are still slightly damp. Losses during the harvesting stage are thereby reduced.
b) Heads may be threshed by means of a combine harvester (Figure 39), threshing machine or even with a slow-speed hammer mill fitted with large screens. Combine harvesters must be fitted with the correct gathering pans and other accessories specially designed for sunflower combining.
c) If the seed/grain is to be stored for any length of time, it must not contain more than 10% moisture. If storage is temporary,

Figure 39: Combine Harvester that can be used for harvesting sunflower.

12% is acceptable.

d) Seeds falling out and poor stand ability may be reduced by harvesting at 20% moisture followed by artificial drying. The recommended drying temperature is $71^{\circ}C$ – $80^{\circ}C$.

4.3. Post-harvest management practices

Drying of the heads: Immediately after harvest, dry the heads in the sun for three days. Spread the heads in thin layer and do turning once in three hours; thresh and clean.

Threshing: This is done manually by some farmers through knocking the heads using a small stick, but mechanized threshing is recommended using a mechanical thresher to separate the grains.

Winnowing: Winnow and clean the seeds. All chaff and foreign matter should be winnowed out after threshing and the seed dried on a tarpaulin to ensure quality. Moisture content should be reduced to 10%.

Sorting: Weed seeds, undesired seeds, stones, and leaves should be sorted out from the desired seeds. Seeds should be sorted according to colour and size to meet the market standards.

Drying of seed: Dry the seeds again under hot sunshine for another two days or a period of one week. Seeds are stored under the shed on polythene mat. Well dried grains should be packed in gunny bags and stored in good leak-proof stores. The storage structure should be cleaned and fumigated with a suitable insecticide such as phosphine.

Storage: Seeds should be below 12% moisture for temporary storage and below 10% for long-term storage. Seed with up to 15 % moisture is satisfactory for temporary storage in freezing weather; however, spoilage is likely after a few days of warm weather. It is best to have on-farm storage available; however, storage in silos, if available, should be used. The risk of aflatoxins is one of the major threats for sunflower in storage and to manage this, the seed must be stored at temperatures between $25^{\circ}C$ and $32^{\circ}C$ and humidity should not exceed 65%. Plastic and metallic grain storage silos and waterproof aerated stores are useful for storage of the sunflower.

Aeration is essential, especially in the larger bins and can be accomplished with floor-mounted dust or portable aerators. Sunflower should be rotated between bins when aeration is not available. An air space should be left in the top of the bin to facilitate checking the condition of stored seed. Sunflower can be stored more than one season under proper conditions (dry, clean, aerated, and in tight bins); however, processors of non-oilseed sunflower for human consumption prefer not to use seed that has been stored more than one season. Rotten and moist sunflower is not acceptable for sale.

Figure 40: Example of a plastic silo (500 Litre capacity)

Figure 41: Example of a metallic silo

Transport: The most frequent mode of transport for sunflower grain is by road trucks; however, tractors, motorcycles, the head and tricycles (tuk tuks) and bicycles are used for transportation to storage or marketplaces.

4.4. Sunflower Processing

The main product derived from sunflower is edible oil and it has 6 major steps of production.

Cleaning: removal of unwanted substances using magnets to attract and remove any metallic substances and sieving.

De-hulling: removal of skins through processes that break the skins and separate them from the kernels (the inner parts of the seeds).

Grinding: Crushing using machines such as hammer mills to reduce size of the particles and increase surface area for oil extraction.

Pressing: Squeezing out of oil from the crushed and heated sunflower seed particles using machines such as a screw press.

Solvent extraction: Solvents are used to remove any remaining oil from the pressed sunflower cake.

Refining: Elimination of any contamination and improving characteristics such as physical appearance, flavour, and odour. (Online: AGRI FARMING).

4.5. Sunflower marketing

Marketing, in this case, refers to activities done to support the buying or selling of sunflower harvested. Marketing includes advertising, selling, and delivering the sunflower to buyers. (Adapted from Online: Investopedia). Marketing has four key marketing mix components.

These four should always be put into serious consideration to ensure the business is driven towards profit making.

(i) Price: Should always exceed the cost of production.
(ii) Product: ensure you have quality sunflower seed/harvest.
(iii) Place: Point of sale should be selected to ensure you attract your target buyers and target price.
(iv) Promotion: Ensure that your target buyers have information about your sunflower harvest; quality, quantity, location, period of availability.

The sunflower value chain can be divided into the contract channel (mainly contract farmers) and uncontracted channel. Farmers are usually contracted by large, small, and medium agribusinesses such as Mukwano industries and Mount Meru. Uncontracted farmers mainly grow local sunflower varieties. They then sell their products to local millers. Large millers maintain contracts with farmers under which farmers are supplied with seeds in return for a promise to sell production to the contractors. In this way, farmers are helped to get quality inputs and predictable prices for their crops. There are also several seed merchants, such as Equator Seeds Limited that are quite active in the sector, as well as other emerging companies. Sunflower production is profitable, but the level profitability varies with price fluctuations. Sunflower production and marketing is predominantly done in an organised arrangement through farmer associations and cooperatives where seed access and marketing is done through these associations and cooperatives.

CHAPTER 5

BENEFIT ANALYSIS OF SUNFLOWER PRODUCTION

5.1 Introduction

Chapter five discusses the accounting financial statements that help to highlight the profitability and or not of the sunflower business. The key financial instrument discussed is the profit and loss account (termed as the cost benefit analysis).

Table 7: Typical cost benefit (Gross margin) analysis for sunflower producers when using improved and unimproved seed.

Revenues (Uganda Shillings)		
	Unimproved	Improved
	variety	variety
Output (kg/acre)	800	1,650
Price (UGX/kg)	1,100	1,100
Total revenue (UGX)	550 000	1,100,000
Costs (UGX)		
Ploughing/acre	160,000	160,000
Planting and seed/acre	40,000	120,000
Weeding/acre	48,000	48,000
Harvesting/acre	48,000	48,000
Drying/acre	12,500	20,000
Bagging/acre	10,000	20,000
Transport	20,000	30,000
Total variable costs	**338,000**	**446,000**
Gross margin/acre)	**212,000**	**654,000**

Adapted from Action Against Hunger, 2014

5.2 Cost benefit analysis

It is estimated that the unit cost of production for the farmer is between 626 and 1,044 UShs per kg. The tables below illustrate the revenue and cost structure of a typical sunflower farmer. These calculations assume that production adheres to Good Agronomic Practices (GAP) and Tables 8 and 9 are specifically for the variety AGSUN 8251.

The cost-benefit analyses for AGSUN 8251 also demonstrate that production with fertilisers produces 30% increase in yield and profits compared to production without use of fertilisers.

Table 8: Cost and Benefit Analysis for sunflower production - a case study of Agsun 8251 (without use of fertiliser)

No.	Activity/particulars	Unit	Quantity	Unit cost	Total cost	Total
1	Land preparation					
1.1	Land clearing/slashing	Acreage	1	20,000	20000	20000
1.2	Primary cultivation	Acreage	1	80,000	80,000	80,000
1.3	Secondary cultivation	Acreage	1	80,000	80,000	80,000
	Sub total			180,000	180,000	180,000
2	Seed	Kilogram	1	80,000	80,000	80,000
3	Planting (labour)	Persons	7	5,000	35,000	35,000
4	Field management				-	
4.1	Insecticides	Litre	1	10,000	10,000	10,000
4.3	Labour cost	Persons	2	5,000	10,000	10,000
4.4	Manual weeding	persons	6	5,000	30,000	30,000
5	Harvesting	persons	5	5,000	25,000	25,000
	Total					**370,000**
						370,000
	Total cost of production				-	
	Line items	**Unit**	**Totals**			
	Total cost of production	Shs	370,000			
	Total marketable yield(TMY)/Season	Kgs	600			

No.	Activity/particulars	Unit	Quantity	Unit cost	Total cost	Total
	Selling price/kg (SP)	Shs	1,500			
	(Average)					
	Total revenue (TMY*SP)	**Shs**	**900,000**			
	Net profit (loss)	**Shs**	**530,000**			

Table 9: Cost and Benefit Analysis for sunflower production - a case study of Agsun 8251 (with use of fertiliser)

Activity/particulars	Unit	Qty	Unit cost	Total cost	Total
Land preparation					
Land clearing/slashing	Acreage	1	20,000	20,000	200,000
Primary cultivation	Acreage	1	80,000	80,000	80,000
Secondary cultivation	Acreage	1	80,000	80,000	80,000
Sub total			180,000	180,000	180,000
Seed	Kilogram	1	80,000	80,000	80,000
Planting labour	Persons	7	5000	35,000	35,000
Field management					
Insecticides	Litre	1	10000	10000	10000
Labour cost	Persons	2	5000	10000	10000
Manuel Weeding	Persons	6	5000	30000	30000
Harvesting	Persons	5	5000	25000	25000
Fertiliser (DAP)	Kilograms	25	4000	100000	100000
					470,000

Activity/particulars	Unit	Qty	Unit cost	Total cost	Total
Total Cost of Production					
Line Items	**Unit**	**Totals**			
Total Cost of Production	Shs	470,000			
Total marketable Yield	Kgs	900			
Selling price/kg	Shs	1500			
Total Revenue	**SHS**	**1,350,000**			
Net Profit(loss)	**Shs**	**880,000**			

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ANNEX 1: ACCESSING FINANCIAL RESOURCES.

Accessing credit increases the capacity to adopt technologies such as resistant and high yielding varieties for sustainable production in the context of climate change adoption. Information is provided below on the types of credit packages provided by government and some finance institutions in Uganda.

Finance and financial products in Uganda can be accessed through internal resource mobilization through own equity or retained earnings, commercial banks, development banks, microfinance, micro deposit taking institutions, Savings and Credit Cooperative organisation, Village Savings and Loan Associations, fund managers, impact investors, and through government development programs such the parish development model.

Parish Development Model

Under the parish development model, the government has recently set up structures and frameworks for planning, budgeting, and delivery of public services. People at the parish level are to decide development priorities under the policies formulated at the national level. Under this arrangement each parish will receive funds that groups can access under a loan revolving fund for production of commodities, processing, marketing, and other income generation activities that the parish would have prioritised.

ANNEX 2: DEFINITION OF KEY TERMINOLOGIES

Term	Definition or description
Achene	The sunflower fruit consisting of hull and “seed”; a small, dry, one-seeded fruit that does not open at maturity.
Adaptation (Autonomous)	Response to experienced climate and its effects, without planning explicitly or consciously, focused on addressing climate change. Also referred to as spontaneous adaptation. (IPCC). Responses to be implemented by individual farmers, rural communities and farmers’ organisations, depending on perceived or real climate change in the coming decades, and without intervention or coordination by regional and national governments and international agreements. (FAO)
Adaptation (Planned)	The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects 1. {WGII, III}. Adjustments to current or expected climate variability and changing average climate conditions. This can serve to moderate harm and exploit beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation. (FAO)
Adaptation benefits	Avoided damage costs or accrued benefits following the adoption and implementation of adaptation measures. (FAO)
Adaptive capacity	The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences 2. {WGII, III}.The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. (FAO)
Adaptive management	A process of iteratively planning, implementing, and modifying strategies for managing resources in the face of uncertainty and change. Adaptive management involves adjusting approaches in response to observations of their effect and changes in the system brought on by resulting feedback effects and other variables. {WGIII}
Agricultural emissions	Emissions associated with agricultural systems - predominantly methane (CH_4) or nitrous oxide (N_2O). These include emissions from enteric fermentation in domestic livestock, manure management, rice cultivation, prescribed burning of savannas and grassland, and from soils. (IPCC)

Term	Definition or description
Agricultural Innovation	Bringing existing or new products, processes and forms of organisation into social and economic use to increase effectiveness, competitiveness, resilience to shocks or environmental sustainability, thereby contributing to food and nutritional security, economic development and sustainable natural resource management. (FAO)
Agro-ecology	An ecological approach to agriculture that views agricultural areas as ecosystems and is concerned with the ecological impact of agricultural practices. (FAO)
Agro-ecosystem	The organisms and environment of an agricultural area considered as an ecosystem. (FAO)
Annual crop	Plant in which the entire life cycle is completed in a single growing season.
Atmosphere	The gaseous envelope surrounding the Earth. The dry atmosphere consists almost entirely of nitrogen (78.1% volume mixing ratio) and oxygen (20.9% volume mixing ratio), together with a number of trace gases, such as argon (0.93% volume mixing ratio), helium and radiatively active greenhouse gases such as carbon dioxide (0.035% volume mixing ratio) and ozone. In addition, the atmosphere contains the greenhouse gas water vapour, whose amounts are highly variable but typically around 1% volume mixing ratio. The atmosphere also contains clouds and aerosols. (IPCC)
Biodiversity	The variability among living organisms from terrestrial, marine, and other ecosystems. Biodiversity includes variability at the genetic, species, and ecosystem levels. (IPCC).The total diversity of all organisms and ecosystems at various spatial scales (from genes to entire biomass). (FAO)
Biomass	The total mass of living organisms in a given area or volume; dead plant material can be included as dead biomass. Biomass includes products, by-products, and waste of biological origin (plants or animal matter), excluding material embedded in geological formations and transformed to fossil fuels or peat. (IPCC)
Bract	Modified, reduced leaf structure beneath ray flowers on a sunflower head.
Canker	Sharply defined dead area of tissue on a stem.
Carbon footprint	Measure of the exclusive total amount of emissions of carbon dioxide (CO2) that is directly and indirectly caused by an activity or is accumulated over the life stages of a product. (IPCC)
Carbon sequestration (Uptake)	The addition of a substance of concern to a reservoir. The uptake of carbon containing substances, in particular carbon dioxide, is often called (carbon) sequestration. (IPCC). The process of increasing the carbon content of a reservoir or pool other than the atmosphere. (FAO)

Term	Definition or description
Climate	Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organisation. The relevant quantities are most often surface variables such as temperature, precipitation and wind. Climate in a wider sense is the state, including a statistical description, of the climate system. {WGI, II, III}
Climate (information) products	Climate (information) products can include climate data briefs that describe the data and information generated from the data, e.g. forecasts releases, weather bulletins, weather maps, etc.,
Climate (information) services	Maintenance of observation programs, analysis of weather and climate data, monitoring the climate, etc. Climate services refers to (the production of) information and products that enhance users' knowledge and understanding about the impacts of climate change and/or climate variability so as to aid decision-making of individuals and organizations and enable preparedness and early climate change action. Products can include climate data products. (IPCC)
Climate change	Climate change refers to a change in the state of the climate that can be identified, e.g. by using statistical tests, by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forces such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods". The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes. {WGI, II, III}, (FAO)
Climate extreme (extreme weather or climate event)	The occurrence of a value of a weather or climate variable above or below a threshold value near the upper or lower ends of the range of observed values of the variable. For simplicity, both extreme weather events and extreme climate events are referred to collectively as "climate extremes". (FAO)

Term	Definition or description
Climate model (Spectrum or hierarchy)	A numerical representation of the climate system based on the physical, chemical and biological properties of its components, their interactions and feedback processes and accounting for some of its known properties. The climate system can be represented by models of varying complexity; that is, for any one component or combination of components, a spectrum or hierarchy of models can be identified, differing in such aspects as the number of spatial dimensions, the extent to which physical, chemical or biological processes are explicitly represented, or the level at which empirical parametrisations are involved. Coupled Atmosphere-Ocean General Circulation Models (AOGCMs) provide a representation of the climate system that is near or at the most comprehensive end of the spectrum currently available. There is an evolution towards more complex models with interactive chemistry and biology. Climate models are applied as a research tool to study and simulate the climate and for operational purposes, including monthly, seasonal and inter-annual climate predictions. {WGI, II, III}
Climate predictions and projections	Climate predictions and projections are interpreted and disseminated for different time periods ranging from months to decades to centuries. Regional and global support services help to improve estimates of future climates through research and modelling. They also provide climate change projections to both national services and user communities.
Climate projection	A climate projection is the simulated response of the climate system to a scenario of future emission or concentration of greenhouse gases (GHGs) and aerosols, generally derived using climate models. Climate projections are distinguished from climate predictions by their dependence on the emission/ concentration/radiative forcing scenario used, which is in turn based on assumptions concerning, for example, future socio-economic and technological developments that may or may not be realised. They are therefore subject to substantial uncertainty. A projection is a potential future evolution of a quantity or set of quantities, often computed with the aid of a model. Unlike predictions, projections are conditional on assumptions concerning, for example, future socio-economic and technological developments that may or may not be realised. {WGI, II, III}
Composite flower(s)	A flower(s) made up of multiple simpler flowers.
Conservation agriculture	Resource-saving agricultural production system that applies to all land based agricultural production systems. It aims to achieve production intensification while enhancing the natural resource base in compliance with three interrelated principles and good production practices of plant nutrition and pest management. These three principles are: (i) soil mechanical disturbance is reduced to its minimum (no-tillage) continuously over time, (ii) permanent soil organic cover with crop residues and/or cover crops is provided to the extent allowed by water availability, and (iii) varied crops associations and/or rotations suitable to the specific agro ecosystem are put in place. (FAO)
Coping capacity	The ability of people, organisations and systems, using available skills and resources, to manage adverse conditions, risks or disasters. The capacity to cope requires continued awareness, resources and good management, both in normal times as well as during disasters or adverse conditions. Coping capacities contribute to the reduction of disaster risks. (FAO)

Term	Definition or description
Corolla	Collective term for petals of the sunflower.
Crop diversification	Species diversification through varied crop associations and/or rotations involving annual and/or perennial crops including trees. (FAO)
Cytoplasmic Male Sterility	Male sterility inherited through hereditary units in the cytoplasm, rather than through nuclear inheritance.
Decarbonisation	The process by which countries or other entities aim to achieve a low-carbon economy, or by which individuals aim to reduce their consumption of carbon. {WGII, III}
Defoliate	To remove leaves of a plant.
Dehull	Removal of outer seed coat (hull) from the seed.
Diploid	A cell that contains two copies of each chromosome; one set of chromosomes is inherited from the individual mother, while the second is inherited from the father.
Disaster	Severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic or environmental effects that require immediate emergency response to satisfy critical human needs that may require external support for recovery. {WGII}
Disk Flower	Tubular flowers that compose the central part of the sunflower head; these produce the seeds.
Drought	The phenomenon that exists when precipitation is significantly below normal recorded levels, causing serious hydrological imbalances that often adversely affect land resources and production systems. (FAO). A period of abnormally dry weather long enough to cause a serious hydrological imbalance. Drought is a relative term; therefore, any discussion in terms of precipitation deficit must refer to the particular precipitation-related activity that is under discussion. For example, shortage of precipitation during the growing season impinges on crop production or ecosystem function in general (due to soil moisture drought, also termed ecological/ agricultural drought), and during the runoff and percolation season. it primarily affects water supplies (hydrological drought). Storage changes in soil moisture and groundwater are also affected by increases in actual evapotranspiration in addition to reductions in precipitation. A period with an abnormal precipitation deficit is defined as a meteorological drought. A mega drought is a very lengthy and pervasive drought, lasting much longer than normal, usually a decade or more. (IPCC. WGI AR5)
Dry spell	Short period of water stress during critical crop growth stages and which can occur with high frequency but with minor impacts compared with droughts. (FAO)

Term	Definition or description
Early warning system	The set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organisations threatened by a hazard to prepare to act promptly and appropriately to reduce the possibility of harm or loss. {WGII}
Ecosystem	An ecosystem is a functional unit consisting of living organisms, their non-living environment and the interactions within and between them. The components included in a given ecosystem and its spatial boundaries depend on the purpose for which the ecosystem is defined; in some cases they are relatively sharp, while in others, they are diffuse. Ecosystem boundaries can change over time. Ecosystems are nested within other ecosystems and their scale can range from very small to the entire biosphere. In the current era, most ecosystems either contain people as key organisms, or are influenced by the effects of human activities in their environment. {WGI, II, III}. An ecosystem is considered as the interactive system formed from all living organisms and their abiotic (physical and chemical) environment within a given area. Ecosystems cover a hierarchy of spatial scales and can comprise the entire globe, biomes at the continental scale or small, well-circumscribed systems such as a small pond. (FAO)
Ecosystem resilience	The capacity of an ecosystem to absorb external pressure or perturbations through change and re-organisation, but still retain the same basic structure and ways of functioning. (FAO)
Emergent risk	A risk that arises from the interaction of phenomena in a complex system, for example, the risk caused when geographic shifts in human population in response to climate change lead to increased vulnerability and exposure of populations in the receiving region. (IPCC)
Emission factor/ Emissions intensity	The emissions released per unit of activity. The amount of emissions of carbon dioxide (CO2) released per unit of another variable such as gross domestic product (GDP), output energy use, or transport (IPCC). Emissions per unit of output, expressed in kg CO2-eq per unit of output (e.g. kg CO2-eq per kg of egg). Amount of greenhouse gases emitted in a kilogramme of carbon dioxide equivalents per unit of output (e.g. Kg, Ha). (FAO)
Enabling conditions	Conditions that affect the feasibility of adaptation and mitigation options and can accelerate and scale-up systemic transitions that would limit temperature increase to 1.5°C and enhance capacities of systems and societies to adapt to the associated climate change, while achieving sustainable development, eradicating poverty and reducing inequalities. Enabling conditions include finance, technological innovation, strengthening policy instruments, institutional capacity, multilevel governance, and changes in human behaviour and lifestyles. They also include inclusive processes, attention to power asymmetries and unequal opportunities for development and reconsideration of values. (IPCC)
Enabling Environment	The context (rules of the game) in which individuals and organisations put their competences and capabilities into actions. (FAO)

Term	Definition or description
Extreme weather event	An event that is rare at a particular place and time of the year. Definitions of "rare" vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of a probability density function estimated from observations. By definition, the characteristics of what is called extreme weather may vary from place to place in an absolute sense. When a pattern of extreme weather persists for some time, such as a season, it may be classed as an extreme climate event, especially if it yields an average or total that is itself extreme, e.g., drought or heavy rainfall over a season. {WGI, II}
Farmer Field School (FFS)	A group of farmers gets together in one of their own fields to learn about their crops and things that affect them (http://www.fao.org/farmer-field-schools/en/). Farmer Field Schools aim to build farmers' capacity to analyse their production systems, identify problems, test possible solutions, and eventually encourage the participants to adopt the practices most suitable to their farming systems. (FAO)
Flood	The overflowing of the normal confines of a stream or other body of water, or the accumulation of water over areas not normally submerged. Floods include river (fluvial) floods, flash floods, urban floods, pluvial floods, sewer floods, coastal floods and glacial lake outburst floods. {WGII}
Forecast (Weather)	Application of science and technology to predict the conditions of the atmosphere for a given location and time: application of current technology and science to predict the state of the atmosphere for a future time and a given location.
Fungicide	A chemical or physical agent that kills fungi.
Fungus (pl. fungi)	A group of organisms that lack chlorophyll and obtain food through absorption, frequently from plants.
Global warming	The estimated increase in global mean surface temperature (GMST) averaged over a 30-year period, or the 30-year period centered on a particular year or decade, expressed relative to pre-industrial levels unless otherwise specified. For 30-year periods that span past and future years, the current multi-decadal warming trend is assumed to continue. (IPCC). Global warming also refers to the gradual increase, observed or projected, in global surface temperature, as one of the consequences of radiative force caused by anthropogenic emissions. {WGIII}
Greenhouse effect	The infrared radiative effect of all infrared-absorbing constituents in the atmosphere. Greenhouse gases (GHGs), clouds, and to a small extent, aerosols absorb terrestrial radiation emitted by the earth's surface and elsewhere in the atmosphere. These substances emit infrared radiation in all directions, but, everything else being equal, the net amount emitted in the space is normally less than would have been emitted in the absence of these absorbers because of the decline of temperature with altitude in the troposphere and the consequent weakening of emission. An increase in the concentration of GHGs increases the magnitude of this effect; the difference is sometimes called the enhanced greenhouse effect. The change in a GHG concentration because of anthropogenic emissions contributes to an instantaneous radiative force. Surface temperature and troposphere warm in response to this force, gradually restoring the radiative balance at the top of the atmosphere. (IPCC)

Term	Definition or description
Greenhouse gases (GHG)	Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, which absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, by the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapour (H2O), carbon dioxide (CO2), nitrous oxide (N2O), methane (CH4), and ozone (O3) are the primary greenhouse gases in the Earth's atmosphere. Moreover, there are a number of entirely human-made greenhouse gases in the atmosphere, such as the halocarbons and other chlorine- and bromine-containing substances, dealt with under the Montreal Protocol. Besides CO2, N2O, and CH4, the Kyoto Protocol deals with the greenhouse gases sulphur hexafluoride (SF6), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs). (IPCC)
Hazard	The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss of property, infrastructure, livelihoods, service provision, ecosystems and environmental resources. In IPCC reports, the term hazard usually refers to climate-related physical events or trends or their physical impacts. {WGII}. "A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation". (FAO). A physical process or event (hydro-meteorological or oceanographic variables or phenomena) that can harm human health, livelihoods, or natural resources. A dangerous phenomenon, substance, human activity or condition that has the potential to cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage. An extreme weather event that threatens people or property. Weather hazards include tropical storms, tornadoes, and droughts.
Herbicide	A chemical or physical agent that kills plants.
Hexaploid	Six sets of chromosomes.
Host	The organism affected by a parasite or disease.
Hybrid	The offspring of two unlike parents.
Impacts (consequences, outcomes)	Effects on natural and human systems. In this report, the term "impacts" is used to refer to the effects on natural and human systems of physical events, of disasters, and of climate change. The consequences of realised risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather and climate events), exposure, and vulnerability. Impacts generally refer to effects on lives; livelihoods; health and well-being; ecosystems and species; economic, social and cultural assets; services (including ecosystem services); and infrastructure. Impacts may be referred to as consequences or outcomes and can be adverse or beneficial. (IPCC)
Inflorescence	A group or cluster of flowers arranged on a stem that is composed of the main branch or system of branches.
Insecticide	A chemical or physical agent that kills insects.

Term	Definition or description
Institutions	Institutions are rules and norms held in common by social actors that guide, constrain, and shape human interaction. Institutions can be formal, such as laws and policies, or informal, such as norms and conventions. Organisations, such as parliaments, regulatory agencies, private firms, and community bodies, develop and act in response to institutional frameworks and the incentives they frame. Institutions can guide, constrain, and shape human interaction through direct control, through incentives, and through processes of socialisation. (IPCC). Institutions encompass formal organisations and contracts as well as informal social and cultural norms and conventions that operate within and between organisations and individuals. (FAO)
Institutional capacity	Institutional capacity comprises building and strengthening individual organisations and providing technical and management training to support integrated planning and decision-making processes between organisations and people, as well as empowerment, social capital, and an enabling environment, including the culture, values and power relations. (IPCC)
Larva (pl. larvae)	The pre-adult form of an insect.
Methane (CH4)	One of the six greenhouse gases (GHGs) to be mitigated under the Kyoto Protocol and is the major component of natural gas and associated with all hydrocarbon fuels. Significant emissions occur as a result of animal husbandry and agriculture and their management represents a major mitigation option. See also Global Warming Potential (GWP) and Annex II.9.1 for GWP values. (IPCC)
Microclimate	Local climate at or near the Earth's surface. (IPCC)
Mitigation (of climate change)	A human intervention to reduce the sources or enhance the sinks of greenhouse gases (GHGs). This report also assesses human interventions to reduce the sources of other substances which may contribute directly or indirectly to limiting climate change, including, for example, the reduction of particulate matter emissions that can directly alter the radiation balance (e.g., black carbon) or measures that control emissions of carbon monoxide, nitrogen oxides, Volatile Organic Compounds and other pollutants that can alter the concentration of tropospheric ozone which has an indirect effect on the climate. {WGI, II, III}. It is the technological change and substitution that reduces resource inputs and emissions per unit of output. Although several social, economic and technological policies would produce an emission reduction, with respect to climate change, mitigation means implementing policies to reduce GHG emissions and enhance sinks. (FAO)
Mitigation (of disaster risk and disaster, in relation to hazard)	The lessening of the potential adverse impacts of physical hazards (including those that are human-induced) through actions that reduce hazard, exposure, and vulnerability. (IPCC). The limiting or lessening of the adverse impacts of hazards and related disasters. (FAO)

Term	Definition or description
Narratives (Scenario storylines)	Qualitative descriptions of plausible future world evolutions, describing the characteristics, general logic and developments underlying a particular quantitative set of scenarios. Narratives are also referred to in the literature as 'storylines'. A description of a scenario (or family of scenarios), highlighting the main scenario characteristics, relationships between key driving forces and the dynamics of their evolution. A plausible and often simplified description of how the future may develop based on a coherent and internally consistent set of assumptions about driving forces and key relationships. Scenarios may be derived from projections, but are often based on additional information from other sources, sometimes combined with a narrative storyline. (IPCC)
Oilseed	Preferred term, equivalent to oil sunflower.
Open pollinated	Naturally pollinated by self or crossing between two related strains.
Perennial	A plant that continues its growth from year to year; not dying once it has flowered.
Pests	Species of diseases, insects and weeds, whose populations may reach a level resulting in yield losses depending on environmental conditions, crop genotype and phenology, and agricultural management practices, including cropping patterns, and use of chemical fertilisers and pesticides. (FAO)
Petiole	The stalk of the leaf.
pH	Expression of acidity or alkalinity of soil or water.
Physiological Maturity	Stage at which a seed has reached its maximum dry weight.
Pollinator	Insect that carries pollen from plant to plant.
Pupa (pl. pupae)	The stage between larva and adult in some insects.
Ray Flower	Flattened, ray shaped flowers on margins of a sunflower head. Commonly referred to as the petals. These are sterile and do not produce achenes.
Resilience	The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions. (IPCC). The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure while also maintaining the capacity for adaptation, learning and transformation. {WGII, III}. The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management. (FAO)

Term	Definition or description
Resolution	In climate models, this term refers to the physical distance (metres or degrees) between each point on the grid used to compute the equations. Temporal resolution refers to the time step or time elapsed between each model computation of the equations. (IPCC)
Risk (Climate)	A combination of hazard exposure, sensitivity to impact, and adaptive capacity. The combination of the probability of an event and its negative consequences. (FAO). Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard. In this report, the term risk is used primarily to refer to the risks of climate-change impacts. (IPCC). The potential for adverse consequences where something of value is at stake and where the occurrence and degree of an outcome is uncertain. In the context of the assessment of climate impacts, the term risk is often used to refer to the potential for adverse consequences of a climate-related hazard, or of adaptation or mitigation responses to such a hazard, on lives, livelihoods, health and well-being, ecosystems and species, economic, social and cultural assets, services (including ecosystem services), and infrastructure. Risk results from the interaction of vulnerability (of the affected system), its exposure over time (to the hazard), as well as the (climate- related) hazard and the likelihood of its occurrence. (IPCC) {WGII, III}
Risk mitigation	The lessening or minimising of the adverse impacts of a hazardous event. Annotation: The adverse impacts of hazards, in particular natural hazards, often cannot be prevented fully, but their scale or severity can be substantially lessened by various strategies and actions. Mitigation measures include engineering techniques and hazard-resistant construction as well as improved environmental and social policies and public awareness. It should be noted that, in climate change policy, "mitigation" is defined differently, and is the term used for the reduction of greenhouse gas emissions that are the source of climate change. (FAO)
Sclerotium (pl. sclerotia)	The hard, resting bodies of certain fungi.
Seed	True seed in sunflower is the kernel; however, "seed" is commonly used to describe the kernel plus the hull, which is equivalent to the achene.
Self-Compatibility	Production of fruits and normal seeds following self-pollination.
Surfactant	Also called a surface -active agent, this is a substance such as a detergent that, when added to a liquid, reduces its surface tension, thereby increasing its spreading and wetting properties. In the dyeing of textiles, surfactants help the dye penetrate the fabric evenly.
Sustainability	A dynamic process that guarantees the persistence of natural and human systems in an equitable manner. {WGII, III}
Sustainability (Economic)	A situation whereby: (i) the value added resulting from upgrading in the value chain (additional profits, wages, taxes, consumer value) is positive for each stakeholder in the extended value chain whose behaviour (in terms of upgrading) is expected to change in order to create the additional value; and (ii) the generation of added value sets in motion, or speeds up, a process of growth and structural transformation. (FAO)

Term	Definition or description
Sustainability (Environmental)	Meeting the needs of the present without compromising the ability of future generations to meet their needs. (FAO)
Tetraploid	Having four sets of chromosomes. In these cases such offspring are sterile and can no longer reproduce because of the odd number of chromosomes, they provide for offspring.
Top dressing	A layer of fertiliser or manure not ploughed in. Surface application of manure or fertiliser to land.
Variety	A subdivision of a species; a distinct group of organisms.
Volunteer Plant	Plant arising from seed dispersed from a previous crop.
Vulnerability	The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt. {WGII}. The propensity or predisposition to be adversely affected; a function of potential impacts (Exposure and sensitivity to exposure) and adaptive capacity. The conditions determined by physical, social, economic, and environmental factors or processes which increase the susceptibility of an individual, a community, assets, or systems to the impacts of hazards. (FAO)
Warm spell	A period of abnormally hot weather. (IPCC)
Weather	The current, local, transient state of the atmosphere (temperature, humidity, atmospheric pressure, wind, precipitation, atmospheric particle count)
Weather-index-based insurance	A class of insurance products that can allow weather-related risk to be insured in developing countries where traditional agricultural insurance may not always be feasible, thereby helping to increase farmers' ability (and willingness) to invest in measures that might increase their productivity. (FAO)

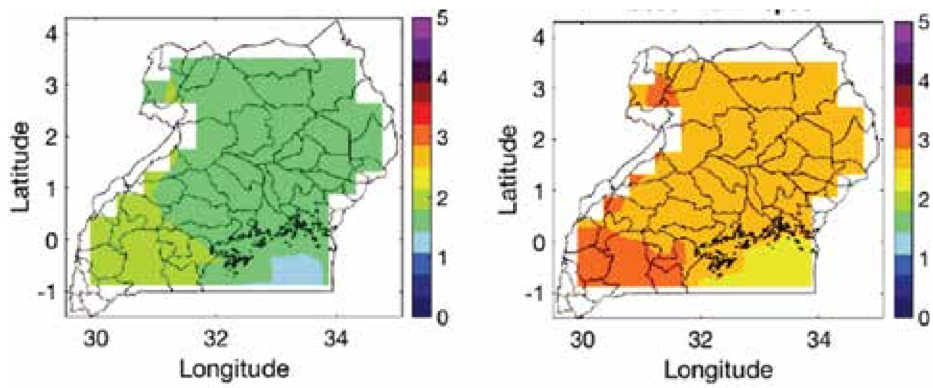
ANNEX 3: CLIMATE PROJECTION MAPS

Figures are in degrees.

Figure 1: Temperature trend from 1961-2005 for the long (MAM;

LEFT) and short (SOND; RIGHT) rainy season in Uganda.

Note: *During both the short and long rainy season, temperature has increased by more than 0.8°C in the country. (Source: CRAFT Project, 2018)*



Figures are in degrees.

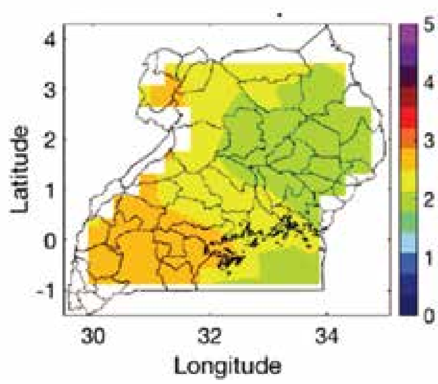
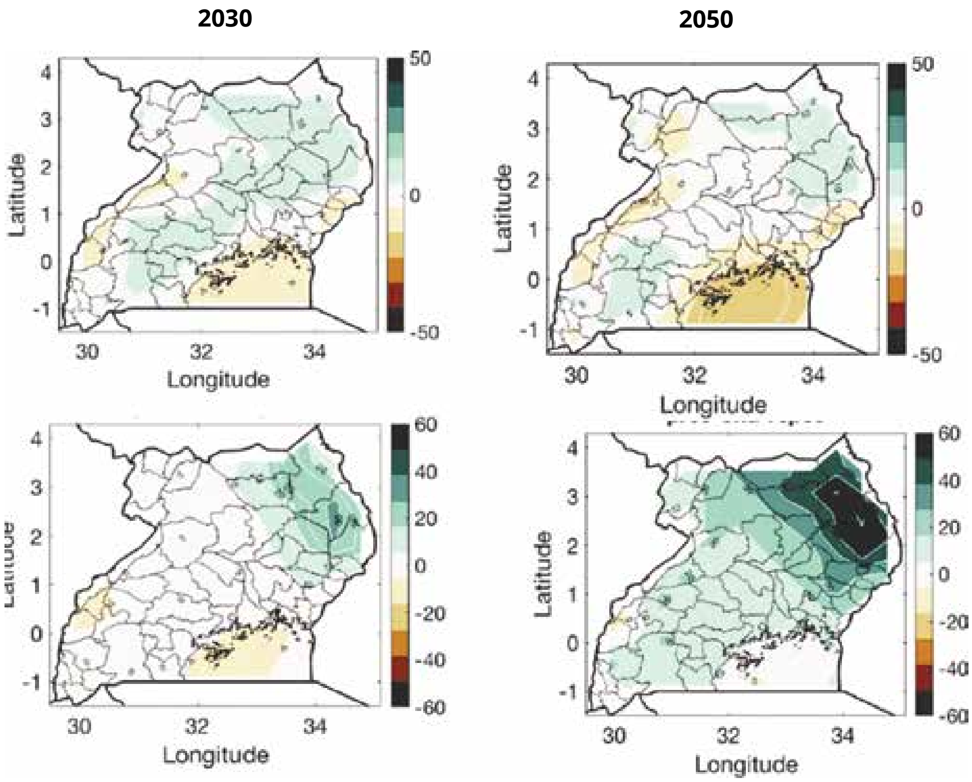


Figure 2: Projected seasonal mean changes in temperature for 2050s under the RCP8.5 emission scenario (worst case scenario), relative to the reference period (1961-2005).

Note: During both the short (September, October, and November; RIGHT) and long (March, April, May) rainy season and temperature is likely to rise by more than 2°C with the highest increase of 3°C over south-western Uganda during the long rainy season (MAM).
(Source: CRAFT, 2018)

Figure 3: Projected seasonal mean changes in rainfall (in percentage) for mid-century under the RCP8.5 emission scenario, relative to the reference period (1961-2005).

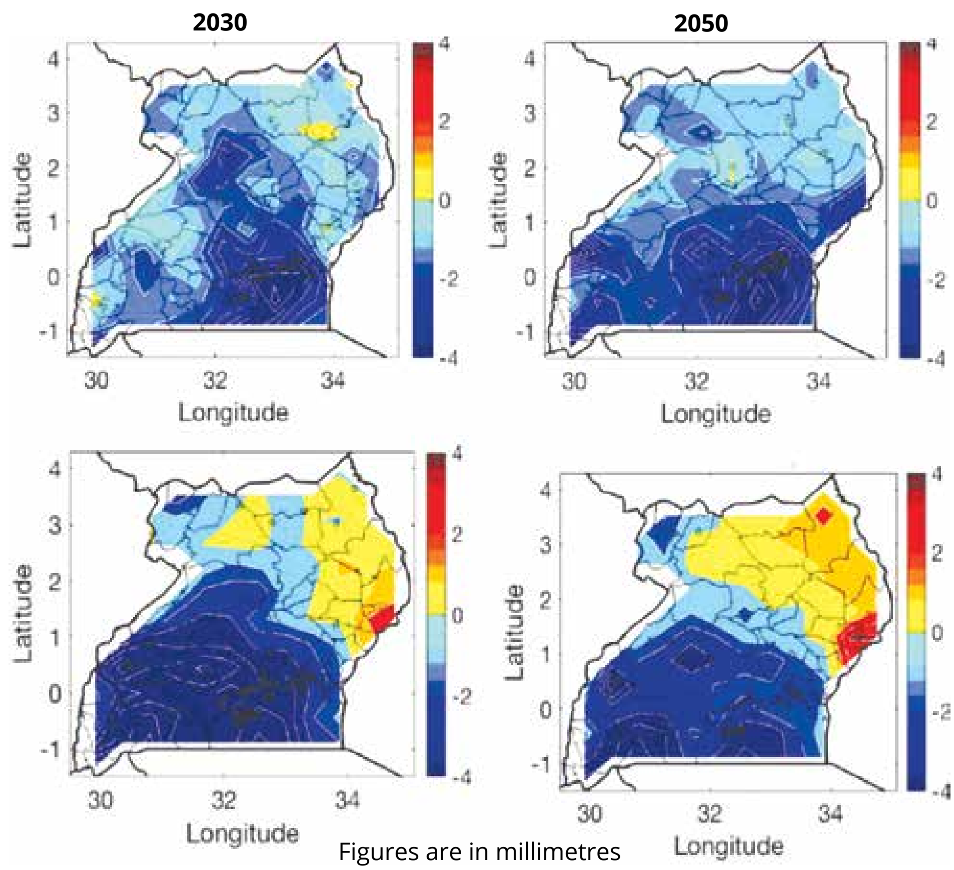
Note: *The seasonal mean rainfall in the short rainy season (RIGHT) is projected to increase over most parts of the country. However, the seasonal rainfall is expected to decrease by 2050s, over much of southern Uganda during the long rainy season (LEFT)*
(Source: CRAFT 2019)



Figures are in millimetres

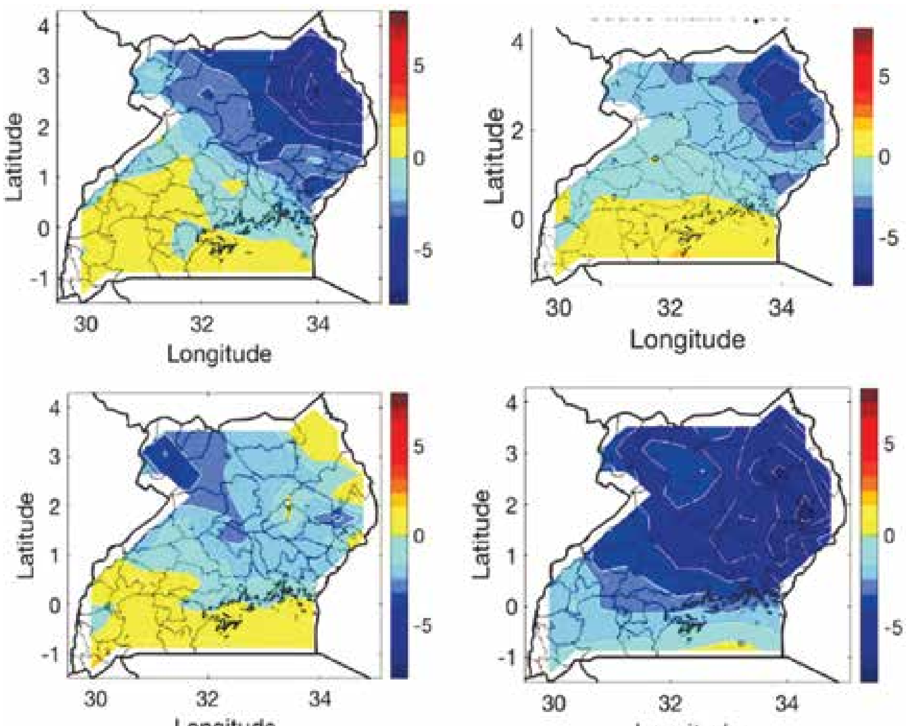
Figure 4: Projected seasonal mean changes in consecutive wet days for mid-century under the RCP8.5 emission scenario, relative to the reference period (1961-2005).

Note: *For the north-eastern part of Uganda, the longest wet spell during the short rainy season (RIGHT) is likely to increase by about 2 - 3 days in the 2050s. However, the length of the longest wet spell in the south-eastern, southern, and western part of the country is expected to decrease by 2 - 4 days in both the short (RIGHT) and long (LEFT) rainy seasons*
(Source: CRAFT, 2018)



Figures are in millimetres

2030 **2050**

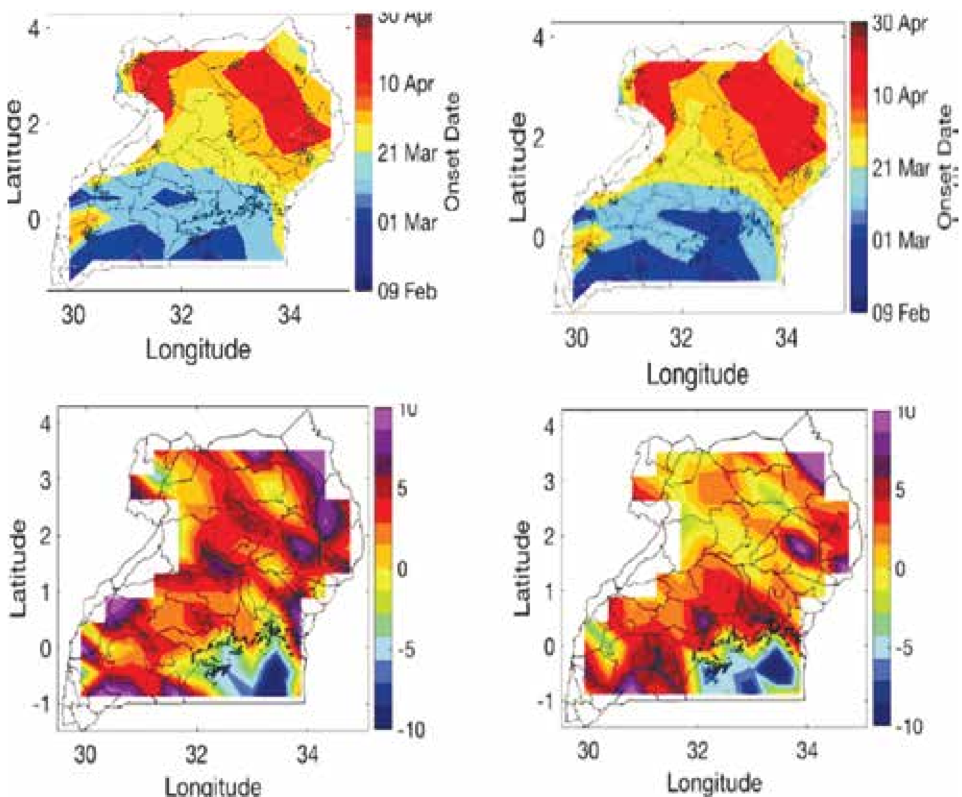


Figures are in millimetres

Figure 5: Change in soybean yield under RCP 8.5 (2050s) compared to current climatic conditions.

Yields were simulated under optimum nutrient management conditions and biotic control (Source: CRAFT, 2018).

2030 **2050**



Figures are in millimetres

Figure 6: Projected seasonal mean changes in consecutive dry days for mid-century (2050s) under the RCP8.5 emission scenario, relative to the reference period (1961-2005).

Note: Dry spells are expected to decrease by 3 - 5 days over most parts of the country except the southern tip during the short rainy season (Source: CRAFT, 2018)

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