MAAIF

Ministry of Agriculture,
Animal Industry and Fisheries

Potato 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.

Potato is an important food and income security crop in Uganda with more women and children involved in production activities. Uganda is the ninth largest producer of potato in Africa with an annual production of 774,600 tonnes harvested from about 106,000 hectares (FAOSTAT 2018). It is grown by over 360,000 smallholder households in Uganda (UBOS 2018). Production is mainly from the highland regions of the country, although it spreads to non-traditional areas. Average yields of potato are 10 MT/Ha with a potential of up to 40 MT/Ha. The low productivity is attributed to several factors among which is climate change. Well as there is content on potato production, post-harvest handling and marketing already but there is none that specifically focuses on potato in relation to climate change. The manual will therefore address the information gap related to potato production in the face of climate change.

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 Potato extension workers manual.

The objective of this manual is to sustainably transform potato 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 document, particularly; MAAIF team, technical members from Makerere, NARO and private stakeholders including progressive potato farmers that provided input into the drafting and validation of this document;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 potato value chain in Uganda.

FOR GOD AND MY COUNTRY

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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 potato value chain and its management in times of climate change. It is comprised of five chapters with coordinated content as summarized below. Chapter one gives some background and a contextual aspect of potato production in Uganda. It also outlines the importance of potato in the food system.

The section further highlights the growth characteristics of the crop and its different growth stages. It illustrates the common varieties grown in Uganda and detailed seed and ware production requirements. The chapter also includes the different potato production constraints and their remedies.

Chapter two defines climate change in general and highlights the major causes of climate change. It also describes the major effects of climate change with a bias towards potato production. It gives an overview of climatic changes in Uganda, its risks, and impact.

Chapter three explains the potato production constraints due to climate change specifically highlighting socio-economic, environmental, and environmental constraints. Chapter four describes climate smart potato production principles. It gives an overview of climate smart agriculture, the corresponding strategies for potato farming and the opportunities and challenges of CSA potato farming in Uganda.

Chapter five introduces and share the economics of potato production. This section discusses record keeping in detail, highlighting the importance of farm records in decision making. The chapter also highlights the characteristics of good records, the different types of key records as well as the cost benefit analysis of potato production.

Climate Smart Agriculture

POTATO VALUE CHAIN

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ABBREVIATIONS

CRAFT: Climate Resilient Agribusiness for Tomorrow

CSA: Climate Smart Agriculture

GHGs: Greenhouse gas

IPM: Integrated Pest Management

UNMA: Uganda National Meteorological Authority

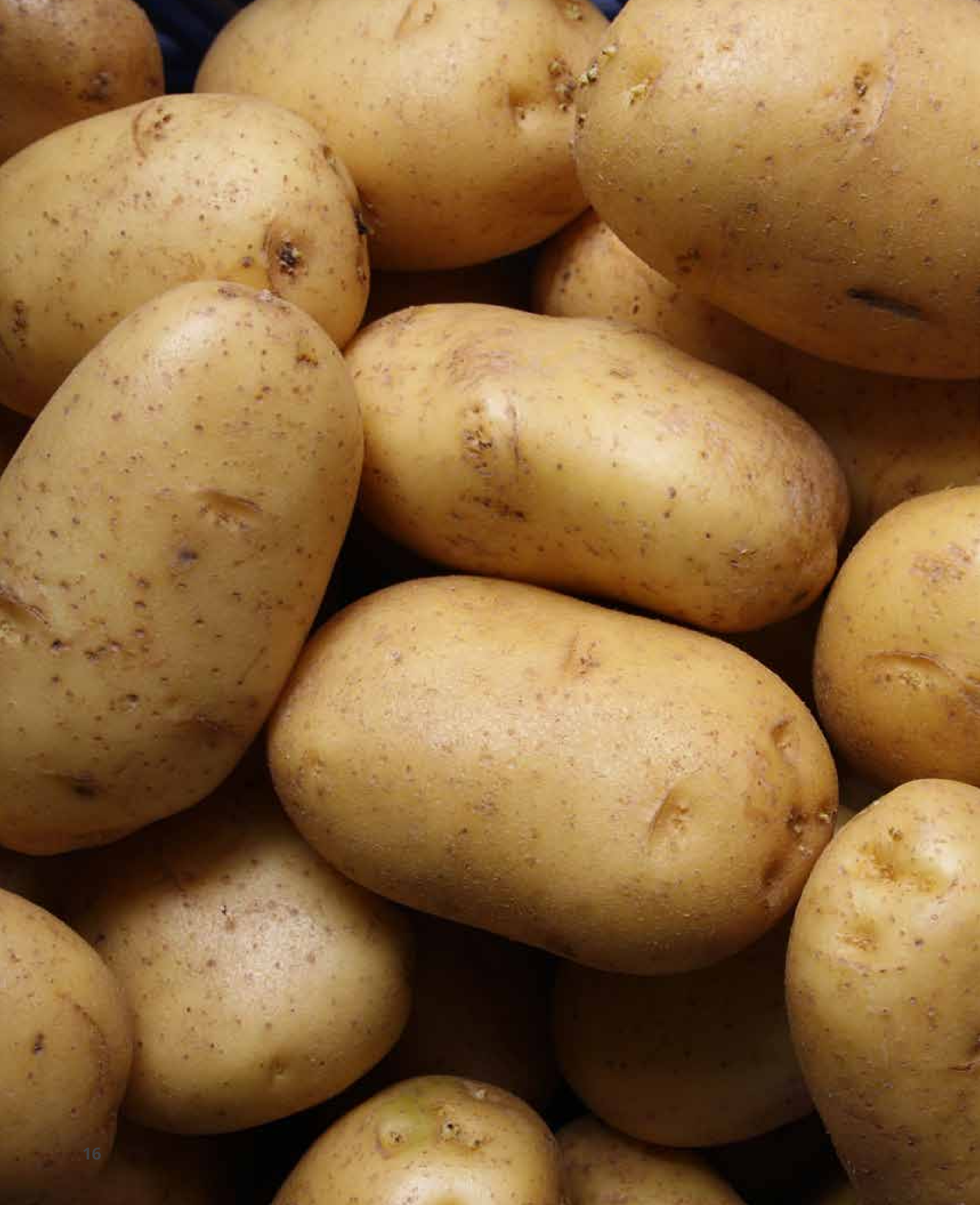
MAAIF: Ministry of Agriculture, Animal Industry and Fisheries

NARO: National Agricultural Research Organisation

PTM: Potato Tuber Moth

RACS: Rooted Apical Cuttings

SSP: Single Super Phosphate



CHAPTER 1

INTRODUCTION

1.1 Introduction

Potato (Solanum tuberosum L.) belongs to the Solanaceae or nightshade family and to the large and diversified genus Solanum. Potato occupies a wide eco-geographical range. It is native to the Andes Mountains in Chile, Peru and Bolivia in South America, and has been cultivated for about 2,400 years. Potato later spread throughout the world including to the warm tropics. Potato was originally a temperate crop that required cool agro-ecological environments, which is why it is grown in the highland areas of Uganda. By 1940, the potato was already being grown in the highlands of Kigezi, Toro and on the slopes of Mt. Elgon in Bugisu and Sebei regions. Recent research, however, has bred new varieties that adapt to lowland areas. Thus, current production is spreading to mid and low attitudes areas (Hakiza et al., 2000).

1.2 Potato production in Uganda

Uganda's potato annual production is at 774,600 tonnes harvested from about 106,000 hectares (FAOSTAT, 2018). It is grown by over 360,000 smallholder farmers, contributing to about 11.9 trillion Uganda shillings, an equivalent 4.4% of the current national annual budget (UBOS, 2018). The major production areas are the highlands of south-western Uganda – Kigezi region, which account for 60% of total national production. Other potato growing areas include Sebei region, Elgon region Rwenzori region and west nile region. Its cultivation has spread to non-traditional areas in central Uganda.

Potato is increasingly becoming an important staple and cash crop within the Uganda farming system. Due to its short maturity period of three to four months, the crop fits well in the farming system. The Potato contributes to food security, poverty eradication and economic development. With increasing urbanisation and rapid population growth, consumption of potatoes in various forms including boiled, roasted, fried, mashed, crisps and chips, is on a rapid upward trend.

- It represents about 43% of the global output of root and tuber crops, followed by cassava with 30% and sweet potato with 17% (FAO, 2008).
- It is important both for human consumption and in the starch industry
- It is an important food crop.
- Potato is an essential source of income and employment.
- The potato crop matures in a relatively short time depending on the variety.
- Responds highly to agro-input use.
- Liked by people in both urban and rural areas.
- It is a rich source of vitamin B6 and vitamin C.

1.3 Importance of potato

On a world scale, potato is the fourth most important staple crop after maize, rice, and wheat with more than 320 million tonnes produced from 20 million hectares (Zhang et al., 2017).

1.4 Growth characteristics of potato crop

The potato plant has a branched stem and alternately arranged leaves consisting of leaflets which are both of unequal size and shape.

- Potato is an herbaceous plant that grows about 60cm high, depending on variety.
- Most flowers are white, pink, red, blue, or purple with yellow stamens.
- Potato leaves are usually green and senescence (dying back) after flowering.
- Fruiting and tuber formation follow flowering, depending on variety.
- In general, the tubers of varieties with white flowers have white skins, while those of varieties with coloured flowers tend to have tubers with coloured skins.
- Potatoes are mostly cross-pollinated by insects such as bees, which carry pollen

from other potato plants .

- Self-fertilisation also occurs to some degree.
- Some varieties, after flowering, produce small green fruits each containing about 300 seeds.
- New varieties are developed from seeds called true potato seed (TPS).New varieties grown from seed can be propagated vegetatively by planting tubers, pieces of tubers cut to include at least one or two eyes, or cuttings; a practice used in greenhouses to produce healthy seed tubers.
- Plants propagated from tubers are clones of the parent, whereas those propagated from (TPS) seed produce different varietiess.

Figure 2: Potato berries (left), true potato seed (centre) and tubers from true potato seed (right). Source: Author.

1.5 Potato growth and development stages

From the tuber, there are five major stages in potato growth and development, namely, sprout development, vegetative growth, tuber initiation, tuber bulking and maturation.

Growth stage 1 (GS1) - Sprout development:

This stage varies from 30 to 90 days depending on variety and prevailing environmental conditions. Sprouts develop from eyes on seed tubers and grow upwards. Roots begin to develop at the base of the emerging sprouts once planted. The nutrient requirement is 100% dependent on the mother tuber.

Growth stage 2 (GS2) - Vegetative growth:

Leaves and branch stems develop from above ground nodes along emerged sprouts. Roots and stolons develop at below ground nodes. Management practices at this stage are weeding, spraying, and ridging or earthing up. Ridging consists of mounding the soil from between the rows around the main stem of the potato plant. This keeps the plants upright and the loose soil prevents insect pests such as the tuber moth from reaching the tubers; and helps prevent the growth of weeds. Ridging should be done two or three times at an interval of 15 to 20 days. The first one should be done when the plants are about 15 - 25 cm high.

Growth stage 3 (GS3) - Tuber initiation:

Tubers form at stolon tips but are not yet appreciably enlarging. In most cultivars, the end of this stage coincides with early flowering. Agronomic practices are earthing up to cover the growing tubers, and monitoring for pests and disease attack. Top dressing and foliar application of nitrogen is recommended at this stage.

Growth stage 4 (GS4) - Tuber bulking:

Tuber cells expand with the accumulation of water, nutrients, and carbohydrates. Tubers become the dominant site for deposition of carbohydrates and mobile inorganic nutrients. More water is required at this stage to enhance tuber bulking..

Growth stage 5 (GS5) - Maturation

Vines turn yellow and lose leaves, photosynthesis decreases, tuber growth slows, and vines eventually die. Tuber dry matter content reaches a maximum and tuber skins set. To facilitate hardening of the tubers, the stems are cut, and this practice is known as dehaulming.

Figure 3: Illustration of potato growth stages and development. Source: author.

1.6 Potato varieties currently grown by farmers in Uganda.

Several varieties are currently being grown by farmers for different purposes: for seed, food, and some for processing. These include Naropot1, 2,3 and 4, Victoria, Kachpot1, Kinigi and Rutuku.

Some farmers also grow commercially imported varieties such as the Sarpomira, Connector, Arizona, Voyager, Markies, Elmundo and Sagitta.

Species: Solanum tuberosum

Variety name/ code	Year of release	Owners	Maintainer and seed source	Optimal production altitude range	Duration to maturity (days)	Grain yield (T/ Ha)	Special attributes
1.Malirahinda	1974	NARO	NARO	> 1600	95-100	10-15	Moderate resistance to late blight and bacterial wilt
2.Victoria 381381.2	1991	NARO	NARO	> 1600	75-90	12-20	Resistant to late blight and bacterial wilt
3.Kisoro 381379.9	1991	NARO	NARO	> 1600	80-100	15-20	Moderate resistance to late blight and bacterial wilt
4.Kabale 374080.5	1991	NARO	NARO	> 1600	100-120	28	Moderate resistance to late blight and bacterial wilt
5.NAKPOT 1 (382171.4)	1999	NARO	NARO	> 1600	90-100	31-38	Resistant to early and late blight resistant to potato leaf roll virus
6. NAKPOT 2 (381403.8)	1999	NARO	NARO	> 1600	95-115	25-28	Resistant to both early and late blight, susceptible to bacterial wilt and potato leaf roll virus
7.NAKPOT 3 (575049)	1999	NARO	NARO	> 1600	85-100	25-34	Tolerant to bacterial wilt, resistant to both early and late blight, resistant to potato leaf roll virus
8.NAKPOT 4 (387121.4)	2002	NARO	NARO	> 1600	118	25-35	Tolerant to bacterial wilt, resistant to both early and late blight, resistant to potato leaf roll virus
9.NAKPOT 5 (381471.18)	2002	NARO	NARO	> 1600	118	25-35	Tolerant to bacterial wilt, resistant to both early and late blight, resistant to potato leaf roll virus
10.KACHPOT1 393382.14	2006	NARO	NARO	> 1600	118	25-35	Tolerant to bacterial wilt, resistant to both early and late blight, resistant to potato leaf roll virus, good for chips

Variety name/ code	Year of release	Owners	Maintainer and seed source	Optimal production altitude range	Duration to maturity (days)	Grain yield (T/ Ha)	Special attributes
11.KACHPOT2 393385.39	2006	NARO	NARO	> 1600	118	25-35	Tolerant to bacterial wilt, resistant to both early and late blight, resistant to potato leaf roll virus, good for chips
12.NAROPOT 1 396038.107	2015	NARO	NARO	> 1600	118	25-35	High yielding, resistant to and late blight, have good processing qualities.
13.NAROPOT 2 396280.82	2015	NARO	NARO	> 1600	118	25-35	Resistant to late blight,have good processing qualities
14.NAROPOT 3 396034.103	2015	NARO	NARO	> 1600	118	25-35	High yielding, resistant to and late blight, have good processing qualities
15.Arizona	2016	AGRICO	AGRICO/ NARO	>1600	118	28- 40	High yielding, good processing qualities
16.Elmundo	2016	KWS	KWS/NARO	>1600	118	28-40	High yielding, good processing qualities
17.Sagitta	2016	HZPC	HZPC/NARO	>1600	118	28-40	High yielding, good processing qualities
18.Markies	2016	AGRICO	AGRICO/ NARO	>1600	118	28-40	High yielding, good processing qualities
19.Connect	2016	DEN HARTIGH	DEN HARTIGH	>1600	118	28-40	High yielding Resistant to late blight. Good processing qualities
20.Sarpomira	2016	DANESPO	DANESPO	>1600	118	28-40	High yielding Resistant to late blight. Good processing qualities
21.Voyager	2016	HZPC	HZPC/NARO	>1600	118	28-40	
22.NAROPOT 4 (Rwangume)	2016	NARO	NARO	>1600	118	25-30	High yielding Resistant to late blight.

1.7 Seed and ware potato production

Farmers have a choice to commercially produce seed and ware potato. However, trained seed multipliers exist in different parts of the country. There are different stages leading to the production of seed and eventually ware potato. The different stages are tissue culture (TC) plants and minituber production (from plantlets or rooted apical cuttings (RACS). The process can be from tissue culture to minitubers or from TC to RACs and then minitubers. Field multiplication follows minituber production. The production of tissue culture plantlets requires a laboratory. At farm level, a screen house or mother shade may be established to raise tissue culture materials and rooted apical cuttings for minituber production. Seed potato can be obtained from research stations and registered seed multipliers.

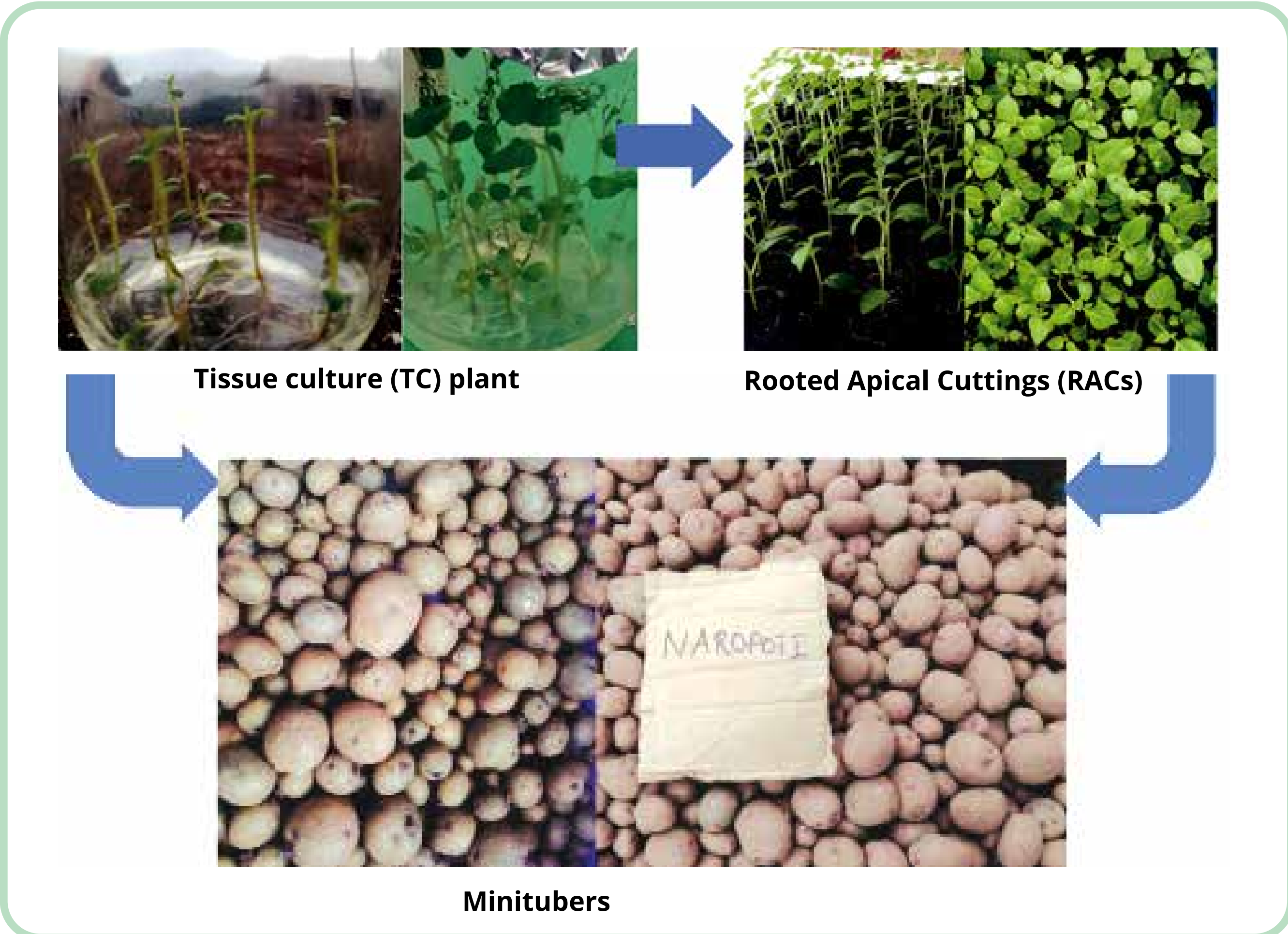


Figure 4: Stages in seed potato production. Source: Author

1.8 Production constraints

Potato yields in Uganda have remained as low as 7 t/ha against a potential of about 25 t/ha which can be achieved under good management and when suitable varieties are deployed (FAOSTAT, 2018). These low yields are due to several confounding factors such as socio-economic constraints, poorly adapted and adopted varieties, abiotic and biotic stresses. Some of these factors are aggravated by the low income of farmers, which limits them from using productivity enhancement inputs (FAO, 2008). Details of these are handled in Chapter 3.

CHAPTER 2

POTATO PRODUCTION AND CLIMATE CHANGE

2.1 Introduction

The chapter define climate change and summarizes the major causes of climate change. It also explains the impact of climate change including ecosystem and food system disruptions and further summarizes the climate change trends in Uganda over the years.

2.2 Climate change and its Causes

Both human and natural factors contribute to climate change. Human activities, such as agriculture and deforestation, are the primary causes of climate change. This emits greenhouse gases mainly carbon dioxide, methane, and nitrous oxide into the atmosphere.

The burning of fossil fuels, such as oil and coal, also contribute to the production of greenhouse gases that cause climate change. None the less some quantities of these gases occur naturally and form a critical part of the earth's temperature control system.

Carbon dioxide is the best-known greenhouse gas, with natural sources including decomposition and animal respiration. The main source of excess carbon dioxide emissions is the burning of fossil fuels, while deforestation has reduced the amount of plant life available to turn CO_2 into oxygen. The atmospheric concentration of CO_2 has been steadily increasing over the years from 300 parts per million to about 400 ppm.

Methane is a more potent but less abundant greenhouse gas. It enters the atmosphere from farming both from animals such as cattle; arable farming methods including traditional rice paddies; fossil fuel exploration; and abandoned oil and gas wells. There are also chlorofluorocarbons and hydrofluorocarbons that were once widely used in industrial applications and home appliances such as refrigerators during the 20th century. They are now heavily regulated due to their severe impact on the atmosphere, which includes ozone depletion, as well as trapping heat in the lower atmosphere.

2.3 General effects of climate change

There are several effects of climate change. While certain effects can be beneficial, particularly in the short term, current and future effects 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.

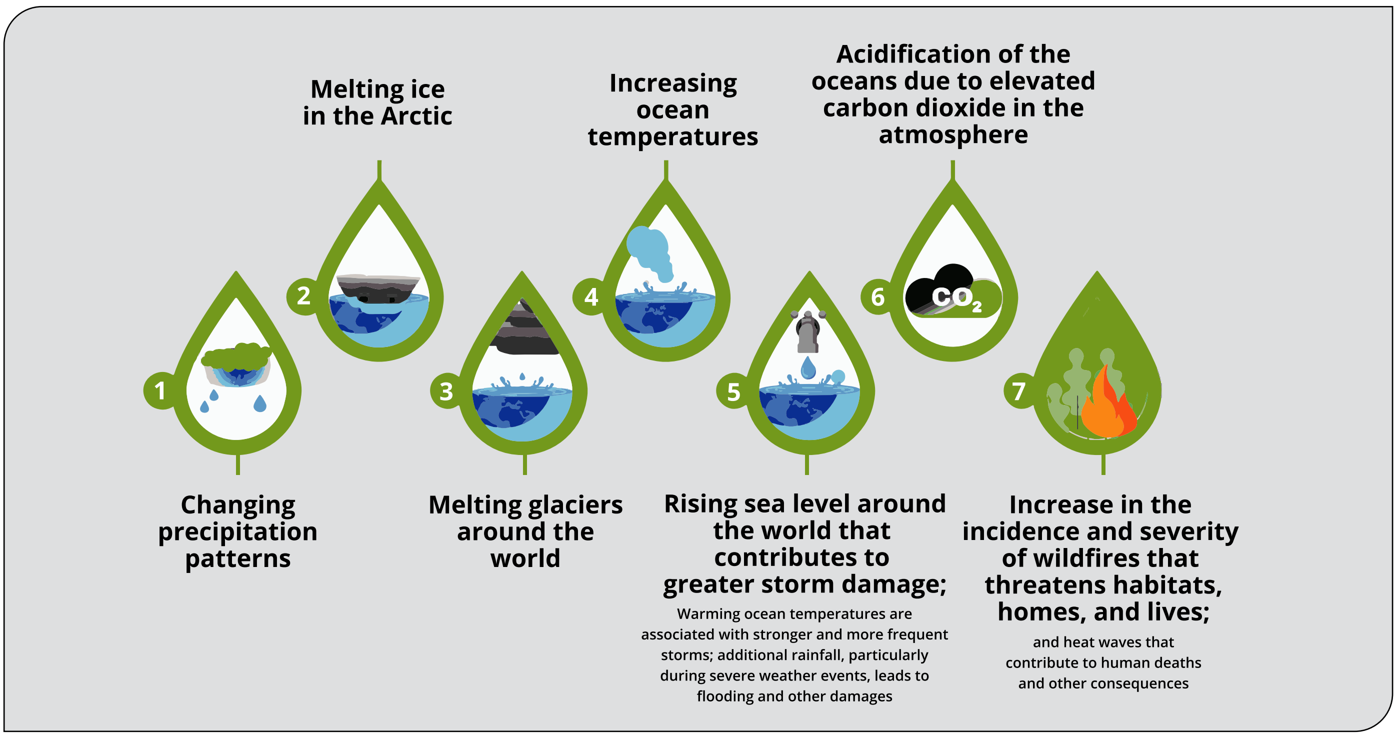
2.4 Overview of climate change: risks, impacts on potato growing in Uganda.

2.4.1 Global Climate Projection.

At the current rate, the earth's global average temperature is projected to rise by 3 - 7°F (-16 to -13°C) by 2,100 (https://snv.org/cms/sites/default/files/explore/2020), and it will get even warmer after that. As the temperature continues to rise, more changes are expected to occur, with many effects becoming more pronounced over time. For example, heat waves are expected to become more common, severe, and lasting longer. Storms are likely to become stronger and more frequent, increasing the chances of flooding and damage in coastal communities.

Climate change will affect different regions,

It also includes:



ecosystems, and sectors of the economy in many ways, depending not only on the sensitivity of those systems to climate change, but also on their ability to adapt to risks and changing conditions. Throughout history, societies and ecosystems alike have shown remarkable capacity to respond to risks and adapt to different climates and environmental changes.

Today, effects of climate change have already been observed, and the rate of warming has increased in recent decades. For this reason, human-caused climate change represents a serious challenge - one that could require new approaches and ways of thinking to ensure the continued health, welfare, and productivity of society and the natural environment. As the climate continues to rise, more changes are expected to occur, and many effects will become more pronounced over time..

2.4.2 Temperature trends in potato growing areas in Uganda.

Scientific modelling shows that temperature in potato growing areas has increased by about 1°C (from 1961 - 2005) for the first rainy season of March, April, May (MAM) in the potato growing areas. During the second rainy season of September, October, November, December (SOND), temperature in the potato growing areas of the country increased by about 1.2°C - 1.4°C. In particular, the temperature trend in the second rainy season increased significantly by about 1.3°C - 1.4°C in Nebbi district and the south-western potato growing areas of Uganda (https://snv.org/cms/sites/default/files/explore).

Projections indicate that in the 2030s the temperatures in the first rainy season is expected to rise by about 1.8°C in West Nile region (e.g Zombo, Nebbi,) and Elgon region (Mbale, Kapchorwa, Kween, Bukwo, Bulambuli, Namisindwa districts and by about 2°C in the south-western potato growing areas. In the second rainy season, temperature in Mbale, Nebbi and the south-western districts in the potato growing areas is expected to rise by 1.4°C, 1.8°C and 2.0°C respectively by the 2030s For the 2050s, the temperature in the potato growing areas of the country is expected to rise by about 2.8°C - 3.0°C and 2.0°C - 2.8°C in the first and second rainy season, respectively. The expected rate of warming is higher for MAM as compared to SOND in most of the potato growing areas, and the highest temperature increment (+3.0°C) is expected around Kigezi region by 2050s. (https://snv.org/cms/sites/default/files/explore).

2.4.2.1 Rainfall projections

The seasonal mean rainfall in the first rainy season is projected to decrease in West Nile and the south-western potato growing areas though a slight increase, of about 10%, is expected in Mbale district. However, the seasonal mean rainfall in the second rainy season is expected to increase by about 20 - 40% in the eastern potato growing areas of the country, e.g., Mbale and Kapchorwa districts, especially in the 2050s. The seasonal mean rainfall in the second rainy season is also expected to increase slightly by about 10% in the potato growing areas around West Nile and in the south-western districts, e.g., Kabale especially in the 2050s.

Similarly, the longest consecutive wet days in the potato 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 eastern potato growing areas of the country (Mbale and Kapchorwa) is projected to increase by about 2 - 3 days in the second rainy season.

2.4.2.2 Precipitation

The seasonal mean rainfall in the first rainy season is projected to decrease in West Nile and the south-western potato growing areas though a slight increase, of about 10%, is expected in Mbale district. However, the seasonal mean rainfall in the second rainy season is expected to increase by about 20 - 40% in the eastern potato growing areas of the country, e.g., Mbale and Kapchorwa districts, especially in the 2050s. The seasonal mean rainfall in the second rainy season is also expected to increase slightly by about 10% in the potato growing areas around West Nile and in the south-western districts, e.g., Kabale especially in the 2050s.

Similarly, the longest consecutive wet days in the potato 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 eastern potato growing areas of the country (Mbale and Kapchorwa) is projected to increase by about 2 - 3 days in the second rainy season.

2.4.2.3 Dry spell duration

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 eastern potato growing areas (Mbale and Kapchorwa) by the 2030s and 2050s. However, dry spells are expected to increase slightly, by about one day, in the south-western potato growing areas of the country especially in the first rainy season and in the 2030s of the second rainy season. The projected increase in the dry spell coupled with the expected decrease in the seasonal mean rainfall accompanied by a decrease in the number of consecutive wet days in the south-western potato growing areas of Uganda for the first rainy season could translate into drought or lack of sufficient rainfall in the region.

2.5 Socio-economic constraints

Socioeconomic factors, such as economic growth, population, demographic factors, technological changes, lifestyle changes and policies, are the driving forces for future emissions. They greatly influence mitigation challenges and the costs of achieving a stringent climate goal (Ying–Yu Liu et al., 2018). Climate change could alter the growing regions and suitability of zones for the varieties that were formerly cultivated hence influencing economic growth. Landslides and floods can cause demographic changes that eventually alter rural farming settlements. The changes in cropping systems will result in an altered lifestyle and food consumption pattern.

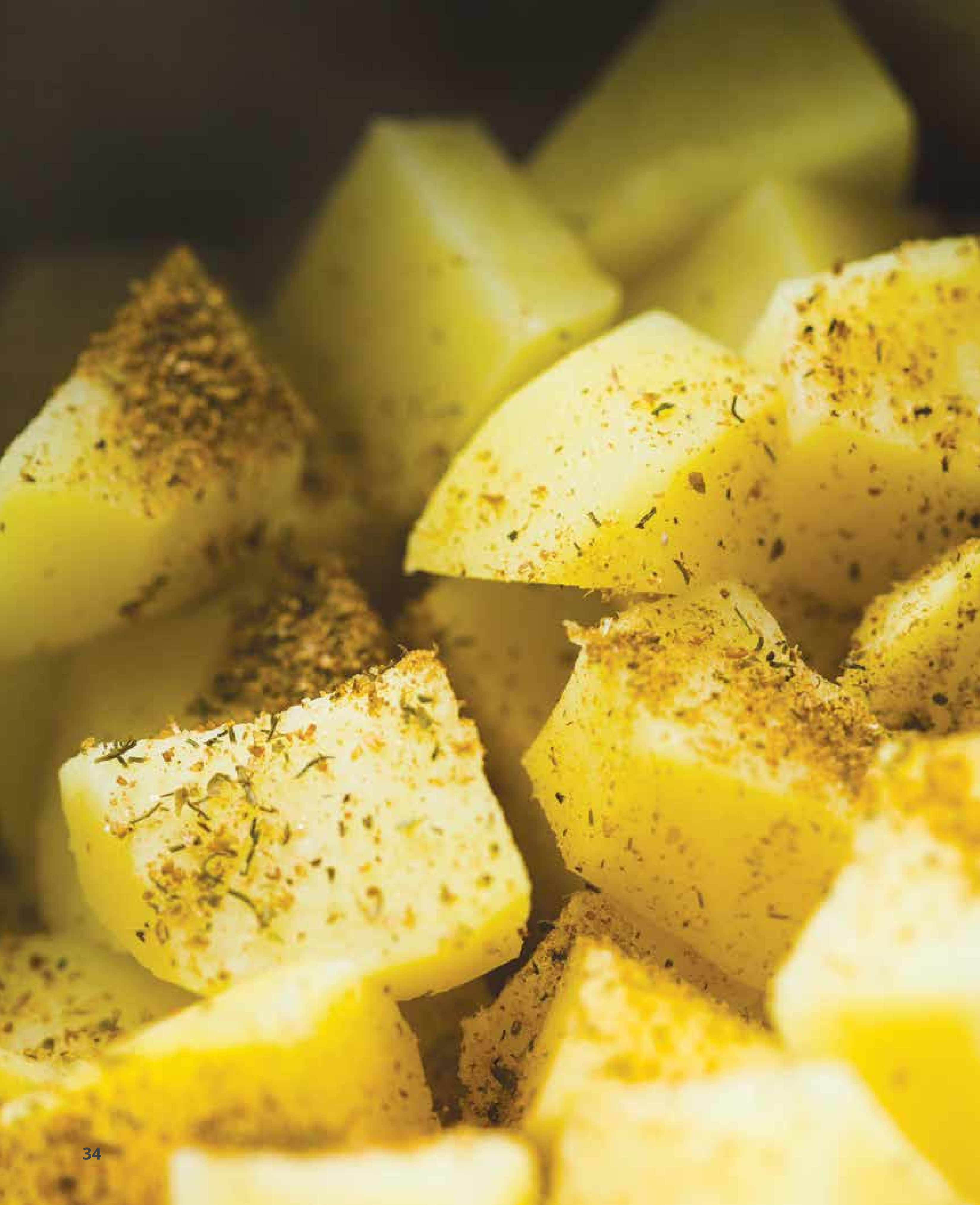
Other factors such as monocropping result in exhaustion of soil nutrients and depletion of soil fertility, short ware potato shelf life, mixed varieties in the market, significant fluctuations of market prices, inadequate supply of clean seed tubers, high cost of inputs, poor marketing channels, and impassable roads.

2.6 Environmental constraints

Environmental constraints vary from one place to another and are mainly caused by variations in rains and temperatures. These include:

- Declining soil fertility, a major constraint in most potato growing areas and is aggravated by the continuous cultivation without adequate replenishment of the mined nutrients. This is complicated by small land sizes where farmers continuously plant potato on the same land. and soil erosion in the hilly areas. The cost of fertilisers is also often prohibitive to most farmers.

- Other causes include erratic and sometimes violent rainfall, moisture and heat stress due to changes in temperature and amount of precipitation. This prevents the crop from realising its full genetic potential, results in reduced yield and tuber quality; and may lead to total crop failure and related losses.



CHAPTER 3

CLIMATE RESILIENT POTATO PRODUCTION

3.1 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 dimension and further explains the potato production requirements, soil water conservation practices including terracing and mulching. The section also highlights the potato production cycle from land preparation, variety selection, planting, sprouting, weed, pest and disease management.

3.2 Climate Smart Agriculture (CSA)

Climate Smart Agriculture (CSA) may be defined as an approach for transforming and reorienting agricultural development under the new realities of climate change (Lipper et al. 2014). According to the Food and Agricultural Organisation of the United Nations (FAO), CSA is defined as "agriculture that sustainably increases productivity, enhances resilience (adaptation), minimizes future climate change related risks (mitigation), and enhances achievement of national food security and development goals". The primary aim of CSA is identified as food security and development while productivity, adaptation, and mitigation are the three interlinked pillars necessary for achieving this goal (Lipper et al. 2014).

3.2.1 Pillars of Climate Smart Agriculture

CSA is based on three pillars: mitigation, for example, minimising greenhouse gas emissions, adaptation of agricultural practices to climate change, and sustainable or increase of agricultural productivity.

3.2.2 The three pillars of CSA

01 **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

02 **ADAPTATION:** CSA aims to reduce the exposure of farmers to short-term risks, while also strengthening their resilience by building their capacity to adapt 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.

03 **MITIGATION:** Wherever and whenever possible, CSA should help to reduce and/or remove greenhouse gas (GHG) emissions. This implies that we reduce emissions for each calorie or kilo of food, fibre and fuel that we produce. We should avoid deforestation from agriculture and manage soils and trees in ways that maximise their potential to act as carbon sinks and absorb CO2 from the atmosphere.

Figure 14: The three pillars of CSA (Source: https://csa.guide/csa/what-is-climate-smart-agriculture 9/7/20)

3.2.3 Sustainable increase in productivity

Ensuring food security for current and future generations relies on increasing productivity in a sustainable manner. This sustainably increases household incomes. With the expected world population increase (9 billion people by 2050), there is need to provide enough food which is rich and balanced in different nutrients such as: vitamins, trace elements and amino acids. Diet must also consider factors such as energy requirements, age, and pregnancy. An additional challenge for the future is the growing demand for animal products such as milk, dairy, and meat, particularly in developing countries. Food security is not only a matter of increasing production, but also avoiding spoilage or waste of food along the value chain, i.e., the range of activities that are necessary to deliver the product to the customer. The amount of food produced only counts if it reaches the individual consuming it.

3.2.4 Adaptation

Extreme weather conditions such as severe rainfall, storms, high temperatures, drought, and floods pose numerous challenges to agriculture. Rising sea levels are a challenge for agriculture in coastal areas. Globally, there are changes in seasonality and average temperatures. While climate change might favour agriculture, for example, by longer growing seasons or higher temperatures, in many countries the effects of climate change on agriculture will be negative.

The need to adapt farming to ensure the resilience of agricultural systems to the changing climate is inescapable. Adaptation can involve changes in practices such as changing the crops or livestock that are grown, use of new technologies and, applying climate or weather data to make decisions for the future. CSA reduces the exposure of farmers and agri-businesses to short-term risks, while also strengthening their resilience by building capacity to adapt and prosper in the face of climatic shocks.

3.2.5 Mitigation

Adapting agriculture to climate change and maintaining food production could help to solve the current problems. However, with rising levels of GHGs, climate change and its consequences will continue to impact our lives and pose new challenges. Currently agriculture, and the related sectors, contribute about a quarter of the human induced GHG emissions, hence a higher potential to reduce these emissions, and to mitigate other detrimental effects of agriculture on the environment through reducing greenhouse gas emissions; and increasing water and energy efficiencies. Very often, mitigating resource input and increasing efficiency goes hand in hand with mitigating emissions. The more the concentration of GHGs in our atmosphere can be reduced, the less likely the extreme climate scenarios will be for the future, and the easier it will be to adapt to climate change. Another important aspect of mitigation is the uptake of carbon in plants and soils, which can help to reduce the concentration of CO_2 in our atmosphere.

3.3 Key principles of CSA

CSA addresses climate change: CSA systematically integrates climate change into the planning and development of sustainable agricultural systems (Lipper et al. 2014).

CSA integrates multiple goals and manages trade-offs: Ideally, CSA produces triple-win outcomes namely: increased productivity, enhanced resilience, and reduced emissions. Through participatory approaches, synergies are identified, costs and benefits of different options weighed based on stakeholder objectives.

CSA maintains ecosystem services: Ecosystems provide farmers with essential services, including clean air, water, food, and materials. CSA adopts a landscape approach that builds upon the principles of sustainable agriculture (FAO 2013).

CSA has multiple entry points at different levels: CSA goes beyond single technologies at the farm level and includes the integration of multiple interventions at the food system, landscape, and value chain or policy levels.

CSA is context specific: The fact that CSA often strives to reach multiple objectives at the system level makes it particularly difficult to transfer experiences from one context to another. What is climate-smart in one place may not be climate smart in another, and no interventions are climate-smart everywhere or every time.

CSA is gender responsive: Gender is an essential aspect of CSA. To achieve food security goals and enhance resilience, CSA approaches must involve the poorest and most vulnerable groups. These groups often live on marginal lands, which are most vulnerable to climate events like drought and floods (Huyer et al. 2015).

3.4 Climate-smart agriculture practices and technologies appropriate for potato farming.

In the table below, is a summary of the general practices and technologies, the details of which are highlighted below the table

Table 3: Climate-smart agriculture practices and technologies appropriate for potato farming.

Group	Component
Crop management practices	• Improved crop varieties (pest resistant, high yields and drought tolerant) • Use of legumes in crop rotation • Intercropping • Early planting at the onset of rain • Changing planting dates • Efficient use of inorganic fertilisers • Pest/disease scouting
General field management practices	Use of live barriers to control run-off and soil erosion Reduced tillage Crop residue management Integrated disease/pest management
Farm risk reduction practice	Diversified crop varieties Irrigation Early Warning Systems (EWS) Crop insurance Monitoring economic injury level of pests/disease

Soil conservation practices	• Use of organic fertilisers • Clean cultivation of weed • Recycling of weed for organic nutrients • Use of mulching • Strip cropping • Minimum tillage • Crop residue recycling • Crop rotation (especially those with different root feeding zones)
Renewable energy and energy efficiency technology	• Solar powered irrigation • Solar powered storage • Energy efficient processing technology
Water conservation	Water harvesting

3.4.1. Site selection

- To increase productivity, it is important to keep the history of the field to be used for potato production.
- The field should not have been under potato or other solanaceous crops like tomatoes, pepper, and eggplants for ideally three seasons. This practice is aimed at controlling soil borne pests and diseases especially bacterial wilt.
- Depending on the purpose of the crop, for example seed potato should be planted in raised areas to avoid water logging, which may lead to tuber rotting.
- Soils should be well drained, friable, and relatively fertile.
- Soil with pH range of 5.2 - 6.4 is considered ideal.

3.4.2. Seed selection

Use of quality appropriate seeds is vital in mitigating the challenges of climate change.

- **Productivity: Potato productivity acan be increased using high yielding crop varieties.**
- **Adaptation through climate risk management: The use of drought tolerant, early maturing, pest and disease resistant potato varieties can significantly reduce the risk of yield reduction or crop failure. Selected seed potato for planting should be tubers that are: undamaged, disease-free.**
- **physiologically mature (well sprouted with multiple sprouts**

3.4.3. Seedbed preparation

- The potato can be grown almost on any type of soil, except saline and alkaline soils.
- Naturally, loose soils, which offer the least resistance to enlargement of the tubers, are preferred, and loamy and sandy loam soils that are rich in organic matter, with good drainage and aeration, are the most suitable.
- The field should be prepared well in advance to allow for decomposition of vegetation into humus. Proper seedbed preparation is CSA practice that enhances potato productivity. It improves on water infiltration, soil aeration and root development.
- This also enhances crop emergence, a key factor for good yields.
- field operation practices include bush clearing; first and second land opening though minimum tillage may be done sometimes.

3.4.4 Planting

Timely planting

- For proper crop growth, planting should be done timely at the on-set of rains.
- Late planting results into low yields.

Spacing

- Planting should be done in furrows at a depth of 5 - 10 cm.
- Recommended spacing is (70 x 30 cm) to have optimum plant population.
- This increase yields by reducing competition for growth requirements and eases management operations.

3.4.5. Soil fertility management

- In most soils, fertility has been reduced, hence the need for addition of soil nutrients in form of inorganic or organic fertilisers.
- Carry out soil testing before fertilizer

Figure 18: Potato planting - A: Making fallows to be trench-like; B: Sprouted tubers placed in furrows. C: Mounds to cover the tubers (Source: Author)

application to know the nutrient deficiencies in the soil, physical and chemical properties.

- The right amounts of fertilizers to apply will depend on the soil testing results.
- Soil improvement can also be achieved through use of rotational crops and fallowing.

3.4.5.1. Organic fertilisers

- Organic manure is highly recommended as a sustainable way of enhancing soil fertility
- Organic manure can be obtained in various ways (compost, farmyard,green and liquid) and so its application varies.
- It can be locally generated using the available means such as zero grazed animals, contoured field grass bands and legume tree hedges

3.4.5.2 Inorganic fertilisers

- The application of these fertilizer should be based on the results of soil testing.
- If a nutrient is identified to be limiting, a more nutrient blend combination is necessary.
- At planting, apply DAP at a rate of 200kg per acre
- However, for potato, N:P: K 17:17:17 is commonly recommended at a rate of 120kg/ acre at top dressing
- Fertilisers are applied in a continuous drill method on the fallows made for planting; however, they are costly and continuous use may result into residual accumulation.

3.4.5.3 Method of fertiliser application

Fertilisers are applied at planting and during vegetative growth. At planting place fertiliser in furrows, cover the fertiliser with light soil and place the seed tubers (Figure 19). During vegetative growth, apply fertilisers by placing them along the furrows or foliar sprays

Figure 19: Fertiliser application: Continuous drill of inorganic fertiliser (Left); Applying composite fertiliser (Right) Source: MAAIF/SLM End of Project Report 2017/2018)

3.4.6. Main soil mineral deficiencies, signs, and correction measures

Table 4: Symptoms of mineral deficiencies and correction measures

Deficiency symptoms	Mineral
	**NITROGEN** **Correction measure:** Foliar application or soil application of Nitrogen based fertilizer
• The yellowing in nitrogen deficiency is uniform over the entire leaf including the veins. • Recovery of deficient plants to applied nitrogen is immediate (days) and spectacular. • Younger leaves turn darker green, older leaves remain yellow. Upward cupping of leaves when deficiency is severe	

PHOSPHORUS

Correction measure:

Soil application of recommended dose of phosphorous should be done at the time of sowing and planting

- The symptoms first develop on older leaves showing some necrotic spots and plants are dwarfed or stunted.
- Phosphorus deficient plants develop very slowly.
- Plants develop a distinct purpling of the stem, petiole and the under sides of the leaves.
- Plant remains stunted, darker than normal colour.
- Lower leaf surface grey green. Leaflets roll upward if deficiency is severe.

POTASSIUM

Correction measure:

Application of potassium based fertilisers.

- Leaflets become rugose (crinkled)
- Some of the leaves show marginal necrosis.
- (Tip burn), and at a more advanced deficiency status show interveinal necrosis.
- As the deficiency progresses, most of the interveinal area becomes necrotic, the veins remain green, and the leaves tend to curl and crinkle.
- Leaves take on a scorched appearance with black pigmentation and necrotic (dead tissue) edges.
- N.B. In contrast to nitrogen deficiency, chlorosis is irreversible in potassium deficiency, even if potassium is given to the plants.

SULPHUR

Correction measure:

Apply sulphur based fertilisers e.g., SSP

- Leaves show a general overall chlorosis.
- The veins and petioles show a very distinct reddish colour. The yellowing is much more uniform over the entire plant including young leaves.
- A reddish colour is often found on the underside of the leaves. With advanced sulphur deficiency, the leaves tend to become more erect and often twisted and brittle.
- Leaflet yellowing is uniform and general.

MAGNESIUM

Correction measure:

Application of magnesium based fertilisers
MAGNESIUM

Correction measure:

Application of magnesium based fertilisers

- The Mg-deficient leaves show advanced interveinal chlorosis. Interveinal necrosis causes a scorched look.
- In its advanced form, magnesium deficiency may superficially resemble potassium deficiency.
- The symptoms generally start with mottled chlorotic areas developing in the interveinal tissue.
- Symptoms appear first on young mature leaves.

3.4.7 Weed control and management.

- Timely weeding is a vital practice for increased yields. In case of chemical weed control, Clethodim is recommended.
- It reduces competition for light, nutrients, and water.
- Weeds may also harbour pests and diseases.
- Weeds provide conducive environment for late blight disease that affects most potatoes.
- First weeding and hilling (ridging or earthing up) should be done at about two weeks after emergence.
- Second weeding is done two weeks after the first weeding or when necessary.
- Ridging is done so that stolons are covered to form tubers. This also allows tuber enlargement, controls potato

tuber moth in the field, tuber blight and conserves soil moisture

3.5 Diseases affecting potato production.

Examples of major diseases are late blight caused by Phytophthora infestans (Mont.) de Bary, bacterial wilt (BW) (Ralstonia solanacearum) (Yabuuchi et al., 1995) and viruses. Diseases are discussed below in details including their identification.

3.5.1 Bacterial wilt (BW) (Ralstonia Solanacearum)

Bacterial wilt in potato is caused by Ralstonia solanacearum. Bacterial wilt or brown rot is the most serious bacterial disease. It limits potato production in most potato growing areas more so in warm regions. The pathogen persists in the soil for several years and has no established chemical control.

Spray with Copper hydroxide, or Copper Oxychloride as a preventive measure.

Potato bacterial wilt presents several symptoms:

- Slow wilting of the plant starting from one leaf to the branch, main stem and progressively to other stems in a grow-ing plant, sometimes accompa-nied by stunting and yellowing.
- Wilting and eventual death of a whole plant maybe rapid.
- A brown ring in place of vascular bun-dles in tubers from infected plants when cut in cross section.
- A milky ooze from the eyes of infected tubers obtained from sick potato plants.
- Soil adhered on the eyes of infected tubers especially in dry conditions.
- Pus-like substance exudates from infected tubers cut in cross-section and pressed.
- Whole tuber rotting and often with a characteristic smell.

Management of bacterial wilt involve use of clean planting materials, removal of volunteer plants of host species, and recommended crop rotations with non-host plants.

3.5.2 Late Blight

Late blight is caused by a fungus called Phytophthora infestans. It is a major disease limiting potato yield and productivity especially in the highlands. The disease accounts for up to 70% yield losses in most growing regions. It causes both foliar and tuber decay. Tubers can become infected when the disease moves down the lower stem, below ground, and through the stolon. Potato tubers can also become infected when late blight spores from infected leaves and stems are washed into the soil via cracks or crevices.

Figure 9: Bacterial wilt in leaves and tubers (Source: Author)

Symptoms of late blight

Leaves

- Early symptoms appear on lower leaves consisting of small, pale to dark green spots that eventually change into brown or black lesion depending on the humidity of the air.
- A pale green or yellow border a few millimetres wide often separates dead from health tissue.
- Whitish sporulation on lower surface of the leave

Stem

- Stems may be infected direct from the leaves or lesions may develop from leaf axils.
- Infected stems at lesion points may break in windy conditions or during field operations

Tubers

- Infected tubers show a superficial and irregular discoloration.
- Dry and brown necrotic lesions penetrate from the surface into the tuber tissue.
- Secondary pathogens (mainly bacterial) may colonise late blight lesions on tubers causing tuber rotting in storage.
- Recent evidence indicates that infection can spread among tubers.

Control measures

Use of resistant varieties Tubers and early planting is a sustainable approach to late blight control and management in Uganda



3.5.3 Viral diseases

The following potato viruses mainly occur in Uganda: Potato virus S (PVS), Potato leaf roll virus (PLRV). The viruses are transmitted by aphids. Yield loses due to viral infetions may vary from 10 - 80% depending on the type of virus and level of infestation. Viruses reduce crop yields through seed tuber degeneration and reduction in the tuber quality.

Control

Use of clean seed (virus indexed varieties)
Source seed from Registered seed multipliers
Timely spraying of insecticides (Azardirachtin) to control the vectors like aphids which can spread the virus to the potato plant

Symptoms

- **Primary symptoms are rolling of upper leaves especially of leaflet bases.**
- **Leaflets tend to be upright and are generally pale yellow or tinged purple, pink or red.**
- **Tubers of highly sensitive cultivars develop necrosis in the flesh.**
- **Secondary symptoms (from grown infected tubers) include rolling of basal leaves, stunting, upright growth, and paleness of upper leaves.**
- **Rolled leaves are stiff and leathery, and sometimes tinged purple on the undersides.**

Figure 11: Viral symptoms in potato. (Source: https://www.agric.wa.gov.au/sites/gateway/files)

3.6 Pests affecting potato, their identification and management.

3.6.1 Potato tuber moth (PTM)

Symptoms

Tuber tunnels and destruction of leaves.

Severe reduction of tuber quality and yields.

Favoured by warm/dry conditions.

Figure 12: Adult PTM and its effects on leaves and tubers. (Source: https://apps.lucidcentral.org/ppp_v9/images/entities/potato_tuber_moth_298)

3.6.2 Cutworm

Symptoms

- **Holes in tubers, eaten plant stems and wilting of plants like bacterial wilting due to damaged basal parts of the stems.**
- **Cuts down the plant stems of potato shoots, eats into tubers, and reduces tuber quality.**
- **Favoured by warm/ dry conditions.**

Figure 13: Effects of cutworms (Source: https://www.potatoesincanada.com/wp-content/uploads/2019/06)

Control measures

Cultural practices for control of cutworms may include prevention of soil crack with regular irrigation, setting tubers deeply, at least two inches (5 cm.), prompt harvesting, and sanitation of the garden through removal of volunteer plants, crop rotation, clean storage practices, plantation of uninfected seed pieces, and destruction of culling piles. Using pesticides, mainly, Rocket.

3.6.3 Aphids

Deformation of leaves and stunted plant growth.

Sucks plant sap weakening the potato shoots.

Vector of viral diseases and sugary excreta encourages fungal growth on the plant.

Accelerated by warm/ dry weather, and presence of alternative host plants.

Figure 14: Aphids and control measures, (Source: https://www.growerexperts.com)

Control measures include use of clean seed, regular field monitoring, tolerant varieties, use of traps and insecticides.

3.6.4 Potato leaf miner

Symptoms

Leaf miner fly adults inject their eggs into potato leaves. Feeding and egg laying by adult flies appear as

These white leaf specks are seen easily with the naked eye and are a good indication that a potato crop is infested with potato leaf miner fly.

Feeding by maggots causes damage because they kill leaves, preventing the plants from producing large tubers

Warm/dry conditions promote aphid infestation.

Figure 15: Leaf miners' effects on potato (Source: https://www.agric. wa.gov.au/sites/ gateway/files/Pota-toLeafMinerFlyMines)

Control measures

- Chemical control using pesticides in high leaf miner populations.
- Yellow sticky traps for population monitoring and reduction.
- Planting clean seed at the beginning of rains.
- Early planting is the best practice as it reduces costs involved in leaf miner management.

Control of the Potato pests

- Crop rotation
- Destroy cull piles and volunteer potatoes
- Sanitation
- Pheromone traps for trapping the moths

Chemical control:

Spray with appropriate insecticides like Acetamiprid, Azadirachtin, Lambda Cyhalothrin, Flubendiamide.

3.6.5 Integrated Pest and Disease Management

Disease and pest infestation is a very big concern for potato growing. Integrated Pest Management (IPM) is key to an economically sustainable potato farming system (Figure 22), it involves the integration of mechanical, chemical, biological and the cultural approaches in the control of pests and diseases. Some examples include:

- Use of resistant varieties.
- Use of early maturing varieties that are high yielding, cold or drought tolerant. Early maturing varieties contribute to disease escape.
- The management of the most common potato diseases and pests is effectively done with the application of multi-dimensional methods.
- IPM derives its effectiveness from the synergetic actions of the different methods exerted on the pests or the causative agents of the diseases.
- Biological methods control the multiplication of the pests and the causative agents.
- Cultural methods do not favour the predisposing factors of the crop to the pest and disease attacks.
- Chemical methods kill the pathogens or pests.
- Host resistance encourages crop inbuilt modification to escape or tolerate the remaining effects of the disease agents.

The cyclic model of IPM is a potato field and application of the different pest and disease management methods.

- Against diseases, with a few basic precautions such as crop rotation, using tolerant varieties and healthy, certified seed tubers, it can help avoid great losses.
- There is no chemical control for bacterial and viral diseases, but they can be controlled by regular monitoring (and when necessary, spraying) of their aphid vectors.
- The severity of fungal diseases such as late blight depends, after the first infection, mainly on the weather-persistence of favourable conditions, without chemical spraying, can quickly spread the disease.
- Insect pests can destroy potato crops. Recommended control measures include regular monitoring and steps to protect the pests' natural enemies.
- Sanitation, crop rotation and use of resistant potato varieties help prevent the spread of nematodes.

3.6.6 Crop Rotation

Crop rotation is the growing of different crops in a sequence on the same piece of land.

Benefits of crop rotation.

1. Crop rotation rejuvenates soil fertility by incorporation of legumes in the rotation.
2. It reduces disease and pest build-up in the field because it disrupts crop specific pests.
3. Crops of different families should be rotated because:
    - Crops of the same family need the same soil nutrients, while crops of different families may need different soil nutrients.
    - Crops of the same family are infested by the same pests and diseases, while those of different families may be infested by different pests and diseases.

Example of crop families

- Leguminous family e.g., beans, Soya bean, field peas, groundnuts, and others.
- Gramineae (grass) family e.g., all grasses, maize, wheat, millet, sorghum, rice.
- Solanaceae family e.g., potato, tomato, eggplant, pepper, thorn apple, Black nightshade tobacco.
- Bracecae family e.g., cabbages, cauliflower, lettuce.
- Cucumbacae family e.g., cucumber, pumpkins, etc.

Figure 22: Cyclic model of IPM

From the above, potato should not be grown successively on the same piece of field, nor should any other crop from its family follow it. Example, potato should not be followed by or follow eggplant, tomato, pepper, and tobacco.

Ideally, potato should be followed by a cereal crop such as maize, wheat, sorghum which should in turn be followed by legumes and if possible, allow the land to rest under pasture for at least a season before putting back the potato.

Diseases like bacterial wilt stay in the soil for long; however, by following suitable rotation practices and seed hygiene, it may be controlled. The potato cyst nematodes may persist in the soil for a period of over 20 years.

3.6.7 Sustainable Land Management Practices

Improving and maintaining soil health is vital for sustainable and productive potato farming. Fundamental aspects of land management in potato include the following:

1. Complete soil vegetation cover.
    - Minimise loss of soil nutrients from the soil through leaching.
    - Reduced rates of rainfall run-off and soil erosion.

2. Appropriate use of inorganic fertilisers.
- Reduce accumulation of contaminants in the soil.

All interventions that improve soil fertility, soil water availability, and reduce the loss of nutrient-rich topsoil through erosion, will improve productivity.

Soil management interventions such as contour ploughing, ridges, micro-catchments, and surface mulching, to landscape level approaches such as terracing, contour stone bunds or reforestation help reduce the risk of run-off and soil erosion.

Inclusion of organic matter, for example, the inclusion of trees in crop fields, and the improved grazing management of natural pastures are all practices that help to increase the sequestration of carbon. Integrated Soil Fertility Management, that advocates for reduced use of inorganic nitrogen fertiliser.

Contouring ploughing is the process of determination of the gradient of the site being selected for potato growing which is intended to verify the drainage ability of the site. Since potato requires well drained soils, contouring will guide how drainage is ensured.

Figure 23: Proper landscaping (Source: MAAIF/SLM end of project report 2017/2018)

3.6.7.1. Use of contour bands

For flat lands, contour bands are mainly used. Banding is the construction of the different biophysical structures for soil and water conservation.

- **There are many types of bands including terraces, grass bands, agroforestry, tree hedges, trash lines and stone lines.**
- **Grass bands, trash lines, stone lines and tree hedges are simple to make once contouring is complete.**
- **Contour bands are useful in minimising soil water loss due to uncontrolled movement; they improve humus content and soil structure.**
- **Stone lines are a remedy for stony grounds, they control soil erosion but at the same time help to ensure productivity of the remaining ground.**
- **Once an appropriate band is established, water loss is reduced, water infiltration is encouraged, soil nutrients are made available, leaching is minimised; all these enhance crop growth and contribute to climate change adaptation.**
- **Bands can appropriately demarcate crops and in so doing they ease the management of pest and diseases as part of the IPM programme.**
- **Banding also eases cropping pattern, crop rotation and enhances land utilisation.**

Figure 24: Typical contour bands (Left) and typical grass band (Right)
(Source: MAAIF/SLM End of Project Report 2017/2018)

3.6.7.2. Use of both contour bands and trenches

Contour bands and trenches are suitable for land preparation on gentle slopes. Contour trenches are used to guide terracing and rehabilitation of degraded land. It is a climate change mitigating practice which increases crop productivity through soil and water conservation. Like any other trench or channel, contour water retention trenches are constructed purposely to trap, hold, and control surface water run-off down slope to increase its seepage into soil.

- This practice minimises soil erosion, landslides are controlled, loss of topsoil nutrient is minimised and hence crop productivity is improved.
- It is a common practice that trenches are constructed following terraces as either reinforcement, or as an additional structure for sustainable usability of the terrace.
- All these biophysical structures are used in an integrated approach for sustainability and better results

(Source: MAAIF/ SLM End of Project Report 2017/2018)

3.6.7.3. Use of both contour terraces and trenches

A terrace is where a piece of land is contoured into bands in a more continuous manner to contain laps of levelled chunks of land for crop growing in a permanent way. Terraces are very important in soil and water conservation;i.e surface water run-off is controlled, landslides are controlled, nutrient loss minimised; a crop resilient growth condition is created even with minimum precipitation hence the production system is climate resilient.

- Terraces are more specialised bands as compared to other types such as grass tree hedge and stone line bands, especially when it comes to making and application.
- All the other types of bands can be contained in a terrace.
- Terraces can be constructed with reinforcements, especially if the land is not arable but with a gradient that can be tamed, thereby expanding arable land in a more sustainable manner.
- Terracing, if it includes check dams, can also be useful in rehabilitating degraded landscapes. This is done by gully filling, controlling surface water run-off by harvesting it into the check dam, and aiding small scale irrigation in the field using the harvested water.
- Terraces reduce nutrient loss by controlling leaching and encouraging the integration of specialised agroforestry tree species.
- If legume agroforestry trees are used, they help in nitrogen flush capture, used as alternative host crops for some pests and make the system climate smart by aiding applications of the IPM plan.
- Terraces facilitate crop rotation, land furrowing and use of improved furrows with legumes, all of which are cultural climate-smart farming methods.
- Terraces can ease the use of live animals for land fertilisation while the fodder grass band can be cut and fed to animals under tethering

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Water management

All practices and technologies aiming at reducing crop water stress through the improved capture and retention of rainfall or the improved scheduling and application of irrigation water will boost crop productivity. Water management interventions such as rainwater harvesting, and supplemental irrigation are specifically designed to reduce or eliminate the risk of crop water stress and yield reduction

Figure 26: Stone and reversed bench terraces used to increase arable land from semi-fragile ecosystems (Left); forward terraces increase productivity by agroforestry and controlled soil erosion (Right)

3.6.7.4 Agroforestry

Agroforestry plays an important role in global efforts to tackle climate change. Forests and trees on farms e.g., leguminous trees such as calliandra are an important carbon sink and this potential can be increased through afforestation efforts.

In most potato growing areas, farms and forests are often part of rural landscapes, which collectively fulfil the livelihood needs of farmers. Climate-smart potato agriculture will involve the inclusion of tree and grass bands in the fields, and the deliberate planting of trees around the farm. Agroforestry practices in potato farming contribute to climate-smart agriculture through:

Incorporating trees in potato farming systems to improve soil quality, leading to higher and more stable crop yields. By adopting agroforestry practices on farms, farmers can harvest tree products, supplement their diets, and develop additional income streams.

Healthy and diverse ecosystems are more resilient to natural hazards. Trees on farms can be used as shelterbelts and windbreakers, and play an important role in protecting against landslides, floods, and avalanches. Trees also stabilise riverbanks and mitigate soil erosion. Agroforestry practices increase the absorptive capacity of soil and reduce evapotranspiration. The canopy cover from trees can also have direct benefits: reducing soil temperature for crops planted underneath and reducing run-off velocity and soil erosion caused by heavy rainfall (De Leeuw et al. 2014).

Actions that increase tree cover (afforestation, reforestation, and agroforestry) and reduce deforestation and degradation, increase carbon sequestration through increased biomass both above and below ground.

3.6.8 Productive use of energy in potato farming

Energy plays a crucial role in every stage of the agri-food system: in the pre-production stage of inputs; in the production of crops, fish, livestock, and forestry products; in post-production and post-harvest operations; in food storage and processing; in food transport and distribution; and in food preparation (FAO 2013). Energy management is crucial in solar irrigation systems, solar processing, and solar driers.

Efficient management of energy sources and diversification of sustainable renewable energy can reduce reliance on fossil fuels, increase energy supply and access, and reduce the impact on the environment. Based on this, energy management in potato growing is aimed at: (i) increasing energy efficiency (ii) generating a supply of renewable energy from the sector and (iii) broadening access to modern energy services.

The use of renewable energy impacts climate-smart agriculture through:

Increasing energy diversification using renewable energy sources; and opening access to energy sources through efficient and affordable small-scale systems.

Through reducing reliance on fossil energy and adoption of more sustainable means of usage of biomass (such as wood and briquettes, or liquid biofuels), can result in increased time and income becoming available which can be used to enhance resilience to climate change impacts. Other adaptation benefits include improved health, rural development, and increased food security.

Bioenergy, solar energy, and other renewables such as hydro and geothermal energy can replace fossil fuels and other high emissions energy sources (e.g., wood and charcoal), and reduce CO_2 emissions, in both the short and long term. Energy management can help mitigate climate change by carrying out life-cycle assessments of energy systems, identifying sustainable renewable energy resources, promoting efficient, and replicable technologies and examining policies to look for areas of improvement.

3.6.9 Potato pre-harvesting, harvesting and post-harvest handling.

Potatoes are normally harvested three to four (3-4) months after planting depending on the variety. Vines turn yellow and lose leaves, photosynthesis decreases, tuber growth slows, and vines eventually die. Tuber dry matter content reaches a maximum and tuber skins set. To facilitate hardening of the tubers, the stems are cut, and this practice is known as dehaulming.

3.6.9.1. Pre-harvesting

- Maturity of potato is indicated by the change of colour of leaves from green to yellow and the drying of the plant thereafter.
- Haulms should be cut leaving a stem of

about 15cm above the ground.

- Dehaulming is done to avoid any further transmission of diseases through the stem to tuber; to enable the tuber skin to harden and, in case of seed, to control size.
- Clean store and spray with insecticides to avoid any existing storage pests.
- Prepare and clean harvesting materials like gunny bags, baskets to avoid any disease transmission through such materials.
- Harvesting tools such as forked hoes, ordinary hoes etc. should be clean. These may be disinfected or sterilised using fire to curb disease transmission.
- A farmer should ensure that he/she does not pass through any other field when going to harvest; or else he/she may also transmit some of the diseases through the soil that may get stuck to the shoes or gumboots or get in contact with a plant infected with other virus diseases.

3.6.9.2. Potato harvesting

- Harvesting can be done using hands or machines
- Harvesting when it is raining or when the soil is damp leads to development and spread of some diseases such as soft rot.
- Harvesting is supposed to be done when the soil is dry.
- In case it rains unexpectedly when lifted potatoes are still in the field, the farmer should make sure that they are properly dry before taken for storage. It is more convenient to harvest potatoes when the soil is dry

Figure 27: Potato harvesting (Source: author)

3.6.9.3 Potato post-harvest handling

Figure 28: Ambient diffuse light storage facility for potato seed.

Figure 29: Improved individual ambient ware potato store piloted in Eastern Uganda. Credit: (CIP/P.Wauters)

Since the newly harvested tubers are living tissue, and therefore subject to deterioration, proper storage is essential to prevent post-harvest losses of potatoes destined for fresh consumption or processing, and to guarantee an adequate supply of seed tubers for the next cropping season.

Poor storage of ware potato may result in "greening" (build-up of chlorophyll beneath the peel) a condition associated with solanine which a potentially toxic alkaloid. Ware potato tubers should be kept at a temperature of 6 - 8°C degrees, in a dark, well-ventilated environment with high relative humidity (85 – 90%).

Seed potato tubers on the other hand are stored, instead, under diffused light to maintain their germination capacity and encourage development of vigorous sprouts. This method is called diffused light storage and it involves storing the potatoes in thin layers on shelves or trays in natural, diffused (indirect) light with good ventilation. It is a low-cost method to improve seed potato storage

3.7 Opportunities and challenges of CSA in potato farming in Uganda

3.7.1 Opportunities of CSA in potato farming in Uganda

There are several opportunities presented by climate smart agriculture in potato farming in Uganda. These include.

- Insurance services
- Weather information
- Soil testing
- Agriculture extension services
- Agriculture credit
- Agro industrialisation

3.7.2 Challenges of CSA in patato farming in Uganda

The promotion of sound agricultural practices to adapt to climate change faces several barriers and challenges. Barriers that are preventing adoption of climate-smart agriculture practices in potato farming can be divided in two broad categories: physical (such as limited access to appropriate farm equipment and tools, inadequate farm inputs) and non-physical (such as inadequate knowledge and information) barriers. Although, CSA may not necessarily require more equipment and tools than conventional agriculture, the adoption of CSA practices results in costs, which can be divided into three categories:

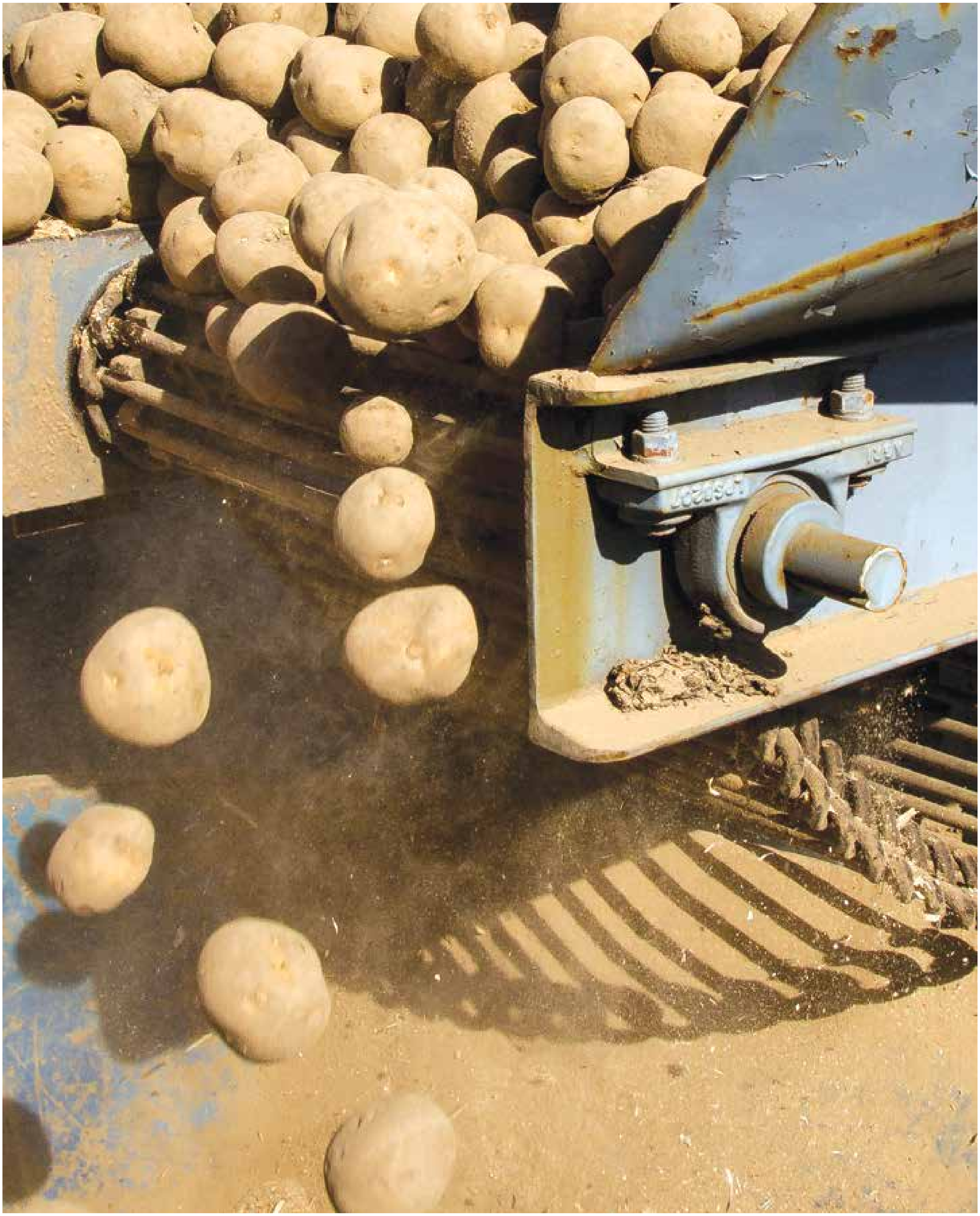
- Investment costs for equipment, machinery, or on-farm structure.
- Maintenance costs, such as recurrent expenses to purchase inputs required to maintain climate-smart agricultural practices.
- Opportunity costs: what farmers forego to adopt the practice.

The use of climate-smart practices and technologies is highly limited among potato farmers in Uganda and below are some of the factors limiting the adoption of these practices:

- Limited access to tailored weather and climate information and services.
- Limited affordable sources of finance to invest in climate smart infrastructure.
- Insufficient sources of improved seed.
- Unreliable input sources, for example, there are counterfeits on the market which end up being destructive to the environment.
- Limited access and availability of technology, for example, solar powered water systems.

Bridging this gap and seeking to fill knowledge gaps require deliberate efforts to stimulate adoption and scaling of CSA among potato farmers. Additionally, adaptation strategies with potential benefit for the entire value chain in Uganda have been reported. Examples of climate-smart business ideas to address high climate related risks and with the potential to improve the viability of the potato value chain in Uganda are:

a) Bundled services, which provide access to drought-tolerant varieties, relevant information, finance, and creation of market linkages.
b) Providing available and affordable water for production.
c) Providing high yielding, drought tolerant and early maturing varieties.
d) Agro-input supply including seed supply.
e) Climate information services and soil testing services. Currently, there are no viable weather-related agricultural insurance products and programmes for potato farmers in Uganda.
f) Access to insurance services.



CHAPTER 4

RECORD KEEPING

4.1 Introduction

This chapter discusses record keeping and record management in potato production. The practice of recording farm activities, farm operations, farm produce, farm inputs and general farm management in a document or documents is referred to as farm record keeping. This is very helpful not only as a reference for farm operations, but also works as a guide to appropriate farm planning and farm development. Potato growing like any other enterprise recommends that various proper farm records are kept, managed, and utilised for effective planning, implementation of the CSA interventions and mitigating the negative effects due to climate change that occur on the farm from time to time. On a given farm, some of the records kept include those pertaining to production, purchase of inputs, labour, sales, and weather forecast.

4.2 Importance of farm records

Records facilitate quick reference to previous activities, and this enables quick and informed decision making. Record keeping also provides useful information for assessing the performance of a business at any time. It also enables development of financial analysis and budgeting. Information to be recorded includes that for human resource, finance, production, operations, storage, and marketing.

4.3 Characteristics of good records

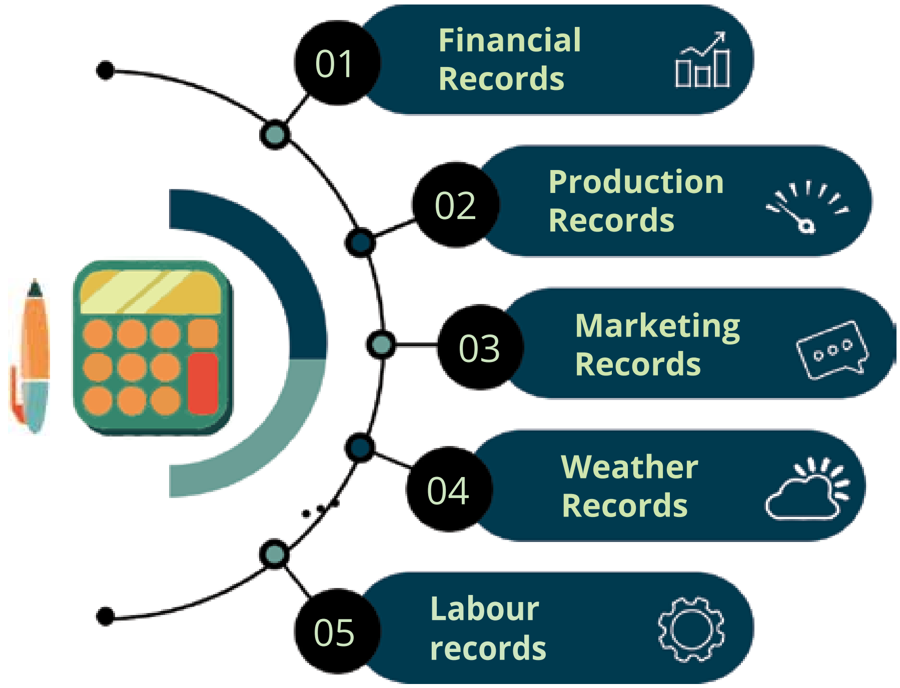
- Records should be simple and easy to use.
- The financial records maintained should have appropriate level of details depending on the type of your business.
- Provides essential information in a timely manner.
- Records must be easy to understand and written in such a way that they can easily be accessed for analysis.

4.4 Types of farm records

Human Resource: These include details of the labour force, leave calendar and profiles of the workers for the farm.

Financial records

- Invoice: A document issued by the seller to the buyer demanding payment for the



goods and services offered. It indicates the quantity, unit price, taxes, and details of the payee.

- Payment voucher: A document prepared to pay service providers after invoices have been received and verified.
- Receipt: A document issued acknowledging payment.
- Pay-in books: Document indicating money you have paid in the bank.
- Cashbook: This contains information of the money banked, received, and spent.

Farm operations records:

These records contain all activities taking place on the farm.

Storage records

- Stock card: A document in form of a card hung on a batch of a food product indicating the quantity of stock you have at that time. You can also have stock card for all inputs at your farm. Keeping track of stock helps with identifying theft, guarding against wastage and unnecessary purchases and planning for production.

- Stack Card: A card fixed to a bag stack used to keep a tally of the number and weight of bags of potato either added or removed from the stack.
- Goods Received Note (GRN): A document issued out to acknowledge receipt of goods.
- Received Stock ledger books: Records of the stock that has been received in the store/ware house.
- Outgong stock ledger books: Records of stock that has been removed from the store.
- Quality control records: Records for quality status of the stored potato.
- Fumigation records: Records indicating fumigation activities carried out on the premises.

Marketing records

- List of customers
- Price lists
- Details of buyers and quantities desired by the market.

4.5 Profitability analysis of potato production

Description	**Stage**	**Sub-stage**	**Item**
A farmer will spend a total of Ush.5.1million per acre on inputs, labour and post-harvest handling.	Production expenses	Inputs	Seeds (80kg bags)
			Fertilizer NPK (50kg bags)
			Fungicides (mancozeb)
			Pesticides
			Bags
			Sub-total
		Labour	Land preparation
			Planting
			Second Cultivation
			Dehaulming
			Fertilizer and pesticide application
			weeding
			Sub-total
		Post-harvest handling	Harvesting and collection
			Transport
			Storage
			Packing and loading
			Sub-total
		Total Expenses	
Profits for a farmer using good agronomic practices as seen above are about Ush.5.8 million per harvest per acre	Revenues	Potatoes	Revenue (120kg bags)
		Profitability per acre	

Item type	Quantity per acre	Frequency per season	Unit cost	Total cost (UGX)
Kgs	12	1	200,000	2,400,000
Bags	4	1	110,000	440,000
Misc	10	1	13,000	130,000
Litres	2	1	20,000	40,000
Number	100	1	1,000	100,000
				3,110,000
Man days	1	1	400,000	400,000
Man days	1	1	250,000	250,000
Man days	1	1	250,000	250,000
Man days	1	1	35,000	35,000
Man days	4	1	56,000	224,000
Man days	1	2	140,000	280,000
				1,439,000
Man days	1	1	280,000	280,000
Bags	84	1	2,500	210,000
Misc	1	1	70,000	70,000
Misc	1	1	70,000	70,000
				560,000
				5,109,000
Bags	84	1	130,000	10,920,000
				5,811,000

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ANNEX 1: ACCESSING FINANCIAL RESOURCES.

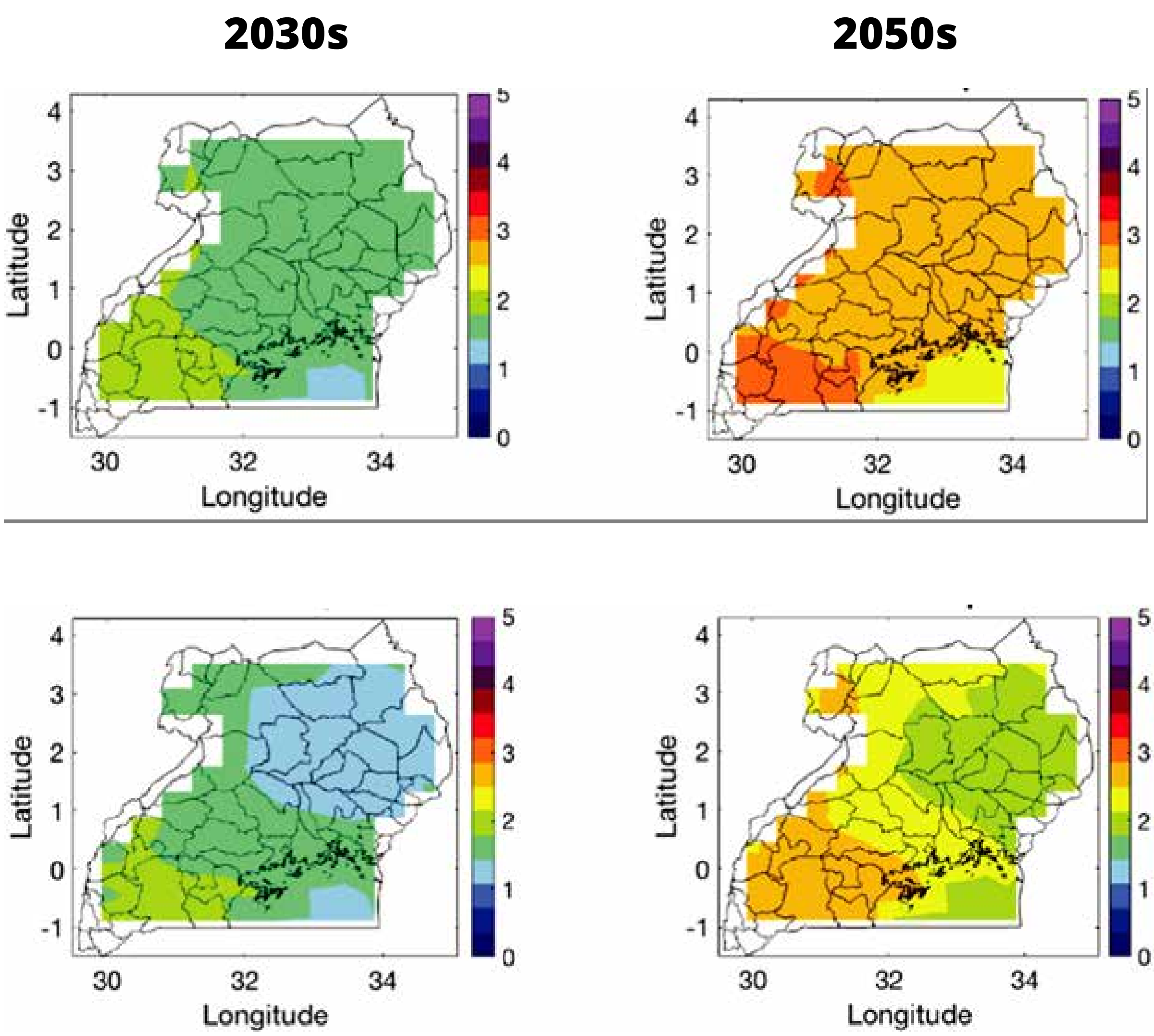
Accessing credit increases the capacity to adopt technologies such as resistant and high yielding varieties for sustainable production in the context of climate change adoption. Information is provided below on the types of credit packages provided by government and some finance institutions in Uganda.

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.

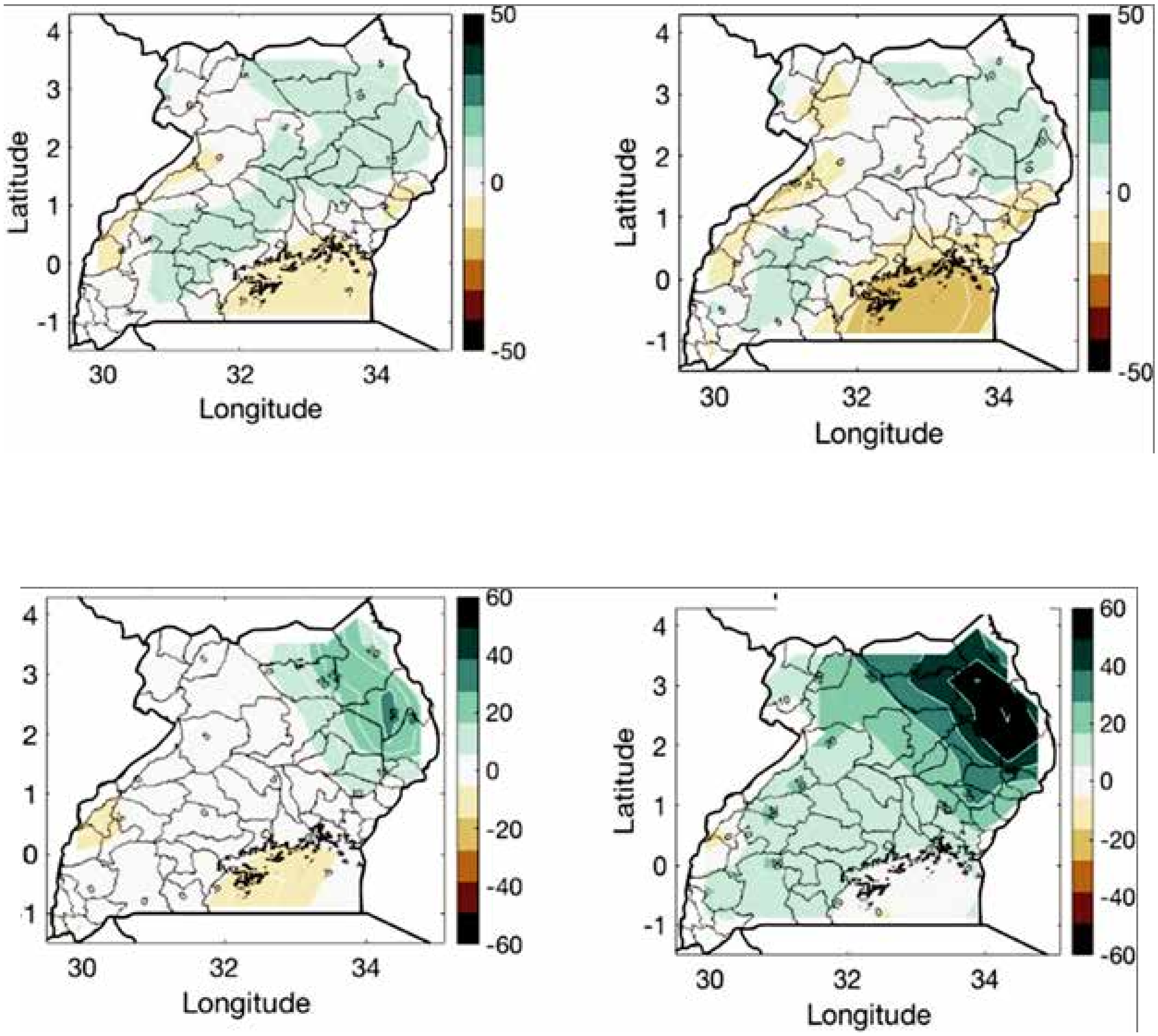
ANNEX 2: CLIMATE PROJECTION MAPS



Figures in degrees

Figure 6: Projected mean changes in temperature for 2030s (Left) and 2050s (Right) under the RCP8.5 emission scenario (worst-case scenario), relative to the reference period (1961-2005).

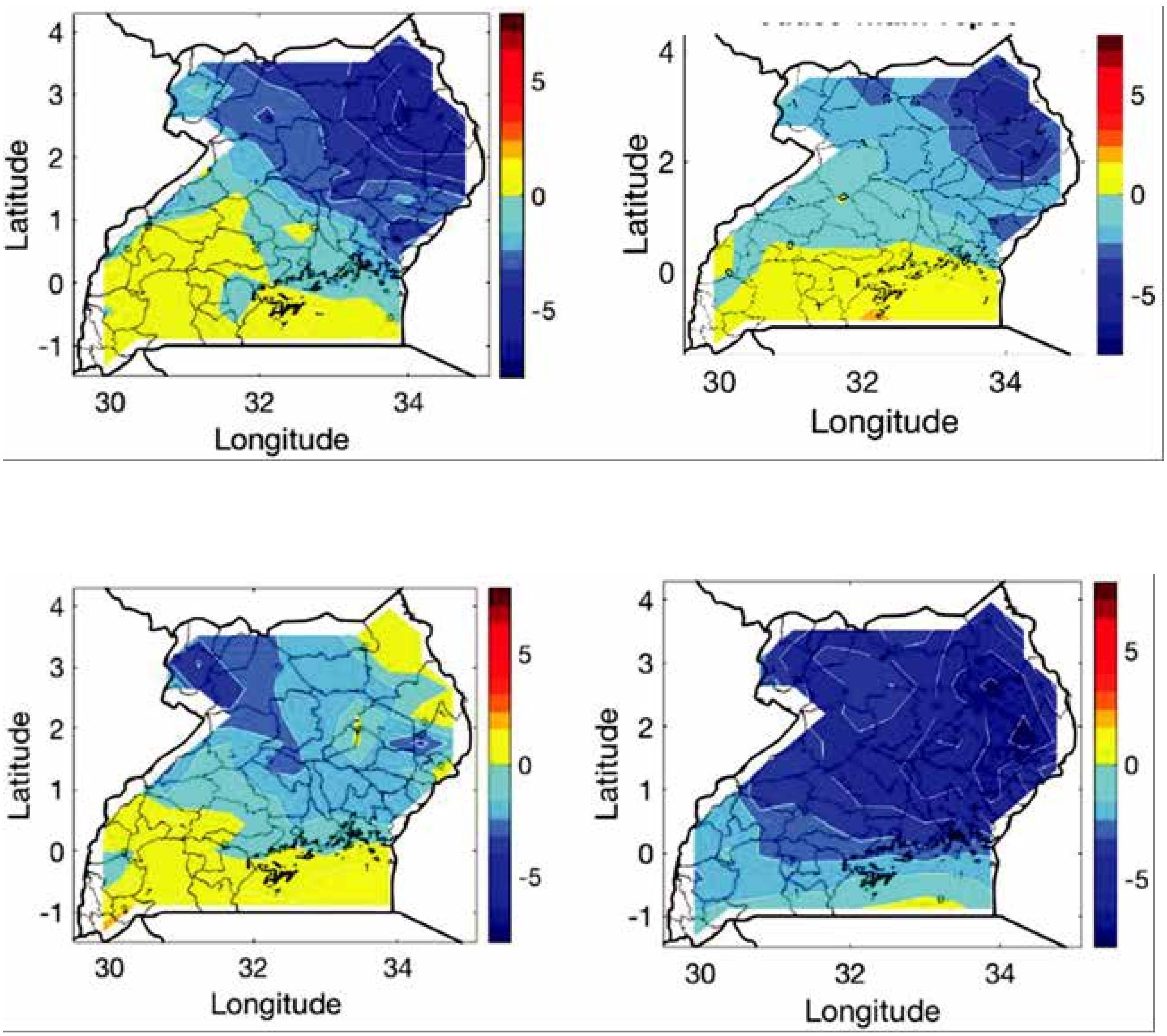
2030s **2050s**



Figures are in millimeters

Figure 7: Projected seasonal mean changes in rainfall (in percentage) for 2030s (Left) and 2050s (Right) under the RCP8.5 emission scenario relative to the reference period (1961-2005).

2030s **2050s**



Figures are in millimeters

Figure 8: Projected seasonal mean changes in consecutive dry days (CDD) for 2030s (Left) and 2050s (Right) under the RCP8.5 emission scenario, relative to the reference period (1961-2005).

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