REPUBLIC OF KENYA

Climate Smart Greengram (*Vigna radiata*) Resource and Training Guide

AFA Our Crops, Our Wealth

KALRO Kenya Agricultural & Livestock Research Organization

CRAFT

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Foreword

The Importance of capacity building of Agriculture Sector Service Providers to the growth and development of greengram in Kenya cannot be overstated. This guide provides insights in climate smart production, processing and marketing modules and challenges faced in greengram value chain development in Kenya. It is an output of the ministry of Agriculture, Livestock, Fisheries and Cooperatives (MALF&C) and Climate Resilience Agribusiness for Tomorrow (CRAFT) manuals review held in Nairobi in January, 2020.

Agriculture is not only impacted upon by climate change but also contributes to the problem. The country's agriculture is predominantly rain-fed and therefore vulnerable to climate change particularly changes in temperature regimes and precipitation patterns and extreme weather events. This leads to, among others, unsustainable land and agricultural water management. Innovative and transformative measures are therefore urgently required to assist stakeholders in the greengram sub-sector to cope with effects of current and projected change in climate patterns.

Greengram is an important pulse crop commonly grown and consumed in Kenya. It is used in several food products, both as a whole seed and in processed form as an excellent source of high quality protein with high digestibility. Greengram is considered to be hardiest among all pulse crops and can tolerate drought to a great extent. Hence, it is successfully grown in any adverse conditions and particularly in drought prone areas.

Greengram production as a nutritious food can be increased if concerted effort and collective action is taken by the government and the private agriculture extension service providers. However, several factors limit investment in greengram value chain. These factors include production systems, level of mechanization climate change, soil and water conditions, pests and diseases among others. These barriers to high productivity in greengram need to be effectively addressed.

The objective of developing this resource and training guide is to harness Knowledge on greengram value chain and harmonize capacity building of agriculture sector service providers and farmers in greengram production and marketing. This will result in increased productivity while mitigating climate change impacts. Am sure it will serve as a basis for influencing future practice to improve greengram value chain in Kenya.

Hamadi Boga, PhD
Principal Secretary
Crop Development and Agricultural Research

Preface

The agricultural sector in Kenya and more so the Greengram farming has been facing a number of challenges ranging from increase production costs, prevalence of diseases and pests, inadequate credit, weather and climate changes, poor marketing infrastructure amongst others.

Recent climate change projections done by the SNV led - Climate Resilient Agri-business for Tomorrow (CRAFT) project shows that, during both the first (MAM) and second (ONO) rainy seasons, temperature in the greengram growing areas of western and south-eastern Kenya is expected to rise by about 1.4°C to 1.8°C and 2.4°C to 2.8°C in the 2030s and 2050s respectively

The temperature increase, with the associated rainfall spatial-temporal changes will impact greatly on the greengram yields in Kenya, which currently ranges from 0.5 to 0.6 tons/ha against a global average yield of 0.73 t/ha, this is far below the potential of the crop (MoALFC, 2016).

To address innovative and transformative measures are therefore urgently required to assist greengram value chain stakeholders to adapt and cope with effects of current and projected change in climate patterns.

The use of climate smart agriculture (CSA) practices, technologies and services have been identified as a viable approach to provide solutions towards increased agriculture sector productivity while addressing impacts of changing climate.

This **Greengram *(Vigna radiata)* Training Aid** compliments learning from the **"Climate Smart Greengram *(Vigna radiata)* Resource and Training Guide**" recently developed by the Ministry of Agriculture, Livestock, Fisheries and Cooperatives early this year in partnership with SNV led-CRAFT (Climate Resilient Agribusiness for Tomorrow) Project, Agriculture and Food Authority (AFA), Kenya Agriculture and Livestock Research Institute (KALRO), and ACT among other stakeholders.

The training aid has been derived from the developed "**Climate Smart Greengram *(Vigna radiata)* Resource and Training Guide**" and has put a lot emphasis on hands-on practical training, imparting of skills and competencies needed for the specific training requirement needs for the greengram small holder farmers -men, women and youth.

The Training Aid should be used in conjunction with the **Climate Smart Greengram *(Vigna radiata)* Resource and Training Guide**. Both are very valuable resources for state and non-state extension service providers.

Acknowledgement

The Ministry of Agriculture, Livestock, Fisheries and Cooperatives do acknowledge the technical and financial support from the Climate Resilient Agribusiness for Tomorrow (CRAF1) project partners lead by Netherlands Development organization (SNV) and Climate Change Agriculture and Food Security (CCAFs) and the African Conservation Tillage Network (ACT), who were very instrumental in the development of the Greengram Training Aid.

Much appreciation goes to the technical team, which included: from SNV, Joseph Muhwanga, Joyce Mbingo and Oscar Nzoka; from CCAFs, John Recha, Joab Osumba and Teferi Demissie; from ACT, Saidi Mkomwa, Peter Kuria and Weldone Mutai; while from the Ministry of Agriculture, Paul Obusuru and Naomi Kihara.

We are also grateful to all that contributed in one way or the other in the development of this Training Aid that may not have been mentioned here. Kindly take this acknowledgement as an expression of sincere gratitude.

Abbreviations and Acronyms

AAS	Agrometeorological Advisory Services
ASALs	Arid and Semi-arid Lands
CA	Conservation Agriculture
CAN	Calcium Ammonium Nitrate
CDD	Consecutive dry days
CRAFT	Climate Resilient Agri-business For Tomorrow
CSA	Climate Smart Agriculture
CWD	Consecutive Wet days
EA	East Africa
EIL	Economic Injury Level
FFS	Farmer Field School
FIFO	First In, First Out
FYM	Farm Yard Manure
GAPs	Good Agricultural Practices
GHG	Greenhouse Gas (emissions)
GPHHPs	Good Post-Harvest Handling Procedures
IPM	Integrated Pest management
KALRO	Kenya Agricultural and Livestock Research Organization
KES	Kenyan Shilling
LGS	Length of the Growing Spell
MA&F	Ministry of Agriculture, Livestock and Fisheries
MALF&C	Ministry of Agriculture, Livestock, Fisheries and Cooperatives
MAM	March-April-May (rainy season)
MICCA	Mitigation of Climate Change in Agriculture
MIS	Market Information System
MT	Metric Tonne
NatAgMet	National Agro Meteorology Unit
NGO	Non-governmental Organization
OND	October-November-December (short rains season)
PHH	Post-Harvest Handling
SNV	Netherlands Development Organization
SSA	Sub Saharan Africa
SWC	Soil and Water Conservation
WRS	Warehouse Receipt System

Module 1: Introduction to Greengram Production

1.0 Overview of the Greengram Subsector

1.1. Introduction

Greengram is an important pulse crop commonly grown and consumed in Kenya. It is believed to have originated from India and its cultivation has spread to several countries of Asia, Africa, and the Americas in the recent times. It is used in several food products, both as a whole seed and in processed form as an excellent source of high quality protein with high digestibility. Greengram is considered to be hardiest among all pulse crops and can tolerate drought to a great extent. Hence, it is successfully grown in any adverse conditions and particularly in drought prone areas.

The module introduces aspects regarding the global and Kenyan greengram production outlook, challenges facing the subsector and the opportunities it presents to farmers and other stakeholders along the value chain.

1.2. Greengram Production Outlook

1.2.1. Global overview

Greengram is an annual legume crop grown for its seed (Plate 1). It is a native crop of India and it is cultivated in several countries of Asia, Africa and America. Currently, greengram is mostly produced in South, East and Southeast Asia, South America and in East Africa. There is potential for expansion to West Africa and Central Asia. The global greengram area is about 7.3 million ha and global output is about 5.3 million tons with India and Myanmar each supplying about 30% of this, China 16%, and Indonesia 5%. Average global grain yield for greengram is 730 kg per hectare (IMIN, 2017).

Plate 1: Greengram grains

In Africa, greengram is grown in various countries as indicated in Figure 1. Tanzania is leading producer of Greengram in the Sub Saharan Africa (SSA) region. However, the biggest exporters in Africa include Egypt, Uganda and Ethiopia while Ghana ranks high at position 9 globally as the leading importer of greengram in Africa. Consumption of greengram in East Africa has been increasing mainly due to the increasing demand by the Kenyan market (Kilimo Trust, 2017).

Figure 1: Geographical Distribution of Greengram in Africa (Source: Infonet Biovision, 2019)

1.2.2 Production and consumption of Greengram in Kenya

Greengram is one of the most popular pulses commonly grown and consumed in Kenya. It is grown in the arid and semi-arid lands (ASALs), for food and sale, with the bulk of the produce sold in local markets. It is a major income generating enterprise in semi-arid eastern Kenya ranking second after indigenous chicken. (MoALF, 2015).

The major producing regions are located in the Eastern, Coast (Taita Taveta, Kilifi and Tana River), Nyanza (Migori, Busia and Homa Bay) and parts of the Rift Valley (Kerio valley, Elgeyo Marakwet Baringo and West Pokot). The Eastern Region Counties of Kitui, Makueni, Tharaka Nithi, Machakos, Meru and Embu are responsible for more than 95% of national production. Production has shown to be highly inclusive with at least 51% of the producers being women (SNV 2015).

According to 2018 Kenya National Crop data , the total hectarage for greengram was 362,938 ha against the production of 206,619 metric tonnes (MT) translating to 570 kg/ha or 6 bags of 90 kg/ha. For Kitui it was 161,390 ha against the production of 91,072 MT translating to 560 kg/ha, approximately 6 bags/ha, and for Makueni was 52,633 ha against production of 52,633 MT translating to 580 kg/ha translating to 6 bags of 90 kg/ha. Figure 2 shows the potential greengram growing areas in Kenya.

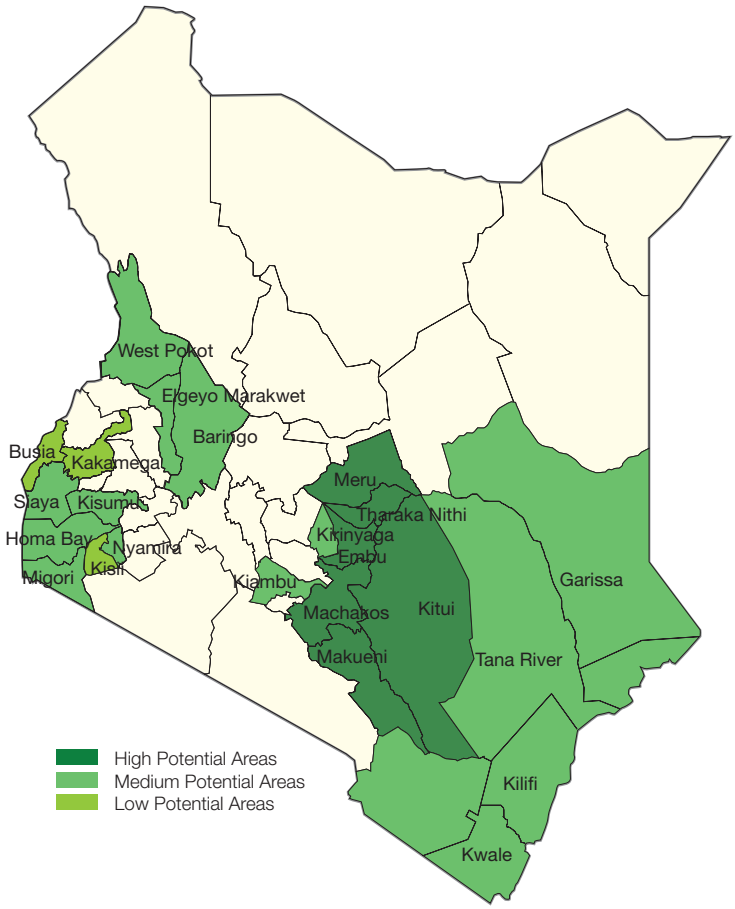


Figure 2: Greengram Producing Counties in Kenya

The key actors along the greengram value chain in Kenya include input suppliers, researchers, producers (farmers), transporters, processors, marketers and consumers. The major institutions involved in greengram research in Kenya are the Kenya Agricultural and Livestock Research Organization (KALRO), local universities, international research institutes, local NGOs and pulses networks. Besides the improved varieties, other inputs into greengram production include labour, fertilizers and chemicals, which are readily available from local agro-input dealers. Marketing agents include aggregators, wholesalers, processors, exporters and retailers. The bulk of the greengram output is marketed as dry grain, with little vegetable trade or processing. Mainly greengram processing entails canning, de-hulling, milling and splitting to make dhal.

Greengram is mainly grown for sale in local and export markets and also for food. It is increasingly becoming recognized as an excellent part of a healthy diet throughout Kenya. It is a nutritious source of food with 24% protein content and is a comparatively low-cost source of protein. It has high levels of iron (6 mg/100 g dry seeds), which is deficient in most Kenyan diets. It is also high in fibre, various vitamins and amino acids.

Greengram contributes significantly to improve soil quality by fixing nitrogen in the soil. It can add up to about 30-40 kg N/ha after the harvest of the crop. Thus, after harvesting, when the greengram residues are left on the surface, the succeeding crop (normally a cereal) requires about 25% less nitrogen application. Crop residues of greengram are a useful fodder and mulch. Sometimes greengram can be specifically grown for hay, green manure or as a cover crop.

1.3. Challenges Facing Greengram Value Chain in Kenya

Despite being an important pulse in Kenyan Arid and Semi-Arid Lands (ASALs), greengram yields have been declining. Recent reports indicate a decline from 460 kg/ha in 2010 to 380 kg/ha in 2013 (MoALF, 2015). Greengram yields in Kenya are generally low than the global average yield of 730 kg/ha. The following are the challenges that have impacted negatively to the greengram subsector:

- **Impact of climate change**. Climate and weather extremes and variability are now the norm: irregular and unpredictable rainfall, frequent droughts during the long rain seasons or severe floods during short rains. The frequency and severity of drought variation in Eastern Kenya affected greengram production, with as much as 79% decrease in productivity in Makueni in 2013 (MoALF, 2016).
- **Land degradation**: due to combination of human-induced processes such as deforestation and inappropriate tillage practices, land degradation has occurred in many farmlands with far-reaching deleterious or undesirable impacts including loss of soil quality, destruction of species habitat and biodiversity, soil erosion, and excessive nutrient runoff into lakes. This has affecting the agricultural land productivity.
- **Decreasing soil fertility:** Most farmers grow greengram as a mono-crop, season after season, without adding any inputs for soil improvement. Due to the continuous loss of nutrients with every harvest combined with inappropriate tillage practices, soil fertility continues to decline. In the long run, nutrients become deficient, thus affecting the ultimate greengram yields. Farmers who use commercial fertilizers also experience declining soil fertility if they do not manage soil fertility sustainably.

- **Limited access to good quality seeds**: Most greengram farmers typically grow traditional varieties. In most cases these landraces are well adapted to local conditions and have low nutrient requirements, but are low yielding. These have long maturity periods (3 to 4 months), small seeds, are prone to pod splitting before harvest thus high postharvest losses, and their grains are stony and hard to cook which reduces their preference for consumption. This is partly because farmers do not carefully select the crop seed, but instead pick seeds randomly from any remaining stock of the previous season.
- **Pest and disease prevalence:** Many pests and diseases are known to attack cultivated greengram while others can cause considerable losses during storage (see Tables 6 and 7). In the traditional farming context in Kenya, direct control measures are rarely undertaken, as the crop is mostly cultivated under low input conditions. In situations where greengram is grown continuously on the same fields without rotation, the risk of pests and diseases increases.
- **Water scarcity:** Due to its drought tolerance, most farmers in the region rely solely on rainfall during the entire growing period. However, pro-longed drought favours pest attack and delays maturity. Therefore, water conservation and, where possible, the additional supply of water through irrigation increases the yield potential of the crop.
- **Weed infestation**: Weeds are a big constraint to greengram production, especially during periods with favourable growing conditions. When water is available, weeds can multiply very fast and outgrow the plants, if the farmer does not intervene in time. Weeds compete with greengrams for space, nutrients and water, hence reducing the yield.
- **Land size and fragmentation**: Kenyan agriculture is characterized by both very small landholdings (0.3–3 ha) and extremely limited irrigation (less than 0.16% of arable land). In greengram growing region this limits mechanization as well as economic viability of the enterprise given the low production. Thus, posing the greatest challenge on sustainably intensifying crop productivity.
- **Unstructured marketing systems**: Lack of farmers' access to structured markets and trade discourages them from engaging in greengram production.
- **Post-harvest losses:** There is a sizeable quantitative and qualitative loss of greengram during different post-harvest operations like threshing, winnowing, transportation, processing and storage. High post-harvest losses arising from poor storage, handling of produce and poor infrastructure, makes farmers lose their crops' full value thus forcing them to sell the grain at a very low price.
- **Inadequate primary processing technologies and services**: Due to the use of old and outdated methods in processing, very high losses have been reported at this stage. To reduce the processing losses and to increase the output, it is suggested to upgrade technology and embrace mechanization hire service provision
- **Limited technical knowledge**: Insufficient farmers' knowledge of greengram management options is a major limitation.

1.4. Strengths, Weaknesses, Opportunities and Threats of the Greengram Subsector

An analysis of the greengram subsector in Eastern Kenya conducted by SNV in 2019, yielded specific weaknesses as well as strengths, opportunities and threats summarized in Text box 1. These challenges are also applicable in other greengram growing areas of Kenya.

Text Box 1: Strengths, weaknesses, opportunities and threats (SWOT) analysis of the greengram

Strength (S)	**Weaknesses (W)**
1. Large arable land that can be utilized for greengram production; 2. Suitable soils and improved water resources management; 3. Greengram is a cash crop for the local community especially in Kitui, Machakos, Tharaka Nithi and Makueni; 4. The greengram producing counties border each other therefore interventions likely to yield economies of scale at production and marketing levels; 5. High number of small holder farmers involved in production.	1. Poor agronomic practices hold the farmers to subsistence production and leading to low yields and poor quality; 2. Undeveloped farmers' production and marketing enterprises / organizations; Weak capacities of farmers' organizations, weak extension services and lack of specific market information services; 3. Weak market linkages as collective marketing and contract farming are absent to guarantee price of the produce.
Opportunities (O)	**Threats (T)**
1. Availability of certified seeds from seed companies; 2. Mechanization: new efficient technologies in production and value addition; 3. Changes in social patterns and lifestyles; High Demand from Supermarkets; 4. Increasing Support and extension services from county government; 5. Availability of financial services from banks, financial institutions and local table banking models; 6. Capacity building and BDS by Government and development partners; 7. National and County Government favourable policy changes; 8. With high number of households involved in the production of pulses.	1. Competition from other pulses e.g. pigeon peas, cowpeas and other cash crops (fruit trees); 2. Product quality standards; 3. Low youth participation; 4. Unreliable rainfall and erratic weather conditions.

Module 1: Introduction to Greengram Production

Module 2: Climate Change and Agriculture

2 Climate Change and Agriculture

2.1. Introduction

Agriculture is not only impacted upon by climate change but also contributes to the problem. The country's agriculture is predominantly rain-fed and therefore vulnerable to climate change particularly changes in temperature regimes and precipitation patterns and extreme weather events. This leads to, among others, unsustainable land and agricultural water management. Innovative and transformative measures are therefore urgently required to assist stakeholders in the greengram sub-sector to cope with effects of current and projected change in climate patterns. Climate smart agriculture (CSA) has been identified as a viable approach to provide solutions towards increased agriculture sector productivity while addressing impacts of changing climate (MoALF, 2017).

There is wide scientific consensus that global climate is changing in part as a result of human activities (IPCC, 2001) and that the social and economic costs of slowing it down and responding to its impacts will be large (OECD, 2001). Climate change is any significant long-term change in the expected patterns of average weather of a region over a significant period of time. Current data demonstrates that climate is changing globally and that human induced greenhouse gas (GHG) emissions, especially carbon dioxide, are causing an increase in global temperatures that creates changes in the earth's climate. The phenomenon multiplies the challenges of achieving the needed growth and improvements in agricultural systems and its effects are already being felt, in the form of reduced yields and more frequent extreme weather events, affecting crops and livestock alike.

According to the UNEP's Information Unit for Climate Change, Kenya, like all the other countries in Africa, has been experiencing extreme levels of climate change in the past few decades. Some of these changes can be attributed to the following issues:

1. Greenhouse gas emissions through burning fossil fuels, cutting down forests and farming activities. This leads to Global warming (The current global average temperature is 1.0°C higher than it was in the late 19th century (IPCC, 2019)).
2. Agriculture sector currently generates 19–29% of total GHG emissions. Without action, that percentage could rise substantially as other sectors reduce their emissions. Ploughing activities, fertilizer manufacture and use, livestock production are major sources of this emission
3. Deforestation reduces vegetation cover which provides carbon sink
4. Industrialization significantly contributes to burning of fossil fuels which leads to increased emission of greenhouse gases.

Climate change has significantly impacted agriculture and is expected to further impact directly and indirectly food production in the region. The 2007 IPCC report showed a clear evidence of increase of mean temperature, increased variability in rainfall amount and distribution, changes in water availability, increase on frequency and intensity of extreme events, sea level rise and salinization, perturbations in ecosystems, which all will have profound impacts on agriculture,

forestry and fisheries in the region. This, coupled with the expected exponential increase in human population (estimated to be 95 million by 2050), poses a serious threat to Kenya's future development and attainment of Kenya Vision 2030. It will also impact on the Government's Big Four agenda especially on food security, increased manufacturing and affordable healthcare. Hence, robust climate projection using high-resolution regional climate models, is highly required in East Africa (e.g. Kenya), which has a very complex topography and high spatial rainfall variability due to different rainfall regimes.

This module attempts to expose learners to effects of climate change and appropriate climate information on greengram production and how this is important in decision making as regards to farm operations. The module covers climate change projections in Kenya, seasonal trends, effects of climate change in greengram production, use of climate information in decision making for farm operations and climate smart agriculture practices in greengram production.

2.2. Climate change projection scenarios

As part of the Climate Resilient Agri-business for Tomorrow (CRAFT) project in East Africa, a climate projection was performed for Kenya, Uganda and Tanzania using a high-resolution data from the Coordinated Regional Climate Downscaling Experiment (CORDEX). The climate projection work was based on two validated regional climate model data that are dynamically downscaled from four Global Circulation Models (GCMs), which has a reasonable skill in East Africa. The GCMs projections were forced by the Representative Concentration Pathways (RCPs), which are prescribed greenhouse gas concentration pathways (emission) trajectory and subsequent radiative forcing by 2100. The climate projection work in the CRAFT project is based on two RCP scenarios, RCP4.5 and RCP8.5, that are representatives of mid-and high-level of emission scenarios, respectively. The following sections (2.2.1 to 2.2.4) summarizes the climate projection work done under the CRAFT project for the greengram growing areas of Kenya.

2.2.1. Temperature Trend and projection in the Greengram growing areas

The temperature trend analysis (from 1961 – 2005) for both the first (March, April, May – (MAM)) and second (October, November, December – (OND)) rainy season show that temperature have been increasing by more than one degree in most parts of the greengram growing Kenya (Figure 3).

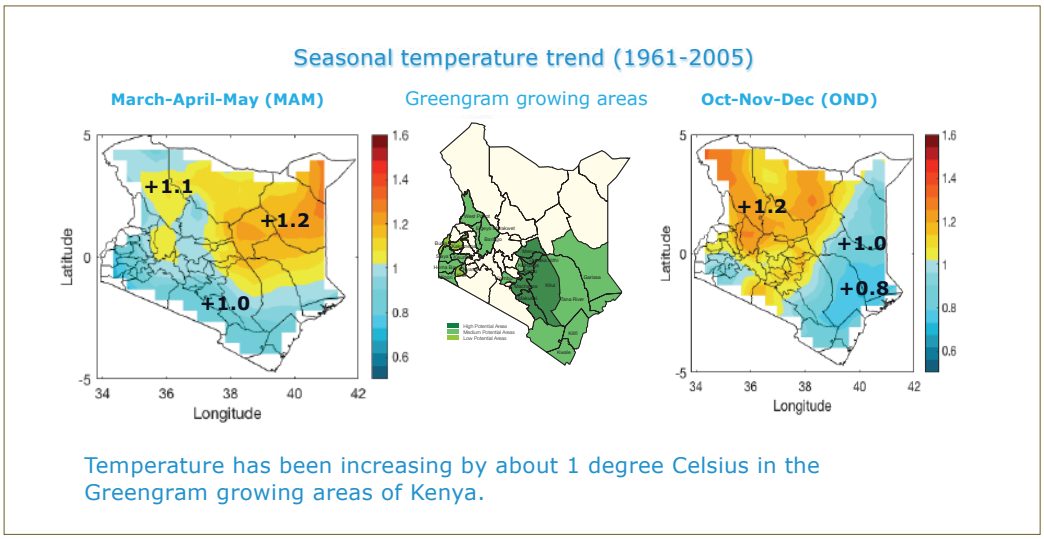


Figure 3. Seasonal temperature trends in Kenya over the last 44 years (source: CRAFT 2019)

During both the first and second rainy seasons, temperature in the 2030s is expected to rise by about 1.4°C to 1.8°C in the greengram growing areas of Kenya (Figure 3). However, the projection model particularly in the business as usual scenario shows that temperature in the 2050s is expected to rise by about 2.4°C to 2.8°C and 2.0°C to 2.4°C in the south-eastern and western greengram growing areas of the country during the first and second rainy seasons, respectively. Figures 4 and 5 demonstrates a rate of warming in the greengram growing of Kenya, whereby temperature over the south-eastern and western greengram growing areas rises in the first rainy season greater than the second rainy season by about 0.4°C.

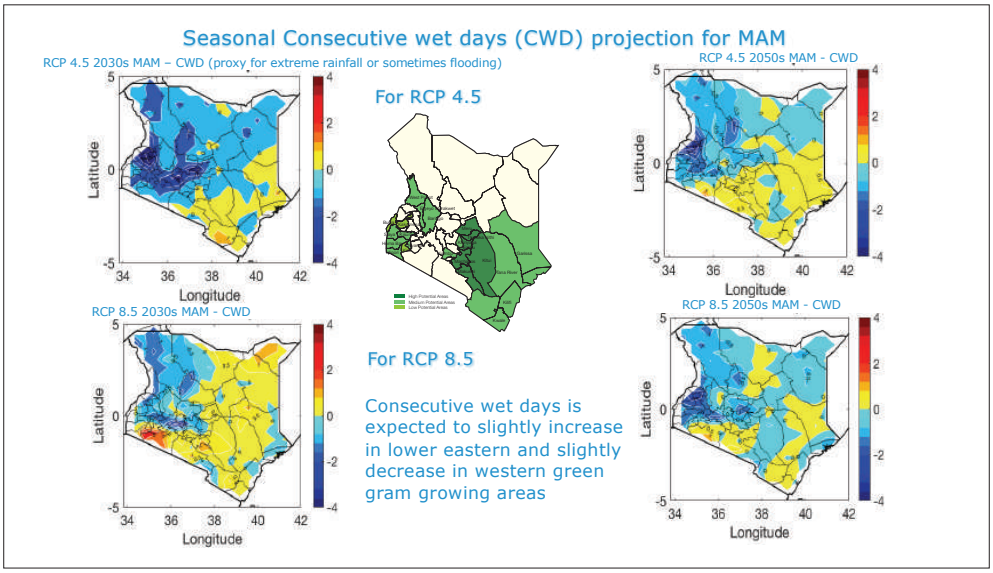


Figure 4. Projected seasonal mean changes in temperature-MAM-long rains- for 2030s (Left) and 2050s (Right) under the RCP 4.5 and RCP 8.5, relative to the reference period (1961-2005 (Source: CRAFT project 2020)

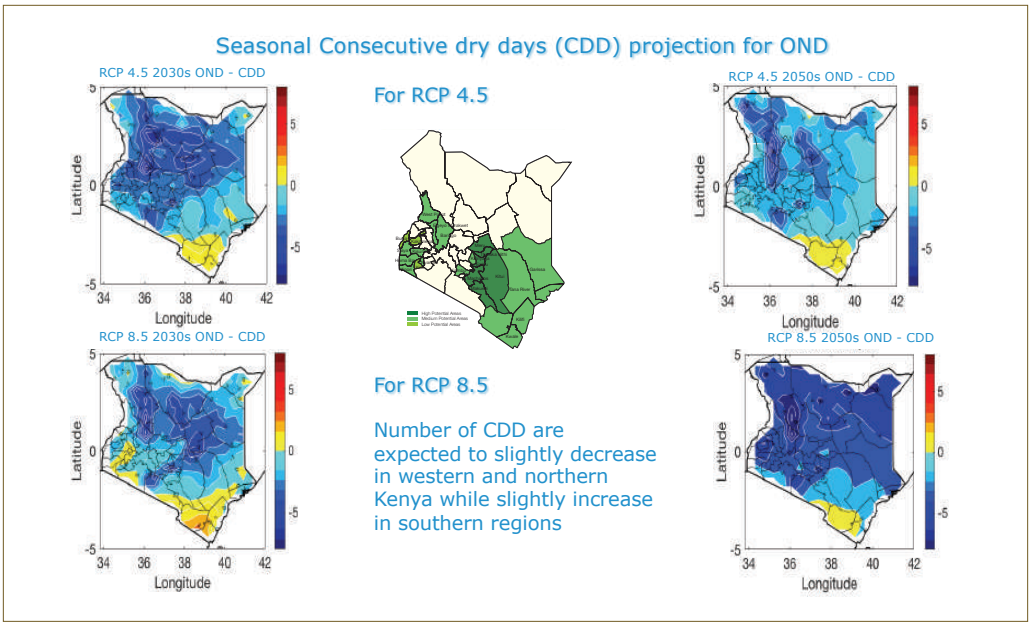


Figure 5. Seasonal temperature projection for the OND- short rain season for 2030 and 2050 under RCP 4.5 and RCP 8.5 (Source: CRAFT project 2020)

2.2.2. Projection of precipitation

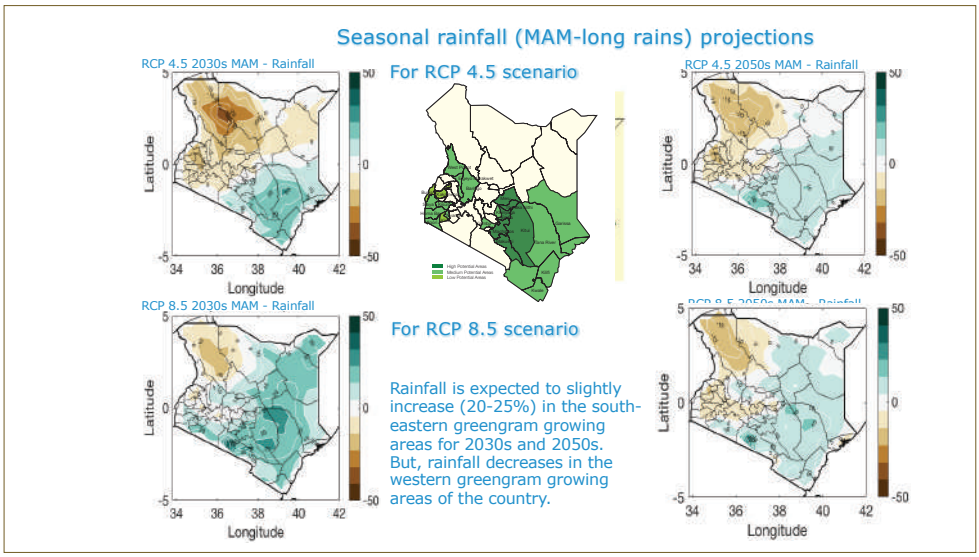


Figure 6. Projected seasonal mean changes in rainfall MAM-long rains - for 2030s (Left) and 2050s (Right) under the RCP 4.5 and RCP 8.5 (Source CRAFT 2020)).

The seasonal mean rainfall in the first rainy season (MAM) is projected to slightly decrease in the western regions of the greengram growing areas by about 10% in both scenarios (RCP4.5 and RCP8.5) and for 2030s and 2050s. However, the seasonal rainfall over the south-eastern greengram growing regions such as Kitui and Makueni counties is projected to slightly increase by about 10-20% (Figure 6). On the other hand, the seasonal mean rainfall in the second rainy season (OND) for 2030s and 2050s under RCP4.5 and RCP8.5 show that rainfall is expected to increase by about 20-30% in the south-eastern greengram growing areas of Kenya, especially during the 2050s (Figure 7). However, the seasonal rainfall in the second rainy season over the western greengram growing areas is expected to slightly increase (5-10 %) in both the scenarios.

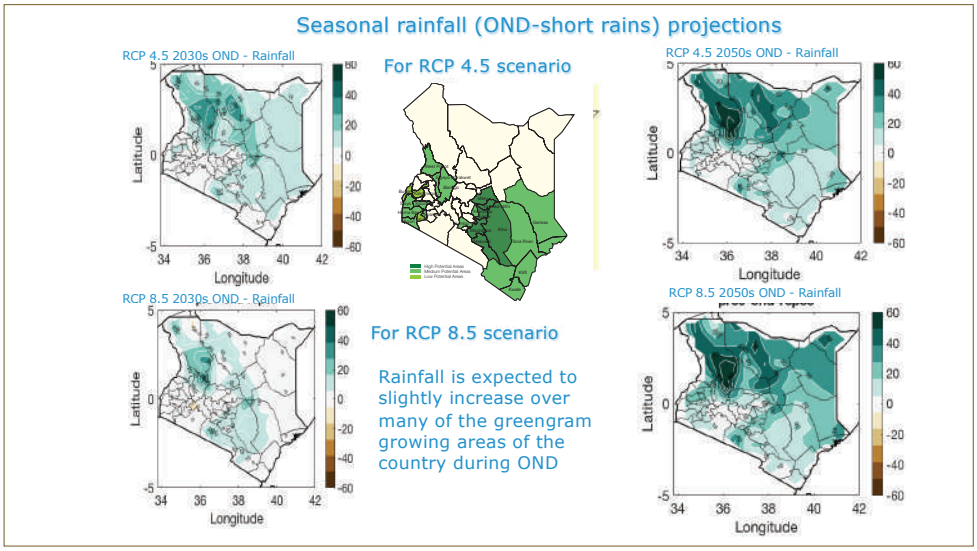


Figure 7. Projected seasonal mean changes in rainfall OND-long rains -for 2030s (Left) and 2050s (Right) under the RCP 4.5 and RCP 8.5 (Source CRAFT 2020).

2.2.3. Onset and length of growing spell

The assessment and prediction of the onset and cessation dates, and length of the growing spell of a rainy season is a very crucial element to the agricultural activities of countries in East Africa, whose agriculture is mainly dependent on the distribution and amount of seasonal rainfall. In the CRAFT project, the onset, cessation and length of growing spell for the first rainy season (MAM) is estimated for the historical (1961-2005) and the 2030s and 2050s for both RCP4.5 and RCP8.5 scenarios. Results show that early onset of the seasonal rainfall is expected in most of the south-eastern greengram growing areas of Kenya by about 10 days (Figure 8). On the other hand, the onset of rainfall is expected to slightly delay over the western greengram growing areas of the country. Similarly, the length of the growing spell in the south-eastern greengram growing area of Kenya is expected to increase by about 10 days (Figure 9) suggesting a late cessation for the region. The length of the growing spell over some of the western greengram growing areas of the country is expected to slightly decrease suggesting an early cessation of the season in the region.

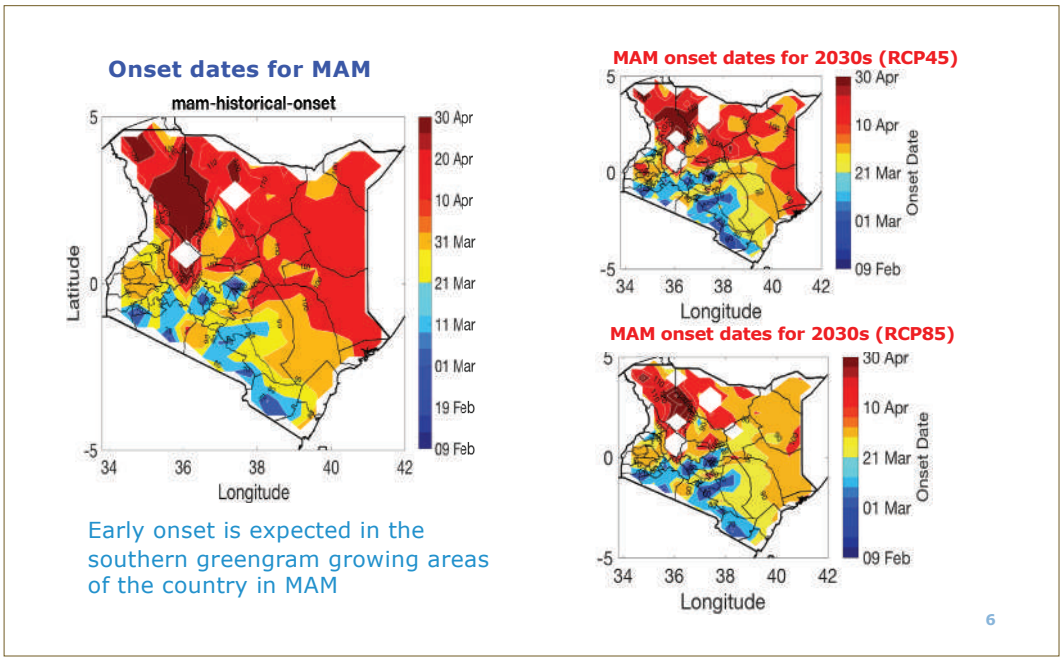


Figure 8. Rainfall onset days for the MAM rainy season for 2030 for RCP 4.5 and 8.5 (Source: CRAFT project 2020).

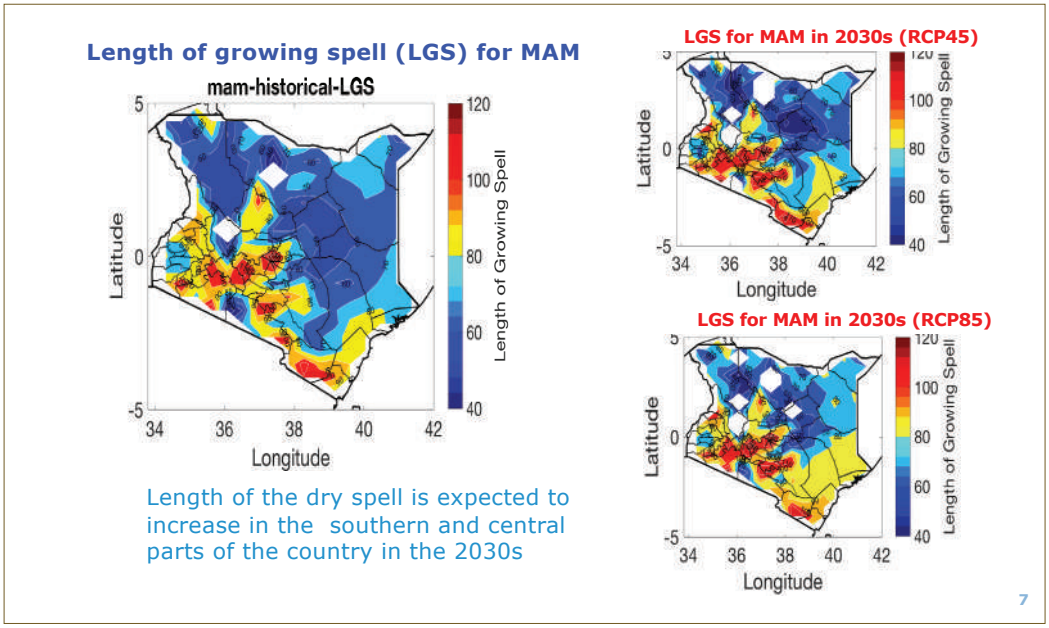


Figure 9. Length of the growing spell (LGS) for the MAM season for 2030 and 2050 (Source: CRAFT project CRA report)

In summary, during both the first (MAM) and second (OND) rainy seasons, temperature in the greengram growing areas of western and south-eastern Kenya is expected to rise by about 1.4°C to 1.8°C and 2.4°C to 2.8°C in the 2030s and 2050s respectively.

The seasonal rainfall over the south-eastern greengram growing areas of the country is expected to increase in both the first and second rainy seasons in the 2030s and 2050s. Early onset and longer length of the growing period is anticipated in this region which favour the greengram agricultural activity in the region. On the other hand, the seasonal rainfall is expected to decline in the western greengram growing areas particularly in the first rainy season. A delay in the onset and a decrease in the length of the growing period is anticipated in the western greengram growing areas of the country which will have a great impact on the agricultural activity of the region.

2.2.4. Projections of extreme rainfall

Precipitation indices such as consecutive dry days (CDD) and consecutive wet days (CWD) are used in the CRAFT project based on the definitions recommended by the Expert Team on Climate Change Detection and Indices (ETCCDI). These indices have been widely used in the detection, attribution, and projection of changes in climate extremes and a detailed description of the indices can be found on the ETCCDI website, http://etccdi.pacificclimate.org/list_27_indices.shtml. CDD has been used as a useful indicator for enhanced dryness and high risk for seasonal drought whereas CWD has been a key indicator of extreme precipitation that could lead to flooding.

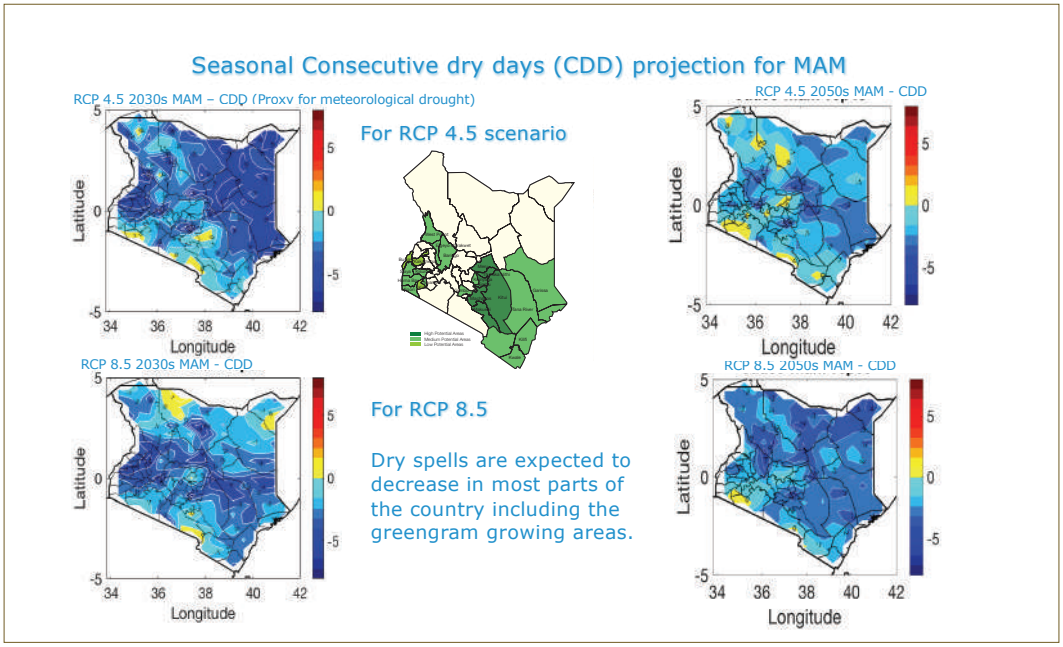


Figure 10. Projected seasonal consecutive dry days for MAM for year 2030 and 2050. (Source: CRAFT project 2020)

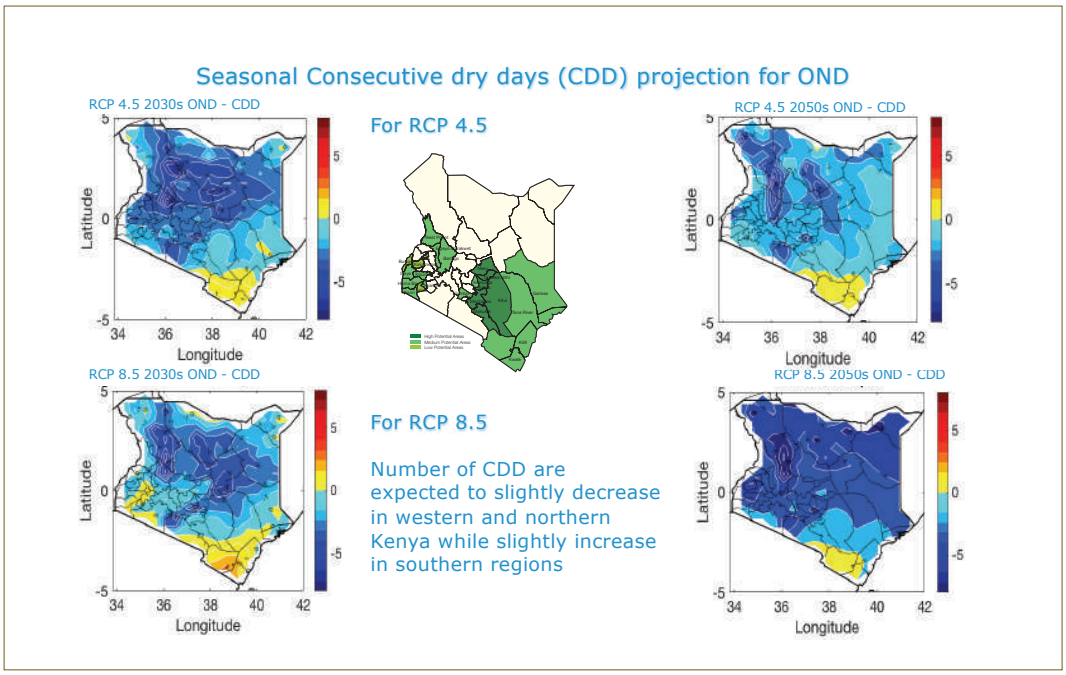


Figure 11. Projected seasonal consecutive dry days for OND for year 2030 and 2050. (Source: CRAFT project 2020)

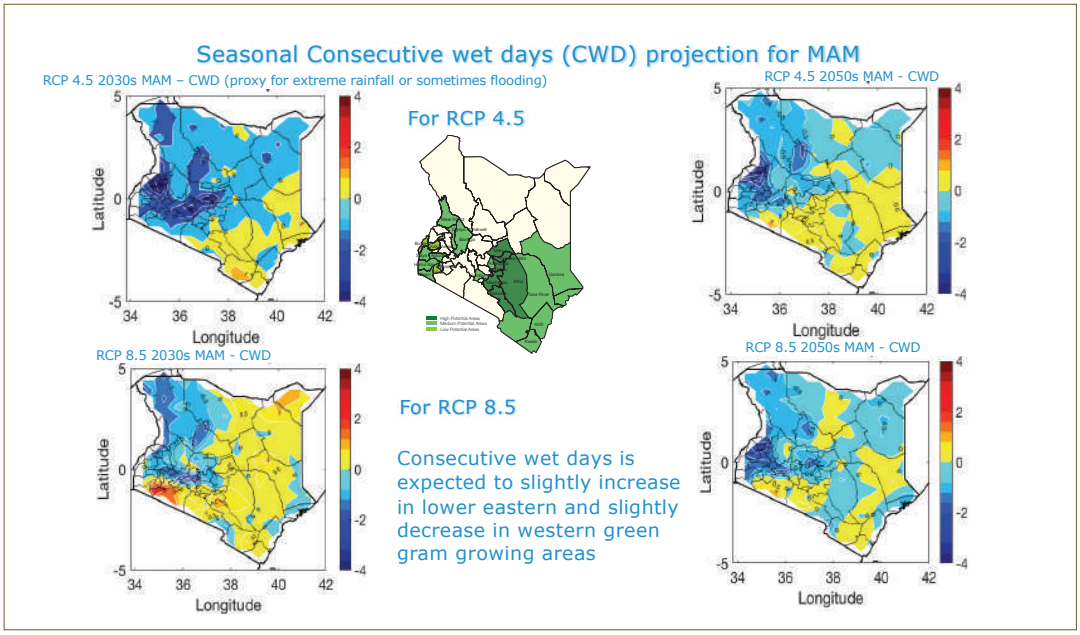


Figure 12. Projected seasonal consecutive wet days for MAM for year 2030 and 2050. (Source: CRAFT project 2020)

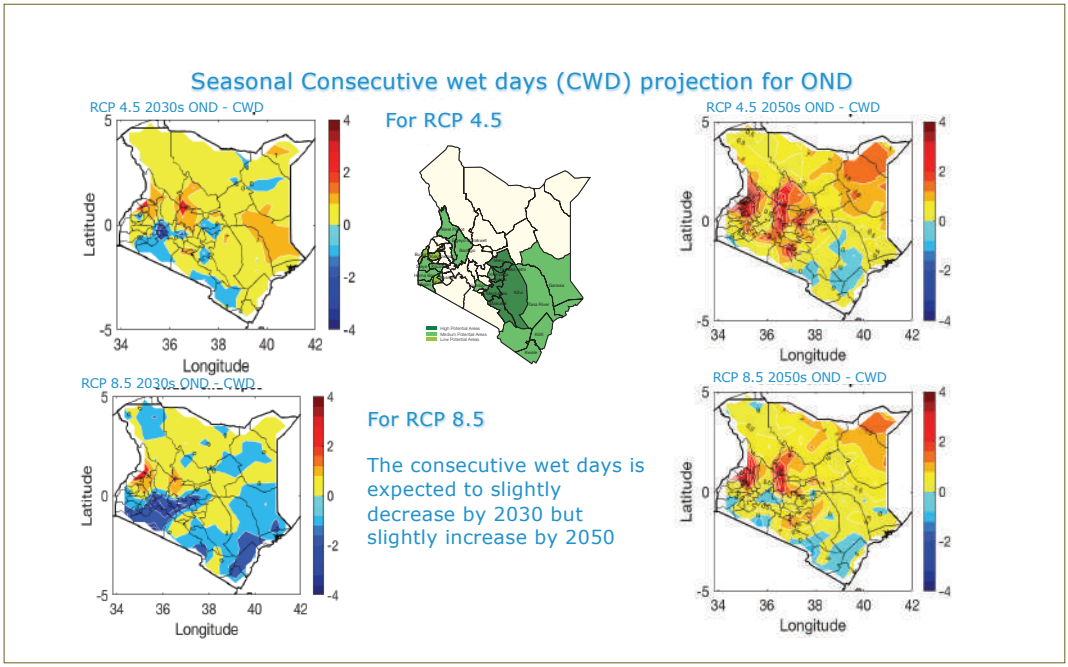


Figure 13. Projected seasonal consecutive wet days for OND for year 2030 and 2050. (Source: CRAFT project 2020)

To manage these changes, it will be prudent for the climate extension services providers to:

- Facilitate famers to adapt through use of climate smart technologies
- Incorporate climate information into agricultural extension services
- Engage farmers and the extension services to consider:
  - Climate risks in business planning and decision-making
  - Other opportunities for managing climate risk – e.g. adaptation investments and climate-oriented insurance
  - Microclimate management – as one of the adaptation measures that has mitigation benefits

2.3. Climate Change Risks, Opportunities and Projected Impact on Greengram

In Kenya, greengram is a crop of major economic importance to the ASALs which constitute 80% of Kenya's land mass. The increase in human population is putting pressure on the arable land, forcing people to migrate into the fragile arid and semi lands. However, climate change threatens development and economic growth in these areas, with increased risks for individuals, businesses, livelihoods, value chains, infrastructure and other assets.

2.3.1 Climate change risks and opportunities

Despite, the greengram potential in Kenya, its production is greatly affected by climate change. A survey conducted by SNV on influence of climate change on production of greengram reveals that climate change is influencing the production of greengram as nearly 100% of the interviewed stakeholders on their experiences confirmed the phenomenon (Figure 14). Most of the stakeholders in the value chain perceived a negative impact. Interestingly, 33.3% of the post-harvest handling (PHH) equipment suppliers experienced a positive impact due to climate change, as did 7.1% of the input suppliers

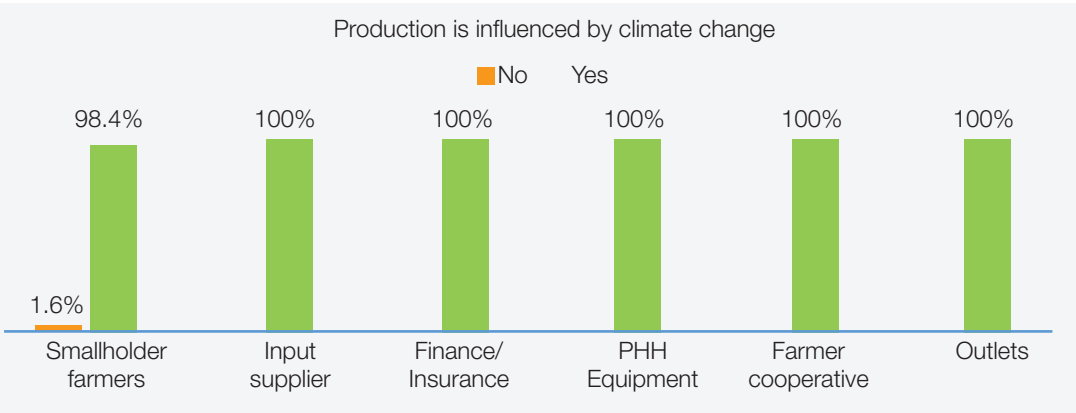


Figure 14: Stakeholder responses on whether climate change influences greengram production (Source: SNV, 2019)

Greengram value chain can be adapted to changes and variabilities in climate and make the production more resilient in semi-arid areas. Figure 15 summarizes some of the strategies across greengram value chain of adapting its production to changes and variabilities in climate in Makueni County.

Green gram	Provision of seeds and other inputs	On-farm production	Harvesting storage and processing	Product marketing
Reduced rainfall	Soil moisture stress; shifts in planting dates and plant maturity period; increased costs of inputs and labour for land preparation (weak draught power)	Reduced vegetative growth, wilting; flowers abortion; early shattering of pods; crop failure	Reduced yields and quality; poor post handling storage and processing, winnowing, sorting; increased post-harvest costs of labour (low volume, disease infested produce)	Poor market linkages due to low volumes produced; low farm gate prices due to low quality produce
Magnitude of impact	Moderate	Moderate	Moderate	Major
Farmers' current strategies to cope with the risks	Use of drought tolerant varieties; recycle seed from previous cropping seasons; capacity building of producers on use of fertilisers both organic and inorganic	Conservation agriculture	Use labour intensive post harvest methods like winnowing, air drying"	Grain banks at farm community level
Other potential options to increase farmers' adaptive capacity	Introduce varieties with efficient moisture use; use available nutrient resources such as manure	Ensure access to land for production through land subdivision; promote irrigation and water harvesting techniques; crop rotation; minimun tillage; cover crops	Bulk commodity through societies to benefit from economies of scale; construct storage facilities equipped with post harvest machines at community level; introduce policy measure to subsidize investment in mechanisation	Contract farming opportunities
Droughts	Reduced animal draught power due to weak animals; reduced capacity to purchase inputs	Late land preparation and less area ploughed; low use of improved varieties and fertilizers	Low volumes; yield loss	Poor market prices; loss of income
Magnitude of impact	Moderate	Moderate-Major	Severe	Severe
Farmers' current strategies to cope with the risks	Use new adapted seed varieties; seed production; use of animal manure	Access land through leasing, sub division of land; use conservation agriculture and water harvesting practices; use of herbicides; use of draught power; conservation agriculture; cover crops	Manual threshing and winnowing; manual sorting; manual dusting and packaging	Sell at farm gate, some aggregate and sell as groups; scouting to identify for best market for produce
Other potential options to increase farmers' adaptive capacity	Introduce water use efficient varieties; develop fertilizer recommendations based on local soil tests	Encourage land adjudication and sub division to ensure access and use of land; Mechanisation e.g. planters	Set up facilities for mechanical threshing, winnowing, grading and packaging; warehouse reseed system and storage facilities	Form cooperatives to aggregate and bulk purchase of inputs; initiate credit facilities for bulk input purchase; introduce policy measure to Improve available marketing

Figure 15: Adapting greengram production to changes and variabilities in climate: strategies across Greengram value chain in Makueni County. Source: MoALF. 2016

2.3.2 Climate change projected impact (modelling study)

In Eastern Kenya, climate change is likely to boost greengram production. In the coming decades, greengram yield is expected to increase during both the MAM and the OND seasons and under all climate change scenarios (Figure 5). The degree of yield increases, however, depends on the growing season and the climate change scenario. During the OND season, yield increases will be boosted by projected increases in rainfall and hence increasing water availability for greengram production under all climate change scenarios (Figure 6). In Kitui and Makueni, yields are likely to increase from a current maximum of 960 kg/ha to 1,080 kg/ha in the 2030s.

During the MAM season, greengram yields also are expected to increase slightly. This is the case despite projections of rising temperatures and erratic rainfall during the season. This is because unlike other crops, greengram is a more resilient crop and relatively more tolerant to drought/water stress than other crops.

With better agronomic practices such as a combination of soil testing and precision fertilizer application, pest, disease and weed control, farmers in Kenya can get much more than what they get now and in the future without these measures.

2.4. Key Climate Information Decisions

2.4.1 Key Decision Points Impacted by Climate Information

For farmers and extension agencies who provide support services in terms of crop management advisories, key decision points impacted by climate information are provided in Table 1.

Table 1: Key decision points impacted by climate information

Key Decision Points	Key Climate Variable that informs the Decision
Sowing Period	Onset of rainy season
Choosing of crops/crop variety	Total rainfall forecast and its intra-seasonal distribution
Irrigation management – in terms of timing of irrigation and quality of water to be applied	Total rainfall and its intra-seasonal distribution
Resource Use Allocation – both labour and finance	Total rainfall and its intra-seasonal distribution
Fertiliser application – the quantity and type of fertiliser as well as the timing of application of fertilisers on crops	Forecast of the distribution of rainfall across the crop growth stages
Timing of pesticides application	Wind direction, wind speed and distribution of rainfall across the crop growth stages
Time of harvest	Forecast of the distribution of rainfall during the crop maturation stage
Timing of drying, threshing and winnowing	Forecast of the distribution of rainfall after harvesting
Packaging and Storage	Forecast of the distribution of rainfall, temperature and humidity during storage

(Source: Madhavan M. and Rengalakshmi R., 2015: FAO. 2019)

The most useful weather forecast information that can assist farmers in making decisions on agricultural management is the early indication of the characteristics of the rainy season. It should include:

- Onset date of the main rains
- Rainfall amount
- Cessation date of the main rains
- Temporal and spatial distribution of the main rains
- Timing and frequency of active and dry periods (wet and dry spells)
  - Probability of extreme events.
  - Number of consecutive wet days
  - Number of consecutive dry days

Primary producers use agrometeorological information for decision-making with a range of scales that can vary from several days to the entire cropping season, or inter-annual time periods. These decisions relate to the choice of crops; the choice of cultivar (early or late flowering); mix of crops; fertiliser use; pest and disease control; timing of the harvest; irrigation scheduling; the area planted with a given crop (and/or rotation of fields); timing and amount of tillage and stocking rates. Strategic planning and marketing decisions mostly use climate information for the following year.

2.4.2 Types of Climate Information for Greengram Production

The four major types of climate information needed by farmers are:

a. Before the beginning of the season, the interpretation of the agrometeorological crop risk analysis to assess the suitability of greengram for the region based on its water requirements and other agrometeorological analysis.

b. Before the beginning of the season, the interpretation of the statistical analysis of rainfall for the determination of the optimum planting date(s) for a specific region;

c. Before the beginning and the end of season, seasonal climate outlooks in order to adapt to the various situations due to the uncertainty inherent in the seasonal climate forecasts.;

d. Throughout the season, seven-day weather forecasts for rainfall and temperature (with a particular focus on forecasts of weather extreme events such as drought, heavy rains and strong winds) and 10-day agrometeorological advices on better adaptation of farmers' practices.

It is important to note that, except for the "*c*" type, other types of information should be tailored to farming communities at the local level and presented in a way that makes it easy to understand. In principle, the four types of climate information are produced by the Agrometeorology Unit of Kenya Meteorology department in close collaboration with agrometeorology and agricultural research units; after which they are disseminated to farmers with the assistance of the agricultural extension officers at the local level.

2.5. Climate Smart Agriculture

Climate change and degraded soil are identified as the major causes of decline in agricultural productivity; any actions that attempt to improve agriculture productivity, must take into consideration how to counter these pertinent and prominent issues. Climate change and weather variability affect agricultural production negatively and it is expected to worsen in the future. CSA practices present an opportunity to reduce such losses, build resilience in the agriculture sector, improve productivity and farmer incomes, and contribute to climate change mitigation.

CSA is an approach that helps to guide actions needed to transform and reorient agricultural systems to effectively support development and ensure food security in a changing climate. CSA aims to tackle three main objectives in order to enhance the achievement of national food security and development goals (FAO, 2010), namely (Figure 16):

- sustainably increasing agricultural productivity and incomes;
- adapting and building resilience to climate change; and
- reducing and/or removing greenhouse gas emissions.

CSA provides the means to help stakeholders from local to national and international levels identify agricultural strategies suitable to their local conditions.

2.5.1 Why Climate Smart Agriculture?

Agricultural activities account for 19-29 percent of global greenhouse gas (GHG) emissions besides being the key driver of deforestation and land degradation, which account for an additional 12-14 percent of GHG emissions. However, the agricultural sector can be an important part of the solution to climate change by capturing synergies that exist among its activities to improve natural resource management while developing more productive food systems.

Any agricultural production system must therefore transform itself if it is to achieve better productivity and profitability. Climate change will make this task more difficult under a business-as-usual scenario, due to adverse impacts on agriculture, requiring spiralling adaptation and related costs.

To achieve food security and agricultural development goals, adaptation to climate change and lower emission intensities per output will be necessary. This transformation must be accomplished without depletion of the natural resource base. Climate change is already having an impact on agriculture and food security as a result of increased prevalence of extreme events and increased unpredictability of weather patterns. This can lead to reductions in production and lower incomes in vulnerable areas.

Figure 16: What is CSA (Source: Papuso and Faraby, 2013)

Despite the many challenges occasioned by climate change, there is great potential for redress through investing in CSA interventions that would increase productivity, resilience and mitigate climate change risks (Figure 16), such as retention of crop residues

and crop rotation, making the soil resilient and becoming a carbon-sink; new improved seeds, drought-tolerant seeds, alley cropping, small-scale irrigation and/or production diversification among others.

Changes in tillage practices have had a significant effect on shifting conventional cereal-based cropping systems to more diversified crop rotations that utilize pulses or oilseeds and that result in less soil disturbance. While increased use of herbicides has been utilized to address weed abundance under reduced or no-tillage, this appears to be moderated after a period of transition to conservation tillage.

Good farming practices can maintain biodiversity and reduce the quantity of GHGs released to the atmosphere, and trap carbon through improved biomass production. CSA increases the soil-carbon content, improves fertilizer and water-use efficiency as well as water-holding capacity, and makes soils easy to work. CSA also increases cost-benefit returns.

2.5.2 Components of Climate Smart Agriculture

The CSA approach is anchored in the principles of sustainable intensification of agricultural production (crops, livestock and fisheries) that is working on landscape level with an ecosystem approach that aims at increasing productivity and system resilience while reducing and removing GHG emissions from the atmosphere.

Sustainable intensification means a productive agriculture that conserves and enhances natural resources. It uses an ecosystem approach that draws on nature's contribution to crop growth - soil organic matter, water flow regulation, pollination and natural predation of pests. It applies appropriate external inputs at the right time and in the right amounts to improved crop varieties that are resilient to climate change and use nutrients, water, and external inputs more efficiently, without causing harm to the fish and livestock ecosystems. Both the sustainable intensification and ecosystem approaches are meant to enhance resilience of livelihoods towards fodder and food insecurity as a result of climate change.

Therefore, CSA constitute a basket of sustainable practices that are applied in an integrated landscape approach, and that are coordinated across agricultural sectors, ensuring they capitalize on potential synergies, reducing trade-offs and optimizes the use of natural resources and ecosystem services. Some farm practices, when implemented in synergy and with care, will limit triggers of climate change and thus qualify to be CSA actions. Such practices include:

- Choosing appropriate farm enterprises for your area, e.g. growing arrow roots in a flood-prone area, growing drought-tolerant greengram varieties in low-rainfall areas, and selecting drought-tolerant livestock species for dry areas
- Diversification of farm enterprises
- Proper timing and application of farm operations
- Soil and water conservation measures
- Minimum or zero tillage
- Permanent soil cover
- Intercropping and crop rotation involving legumes
- Farmyard manure management and use
- Biogas production reduce release of methane to the environment
- Composting to improve soil fertility
- Beekeeping to conserves the environment
- Climate smart dairy production systems
- Pasture land rehabilitation and management
- Preserving hay for use during drier seasons
- Practicing integrated farming systems for synergy of farm enterprises.

Module 3: Climate Smart Greengram Production Practices

3.0 Climate Smart Greengram Production Practices

3.1. Introduction

The productivity of greengram in Kenya is still below its yield potential due to a number of constraints such as low yielding varieties, disease and insect pest problems, variable climatic and soil conditions, limited access to improved varieties, inadequate knowledge on and poor crop management practices.

This module exposes to learners how some of these challenges are addressed by providing information on improved varieties, seed sources and climate smart crop management practices aimed at increasing crop productivity. It is focused on climate smart and resilient greengram production. It covers ecological requirements, varieties and varietal selection and greengram cropping systems. It also captures climate smart land preparation, planting, crop nutrition, field management which includes crop protection.

3.2. Greengram Varieties and Ecological Requirements

3.2.1. Growth Characteristics of Greengram

Plate 2: Greengram plant

Greengram is one of the most important legume crops in Kenya. It is a warm season annual, highly branched with trifoliate leaves. The plant has upright, bushy and vine types of growth habit, with plants varying from 30-150 cm in height. The root system consists of a well-developed taproot with deeply placed lateral roots. Stem is much branched with a tendency to twine at the tips, angular and covered with long spreading hairs. Leaves alternate, 3-foliolate (sometimes 5-foliolate) and dark green in colour (Plate 2). The pale yellow flowers are borne in clusters of 12–15 near the top of the plant. The pods are linear sometimes curved, round slender and hairy. Mature pods are variable in colour (yellowish-brown to black), up to 13 cm long, and contain 10 to 15 seeds.

Greengram is self-pollinating. Mature seeds are green in colour. Germination is epigeal with the cotyledons and stems emerging above ground. Greengram usually matures in 60 to 90 days. The early maturing varieties can often produce before drought destroys the crop.

3.2.2. Greengram Varieties and Sourcing

The development and upgrading of any value chain is dependent on improved varieties available. Choice of variety is the first and the most important step in integrating greengram into the farming system. KALRO in collaboration with International Centre for Tropical Agriculture (CIAT) and International Institute for Tropical Agriculture (IITA) and other partners have developed and released several improved greengram varieties for cultivation in Kenya (Table 2). KAT N26 and KS20 are varieties marketed by KALRO seed unit (KSU) and Kenya Seed Company (KSC) respectively and have been in the market for more than 10 years. Recent introductions by

KALRO marketed by KSU are Ndengu tosha, Karembo and Biashara. The indigenous (local) varieties also exist and are still grown by some farmers. Below are the characteristics of the local and improved varieties:

i. **Characteristic of Local varieties**
   1. Has small seeds.
   2. Plants mature at different times.
   3. Matures late.
   4. Low yielding
   5. Has a lot of stony seeds, which makes greengram meal difficult to eat.
   6. Grows in dry areas

ii. **Characteristic of Improved varieties**
   1. Has large seeds.
   2. Gives high yields and plants ripen at the same time.
   3. Matures early.
   4. More preferred/well placed in the market
   5. Easy workability in value addition (e.g. splitting, milling)
   6. Does well in dry areas

It is recommended that farmers use certified seed from accredited sources. Certified seeds are currently available with the approved agro-input dealers as well as the research stations that conduct seed bulking. When purchasing the seeds one needs to determine the best variety that suits the weather conditions, season and the market demand/target market. Other considerations are susceptibility to diseases and pests, planting method and the yield potential (Text Box 2).

Use of certified seed leads to high germination and uniformity in maturity hence improved yields. Seed quality and purity is essential as seed mixtures may cause uneven germination, affect the harvesting due to lack of uniformity in maturity and may greatly lower the value of the produce during marketing. Where seeds are sourced from own seed, the local market or other farmers, seeds that are healthy, uniform, undamaged and free from insect pests and fungi should be selected. Note that such seeds should only be recycled for a maximum of three seasons for high varietal productivity.

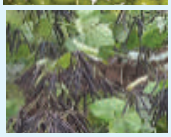
In order to overcome the challenge of seeds affordability, farmers are advised to use different strategies that will aid them to acquire certified seeds—these include procuring seeds through cooperatives, aggregation centres or contractual systems with inputs suppliers or buyers.

Text Box 2: Seed selection and characteristics of good seed

Selection of Seeds
- Authentic source
- Genetic purity
- Tolerance to –drought, pest & diseases
- High germination rate
- Fulfil climatic requirements
- Suitability for soil
- Pre-treatment required or not

Characteristics of good seed
- Pure, viable, vigorous and with high yielding potential
- Free of weed seeds
- Free from diseases and pests
- Tolerant to diseases
- Not broken or damaged
- Not be wet or damp
- Not more than two seasons old
- High germination percentage (more than 85%)

Table 2: Greengram varieties and their attributes

Variety		Attributes
KAT N26 (Nylon)		• Adapted to ASAL areas of Kenya • Grains have shiny green colour. • Potential yield of 1000 -1500kg/ha • Medium seed size (4-5g/100 seeds) • Matures in 80-90 days, pods are black when dry and grains are shiny green in colour. • Has a determinate growth habit. Flowers are auxiliary on short peduncles and purple in colour • Flowers in 40-45 days
Ndengu tosha		• Large pod size • Grains have shiny green colour. • Mature in 65-75days, pods are black • Potential yield 1800-2300kgs/ha • Large seed size (6-7g/100 seeds) • Tolerant to major mung bean diseases
Biashara		• Large pod and grain size • Dry pods are brown in colour • Grains have shiny green colour. • Mature in 70-75days • Potential yield 1800-2100kgs/ha • Large seed size (8-10g/100 seeds) • Tolerant to aphids, resistant to yellow mosaic and moderately resistant to powdery mildew
Karembo		• Large pod size • Dry pods are brown in colour • Grains have shiny green colour. • Mature in 65-75days • Potential yield 1800-2100kgs/ha • Large seed size (8-10g/100 seeds) • Tolerant to major mung bean diseases
KS 20 (Uncle/ Makueni)		• Dull green in colour • Pod are cream in colour • Mature in 75-80days • Potential yield 1000-1200kgs/ha • Large seed size (6-7g/100 seeds) • Large pod and grain size • Non-stony seed • Pods turn brown when dry while grains are bigger in size compared to N26

(Source: KALRO Katumani, 2016)

3.2.3. Ecological Requirements

Greengram is one of the most sustainable crops a farmer can grow in low rainfall areas. However, heavy rainfall results in increased vegetative growth with reduced pod set ting and development. It is both heat and drought tolerant. Heavy clay soils restrict root growth and therefore should be avoided or amended/improved by addition of organic matter. Table 3 provides summarized ecological requirements for greengram production in Kenya.

Table 3: Summary of greengram ecological requirements

Parameter	Ecological Requirement
Soils (edaphic) requirements	Greengram is grown on a wide range of soils including red laterite soils, black cotton soils and sandy soils. A well-drained loamy to sandy loam soil is best for its cultivation. The crop does not grow well on saline and alkaline soil or waterlogged soils. It is fairly well adapted to sandy loam soils and a dry condition, which gives it a competitive advantage and permits it to fit in various cropping systems as an intercrop, rotation, and relay crop. It can be profitably grown in different types of soil with pH ranging from 5.5 to 7.5.
Altitude	Greengram is best grown at an altitude of 0-1600m above sea level. At elevations of more than 1800m above sea level, it has very poor pod set
Rainfall	With 350-700 mm rainfall per year, well distributed during the growing period of 60 - 90 days, is suitable for cultivation. Too much rain or long dry spells reduce yields. Excessive rainfall during flowering causes flower abortion while dry weather conditions are important during harvesting. In water logged areas the leaves look rusty and plants lodge.
Temperature	A warm humid climate with temperature ranging from 25°C to 30°C,

3.3. Greengram Cropping System

Greengram in Kenya can be grown either as a single crop (mono-cropping) or as an intercrop (mixed cropping) with other crops by small scale farmers. Intercropping plays an important role in sustainable agricultural system as it improves the productivity and stability of yield and helps in soil conservation (Figure 17). The most important benefit of intercropping greengram with other crops is the increase in production per unit area as compared to sole crop yield. Intercropping makes better use of production elements like water, nutrients, light and space.

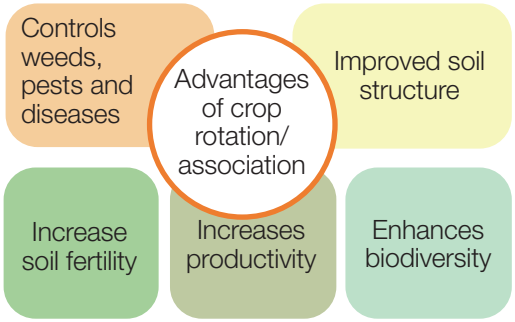


Figure 17: Advantages of crop rotation and/or associations

The most common intercrops involve greengram with sorghum, maize, pearl millet, cassava, citrus and sometimes finger millet. It can also be strip cropped with other legumes such as cowpea, pigeon pea and common beans. Greengram can also be

grown in rotation. It is advisable that greengram should be followed by a cereal crop such as sorghum, maize, pearl millet or finger millet in the rotation.

3.4. Climate Smart Greengram Production

3.4.1 Necessary CSA practices

These are other supportive climate smart practices that compliment land preparation activities. These include soil and water conservation (SWC) structures, agroforestry, improved fallows with shrubs, fallow trees and cover crops and boundary tree lines for wind breaking.

Soil and water conservation

Both soil and water conservation is critical in greengram production in semi-arid and arid areas. Inappropriate land use activities often cause changes in soil conditions, which in turn contribute to soil erosion. There are always strong links between measures for soil conservation and measures for water conservation, and this applies equally in semi-arid areas. Many measures are directed primarily to one or the other, but most contain an element of both. Reduction of surface run-off by structures or by changes in land management will also help to reduce erosion. Similarly, reducing erosion will usually involve preventing splash erosion, or formation of crusts, or breakdown of structure, all of which will increase infiltration, and so help the water conservation. Proper soil management aims at creating optimum conditions for plant growth through improved soil fertility and structure, increased infiltration rates, improved water-holding capacity, and reduced runoff and erosion.

Soil conservation refers to deliberate efforts to prevent and reduce the amount of soil lost through erosion. It seeks to increase the amount of water seeping into the soil, reducing the speed and amount of water run-off. Erosion is prevented by keeping enough vegetation to protect the soil surface and binds the soil together and maintains soil structure.

Water Conservation is a way of tapping/retaining as much water as possible and storing it in situ (in the soil through free percolation) or in tanks or reservoirs. It allows water to sink into the soil increasing soil moisture levels. It ensures a protective cover of vegetation on the soil surface, slowing down the flow of running water and spreads the water over a large area.

Soil and water conservation measures can be categorize as biological or physical conservation measures.

a) Biological conservation measures

These often include measures such as mixed cropping, mulching, organic matter management, contour cultivation and agroforestry. Good crop management can reduce soil erosion by water and wind and often contributes to improved soil productivity and increased yields. A number of these practices fall under ‘good’ crop management and soil cover e.g. intercropping, crop rotations, strip cropping, mulching and cover cropping.

- **Cover crops**

  One of the most important components in CSA is the use of legume cover crops. Cover crops (Plate 3) are often crops belonging to the legume family, implying that such crops have the ability to convert atmospheric nitrogen into plant usable forms through a process called biological nitrogen fixation. Cover crops are planted in rotation or intercropped with the main crop to enhance generation of biomass with the objective of conserving or restoring the

Plate 3: Velvet bean, at early flowering stage (left) and seed, pods and flower (right)

productivity of the land. In CSA systems, the nitrogen-rich leafy biomass is left on the surface to decompose and release nutrients.

Legumes adapted to dry conditions and suitable to serve as cover crops in the ASAL CSA systems of Kenya include: Velvet bean (*Mucuna pruriens*), Lablab (*Dolichos lablab*), *Stylosanthes spp.* and *Crotalaria spp.*

The selection of cover crops should depend on:

i. Tolerance to different environmental conditions (e.g. drought; low soil fertility; low pH)

ii. The levels of lignin (giving woodiness) and polyphenols within the leafy and stem materials to be used as green manures, which give the residues a higher resistance to decomposition and thus results in soil protection for a longer period.

- **Crop residues and mulching**

  Crop residues, by-products that result from the cultivation of cereals, legumes, root crops and tubers among others, perform various functions in smallholder farming systems. In CSA systems, crop residues are left on the soil surface as mulch more as compared to their use as an organic amendment. However, depending on source, crop residues, particularly those from leguminous materials such as groundnuts, cowpea, or pigeon pea, can be a very important source of essential plant nutrients. This suggests that crop residues play an indirect role in soil fertility management.

  In addition, crop residues left on the soil surface as mulch have positive effects on the soil physical (soil structure; porosity; erosion control; increased infiltration; reduced compaction) and biological (better micro-environment for beneficial soil organisms; smothering weed; increased soil organic matter contents) properties. Mulch insulates the soil helping to provide a buffer from heat and cold temperatures. In greengram production, mulching can be achieved through build up crop residues if mulching materials are not available.

b) Physical soil conservation measures

Physical soil conservation structures are often permanent features made of earth or stones designed to protect the soil from uncontrolled runoff and erosion and retain water where needed. Selection and design of structures depend on

- Climatic characteristics of the area, in particular rainfall distribution and intensity
- Topography of the land
- The need to retain or discharge the runoff

- The size of the farm
- Soil type in terms of texture, drainage and depth
- Availability of an outlet or waterway
- Adequacy of existing agronomic conservation measures
- Cost of structure and
- Labour availability

They are normally put as transition to CSA.

Some of the common physical conservation measures include: infiltration ditches, water-retaining pits, contour bunds, grass strips, cut-off drains, broad beds and furrows and terraces

i) Infiltration ditches

This is a structure designed to harvest water from roads or other sources of runoff. It consists of a ditch 0.7-1.5m deep, dug along the contour, upslope from a crop field. Water is diverted from the runoff source into the ditch, which is blocked at the other end. The trapped water then seeps into the soil.

ii) Contour bunds

These are permanent ridges of soil that are built by excavating a channel on a slope along a contour line (line having the same height). Contour bunds are popular in hilly or mountainous and in semi-arid areas and are mostly used to harvest water, enhance the retention of runoff water, and prevent soil erosion and flooding.

iii) Cut–off drains

Cut-off drains are dug across a slope to intercept surface runoff and carry it safely to an outlet such as a canal or stream. They are used to protect cultivated land, compounds, and roads from uncontrolled runoff, and to divert water from gully heads.

iv) Water-retaining pits

These are water-harvesting pits used in semi-arid areas. A series of pits are dug into the ground where runoff normally occurs. The soil from the pit is used to make banks around the pits. Furrows carry excess water from one pit to the next. The pits are dug along the contours to catch and retain incoming runoff and hold it until it seeps into the ground. The size of the pit depends on the amount of runoff: a typical size is 2m square and 1m deep.

v) Broad beds and furrows

In this system, runoff water is diverted into field furrows (size 30 cm wide x 30 cm deep). The field furrows are blocked at the lower end. When one furrow is full, the water backs up into the head furrow and flows into the next field furrow. Between the field furrows are broad beds about 170cm wide, where crops are grown (Fig 18).

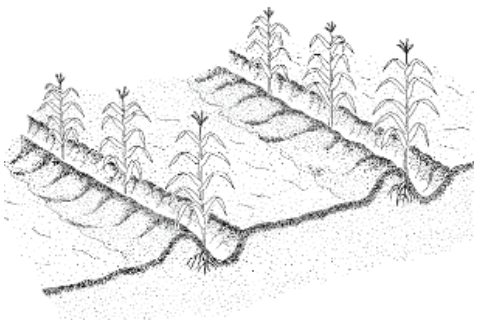


Figure 18: Contour furrows with planted maize

vi) Terraces

Terracing is the process of reducing the length and/or steepness of a slope in a planted zone using soil embankments and channels that are constructed across the slope. The change in slope profile reduces runoff speed – especially on erosion-prone elevated lands, thus reducing soil

erosion. It also allows some water to sip into the soil. There are many designs of terraces which can be used in the Kenyan farming system. These include:

- **Fanya Juu** means throw the soil upwards. This kind of terrace is made by digging a trench along the contour and throwing the soil uphill, to form a ridge. The ridges are stabilized with fodder grasses and in between cultivated portions. The ditch traps the water and makes it infiltrate the land slowly. They are suitable for soil too shallow for level bench terracing and moderate slopes below 20%. However, they are not applicable on stony soils.
- **Fanya Chini** - are made by digging a trench along the contour and the soil is put on the lower side of the contour trench. It is used to conserve soil and divert water. The ridge can also be used to grow fodder. This is applicable on slopes of up to 20%.
- **Bench terraces** - are level or nearly level steps constructed or formed on the contour and separated by ridges known as risers. They are formed by excavation or developed from grass strips or Fanya Juu terraces. Suitable on slopes up to 55%.
- **Stone terraces**- are useful in areas with steep slopes in stony environments. Stone lines are permeable (they do not pond runoff water), but can effectively slow down the speed, filter it, and spread the water over the field, thus enhancing water infiltration and reducing soil erosion. The measure also has potential to rehabilitate eroded lands by trapping silt (Fig 19).

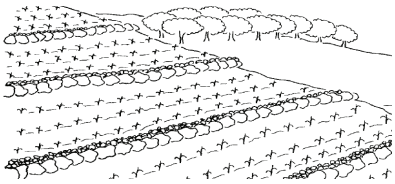


Figure 19: Stone terraces on a hilly terrain

vii) Wind Breaks

Windbreaks are linear plantings of trees and shrubs designed to enhance crop production, protect people and livestock, and benefit soil and water conservation. In Integrated Pest Management, by incorporating plants that attract beneficial insects, windbreaks can also serve to increase biological control of crop insect pests. A windbreak should be planted at right angles to the prevailing wind. It can either consist of a single line of trees with a spacing of 1.5-2.0 m, or two lines with a spacing of 4-5 m within the line and 2-4 m between the lines. Examples of species that can planted in greengram fields include: Acacia albida, Gliricidia sepium, Grevillea robusta, Macadamia tetraphylla and Mangifera indica,

viii) Agroforestry and Fallow Trees

Agroforestry is a land-use system in which trees or shrubs are grown in association with agricultural crops, pastures or livestock. This integration of trees and shrubs in the land-use system can be either a spatial arrangement, e.g. trees growing in a field at the same time as the crop, or in a time sequence, e.g. shrubs grown on a fallow for restoration of soil fertility.

When land is fallowed due to the need to restore soil fertility after a period of cultivation, shrubs can be sown to speed up the process. These shrubs can fix nitrogen and add organic matter to the soil. Improving fallows is relevant where farms are relatively large, and where labour is more of a constraint than size of farm holding. The main benefits are quick restoration of soil fertility and wood production.

Examples of species of beneficial shrubs that can be used for improved fallows are Nitrogen-fixing shrubs which are fast growing. These include *Sesbania spp*. and *Gliricidia sepium* and *Tephrosia spp*.

3.4.2 Land Preparation

Land preparation is important to ensure that the greengram field is ready for planting. Poorly prepared land leads to low yields. A well-prepared field controls weeds, recycles plant nutrients, and provides a soft soil mass and a suitable soil surface for direct seeding. It is important to prepare the land properly to ensure good germination of your greengram. Land preparation should be done early enough so that planting can start at the onset of the rain. This requires proper planning guided by several factors as indicated in Text Box 3.

Land preparation covers a wide range of climate smart operations that makes the seedbed ready for planting. The type of operation to be carried out depends on the topography/terrain, and condition of the land. It is advisable that initial land preparation begins after your last harvest or during fallow period.

Text Box 3: Critical factors to consider before land preparation

- Field selection;
- Mechanical actions to be implemented;
- Chemical needs for pre-plant soil improvement;
- Tools and equipment needed;
- Labour needs;
- Planting station preparation;
- Financial requirements and
- Time schedule.

3.4.3 Climate Smart Methods of Land Preparation

The purpose of land preparation is to provide the necessary soil conditions which will enhance the successful establishment of the young crops. The conventional methods of land preparation have been ploughing (Plate 4) and harrowing which has over the years been proved to be detrimental to the farmer, soil and environment (Table 4).

Climate smart land preparation practices avoids the above problems caused by conventional tillage. They reduce the amount of tillage, or eliminate it altogether when seeds are planted directly into the soil.

Plate 4: Preferred tractor ripping (left) and undesired tractor ploughing (right)

Table 4: Effects of conventional compared to CSA practices

Undesired Conventional Practices	Desired CSA Practices
Drudgery where manual ploughing is used	Saves labour and time
Excessive pulverization	Maintains soil structure
Presence of hardpans due to cultivation at the same depth	Ameliorates/breaks the hard pans
Destruction of the soil flora and fauna through exposure to sunshine and rainfall	Increases biodiversity
Soil erosion through water and wind	Reduces water and wind erosion
Soil degradation through destruction of structure	Maintains soil structure, Improve soil quality
Nutrient leaching	Improves water holding capacity and nutrient retention
Cuts the amount of organic matter in the soil, so reducing soil fertility	Improves soil organic matter
Costs of fuel and labour increased	Reduced cost of fuel and labour by up to 40%
Contributes to greenhouse gas emission	Enhances carbon sequestration (carbon sink) and reduces GHG emission

The practices maintain a cover of vegetation or mulch on the soil surface and raise the organic matter content of the soil, improving fertility and reducing the amount of CO_2 that is produced. It helps to rehabilitate the soil flora and fauna. It also protects the soil from erosion, so helps keep rivers free of silt. These practices include:

a) Weeds, cover crop and residue management

Minimum soil disturbance practices in CSA requires proper weed control which can be done or achieved through different methods depending on the intensity of weeds infestation. It can either be mechanical (shallow weeding), biological (mulching, cover crops or optimal plant spacing) or chemical weed control. In chemical weed control, surface application of pre- and post-emergence herbicides is paramount. One or two properly timed applications may be necessary.

b) Planting basins

Instead of hoeing the whole field, you dig planting basins only where you want to plant the crops. Planting basins are small pits in the ground used for planting different types of crops. They are about15 cm wide, 30 cm long, and 15 cm deep – about the size of a man's foot (Figure 20).

Planting basins (Plate 5) are dug using a hand hoe to loosen the soil and break up the hardpan. They are dug slightly deeper than the depth to which you normally hoe, so that they break through the hardpan.

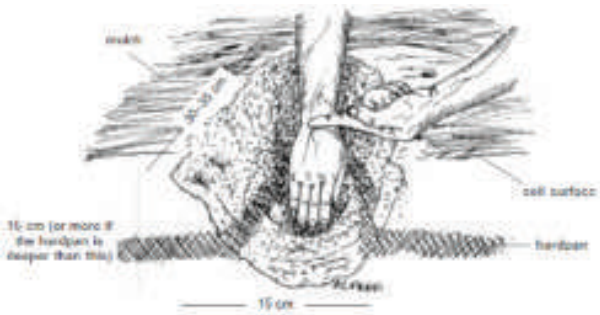


Figure 20: Close-up of a planting basin (Source: IIRR & ACT, 2006).

You should dig the planting basins at any time during the dry season, so they are ready for planting at the beginning of the rainy season.

After you have prepared the basins properly and spaced them correctly, you can apply fertilizer, manure and lime very precisely to avoid wastage.

Plate 5: Planting basins

c) Subsoiling

If the hardpan is deeper or if the soil is heavy, you may have to use a subsoiler. A subsoiler is a chisel-shaped implement designed to work at a depth of about 30 cm, just below the level of the hardpan. It breaks the hardpan and allows water to infiltrate easily into the soil. You may need at least four strong oxen to pull a subsoiler. Subsoilers can also be mounted on a tractor. Subsoiling deep hardpans in heavy clay soils generally needs a tractor. You do not have to subsoil every season! You may have to do it only once, when you first switch to conservation agriculture. It may be necessary to do it again periodically, once every few years. Consider hiring someone to do it for you rather than buying the equipment and doing it yourself.

d) Ripping

If the soil is fairly light, and if the compaction or hardpan is near the surface, you can use a ripper to loosen the soil. A ripper is a chisel-shaped implement pulled by animals or a tractor (Plate 6). It breaks up surface crusts and opens a narrow slot or furrow in the soil, about 5–10 cm deep. Unlike a mouldboard plough, a ripper does not turn the soil over. You can rip the soil during the dry season, or at planting time.

If used for planting, ripped lines are usually spaced at the recommended spacing of the crop. The ground in between the rows is left undisturbed, except for controlling weeds. Rainwater concentrates in the planting lines and sinks into the soil where the crop roots are growing. If you rip at planting time, you can sow seeds in the slot by hand, or using a planter attached to the ripper.

You can rip along the same lines season after season. If possible, plant a different crop in the row in the next season to rotate the crops, or in between the rows to have an improved field in future. Plan to improve the field year after year.

Plate 6: 3-tine tractor drawn chisel plough/ripper

3.5. Crop Nutrition

3.5.1 Nutritional requirement of Greengram

It is important to carry out a soil testing to determine the status of the soil in terms of nutrient availability with respect to what greengram requires. The crop should be supplied with enough nutrients for optimal production.

3.5.2 Nutrient Application

Greengram obtains nitrogen through its symbiosis with the nitrogen-fixing bacteria in the roots. Therefore, application of nitrogen fertilizer to greengram crops in high amounts is not needed and excessive nitrates from applied fertilizer will restrict N Fixation and lead to nitrous oxide emissions. However, inoculation of the seed with Rhizobia before sowing is highly recommended in fields where greengram cultivation is taken up for the first time in order to increase nodulation and thus nitrogen fixation leading to 10-15% increase in yield, and also minimizes the use of nitrogenous fertilizers for the subsequent crop. If soil is of poor fertility, 10-12 tonnes/hectare of well decomposed farmyard manure (FYM) should be applied. The FYM is either applied in rip lines or planting basins one month before sowing to improve the soil conditions.

In commercial production of greengram, fertilization rate and type of application depends on the results of soil analysis. However, in the absence of such analysis and during dry season cropping, basal application of 10 kg/ha of Nitrogen and 10 kg/ha of Phosphorous.

Basal fertilizer should always be applied before or at planting, under the seed, making sure that it does not get into direct contact with the seed. This is achieved by covering the fertilizer with a layer of soil (1-2 cm thick) before seeding.

Specific methods of manure and basal fertiliser application under the “planting basins” and “ripper –tine planting furrow” are elaborated in Table 5.

In order to improve on nutrient uptake by the greengram, stimulate growth among other benefits, the basal fertilizer and/or manure should be mixed with a soil conditioner e.g. lime, if the pH is low.

Seed treatment with Bio fertilizer at one packet (50 g/ha) of Rhizobia is recommended. Foliar feeds should be applied before flowering and at fruiting stage to boost yield.

Table 5: Different methods of manure and basal fertilizer application

Basin method	Ripper-tine method	Direct Seeding
• Apply 1-2 handfuls of well-decomposed manure/ compost in each basin and mix with soil	• Apply 1-2 handfuls of well-decomposed manure/ compost over 30 cm along each planting line/furrow	• Apply on rip lines at the rate of 10-12 tonnes/ha prior to planting on the rip lines
• Apply 2 heaped soda bottle caps/teaspoon (equivalent of 50 kg/ha NPK) of basal fertilizer per basin	• Apply 2 heaped soda bottle caps/teaspoon (equivalent of 50 kg/ha NPK) of basal fertilizer over 30 cm along the furrow/planting line	• Apply the recommended (10 kg/ha of N and 10 kg/ha of P) amount of basal fertilizer.

3.6. Planting

3.6.1. When to Plant

Deciding when to plant is one of the most important decisions a farmer has to make. The main aim is to make sure the seeds germinate quickly and evenly. However, farmers are advised to be guided by weather information/forecasts, given the climate change prevalence and the planting window thereof. Some guidelines include:

- Plant seeds just before or at the onset of the rain, if production is rain fed.
- When planting at the onset of the rain, plant when there is enough moisture for the seeds to germinate evenly.
- Mulching will improve the moisture level in the soil where you put the seed.
- Plant at the right depth for your crop. This helps the seeds to germinate and emerge evenly.
- Try to finish planting a field in one day for uniform crop establishment.

3.6.2. Spacing and Seed Rate

When planted alone, sow at 45cm between rows and 15-20cm between plants. One hectare of land will require 10 to 20 kg of seed for planting at a depth of 3-5cm. The amount of seeds used depends on the planting method and the number of seeds per hole.

When planting along the rip-lines, place the seed in the furrow.

Row sowing is more advantageous as it requires less seed, produces a more even crop that is easier to manage and will have higher yield potential. See the illustration below for row sowing (Figure 21).

The correct plant density is an important factor in maximising yield of greengram. It is also an important factor towards biological weeds suppression. To obtain the targeted density it is necessary not only to have quality sowing seed but also be able to accurately calculate seeding rates. It is recommended that the sowing rate is calculated using germination test results, seed count per kilogram, the target plant population and establishment.

The seed rate varies with seed size and season. In the case of bold-seed types a seed rate of 16 - 25 kg/ha is appropriate. It is advised to establish a plant population of 25 plants/m^2 for obtaining good seed yield. The number of seeds per kilogram of greengram seed can vary widely. It may range from 10,000 to 20,000, depending on variety and growing conditions. Thus,

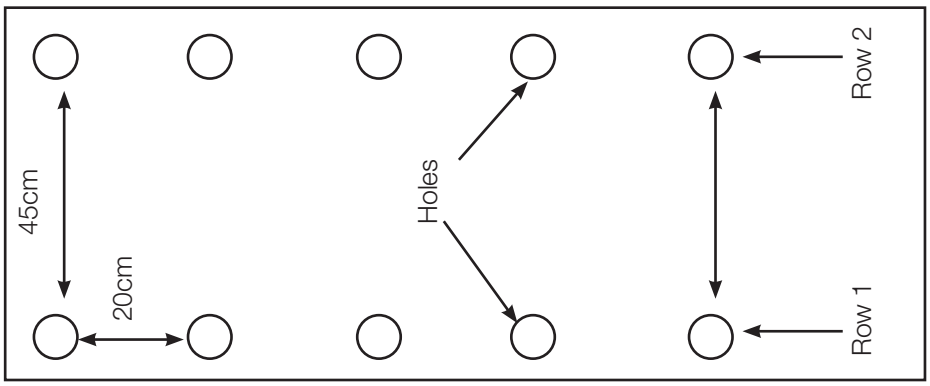


Figure 21: Illustration of between row and in-row spacing in planting.

Calculating Seed Rate

Seed rate can be calculated using the equation:

$$\textbf{Seed Rate (kg/ha)} = \frac{\{\text{Target Plant/Density/ha}\}}{\{\text{Seed kg} \times \text{Germination \%} \times \text{Establishment \%}\}}$$

Example:
Target Plant Density = 250,000/ha (i.e. 25 plants per square metre)
Seeds/kg = 13,500
Germination rate = 95%
Establishment rate = 85%

Therefore, $\textbf{Seed Rate (kg/ha)} = \left\{\frac{250{,}000}{(13{,}500)\times(95/100)\times(85/100)}\right\} = \textbf{24 kg/ha}$

it is recommended to calculate the seed rate every season/year since it varies greatly depending on the variety, germination, size of seed and sowing conditions.

Establishment percentage can be adjusted according to your confidence in your sowing operation and field conditions. A realistic estimate of establishment is 80% - 85%. Germination test can be carried out as illustrated in Text Box 4.

Text Box 4: How to test the germination percentage

1). Before planting, take a clay pot, and fill it with sandy-loam soil.
2). Put 100 seeds 1 cm deep into the soil in rows.
3). Cover the seeds with soil.
4). Add water so that the soil is moist.
5). After 5-6 days, count the number of seeds with healthy roots and shoots.
6). Calculate the germination percentage with this equation:

Germination percent (%) = Number of healthy germinated seeds

Note: Acceptable germination percent should be at least 85%. If it is lower than this, do not use the seeds. Replace them with another batch. To ensure uniform germination seeds can also be soaked in water overnight. This can also lead to uniform maturity.

3.6.3. Seed Dressing

When planting uncertified seeds seed dressing is important to control pests and diseases. Soak 1 kg of seed in 200 ml of water mixed with 3 ml of imidacloprid 17.8 SL or 5 g of thiamethoxam 25 (both insecticides) for 45 minutes to one hour and dry the seed under shade. Shade dried seed should be treated with a fungicide (captan or thiram) at 3 g/kg seed or with a bioagent (trichoderma harzianum at 5-10 g/kg seed) against seed borne fungi followed by biofertilizers (Rhizobium spp., AMF- Glomus spp./PSB-Pseudomonas spp. each at 30 g/kg seed), before sowing. Make sure you sow immediately after soaking. The outer shell of the seed has become fragile which is the first step in the germination process. Light watering after sowing the seeds will help to germinate the seeds faster.

3.6.4. Climate Smart Planting Methods

a) Planting in Basins

After mixing fertilizer and/or manure with soil in the basin the determined number of seeds per basin are placed on the dug basin (Plate 5) by hand, then covered with soil.

Do's and don'ts when using planting basins

- Remember that the basins are permanent, and you will come back to plant the same place next season, and the season after that. So take care the first time.
- Don't plant in a basin which is not nearly filled with soil – the crops will drown!
- Don't dig basins during the rainy season. Hardpans are best dealt with in the dry season.

Planting in rip-lines

As soon as you have ripped the soil, you can sow seeds in the ripped opening/furrow (Figure 22). You can use any suitable method: by hand, using a planting stick or machete, jab planter or with a planter attached to the ripper. Cover the seed after sowing so it is not eaten by birds or animals

Figure 22: Rip-line planting furrow

b) No-till / Direct Seeding

In this system, crop seed is placed in a narrow strip or planting furrow opened with a disk coulter followed by furrow opener (Plate 7). With little or no modification, most planters can be used in no-till systems. No-till planting is well suited to many soils. Residue, when uniformly spread, increases water infiltration and reduces soil moisture evaporation.

Plate 7: Animal drawn direct seeder (left) and tractor drawn seeder (right)

3.7. Field Management

Field management begins with the sowing of seeds, continues with crop maintenance during growth and development and ends with crop harvest. This involves field practices or operations carried out in crop field to facilitate proper growth and optimum yield of the crop.

Field management practices may be carried out manually or mechanically. The method used will depend on the availability of the necessary equipment and tools or the service providers to offer the services. Some of these field management practices for greengram are discussed below

3.7.1. Thinning

Germination occurs within 5-7 days depending on the variety and environmental factors. Farmers should check after emergence to ensure ideal plant population. High plant population can lead to poor crop growth, especially under drought conditions and low plant population will ultimately affect yield. Thus, the farmer can either thin to ensure the recommended plant population and optimum utilization of sunlight, space, nutrients, moisture and other inputs which ultimately increase yield.

Thinning is done within 2 weeks after emergence and when the soil is moist.

Thinning should be done at first weeding or immediately after first weeding. Thinning under moisture stressed dry soils affects the root system of the remaining plants. Thus, it is recommended that thinning should be done when the soil is moist. Leaving 2 plants per hole is ideal to compensate for a gap within the row.

3.7.2. Integrated Pest and Disease Management

a). Weed management

Weeds can cause up to 50% grain yield loss if not controlled, especially at an early stage. The magnitude of grain loss varies with the intensity and type of weeds present in the field. One or two weedings at 25 and 40 days after sowing are recommended to keep the weeds under check. Late emerging weeds have a lesser effect on yield than the early emerging weeds.

Weeds harbour pests and compete for nutrients, moisture, space and sunlight, therefore timely weed control is critical. When the crop begins flowering, weeding should be minimized in order to avoid crop disturbance that may cause flower fall.

You can manage weeds by the following methods:

- By hand weeding
- Using equipment to cut or crush the weeds.
- Using herbicides.

i) Weeding by hand

You can pull out weeds by hand, or slash them with a machete, sickle, slasher or billhook. You can also use a shallow weeder/hoe for shallow weeding (Plate 8) to avoid disturbing the soil too much. Here are some advantages of hand weeding:

- Uprooting weeds by hand disturbs the soil less than using most types of equipment.
- Shallow weeding reduces excessive soil disturbance
- Hand tools are cheap and can be bought in most markets.

Hand weeding has several disadvantages:

- It is hard work and takes a long time.
- The weeds may regrow easily.

The stalks may not be crushed well, making it difficult to plant crops through the residue.

Plate 8: Weed management with shallow weeder

ii) Using equipment (animal- and tractor-drawn weeders)

To use an animal- or tractor-drawn shallow weeders, plant the crops in rows with the same spacing as the weeder blades. Weeding by draught animal or tractor power is quicker and easier than by hand. Using an animal-drawn weeder can take less than one-fifth of the time needed for hand hoeing.

However, weeders have several disadvantages:

- They can damage crop roots. This may be a problem especially in arid and semi-arid areas.
- They may carry weed seeds from place to place.
- They may not work properly if the field is wet, has crop residues or mulch.

iii) Chemical weed control

This involves the use of herbicides to control weeds. Herbicides are quick and easy to apply, and do not disturb the soil. Some herbicides kill only certain types of weeds. Herbicides are applied before or after the crop emergence depending on the type of herbicide. Not many smallholder farmers use herbicides because they are expensive and hard to find. Some are reluctant to use due to own reasons. They also need special equipment, such as sprayers or wipers. It is important to use the right amounts of chemicals, mix them with clean water, and handle them safely. If you are considering using herbicides, get training on how to use them the right way.

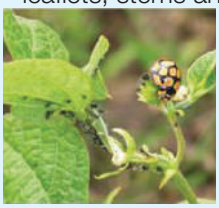
It is advisable that farmers should use recommended herbicides available from the certified agro dealers. Various equipment used to apply herbicides include weed wiper (such as a Zamwipe), knapsack sprayer, hand-pulled sprayer, animal-drawn sprayer and tractor-mounted boom sprayer. Where available farmers can use the spraying service providers to spray their crops.

b). Insect pest management

Insect pests can significantly affect the overall profitability of a greengram crop, reducing both yield and seed quality with damage ranging from 80-100%, if no control is undertaken. Pest control should be done timely before the damage reaches the economic injury level (EIL). EIL is the level beyond which the pest causes economic damage to the crop hence control measures are mandatory. Insect pests can attack greengram at any stage from seedling to harvest and/or storage, but the crop is most susceptible from budding onwards. Accordingly, insect damage is one of the main reasons for downgrading greengram quality. Crops should be inspected daily/ more regularly from the vegetative stage through to budding, budding-flowering through to the completion of pod fill. Crops which are producing buds, but not flowers, may contain damaging levels of sucking insects, causing the buds to abort before the flowers open. The preferred method for insect checking is to use a beat sheet between rows to identify, monitor and count insect numbers.

The major pests affecting greengram in Kenya are illustrated in Table 6. The use of integrated pest management (IPM), which is the use of different available pest control techniques meant to reduce pest's population below the economic injury level is recommended.

Table 6: Greengram pest management and control

Type of Pest	Symptoms	Control Methods
Aphids *Soft bodied, green or black insect pests which suck plant sap)* 	• Affected plants stay short and twisted • Feeds on young plants, leaflets, stems and pods.  *Ladybird beetle feeding on aphid colonies* Excretion of honey dew leads to growth of sooty mould	• Plant early • Maintain weed free fields • Avoid excess use of nitrogen • Conserve natural enemies • Spray with Endosulfan, Imidacloprid, Lamda-cyhlothrin, Thiamethoxam, Acetamiprid • Spray foliar fertilizer (Sodium and Potassium system) to clean the sooty mould • Natural enemies such as green lacewings (Chrysopidae), ladybird beetles, minute pirate bug, syrphid fly, and parasitic wasps keep aphid populations in check in the field.
Bean Fly	Plants that have been attacked are yellow and may wilt.	• Use certified seed • Practice crop rotation • Spray with Thiophanate methyl or copper oxychloride • Seed dressing with Imidacloprid • Drench soil with Imidacloprid, Profesofos or Cypermethrin
Thrips *Threshold/EIL (4-6 thrips/flower)* 	• Attacks plant petioles and leaves • Leaves have tiny holes surrounded by discoloured areas.	• Plough and harrow before planting. It can reduce subsequent thrips attacks by killing pupae in the soil. • Conserve natural enemies e.g. predatory bugs (Orius spp. and Anthocoris spp.) and predatory thrips. • Spray with bio-pesticides (e.g. Spinosad) or other insecticides (e.g. Endosulfan, lufenuron, Lambda-cyhalothrin)
Pod borers e.g. African bollworm *Threshold (3 larva/m^2)* 	• Feeds on leaves and bores into the pods to eat seeds • Scrapped leaves tissue • Damaged flower buds and flowers	• Dry grains to 12% moisture content (MC) prior to storage • Use improved storage structures • Spray with Dimethoate, Imidacloprid, Thiamethoxam, Lambda-cyhalothrin and Acetamiprid

Type of Pest	Symptoms	Control Methods
Pod sucking bugs *(e.g. giant coreid bug, green stink bug)* *Threshold (3 larva/m²)*	Cause necrosis, pod malformation, premature drying, formation of empty pods, shrivelling of seeds	*Giant Coreid* *Stink bug* Spray with Imidacloprid 200g/l
White flies	• They suck plant sap leading to retarded growth • Attacked leaves become shrunk • secrete honeydew as they feed causing sooty mould	• Mount yellow sticky traps to trap adults- 4 traps/ 300m2 at 50cm above the ground. • Spray with pepper at rate of 30 chopped peppers put in 1 litre warm water. Soak for 1 day, dilute in 10 L water • Spray with Thiamethoxam, Fipronil, Lambda-cyhalothrin, etc. • Spray phosphorous pentoxide 100ml/20l to clean the sooty mould
Caterpillars/ Cutworms	Attacked leaves and pods are left with windows	• Alphacypermethrin or Fipronil • Dress seeds with Imidacloprid 600g/l
Foliage beetle	They feed on young plants leading to defoliation	• Conduct deep ploughing. • Remove the plant debris and weeds from the field. • Application of neem seed kernel extract (5%) as a repellent for egg laying. • Spray with Thiamethoxam, Fipronil, Lambda-cyhalothrin, etc.
Weevils	• They feed on stored grains • Start attacking the pod while crop is in the field • The larvae can stay undetected in the seed until the adult emerges. • Holes on stored grains	• Clean the store prior to storage e.g. boil used storage sacks in hot water and dry in the sun before reuse • Dress with Malathion, Pirimiphos-methyl, or Permethrin • Drying grain thoroughly (to about 12% MC) before storage • Store beans in air-tight containers if possible e.g. hermetic bags

c). Integrated Disease Management

Effective disease management relies on adopting several strategies. The incidence and severity of diseases will depend on the interaction between the pathogen, the host, the environment and vectors in the case of viruses and bacterial parasites. For a disease to occur, three conditions must be met. Firstly, a pathogen has to be present on or in the plant. Secondly,

there needs to be suitable environmental conditions for the pathogen. Thirdly, the plant must be susceptible to the disease (Figure 23).

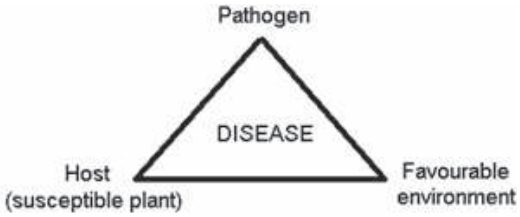


Figure 23 : Disease (and pest) control triangle

Utilising an integrated disease management strategy is the most effective way to minimise the risk of disease epidemics. The three aims of integrated disease management are to reduce pathogen inoculum carrying over from one season or field to the next, exclusion of the pathogen, and protection of the host. The most important greengram diseases in Kenya are illustrated in Table 7.

Table 7: Greengram diseases, symptoms and potential control measures

Disease	Symptoms	Control Measures
Powdery mildew	• White patches appear on leaves and other green parts, which later become dull coloured. Infected plants have a greyish-white powdery growth on the surface of leaves, stems and pods • Caused by fungus *Podosphaera fusca* is a major disease of greengram causing severe yield loss.	• Sowing of resistant or moderately resistant varieties where available • Improve aeration by thinning or pruning some of the foliage. • Apply fungicides like Difenoconazole, or Sulphur. • Spray neem seed kernel extract @ 50 g/L or neem oil @ 20 ml/L or water soluble sulphur 80 WP @ 4 g/L or carbendazim 50 WP @ 1 g/L twice at 10 days' interval from initial disease appearance • Good agronomic practices such as control of volunteer seedlings and other host crops and weeds prior
Yellow mosaic virus	• The leaves are mottled with yellow, white, and light and dark green spots, which appear to be elevated. This gives the leaves a blister-like appearance. • Small yellow specks along the veinlets of leaves which spread over the lamina to produce yellow mosaic symptoms the pods become thin and curl upwards.	• Plant resistant varieties • Spray with Benomyl or Copper oxychloride • Diseased plants should be rogued out to prevent further spread of the disease. • Use of disease free seeds • Control white flies

Common mosaic virus	• Viral disease spread through infected seed and aphids • Cause yield loss of up to 90% • Favoured by temperature range 20-25°C • Leaf mottle	• Control aphid vectors
Rust	• Caused by a fungus • It appears as circular reddish brown pustules • Less abundant on pods and stem	• Properly spacing plants to allow for air flow • Prevent infected plant tissues from rubbing against other plants. • Select rust-resistant varieties. • Pick off, remove and destroy infected leaves and remove all fallen debris. • *Bacillus subtilis*, *Bacillus* sp. and *Arthrobacter* sp. are used as biocontrol agents of rust. • Spray fungicides with the following active ingredients: triadimefon (0.02%), triadimenol (0.1%), tridemorph (0.07%), hexaconazole, maneb, tebuconazole, mancozeb+sulfur and chlorothalonil which are applied before flowering according to manufacturer's guidelines.
Bacterial blight	• Leaves become yellow and fall prematurely	• Keep foliage dry and don't touch it when it's wet. • Don't wound the plants, as this is how the bacteria get inside. • Keep weeds and pests to a minimum. • Destroy affected plants. • Spray with Metalaxyl
Angular Leaf Spot	• Fungal disease • Yield losses: up to 50% • Its development favoured by humid (wet) conditions • Mode of spread is through seed, plant debris mostly and wind-blown spores • Brown spot on the leaves	• Crop rotation • Use fungicides • Deep ploughing to destroy plant remains • Cultural practices- e.g. rotations to break the lifecycle of the pathogen

3.8. Greengram crop calendar

The greengram crop calendar (Figure 24) is a tool that provides timely information on planting, sowing and harvesting periods in specific agro-ecological zones. It also provides information on the sowing rates of seed and planting material and the main agronomic practices. This tool supports farmers and agriculture extentionists in Kenya in taking appropriate decisions on greengram with respect to agro-ecological dimension and climate information advise.

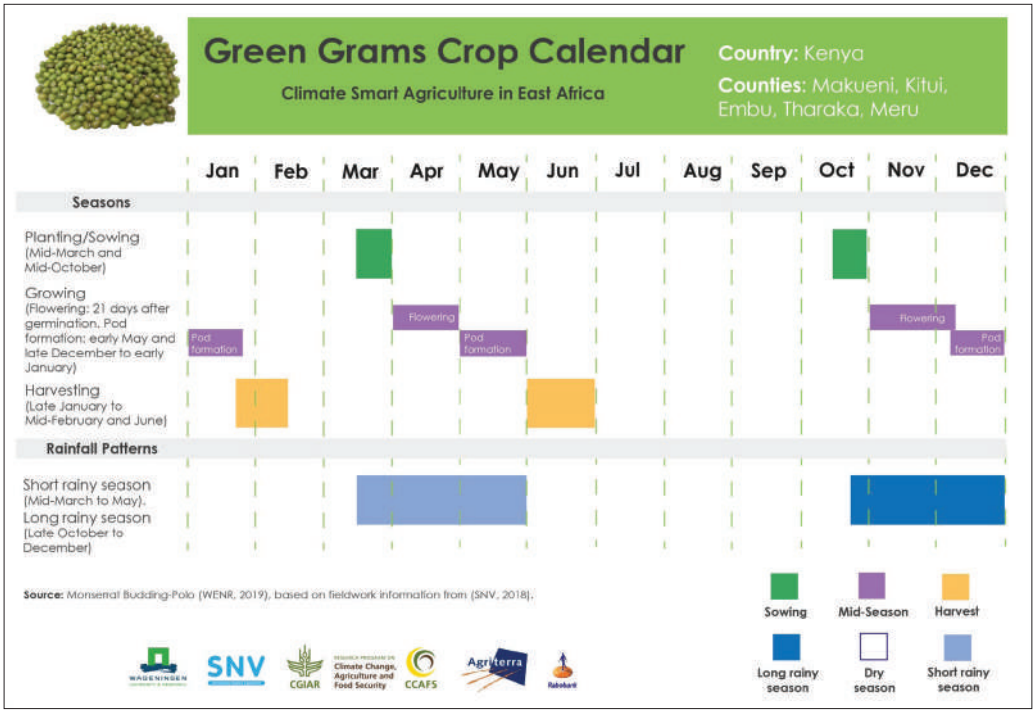


Figure 24: Greengrams cropping calendar for selected counties in Kenya

3.9. Crop insurance

Risk and uncertainty are inherent in greengram production systems. The producers are exposed to numerous risks arising from various disasters including vagaries if weather, biological perils that include pests and disease epidemics, hailstorms and fire. Greengram farmers in the ASAL areas remain vulnerable to natural disasters, posing a significant social and economic problem. Severe drought, in particular, strikes these areas in Kenya approximately every 3 to 5 years, and the losses are major. Such devastating droughts push better off farmers and pastoralists into poverty, and the already poor into destitution, which they may take several years to recover from. They can also make it costlier or simply impossible for those affected to take out loans, limiting opportunities for greengram producers to invest in better tools and technologies to increase productivity.

Crop insurance can provide much-needed protection to keep farmers out of extreme poverty, and enable them to invest in their future. To cushion the farmers crop insurance can smooth agricultural income shocks and thereby provide protection for vulnerable farmers. Crop insurance can provide much-needed protection to keep farmers out of extreme poverty, and enable them to invest in their future in the event of climate extremes.

Agricultural risk management is expected to contribute to the stabilization of farmers' incomes and earnings, increased investment in agriculture through leveraged access to finance, and increased farmers' resilience through restocking, enhanced adaptation and reduced dependency on food aid, and *ad hoc* post-hazard intervention strategies.

The private insurance companies and donors have shown great commitment to the development of innovative index-based crop and livestock insurance for small farmers.

Though few commercial crop producers in Kenya purchase crop insurance while the majority of small holder farmers have low levels of awareness and understanding of the role of agricultural insurance there is need for the greengram farmers to be sensitized and encouraged to insure their crops especially when they sign contracts.

The primary data required for weather index-based insurance products for crop insurance is the data on insured commodity which, include historical or real data of production or yields, agro-meteorological data, early warning data and farmer-based data.

Currently the three major agricultural insurance products being implemented in Kenya are;

(i) Multi-peril crop insurance (MPCI) is a traditional indemnity insurance product against all perils at farm level. The pay-outs are determined through a farm-level loss assessment process. Its transaction cost and moral hazard level are high but basis risk is low and claim settlement time is medium;

(ii) Area Yield Index Insurance (AYII) is a product based on average losses at the regional level, rather than farm level. The pay-outs are based on crop cutting experiments. Its transaction cost, basis risk and claim settlement time are medium. However, the moral hazard level is low; and

(iii) Weather Index Insurance (WII) is based on weather parameters (such as rainfall, temperature, or soil moisture) correlated with farm-level yields or revenue outcomes. It is also at regional level. Its transaction cost, moral hazard level and claim settlement time are low with high basis risk.

The key actors in the industry include the Kenya Government at both the national and county level; the Ministry of Agriculture, Livestock and Fisheries; the Kenya National Bureau of Statistics (KNBS); Insurance Regulatory Authority (IRA); insurance companies, Association of Kenya Insurers (AKI); banks/financial Institutions; agro-dealers; farmers' associations; Kenya National Farmers Federation (KENAFF); farmers; and, training and research institutions.

Extension agents should consult the local agriculture extension offices to get more information on the available insurance service providers in the area.

Module 4: Harvesting and Post-Harvest Management

4 Harvesting and Post-Harvest Management

4.1. Introduction

CSA offers an opportunity to encourage farmers to manage their farms as a business, rather than merely a way to feed their families. When a smallholder farmer achieving low yields applies CSA practices, yields and total production increases, and this raises the issue of labour required to harvest the crops and handle crops residues at the same time. Farmers have to therefore adopt harvesting techniques and methods that will handle increasing yields and crop residues for soil cover. Where yields are higher than usual, farmers need to prepare good storage facilities that are large enough to store the higher yields before sale.

This module summarizes the activities involved during harvesting and post-harvest management in greengram production. It covers the harvesting processes, post-harvest handling, grading and quality control, storage management, transportation and postharvest losses and utilization of greengram.

4.2. Harvesting

Appropriate harvesting techniques are important for the farmer who adopts CSA since in CSA systems, production and yield increases over time, and due to improvement in soil moisture farmers can grow additional crops in the cropping system that can mean more labour is required to harvest the extra produce.

The general practice in CSA is that farmers should leave crop residues on the ground during harvesting. One of the advantages of chopping or shredding and spreading these crop residues on the soil surfaces in the right amount leaves little space and light for weeds to grow, besides, the importance of reducing soil temperature, reducing erosion, conserving moisture and adding organic matter to the soil for incorporation into the soil by earthworms and termites, and other microorganisms. When cleaning or processing the harvest, farmers should return any residue back on to the soil as mulch or make compost.

Greengram matures within 60-90 days after sowing, depending on environmental factors as well as the variety. Harvesting should commence when the pods turn from green to black (N26) or from green to yellowish for others. Physical maturity is when 95 per cent of the pods turn black.

Harvesting is generally done by hand-picking. Harvestable pods are picked by hand and this is repeated after every 3 to 5 days depending on variety and weather. You can pick and dry individual pods or cut the stems of the plants about 10 cm high and dry it for about two days, then thresh and clean. The roots are left in the ground. Old roots and organic matter in the soil improve the soil texture and structure. The cut materials should be returned to the field after threshing. The frequency of harvesting depends on the available soil moisture and fertility, and on the condition of the crop – done at minimal moisture content and when shattering is minimal.

There are also small mechanical harvesters in use (Plate 9) but these are limited to the variety grown since they require the crop to mature uniformly to avoid harvest losses. Farmers can use combine harvesters with a shredder and spreader attachment to chop and distribute the residue evenly on the ground surface. This is important for soil moisture retention, weed suppression and facilitates direct seeding of the next crop.

Plate 9: Greengram combine harvester

4.3. Post-Harvest Management

4.3.1. Drying, Threshing and Winnowing

Manually harvested pods should be dried for about 2-3 days then threshed, winnowed, sorted and graded ready for consumption, marketing or storage.

Plate 10: Moisture meter

a). **Drying**

Harvested pods are dried to allow threshing to be done. After threshing and winnowing clean and sort the seeds and sun-dry to a moisture content of 13%. To get thorough drying, spread thinly and ensure frequent turning of the grains.

Two methods commonly used to check the moisture content of the cleaned grains are the salt method (appendix 8.4) or using the moisture meter (Plate 10). The ***salt method*** is quick and easy but will only indicate that grain is above or below 15% moisture content.

b). **Threshing**

Threshing must be done either on canvas, polythene sheets or tarpaulins among

others, to avoid contamination. Threshing can be done using either mechanical or manual methods. Beating sticks are used in manual threshing. In mechanical method, you can use pulse thresher (Plate 11) which makes work easier and faster. It also causes less splitting of seeds, low number of seeds left in pods, is less laborious particularly for women who are mainly the ones doing manual threshing. Mechanical threshing also provides an opportunity for youth employment in providing the threshing services.

Plate 11: Mechanical threshing of greengram

Winnowing

Winnowing is done to separate foreign materials from grains. This can be done manually using baskets or other containers, or mechanically by the pulse threshers.

4.3.2. Grain Quality and Standards Requirements

Standards and indicators

Globally consumers and markets are protected by standards. For the Kenyan farmers and exporters their produce should meet set quality standards to access international markets.

The attributes of quality involve colour, flavour, texture, nutritional value and freedom from harmful substances such as microorganisms, insects, pests and their products (Plate 12). Chemical parameters considered include oil content, acidity, protein, moisture and presence or absence of toxins. All produce intended for human consumption should be free from foreign odours, moulds, foreign materials and other contaminants.

Plate 12: Good and bad GG (photo by Gachuhi)

a). **Grading**

Grading enables farmers to have quality in their produce which leads to high demand hence high selling price. Grading is arrived at by removing or addressing as much as possible the following quality attributes:

- Foreign matter e.g. metals, stones, plastics, glass etc.
- Chaff or trash
- Broken grain and pest damaged
- Rotten and diseased
- Defective or discoloured.
- Immature or shrivelled or stained
- Mouldiness (infected by fungus)
- Other contaminants.
- Moisture Content

Grading enables farmers to have quality in their produce which leads to high demand hence high selling price. Grade one fetches the highest price.

There are three grades of greengram, according to standard (CD-ARS 865:2012) developed by the African Organization for Standardization (ARS, 2014), summarized in Table 8.

Table 8: Greengram specific grade requirements

Characteristics		**Maximum limits**			**Method of test**
		Grade 1	Grade 2	Grade 3	
Moisture % max m/m		14.0	14.0	14.0	ISO 24557
Purity % Max m/m		99.0	99.0	99.0	ISO 605
Defective,% max m/m		2.0	4.0	6.0	
Immature grain % max m/m		2.0%	3.0	4.0	
Contrasting classes		0.5%	1.0	2.0	
Classes that blend max % m/m		5.0%	10.0	15.0	
Germination, excluding hard seeds		90%	n/a	n/a	
Sprout test		suitable	n/a	n/a	
Foreign material,% max m/m	Organic	0.65	0.65	0.65	
	Inorganic	0.25	0.25	0.25	
	Filth	0.1	0.1	0.1	
Other edible grains % max m/m Any edible grain (including oilseeds) other than Greengram		0.1	0.5	3.0	
Inset/pest damaged % Max m/m, Grains per cent by count clean-cut weevil bored		1	2	3	
Total Aflatoxin (AFB1+AFG1+AFG2), ppb				10	ISO 16050
AflatoxinB1 only, ppb				5	
Fumonisin, ppm				2	AOAAC 2001.04

Source: ARS, 2014.

b). **Ungraded and rejected greengram**

Ungraded does not fall within the requirements of grades 1, 2 and 3 of this standard but meets the minimum requirements provided in Table 8 and are not rejected greengram. Ungraded greengram can be sorted out to grade 1, 2 or 3 in accordance with the relevant procedures.

Rejected greengram are grains that are either musty; have a commercially objectionable odour; infested with insects, insect webbing or filth; which contains any unknown foreign substances such as broken glass or metal fragments; or which are otherwise of distinctly low quality. The characteristics cannot satisfy the conditions under grade greengram and shall be graded as rejected and unfit for human or animal consumption.

4.3.3. Packaging

Packaging for storage should be done in 50 or 90 kg bags, checked and certified. Farmers deliver their produce to the central collection store/aggregation centre and are issued with a delivery receipt/slip after checking and confirming the weight and grade. Bags should be labelled according to grade and variety. To prevent pest damage for long storage farmers can also pack in hermetic bags.

Plate 13: Packed greengrams

Packaging for retail market is done in 1 kg, 2 kg, 5 kg and 10 kg or other appropriate package (Plate 13) as per the market needs.

4.3.4. Storage and Transportation

Dry greengram should be stored either in covered tins, drums, pots, bags or metal silos. The grain should be protected from weevils using insecticides (e.g. Pirimiphos-methyl, at 50g per 90 kg bag). To be climate friendly it is advisable to use the hermetic bags, sealed drums or metal silos for storage to avoid pest damage. These options are affordable and economical since they can be re-used for longer periods of time and do not require chemicals.

a). **Requirements and recommendations for good storage**

Greengram is very susceptible to attack by bruchid beetles and should therefore be stored soon after drying in airtight containers or bags in a clean ventilated room. Treatment of grain is recommended for a longer storage period. Proper drying of the greengram is highly recommended in order to prevent contamination with aflatoxins and development of pathogens.

Requirements to be fulfilled for safe storage of greengram include;

- **Proper site selection**: It should be on a raised well-drained place, easily accessible.
- **Selection of storage structure**: The size of the structure should match the quantity of greengram to be stored. It should be protected from humidity, excessive heat, direct sunrays, insect and rodents. It should be raised to a height of not less than 30 cm from ground to prevent dampness.
- **Cleaning of storage structures**: Storage structures should be properly cleaned and fumigated using biofumigants that are environmentally friendly.
- **Cleaning of bags**: It is recommended to use new bags. When using old bags, they should be properly cleaned, dried and fumigated.
- **Separate storage of new and old stock** to check infestation and to maintain hygienic condition of the store/warehouse.
- **Cleaning of vehicles**: The vehicles used for transporting greengram should be properly cleaned.
- **Use of pallets**: Pallets should be used before stacking bags to avoid absorption of moisture from floor.
- **Proper aeration**: There should be proper aeration to regulate humidity and temperature.

- **Regular inspection**: Regular inspection of stored greengram should be carried out to check infestation.

b). **Storage Pest control**

Greengram is very susceptible to bean weevil attack and are best stored immediately after sun drying. Common storage pests of greengram (Plate14) include weevil *(Sitophilus species)*, Anjoumis moth *(Sitotroga cerealella),* Khapra beetle *(Trogodema granarium),* Termites, Rodents (rats, mice) and Birds *(*feral pigeons, house sparrows and starlings*).* Moulds are also destructive to grains and occur when the humidity of the grain is favourable (higher than 16%).

Storage pest control involves the use of chemicals and other non-chemical methods (hygiene in warehouse, store management and rodent proofing). For chemical control the grains should be dusted with locally recommended chemicals, including those having the following active ingredients: organophosphates, pirimiphos-methyl or permethrin.

NB: For all pesticides always follow manufacturer's application manual

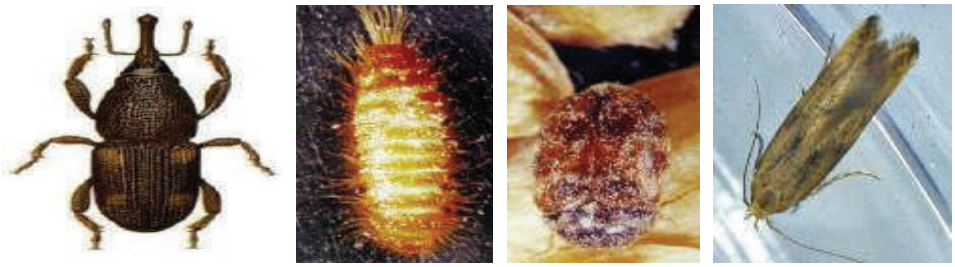


Plate 14: Common storage pests from L to R - weevil *(Sitophilus spp),* Anjoumis moth *(Sitotroga cerealella),* Khapra beetle *(Trogodema granarium-* larva and adult*) (Source: CABI)*

Integrated Pest Management (IPM) involves the use of non-chemical (Plate 15) and chemical methods of pest control. IPM gives priority to non-chemical control measures, use of traditional methods and only results to use of chemical controls when other options are unlikely to offer sufficient protection. An IPM system would, therefore, supplement good warehouse keeping with a combination of physical methods, chemical and biological control practices and/or good hygiene and management practices as summarized below:

Plate 15: Storage of dry greengrams in air tight storage containers and hermetic bags

Physical methods

- Use of hermetic bags,
- Insect-resistant packaging.
- Storage design for pest (rodent and bird) exclusion.

Chemical control practices

- Judicious use of pesticides and fumigants.
- Use of treated bags

Biological control practices

- Biological control (parasites, predators (such as cats) and pheromones).
- Use of pest resistant varieties.

Good hygiene and management practices

- Storage management – first in, first out (FIFO).
- Thermal disinfestations.
- Irradiation techniques.
- Use of ambient aeration, and refrigerated aeration. Atmospheric gas modification (hermetic, CO2, N2)
- Adequate grain cleaning prior to storage
- Improved harvesting and threshing techniques.
- Monitoring, evaluation and inspection of stored commodities, storage structures and their immediate surroundings.

c). **Transportation**

Greengram is transported through various means depending on the stage of post-harvest operations and/or marketing. It may be through road (headload, draft animals, pack animals, tractor trolleys, trucks), railways or water transport.

Choice of the transportation mode should be determined with a view to reduce costs, accessibility, safety of produce (weather/theft) and timeliness

4.3.5. Post-Harvest Losses management

These are the losses that occur during and after harvesting due to late harvest, insufficient drying, improper threshing, poor storage, poor packaging and extended storage due to low market prices.

Without proper harvesting and post-harvest management practices, produce can easily be lost. Harvesting before the crop is physiologically mature, as well as late harvesting, can lead to poor quality and fungal and bacterial infestations.

There is a sizeable quantitative and qualitative loss of greengram during different post-harvest operations like threshing, winnowing, transportation, processing and storage. Hence, it is appropriate to give due emphasis to reduce qualitative as well as quantitative losses during post-harvest operations.

Poor storage leads to losses in quantity, quality and value. The value may reduce due rotting, fungal (aflatoxin) or pest infestation and contamination among others.

Categories of quantitative and qualitative post-harvest losses include;

- **Weight Loss** - due to reduced moisture content or feeding by insects, rodents and birds or from the growth of micro-organisms.
- **Quality Loss** - quality is assessed and products graded on the basis of appearance, shape, size, smell, flavour, foreign matter content and contaminants.
- **Nutritional Loss** – where rodents and some insect larvae may feed preferentially on the germ of the grains, weevils feed on the endosperm, reducing the carbohydrate content and eating the bran of cereals, thus reducing the vitamin (especially thiamine) content. High moisture content and the associated growth of microorganisms also lead to changes in the vitamin content of the grain.
- **Loss of Seed Viability**: Loss in seed germination rate, caused by changes in light, temperature, moisture content, excessive respiration, infestation and, in some cases, the methods used to control infestation. Insects that selectively attack the germ will cause a greater loss in germination than others.

4.3.6. Utilization of Greengram

Greengram are consumed in a number of ways e.g. whole seeds may be boiled, fried alone or with meat/vegetables and eaten as a relish with thick maize porridge (ugali). The grains may also be split (dhal) by removing the seed coat through grinding and the split seeds may be eaten boiled or fried.

The split seeds may also be ground into flour which may be further processed into highly valued noodles, bread, biscuits, vegetable cheese and extract for the soap industry. It is also blended with other cereal flour (fortification) to make pastries, cakes and other products. It can also be used as a vegetable in form of immature pods or by sprouting the seeds (greengram sprouts). More than 27 different recipes can be made with greengram (Plate 16).

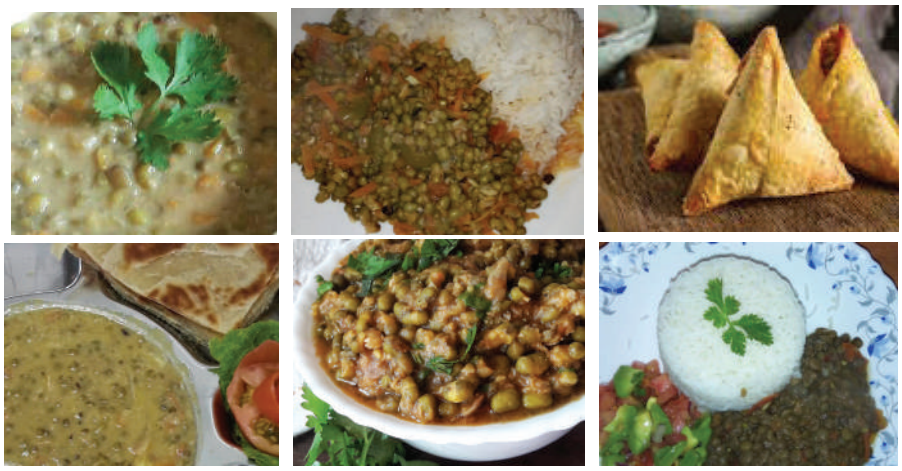


Plate 16: Different greengrams recipes (Source: www.cookpad.com/ke/search/dengu)

Greengram by-products such as bran, meal and hull, have been used as animal feed mainly in India and other Asian countries. Greengram can also be grown as fodder for livestock feed. Table 9 shows the chemical composition and nutritive value of different by-products of greengram.

Table 9: Chemical composition and nutritive value of greengram and its by-products (percent, dry matter basis)

Parameter	Seeds	Straw	Bran
Crude protein	19.5–29.4	8.7–11.6	19.2
Ether extract	0.2-3.7	2.3-2.4	2.2
Crude fibre	4.3-12.4	26.6-29.9	26.2
Neutral Detergent Fibre (NDF)	15.6	63.5	43.5
Acid Detergent Fibre (ADF)	6.6-10.3	32.0-47.2	26.4
Lignin		4.8	4.3
Ash	0.9-14.0	6.1-12.1	4.8
Calcium	0.08-0.47	2.7	0.4
Phosphorus	0.36-0.62	0.2	0.3
Dry matter (as fed)	90.0	88.2	95.3

Source: Feedipedia, 2019

a). Nutrition composition

Greengram recipes are among the highly nutritious meals enjoyed in Kenyan homes. They are easily accessible and easy to prepare as well. Good nutrition is important for maintaining the immune system for good health. Nutritional status of any community is recognized as an important indicator of national development. Primary cause of malnutrition is low dietary intake of various food nutrients required by the body. This can be addressed by consumption of greengram which is rich in protein, folate (vitamin B9), iron and phosphorus (Table 10). The growing and utilization of greengram is one of the possible potentially successful approaches for improving household nutrition, food security and income.

Table 10: Nutrients in 100g of greengram and recommended daily intake (RDI) for children 1 -3 years

Nutrient parameter	Greengram	RDI 1-3 years	Weight of greengrams (to meet RDI) (g)
Energy Kcal	322	1300	400
Protein (g)	23.8	16	67
Calcium (mg)	132	500	379
Iron (mg)	6.7	10	150
Zinc (mg)	2.6	10	385
Magnesium (mg)	189	60	32
Phosphorus (mg)	367	800	218
Folate ((µg)	625	160	25
Vitamin A (IU)	111.5	400	259
Vitamin C (mg)	4.8	30	625
Vitamin K (µg)	9	15	167

b). Value addition

Value addition is a change of a product from original physical state to an enhanced new form. Greengram can be value-added into quality seed, de-hulled, split grain or flour (Plate 17). Mature seed or sprouted grains and flour are used in a variety of dishes such as soups, porridge, snacks and bread. The processed flour can be used to make diverse bakery products such as cakes, biscuits, crackers, porridge and snacks. In Kenya it is most commonly consumed as whole seeds boiled with cereals such as maize, rice or sorghum. The boiled seeds can also be fried with meat, vegetables and eaten alongside with "ugali" or "chapatti".

Grains can also be dehusked and split or can be polished to give the dehusked and split grains a small quantity of oil treatment. The plant residues or weathered or cracked seeds are fed to livestock. The fresh vines are used as fodder, green manure or as a cover crop (Swaminathan et al., 2012).

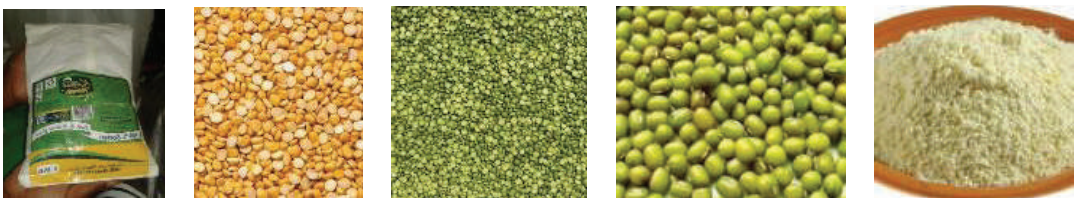


Plate 17: From L to R: Greengram whole grain, split green and split yellow dry grains, flour and packed grains (Source: Mwailu)

c). Greengram recipes

Greengram can be used to make nutritious products for inclusion into family diets and for income generation. School children can also carry the snacks to reduce hunger and malnutrition. The conversion rates for the recipes are as follows:

Dry Weights

Local	Metric
1 Teaspoon full	10g
1 Tablespoon full	20g
1 Plastic cup	150g

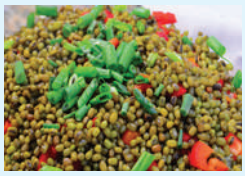
Liquid Measures

Local	Metric
1 cup	150ml

Presented in Table 11 below are the various recipes made from greengram

Table 11: Recipes using greengram grains and flour

Product Name	Ingredients	• Preparation Method
Greengram, Sorghum Porridge This is a food made by boiling ground or crushed grains of greengram, cassava and sorghum in water or milk. Often served with added flavorings such as sugar or honey in a bowl and eaten with a spoon 	½ cup greengram flour 1½ cup sorghum flour 10 tablespoons cassava flour 4 tablespoons sugar 5 Cups water 1 tablespoon lemon juice	• Boil four cups of water. • Mix all the flours and make paste with the remaining one cup of water. • Pour the paste into the boiling water and keep stirring to prevent lumps. • Let the content in the pan continue to cook and form a gel then leave to boil for 20 minutes. • Remove from fire, add lemon juice, sugar and mix well, cool and serve. Note: The flour can also be made into a paste two days before cooking and let to ferment and then used. A little paste can be retained each subsequent day to act like a starter and water plus new flour is added daily.
Greengram, Sorghum Meal A food made by boiling a mixture of greengram and sorghum. Maybe eaten as a stew with other food like rice or eaten as a complete meal on its own 	1/2 cup greengram grains I cup sorghum grains 1 medium sized onion 2 medium sized tomatoes 2 tablespoons oil 1 teaspoon mixed spices 1/2 teaspoon salt	• Boil sorghum grains until they are almost cooked. • Add greengram grains and cook until done. • Add sliced onions in pan with oil and fry until golden brown. • Add sliced tomatoes and simmer until they are cooked. • Add the sorghum and greengram mixture and salt to taste. • Cook for a further 15 minutes. • Serve hot.
Greengram, Sorghum Mandazi A meal made from a mixture of greengram, sorghum and wheat flour, deep fried and eaten as a snack 	½ cup greengram flour ½ cup sorghum flour 2 cups wheat flour 3 tablespoons margarine 2 eggs 2 Tablespoon baking powder 4 Tablespoons sugar 1 cup milk or water 2 Tablespoons grated lemon rind or ginger Pinch of salt.	• Mix all the flours, margarine, baking powder • Add sugar, grated lemon rind and salt • Use rub-in method until all ingredients are well mixed. • Add milk or warm water, eggs and mix into a soft dough. • Let the dough stand for 15-20 minutes. • Roll out the dough to 0.5cm thickness and cut into desired shapes. • Deep fry in hot oil until they turn golden brown in colour. • Drain excess oil and serve hot or cold.

Product Name	Ingredients	• Preparation Method
Greengram Sorghum chapatis A meal made of greengram, sorghum and wheat flour, shallow fried and eaten with a stew like meat, greengram etc. 	½ cup greengram flour 1 cup sorghum flour 2 cups wheat flour 1 teaspoon salt 6 Tablespoons cooking oil (as required)	• Mix all the flours, and salt in a bowl. • Add warm water little by little while kneading to soft dough. • Add cooking oil and continue kneading the soft dough. • Let the dough stand for 15-20 minutes. • Roll out dough to 0.5cm thickness and spread oil on top. • Cut into long strips of equal sizes and fold each strip around your finger. • Form a ball from the round shapes. • Using a rolling pin, roll each ball to form a round plate shape of 0.5cm thickness. • Shallow fry both sides of the chapatti till golden brown. Use very little oil to avoid sticking to the pan • Place chapati on grease proof paper to remove excess oil. • Serve hot or warm.
Greengram Samosas A food made by deep frying a mixture of greengram and wheat flour, eaten as a snack 	2 cups greengram grains 2 fingers shallot onions 11/2 litre Cooking oil 1/2 teaspoon salt 3 cups wheat flour	• Boil greengram until they are cooked. • Use warm water to mix 2cups wheat flour into soft, smooth dough. • Cut the dough into small round sizes and roll one at a time to a thickness of 0.5cm • Place the pieces on top of the other to form layers. • Divide each layer by applying oil and rolling out. • Shallow fry the rolled out pieces without oil on both sides. • Peel the pieces out and cut into halves. • Fold each piece into triangles • Make paste from the remaining 1 cup wheat flour. • Cut onions and mix with salt and greengram. • Put two tablespoons of greengram into each folded triangle. • Seal with the paste and deep fry until golden brown. • Drain off the oil and serve hot/cold.
Greengram Stew Made by boiling and frying greengram (may be in a mix with carrots, potatoes etc.) and eaten with other food like ugali, chapati, rice etc. 	1 cup greengram 1 medium sized onions 2 medium sized tomatoes 2 tablespoons cooking oil 1/2 teaspoon salt Adequate water	• Boil greengram until they are cooked. • Place pan with oil on the stove • Wash and cut onions. • Add the onions to the oil and fry till golden brown. • Add tomatoes and fry until tomatoes are cooked. • Add greengram and water to desired consistency then let it simmer for 20 minutes. • Serve with rice, chapattis, ugali, boiled bananas potatoes or cassava.

Product Name	Ingredients	• Preparation Method
Greengram Sorghum Onion Bites A snack made by deep frying a mixture of greengram, sorghum, wheat flour and onion rings, eaten as a snack 	1/2 cup greengram flour 1 cup Sorghum flour 2 cups Wheat flour Pinch of Salt ½ teaspoon Chili powder 3 teaspoons Baking powder 4 cups water 2 liters cooking oil 6 whole Spring onions/2 Medium bulb	• Mix all the dry ingredients in a mixing bowl. • Clean and cut the onions and add to the flour. Add water and mix the contents into dough. • Knead the dough well while adding 4 tablespoons of oil. • Leave the dough to relax/mature. • On a floured surface, roll the dough to about 0.5cm cm thickness. • Cut into desired shapes. • Deep fry while turning till golden brown. • Remove from oil, drain and serve warm or cold.
Greengram Sorghum Crackies A food made by deep frying a mixture of greengram, sorghum, ginger, wheat flour and eggs, eaten as a snack 	1 cup greengram flour 3 cups Sorghum flour 1 cup Wheat flour ½ cup Sugar 2 Tablespoons Ginger 5 Table spoons baking powder Pinch of Salt 2 liters Oil Egg /optional Warm water 5 cups	• Sieve all dry ingredients in a bowl and mix well. • Beat the egg and add to the contents in the bowl and knead, while adding warm water, to form smooth dough • The dough should be softer than that for Mandazi. • Pack dough in noodle machine. • Heat oil and drop in contents from the machine by turning the handle clockwise. • Turn contents in oil and let fry till golden brown (cooked) • Remove and drain oil, cool and store in a covered container • Serve cold or warm
Greengram Fried Snack Deep freed and eaten as a snack 	11 cups greengram 1 litre cooking oil 1 teaspoon salt 1 Tablespoon spice of choice Adequate water.	• Clean the grains of any foreign matter • Wash then boil for 20 minutes • Sundry for 15 minutes. • Deep fry in hot oil till cooked (10mins) • Drain of oil, salt, spice and let cool • Serve cold or warm
Greengram Biscuits A mixture of greengram, sugar, milk and wheat baked and eaten as a snack 	– 1 cup greengram flour – 2 cups wheat flour – 1 cup margarine – 1 cup sugar – 1 cup milk/water	• Sift the dry ingredients and mix in a bowl • Melt sugar and margarine and add to the mixed flours. • Knead the mixture into soft dough. • Add milk or water and mix to desired consistency. • Roll out to 0.5 cm thickness and cut to desired sizes. • Using a fork punch the upper side of the dough. • Grease a baking tin and spread flour on it. • Arrange cut dough pieces and bake at 345^{0}C for 20 minutes. • Serve hot or cold as a snack.

Product Name	Ingredients	• Preparation Method
Greengram Finger Millet Cake A mixture of greengram, finger millet, wheat flour, sugar, milk, eggs etc. baked and eaten as a snack 	1 cup greengram flour 1 cup finger millet flour 2 cups wheat flour 3/4 cup margarine 4eggs 1 cup milk/water 3 Tablespoons of sugar 3 teaspoons baking powder 2 Tablespoons vanilla essence 1 Tablespoon grated lemon.	• Cream sugar and margarine in a bowl until it turns into a smooth paste. • Sift and mix the dry ingredients then add in the paste. • Whisk the eggs and add to the paste mixture in the bowl. Add milk or water and continue stirring to a thick consistency. • Add vanilla essence and grated lemon rind and mix well. • Grease a baking tin and spread flour on it. • Pour the mixture into the tin. • Bake in a preheated oven at 350^{0}C for 45 minutes or open fire bake. • Serve cold or warm. Eaten with milk, juice, tea or soda
Sprouted greengram salad (How to sprout greengrams: Wash the greengram thoroughly, soak them in distilled water then place the greengram in a container with a lid for 24 hours. Rinse them before use / consumption) greengram sprouted, boiled or stir-fried alone or with other vegetables and eaten as salad 	2 cups of sprouted greengram 1 small or medium sized onion, finely chopped 1 medium sized tomato, finely chopped 1 green chili (optional), finely chopped 1/4 tsp red chili powder 1/2 tsp chaat masala (optional) 1 tsp lemon juice or as required 1 boiled potato or sweet potato (optional) A few coriander leaves and lemon slices for garnishing Rock salt or black salt as required	• Rinse the sprouted greengram in water. • Either steam, stir-fry or boil till completely cooked. • Strain the cooked sprouts. • Mix all the ingredients except the salt and lemon juice in a bowl. • Season with salt and add a few drops of lemon juice. Garnish with lemon slices and coriander leaves. • Serve immediately

Module 5: Marketing and Market Dynamics for Greengram

5 Marketing and Market Dynamics for Greengram

5.1. Introduction

There are different ways and options to sell farm produce to buyers. These include selling directly to traders who visit farms during harvest time, selling in nearby local market, and selling directly to consumers and processors, cooperatives or aggregators. Farmers can also send or take their produce to a more distant market. In some counties, farmers may have relationships with traders who have provided them with some form of credit, and they must therefore sell at least part of their produce through those traders.

This module covers aspects related to greengram markets, marketing processes and strategies and market information systems.

5.2. Market

A market is a physical or virtual designated space where sellers and buyers meet regularly for selling and buying of commodities and services. About 70% of the greengram produced in Kenya is marketed. Domestic trade is characterized by informality especially among retailers and some wholesalers with middlemen playing a major role of linking the big players such as exporters to farmers.

There are very few commonly traded varieties largely determined by consumer preferences and availability. Price of greengram in Kenya ranges from Kshs. 40 to 100 per kg depending on quality, seasonality and market forces of demand and supply.

Greengram marketing challenges and recommendations are summarized in Table 12.

5.3. Marketing Strategies

Greengram is a crop with existing and emerging market opportunities regionally and internationally especially in India. It is therefore vital to establish and understand strategic national, regional and international markets (in terms of dynamics and requirements) that can be tapped into by all greengram value chain actors in Kenya.

5.3.1. Aggregation and Group marketing

The Kenya Government is encouraging farmers to come together and consolidate their produce in order to have a bargaining power with the buyers. Most buyers also prefer to trade with farmers whose products are aggregated for the necessary volumes to be collected to reduce the consolidation/transportation costs. Smallholder farmers in Kenya are increasingly adopting collective marketing strategies and receiving higher prices for their output. Educating farmers to understand how markets work, how they can earn more money through collective action and how to put these ideas into practice may require the organization of many group meetings, training sessions and marketing.

Benefits of aggregation and group marketing

- Act as incentives to increasing smallholder agricultural production.
- Lead to increased economies of scale.
- Result in reduced transaction (storage and transport) costs.

Table 12: Greengram marketing challenges and recommendations (Source: Kilimo Trust, 2017)

Challenges	Recommendations
Demand not matched by production- low, unreliable and scattered production	• Promote good agricultural practices and labour saving production technologies in addition to access to certified seed • Establish sustainable structured business linkages along the entire value chain • Invest in farmer institution development for increased bulking
Poor quality greengram- low compliance to standards	• Capacity building of stakeholders on good post-harvest handling procedures and meeting standards • Invest in simple improved postharvest handling and processing technologies at all levels
Informality of businesses	• Create awareness on the benefits of formalization and support greengram businesses to formalize
Poor transport infrastructure	• Improve transport infrastructure along greengram trade corridors
Limited access and utilization of productive assets especially finance	• Improve access to affordable financing products to enhance commercial production to tap into the export market opportunities • Availability of short term credit • Support the financial institutions to tailor products for agricultural value chains
Information gap for the actors especially about market opportunities	• Support existing market information systems and information sharing platforms to provide up to date information • Conduct or support timely market assessments and dissemination of this information to the target stakeholders
Low business orientation limiting scaling up and bulking	• Capacity building through Farmer Business Schools among the farmers • Organizing and strengthening of producer groups • Capacity building and creating awareness on market opportunities and cross border trade requirements and what is currently already possible
Market distortion by middlemen	• Creating direct linkages between producers, traders and exporters

- Increase the bargaining power of smallholder farmers, thereby increasing profitability.
- Increase access to better markets.
- Attract agricultural financing for the improvement of agricultural infrastructure (farm inputs and construction of storage facilities).
- Lead to increased quality control.
- Possible to access climate smart products and service in a group
- Easier to do value addition – packaging, cleaning, etc. and thus get better prices

Through aggregation farmers are expected to determine the cost of production and add a mark-up over that cost to be able to make some profit. This helps them to determine the minimum price they should offer their produce.

5.3.2. Market contracting

Drawing marketing/trade contracts is becoming increasingly popular between farmers and the private sector. Major reasons for this are: avoiding risks, securing supply and markets, accessing finance and sharing information. The main elements of trade contracts vary depending on the type of contract. Some of the key features are;

- Quality or grade of grain delivery or to be delivered;
- Location of delivery;
- Date by which delivery is to be completed;
- Quantity being contracted;
- Price or formula to be used in determining the net price;
- Price adjustment if you are unable to meet the specified grade;
- Signatures of both parties and date of signing.

Three principles of trade contracts are:

- A contract is a promise or set of promises, the performance of which the law (e.g. Kenyan rules of Trade) recognizes a duty of and for the breach of which the law gives a remedy (e.g. arbitration/mediation).
- Every contract involves at least two contracting parties and they may enter into that contract in the words they say (an express contract) or by the actions they take (an implied contract).
- Contracts are negotiated.

Key requirements of trade contracts are:

- The parties must make clear their mutual agreement to the same terms, which is usually accomplished by an offer and an acceptance.
- Before entering into any contract, it is crucial to understand exactly what is required of all parties.
- Contracts are legally binding documents requiring performance.
- Failure to perform on the contract can be costly and can result in legal action. For example, if a seller fails to deliver, the buyer can cover by purchasing substitute goods and charging the net cost back to the seller.

The benefits of trade contracts include:

- Specifying the responsibilities and obligations of the seller and buyer.
- Reducing risks such as market (price risk) and performance risks.
- Making the grain availability and delivery predictable
- Ensuring grain sales over an expected period of time to both farmers and traders.

5.3.3. Warehouse receipt system (WRS)

WRS is a method of trading with grain, which allows the commodity to be deposited in a certified warehouse. The depositor can then decide to immediately sell the grain or store it while awaiting a better price.

The WRS involves issuing of warehouse receipts, which guarantee the existence and availability of a commodity of a particular quantity, type and quality in a named storage facility for specific individuals. The authorized issuer of the warehouse receipt holds the stored commodity by way

of safe custody; implying that the issuer is legally liable to make good any value lost through theft or damage by fire. The depositor can access financing from the banking sector, which would be essential in land preparation, purchasing of agro-inputs or purchasing more stock in the case of millers as he or she awaits a better price for the grain

The following details shall be included on each warehouse receipt:

- Name of depositor
- ID of depositor
- Contact details of depositor
- Warehouse name, location and certification number
- Date of deposit
- Commodity deposited
- Grade deposited
- Quantity - net and gross weight
- Date until which storage has been paid

WRS Benefits

a) Aggregation of tradable volumes, especially from small-scale producers.
b) Being able to engage professional management of the commodity while in storage to ensure good condition. This reduces post-harvest losses and quality problems
c) Delaying sale of the commodity when prices are low while accessing finance to pay for outstanding loans and costs.
d) Receiving loans from banks at affordable interest rates, while using the commodity as collateral.
e) Access to a larger and more formal market and ability to sell to anyone in the market.
f) Being able to transfer the commodity from one owner to another without the added cost of transporting the commodity from one store to another

5.4. Market Information System

All information about the buying and selling of products and services can be classified as market information. Market information encompasses information about prices and quantities and information about both input and output markets.

Market information can be accessed and shared through exhibitions of the product at platforms and events that bring together various actors within the value chain. Such platforms include; farmers field days and market events that bring together stakeholders along the value chain such as input suppliers, traders, extension service providers, financial institutions, private companies and government agencies. Product samples are presented and demonstrated to potential buyers.

Examples of market information:

Categories	Examples of market information
Inputs	location and contacts of input suppliers; type and quality of inputs available prices of different inputs
Demand	size of local, regional and national markets; growth or trends in demand; seasonality of demand
Buyers	location and contact; volume requirements; quality specifications; packaging requirements; seasonal demand; prices offered; payment conditions; support services provided (inputs, credit etc.)
Prices	prices in different markets; price differences according to grade or quality; price seasonality; price volatility within seasons; price trends
Competition	main supplying areas; quality of supply from different areas; seasonality of supply from different areas; imports
Marketing costs	transport; market fees; unofficial charges; Other

Farmers are constantly making production and marketing decisions. Market information can help them make choices, from the very first stages of the production planning process up until the moment when the produce is actually sold. Extension workers should support farmers to access market information.

The following are important questions an extension worker should address when supporting farmers on market information. Farmers should share their own experiences about:

- What and how much should farmers produce?
- Should farmers grow off-season crops?
- Which varieties should be planted?
- Which post-harvest operations should farmers undertake?
- Should farmers store their crops?
- Where should farmers sell their products?
- Who should farmers sell to?
- Should farmers sell individually or as a group?
- How should farmers negotiate with buyers?

Processing and analysis of market information

Many farmers find it difficult to interpret market information and fully appreciate its implications to their farming business. Extension workers should be knowledgeable of the existing market environment for greengram. They should also work closely with selected farmers to interpret market information.

Appendix 8.2 lists approaches which can be adapted to process market information. The reader can use the check list to assist farmers to produce for the target market.

Plate 18: Packaged greengram products

Module 6: Socio-Economic Aspects of Greengram Production

6 Socio-Economic Aspects of Greengram Production

6.1. Introduction

Extension service providers should support smallholder farmers in the adaptation and adoption of CSA techniques in greengram production through the improvement of farm management, value addition and marketing techniques. By doing so, farmers can be better prepared to detect opportunities for traditional products in rural economies by adopting a business approach which includes formal agronomic, commercial and economic evaluations for potential market options. Farmers are continually exposed to new information that affects how they organize their farming; what commodities they produce, how they are produced, what inputs they use, how much of each input they use, how to finance the business, and how and when to market their produce. Smallholder farmers have traditionally lacked a business and marketing orientation because farming effort was concentrated on subsistence production.

This module covers the economics of the greengram subsector under CSA, farming as a business, cost benefit analysis, gender issues in greengram value chain and the barriers to CSA adoption.

6.2. Economics of Greengram under CSA

The benefits of adopting CSA in greengram subsector accrue at the farm, the national/regional and global level. Significant social benefits that accrue from the adoption of CSA practices at farm level include

- **Reduction in on-farm costs**. This comes as a result of savings in time, labour and mechanized machinery in the range of 50 to 70%. Savings in labour and drudgery have a positive impact of attracting the youths to farming and making farming less laborious for women. They also increase profit margins making farming as a business real.
- **Increase in soil fertility and moisture retention**. Has the positive effect in long-term yield increase, decreasing yield variations and greater food security. Minor fluctuations in weather conditions produce no effect on crop yields. Fertile soils do also cushion farmers against the negative effects of flooding.
- Recharge of aquifers and re-emergence of dried wells. More regular river flows, reduced flooding and the re-emergence of dried wells are outcomes of improved infiltration from adoption of CA as a CSA practice.
- **Stabilization of soil and protection from erosion** leading to reduced downstream sedimentation into lakes and dams and water pollution. The lifespan of dams providing irrigation water or serving urban centres with drinking water can be prolonged significantly if CA is practiced in entire watershed areas. Farmers practising CSA should be involved in such watershed schemes and benefit from it. Broad practice of CA can reduce toxic contamination of surface and groundwater and also the costs of water purification. Municipal or private operators of water purification plants should share the benefits with the farmers.

- **Reduced water consumption for agricultural production.** Water consumption for agricultural production is steadily increasing in Kenya, leading to exhaustion of groundwater resources, drying-out of rivers and lakes. Agricultural uses are conflicting more and more with urban uses. The increased water conservation and water use-efficiency of CSA systems is therefore of utmost importance for the future of the country.
- **Reduced GHG emissions.** CSA practices lead to increased soil organic matter, and thus sequester carbon. Large scale application of CSA practices can sequester considerable amounts of carbon.

6.3. Greengram farming as a Business

Greengram farming is an activity whereby natural resources including seeds, water, fertiliser labour and land are used to generate greengram produce which is of higher value than all the resources combined. The resources used in the farm are called ***inputs*** and the products obtained are called ***outputs***.

The farmer must run his/her farm as an economic production unit. The aim must be to produce output of which, the total value of outputs exceeds the total value of the inputs. Doing so, leads to making a ***profit***. If the total value of the inputs is higher than the total value of outputs, there will be a ***loss***.

The total value of the outputs is called ***gross output*** and the total value of all inputs is called ***total costs***.

Total value Output - (minus) **Total Value Input** = (equals) **Profit or Loss**

How farmers can make their CSA greengram farming a business:

- Choosing the right variety best suited to the area and planting times as dictated by the market.
- Getting information on the production, post-harvest processing and storage, value addition and marketing. Farmer groups can be one of the vehicles for acquiring and sharing information more easily.
- Adding value to their produce. This includes sorting and grading, storage, processing and packaging.
- Keeping records of their crops or what they buy and sell. Records tell whether farmer is making profit or would make more money by switching to CSA.

6.3.1. Record Keeping

Record keeping is important in a farming business for it is the only way to inform the farmer entrepreneur how the business is doing. Extension workers should help farmers to understand how to keep written records so that they can accurately evaluate the benefits of new agricultural practices. Therefore, a systematic process of gathering data and recording it should be set up. Farmers should keep the following documents:

- Production records
- Operation records such as labour, farm inputs, tools and equipment costs
- Cash transactions
- Sales Records such as quantity of sale, value, and name of buyer.

The examples of records are shown below:

Production record

Enterprise	Land size	Expected yield	Total Yield
Greengram	1 hectare	800 kg	800 kg/hectare

Labour record

Date	Activity	No. of workers	Time taken (hrs)	Total time taken (hrs)
22-9-2019	Land preparation	2	4	8
2-10-2019	Planting	2	4	8
15-10-2019	Weeding	4	6	24

Cash inflow record

Date	Sale/Output	Quantity (kg)	Unit price (KShs/kg)	Total income (KShs)	Comments
2-10-19	Sold greengram	200	80	16,000	Sold at farm gate
9-10-19	Sold greengram	180	85	15,300	Sold at market
19-10-19	Sold greengram	300	82	24,600	Sold at farm gate
26-10-19	Sold greengram	150	90	13,500	Sold at farm gate
		830		69,400	

Cash outflow record

Date	Payment/ Transac-tion	Quantity	Unit price (KShs)	Total Income (KShs)	Comments
08-8-2019	Purchased seed	100	200	20,000	Bought from Binge Agrovet
09-8-2019	Purchased fertilizer	250	70	17500	Bought from Sam
09-8-2019	Purchased foliar	2	110	220	Bought from John
12-8-2019	Labour	4	400	1600	Own labour
16-8-2019	Ripping labour	4	400	1,600	Hired
18-8-2019	Labour	10	400	4,000	Hired
22-8-2019	Pesticide	2	1500	3,000	Bought from Simon
23-8-2019	Transport	2	5000	10,000	Hired from Boom shop
25-8-2019	Bags	50	30	1,500	From Smart sellers
6-10-2019	Harvesting	6	1200	7,200	Hired locally
Total				66,620	

Consumption record

Date	Consumed item	Quantity (kg)	Unit price (KShs)	Total Value (KShs)	Comments
5-8-2019	Greengram	2	100	200	Family
5-8-2019	Cowpeas	2	80	160	Family
12-8-2019	Greengram	10	100	1000	Visitor
Total		16		1360	

Profit and loss record

	Quantity	Unit price (KShs)	Total (KShs)
Income			
Sales	2000kg	30	60,000
Home consumption	20kg	40	800
Others			400
Total Income (a)			**61,200**
Expenses			
Seed	100	100	10,000
Fertilizer	4 bags	3500	14,000
Pesticide	2 litres	1500	3,000
Ripping	6	500	3,000
Planting	12	300	3,600
Weeding	8	250	2,000
Harvesting	10	300	3,000
Total expenses (b)			**38,600**
Profit (a-b)			**22600**

6.3.2 Farm Management

The farmer is both a cultivator and manager. The first role of the farmer is to take care of greengram in order to get useful products (food and income). This includes the preparation of the seedbed, the sowing of the crop, the elimination of weeds, the management of soil moisture and measures for the control of pests and diseases.

Farm management involves primarily the making of decisions, or choices between alternatives. The decisions each farmer must make as manager include choosing between the varieties and other crops that might be planted in rotation or mixed cropping with greengram. The decision needs to take into account the climate aspects and how to distribute the five capital resources among different tasks, especially at times of the year when several tasks need to be carried out at the same time.

As agriculture becomes more market driven, and commercial in nature, the farmer must develop better skills in buying and selling. Farmers must decide whether or not to purchase improved seeds, fertilisers and pesticides or new implements. They must decide whether or not to employ additional labour to work in the field. The farmers must decide how much of each crop to be kept for home consumption and how much to be sold. They must decide when and where to sell the produce and whom to sell to. Extension agents should be knowledgeable about the various analytical tools in farm planning as described below.

6.4. Cost Benefit Analysis of Greengram

6.4.1. Gross Margin

Gross margin is a simple, useful and practical tool to assess the performance of a farm business by comparing the return or profit from its different farm enterprises. The gross margin for an enterprise is the output (income) from the enterprise minus its variable costs.

A study on greengram production (ACT., 2015) in Makueni County, under conventional and Conservation Agriculture (climate smart) (Table 13) showed that:

- The highest greengram production (1.75 ton/ha) was obtained under CA. The yield under conventional farming was 1.25ton/ha
- The gross margin under CA (KShs 101, 500) was higher than that obtained under conventional farming practice (KShs 52,500).

Gross Margin = Gross Output – Variable costs

Calculating gross margins requires the farmer's best estimates of yields or output for each enterprise and expected prices. The calculation of total variable costs requires identifying each variable input needed, the amount required, and its purchase price.

Table 13: Gross Margins Analysis of Greengram Production

		Conventional Farming	**CA**
Yield levels (t/ha)		1.25	1.75
Selling Price (KShs/t)		80,000	80,000
Gross Income (KShs/ha)		100,000	140,000
Total Variable Costs (TVC)	Land preparation Farm inputs e.g. seeds, chemicals fertilizer Planting and weeding Harvesting, shelling, Winnowing Transport Storage	7500 12500 15000 10000 1250 1250 **47,500**	5000 12500 10000 7500 1750 1750 **38,500**
Gross Margin (GM)		**52,500**	**101,500**

Source: ACT, 2015

Positive gross margin represents a contribution toward paying the fixed costs. Therefore, *maximising gross margin is equivalent to maximising profit (or minimising losses) because the fixed costs are constant*.

6.4.2. Partial Budget

Partial budget is a useful instrument that can be used to assess the effect of marginal changes on overall profitability as well as in choosing between technology and enterprise. The objective of partial budget is to make an overview of the costs and income of different production systems (e.g. conventional vs. Conservation Agriculture).

A partial budget is based on costs and benefits.

Costs are mainly made up of variable costs: those costs, which are derived directly from the cultivation of the crop. The other part is formed by fixed costs.

Variable costs are derived directly from the cultivation of the crop and include operational costs and the cost of inputs. Operational costs are related to the operations that are executed in the field, like land preparation, seeding, spraying, etc. and the associated costs, like fuel, lubricants, repair and maintenance of the equipment, costs for hiring machinery and labour costs. Operational costs should be calculated for all operations realised in the field: land preparation, fertiliser application, seeding, pest and disease control, including weeding and harvesting.

Fixed costs are based on the costs of owning equipment and machinery contributed by purchase price, tax on purchase, type of interest paid to bank or money lender, and insurance costs, or in case of purchase of land with a loan from the bank, the interest.

Benefits are calculated through an estimation of the crop yield (Kg/ha) and the price of the product. Farm income sometimes depends on subsidies offered by the government for certain activities. These should also be taken into account in the budgeting exercise.

Partial budgeting procedure

The changes in cost and revenue needed for a partial budget should be answered on the basis of what would happen if the proposed alternative were implemented. They can be identified by considering the following four questions:

- What new or additional costs will be incurred?
- What current costs will be reduced or eliminated?
- What new or additional revenue will be received?
- What current revenue will be lost or reduced?

The partial budget format

Problem			
Additional Costs	KShs	Additional Revenue	KShs
Reduced Revenue	KShs	Reduced Costs	KShs
A. Total Additional Costs and Reduced Revenues		B. Total Additional Revenue and Reduced Costs	
Net Change in Profit (B minus A)			

- ***Additional costs*:** This portion of the partial budget includes any new costs associated with a proposed change. These costs can be *fixed* or *variable*. If you add a new crop enterprise to your business, calculate and include under additional costs variable cost items, such as seed, fertilizer, lime, fuel and oil, rent, hired labour. You may also need additional investments for land, machinery, equipment, or buildings. Annual fixed costs, such as depreciation, interest on average value, some repairs, taxes and insurance, fall into this category. If an asset has a useful life of more than 1 year, allocate this investment over its useful life. If you can make a change without additional investments or more labour, do not enter these as additional cost.
- ***Reduced revenue*:** A proposed change in the farm operation may reduce farm income because of changes in production practices – enterprise being eliminated, reduced in size or output. For example, if you decide to eliminate or reduce the acreage of cowpeas and increase the acreage of greengram, you would record a reduced income from cowpeas in this partial budget.
- ***Additional revenue*:** A proposed change may bring additional income from an enterprise if it is added or increased in size or if output is increased for the particular enterprise. For instance, if greengram replace cowpeas, the income from greengram becomes an *additional income*.
- ***Reduced costs:*** If greengram replaces cowpeas in the proposal, the expenses associated with not planting cowpeas are reduced costs. Reduced costs are either variable or fixed. If you no longer use or if you use less of a variable input like fertilizer, you reduce fertilizer costs. You may be able to reduce the appropriate fixed costs of depreciation, interest on average value, some repairs, taxes and insurance, if there is a reduction or elimination of investments in land, buildings, equipment, machinery. In some cases, you cannot reduce costs for building and other fixed items, since the business will be stuck with them. This can also be true of labour when the change requires less labour. If labour time is reduced and there is a productive use for this labour, you would record the labour value as an additional income.

6.4.3. Cash Flow Analysis

This section examines the use of the cash flow in farm planning and as a tool for evaluating the financial performance of the farm as a whole. The cash flow guides decision making to assess whether the farm is able to generate a cash surplus or incur a cash deficit and to find the time of the year where additional financial resources may be required. The concept of cash flow is simply the flow of money into the farm from sales and the flow of money out of the farm in the form of purchases. The difference between the inflows and the outflows is known as net cash flow.

Net Cash Flow = Cash Inflows - Cash Outflows

Cash Inflows include sales of crop products, other farm income sources, sales of capital assets and borrowed money and non-farm income. ***Cash Outflows*** include production costs, capital expenditures, loan payments, and family living expenditures.

Example of an Agricultural Cash Flow Statement

Name (s)			For Year		
Part I Cash Inflows					
Crop		**Livestock**		**Other Revenue**	
Maize		Cattle & calves		Non-farm income #1	
Greengram		Sheep & goats		Non-farm income #2	
Wheat		Dairy products		Ag program payments	
Hay		Poultry		Custom work	
Pearl millet		Breeding livestock		Sales of capital assets	
Other crops		Other livestock		Other sales	
Sub totals	(KES) (a)		KES (b)		KES (c)
Total Cash Inflows (Crop + Livestock + Other Revenue)				KES (a+b+c)	
Part II Cash Outflows					
Production Expenses					
Car and truck expenses			Rents and leases		
Chemicals			(a) Machinery & equipment		
Conservation			(b) Other (land, animals, etc.)		
Custom hire			Repair and maintenance		
Feed expenses			Seed and planting		
Fertiliser and lime			Storage and warehousing		
Freight and trucking			Supplies purchased		
Gasoline, fuel and oil			Taxes (real estate)		
Insurance			Utilities		
Interest			Vet and Medicines		
Labour			Other expenses		
Total Production Expenses					KES (d)
Part II Other Cash Outflows					
		Annual family living expenses[1]		KES (e)	
		Purchase of Capital Items		KES (f)	
		Principal Payments on term debt			
		(a) Intermediate debt		KES (g)	
		(b) Long-term debt		KES (h)	
		Total Cash Outflows		KES (d+e+f+g+h)	
		Cash Position		KES (a+b+c)-(d+e+f+g+h)	

Practical applications of Cash Flow for farm planning and management include:

- The actual cash flow from one year can be used to project the cash flow for the next year. In this way, farmers will know that they have cash reserves available and will not be surprised by cash shortfalls.
- Another application is to provide solutions to cash shortfalls: The cash flow has an important function of identifying cash shortfalls and ways of addressing the problem, this might be done by borrowing additional funds, mobilising savings or selling assets.

6.4.4. Visioning and Action Planning

The extension agent should have the understanding of how to support farmers to carry out vision setting and action planning for CSA. Considering the knowledge and skills extension workers would have acquired from the CSA course and in line with Ministry of Agriculture's target programmes and other experiences, they should be able to develop an **action plan** for implementation of a CSA programme on greengram for a given period of time (section 5.5: Learning activity).

6.5. Gender Issues in CSA Greengram Value Chain

Advancement of women and youth in the greengram subsector is needed since they provide the bulk of the workforce. Women constitute approximately 75% of the rural agricultural labour force in Kenya. Gender targeting on better access productive resources and market opportunities requires affirmative targeting and capacity building, by reducing the burden of reproductive role on women in the household (Plate 19).

Plate 19: Women and youth involvement in greengram value chain harvesting (left) and trading (right) activities.

Studies show that CSA activities have had a direct positive impact on gender equality in the form of enhanced food resources and incomes. With increased productivity more jobs are created for the youth and women in the farm, aggregation centres and the warehouses. The women and youth are able to start small businesses especially through value addition on the greengram, to take advantage of the time and labour saved by applying CSA practices).

In many communities and families, men and women tend to be responsible for different roles. They play different roles, know different things and have different interests, priorities and needs. They have different backgrounds and experiences, and their families, neighbours and society as a whole expect men to fulfil certain roles and women to perform others.

CSA in greengram and other value chains may affect men and women in different ways; thus making them more (or less) willing to adopt it or may influence a particular technique they decide to use. Gender analysis methodology (Text Box 5) will be used by farmers to identify, understand, and describe gender differences and the impact of gender inequalities on implementation of CSA in greengram production. The extension agent should guide the farmers to determine gender related issues that can influence adoption of CSA practices in the greengram subsector.

Text Box 5: Guide Gender Analysis

Extension service providers should work with farmers to undertake analysis of gender issues to understand the dynamics that affect them in choosing farming technologies, particularly CSA. Be aware that the gender of extension staff will also influence the outcome of these discussions. The following steps will be taken:

- Understand roles, viewpoints and cultural beliefs of men and women and how they affect management of farms. Extension staff can do this by observing what people do, discussing with key informants and different interest groups, and participatory rural appraisal exercises.
- Extension agent should consider holding separate meetings for women to make sure they have the chance to express their views. Questions such as what are the roles women and men's roles play in farm operations (who does what, when and why). How is changing farm operations technologies will affect the roles and responsibilities of men and women. Do women and men participate equally in project planning, implementation, monitoring and evaluation? If not, why? Are there women occupying leadership positions in the community?
- Check if CSA can have unforeseen effects, for example – in the first few seasons, men's workloads may fall (no ploughing) while women's may increase (more weeding).
- Discuss the changes with men and women and encourage them to be flexible in taking new roles. Train women how to handle animal drawn ripper and encourage men to do weeding. Men may be more willing to weed if they use herbicides.
- Talk with families (men and elders) to ensure that women are not overburdened. Facilitate to get solutions in case women or men experience more burden due to CSA practices.
- Extension workers should plan to conduct extension activities to everyone, men, and women, young and old people. Pay attention to women.

- Ensure that both women and men are involved in planning, designing and implementing CSA activities. Women should be encouraged to take leadership positions in groups because they can actively participate in decision making processes that affect them.
- Check whether there are likely restrictions in women or men using CSA related equipment. A weed wiper, for example, may be more appropriate for women than a sprayer.
- Find out how men and women in a particular community get information. For example, men may listen to the radio or ask retailers for advice, while women may get information from the local market. Use the appropriate channels to spread messages on CSA. Tailor messages to your audience.
- Help farmers to get inputs, credit and assist them with accessing markets through sourcing and providing them relevant information.
- Understand people's culture and beliefs that may help or hinder efforts to promote CSA practices. As an extension agent, you need to do the following:
    - understand and respect the culture,
    - facilitate discussion on culture and whether it has implications on adoption of CSA practices,
    - build on the culture and work with respected community members to identify and correct on the limitations that hinder adoption of CSA technologies.

6.6. Barriers to CSA Practices and Technologies Uptake and Possible Solutions

Adoption of new technologies, innovations or practices take place within a socio-cultural environment and requires key capital inputs such as labour, finances, and social capital. Studies conducted on possible barriers to adoption of CSA practices concluded among others, high costs of inputs, lack of financial resources, market access and price fluctuations, lack of adequate knowledge about CSA practices, risks associated with climate change/variability and shortage of labour.

To successfully adopt CSA practices, smallholder farmers often need financial resources and/or credit for acquiring agricultural inputs (land, equipment, labour, seeds and other farm inputs); and farmers may fail in their activities when any or all of these inputs is absent or available in limited quantities or volumes.

Effective partnerships and collaboration with other interested organizations is another avenue that can generate substantial synergy to accelerate the adoption rate of the promoted CSA practices.

To overcome some of the financial constraints to adoption of CSA practices at the local level, there is a need for farmers to embrace collective action to mobilize resources through cooperatives, cost-sharing and group credit access. Deliberate arrangements are required to support farmer-to-farmer dissemination of promising improved practices to enhance adoption.

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8 Appendices

8.1. Glossary

Ameliorate is to make or become better, more bearable, or more satisfactory

Carbon Sequestration is a natural or artificial process by which carbon dioxide is removed from the atmosphere and held in solid or liquid form.

Climate change is a change in the statistical properties of the climate system that persists for several decades or longer—usually at least 30 years. These statistical properties include averages, variability and extremes. It refers to any change in climate over time, whether due to natural variability or as a result of human activity, which is basically reflected on the significant changes in global temperature, precipitation, wind patterns and other measures of climate that occur over several decades or longer.

Climate predictions are estimates of future natural conditions

Climate projections are estimates of future climates under the assumptions of future human related activities such as socioeconomic and technical developments.

Climate represents the integrated composite of the long-term prevailing weather and can be represented by a long-term average (30 years) of specific elements, together with their variation or the frequency of occurrence of extreme weather conditions.

Consecutive dry days is defined as the maximum number of consecutive days with rainfall amount less than 1mm. A useful indicator for enhanced dryness and high risk for seasonal drought

Consecutive wet days is defined as the maximum number of consecutive days with rainfall amount more than 1mm. A key indicator of extreme precipitation

Economic Injury Level is the level beyond which the pest causes economic damage to the crop hence control measures are mandatory.

Gapping is the practice of replacing the seeds that have not germinated. It is mainly done to ensure the optimum plants per unit area

Integrated disease management is the practice of using a range of measures to prevent and manage diseases in crops.

Standard According to International Standards Organization (ISO), a standard is a documented agreement containing technical specifications or other precise criteria to be used consistently as rules, guidelines, or definitions of characteristics to ensure that materials, products, processes and services are fit for their purpose.

Thinning is the practice of uprooting excess plants that have germinated where they are more than two plants per planting station.

Weather forecasting is the prediction of what the atmosphere will be like in a particular place by using technology and scientific knowledge to make weather observations. It is a way of predicting things like cloud cover, rain, snow, wind speed, and temperature before they happen

Weather is the state or condition of the atmosphere at a specific place and time (as represented by weather elements such as air temperature, pressure, humidity, precipitation, wind, solar radiation) over a short period of time.

8.2. Farmer Checklist for Greengram Production

Farmer checklist for greengram production

(i). Discuss the variety choice and marketing strategy with greengram marketer/off taker – establish market before producing
(ii). Purchase approved seeds from reliable and trusted sources, if using farmer-retained seed, test for germination % and vigour before planting and replace every three years.
(iii). Avoid fields that are not suitable in terms of soil requirements
(iv). Assess weed status of the selected field and control weeds appropriately
(v). Stay within the recommended planting period and plant appropriately
(vi). Fertilise according to history of the field and soil test analysis results
(vii). Ensure effective inoculation
(viii). Ensure good and even plant establishment
(ix). Monitor disease status in the crop
(x). Timely insect control is essential. Check crop throughout, but more intensive at least every week during vegetative stages and twice weekly from budding through to pod fil (depending on pest pressure)
(xi). Timely harvest is important. Plan wisely on the harvesting method and time.

8.3. Greengram Key Management Tips

Greengram Key Management Tips

- Select soil that drains freely.
- Use high-quality seed, and check the germination percentage, disease status and varietal purity of seed.
- Fertilise according to soil test analyses, yield potential and field history.
- Inoculate seed using recommended inoculant.
- Calculate the required seeding rate to achieve a plant establishment of 20–30 plants/m2 (25 kg/ha).
- Select row spacing to fit your farming system: wide rows offer more flexibility in sowing, and weed and insect management; narrow rows offer higher potential yields and greater weed competition.
- Assess potential weed problems and carefully plan weed control options (options for broadleaf plants are limited).
- Begin insect monitoring from the late vegetative (bud initialisation) stage (28–35 days after planting) to ensure timely and effective control decisions.

8.4. Checking the Moisture Content of Threshed Grain using Salt method

Procedure of Salt Method

i) Dry salt will absorb moisture from the grain. This principle can be used to determine whether a cereal grain sample has moisture content of above or below 15%. The method uses the following:

- A clean, dry glass of about 750ml capacity with a cup that makes it airtight
- A cup of common salt 250-350g of the grain to be tested

ii) The salt must first be dried by spreading it out on some plastic sheeting in the hot sun and leaving it for at least 3 to 4 hours until it is hard. It should be turned at intervals during this time. It can also be dried in an oven.

iii) The dry salt should be placed in a sealed container until it is ready for use.

iv) The grain is tested by putting it into the bottle (which should be about one third full) and adding 2 to 3 tablespoons (20 to 30g) of dry salt. The bottle should be closed tightly with the cap, shaken vigorously for 1 minute to mix the salt and grain, and then left for 15 minutes.

v) If the salt sticks to the side of the bottle, the moisture content of the grain is above about 15% and is not safe for storage. If the salt does not stick to the bottle, the moisture content is below 15% and the grain is safe for storage

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