MAAIF

Ministry of Agriculture,
Animal Industry and Fisheries

Soybean Value Chain

A CLIMATE SMART AGRICULTURE APPROACH

AN EXTENSION WORKERS MANUAL

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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.

Soybean is one of the priority oil crop commodities which will contribute towards the attainment of the AGI goal. The commodity is a multipurpose legume crop used for food, feed, industrial processing, and source of income.Soybean production in Uganda is predominantly small scale estimated at 107,600MT from the estimated production area of 189,700Ha (UBOS 2018). This gives an average of 1.2MT/Ha against a research average of approximately 2.5MT/Ha.

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. The recent climatic changes have exacerbated these existing challenges. In response to the climatic change, Makerere University in collaboration with NARO, has developed and released improved soybean varieties (Maksoy series) in Uganda to boost the soybean productivity and resilience.

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, the Ministry of Agriculture, Animal Industry and Fisheries in collaboration with SNV have developed a harmonized Soybean extension workers manual.

The objective of this manual is to sustainably transform soybean value chain from a predominantly subsistence, low input, and low productivity, to a fully commercialized farming business, with the expectation of 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 technical staff and stakeholders that provided input into the drafting and validation of this document; 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 soybean 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 soybean value chain and its management in times of climate change. It is comprised of six chapters of coordinated content as summarized below. First chapter of this manual is focused on the soybean and its development and also describes the status of soybean in Uganda and its significance. Chapter two introduces the concept of climate change and the three pillars of climate smart agriculture which are important for decision making in implementation of Climate Smart Agriculture (CSA) practices and focuses on the major constraints to soybean production which are attributed to weather and climatic variations and how they impact productivity. Chapter three presents the climate resilient field management processes which begin with selection of the appropriate soybean variety to planting and pests which include insects, aphids, bugs, worms, and others; and diseases such as fusarium root rot and their management and control methods including integrated pest management prioritizing biological control and organic substances. The safe use of agrochemicals is recommended as a last option.

Chapter four describes the best post-harvest management practices and technologies with some illustrations for emphasis. Chapter five introduces the component of record keeping and calculation of profits and losses and shows potential for generating a gross income per acre. The manual integrates a gender component and maps out its interaction with CSA to support users in appreciation of gender responsiveness in implementation of CSA interventions and planning for capacity enhancement. For instance, early post-harvest handling is done by women and as such, tools, knowledge, and skills for the same would ensure women are largely involved. It is critical for the users of the manuals to appreciate the dynamism of this information and make provision for adjustments based on the setting and the times. The manual concludes by presenting an array of environmental restoration practices which are key in climate smart agriculture.

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ABBREVIATIONS

ASL:	Above Sea Level
CCAFS:	Climate Change, Agriculture and Food Security
CDD:	Consecutive Dry Days
CGIAR:	Consultative Group for International Agricultural Research
CRAFT:	Climate Resilient Agribusiness for Tomorrow
CSA:	Climate Smart Agriculture
CWD:	Consecutive Wet Days
FAO:	Food and Agricultural Organisation of the United Nations
GHG:	Greenhouse Gas Emissions
IITA:	International Institute for Tropical Agriculture
KAR:	Kings African Rifles
MAAIF:	Ministry of Agriculture, Animal Industry and Fisheries
SNV:	Netherlands Development Organisation
VSLA:	Village Savings and Loans Association
WUR:	Wageningen University and Research

CHAPTER 1

BACKGROUND

1.1 Introduction

Soybean is both food and a cash crop for many farmers in Uganda. The crop generates revenue for all value chain actors from input business to the consumer market (Stagnari et al., 2017).

The Soybean enterprise presents several options for value addition and attracts high demand due to its high average protein content of about 40%. This wealth in protein is the reason why soybean is also processed into soy milk, a valuable protein supplement in infant feeding and soybean oil cake which is the most important protein component in the animal feed industry. Soybean seeds also contain about 20% oil on a dry matter basis, and this is 85% unsaturated and cholesterol-free. With these qualities, soybean is among the major industrial food crops and a prime source of vegetable oil in the international market because it is more protein-rich than any of the common vegetable or animal food sources.

1.2 Importance of Soybean

Soybean is a major source of protein and contains significant amounts of the essential amino acids for the human body.

Its oil contains linolenic acid (omega-3 fatty acid), which reduce the risk of heart disease and saturated fatty acids (Clemente and Cahoon, 2009).

Soybean is the primary ingredient in many processed foods, such as margarine, soy ice cream, soy milk, soy yogurt, soy cheese, soy cream cheese, soybean oil, tofu, veggie burgers, soy nut butter, soy crisps, etc.

It is also used to make soybean infant formulas used by lactose-intolerant babies, who are allergic to cow milk proteins (Merritt and Jenks, 2004). Consumption of soybean-based foods may also reduce the risk of colon cancer, maybe, due to the presence of sphingolipids (Symolon et al., 2004).

Soybean is also a raw material for industrial products including oils, soap, cosmetics, resins, plastics, inks, crayons, solvents, and clothing.

Soybean oil is the primary source of biodiesel (Radich, 2004). It has ability to fix nitrogen from the atmosphere and thus replenishes and improves soil fertility, minimising fertilisation costs for small holder farmers (Zortea et al., 2018, Van Vugt et al., 2018).

1.3 Status of Soybean and its Production in Uganda

Soybean production in Uganda was on an upward trend and its production increased from 158,000 to 180,000 metric tonnes between 2004 and 2010. However by 2018, Soybean production in Uganda was at 107,600MT from the estimated production area of 189,700Ha (UBOS 2018), an average of 1.2MT/Ha against a research average of approximately 2.5MT/Ha.
To date, Makerere University in collaboration with NARO, has developed and released improved soybean varieties in Uganda to boost the soybean productivity, namely: Maksoy 1N, Maksoy 2N, Maksoy 3N, Maksoy 4N, Maksoy 5N, Maksoy 6N (Tukamuhabwa and Obua, 2015).

To achieve higher yields, soybean farmers need to be flexible and willing to do things differently including: taking farming as a business, farmer to farmer learning, and adopting improved practices and technologies. It is expected that simplifying information and knowledge as well as translating it into local languages and disseminating it widely through various channels will be one approach that will contribute to increased soybean yields.

Table 1: Soybean acreage per household and yields (kg/acre) in the regions of Uganda

Region	Acres	Average yield - kgs
Northern	1.30	728.7
Western	1.02	282.3
West Nile	0.52	100.4
Eastern	1.51	632.6
Central	0.76	259.4
Overall Average	1.02	400.7

(Tukamuhabwa et al., 2016)

CHAPTER 2

SOYBEAN PRODUCTION AND CLIMATE CHANGE

2.1. Introduction to climate change

Climate change refers to significant change in global temperature, precipitation, wind patterns and other measures of climate change that occur over several decades or longer.

2.2. Causes of climate change

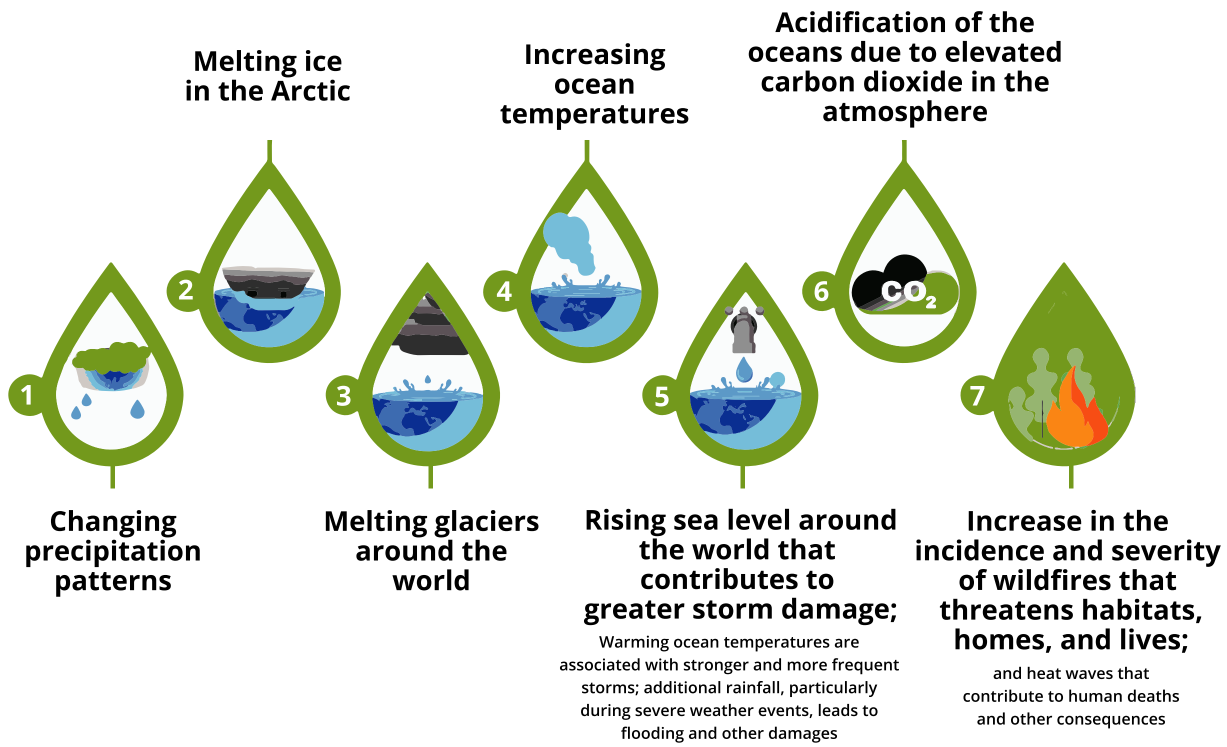
Both human and natural factors contribute to climate change. Human activities, such as agriculture and deforestation, are the primarily causes of climate change. This emits greenhouse gases mainly carbon dioxide into the atmosphere. The burning of fossil fuels, such as oil and coal, also contributes to the production of greenhouse gases that cause climate change. Key greenhouse gases include carbon dioxide, methane, and nitrous oxide. However, 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 CO2 into oxygen. The atmospheric concentration of CO2 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. 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 to 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 trends in Uganda

Climatic projections show that by the 2050s, the entire country will have overall increased temperatures. The projections show that temperature increases will be higher in the south-west and western regions of the country where temperatures are predicted to rise by 3.2°C during the long rains [March, April, and May (MAM)] and 2.8°C during the short rains [September, October, November and December (SOND)] compared to 2.8 and 2°C for the rest of the country during the same periods. Projections show increased rainfall particularly in the northern and north-eastern

parts of the country by as much as 40-50%. These changes will affect the yield of soybean which is predicted to reduce by 800 kg per hectare in the areas of Sironko and Tororo in eastern Uganda and yet the current average yield is 700 kg per hectare. In Mbale, yield is expected to reduce by 1,000 kg per hectare. Practice of CSAs needs therefore to be adopted today. Specific CSAs targeting the south-western, western, northern, and north-eastern Uganda are suggested in Chapter 3.

2.5 Environmental constraints

Abiotic stress due to global climate change also affects crop yields (Courtney et al., 2017). High temperature or the water stress imposed during soybean seed development causes changes in seed coat morphology leading to negative effects on seed quality, seed germination rate, and seedling vigour which eventually reduce yields (Smith et al., 2008). Other abiotic factors include seed quality during storage period, moisture content of seed, environmental factors during pre- and post-harvest stages, duration of storage, and temperature and humidity of the storage environment (Biabani et al., 2011). Droughts also induce pod shattering which causes yield losses ranging from 57 - 175 kg/ha and 0 - 186 kg/ha in susceptible and intermediate susceptible soybean varieties respectively (Tukamuhabwa et al., 2002).

2.6 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. The demographic changes can occur due to landslides and floods that alter rural farming settlements, lifestlye changes and food consumption pattern due to changes in cropping systems. Other factors such as monocropping results in exhaustion of soil nutrients and depletion of soil fertility.

2.7 Biotic constraints of climate change

Climate change influences the virulence of various pests and diseases for instance the occurrence of soybean fungal diseases and aphids which is likely to be more prevalent with rising temperatures and humidity. This will imply more frequent use of pesticides and emergence of new evasive weeds. Frequent use of pesticides results in resistance.

Distortion of the known pests in an area will influence the phytosanitary measures and regulations more frequently due to climate change. For instance the migratory pests like African army worm and desert locusts that attacked and destroyed crops in the soya growing regions of mainly northern and eastern Uganda.

2.8 Other constraints of climate change

Constraints include wilt due to drought, leaching due to too much water and too much vegetation due to heavy rains.

Processing equipment for soybean is also unavailable in many areas and people lack knowledge of soybean preparation for home consumption (IITA, 2009).

CHAPTER 3

CLIMATE RESILIENT SOYBEAN PRODUCTION

3.1 Introduction

The chapter explains concepts of a resilient system and the three pillars of climate smart agriculture. It also describes the key characteristics of climate smart agriculture and the impact on gender dimensions. The chapter also outlines the soybean production requirements, soil water conservation practices including terracing and mulching. It also highlights the soybean production cycle from variety selection, germination testing, inoculation, planting, germination, and weed management.

3.2 Climate Smart Agriculture

The principal goal of CSA is food security; while productivity, adaptation, and mitigation are identified as the three interlinked pillars necessary for achieving this goal.

3.2.1 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.

3.2.2 Key principles of CSA

CSA systematically adds climate change into planning and development of agricultural production to eventually produce sustainable systems.

Integrating many goals and managing options

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

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.

Many entry points at different level

Climate Smart Agriculture 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

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.

Gender 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 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.

3.3 Soybean production requirements

3.3.1 Ecological requirements should guide site selection.

RAINFALL:
Soybean is a moderately drought tolerant crop requiring a minimum of 400mm of well distributed rainfall during the vegetative growth period which lasts 3 - 4 months. High moisture requirement is critical at the time of germination, flowering and pod-forming stage. Short duration varieties are recommended in areas where soybean is produced under rain-fed conditions. However, dry weather is necessary for ripening.

TEMPERATURES:
Soybean grows well under warm and humid conditions. For good germination, soil temperatures should be above 15°C and for growth about 20 - 25°C.

SOILS:
Soybean can grow on a wide range of soils, but it thrives best on sand, clay loams and alluvial soil of good fertility. The soils should be well drained, fertile, and rich in phosphorus and calcium with a pH range of 5.6 - 7.0. Problems may occur in fields where the pH is outside of this range. High-fertility, medium-textured soils grow large soybeans, whereas clay soils tend to grow shorter soybeans with a more open canopy. Lighter soils also struggle to retain moisture.

ALTITUDE:
Soybean performs well between 0 - 2000 m above sea level. At altitudes higher than 2000 m ASL, the late maturing varieties take as long as 180 days (6 months), but they yield more than the early maturing varieties (Online: Shamba.com)

3.3.2 Land preparation

Tillage is one of the major methods of land preparation. The common tillage options include:

a) No-tillage: Soil is left undisturbed, and seed is directly seeded in the opened slot. However, weed control challenges prevent widespread adoption of no-till.
b) Minimum tillage: The concept of minimum tillage is widely accepted in large scale mechanised crop production systems to reduce the erosive impact of raindrops and to conserve the soil moisture with the maintenance of soil organic carbon. Conservation tillage improves the infiltration rate and reduces run-off and evaporation losses. It also improves soil

health, organic matter, soil structure, productivity, soil fertility, and nutrient cycling, and reduces soil compaction. Less tillage reduces soil compaction and saves time, energy, and labour.

c) Conventional tillage: Crop residue is incorporated into soil with little residue left on soil surface.

3.3.3 Soil fertility management

Soybean requires fewer inputs especially inorganic fertilizer because it fixes its nitrogen. Soil testing is recommended to understand fertility needs, both in terms of cost and environmental factors. The essential elements required for soybean growth are shown in Table 3.

Table 3: Essential elements of soybean

Essential Element	Symptoms of Deficiency	Importance of the Element
MICRO-NUTRIENTS		
Nitrogen (N)  The N deficient leaf	• Lower leaves become chlorotic or pale green	• Chlorophyll (photosynthesis) • Amino acids (protein) • Nucleic acids (DNA)
Phosphorous (P)  Phosphorous deficient soybean plants	• Lower leaves become chlorotic or pale green • Plants may have small • Plants appear stunted overall	• Plant development • Nodule formation and N fixation • Pod formation through to seed maturity

Potassium (K)  Potassium deficiency showing chlorosis of the lower leaves	• Older leaves begin to yellow • Chlorosis, starting at the tip and moving down the leaf margin as the plant translocate K from older tissue to new growth	• Photosynthesis • Tolerance to drought • Pod filling
Calcium (Ca) 	• Reduced leaf expansion, primary leaves are often cup-shaped when they emerge • Brown spots on young leaves and premature leaf death occurs	• Required for proper development of cell walls in the plant, root growth • Development and transportation of food across the plant
Magnesium (Mg) 	• Deficiency symptoms are in the beginning light green to yellow along the leaf veins. • The leaf base eventually gets whitish to light brow patches along the leaf veins and leaf margins. • Leaf edges also become whitish in colour	• Is important in the formation of chlorophyl which is very important in production of food for the plant
Sulphur (S) 	• All leaves may become yellow, resulting in stunted growth • Sulphur deficiency Unlike nitrogen, sulphur deficiency appears on younger leaves • Leaf symptoms resemble those of N or P deficiency but the development of thin, hard and elongated stems is one way of knowing that it is sulphur deficiency	• Required to fix nitrogen in the soil • It is important in seed development • It is important for the photosynthesis process which produces food for the plant

***Micronutrients** deficiencies are rare but can occur in highly weathered soils, organic soils or high pH soils*

Iron (Fe) 	• Interveinal chlorosis of leaves • Leaf veins remain dark green during V1 to V3. • Severe IDC that extends beyond V3 can impact yield	• Is important ithe formation of chlorophyl and the process of photosynthesis which provide food for the plant
Manganese (Mn) 	• Occurs in the mid growth stages of the crop during which leaves will become yellow in patches of the field	• Is important in the proper functioning of enzymes involved in the process of photosynthesis which is very
Boron (B) 	• Deficiency symptoms consist of stunting, swollen nodes, and the death of the growing points such as buds. Older leaves may become thick, dark green, leathery and cupped downward. Old leaves may take longer to fall off the plant	• Boron is essential for all plant growth and is known to promote flowering and seed formation

3.3.4 Nitrogen (N) fixation

Nitrogen fixation, facilitated by rhizobia bacteria, is the process that converts unusable nitrogen gas (N2) to useable ammonia (NH3). In soybean, these bacteria live in root nodules. The symbiotic process of nitrogen fixation begins shortly after crop emergence and becomes the main source of nitrogen for plants within two subsequent weeks. The plant continues to supply nutrients, energy and housing to the rhizobia bacteria and the bacteria in turn fix nitrogen into its usable form within the soybean plant. Soybean being a legume, can fix nitrogen in the soil from the atmosphere through nodules that will develop on its roots and rhizobia that occupy the nodules. This nitrogen will be used by the soybean crop, and some will remain in the soil. The ability to fix nitrogen can be increased by inoculating the soybean with rhizobia. An average of 50 to 60% of soybean nitrogen requirements are fixed by the crop. Nodules turn pink or red inside when nitrogen fixation occurs, whereas non-fixing nodules are white or brown inside.

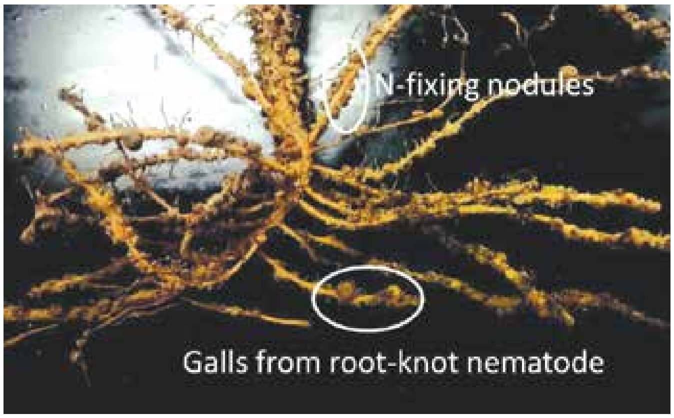


Figure 7: Nitrogen Fixation nodules

Nitrogen fixation may be negatively impacted by extreme heat or cold, excessive soil moisture that depletes oxygen, salinity, or compacted soils. Using nitrogen from the soil requires less plant energy; therefore, soybean prefers to obtain N in this manner. When there is too high N in the soil, the field becomes poor for soybean crop because soybean will not maximise nodulation, yet when soybean is properly inoculated, crops do not require an in-season fertiliser.

Figure 10: (1) Root nodule formation; (2) Soybean roots with healthy nodules; (3) healthy nodules actively fixing nitrogen. *(Source: BASF USA, 2015; Jennifer Dean in USDA, 2015)*

3.4 Pests and diseases and their management

Table 2: Major pests and diseases of Soybean and their management

Pests	Damage	Management
Soybean stem borers 	Larval tunnelling and eventual girdling of main stem which may cause lodging.	Harvesting as early as possible to avoid lodging
The groundnut leaf miner *Aproaerema modicella (Webworm)* 	Soybean yield losses ranging from 37 - 65% in Uganda (Namara et al., 2019).	Moderately resistant exotic varieties and two commercial lines have been identified among the 160 genotypes that were tested in Uganda.
Soybean aphid 	• Feeds on stems and undersides of leaves leading to stunted growth. • reduction in number of pods, seed size and quality; lower yield. • Vector of Soybean mosaic virus (SMV).	• Application of insecticides. • Growing Soybean aphid-resistant varieties. • Strip cropping of soybean among maize or wheat. • Enhancement of soil K deficiencies. • Generalist predators.

Stink bugs 	• Feed on pods and seeds and affect. • seed germination, quality which leads to pod distortion. • The pods eventually detach from the plant. • Yield losses ranging from • 25% to 60% -The bugs inject toxins into pods and seeds leading to necrosis. • The affected pods are shrivelled and the seeds are discoloured. • Damage by this pest can cause low seed oil content.	• Remove any nearby weeds or overgrowth, as they commonly use these for cover. Also, remove any hiding places like old boards, logs, etc. • Most insecticides labelled “for use on soybeans” provide effective stink bug control. Insecticide applications are generally made from pod set (R3) to full seed set (R6). It is not necessary to apply the insecticides before or after these stages. After an insecticide treatment has been made, be sure to scout the field to ensure that stink bug populations remain under control. Always read and follow the direction provided on the label of the insecticide.
Green semilooper *(Thysanoplusia orichalcea)* 	• Causes window like feeding • patterns underside of the leaves. • Severe infestation causes defoliation of the whole plant.	• Large populations of soybean loopers are usually observed during late season. Thus, later-maturing soybeans are at greater risk • to infestation. Soybeans are more tolerant to defoliation as they mature, with the R3 – R5 stages being the most sensitive and R6 much less so (you can probably tolerate over 50 or 60% defoliation at this stage). R7 soybeans are safe from yield loss to defoliators like loopers. • If plants are in the late vegetative stages, consider applying an insecticide when approximately 35% of foliage has been lost, or when soybean looper worms (one-half inches or longer) are present with 8 or more per row-foot. • If plants are blooming or filling pods, then plan to apply the insecticide when at least four worms (one-half inches or longer) are present per rowfoot or if there has been more than 20% loss of foliage. • Soybean loopers are sometimes difficult to control with insecticides because resistance has been confirmed for pyrethroid, carbamate, and organophosphate insecticides. Always read and follow labels on the packaging of the insecticides.

Bean Leaf Beetle 	• Adult bean leaf beetles can transmit various plant pathogenic viruses including: • Bean pod mottle virus (BPMV), • Cowpea mosaic virus, Cowpea • chlorotic mottle virus, and • Southern bean mosaic virus.	• Application of insecticides. • 5 - 10% of the field can be planted as a trap crop by sowing 2 - 3 weeks earlier than recommended. • The trap crop can be treated with insecticide within two weeks after emergence to kill colonising bean leaf beetles, and thus limit infestation of adjacent soybean fields planted at recommended dates.
Bruchid beetles *(Callosobruchus spp)* 	• Lays eggs on pods before harvest and extends into storage. • Damage affects seed quality and germination. • Can cause losses of up to 100% in 3 - 6 months of storage.	Bruchids in soybean can be controlled by applying rice husk ash at a rate of 1-10% of the seed weight.
The root-knot nematodes 	• Cause damage resulting into yield losses ranging from 25 - 70%. • Nematodes produce numerous galls on soybean roots due to feeding and laying of eggs. • The infected plants become stunted, yellowish and wilt.	• Destroy crop plants, particularly the roots, as soon as possible after harvest to avoid the build-up of nematodes in the soil. • Proper weed control. • Remove soil and plant roots from tillage and planting equipment before using them in another field. • Clean shoes and other implements that may carry soil from infested fields into non-infested areas.

Diseases	Damage	Management
Soybean rust: caused by *hakopsora pachyrhizi* 	• The infected leaves have small tan to dark brown or reddish-brown lesions on which small raised pustules ("bumps") occur on the lower surface of the leaves. • Pustules produce a large number of spores. • Brown or rust-colored powder falls when severely infected leaves are tapped over a white paper or cloth. • Severe infection leads to premature defoliation.	• Planting resistant varieties. • This is the best option to control disease. • Planting in a good seedbed. Poorly drained or compacted soil should be avoided. • Planting seeds treated with fungicides. • Rotating crops with maize to prevent the increase in inoculum levels in the field. • Use of a foliar fungicide except on high-value fields (e.g., seed production fields) or in years when the weather is especially favourable for disease development.
Bacterial pustule: caused by *Xanthomonas axonopodis pv. Glycines* 	• Specks to large, irregular spots with raised light coloured pustules in the elevated centres of the spots on the lower surface. • The elevated pustules sometimes have cracks in them. • Later lesions join together, and the dead areas tear away to give a ragged appearance to the leaves. • Symptoms of rust and bacterial pustule sometimes appear similar.	• Planting resistant varieties. This is the best option to control disease. • Planting in a good seedbed. Poorly drained or compacted soil should be avoided. • Planting seeds treated with fungicides. • Rotating crops with maize to prevent the increase in inoculum levels in the field. • Use of a foliar fungicide except on high-value fields (e.g., seed production fields) or in years when the weather is especially favourable for disease development.

Bacterial blight: caused by *Pseudomonas syringae pv. Glycinea* 	• Small, angular, water-soaked lesions. • As infected tissues die, the centres of the lesions soon turn dark reddish-brown to black, surrounded by a water-soaked margin bordered by a yellowish green halo and fall out so that leaves appear tattered or shot-holed. • Infected young leaves are chlorotic.	• Planting resistant varieties. This is the best option to control disease. • Planting in a good seedbed. Poorly drained or compacted soil should be avoided. • Planting seeds treated with fungicides. • Rotating crops with maize to prevent the increase in inoculum levels in the field.
Frogeye leaf spot: caused by *fungus Cercospora sojina* that survives in infected soybean residues and seeds. 	• Brown, circular to irregular spots with narrow, reddish-brown margins on the leaf surfaces. • The central areas of the spots turn ash grey to light brown. • Sometimes lesions can develop on stems and pods from where mature seeds are infected. • Infected seeds may show discoloration of the seed coat that ranges from small specks to large blotches of light to dark grey or brown.	• Planting resistant varieties. This is the best option to control disease. • Planting in a good seedbed. Poorly drained or compacted soil should be avoided. • Planting seeds treated with fungicides. • Rotating crops with maize to prevent the increase in inoculum levels in the field. • Use of a foliar fungicide except on high-value fields (e.g., seed production fields) or in years when the weather is especially favourable for disease development.

Phytophthora root and stem rot *(Phytophthora sojae)* 	• Seed rot Pre and post-emergence damping off. • Older plants may turn yellow and leaves may wilt. • Roots appear rotten and a brown discoloration extends from the soil line up into branches and petioles. • The lateral and tap roots are destroyed. • The stems appear water soaked, with chocolate-brown lesions that start at the soil line and move upward and may cause girdling. • Inner stems may or may not appear brown in colour. • Plants wilt and may die if infection is severe	• Provide for proper water drainage in your garden or field. • Plant treated seeds. • Practise crop rotation. • In case of risk avoid the zero tillage practices.

3.5 Soil and water conservation practises

The measures involved in soil and water conservation are described below.

3.5.1 Contour farming

Contour farming is one of the most used agronomic measures for soil and water conservation in hilly agroecosystems and sloping lands. All the agricultural operations, vis-a-vis ploughing, sowing, inter-culture, etc., are practised along the contour line. The ridges and furrows formed across the slope build a continual series of small barriers to the flowing water which reduce the velocity of run-off and thus reduce soil erosion and nutrient loss. This conserves soil moisture in low rainfall areas due to increased infiltration rate and time of concentration, while in high rainfall areas, it reduces the soil loss. In both situations, it reduces soil erosion, and conserves soil fertility and moisture, thereby improving overall crop productivity. However, the effectiveness of this practice depends on rainfall intensity, soil type, and topography of a particular locality.

3.5.2 Crop rotation

Crop rotation is the practice of growing different types of crops in succession on the same field to get maximum yield from the least investment without impairing the soil fertility. Diversification of crops varieties, including replacement of plant types, cultivars, and hybrids, with new varieties intended for higher drought or heat tolerance is advocated as having the potential to increase productivity against temperature and moisture stresses.

Crop rotation sequences are also critical decision-making criteria for a soybean growing site. Crop rotation sequences are important for diversity and lead to improved yield due to better weed, disease, and insect control. Short rotation sequences with other crops such as peas and dry beans can lead to an increase of white mold. Farmers should make sure to have a longer rotation between these crops or to select resistant varieties to reduce the susceptibility of sclerotinia stem rot (white mold) in the soybean crop. In the case of phytophthora root rot, it can be found in dry beans and potatoes. If maize is to follow the soybean crop, consider selecting an earlier maturing variety and planting the soybean earlier to allow timely planting of maize. Not growing soybeans for one or two years in the same field improves yield per acre. The best rotation benefits are realised when cereals follow the soybean crop.

Benefits of crop rotation include:

- Improvement in productivity and risk of failure of one of the crops in the system.
- Replacing soybean and introducing intercrops such as maize, sorghum and finger millet increases overall productivity and ensures sustainable crop production.
- Better planning of fields to strategically adopt to the cycle and always have soybean production.
- Reduction in cost of cultivation: Income of farmers can be substantially raised due to the combined yield of the crops, lesser risk, and more secure incomes under uncertain weather conditions.
- Counteracting the relationship between host-insect-pest, pathogens/weeds.
- A rotation with high canopy cover crops helps in suppressing weed growth, decreases pests and disease infestation, and increases input use efficiency.
- Improvement in soil fertility and soil physical environment: There is optimum use of native and applied nutrients, effective use of available/recipient water, reduction soil erosion, restoration of soil fertility and conservation of soil and water.

3.5.3 Cover crops

The close-growing crops having high canopy density, known as cover crops, are grown for protection of soil against erosion. Legume crops have good biomass to protect soil compared to the row crops. The effectiveness of cover crops depends on crop geometry and development of canopy for interception of raindrops which helps in reducing the exposure of soil surface to erosion. It has been reported that legumes provide better cover and better protection to land against run-off and soil loss as compared to cultivated fallow and sorghum. The most effective cover crops are cowpeas, green gram, black gram, groundnut, etc.

Advantages of cover crops include.

- Protection of soil from the erosive impact of raindrops, run-off, and wind act as an obstacle to water flow, reducing flow velocity, and there by reduce run-off and soil loss.

- Increase soil organic matter by residue incorporation and deep root system. Improve nutrients availability to the component crop and succeeding crops through biological nitrogen fixation.
- Improving water holding capacity of the soil. Improved soil quality, suppresses weed growth, and boosts crop yields.

3.5.4 Crop residue management

The practice of burning wheat/rice stubbles before seedbed preparation for soybean and other crops is also a common practice. Whereas crop residue left on the surface before and during planting operations provides cover for the soil at a critical time of the year, it reduces tillage operations and leads to less of turning the soil. The pieces of crop residue protect soil particles from rain and wind until plants can produce a protective canopy. Ground cover prevents soil erosion and protects water quality (Verhulst et al., 2009). Residue improves soil tilth, soil health, reduces water pollution and adds organic matter to the soil as it decomposes. The use of crop residue in soybean–wheat cropping system brings out the sustainability and stability in system productivity (Billore et al., 2008 a,b).

3.5.5 Intercropping

Cultivation of two or more crops simultaneously in the same field with a definite or alternate row pattern is known as intercropping. It may be classified as row, strip, and relay intercropping as per the crops, soil type, topography, and climatic conditions. Intercropping involves both time-based and spatial dimensions. Erosion-permitting and resisting crops should be intercropped with each other. The crops should have different rooting patterns. Intercropping provides better coverage on the soil surface, reduces the direct impact of raindrops, and protects soil from erosion.

Advantages of intercropping include. High total biomass production. Efficient utilisation of soil and water resources. Reduction of marketing risks due to the production of a variety of products at different periods. Drought conditions can be mitigated through intercropping. Reduces the weed population and epidemic attack of insect pests or diseases. It improves soil fertility.

3.5.6 Strip cropping

Growing alternate strips of erosion-permitting and erosion resistant crops with a deep root system and high canopy density in the same field is known as strip cropping. This practice reduces the run-off velocity and checks erosion processes and nutrients loss from the field.

Types of strip cropping include:

Contour strip cropping: The growing of alternate strips across the slopes on the contour to reduce the direct beating action of raindrops on the soil surface, length of the slope, run-off flow and increases rainwater absorption into the soil profile.

Field strip cropping: It is useful on regular slopes and with soils of high infiltration rates, where contour strip cropping may not be practical.

Wind strip cropping: The planting of tall-growing row crops (such as maize, pearl millet, and sorghum) and close or short-growing crops in alternately arranged straight and long, but relatively narrow, parallel strips laid out right across the direction of the prevailing wind, regardless of the contour.

Permanent or temporary buffer strip cropping: The growing of permanent strips of grasses or legumes, or a mixture of grass and legumes in highly eroded areas or in areas that do not fit into regular rotation, i.e., steep, or highly eroded slopes in fields under contour strip cropping.

3.5.7 Mulching

Mulch is any organic or non-organic material that is used to cover the soil surface to protect the soil from being eroded away, reduce evaporation, increase infiltration, regulate soil temperature, improve soil structure, and thereby conserve soil moisture. Mulching prevents the formation of hard crust after each rain. The use of blade harrows between rows or interculture operations creates "dust mulch" on the soil surface by breaking the continuity of capillary tubes of soil moisture and reduces evaporation losses. Mulching also reduces the weed infestation along with the benefits of moisture conservation and soil fertility improvement. Hence, it can be used in high rainfall regions for decreasing soil and water loss, and in low rainfall regions for soil moisture conservation. Organic mulches improve organic matter, consecutively improving the water holding capacity, macro and microfauna biodiversity, their activity, and fertility of the soil.

Inorganic mulches have a longer life span than organic mulches and can reduce soil erosion, water evaporation losses, suppress weeds but cannot improve soil health. This practice is costly and labour intensive, therefore, suitable for cash crops such as fruits and vegetables. Polyethylene mulch is commonly used for the conservation of soil and water resources to increase crop productivity.

3.5.8 Terracing

Terraces are earthen embankments built across the dominant slope partitioning the field in uniform and parallel segments. Generally, these structures are combined with channels to convey run-off into the main outlet at reduced velocity. It reduces the degree and length of the slope and thus a reduced run-off velocity, soil erosion, and improved water infiltration. It is recommended for the lands having a slope of up to 33% but can be adopted for lands having up to 50 - 60% slope, based on socio-economic conditions of a particular region. Where plenty of good quality stones are available, stone bench terracing is recommended. Sometimes, semi-circular type terraces, known as half-moon terraces, are built at the downstream side of the plants.

Based on the slope of the benches, the bench terraces are classified into the following categories:

Bench terraces sloping outward: These terraces are used in low rainfall areas having permeable soils. A shoulder bund is provided for stability of the edge of the terrace and thus has more time for rainwater soaking into the soil.

Bench terraces sloping inward (hill-type terraces): These are suitable for heavy rainfall areas where a higher portion of rainfall is to be drained as run-off. For this, a suitable drain should be provided at the inward end of each terrace to drain the run-off. These are also known as hill-type terraces.

Bench terraces with level top: These are suitable for uniformly distributed medium rainfall areas having deep and highly permeable soils. These are also known as irrigated bench terraces because of their use in irrigated areas.

3.6 Variety selection

Farmers should always use recommended soybean varieties that are high yielding, drought tolerant and adapted to prevailing climate conditions. Factors to consider when selecting a good variety: High yielding varieties should be considered first (Pedersen 2007). High oil and protein content varieties. Varieties with resistance to soybean. Variety selected should be based on maturity suited to the ecological zone; early maturing varieties compared to late maturing varieties in areas with low rainfall. Varieties with resistance to lodging, drought tolerance, pests, and diseases. Varieties that have shattering resistance

Table 4: Soybean varieties in Uganda

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. Bukalasa 4	1967	NARO	NARO	1000 - 1600	90-95	1.0	Susceptible to bacterial pustule and rust, shatters, lodges
2. S 38	1968	NARO	NARO	1000 - 1600	90-100	0.8	Susceptible to bacterial pustule and rust, shatters, lodges
3. Congo 72	1969	NARO	NARO	1000 - 1600	90-100	0.5	Resistant to rust, Resistant to shattering
4.Kabanyolo 1	1971	NARO	NARO	1000 - 1600	90-100	2.0-3.0	Susceptible to bacterial pustule and rust, susceptible to shattering and lodging
5. Nam 1 (CAL 131)	1989	NARO	NARO	1000 - 1600	100-115	2.0-2.5	Resistant to bacterial pustule, susceptible to rust, resistant to shattering
6. Nam II (L73)	1994	NARO	NARO	1000 - 1600	115-120	2.0-2.5	Resistant to bacterial pustule, susceptible to rust, good pod clearance, big seeded with black hilum, resistant to shattering
7. Namsoy 3 (NG7-3)	2000	NARO	NARO	1000 - 1600	100	1.5-2.0	Resistant to bacterial pustule and frog eye leaf spots, resistant to shattering, improved nodulation, early maturity
8. Maksoy 1N	2004	MAK	MAK	1000 - 1600	95	1.0 – 2.0	Resistant to soybean rust, very resistant to pod shattering, oil content 17% and protein content 41%.
9. Namsoy 4M	2004	MAK	MAK	1000- 1600	100	1.0 – 2.0	Resistant to soybean rust, resistant to pod shattering, oil content 19% and protein content 43%.
10. Maksoy 2 N	2008	MAK	MAK	1000- 1600	105	2.0 – 2.5	Tall variety reaching 1 meter, resistant to shattering and bacterial pustule
11. Maksoy 3 N	2010	MAK	MAK	1000 - 1600	100	1.5 – 2.5	Resistant to Soybean rust, protein content 48%
12.Maksoy 4N	2014	MAK	MAK	1000-1600	100	1.5-2.5	High yielding, Early maturing, Tolerant to Soybean rust
13.Maksoy 5N	2014	MAK	MAK	1000-1600	96	1.5-2.0	High yielding, Early maturing, Tolerant to Soybean rust.
14.Maksoy 6N	2017	MAK	MAK	1000-1600	93	1.8-2.5	High protein and oil content Resistant to soybean rust
15. SC Saga (COMESA)	2019	SEED CO	SEED CO	1000 -1600	92	1.5 – 2.9	High yielding, early maturity, resistant to soy bean rust, resistant to lodging, High oil content.
16. SC Signal (COMESA)	2019	SEED CO	SEED CO	1000 -1600	97	1.0 – 1.4	High protein and oil content. Resistant to lodging Moderately resistant to soybean rust.
17. SC Sentinel (COMESA)	2019	SEED CO	SEED CO	1000 - 1600	94	1.5 – 2.0	High protein and oil content. Resistant to lodging

3.7 Germination Test

Farmers can conduct a simple germination test to determine seed viability before planting, as follows:

a) Dampen a paper towel, wringing out excess water if necessary and ensure that the towel is not too wet. Soybean seeds must be in a moist environment to begin germination, but too much can damage the seeds and encourage mold.

Figure 9: Results of soybean germination test (Source: Shawn P Conley, 2018)

b) Select the seeds (count 100 soybean seeds) you wish to germinate and place them on the paper towel, folding it over so that they are covered on both sides.
   If germinating many soybeans, you may use a second damp paper towel to cover them.
c) Place the paper towel and the seeds in a warm location (23° and 30°C) to germinate.
d) Allow the seeds to sit undisturbed for seven days and count the number of seeds that have germinated. Keep the paper towel moist, spraying it with mist from a water sprayer to keep it from drying out. Viable soybean seeds have a germination rate of around 90%.

3.8 Inoculation

Using inoculants is a vital part of any integrated management strategy for the successful establishment and maximised yield potential of soybean crops. Inoculants enhance the unique and mutually beneficial relationship between soybeans and nitrogen-fixing bacteria called rhizobia. The legume plant works together with the rhizobia to make nitrogen available for the plant to use. Rhizobia are in nodules on the plant's roots and convert atmospheric nitrogen into ammonia, a form that can be readily taken up by the crop. In return, the plant provides the rhizobia with energy, water, and nutrients.

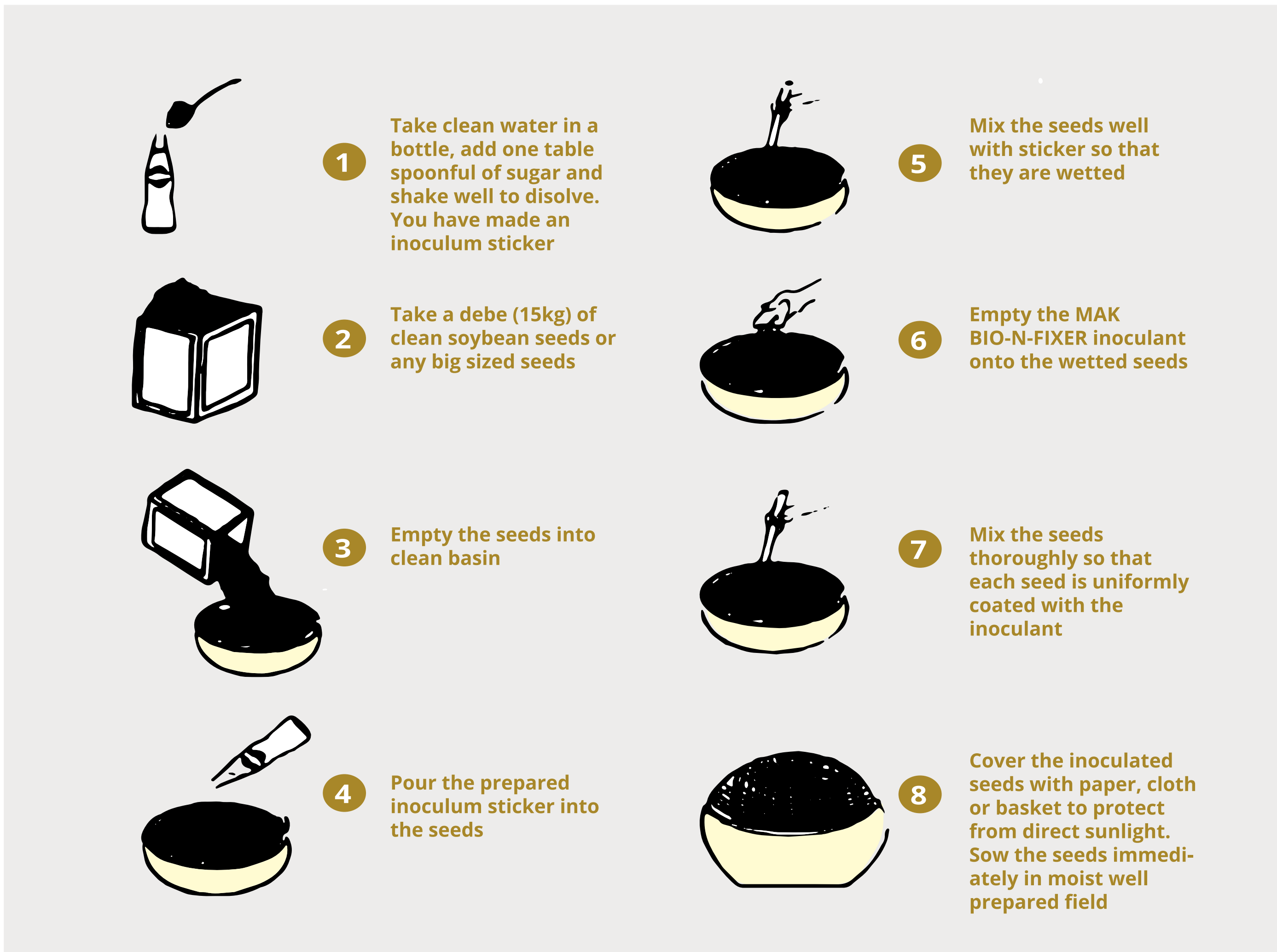


Figure 1 Tukamuhabwa P and Obua, 2015

All inoculants have a designated shelf life and precise handling requirements. Each product has individual recommendations; however, in general, when handling inoculants, the following precautions should be taken:

Inoculants should be stored in a cool, dry place, out of direct sunlight and drying winds (not	It is also important not to stack granular inoculants Inoculants should be stored in a cool, dry place, out of direct sunlight and drying winds (notnts to prevent clumping	In addition, seed-applied liquid and peat inoculants need to be planted within the stated window otherwise the seed must be re-inoculated.

Farmers must also consider inoculant compatibility with additional soybean inputs. Seed treatments are not always compatible and can negatively impact rhizobia on-seed survivability.

3.8.1 Choosing the right inoculant.

Inoculants are available in several different formulations including liquid, peat, granular and solid core granular. They all work effectively but there are some limitations with certain formulations in order of increasing stability as par the list below:

Liquid inoculants are applied directly on the seed or in furrow and are relatively inexpensive; however, performance can be limited on virgin or very dry soils.	Peat inoculants are applied directly on the seed; are most commonly used, inexpensive and contain a sticking agent that restricts use with certain seed treatments.	Granular inoculant (primarily peat) is applied in furrow.	Solid core granular inoculant (primarily clay granular) has a very uniform size that provides more even application with less dusting off.

3.9 Planting

Farmers cannot predict the exact planting dates due to climate variability, however, researchers recommend that planting soybean should be done at the onset of rains for those practicing rainfed agriculture. Benefits to early planting include tapping the nitrogen flash, to catch short seasons. The risks of not planting early include slow germination, seedling diseases and insect infestation. Delayed planting also negatively impacts yield.

3.9.1 Utilising weather forecasts

Preseason information is often conveyed to the public. This information indicates if the rains will come, when they will begin, expected amounts of rains and when they are likely to end. Soybean farmers should then plan to plant within days indicated for the onset of rains.

3.9.2 Seed rate

Seed rate is based on the seed quality, seedbed, and environment. Seed rate is 20-25kg per hactare depending on variety and spacing.

3.9.3 Plant spacing

Spacing should be 50cm between rows and 10 - 25 cm between plants. For dibble planting by hand hoe, one seeds per hole are planted. Best practice when planting by hand for effective row planting is to use a stretched string from one end of the field to the other and plant along that line (Figure 11)

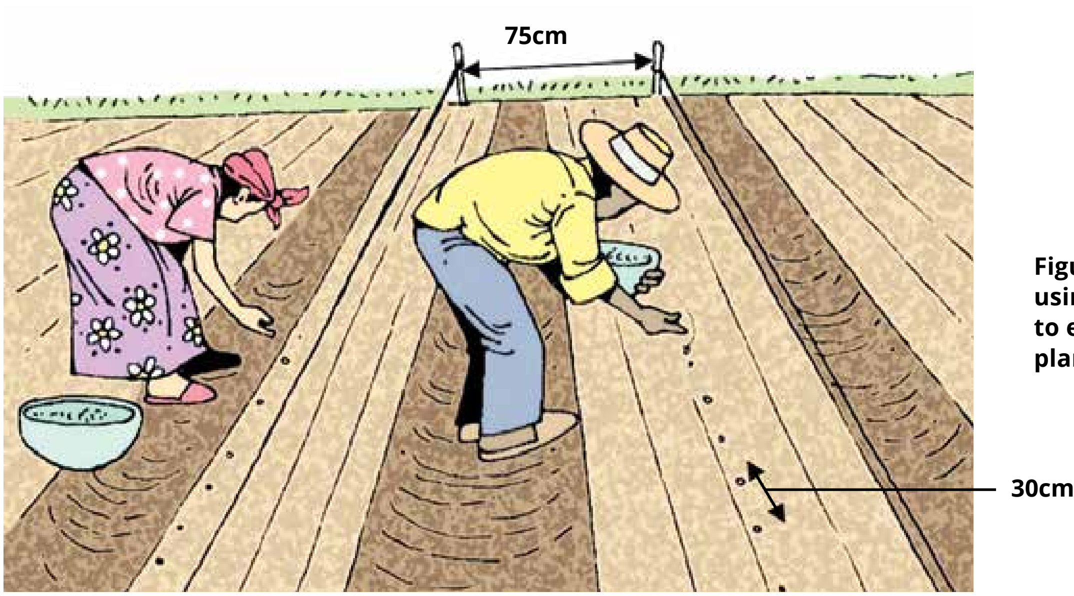


Figure 11: Hand plantihng using a stretched string to effectively manage row planting.

3.9.4 Seed depth

Farmers should not sow seeds deeper than 2 -5 cm depending on soil type, conditions, and tillage. They can plant seeds shallower in heavy soils, such as high-clay soils, or in wet and cold conditions. Uniform seed placement promotes uniform emergence, which is better than staggered emergence as it often results in plant-to-plant competition. Seeds planted deeper than recommended depth may result in loss of potency or failure of seedlings to emerge. In addition, as the planting depth increases, the length of the hypocotyl (elongation) is also affected, producing a poor overall emergence. The time required from planting until emergence is also affected, thus emergence can vary from 5 to 21 days depending on soil, temperature, and moisture.

3.9.5 Seed emergence, growth, and reproductive stages

3.9.5.1 Germination and emergence in soybean

Soybean seed germination requires moisture and adequate soil temperatures. The critical seed moisture content for soybean germination is 20%. A soybean seed that has absorbed water, has a split seed coat, or has an emerged radicle and will continue to germinate and grow as normal once the seed is rehydrated if the seed (embryo) remains above 20% moisture. Germination and emergence are more efficient with warmer soil temperatures closer to 25°C. The time between planting and emergence decreases as soil temperature increases.

Figure 12: Early growth and development of soybean and VE stage of soybean. *Source: BASF USA, 2015; K-State Research and Extension, 2016)*

3.9.5.2 Germination and emergence problems

Earlier planting in waterlogged soil may result in low germination, increased incidence of seedling diseases and poor stands. Vegetative emergence (VE) is also difficult under stressful conditions for planting to take place; the worst being soil crusting caused by short duration heavy rains that disperse soil particles, followed by rapid drying. Soybean stands with poor emergence are often gap filled.

3.9.5.3 Growth stage

Soybean development is characterised by two distinct growth phases; the vegetative (V) phase which covers growth stages from emergence to flowering, and the reproductive (R) phase which covers growth stages from flowering through maturation (Gary and Dale, 1997). Description of the stages includes leaf, flower, node, pod, and seed development. A leaf is considered fully developed if at the node directly above it (the next younger leaf) has expanded enough so that the two lateral edges on each of the leaflets have partially unrolled and are no longer touching.

3.9.5.4 Vegetative phase

The vegetative phase combines several stages starting with the emergence of seedlings, unfolding of unifoliate leaves, through to fully develop trifoliate leaves, nodes formation on the main stem, nodulation, and the formation of branches. Detailed descriptions of the vegetative phase are outlined in Table 5

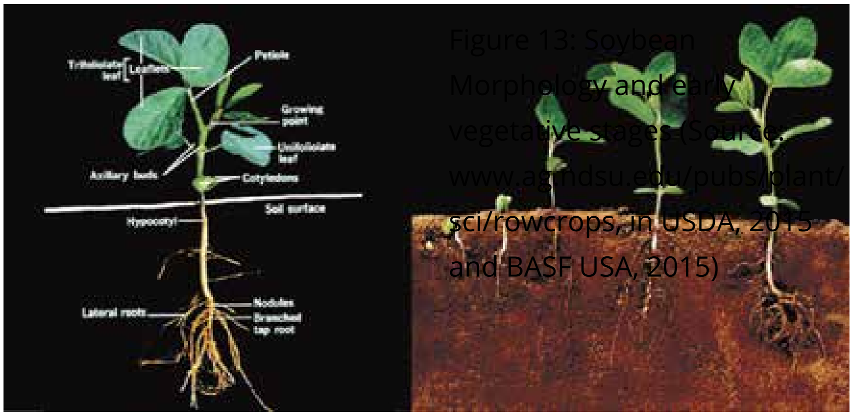
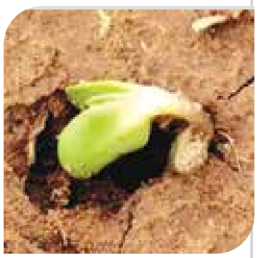


Figure 13: Soybean Morphology and early vegetative stages (Source: www.ag.ndsu.edu/pubs/plant/sci/rowcrops, in USDA, 2015 and BASF USA, 2015)

Figure 13: Soybean Morphology and early vegetative stages (Source: www.ag.ndsu.edu/pubs/plant/sci/rowcrops, in USDA, 2015 and BASF USA, 2015)

Table 5: Vegetative growth phase (stages, description, and number of days between the stages)

Stages	**Description**	**Management practices and micro-climate management issues (e.g. temperature and water management)**	**Average Days**	**Range in Days**
VE 	• Emergence. • Cotyledon emerge through the soil. • Primary and lateral root growth begins. • Functional root hairs develop (root hairs are essential to nutrient uptake and water absorption).	• Check final stand and uniformity. • Replant if the stand is poor. • Requires moisture. • Warm soil temperatures activate the enzymes necessary to initiate the process, which includes releasing food sources from the cotyledon and the beginning of radicle (young root) elongation. • Temperature minimum is 10°C; however, germination and emergence are more efficient with warmer soil temperatures closer to 25°C. • Time between planting and emergence decreases as soil temperature increases.	10	3-5

Stages	Description	Management practices and micro-climate management issues (e.g. temperature and water management)	Average Days	Range in Days
VC 	• Cotyledon/full unifoliate leaves (cotyledons are the main nutrient reservoir for young soybean plants). • Unifoliolate leaves expand (leaf edges are not touching).	• Scout for proper emergence (damaged cotyledons can lower yields). • Replant if the stand is poor. • Unrolling unifoliate leaves – unfolding of the unifoliate leaves so that the leaf edges are not touching the unifoliate node. • Animal based manure application to soybean in Ibadan (Nigeria) was done, using the ring method - 3 cm deep and 5 cm away from the stem 2 weeks after germination and this resulted in production of fresh yield increases 7 times higher than where no manure application was done (Taiwo et al., 2019).	5	3-10
V1 	• First trifoliate/first node. • One set of unfolded trifoliate leaves. • A number of fully developed trifoliate leaves. • Trifoliolate leaf unrolls. • Fully developed leaves at the unifoliolate nodes (plant self-sustaining as newly developed leaves carry out photosynthesis) • New nodes appear	• Scout for early season weeds, insects, and diseases. • Weed your field to prevent competition of young plants with weeds.	5	3-10

Stages	Description	Management practices and micro-climate management issues (e.g. temperature and water management)	Average Days	Range in Days
V2	• Second trifoliate- two sets of unfolded trifoliate leaves. • Fully developed trifoliate leaves at nodes above the unifoliate node. • Trifoliate leaves are alternately arranged and the leaflet margins do not touch. • New trifoliate appear every 3 to 10 days depending on growing conditions. • Nodulation established on the roots and nitrogen fixation continues until the late reproductive stages. • Between V2 and V5, roots grow exponentially within the top six inches of the soil. • Roots infected by Bradyrhizobium japonicum begin actively fixing nitrogen through the nodules. Effective nodulation results in higher yields and more protein when compared to non-nodulated soybean plants).	• Check for proper inoculation • Scout for early-season weeds, insects and diseases. • Apply post-emergence herbicides if needed. • Nitrogen fertilisation not recommended, if nodulation has been established effectively because it will inhibit nitrogen fixation activity if applied in large quantities.	5	3-10
V3-Vn*	• Third trifoliate. • Plant has three emerged trifoliate leaves. • In case of damage to the growing point, axillary buds continue to grow and permit the plants to compensate yield or final productivity.		5	3-10
V4 	• Fourth trifoliate. • Four unfolded trifoliate leaves • (four emerged trifoliate). • Axillary buds may produce secondary branching, (especially with low-density plant populations).		5	3-8

Stages	Description	Management practices and micro-climate management issues (e.g. temperature and water management)	Average Days	Range in Days
V5	• Fifth trifoliate. • Final number of nodes is determined.		5	3-8
V6	• Six trifoliate. • Unrolling of the six trifoliate leaves. • Primary root system continues to grow and several major lateral roots rapidly grow across inter-row spaces. • The cotyledons and unifoliate leaves are mature and may begin senescence.		3	2-5

3.9.5.5 Transition to the reproductive phase

In indeterminate soybean varieties, the later vegetative and early reproductive stages overlap, and growth continues as the soybean initiates seed development. However, with determinate soybean varieties, the onset of reproductive growth terminates the vegetative growth. Time from planting, environmental conditions, and soybean type, all determine soybean growth prior to R1. The number of pods per plant, number of seeds per pod and weight per seed determine soybean yield, whereas the maximum number of seeds per pod and seed size is determined by genetics. The stages that comprise the reproductive phase (R) begin with the first flower stage (R1) and continue until the plant reaches full maturity.

3.9.5.6 Reproductive phase

The reproductive phase begins with flower bud formation stage, through full bloom flowering, pod formation, pod filling to full maturity. Detailed description of the reproduction stages is outlined in Table 6.

Table 6: Reproductive phase (stages, description, management practices and number of days between stages)

Stages	Description	Management practices and Microclimate management issues *(eg. Temperature and water management)*	Stage Range	Average Days	Range in Days
R1- Beginning of flowering 	• Plant has one flower open at any node on the main stem • Flowering begins between the third and sixth nodes of the main stem and progresses both upward (Indeterminate) and downward (Determinate). • Branches begin to flower a few days after the main stem. • Flower petals are white or purple and are self-pollinated. • Vertical root growth also increases dramatically and secondary roots and root hairs proliferate.	• Scout for insects and diseases. • Spray foliar insecticide or fungicide, if necessary. • The flowering period generally begins 6 to 8 weeks after seedling emergence; however, it may begin earlier if soybeans were planted late, since development accelerates with warmer temperatures. Generally, yield increases as the length of time between R1 and maturity increases this is the reason why early planting tends to increase yield and is a recommended practice.	R1-R2	3	
R2 stage – full bloom.	• An open flower is found on one of the top two stem nodes with a fully developed leaf. • Soybean plant is growing rapidly, accumulating dry weight and nutrients in the vegetative plant structures. • Approximately 50% of total nodes are formed. • Flowering continues and extends through to R5. It is estimated that 60% to 70% of flowers will abort naturally and never contribute to yield. • Flower abortion, often caused by drop, increases under hot and dry conditions. • Peak nitrogen fixation occurs at R2 within the soil. • Roots completely cross the inter-row field space. • Growth of several lateral roots turn downward. • Lateral roots and the taproot continue to elongate deep into the soil until late in R6 stage. • Nitrogen fixation in the soil is at its peak during this stage.	• Scout for insects and diseases. • Spray foliar insecticide or fungicide, if necessary. • Use of anti-transpirants to minimise water loss on account of evapotranspiration under drought conditions, such as KNO3, Super Gro, among others at 15 days after flowering stage is effective to minimise the drought effect on soybean productivity during drought period (Billore, 2017).	R2-R3	10	5-15

Stages	Description	Management practices and Microclimate management issues *(eg. Temperature and water management)*	Stage Range	Aver-age Days	Range in Days
R3 – pod development. 	• Pods are 5mm long at one of the four upper most nodes on the main stem with a fully developed leaf. • Overlapping development stages, such as, developing pods, withering flowers, open flowers and flower buds are seen. This allows the soybean plant to compensate for stress-induced losses. • Pods may spontaneously abort; less often than flower abortion.	• Scout for insects and diseases. • Spray foliar insecticide or fungicide, if necessary. • Address water stress because it affects pod formation. • Irrigation is critical (where possible).	R3-R4	9	5-15
R4 – full pod 	• Pods are 2 cm long in one of the four uppermost nods on the main stem with a fully developed leaf. • 50 % of nitrogen uptake occurs. • This marks the beginning of the most crucial period of plant development, in terms of final yield determination (no. of pods, no. of seeds and the seed weight determine yield potential). • Plants have lots of pods, although pods are not full. • Plant stressors between R4 and R6 reduce yield more than any other period of development. Yield compensation is limited to no. and size of beans per pod). Flowering soon stops (importance of retaining developed pods).	• Beyond this stage, management practices should concentrate on ensuring that pod loss is minimal because once follower development stops there will be no more pod formation.	R4-R5	9	4-26
R5 – seed development 	• Seed is 3 mm long in one of the four uppermost nodes on the main stem. • Rapid seed fill occurs (dry weight and nutrients from leaves, petioles and stems redistribute to seed production). • Primary and lateral roots grow strong until R5 and the deeper roots and laterals grow until R6. • Demand for water and nutrients is immense during this seed filling period (moisture is critical for nutrient availability to the plant). • The plant attains its maximum height, node no. and leaf area whereas, dry weight accumulation continues.	• Scout for insects and diseases (late-season diseases can severely lower yields). • Spray foliar insecticide or fungicide, necessary. • Irrigation will increase effectiveness of pod filling if the conditions are dry.	R5 - R6	15	11 - 20

Stages	**Description**	**Management practices and Microclimate management issues** *(eg. Temperature and water management)*	**Stage Range**	**Aver-age Days**	**Range in Days**
R6 – full seed  	• Final growth stage prior to maturation. • Pods contain a green seed that fills the pod cavity in one of the four uppermost nodes on the main stem. • Most nutrients have been taken up by the time the plant reaches this stage. • The rapid rate of whole plant nutrient and dry weight accumulation begins to slow. • Three to six trifoliate leaves may have already fallen from the lowest nodes before rapid yellowing begins. • Root growth terminates in the middle of R6. • Senescence, leaf yellowing and death begin at the end of R6. • Potential for yield reduction is still high as the soybean plant concludes development. • Stress causes yield loss, mostly by reduction of seed size; pods and seeds are still susceptible to dropping.	• Scout for insects and diseases (late-season diseases can severely affect yields). • Spray foliar insecticide or fungicide, if necessary.	R6 - R7	18	9-30
R7 – beginning of maturity 	• One pod on the main stem has reached mature pod colour. • Not all pods are mature, but very little additional pod growth occurs as accumulation of seed dry weight slows and eventually ceases. • Seeds are usually yellow. • Physiologically mature and with approximately 60% moisture. • Stress can still alter seed size and final yields. • Less prone to drop.				

Stages	Description	Management practices and Microclimate management issues *(eg. Temperature and water management)*	Stage Range	Average Days	Range in Days
R8 – full maturity. 	• 95% of pods reach their (pods) mature colour. • However, soybeans are still not ready for harvesting until they attain their harvest shape and desired moisture content. • Leaves senesce (no value for increasing yield because seed growth is complete). • Pod splitting or excising pods affects grain yield.	• Scout for green stem syndrome. • If plant is still green, harvest slowly. • Soybean moisture should drop to between 14% and 20% prior to harvest and this should occur five to 10 days after R8.	R8 - to harvest of pods		5-10

(Images (R1 through R8) - Source: BASF USA, 2015).

3.9.6 Weed management.

Soybean faces severe weed competition during early stages of crop growth that result in a loss of about 40 - 60 % of the potential yield depending on the weed intensity, nature, environmental condition, and duration of weed competition (Kachroo et al., 2003). Weed species compete for resources, such as moisture, nutrients and sunlight, hamper harvesting operations, host plant diseases and insects, contaminate and reduce the quality of soybean grains. Weeds are classified according to their lifecycle and may grow on annual, biennial, or perennial basis in early vegetative stages of soybean. Annual weeds complete one lifecycle per season and are seasonal varieties. Biennials complete one lifecycle over two years, whereas perennials regrow every season for at least three years. Competitiveness of a specific weed is determined by its growth habits, time of emergence and size. Before considering weed management strategies, growers should understand their lifecycle, weed biology, especially those species with rapid germination, plentiful seed production, widespread seed dispersal and seeds that can lie dormant and survive in harsh conditions. For effective control of weeds, farmer must also consider the field history, past challenges, and new problems.

Weed control methods prior to planting until canopy closure include:

Cultural control: Cultural control methods include hand and mechanical cultivation via tillage, planting narrow rows and a high plant population that help with earlier canopy closure which decreases weed competition. Hand weeding though cost effective, it facilitates the spread of perennial weeds with underground tubers and rhizomes.

Chemical weed control: The method involves application of herbicides via an on-farm sprayer.

Farmers can apply herbicides as preplant, pre-emerge, post-emerge. Early applications are best when weeds are less than four inches in height. Herbicides can have contact or systemic activity or both. Contact herbicides cause rapid dry down when they encounter plant (weed) tissue, whereas systemic herbicides are translocated to growing points of plant where natural senescence occurs. Farmer should consider the following prior to and during herbicide application:

a) Weed species present in soybean field and correct product(s) most effective against them.
b) Growth stage of the weeds, wind direction and the timing of the application to optimise efficacy.
c) Appropriate rate.
d) Read herbicide products instructions on the label, for application, timing, and limitations.
e) Field history of herbicide because residue may build up and can affect the crops that may be grown in future rotations.
f) Consult technical people and product labels before applying any herbicide.

intergrated weed management approach is recommended, that includes rotation of crops and seed systems; and different agronomic practices that help the crop to out-compete the weeds, such as:

a) Higher seed rates and in narrow rows to help shade out the weeds. Faster canopy closure may need one herbicide pass, rather than two.
b) Effective burndown to start with clean fields.
c) Varying planting dates: early planting helps out-compete weeds that benefit from more growing days.
d) Clean equipment: this prevents the transfer of resistant weeds from one field to the next.
e) Fertility: ensure adequate levels of essential nutrients to encourage a competitive stand.
f) Rotation of crop types with modes of action, including a variety of different crop types, such as cereals, pulses, and forage crops to switch up herbicide chemistry which controls weeds.
g) Application at full label rates and applying herbicides at reduced rates increases the chances of weeds survival and in turn, increases the risk of resistance. Application should be at correct timings and with correct water volumes.
h) Use and rotation of multiple modes of action (MOA), both within and between seasons. Rotating within a season to control weeds that escaped burndown and managing them before they set seed.
i) Proper scouting for weeds both pre- and post-herbicide application. This allows management options prior to weed seed set.
j) Keeping records of weeds identified and all herbicides used, to have a management plan.


RPM
720

CHAPTER 4

HARVESTING, POST-HARVEST HANDLING, STORAGE AND MARKETING OF SOYBEAN

4.1 Introduction

The chapter describes harvesting technics, post-harvest practices and technologies for soybean which include drying, storage, processing, and value addition. It also discusses soybean marketing. The section explains the process involved from farm to consumer, and the stages in which soybean must undergo such as harvesting, threshing, cleaning, drying and storage. During these operations, harvest is lost due to improper handling, inefficient storage facilities, biodegradation due to diseases and pests.

4.2 Harvesting

Soybeans reach full maturity during the R8 stage. At R8, 95% of pods have reached straw colour and moisture levels are optimum for harvest after five to 10 days with good weather conditions (BASF USA, 2015). Maturity of soybean mostly depends on the variety and requires well timed harvesting to reduce extreme losses, such as shattering losses, deteriorated seeds, especially when it is still raining (SARI, 2012). In the developing countries, harvesting of soybean can be performed mainly manually using hand cutting tools such as sickles, knives, cutters, or hoes. Harvest should take place any time between 14% and 20% moisture; these moisture levels may require additional drying (Cholette, 2018). If moisture falls below 12% prior to harvest, seeds may crack and split, whereas below 11% moisture, pods may shatter leaving beans in the field (Bauche, 2017). High moisture accumulations in the crop lying in the field may even lead to mold growth in the field. Harvested crops should be spread loosely on tarpaulin or any other material and allow them to dry in the open for two to five days before threshing. Farmers should not harvest soybean by hand pulling since this might take away the nutrient that the soybean has added to the soil (Dugje et al., 2009). Most farmers in Uganda harvest soybean manually because their farms are usually small (0.25 to 2 ha). Mean yield for soybean in Uganda ranges from 100 - 700 kg per acre.

4.3 post-harvesting handling

4.3.1 Drying

Drying is a critical step after harvesting to maintain the crop quality, minimise storage losses and reduce transportation cost. Drying can be performed naturally (sun or shade drying) or using mechanical driers. Natural drying or sun drying is the traditional and economical practice for drying the harvested crop and is the most popular method in developing countries. Sometimes, whole crop without threshing is left in the field only for drying. Sun drying is weather-dependent, requires high labour, is slow, and causes large losses. Unseasonal rains or cloudier weather may restrict the proper drying, and if the crop is stored at high moisture, this leads to high losses due to mold growth. Some farmers use mats or plastic sheets for spreading the grains (Figure 16), which reduces the contamination by dust and makes the collection of grains easy.

Figure 14: Soybean plants at R8 stage; stems and mature pods are brown *(Source: Tukamuhabwa)*

Mechanical drying addresses some of the limitations of natural drying, and offers advantages, such as reduction in handling losses, better control over the hot air temperature, and space utilisation. When using heated air for drying soybeans, temperatures should not be above 35 - 37°C, because seed coats begin cracking and/or splitting and too high temperatures in five minutes causes 100% cracking in soybeans. Caution is also required when stirring or recirculating loads, particularly when the moisture content of the soybeans falls to 12% or lower (Cholette, 2018). Mechanical driers have limitations, including high initial and maintenance cost, adequate size availability, and lack of knowledge to operate these dryers, especially with smallholders. Due to these limitations, these dryers are rarely used by smallholders in the developing countries (Alavi et al., 2012). However, with climate variability and climate change, producer associations and cooperatives would consider investing in equipment such as dryers to be able to dry grain even in the event of unexpected rains. In addition, soybean dried in a dryer is likely to have more uniform drying and less contamination, all of which raise the quality of the soybean, creating opportunity for obtaining a higher price than for the dried manually.

4.3.2 Threshing and cleaning

The purpose of the threshing process is to detach the grain from the pods The operation can be performed manually or using threshers. Grain spillage, incomplete separation of the grain from chaff, grain breakage due to excessive beating, are some of the major reasons for losses during the threshing process (Shah, 2013). Delay in threshing after harvesting of crop results in quantity and quality loss. The crop is susceptible to rodents, birds, and insect attack (Alavi, et al., 2012).

The cleaning process is done after the threshing to separate whole grains from broken grains and other foreign materials, such as straw, stones, sand, chaff, and weed seed. Winnowing is the most common method used for cleaning in Uganda. There exists both manual and automatic equipment on the market in Uganda that can be used for bulk processing of soybean and are cost effective (Figure 15). Such equipment can be purchased by individuals, groups, associations, or cooperatives to facilitate timeliness of production operations which is critical in CSA. Poorly cleaned grains can increase the insect infestation and mold growth during storage, add unwanted taste and color, and can damage the processing equipment. Large amount of grain is lost as spillage during this operation, and grain losses during winnowing can be as high as 4% of the total production (Sarkar et al., 2013).

Figure 15: Soybean threshing machine

4.3.3 Storage

Soybeans must be stored at or below the safe moisture condition for all seeds and grains (Pratt et al., 2009). Soybean grain should be dried to 13% moisture for storage of six to twelve months and 10 -11% for longer storage (Baloch, 2010). High moisture content in stored soybean encourages the development of various agents of deterioration, such as insects and micro-organisms (Dugje et al., 2009). Soybean should be stored on raised platforms, in a dry cool place (Figure 17) preferably in vaccum hematic bags. The grain can be stored in plastic and metallic waterproof and airtight silos (figure 17 and figure 18 respectively). Good storage management can greatly influence the storability of soybean and successful germination. Soybean should not be exposed to high temperatures, as it will increase deterioration and reduce seed viability (Dugje et al., 2009). In developing countries such as Uganda, about 50% - 60% of the grains are stored in the traditional structures at the household and farm level for self-consumption and seed (Grover and Singh, 2013).

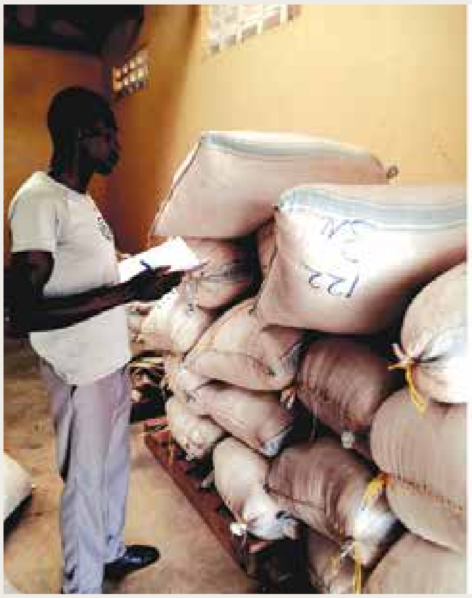


Figure 17: Proper storage of Soybean after drying.

Figure 18: Example of a plastic silo – 500-litre capacity

Figure 19: Example of metallic silos

4.4.3 Soybean processing and value addition

The major soybean products in Uganda are soybean meal, soybean oil, flour, feed cake and several soybean-based food products such as soya tofu, yoghurt, and soya milk. Soya bean must be roasted to destroy trypsin inhibitor before processing into consumable products.

4.4 Soybean marketing

4.4.1 Key aspects of Soybean marketing

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

(i) Price: Should always exceed the cost of production.
(ii) Product: Ensure you have quality soybean and its products.
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 soybean in terms of quality, quantity, location, period of availability.

4.4.2 Marketing channels for soybean

The relative importance and resilience of these channels is directly linked to the risk associated with the channel by the farmers. The oilseed market is not a linear flow from farmer to processors. The market is more like a web of informal and formal actors and channels, with complex interdependencies (Figure 20). Farmers do not exclusively stick to one channel, but different volumes go through different channels (Vorley et al., 2015). Soybean farmers should make decisions on which marketing channel to pursue based on factors that deliver benefit for them. This benefit could vary from farmer to farmer while some farmers may prioritise maximisation of profit, others could prioritise timely payment for their soybean. Management of effects of climate variability on soybean marketing involves access to timely market information, formation of groups for cost effective marketing and formation of platforms and participation in platform activities.

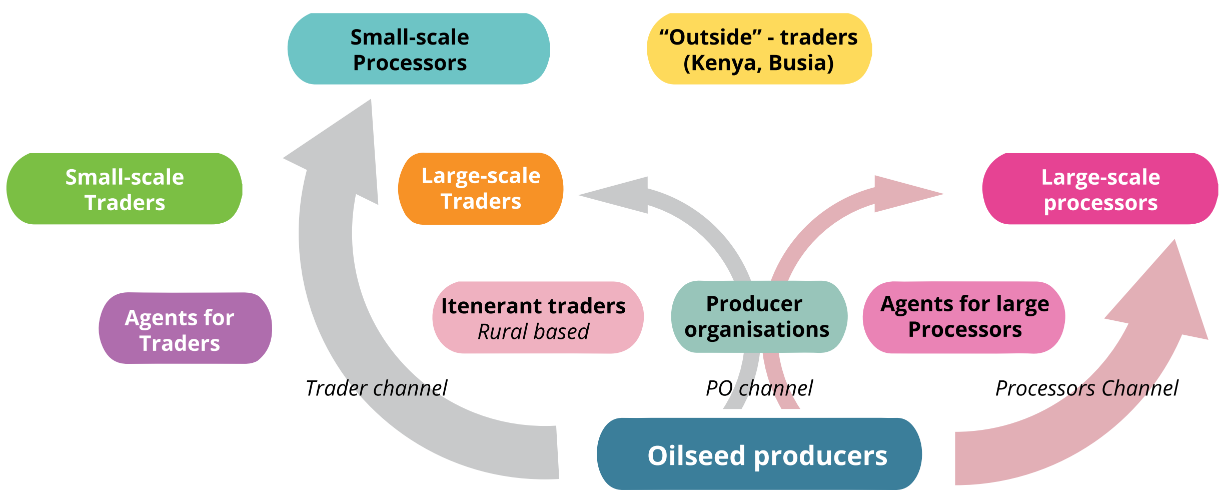


Figure 20: Marketing channels for oilseeds *(soybean, sunflower, and sesame). Source: Vorley et al., 2015*

4.4.4 Marketing strategies

Many buyers, both within and outside the country are sometimes willing to pay a premium price for good-quality grains. Linkages can be made directly to buyers or buyers' agents through projects working in different areas, by developing a preferred buyers' network in each of the districts; or participating in product platforms such as Oil Seed Platforms which were key in linking buyers and farmers and enabled building of trust and transparency.

CHAPTER 5

RECORD KEEPING AND PROFIT AND LOSS ANALYSIS FOR SOYBEAN.

5.1 Introduction

This chapter discusses record keeping for soybean agribusiness in detail. It also highlights some characteristics of appropriate records. In this section a profit and loss account for soybean production is illustrated based on data as it was by the time of developing this manual.

5.2 Record keeping

This is the documentation of all the activities. 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 enables development of financial analysis and budgeting. Information to be recorded includes human resource, finance, production, operation, storage, and marketing. A more detailed description of each is provided below.

a) Human resource records which include details of the labour force, leave calendar and profiles of the workers for the farm.
b) Financial records which include.
   (i) Invoices: An invoice is 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.
   (ii) Payment vouchers: A payment voucher is a document prepared to pay service providers after invoices have been received and verified.
   (iii) Receipts: A receipt is a document issued acknowledging payment.
   (iv) Pay-in books: Documents indicating money paid in the bank.
   (v) Cash book: This contains information of the money banked, received, and spent.
c) Operational records are records that contain all activities. The farmer or other actor in the soybean value chain should design a simple comprehensive

record entry/ report which can easily be understood by all the people on the farm. Records must be easy to understand and written in such a way that they can easily be accessed for analysis.

d) Storage records include.
   (i) Stock card: It is a document in form of a card hung on a batch of soybean indicating the quantity of stock available at that time. It can also be a stock card for all inputs at the farm. Keeping track of stock helps with identifying theft, guarding against wastage and unnecessary purchases, and planning for production.
   (ii) Stack Card: Card fixed to a bag used to keep a tally of the number and weight of bags of soybean either added or removed from the stack.
   (iii) Goods Received Note (GRN): Document issued out to acknowledge receipt of goods.
   (iv) Received Stock ledger books: Records of the stock that has been received in the store/warehouse.
   (v) Outgoing stock ledger books: Records of stock that has been removed from the store.
   (vi) Quality control records: Records for quality status of the stored soybean.

e) Fumigation records indicating fumigation activities carried out on the premises.

f) Marketing records include.
   (i) List of customers.
   (ii) Price lists.
   (iii) Details of buyers and quantities desired by the market.

5.3 Characteristics of good records

a) It should be simple and easy to use. If the record keeping system is complicated, it is more likely to generate mistakes.

b) The financial records maintained should have appropriate level of details depending on the type of the business. Complex operations require a more detailed system.

c) A good system provides essential information in a timely manner.

5.4 Profit and or loss calculations

Record keeping will enable all actors in the soybean value chain to be able to calculate their profits or losses. Knowledge of this is critical for decision making for the purpose of business improvement. It is also important for tracking methods and practices that produce economic benefit, as such climate smart approaches that produce highest economic benefit can be prioritised. One of the simplest ways of calculating profit or loss is through profit and or loss analysis in which the sum of the total of the variable costs is deducted from the total revenue obtained from the sales of products or produce (Table 7).

Table 7: Profit and loss Analysis (per acre) for soybean production with fertiliser and improved varieties.

Activities and their units	Total (UGX)
Variable costs	
First ploughing	150,000
Second ploughing	120,000
Rhizobia (3 packets needed @ packet 200gms)	3000
1 kg of sugar for Rhizobia mixing all 3 packets	4,000
Seeds (20 - 25 kg per acre at the price of 4,000 – 6,000 per kg	150,000
Cf foundation seed costs 6,600 at present)	
Planting	50,000
Weeding	50,000
Pest and disease control	50,000
Harvesting	100,000
Threshing and winnowing (Cleaning)	50,000
Post-harvest; Drying	30,000
Bags (700Kg - 7 bags @ 1,500 each)	10,500
Transportation (ton @ 25,000 each)	100,000
Total Costs	**867,500**
Revenue	
Output (700 Kg)	
Price (kg @ 2,000 x 700kgs)	1,400,000
Total Revenue	
Gross profit/loss (UGX per acre)	**532,500**

Note:

These costs are likely to have slight variations from region to region or even location so it will be more practical if the profit/loss is recalculated in real time.

All actors in the soybean value chain should conduct the profit and loss analysis for their businesses and always identify changes in their actions that can lead to increased gross margins without compromising the quality of their products/produce or services.

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ANNEX 1: ANNEX 1: ACCESSING FINANCIAL RESOURCES..

Accessing credit increases the capacity to adopt technologies such as resistant and high yielding soybean varieties for sustainable soybean 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
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 ecosys-tems 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)
Carbon footprint	Measure of the exclusive total amount of emissions of carbon dioxide (CO_2) 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)
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}

TERM	DEFINITION OR DESCRIPTION
Climate (information) products	Climate (information) products can include climate data briefs that describe the data and information generat ed 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 modu lations 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)
Climate model (spectram 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 spects 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}

TERM	DEFINITION OR DESCRIPTION
Climate variability	Climate variability refers to variations in the mean state and other statistics, such as standard deviations, the occurrence of extremes, etc., of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability). {WGI, II, III} (FAO)
Climate-smart agriculture (CSA)	Agriculture that sustainably increases productivity, resilience (adaptation), reduces/removes greenhouse gases (mitigation), and enhances the achievement of national food security and development goals. (FAO). It is an approach for developing actions needed to transform and reorient agricultural systems to effectively support sustainable development and ensure food security under climate change. (FAO)
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)
Crop diversification	Species diversification through varied crop associations and/or rotations involving annual and/or perennial crops including trees. (FAO)
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}
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}
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 run-off 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 green house 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)
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)

TERM	DEFINITION OR DESCRIPTION
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.
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)
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 (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), and ozone (O_3) are the primary green-house 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 CO_2, N_2O, and CH_4, the Kyoto Protocol deals with the green-house gases sulphur hexafluoride (SF_6), 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.

TERM	DEFINITION OR DESCRIPTION
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)
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)
Methane (CH_4)	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)
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)

TERM	DEFINITION OR DESCRIPTION
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)
pH	Expression of acidity or alkalinity of soil or water.
Methane (CH_4)	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)
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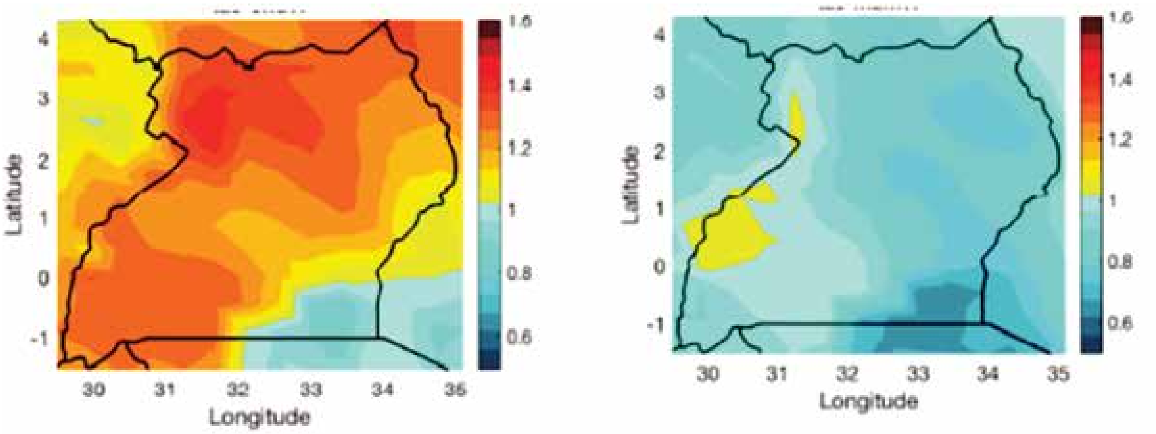
Pests	Species of diseases, insects and weeds, whose populations may reach a level resulting in yield losses depending on environmental conditions, crop genotype and phenology, and agricultural management practices, including cropping patterns, and use of chemical fertilisers and pesticides. (FAO)
pH	Expression of acidity or alkalinity of soil or water.

TERM	DEFINITION OR DESCRIPTION
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)
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)
Sustainability	A dynamic process that guarantees the persistence of natural and human systems in an equitable manner. {WGII, III}
Sustainability (Econom-ic)	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)
Sustainability (Environmental)	Meeting the needs of the present without compromising the ability of future generations to meet their needs. (FAO)

TERM	DEFINITION OR DESCRIPTION
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	A class of insurance products that can allow weather-related risk to be insured in developing countries where
insurance	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)

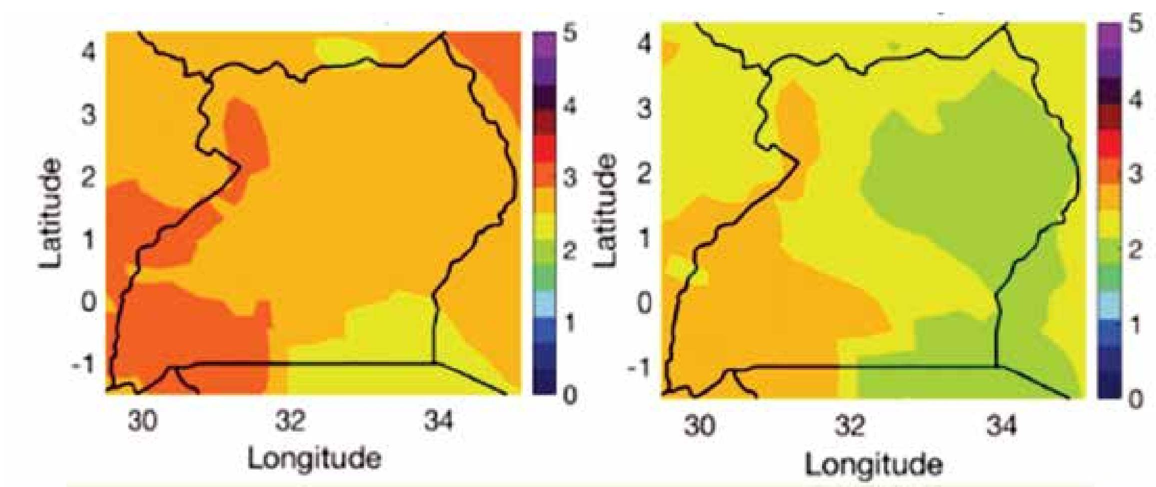
ANNEX 3: CLIMATE PROJECTION MAPS



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)

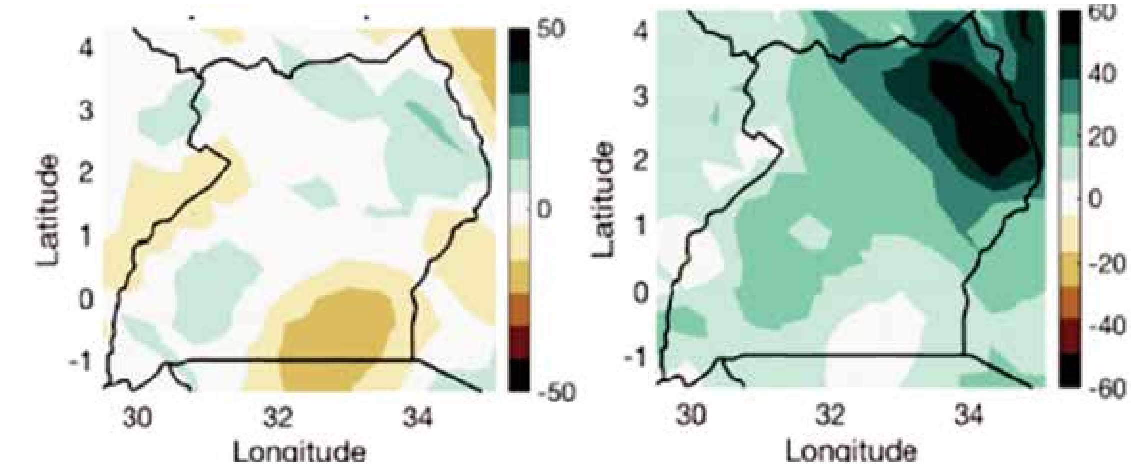
Figure 1: Temperature trend from 1961-2005 for the long (MAM; LEFT) and short (SOND; RIGHT) rainy season in Uganda.



Note:

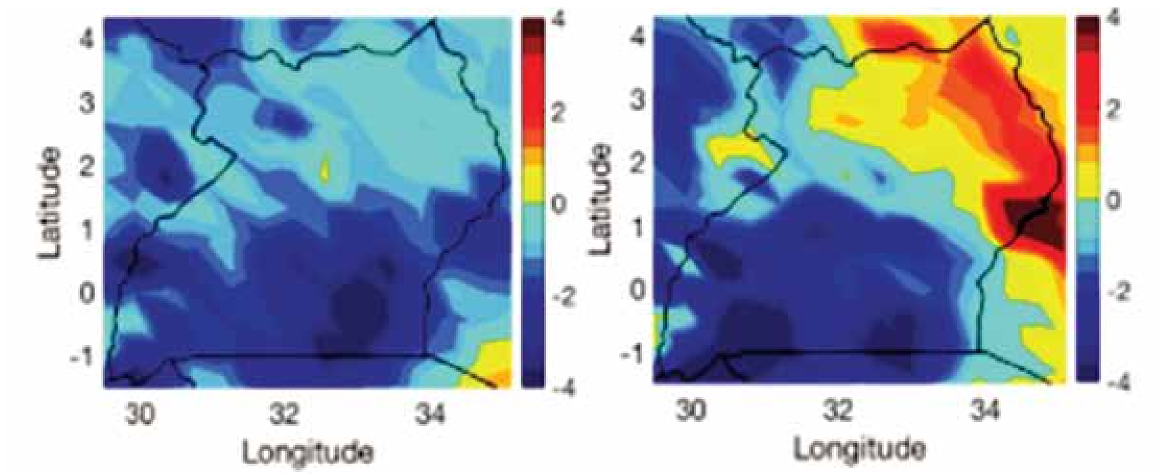
During both the short (September, October, and November; RIGHT) and long (March, April, May) rainy season and temperature is likely to rise by more than 2°C with the highest increase of 3°C over south-western Uganda during the long rainy season (MAM). (Source: CRAFT, 2018)

Figure 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:
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)

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:

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

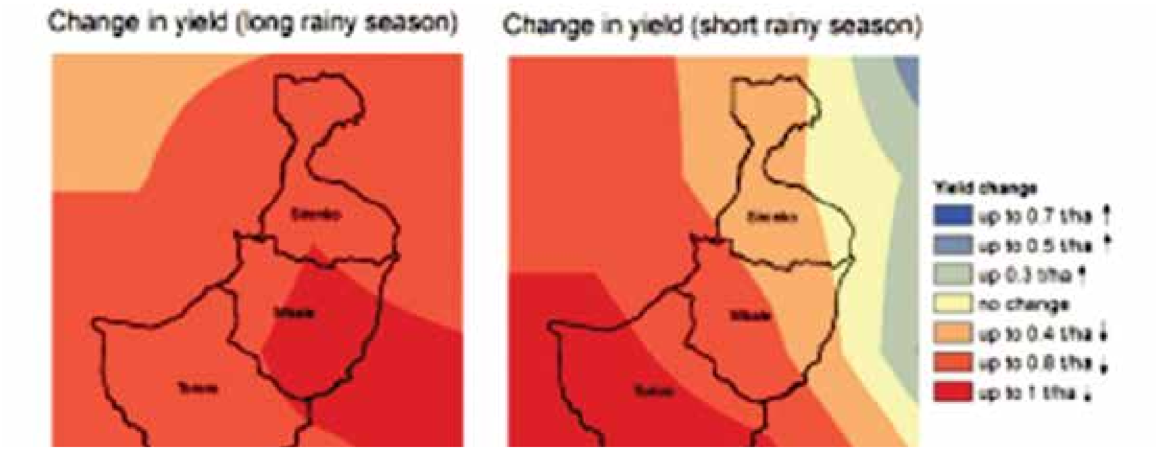
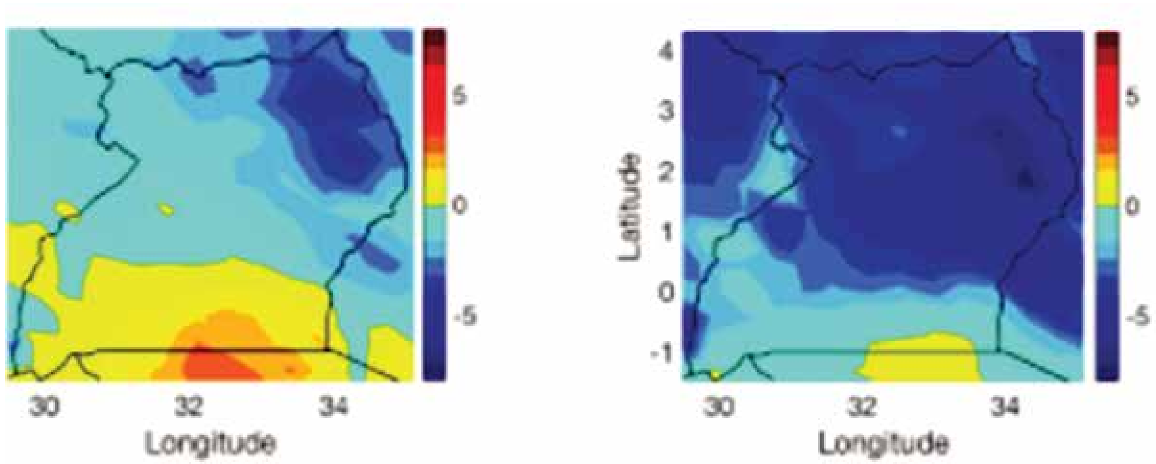


Figure 5: Change in soybean yield under RCP 8.5 (2050s) compared to current climatic conditions. Yields were simulated under optimum nutrient management conditions and biotic control (Source: CRAFT, 2018)



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)

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).

SNV Netherlands Development Organisation
Plot 36, Luthuli Rise Bugolobi
P.O. Box 8339, Kampala Uganda
Tel: +256 (0) 414 563 200, +256 (0) 312 260 058
Email: uganda@snv.org
www.snv.org/country/uganda

Ministry of Agriculture, Animal Industry and Fisheries
P.O Box 102, Entebbe Plot 16-18, Lugard Avenue, Entebbe Uganda.
Email: info@agriculture.go.ug
Tel: 041 4320004