CRAFT

Climate resilient value chains for improved livelihoods

Republic of Kenya

Ministry of Agriculture, Livestock, Fisheries and Cooperatives

Climate Smart Sorghum Production Training Aid

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FOREWORD

The government of Kenya has outlined the importance of agriculture to the national economy through the Vision 2030, the Medium-Term Plan III Implementation framework, and most recently the President's Big Four priority agenda for 2017-2022, which emphasizes the importance of 100% food and nutrition security for all Kenyans. This is further supported by the development and implementation of the Food and Nutrition Policy (FNSP)2012; and the Agricultural Sector Growth and Transformation Strategy (ASTGS) 2019 – 2029. The policy documents are based on the fact that food and nutrition security requires a vibrant, commercial and modern agricultural sector that supports Kenya's economic development sustainably.

The National Adaptation Plan (2015-2030) and the Kenya Climate Smart Agriculture Strategy 2017-2026 also ensures that the food production systems in Kenya is developed sustainably.

Sorghum is an important cereal crop grown mainly for subsistence in Kenya that contributes to food and nutrition security of most food insecure household in the Arid and Semi - Arid Lands (ASAL). Sorghum is thus typically grown by smallscale farmers and is mainly used for home consumption. Sorghum is a vigorous, handy and drought tolerant crop that performs well in many agro-ecological zones; there are various varieties well adapted for dry land zones with low agricultural potential.

Besides being grown for consumption; sorghum is considered a good crop for silage to feed livestock because of high yields, high sugar content and the juiciness of the stalks thus grown as a fodder crop. Sorghum is also increasingly becoming an important cash crop especially with contract farming for brewing alcoholic beverages, baking, flour blending, starch, dextrose, syrup, wax and bioethanol production industries. This has considerably increased the demand for sorghum thus the need to increase sorghum production.

More investment in sorghum production will contribute towards achieving food and nutrition security, wealth and employment creation for women, men and youth. With rural to urban migration, population growth, changes in consumption patterns, tastes and preferences has changed immensely. A high majority of the population has become more conscious about their diets with preference to high nutrient dense foods such as sorghum and sorghum products.

The Training Aid addresses challenges facing the sorghum value chain; low levels of technology adoption; inadequate market information, high costs production, pests and diseases management and issues of climate change.

Climate smart agriculture technologies, innovations and practices addressed in the training aid will help the farmer and other stakeholders cope and become more resilient to climate change shocks. Climate smart agriculture practices such as management of organic matter, farm yard or green manure, crop specific fertilizers, mixed cropping, conservation agriculture, integrated pest management (IPM), mechanization, agroforestry, circular agriculture and grain bulking when adopted in the sorghum value chain will make sorghum production sustainable. Maximum yields of 3 to 4 t ha^{-1} at farm level can be achieved making sorghum value chain a more sustainable and competitive value chain.

The Climate Smart Sorghum Production Training Aid will serve as a guide and a reference in the preparation of training modules/guide/aids for facilitators, extension service providers, farmers, agri-entrepreneurs, processors and all other actors along the sorghum value chain.

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CONTENTS

FOREWORD III

OUTLINE OF THE SORGHUM TRAINING AID VIII

A GUIDE TO THE FACILITATOR 1
Adult Learning 1
The Role of the Facilitator 1

1 OVERVIEW OF SORGHUM VALUE CHAIN 3
Learning objectives 3
Introduction 3
Importance of sorghum 4
Challenges facing Sorghum Value Chain in Kenya 4
Learning Exercises 4
Learning Exercise 1.1: Situation analysis regarding sorghum production 4

2 CLIMATE CHANGE AND AGRICULTURE 5
Introduction 5
Learning objectives 5
Climate change, causes and impacts 5
Climate change projections scenarios for sorghum in Kenya 5
Climate change risks and opportunities on sorghum value chain 8
Key Climate Information decisions 8
Strengthen resilience to climate change and vulnerability 10
National Food Security and Development Goals 10
Sustainable increased productivity and income 10
Reduce agriculture contribution to climate 10
Climate Smart Agriculture (CSA) 10
Pillars of climate smart agriculture 10
Learning Exercises 11
Learning Exercise 2.1: Describing climate change, its impacts and its future scenarios 11
Learning Exercise 2.2: Describing climate smart agriculture and how to prepare for difficult seasons as adaptation strategies 11

3 SORGHUM PRODUCTION IN A CHANGING CLIMATE 13
Introduction 13
Learning objectives 13
What is sorghum? 14
Why is sorghum adapted to drier environments than other cereals? 14

Sorghum ecological requirements 15
Soil and water management in climate smart sorghum production 15
Soil management adaptations 15
Soil Water Management Adaptations 16
Terraces 16
Sorghum management practices under climate smart agriculture 19
Sorghum variety selection 20
Farm selection and land preparation 23
Planting and seed rates 24
Thinning 24
Crop nutrition 24
Integrated Weed Management (IWM) 27
Sorghum parasitic weed control (Striga Weed) 27
Integrated Pest Management (IPM) 28
Integrated Diseases Management (IDM) 30
Harvesting and Post-harvest Management of Sorghum Grain 32
Harvesting 32
Drying the panicles, threshing and drying grain 33
Threshing 33
Drying the grain before storage 34
Methods of testing grain moisture content 34
Packaging 35
Sorghum storage 35
Importance of sorghum in livestock production 36
Learning Exercises 37
Learning Exercise 3.1: Demonstration of water and soil management techniques 37
Learning Exercises 3.2: Sorghum Management Practices under Climate Smart Agriculture 38

4 ECONOMICS OF SORGHUM PRODUCTION AND MARKET ACCESS 39
Introduction 39
Learning Objectives 39
Record Keeping 39
Sorghum Enterprise Management 39
Sorghum Enterprise Analysis 40
Sorghum Profitability 40
Sorghum Marketing 44
Warehouse Receipting System (WRS): 44
Sorghum Processing and Utilization 45
Sorghum Market Outlets 47
Marketing Constraints and Opportunities 47
Learning Exercises 48
Learning Exercises 4.1: Economics of Sorghum Production and Market Access 48

5 GENDER AND SOCIAL INCLUSION IN THE SORGHUM VALUE CHAIN 49
Introduction 49
Learning objectives 49
Importance of gender and social inclusion in the sorghum value chain 49
Opportunities for women and youth in the sorghum value chain 50
Gender gaps and social and economic inequities that needs to be addressed 50
Impact of climate change on specific gender role 50
A Gender-responsive approach to Climate-Smart Agriculture 51
Gender concerns and stakeholder engagement in climate smart sorghum production 51
Learning Exercises 52
Learning Exercise 5.1 Gender and social inclusion in the sorghum value chain 52

ANNEXES 53
Annex 1: Definition of Terminologies 53
Annex 2: Strength, weaknesses, opportunities and threats to sorghum value chain. 55
Annex 3. Avoidable cost as related to the decisions' time span. 56

LIST OF FIGURES

Figure 1. Rain fed sorghum suitability map for Kenya 3
Figure 2. Seasonal temperature trends (1961-2005) for MAM and OND rainfall seasons 6
Figure 3. Projected seasonal mean changes in temperature for the March- April- May rains for 2030s and 2050s under the Representative Concentration Pathways (RCP) 4.5 and RCP 8.5, relative to the reference period (1961-2005). 6
Figure 4. . Projected seasonal mean changes in MAM rains for 2030s and 2050s under the RCP 4.5 and RCP 8.5. 7
Figure 5. Projected seasonal consecutive dry days for MAM rainy season for year 2030 and 2050. 7
Figure 6. Sorghum Cropping Calendar (Coast, Lower and Upper Eastern, and Northern Kenya) 9
Figure 7. Sorghum Cropping Calendar (Mid and High altitude areas of Kenya) 9
Figure 8. Scheme of Climate Smart Agriculture 10
Figure 9. A sorghum Plant 14
Figure 10. Sketch of fanya juu terrace 16

Figure 11. Sketch of a level bench terrace 17
Figure 12. Zai pits for conservation of rainwater for sorghum production 17
Figure 13. Tied ridges 18
Figure 14. A sub-soiler (left) A sub-soiler fixed on oxen plough (right) 23
Figure 15. A Chisel plough. 23
Figure 16: A ripper (Left) and A Ripper fixed on oxen plough 24
Figure 17. Striga hermonthica infested sorghum field 27
Figure 18: Mature sorghum crop ready for harvesting. 32
Figure 19. Drying sorghum panicles for threshing 33
Figure 20. Motorized sorghum thresher. 33
Figure 21. Grain Moisture meter. 34
Figure 22. Salt moisture testing method 35
Figure 23. Hermetic storage technology 35
Figure 24. Marketing map for sorghum in Kenya 47

LIST OF TABLES

Table 1. Sorghum ecological requirements 15
Table 2. Differences between conventional agriculture and climate smart agriculture 19
Table 3. Improved suitable sorghum varieties, sources and ecological suitability 20
Table 4. Nutrient requirements in sorghum and deficiency symptoms 25
Table 5. Major insect pests of sorghum in Kenya 28
Table 6. Major diseases of sorghum in Kenya 30
Table 7. Sorghum Gross Margin Calculation per Hectare 41
Table 8. Various possibilities for opportunity cost calculations 43
Table 9: Local recipes of value-added products of indigenous versions of popular products 45

OUTLINE OF THE SORGHUM TRAINING AID

This Training Aid document compliments learning from the “Climate Smart Sorghum Production Training and Resource Guide” published by the Ministry of Agriculture, Livestock, Fisheries and Co-operatives in February 2020 in partnership with SNV led - CRAFT (Climate Resilient Agribusiness for Tomorrow) Project, Agriculture and Food Authority (AFA), and Kenya Agricultural & Livestock Research Organization (KALRO) among other stakeholders. The learning approach places emphasis on hands-on practical training and imparting of skills needed for the specific trainees.

It has been produced to support extension officers in sorghum sub sector, in Kenya and providing climate change adaptation training to farmers in their jurisdiction. The training aid provides information on several key adaptation initiatives including climate change and agriculture, climate smart agriculture, sorghum production in changing climate, soil and water management techniques, economics of sorghum production, gender and social inclusion and policy.

It is recommended that extension officers support farmers in understanding how to implement climate change adaptation techniques through; plenary Introduction, brainstorming, small group discussions, practical (field) activities, plenary discussion / presentation, training materials, and training evaluation methods such as pre- and post-tests, participants’ feedback such as through recaps, and training evaluation checklists. These will help farmers to learn from practical experiences.

A GUIDE TO THE FACILITATOR

In facilitating training, it is essential to understand how adults learn, the role of the facilitator and participatory learning techniques that can be applied. Facilitators have an important task to deliver key messages which excites interest and enthusiasm among the target group to learn and make decisions that lead to positive actions. The Extension Worker/agent and the Lead Farmer are central to the Farmer learning process and their role as Trainers/ Facilitators is critical in enhancing access to technical support to smallholder farmers for increased production and productivity. This section of the Training Aids provides a guide for these facilitators to conduct trainings that lead to positive change in farming practices and improve farmers' livelihoods.

Adult Learning

The target audience (farmers) in trainings are adults (men and women) and youth with experience, knowledge and skills. Each adult and youth brings to the learning experience, preconceived thoughts and feelings that will be influenced by motivation, the amount of previous experience, the level of engagement in the learning process, and how the learning is applied. Learning something new is not just achieved in an instant. Referring back and making use of the knowledge and skill is the basis of the adult learning process. The new learning will have to be internalized by making it relevant to one self. Only after this can the learning be applied when confronted with a similar situation. Remember the 20.40.80 principle of adult learning: Adults remember 20% of what they hear, 40% of what they hear and see, and 80% of what they hear, see, and do. It is advisable to use as much creativeness as possible.

The Role of the Facilitator

A facilitator is not an instructor and creates conditions for farmers (men, women, and youth) to learn by arranging opportunities for them to observe and interpret differences, to carry out simple tests and exercises, and through discussions. The facilitator encourages farmers to adopt an active role in the learning process through making use of participatory approaches which engage the participants as much as possible.

The main features of the attitude and role of a facilitator are:

- To listen to farmers (men, women, and youth) and respect their knowledge, experiences and perceptions,
- To give farmers the confidence to share their knowledge and experiences,
- To create suitable conditions and activities from which farmers can learn,
- To be responsive to farmers' needs and flexible in organizing the training,
- To increase farmers' knowledge, skills and problem-solving ability

Facilitation and Learning Techniques

Facilitation is a process which is driven by a Facilitator who manages a learning environment (conducive atmosphere); through exchange of ideas; which involves examination of an issue of common interest; which should lead to change or development.

Facilitation may include the following:

Plenary Introduction

A plenary introduction is normally the first activity to start a new training session. Its' main objective is to introduce the subject and to familiarize the participants to some basic concepts by referring to familiar and related topics.

Brainstorming

The main objective of a brainstorming session is to introduce new topics and to discover new ideas and responses very quickly by having the group describing the topic or idea by listing an exhaustive list of related characteristics and condition

Small group discussions

Instead of discussing one subject with the whole group, more subjects can be discussed by using small groups. The main objective is to give every participant a way to actively participate in the discussion.

Practical (field) activities

To give participants the opportunity to go to the field and experience a new technology by watching and doing. The objective is to learn through practicing new practice.

Plenary discussion / presentation

The plenary discussion can follow directly after small group discussions but does not need to do so. The objective of the plenary discussion/presentation is to synthesize the ideas of the participants about a (new) topic or information that is discussed within the group. A training session using the method of plenary discussion may split up in small groups.

Training Materials and Methodology

Such materials as markers, flip charts, masking tape, posters, training manual and a session guide for guidance during the training are needed for each session of the training. Fact sheets are particularly important especially if they are written in local language or dialect. Be prepared for illiteracy. And adapt training accordingly. The use of visual training aids such as pictures is also encouraged. The training methodology will be carried out through group discussion, brainstorming and plenary presentation, demonstrations, charts, visual aids /posters, activities, and case studies and practical exercises.

Training Evaluation Method

It is important to evaluate the training so that the facilitator is informed about the impact of the training in terms of knowledge retention. Different evaluation methods can be used e.g.: Pre- and post-tests, Participants' feedback such as through recaps, Final training evaluation checklist.

1 OVERVIEW OF SORGHUM VALUE CHAIN

Learning objectives

By the end of the chapter, the following outcomes should be achieved:

- To discuss the global sorghum production outlook.
- To state the Importance of sorghum value chain.
- To describe challenges facing Sorghum Value Chain in Kenya.
- To describe the status of production and the value chain constraints.

Introduction

Current sorghum production: Kenya produced about 206, 234 MT of grain sorghum under an area of 229,883 hectares in 2018. The suitable areas for sorghum production in Kenya are shown in Figure 1.

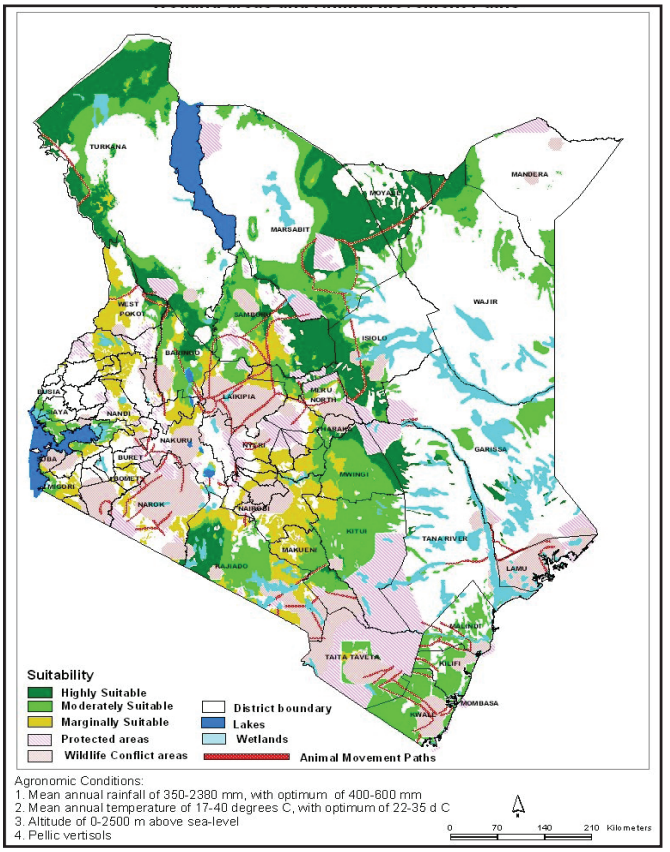


Figure 1. Rain fed sorghum suitability map for Kenya

Source: KALRO Soil Survey, 2020

Importance of sorghum

Sorghum is a staple food, nutrition and income security crop for many people. It is utilized as food, animal feed and industrial raw material. Sorghum commercialization generates revenue of approximately KShs. 4 billion resulting from brewing industry, sale of seed, and engages over 250,000 farmers across the country.

Challenges facing Sorghum Value Chain in Kenya

Sorghum is a climate-resilient crop but its production faces several constraints such as; pests and diseases, inability of farmers to afford inputs, limited climate-smart approaches to the sorghum production, institutional bottlenecks such as inadequate research capacity and facilities, policy impediments, poor marketing, marketing information systems and poor physical infrastructure.

Learning Exercises

Learning Exercise 1.1: Situation analysis regarding sorghum production

Objective:

To capture the current situation of sorghum productions

Materials required:

Flip charts, marker pens and two posters – SWOT analysis of sorghum (Annexed)

Method:

1. Break the participants into groups
2. Provide each group with marker pen and flip charts
3. Assign each group to discuss the following issues using the posters in a question-posing mode, allowing participants to discuss and discover what they represent. The agreed responses should be captured in flip chart for plenary presentation: Ask participants
    - Discus the Importance of sorghum
    - State the challenges facing Sorghum Value Chain in Kenya
    - To indicate the highest, average and lowest sorghum yields in their area.
    - To analyse the causes of low sorghum yields and production,
    - To describe what can be done to improve the yields and production.
    - To list/map out the sorghum growing areas in Kenya/their county
    - To explain the strength, weaknesses, opportunities and threats to sorghum value chain.
4. Afterwards, each group will present to the plenary for discussion and establishment of the situation on sorghum production in their region
5. Summarize the discussion notes as situation analysis of sorghum production in the region

2 CLIMATE CHANGE AND AGRICULTURE

Introduction

Kenya's agricultural production systems is highly affected due to the low adaptive capacity and the high exposure to climate related risks. The major agricultural activities are prone to risks and uncertainties of nature which is affected by climate change either in intensity, scope or frequency. Climate change is expected to modify risks, vulnerabilities and the conditions that shape the resilience of agriculture systems as well as introducing new uncertainties.

Learning objectives

The overall objective of this topic is to inform farmers on the importance of climate change and sorghum production.

By the end of this session the participants will be able to:

- Define what is climate change and its cause
- Explain how various climate variables (e.g. temperature , rainfall etc.) affects sorghum production
- Discuss the different climate projection scenarios and impacts on sorghum
- Describe the risks and opportunities resulting from climate change scenarios on sorghum
- Describe different types of climate information for sorghum and its importance in making farming decisions
- State the importance of the sorghum crop calendar in Kenya
- Define Climate Smart Agriculture (CSA).
- Explain the pillars of climate smart agriculture
- Describe the effect of Climate change on resilient crop production
- Describe the CSA practices and technologies and their potential to address the challenges in sorghum production

Climate change, causes and impacts

Climate change is largely attributed indirectly or directly to human activities that alter the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable periods.

Climate change projections scenarios for sorghum in Kenya

Recent climate projections generated by the Climate Resilient Agri-business for Tomorrow (CRAFT) project in some of the sorghum growing regions in Kenya (CRAFT, 2020) shows that:

- There will be a definite increase in temperature both in March-April-May (MAM) and October-November-December (OND) seasons (Figure 2 and Figure 3).

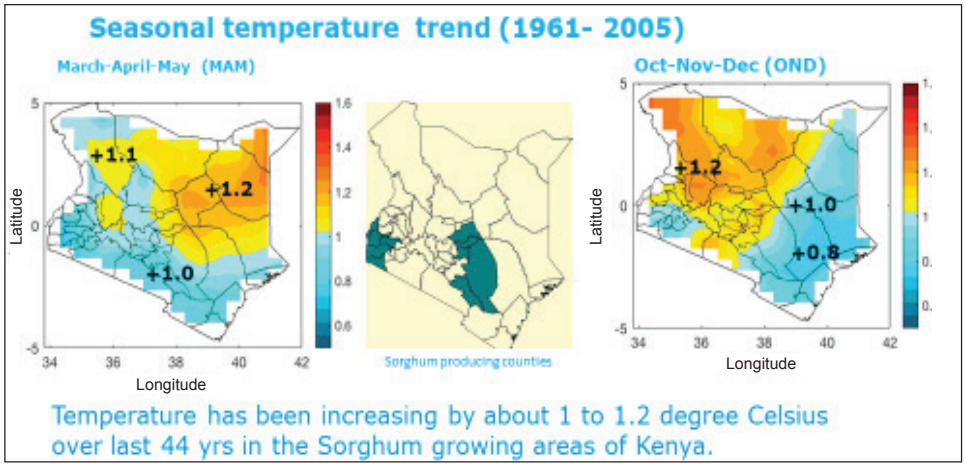


Figure 2. Seasonal temperature trends (1961-2005) for MAM and OND rainfall seasons
(Source: CRAFT project, 2020)

- During the March and April rainy season, the model projection for both the 2030s and 2050's shows a temperature rise in all parts of Kenya particularly in the western half of the country.

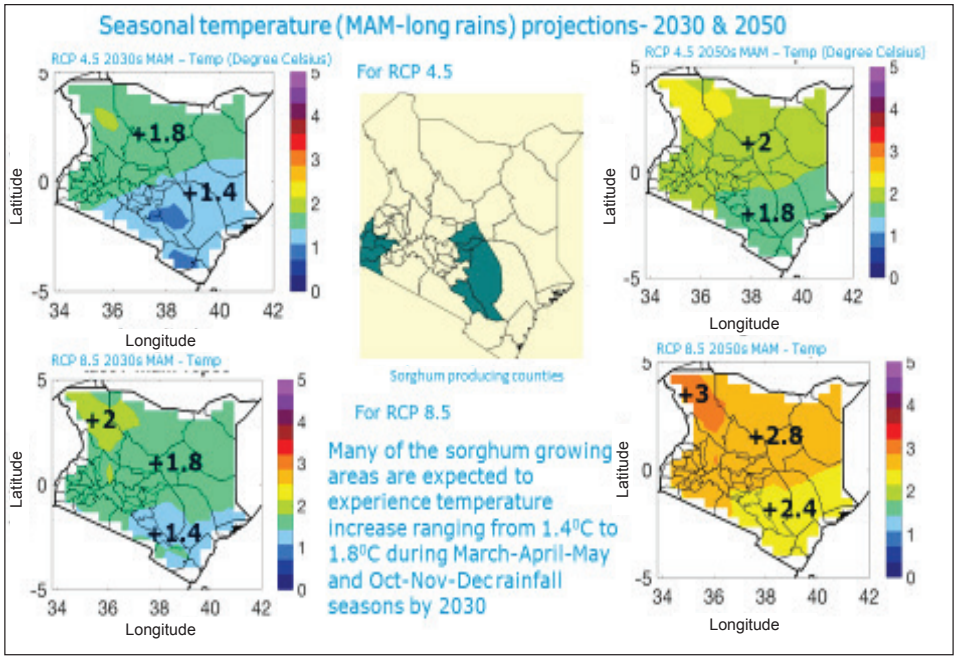


Figure 3. Projected seasonal mean changes in temperature for the March- April- May rains for 2030s (Left) and 2050s (Right) under the Representative Concentration Pathways (RCP) 4.5 and RCP 8.5, relative to the reference period (1961-2005).
(Source: CRAFT project, 2020)

- While rainfall is expected to increase in most parts of Kenya during the Novemeber- December season, the March- April season is expected to suffer from a long dry spell and a decrease in seasonal rainfall particularly in the north western parts of the country (Figure 4).

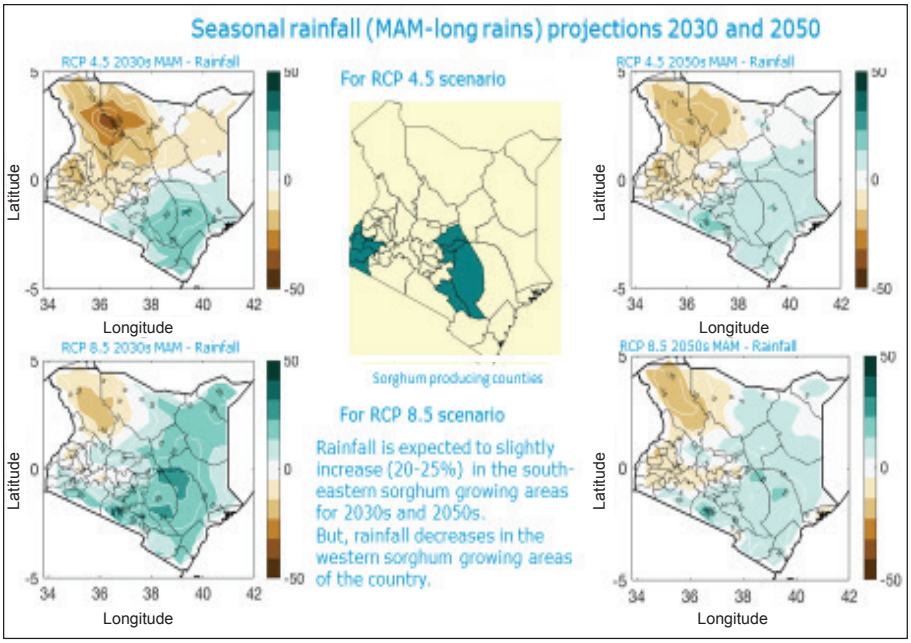


Figure 4. . Projected seasonal mean changes in MAM rains for 2030s (Left) and 2050s (Right) under the RCP 4.5 and RCP 8.5.

(Source: CRAFT project, 2020)

- A decrease in the seasonal rainfall and wet-spells accompanied by an increase in the number of consecutive dry days (CDD) in the north-western part of Kenya could lead to shortage of water and drought in the region (Figure 5).

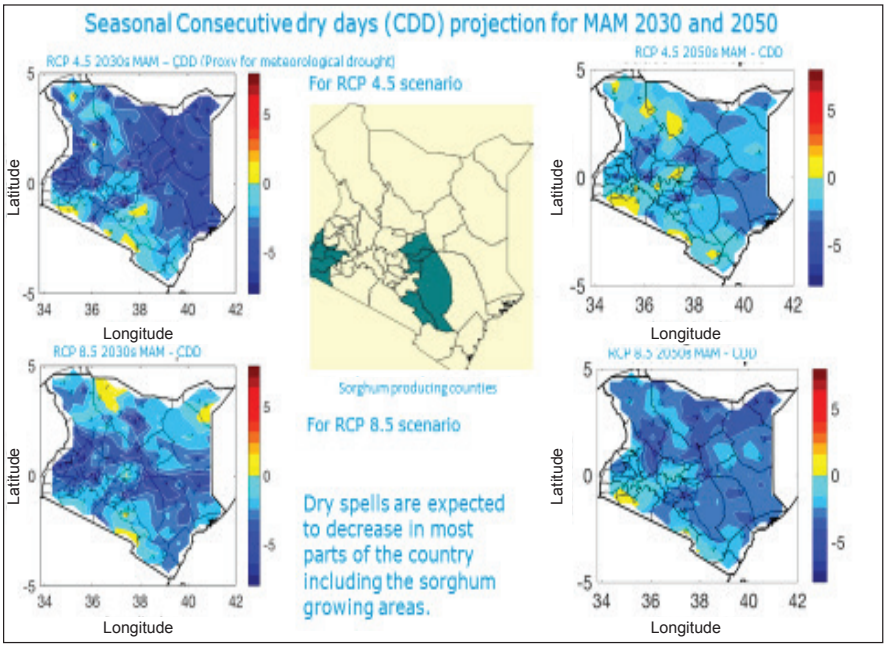


Figure 5. Projected seasonal consecutive dry days for MAM rainy season for year 2030 and 2050.

(Source: CRAFT project, 2020)

Even though many of the sorghum growing areas will experience increase in rainfall, the benefits to sorghum growing will not be much due to expected increase in evapotranspiration due to the projected increase in temperature.

Climate change risks and opportunities on sorghum value chain

For sorghum value chain actors to be able to adapt and cope better with expected risks and exploit opportunities presented by the projected climate changes there will be a need to: -

- Promote use of climate smart agronomic technologies and practices such as use of quality seeds of well-adapted varieties, biodiversity management, Integrated Pest Management, Improved water use and management, sustainable soil and land management for increased crop productivity and sustainable mechanization
- Promote use of climate smart inputs and services e.g. soil testing, appropriate and high yielding certified seeds, crop specific fertilizers etc.
- Incorporate climate and agro-weather information into agricultural extension services
- Mainstream climate risk considerations in business planning and decision-making
- Enhance climate based insurance
- Crop and enterprise diversification

Key Climate Information decisions

In sorghum production, climate information for decision-making affects part or the whole season in terms of resource use and distribution, the cropland area to be used, land preparation methods, the choice of variety, crop combinations, input use rates and amounts (seed, fertilizer, and pesticides), time of pesticide application, irrigation plans, management of the weeds, pests and diseases, harvesting, postharvest processing (threshing and winnowing), packaging, storage, and marketing of the products.

Sorghum crop calendar in Kenya

Sorghum calendars provides information to allow timely planning of all farm activities such as and preparation, planting, crop establishment and management, harvesting and storage, and the main agricultural practices of the crop in specific growing areas and seasons. The calendars supports extension agents and farmers in planning and making decisions in the different times of the year in the different agro-ecologies (Figure 6 and Figure 7).

Sorghum Cropping Calender (Coast, Lower and Upper Eastern, and Northern Kenya)												
	Counties: Lamu, Kilifi, Mombasa, Taita Taveta, Makueni, Kitui, Machakos, Tharaka Nithi, Meru, Embu, Isiolo, Wajir, Mandera and Marsabit											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall seasons												
Activities												
Planting/sowing												
Flowering (45 -70 days after germination)												
Grain filling (Milk stage: 10 days, Dough stage: 10 days, Hard Dough-14 days)												
Harvesting (Early varieties: 90 days, Late varieties: 135 day)												

Figure 6. Sorghum Cropping Calendar (Coast, Lower and Upper Eastern, and Northern Kenya)

Source: Modified from FAO Crop calendar, 2018

Sorghum Cropping Calender (Mid and High altitude areas of Kenya)												
	Counties: Laikipia, Kajiado, Narok, West Pokot, Siaya, Kisumu, Homabay, Migori, Bungoma Vihiga, Kakamega, Busia, Baringo)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall seasons												
Activities												
Planting/sowing (Mid Mar to Mid Apr and Mid Oct to Mid Nov)												
Flowering (45 -70 days after germination)												
Grain filling (Milk stage: 10 days, Dough stage: 10 days, Hard Dough-14 days)												
Harvesting (Early varieties: 90 days, Late varieties: 135 day)												

Figure 7. Sorghum Cropping Calendar (Mid and High altitude areas of Kenya)

Source: Modified from FAO Crop calendar, 2018

Climate Smart Agriculture (CSA)

Climate Smart Agriculture is the agriculture that sustainably increases productivity and income, enhances resilience (adaptation), reduces/removes GHGs (mitigation) where possible, and enhances achievement of national food and nutrition security and development goals. This can be achieved by adoption of appropriate practices, having enabling policies, having functional institutions, and adequate financial support (Figure 8)

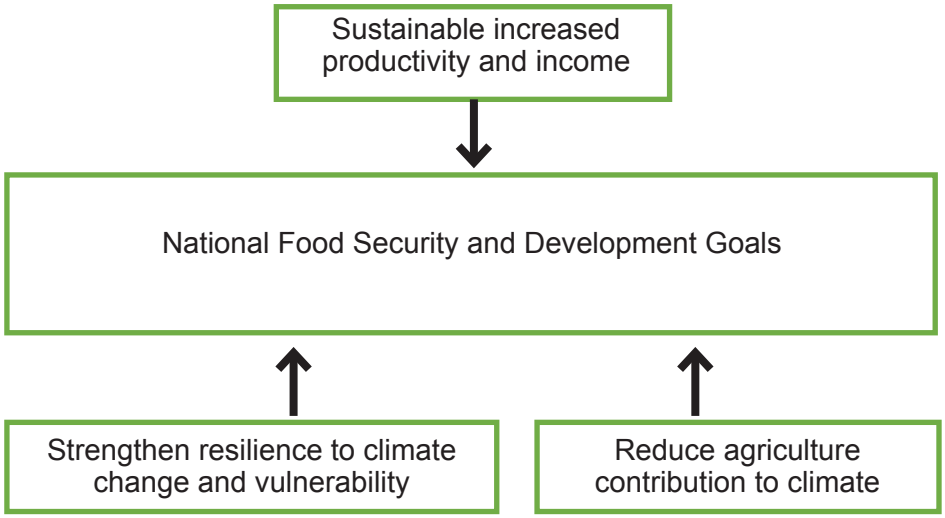


Figure 8. Scheme of Climate Smart Agriculture
Source: FAO 2013a, Climate Smart-Agriculture; Sourcebook. Rome, Italy: Food and Agriculture Organization of the United Nations

Pillars of climate smart agriculture

There are three pillars of climate smart agriculture, these include:

a) **Productivity:** climate smart agriculture increases agricultural productivity and incomes from crops, livestock and fish, without having a negative impact on the environment. This will raise Food and Nutritional security.

b) **Adaptation:** climate smart agriculture reduces the exposure of farmers to short-term risks, while also strengthening their resilience by building their capacity to adapt and prosper in the face of shocks and longer-term stresses.

c) **Mitigation:** climate smart agriculture helps to reduce and/or remove greenhouse gas (GHG) emissions.

Learning Exercises

Learning Exercise 2.1: Describing climate change, its impacts and its future scenarios

Objective

To describe the importance of climate change and sorghum production.

Method

1. Organize the participants into groups.
2. Provide each group with marker pen and flip charts
3. Assign each group to discuss the following issues using the flyer in a question-posing mode, allowing participants to discuss and discover what they represent. The agreed responses should be captured in flip chart for plenary presentation: Ask participants
    - To describe what climate change is from their experience
    - To state the impacts of climate change on sorghum production
    - To identify climate change risks and opportunities on sorghum
    - To list key decision points in sorghum production and link it to the climate variable (temperature, rainfall, drought etc.) that informs that decision
4. Afterwards, each group will present to the plenary for discussion and establishment of the impacts of climate change, risks associated with and opportunities for sorghum production, identified technologies and needed climatic information
5. Summarize the discussion notes on climate change, its impacts and future effects

Learning Exercise 2.2: Describing climate smart agriculture and how to prepare for difficult seasons as adaptation strategies

Objectives

To understand climate smart agriculture and its importance in increasing agricultural productivity, adapting and building resilience to climate change; and reducing and/or removing greenhouse gas emissions.

Method

1. Break the participants into groups.
2. Provide each group with marker pen and flip charts
3. Assign each group to discuss the following issues using the poster in a question-posing mode, allowing participants to discuss and discover what they represent. The agreed responses should be captured in flip chart for plenary presentation: Ask participants;
    - To describe what Climate Smart Agriculture is from their experiences
    - To state and describe the three pillars/principles of Climate Smart Agriculture

4. Afterwards, each group will present to the plenary for discussion their findings on the assigned exercise.

5.Summarize the discussion notes on climate smart agriculture.

Review Questions

1. What is climate change and how does it affect sorghum production?
2. What are the causes of climate change?
3. Describe the risks and opportunities resulting from climate change for sorghum
   How are the climate projections relevant to sorghum producing farmers?
4. Describe different types of climate information, which climate information should sorghum-producing farmers require and its importance in making farming decisions
5. What is climate smart agriculture and why is it relevant to sorghum producing farmers?
6. What climate smart agriculture practices are useful to sorghum farmers and their potential to address the limitations in sorghum production?

3 SORGHUM PRODUCTION IN A CHANGING CLIMATE

Introduction

Due to the changing climate towards drier and hotter conditions, farmers should adopt climate smart agricultural practices while growing sorghum. Various sorghum varieties grow in different ecological areas and have different end uses. Diseases and pests are also affecting the crop in more severe ways with new pests and diseases emerging. Harvesting and post-harvest loses greatly reduce the yield from sorghum crop. There is therefore need to train farmers on the sorghum plant aspect, proper variety selection, seed acquisition, mechanized cultivation practices, pest and disease control, harvesting and storage to mitigate yield reduction. Sorghum farmers need also to be able to make wise decisions on the type of sorghum enterprise to undertake in order to benefit from the crop.

Learning objectives

The overall objective of this chapter is to enlighten participants on climate smart agricultural practices in sorghum production to reduce the negative effects of the changing climate.

By the end of the chapter participants should be able to:

- Describe the physiological characteristics of sorghum
- Describe the ecological requirements and areas suitable for sorghum cultivation in Kenya
- Describe soil and water management adaptations applicable to climate smart sorghum production
- Differentiate the sorghum varieties and their attributes
- Describe climate smart options for land preparation and planting and their advantages.
- Explain the various climate smart field management methods such as crop nutrition, weed, disease and pest control for sorghum production
- Describe climate smart harvesting and post harvesting method to reduce sorghum yield losses
- To understand the importance of sorghum in livestock production

What is sorghum?

Sorghum is a plant which grows to 1-3 meters tall, has maize like leaves and a terminal grain panicle (Figure 9). The panicle may be tight or open, round or droopy, short or long. The grain colour ranges from red, orange, bronze, tan, white or black.

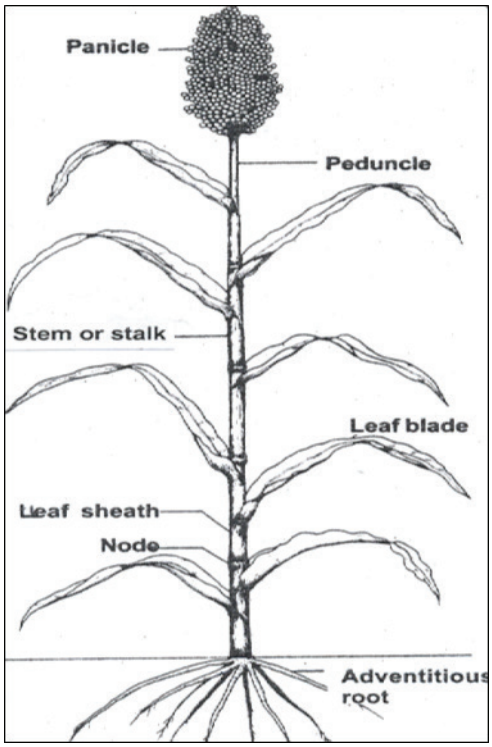


Figure 9. A sorghum Plant.
Source: Murdy, D.S., Tabo, R & Ajayi, O. 1994. Sorghum Hybrid Seed Production and Management

Why is sorghum adapted to drier environments than other cereals?

This is mainly due to a number of physiological and morphological characteristics such as;

- Extensive root system
- Reduced leaf area
- Waxy bloom
- Leaf rolling
- Stay green
- Ability to compete with most weeds.

Sorghum ecological requirements

Table 1. Sorghum ecological requirements

Parameter	Sorghum requirement
Soils (requirements	• Deep, fertile, well-drained loamy, clay, clay loam, or sandy loam soils with a pH of between 5.5 and 8.5.
Altitude	• 0 – 2500 masl • Agro Ecological Zones (AEZ): LM3 (low-midland, Level, 3), LM4 (Lower Midland, Level 4) and LM5 (Lower Midland, level 5)
Rainfall	• 450- 900 mm annually, it can produce under 250-300mm seasonal rainfall
Temperature	• 7 to 10°C for seed germination, 20-35°C for optimum growth

Soil and water management in climate smart sorghum production

Effective soil and water management techniques can improve soil fertility and increase sorghum production in a sustainable manner in a changing climate.

Soil management adaptations

Conservation agriculture

Grow sorghum in an area of the land protected by at least 30% soil cover, and with minimum cultivation. Protect soil from erosion by subjecting its structure to least disturbance.

Use cover crops

Use of cover crops is an important principle of conservation agriculture. Plant cover crops to prevent soil erosion, improve soil properties, biodiversity in the soil and soil fertility.

The main cover crops for sorghum are legumes: Common bean, Soybean, Crotalaria, cowpea, Desmodium, Lablab, Jackbean, Siratro, Velvet bean or Mucuna, Alfalfa, Pigeon peas, green grams, and groundnuts.

Mulching

Practice mulching to minimize the effects of the fluctuating weather patterns that increasingly expose soils to increasing temperatures and longer drought periods as a climate change adaptation technique. Mulching in sorghum fields should be done before or at the beginning of the season. Sorghum seeds can also be planted between mulching materials, or mulching materials be applied in between sorghum rows of an established sorghum crop.

Green Manures

Grow green manure to add organic matter to the soil.

Compost Application

Compost is the controlled decomposition of organic matter (mainly animal manure and plants materials) which can be incorporated easily into the soil.

Agroforestry

Grow crops together with trees at the same time, in rotation, or in separate plot and materials from one are utilized to benefit the other by providing vegetative cover all year.

Soil Water Management Adaptations

Terraces

Build either bench or *fanya juu* terraces to control runoff on slopes. In *Fanya juu* terraces heap soils up the slope to create an embankment, which forms a barrier for running water hence leaving the trench for collecting running water (Figure 10).

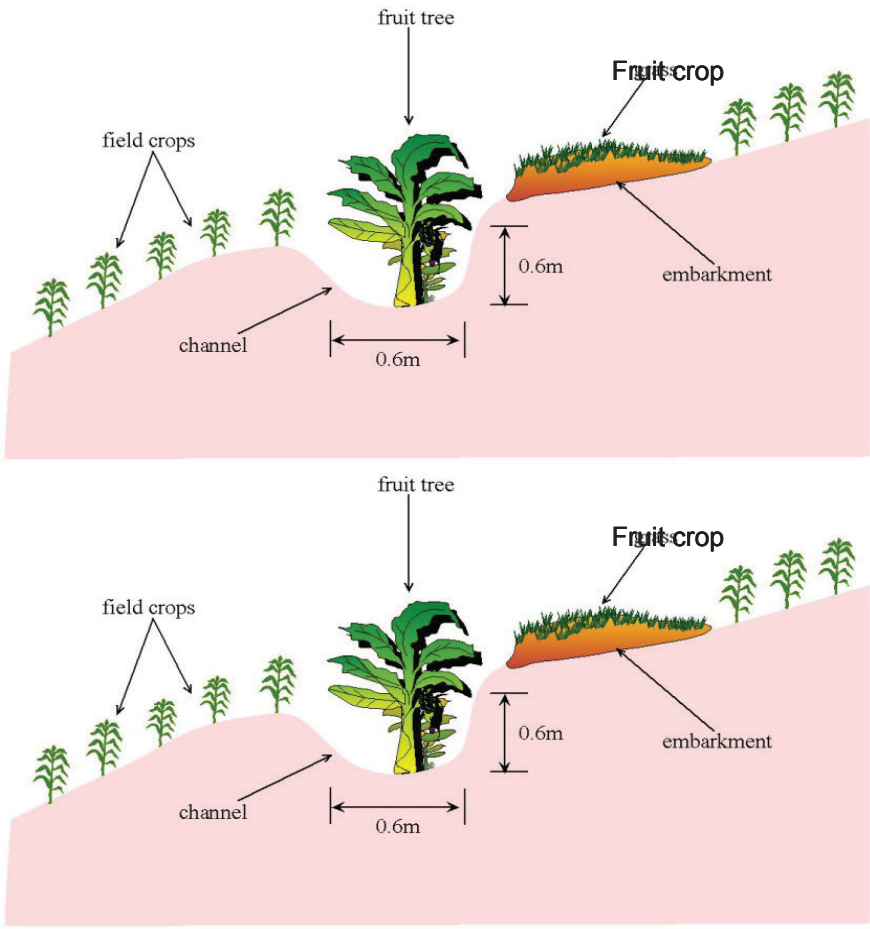


Figure 10. Sketch of *fanya juu* terrace

Source: Mati, 2012 (Soil and Water Manual 5: Soil and Water Conservation Structures for Smallholder Agriculture)

Unlike the *fanya juu* terraces, **bench terraces** do not have water retention canal on the lower side of the terrace and are closely spaced compared to the *fanya juu* terraces. In bench terraces, convert slope into series of level steps and ledges for water conservation. Grow sorghum on the flat area and close the terrace growing grass at the bottom of the terrace (Figure 11).

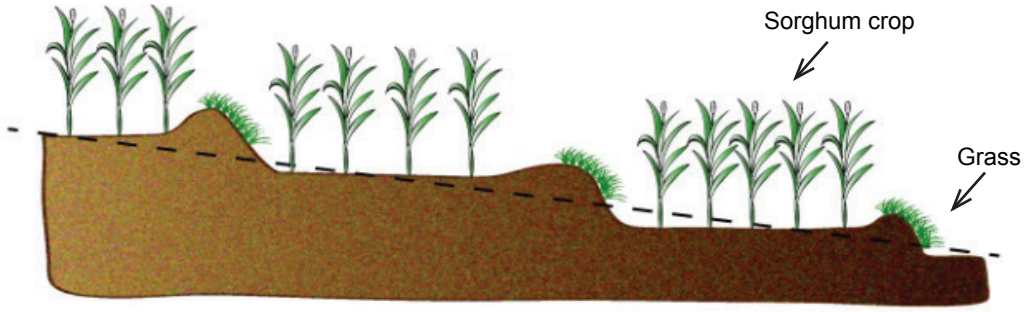


Figure 11. Sketch of a level bench terrace
Source: Mati, 2012 (Soil and Water Manual 5: Soil and Water Conservation Structures for Smallholder Agriculture)

Zai Pits

Zai pits are shallow wide pits dug to collect and retain runoff to allow infiltration into the soil (Figure 12).

Figure 12. Zai pits for conservation of rainwater for sorghum production
Source: IIRR and ACT, 2005. Conservation Agriculture: A manual for farmers and extension workers in Africa

Tied ridges

Create this by making a series of cross-ridges that block or interrupt the furrows thus preventing flow of water along the furrows, hence allowing trapped water in the rectangular basins to infiltrate into the soil. Conserve soil moisture in drought-prone areas increasing sorghum yield, prevent water erosion, and it is simple to use and maintain (Figure 13).

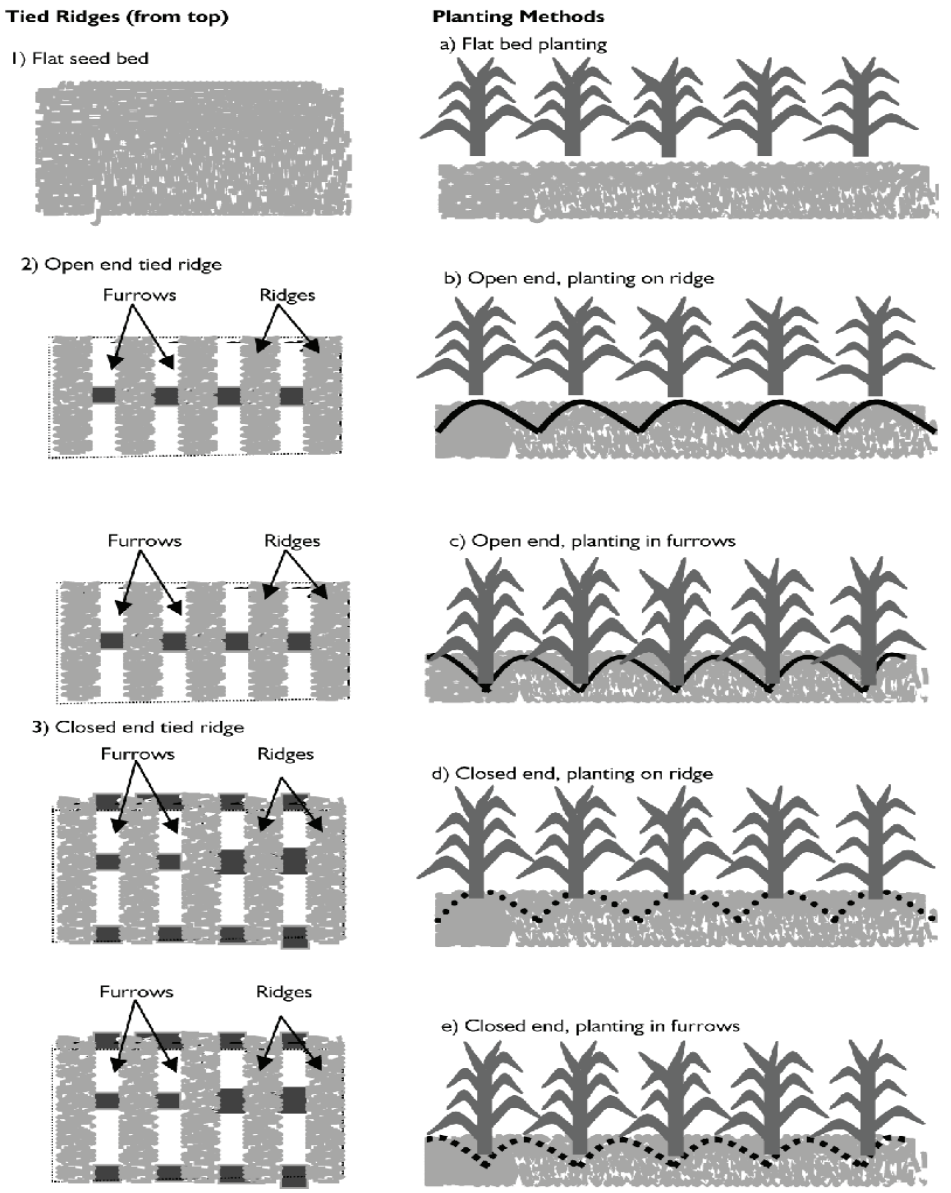


Figure 13. Tied ridges

Source: Gebrekidan, 2003

Sorghum management practices under climate smart agriculture

A number of benefits are associated with growing grain sorghum, including its versatility and strong market demand. Sorghum is well suited for dry conditions, areas with uneven rainfall distribution that may adversely affect the growing season of other crops, and high year to year variation in rainfall and water supplies. Other advantages to growing sorghum include its ability to be grown on marginal soils and its shorter growing season (Table 2).

Table 2. Differences between conventional agriculture and climate smart agriculture

Features	Conventional Agriculture	Climate-Smart Agriculture
Use of technology	Energy sources mainly from human, animal and fossil fuel	Energy efficient machinery for agricultural power for irrigation or tillage
Inputs in agriculture	High use of fertilizer, pesticides and herbicides Inefficient application	Use of ecologically friendly inputs such as fertilizer, pesticides and herbicides Efficient application
Area of agricultural land	Deforestation and conversion of grasslands for agricultural land area	Intensive use of existing agricultural land area
Natural resources	Depletion of natural resources used in agricultural production systems.	Conservation, restoration, and sustainable management of natural resources in agricultural production systems
Production and marketing	Specialization in production and marketing systems	Diversification in production, input and output marketing systems

For a farmer to be successful in realizing maximum yields per acreage, it is very important to make use of the latest climate smart production practices.

Sorghum seed acquisition

Use certified seed of improved varieties. **Sources of sorghum seed:** KALRO Seed Unit (KSU), Kenya Seed Company LTD, Dry Land Seed Company, East African Seed Company and AgriSeed Co Ltd among others

Sorghum variety selection

Plant improved sorghum varieties which are suited to the area of cultivation and for the intended end use (Table 3).

Table 3. Improved suitable sorghum varieties, sources and ecological suitability

Variety	Source & Description	Suitability	Attributes
 **Gadam**	• Released in 1994 by KARI (KALRO) • Grain yield: 2-2.5 t ha^{-1} • Maturity: 2.5 -3 months (early) • Open pollinated (OPV) • Chalky white grains with a brown testa • Plants are short to medium in height.	• Lower Eastern (Makueni, Kitui and Machakos) • Upper eastern (Embu, Tharaka, Meru) • Western (Siaya, Homabay, Busia, Bungoma, Kakamega). • Taita Taveta	• High drought and heat tolerance • High malting and brewing quality • High demand in brewing industry • Suitable for human and animal consumption.
 **KARI Mtama-1**	• Released in 2000 by KARI (KALRO) • Grain yield: 3.4 t ha^{-1} • Maturity: 3.5-4 months • Open pollinated (OPV) • Cream white grains • Plants are medium to tall in height.	• Lower Eastern (Makueni, Kitui and Machakos) • Upper eastern (Embu, Tharaka, Meru)	• High malting and brewing quality (demand in brewing industry due to white grain) • Sweet, palatable and highly digestible low tannins grain (Milling and feed industry)
 **Sila**	• Released in 2006 by AgriSeed Co Ltd • Grain yield: 2-4 t h^{-1}, Fodder yield: 4 t/ha. • Maturity: 3 – 3.5months. • Open pollinated (OPV) • White grains • Plants are medium in height.	• Upper eastern (Embu, Tharaka, Meru) • some parts of lower eastern Kenya where temperatures are not very harsh • western Kenya	• Dual purpose for the production of grain and fodder • High malting quality (high demand for malting) • Good for human consumption and animal fodder.

Variety	Source & Description	Suitability	Attributes
 **Seredo**	• Released in 1970s by KARI (KALRO). • Maturity: 3 months. • Grain yield: 2.7 t ha^{-1} • Open pollinated (OPV) • Brown grains • Plants are medium in height.	• Dry humid areas • Dry low lands (western and eastern Kenya)	• Relatively bird tolerant due to tannin content in grain • Good milling capacity Mainly used for home consumption • Blending with cassava and maize flour in milling industry. • Grain fed directly to chicken.
 **Serena**	• Released in 1970s by KARI (KALRO). • Maturity: 3 months. • Grain yield: 2.7 t ha^{-1} • Open pollinated (OPV) • Brown grains • Plants are medium in height.	• Most of the sorghum growing counties.	• Relatively bird tolerant due to tannin content in grain • Good milling capacity Mainly used for home consumption • Blending with cassava and maize flour in milling industry. • Grain fed directly to chicken.
 **Kamani** (KM 32-1)	• Released in 2019 by KALRO Katumani • Grain yield: 2.7-3.8 t ha^{-1} • Maturity: 3 months • Open pollinated (OPV) • Large White grains • Plants are short and uniform	• Dry low lands • Dry cold zones • Some humid zones. • Lower eastern • Upper eastern • Naivasha, Laikipia, Marigat, Busia and Homabay.	• It has a stay green stress tolerance. • Malting (brewing) quality • Tolerant to covered kernel smut disease • Good for human consumption.
 **E97**	• Released in 2017 by Rongo University. • Grain yield: 4-4.5 t ha^{-1} • Maturity: 3 months • Open pollinated (OPV) • Large White grains	• Western Kenya (Kakamega county), • Low land areas of Lake Victoria basin (Homabay, Migori, Siaya, Kisumu, Busia) • Eastern Kenya, (Machakos, Kitui, Embu).	Tolerant to head smut. Moderately tolerant to striga weed

Variety	Source & Description	Suitability	Attributes
BJ28 	• Released in 1978 by KARI Lanet • For grain (food) and forage • Grain yield: 2.5-3 t ha^{-1} • Open pollinated (OPV) • Plants are tall	• Dry high lands • 750-2300 masl	• Silage: dry matter digestibility: 52 - 65%, Crude protein: 8-12% Neutral detergent fiber: 60-75%, acid detergent fiber: 34 - 40%. • Ensiled grain: 90%. Digestibility
Ikinyaluka: 	• Released in 1997 by KARI Kakamega • For grain (food) and fodder production • Grain yield: 8 t ha^{-1} • Open pollinated (OPV) • Plants are tall	• Dry high lands 750-2300 masl.	• Silage: dry matter digestibility: 52 - 65%, Crude protein: 8-12% Neutral detergent fiber: 60-75%, acid detergent fiber: 34 - 40%. • Ensiled grain: 90%. Digestibility
E 1291 	• Released in 2000 by KARI Lanet, • Dual Purpose for grain and forage • Grain yield: 2.7 t ha^{-1} • forage : 2.7t ha^{-1} • Open pollinated (OPV) • Red grains • Plants are tall	• It is well suited to 750-2300 masl in dry high lands and high potential areas.	• Good for sorghum beverage. • Silage: dry matter digestibility: 52 - 65%, Crude protein: 8-12% Neutral detergent fiber: 60-75%, acid detergent fiber: 34 - 40%. • Ensiled grain: 90%. Digestibility
E6518 	• Released in 2000 by KARI Lanet, • Dual Purpose for grain and forage • Grain yield: 3.4 t ha^{-1} • forage : 7.2 t ha^{-1} • Open pollinated (OPV) • Red grains • Plants are tall	• It is well suited to 750-2300 masl in dry high lands and high potential areas.	• The variety is well adapted to cold dry zones. • Silage: dry matter digestibility: 52 - 65%, Crude protein: 8-12% Neutral detergent fiber: 60-75%, acid detergent fiber: 34 - 40%. • Ensiled grain: 90%. Digestibility

Farm selection and land preparation

Farm selection: Select a farm with good soil fertility and water conservation structures. Avoid isolated fields near birds roosting sites.

Land Preparation: Prepare land before the onset of rains and after harvesting so as to eliminate and control undesirable crop volunteers and weeds.

i). **Zero tillage.** This involves using herbicides on weeds and unwanted crops so as to reduce soil erosion, formation of hard pan, conserve soil moisture and maintain good soil structure

ii). **Minimum tillage implements.** This is carried out where the land has developed hardpans limiting crop roots from penetrating deep into the soil and stopping water infiltration.

Minimum tillage implements for breaking hardpans include:

- **Sub-soiler.**This is attached to oxen drawn plough to break the hardpan made by oxen moldboard plough (Figure 14) and chisel ploughs.

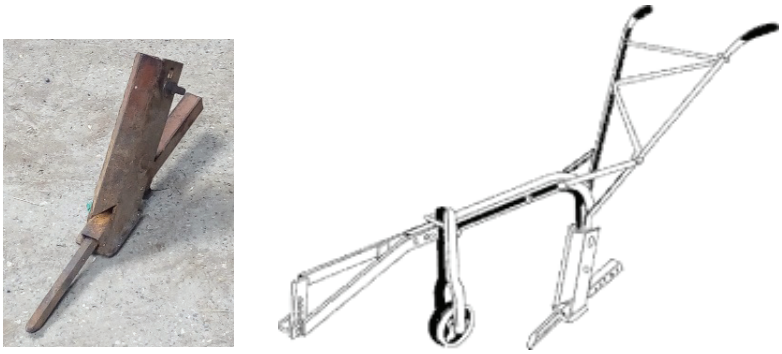


Figure 14. A sub-soiler (left) A sub-soiler fixed on oxen plough (right)

- **Chisel plough.** This is attached to tractor drawn plough to break hardpans is created by tractor moldboard plough (Figure 15).

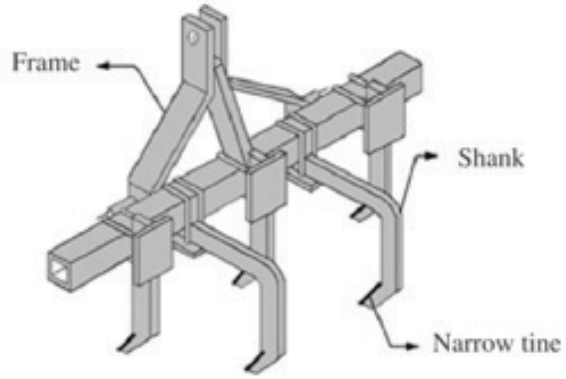


Figure 15. A Chisel plough.
Source: Abo Al-kheer, 2010

Planting and seed rates

Planting date: Seek and use climate information to guide the planting date. Plant timely to use the planting window effectively to maximize yield and to reduce losses.

Spacing and seed rate: Plant in rows as per recommended spacing on seed packets. Generally, Seed rate of 810kg ha^{-1} is recommended to achieve a plant population of 130000-150000 plants ha^{-1}. The general spacing is 75 cm inter-rows and 15-20 cm inter-plants in a row.

Mechanized Planting: Use a calibrated **sorghum planter** for correct seedling spacing and seed rate (reduces thinning labour)

Hand planting: Use a **ripper** for minimum tillage to make rows on a land that is not ploughed then place seed manually (Figure 16).

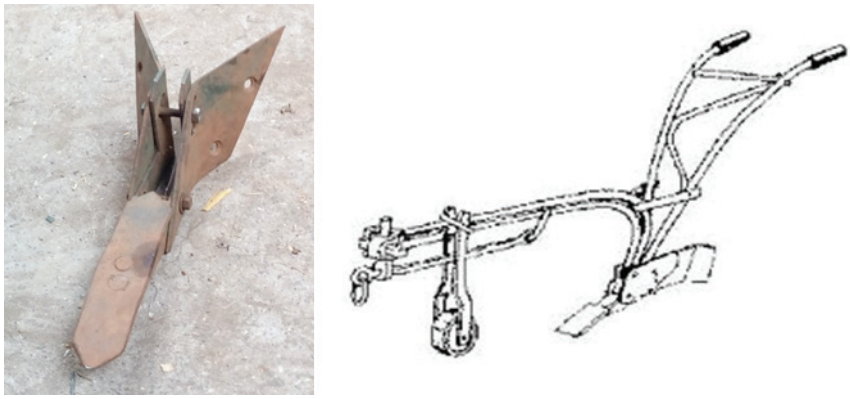


Figure 16: A ripper (Left) and A Ripper fixed on oxen plough
Source: Kisilu RK (left) and Infonet Biovision.org (right)

Thinning

If hand planted, uproot (thin) excess seedlings when the soil is moist to leave 1 plant per hill 3 weeks after emergence and first weeding. Sorghum planted with a calibrated sorghum planter has the proper seedling spacing and does not need thinning.

Crop nutrition

Sorghum plant needs macronutrients and micronutrients in soil especially nitrogen (N) and phosphorus (P) for adequate crop growth. Test/analyze farm soils to get the micronutrients a macronutrients levels and soil pH range for proper decision on fertility before the onset of the season. Observe the deficiency symptoms of important nutrients in sorghum plants (Table 4).

Table 4. Nutrient requirements in sorghum and deficiency symptoms

Nutrient and Importance	Deficiency symptoms	Correction measure
Nitrogen(N) Formation of plant proteins and enzymes • A component of chlorophyll, which enables photosynthesis to produce energy for growth and grain yield	• Yellowing (chlorosis) of leaves • Stunted plants • Small heads • Reduced seed	• Top dress Urea 8-10 Kg N / acre or • Calcium Ammonium Nitrate (CAN) 50 Kg/ acre. • Regular use of organic manure
Phosphorus (P) • Root development • Maturity at the right time • Plant resilience against disease	• Plants turn dark green with purple cast. • Small leaves and plants • Poor grain filling	• Di Ammonium Phosphate (DAP) foliar spray of 2%, 2-3 sprays at an interval of 15 days on the seedlings • Organic manure
Potassium (K) • Movement of water, nutrients and carbohydrates in plant tissue, photosynthesis, • opening and closing of the stomata, which regulates the exchange of water vapor, oxygen and carbon dioxide	• Yellow/brown discoloration and scorching along outer margin of older leaves which begins at leaf tip in sorghum • Stunted plant growth • Reduced yield. 	• Foliar spray of Potash (potassium chloride or KCl) fertilizer @ 1%. • Wood Ash: applied directly as a fertilizer or added to your composite pile
Magnesium (Mg) • Gives leaves their green colour (chlorophyll) to capture sun energy needed for photosynthesis • Metabolism of carbohydrates • For cell membrane stabilization.	Older leaves have yellow discoloration between veins, finally reddish-purple from edge inward 	• Apply a soluble Mg source such as kieserite or Mg chloride.

Nutrient and Importance	Deficiency symptoms	Correction measure
Calcium (Ca) • Calcium pectate, holds the cell walls of plants together • Metabolic role in carbohydrate removal • Maintains chemical balance in the soil, reduces soil salinity, and improves water penetration.	• Delayed emergence of primary leaves • Terminal buds deteriorate • Leaf tips may be stuck together to form sword-like projections • Plants stunted • Leaves brittle, brown, sticky near margins and turn brown	• Liming. Adding lime to boost calcium and raise soil pH making it less acidic. • Foliar application of CaSO4 2% twice
Zinc(Zn) • A key component of many proteins and enzymes. • Growth hormone production • Internode elongation	• Broad white to yellow bands appear on young leaves on each side of the midrib. • Plants get stunted and have shortened internodes.	• Apply Zinc sulfate at planting or a few weeks when symptoms start showing
Sulphur (S) • Formation of plant proteins, enzymes, vitamins, and chlorophyll • Metabolism of nitrogen.	• Deficiency appears first on younger leaves, new growth is pale yellow	• Fertilizers or amendments containing sulfur. E.g. ammonium sulfate, calcium sulfate etc. • Use of organic manure

Crop nutrition can be improved and nutrient deficiencies corrected. These can be achieved by:

- Broadcasting well-decomposed manure/ organic fertilizers: to improve soil organic matter, moisture retention and structure before planting or placing manure along the planting furrows and mixing with the soil before seeds are sown. Required manure quantity is 2 tons per acre.
- Applying soil amendments (lime, rock phosphate and gypsum): to correct soil acidity and salinity, when recommended by a soil test result before planting.
- Applying inorganic fertilizers: to provide the essential macronutrients nitrogen (N) and phosphorus (P) at 60 kg of N and 30 kg of P_2O_5 per hectare, therefore one bag (50kg) per acre of DAP at planting and top dress with one bag (50kg) of CAN per acre.

Integrated Weed Management (IWM)

Do first weeding 2-3 weeks after emergence, and the second weeding when the weeds are observed. Integrated weed management (IWM) involves:

a) Preventive weed control: use of weed free seed and cleaning of farm equipment

b) Cultural weed control: crop rotation, cover crops, intercropping sorghum with legumes, use competitive varieties and good soil fertility.

c) Chemical: Use herbicides to prevent soil disturbance, reduce labor, time and expenses

d) Mechanical/Physical weed control: Weed pulling, Mowing and Mulching

Sorghum parasitic weed control (Striga Weed)

Striga, (*Striga hermontheca* (Del.) Benth) commonly known as witch weed, is a parasitic weed which attacks sorghum (Figure 17) by attaching its roots to sorghum roots, taking up the water, mineral nutrients, and photosynthetic assimilates thereby causing 20-80% grain yield loss under severe infestation.

Figure 17. Striga hermonthica infested sorghum field
Source: Musselmanet al, 2000.

Control Striga weed by:

- Intercropping sorghum with *Desmodium:* inhibits striga seed germination (Khan et al, 2006).
- Planting legume trap crops (cotton, groundnuts, sunflower, linseed and cowpea): induces the *Striga* seeds to germinate without supporting attachment of the parasite. .
- Planting resistant/tolerant sorghum varieties
- Weeding regularly before the weed flowers.

Integrated Pest Management (IPM)

Constantly scout for sorghum pests is carried out in order to identify and control them (Table 5).

Table 5. Major insect pests of sorghum in Kenya

Pest	Symptoms	Control
   Stem borer	• Small pin holes in lines in younger leaves caused by larvae. • Drying and eventual death of the growing point of the sorghum called '*deadheart*' due to larvae feed on whorl. • Patches of transparent leaf epidermis (window panes) in older leaves. • Holes in stem caused by larvae tunneling into the stem can result in broken stems	• Practice crop rotation • Timely planting • Plant Napier grass around the sorghum fields as a catch crop. • Spray with insecticide
  Shoofly	• Wilting and drying of the central leaf known as '*deadheart*' as a result of larvae attack • The damaged plants produce side tillers which may also be attacked.	• Plant shoot fly resistant varieties • Planting in time • Use systemic insecticides

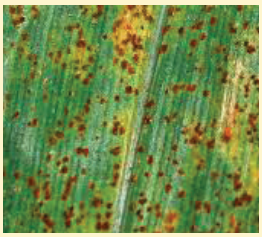
Pest	Symptoms	Control
 Fall armyworm (FAW)	• Small holes and “window pane” on leaves due to larvae feeding deep in the whorl. • Ragged appearance on the leaves resulting from heavy consumption by larvae. As plants begin to boot larvae may damage the panicles.	• Plant on time as per weather information • Use systemic insecticides
 Locusts	• Large swarms of locusts can completely strip the foliage and stems of plants such as forbs and grasses causing total destruction	• Spray with insecticides • Request for governments intervention in case of big swarms
 Birds	• Bigger birds such as doves consume whole seed • Smaller birds such as the *Quelea quelea* break the seed and eat portions exposing the white endosperm of the seed mainly during milky stage.	• Avoid isolated farms • Plant in clusters of many farmers • Use bird scaring devices • Harvest early at soft dough stage
 Sorghum midge	• The larvae eat the young seeds in the heads. • Moderate infestations leave a few round, full grains amongst undeveloped shriveled grains. However, when infestations are severe, full grains are absent.	• Plant on time as per weather information to escape the sorghum midge population build up • Plant sorghum varieties with same maturity period at the same time within the communities • Remove alternative hosts such as Johnson grass and Sudan grass • Practice field sanitation and crop rotation with other none host crops • Use resistant or tolerant sorghum varieties.

Integrated Diseases Management (IDM)

Constantly scout for sorghum diseases in order to identify and control them (Table 6).

Table 6. Major diseases of sorghum in Kenya

Disease	Symptoms	Control
 **Covered kernel smut** Cause: Fungus	• The individual grains are replaced by oval or cylindrical structures called sori • The sori have a creamy coloured skin and when broken they release black substance which is the fungal spores • The disease is seed born	• Use disease free certified seed • Uproot the infected plants and burn to prevent further spread of the disease • Destroy disease carrying crop residues by burning • Rotate with non-host crops especially legumes • Use resistant varieties
 **Head smut** Cause: Fungus	• The panicle is completely replaced by a large smut gall covered by a thick whitish membrane, while still enclosed in the boot • The membrane soon ruptures, often before the head emerges, exposing a mass of dark powdery spores • The affected plants are shorter than the healthy plants due to a lack of elongation of the peduncle	• Use of sorghum disease free certified seed • Uproot the infected plants and burn to prevent further spread • Destroy disease carrying crop residues by burning • Rotate with non-host crops especially legumes • Plant resistant varieties
 **Ergot** Cause: Fungus	• The fungus infects the sorghum flowers converting them into a white fungal mass (sphacelia) • The infected flowers exude an amber-colored, sticky fluid, or “honeydew,” which drips onto the leaves and soil further spreading the spores	• Plant clean seed • Burn crop residue • Where possible spray fungicides
 **Anthracnose** Cause: Fungus	• Small circular red spots on leaves with distinct margins • As the disease progresses, the spots increase and coalesce to cover most of the leaf surface • Plants becomes defoliated and may die before reaching maturity	• Practice crop rotation with legumes crops to break the disease lifecycle • Practice field sanitation by destroying sorghum residues • Use resistant or tolerant varieties

Disease	Symptoms	Control
 **Leaf blight** Cause: Fungus	• Reddish-purple or tan spots that coalesce to form large, elongated lesions	• Burn crop residues • Practice crop rotation • Use resistant or tolerant varieties
 **Rust** Cause: Fungus	• First pale yellow or orange spots appear on the upper surface of leaves (pycnia) • Then yellow or orange spots appear on lower surface of leaves • Brown spores appear on both surfaces of lower leaves and stems • The spots turn black (telia) • Severely infected leaves turn yellow, dry up and die	• Practice crop rotation to break the disease lifecycle • Destroy sorghum residues before the onset of the rains • Use resistant or tolerant varieties
Grain mold Cause: Fungus	• Grain mold affects short duration varieties under rainy season in warm and humid conditions • Causes discoloration of grains to light whitish, pinkish, grayish or black. • It affects grain weight, viability, quality and market price	• Grow mold resistant cultivars. • Avoid growing early-maturing mold-susceptible cultivars in high rain potential and humid zones. • Harvest physiologically matured crop without delay and quickly dry grains after threshing
Charcoal rot 	• Charcoal rot affects sorghum plants subjected to moisture stress during the pre-flowering period • Lodging of plants • Premature drying of stalks • Root rot • Reduction in filling up of grains.	• Practice timely planting to escape moisture stress • Do crop rotation • Apply optimum plant population to reduce the incidence • Adopt intercropping other than sole cropping • Grow drought tolerant, lodging resistant, and non-senescing Varieties
Common storage molds and mycotoxins 1. Aflatoxin 2. Fusarium 3. Penicillium 	• Aflatoxin is a toxin produced by the fungus Aspergillus flavus. • Mold infestation in storage can be recognized by a gray-green or yellow-green mold growing on grain	• Dry grain to the recommended moisture • Store in well ventilated stores to control the relative humidity and temperature during storage • Use of aflasafe chemicals • Timely harvesting • Proper threshing

Harvesting and Post-harvest Management of Sorghum Grain

Climate change creates conditions that increase harvesting and postharvest losses. The prolonged rainfall seasons affecting harvesting time and the increased temperature enhancing the storage pests' damage and harmful fungal infestation are some of the impacts. This has increased post-harvest quantity losses to about 10 to 30% depending on the crop, with that of cereals estimated at 10%, and quality losses in terms of nutritional value, health hazards such as aflatoxin, poor quality grains leading to reduction in marketing opportunities and low prices. Post-harvest losses can be reduced through appropriate technologies, mainly during storage hence boosting food security.

Harvesting

Harvest sorghum on time, when the grains are physiologically mature (Figure 19). Early sorghum varieties mature within 3 months while late varieties mature within 4 months. A mature sorghum crop ready for harvesting is indicated (Figure 18)

Figure 18: Mature sorghum crop ready for harvesting.

Source: Kisilu, R. K., 2020

Drying the panicles, threshing and drying grain

Drying panicles

Spread the panicles on a tarpaulin or mats (Figure 19) under the sun for a minimum of 3 days while frequently turning until the grain attains moisture content of below 15%. Grains are easy to separate from the husks or glumes of a well dried panicle during threshing.

Figure 19. Drying sorghum panicles for threshing
Source: Esilaba, et al. 2019

Threshing

Use sorghum threshers (Figure 20) placed on a tarpaulin or mats to avoid contamination with stones and soil. Sorghum threshers lessen the time and increases efficiency and the quality of the grain.

Figure 20. Motorized sorghum thresher.
Source: https://www.cornmachine.com

Drying the grain before storage

Dry grain on mats or tarpaulin under direct sun or solar drier if available and turn regularly. Test the grain moisture content to make sure it is between 12-13%.

Methods of testing grain moisture content

Moisture meter: Grain moisture meters are available with extension providers and can be availed on request. (Figure 21)

Figure 21. Grain Moisture meter.
Source: Murenga Mwimali, 2020.

Salt moisture testing method: For farmers who cannot access the moisture meter

Materials: 8g of dry salt, a transparent dry glass or clear plastic bottle, 160g of sorghum grain. **Method:** Put the grain into the dry bottle, add the dry salt, close the bottle tightly, shake for one minute, and allow the grain to settle for about 15 minutes.

Results: If the salt sticks to the side of the bottle the grain moisture content is above 15% and needs more drying. If the salt does not stick to the bottle the grain is below 15% in moisture content and safe for storage (Figure 22).

Figure 22. Salt moisture testing method

Packaging

Package the grain for storage using Hermetic storage technology (HST) bags to reduce health risks from chemical dusting and storage cost.

Hermetic Storage Technology (HST): The bag has an outer Woven Polypropylene (WPP) bag and the inner liners. The WPP bag protects the inner liners that give hermetic properties to block oxygen and other gases and water vapour from entering or exiting once the hermetic bag is closed suffocating any living organisms inside thereby protecting the dried grains from damage. The stored grain can last up to two years with no appreciable loss of quality and the bag is reusable (Figure 23)

Figure 23. Hermetic storage technology

Sorghum storage

Store the grain bags in a clean, dry, tidy, well fumigated, and well aerated structure with correct uniform temperature to maintain quality and quantity by preventing damage and deterioration caused by adverse weather conditions, contamination by microbial infestations and storage pests. Store new and old grains separately.

Construction of storage structures

The size of the structure depends on the amount of grain to be stored.

Specifications:

- Raise the floor at 90cm from the ground to protect grain against rodent and advance weather conditions such as floodwaters.
- Fit the pillars with conical rodent guards made of metal sheets.
- Make the flour with good quality concrete to avoid rodents from coming up.
- Construct the walls using stone or local brick and plaster smooth to avoid pest breeding crevices.
- Roof with corrugated iron sheet.
- Close the gaps between the wall and the roofing sheets with cement or wire mesh with 12mm openings to keep birds out
- Construct a tightly fitting door to prevent entry of rodents
- Construct ventilation openings to allow aeration and control temperature of the grain.
- Screen the ventilation openings with mesh not exceeding 12mm to keep out insects and birds.

Importance of sorghum in livestock production

Sorghum as feed grain

Sorghum grain is a significant component of feed for cattle and chicken. It has similar feed characteristics as maize, provides about as much energy, and has higher crude protein content. Currently, low-tannin high digestible sorghum varieties have been developed.

Process sorghum grain for animal feed by milling, early harvesting, steam-flaking or popping to ease digestion, increase rate and extent of starch absorption and improve its feeding value.

Sorghum for fodder

Fodder sorghum varieties containing 52 to 65% dry matter digestibility have been released in Kenya. They are classified into three key classes;

- **Forage sorghums:** Sweet sorghum varieties and hybrids, tall plants (24 m) with sweet thick stems. They do not regrow fast after cutting and are best utilized as a silage crop, hay or grazed.
- **Sudan Grass:** Varieties with small, fine stems and leafy growth. Regrow rapidly after cutting or grazing. Can be harvested as pasture, green chop, or hay. The thinner stems give it better drying characteristics for hay making
- **Sorghum-Sudan Grass Hybrids:** Crosses between Sudan grass and other sorghums to develop hybrids. Varieties have taller, thicker stems and high yielding than Sudan grass. Harvested for silage or hay-making

Utilization of Fodder Sorghums

- **As Green chop and grazing:** For grazing, plant Sudan grass or sorghum x Sudan grass hybrids. Graze or cut the crop at 0.2m above the ground when it is 0.6- 0.9m tall, before flowering when the nutritive value and palatability are high.

- **As Hay:** Plant Sudan grass and sorghum x Sudan grass hybrids for hay making with high seed rates to get high plant population and induce thinner stems that dry easier. Harvest hay before head emergence or at booting stage and dry uniformly and rapidly

Basic Method of Making Hay

- Cut forage sorghum before full maturity and before seeding, to maximize its nutritive value

- Cut more leaves than stems since leaves have high nutritional value.

- Chop forage into small pieces and lay it out in the sun in thin layers as possible and turn regularly to dry for 2 to 3 days. Do not over dry hay to avoid fermentation

- Store dried hay in form of bales when the moisture content is less than 15%.

  As Silage: Plant forage and grain sorghum types for silage production. Harvest the fodder sorghum at the mid to late soft dough stage of grain maturity and store as silage for year-round feed supply for beef and dairy cattle.

Learning Exercises

Learning Exercise 3.1: Demonstration of water and soil management techniques

Objective

Demonstrate some of the best technologies and practices for soil and water management that help sorghum farmers adapt to climate change

Demonstration

- Mulching
  i. Invite two participants to take part in this exercise, lead them to prepared plots.

  ii. Let one of the participants to cover one plot with mulch, while we will leave the other plot uncovered. Ask your assistants to cover one of the plots with mulch. Make sure it is evenly divided over the plot.

  iii. Take your buckets with water and say that we will now let it rain on our plot. Ask your assistants to let it rain (meaning: they should not pour the water directly from the bucket on the plots but rather sprinkle it with their hands, 1 bucket per plot).

- How to compost.
- Construct tied ridges and zai pits
- Construct terraces
- Make tied ridges

Learning Exercises 3.2: Sorghum Management Practices under Climate Smart Agriculture

Objectives

To enlighten participants on the importance of practicing climate smart agronomic and management practices in sorghum farming to improve production

Method

- Break the participants into groups.
- Provide each group with marker pen and flip charts
- Assign each group to discuss the following issues on sorghum management practices capturing their points in a flip chart or Manila paper for plenary presentation.

Ask participants

- To describe the differences between conventional agriculture and climate smart agriculture and advantages and disadvantages of each over the other
- To state the physiological characteristics of sorghum
- To explain sorghum ecological requirements
- To state the importance of acquiring quality Sorghum seed for planting
- To give the various Improved suitable sorghum varieties, sources and ecological suitability
- To outline climate smart land preparation methods and implements for sorghum cultivation
- To discuss the climate smart agronomic practices applied on sorghum from planting to harvesting
- To describe the deficiency symptoms of important nutrients in sorghum plants
- To describe the important sorghum pests and diseases and their control measures
- To discuss the proper harvesting and post-harvest management of sorghum grain to minimize quality and quantity losses
- Discuss the importance of sorghum in Livestock Production

Let each group present to the plenary for discussion on sorghum management practices under climate smart agriculture and summarize the notes

Summarize the discussion notes on sorghum production in a changing climate

4 ECONOMICS OF SORGHUM PRODUCTION AND MARKET ACCESS

Introduction

Economics is the planning of resource use to enhance productivity. The key factors to consider in enhancing productivity include suitability of the seed variety, weather forecasts, access to stable markets, adherence to recommended input combinations and proper crop management in the field. Other factors that may influence profitability in sorghum production include; land size to cultivate, tillage system to use, type of fertilizer and nutrient supplements to use, weed control, pests and diseases control, how to harvest and process, marketing strategy such as warehouse receipting, contract farming, use of middle men, value addition, and group or individual farming.

Learning Objectives

The overall objective of this topic is to enlighten participants about the importance of understanding the economics of sorghum production and market access.

By the end of this session the participants will be able to understand:

- Record keeping and its importance
- How to collect information and data for gross margin calculation and enterprise analysis
- Sorghum enterprise planning, management, analysis and its applications
- Calculation of sorghum enterprise gross margins and its importance
- Sorghum enterprise analysis through performance indicators
- Sorghum marketing - constraints and opportunities
- Sorghum farming business
- Sorghum processing and utilization of products

Record Keeping

Farmers should keep record because it provides the information and data needed for planning, performance analysis, maximization of profits, and minimization of risks, especially the prevailing uncertainties, and promotes more informed decision-making in a timely and accurate manner. Examples of financial records include the following; cashbook, ppayroll or labour, sales/consumption and profit and loss accounts. Examples of physical records include; farm inventory, farm management practices record, and input records and production records.

Sorghum Enterprise Management

Sorghum enterprise management is a decision making process which affects its profitability. This includes; what variety of sorghum to cultivate, to what extent, how to produce it and how to obtain the

production resources such as land, labour, capital and management. Once the decision of sorghum production has been made, then the production costs and returns are analysed based on these premises. The sorghum enterprise performance will be based on the technical (physical) and economic (monetary) performance indicators.

Sorghum Enterprise Analysis

Sorghum enterprise analysis is a management tool which enables us to evaluate the enterprise's profitability and the reason for it.

The cost analysis of production gives a good idea about expenditures, and/ or losses incurred due to production of products in this case sorghum. A production process is a transformation of inputs to outputs, thus the cost of production of the sorghum reflects the value of inputs which are essential for that process.

Costs may be calculated for the following purposes:

- Farm/enterprise planning.
- Comparative enterprise analysis.
- Price determination and policy.
- Production, monitoring, control and evaluation.
- Accounting and bookkeeping.

Sorghum Profitability

Profitability analysis allows one to forecast future trends of the firm. The aim is to identify the most and least profitable products or services, help change the product mix to maximize profits in the medium/long term, isolate and remedy the causes of decreasing profit margins.

Sorghum Enterprise Gross Margin

The gross margin is the real change in farm /enterprise profit which occurs as a result of an implementation of a particular activity (e.g. sorghum). Gross margin is the difference between income (returns) and variable (avoidable) costs. It is calculated per production unit (one acre) or per unit of output (kg of beans).

To calculate the gross margin, classify the costs according to the criteria of being variable (avoidable) or fixed (unavoidable).The classification of costs is carried out according to the case under consideration (Table 7).

Table 7. Sorghum Gross Margin Calculation per Hectare

	Conventional agriculture				Climate smart agriculture			
Intermediate input	**Unit**	**Qty**	**Price**	**Total Cost Ksh/Ha**	**Unit**	**Qty,**	**Price**	**Total Cost Ksh/Ha**
Variable Inputs								
1. Land preparation								
2. Herbicide application								
3. Ploughing								
4. Harrowing								
5. Ridging/furrowing								
6. Soil & water conservation agriculture structures								
7. Labour								
Sub total								
Planting								
1. Certified seeds								
2. Planting								
3. Manure								
4. Fertilizer DAP								
5. Labour								
Sub total								
Crop management								
1. Weed control								
• Integrated weed management								
• Hand weeding								
2.Thinning								
3.Fertilizer CAN								
4.Disease management								
• Integrated disease management								
• Non-integrated disease management								
5.Pest management								
• Integrated pest management								

	Conventional agriculture				Climate smart agriculture			
Intermediate input	**Unit**	**Qty**	**Price**	**Total Cost Ksh/Ha**	**Unit**	**Qty,**	**Price**	**Total Cost Ksh/Ha**
• Non-integrated pest management								
6.Labour								
Sub total								
Harvesting & post harvesting								
1.Cutting heads								
2.Machine Threshing & 3.winnowing								
4.Hand threshing and 5.winnowing								
6.Packaging								
• Hermetic bags								
• Normal bags								
7.Transportation								
7.Labour								
Sub total								
TOTAL VARIABLE COST (VC)								
Production				**Total**				**Total**
Yields/Acre (Bags) (Y)								
Price/bag (90kgs) (P)								
Total Revenue (TR) = (P*Y)								
Gross margin (TR –VC)								

Gross Margin, Cost Benefit Analysis for Sorghum Enterprise

- Gross margin (Kshs) per hectare= Total Revenue less Variable Costs (TR-VC)
  This is the profit accrued from the enterprise without including the fixed (unavoidable) costs
- Gross margin per Ksh income= Gross Margin divided by Total Revenue (GM/TR)
  It shows that from every shilling earned from the investment, what remains as a profit
- Gross margin per man day= Gross Margin divided by Number of man days (GM/mdays)
  This shows the contribution of the worker to the profit earned per day. It will assist to determine whether to pay more or less to the worker than what he contributes hence assists to come up with the payments wage rate per day.
- Return to Ksh invested= Total Revenue divided by Total Variable Costs (TR/TVC)

This shows the profit/loss you get from every shilling you put into the enterprise investment.

Production Costs

Costs are classified into two categories;

- Variable costs (avoidable costs)
- Fixed costs (unavoidable costs)

Fixed Costs-Sorghum

There are two main groups of fixed (unavoidable) costs:

1. Costs incurred in the past, before the period related to the relevant activity period e.g. investments in machinery, building, land bought etc.
2. The costs incurred during the relevant time period but not connected with the activity in question e.g. overhead costs.

The classification is determined by events in relation to the decision to be made (Annex 3).

Opportunity (Alternative) Costs.

Opportunity cost represent the cost of an opportunity which is foregone because limited resources are used in the chosen alternative and therefore cannot be disposed of or used for other possible income, in producing or expense reducing alternatives" (Table 8).

There are three basic possibilities when calculating opportunity cost as determined by the prevailing conditions.

Table 8. Various possibilities for opportunity cost calculations

Conditions	The opportunity cost is:
• Resources that cannot be sold and they are in surplus	Zero (0)
• Lack of resources, additional amount cannot be bought	The gross margin per unit obtained by another alternative which must be forgone.
• Resources can be bought in any amount to the need	The market price

Performance indicators of an enterprise

Indicators are values (signals) which can be used for comparing the performance of an enterprise in different cases. They are physical (technical) or financial (monetary) quantities usually related to a single unit of production or resource for example:

Economic (monetary) indicators.

- Gross margin per hectare of sorghum.
- Gross margin per man day.
- Variable (avoidable) cost per kg of sorghum.
- Gross margin per kg of sorghum.

Another group of indicators might include proportions and prices.

- Price of one kg of sorghum.
- The ratio between the fertilizer cost and variable cost (%).
- Daily wage rate.

Technical Indicators

- Sorghum production per hectare (kg/bags).
- Amount of sorghum consumed at home.
- Quantity of fertilizer per hectare.
- Number of work days per hectare.
- Quantity of manure used.

To evaluate the performance of a specific enterprise (sorghum), compare it with the criteria:

- Performance of the sorghum enterprise in the previous year(s).
- Planned budget for the sorghum enterprise.
- Performance of other farmers.
- Standards or norms.
- Performance of the other enterprises on the farm.

Sorghum Marketing

Agricultural marketing covers the services involved in moving an agricultural product from the farm to the consumer. Several activities involved include; planning production, growing, harvesting, grading, packaging, transport, storage, agro-food processing, distribution, advertising and sale.

Production in Kenya is low with farmers producing only enough for home consumption. Important marketing strategies include;

a) Market based production (production decisions are market informed),

b) Use of business models -such as contract farming

c) Use of warehouse receipting systems.

Market Based Production: is an approach where the farmer conducts market research to understand the needs and trends in the market before deciding what and how much to produce at what time. This would, for example, help the farmer to know which varieties are in highest demand and in which market segments.

Contract farming: This is the arrangement where the farmer enters into an agreement in which the farmer agrees to sell to the buyer a given quantity of a particular grain at a specified price and other conditions and the buyer agrees to buy the given quantity and quality at the agreed price.

Warehouse Receipting System (WRS):

The Warehouse Receipt System Act of 2019 of the Laws of Kenya works in such a way that farmers deposit their produce to the licensed warehouse also called collateral operator. The operator issues the farmer with a legally recognized receipt showing the type of produce for example, sorghum grain, the quantity and quality of the produce. The farmer (depositor) can then use that receipt as collateral

to access credit including farm inputs. The Warehouse Receipt System also provides farmers with good storage for their produce.

Sorghum Farming Business

Farming is considered a business because like any other profit making business, farmers seek to combine the three main factors of production namely land, labour and capital to produce goods that they aim to sell at a profit. To earn a profit sustainably, it is important that sorghum farmers effectively understand the prevailing forces of demand and supply. Before investment of resources, farmers should assess available markets and decide for which customer(s) to produce for, the quality required as well as the quantity and timing of supply to that market. Some of the common uses of sorghum for which farmers may produce the crop include; food, livestock feed, brewing and ethanol production.

Sorghum Processing and Utilization

Sorghum Products

The diversification and commercialization of sorghum products is envisaged to create a market and consumption demand to benefit the key players in the sorghum value chain particularly the small-holder farmer and consuming public. Value addition can also be done to sorghum to produce different products. Some of these products include Sorghum cowpea *pilau*, sorghum chapatti, sorghum cake, gluten free sorghum bread, sorghum beverage and sorghum beer (Table 9).

Table 9: Local recipes of value-added products of indigenous versions of popular products

Product	Recipe
 **Sorghum cowpea *pilau* (sorghum with cow pea)**	500g pre-boiled de-hulled sorghum (2 cups), 500g cowpeas (2 cups), 2 chopped onions, 50 ml oil (4 tablespoons), 15 g *pilau* masala (1 tablespoon), 1 crushed ginger, ginger powder (1 teaspoon),), one clove of crushed garlic, 1 bunch of coriander (*dhania*), one capsicum, salt to taste.
 **Sorghum Chapatti**	500g/2 Cups of sorghum flour, 500g/2 Cups of wheat flour, 10g of salt, 1/2 Cup of cooking fat and warm water (Makes 8 chapattis)
Sorghum *Ugali* 	2 cups (255 g) of whole maize flour (white), 1 cup (132 g) of red sorghum flour 1 cup of finger millet (113 g) flour 5 cups (1139 g) of water

Product	Recipe
 **Sorghum Cake**	3 cups of sorghum white flour, ١ cup of Wheat flour, ٤ tablespoons of sugar, 4 tablespoons margarine, 3 Eggs, 3 cups of milk or water, 1/2 teaspoon of baking powder, 1 pinch of salt
 **Gluten free sorghum bread**	3 teaspoons of active dry yeast (10.5 g), 2 teaspoons of granulated sugar (4.2 g), 1 1/2 cups of warm water, 3 1/2 cups of sorghum flour (٤٤٤,٥ g), ١ cup of corn-starchstarch (120 g), 1/3 cup of tapioca starch (40.66 g), 1 teaspoon of salt (5 g), 1 teaspoon of xanthan gum (2.5 g)
 **Sorghum beverage**	Sorghum grains (especially red or brown)
 **Sorghum beer**	1 kg of Sorghum grain with brewing/malting quality 7g of Baking Yeast

Sources: AgIn, (2018), Austin Harris, KF11 Rwanda, Coretta Kai (2017), Felicia Lim, (2017), Kenyan Food recipes 2018, SmartFoodKenya, (2017), KALRO Katumani food utilization program,

Sorghum Market Outlets

Market outlets for sorghum include the rural consumers, rural and urban market centres, the brewing industry, schools, hospitals and export market (Figure 24).

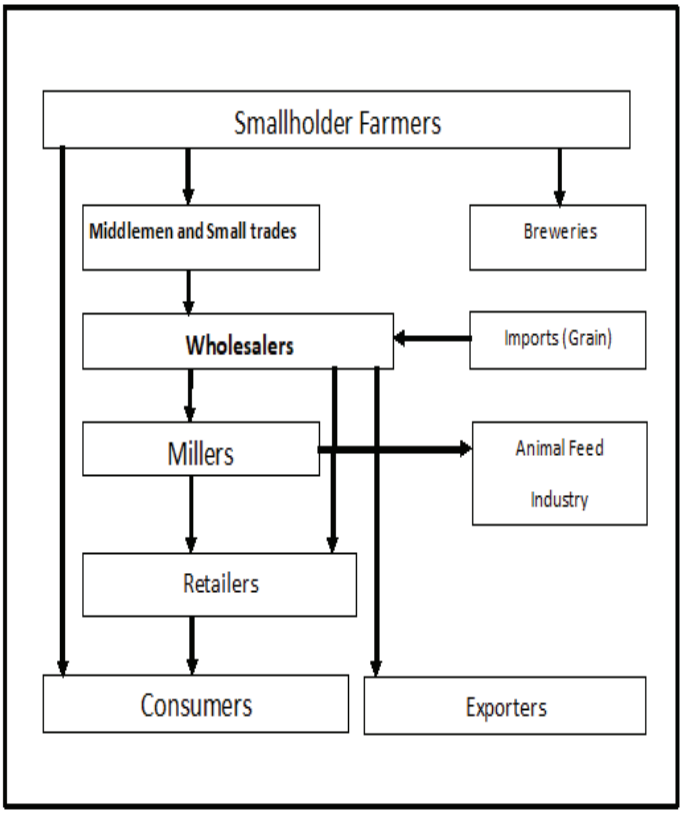


Figure 24. Marketing map for sorghum in Kenya
Source: FAO, 2013.

Marketing Constraints and Opportunities

Challenges faced in the sorghum value chain include;-

- **Low pricing**: This is mainly due to their seasonality, perishable nature and collusion by buyers. In Kenya, sorghum prices are volatile and rise or fall depending on the seasons.
- **High cost of inputs**: Cost of production has a direct effect on pricing. High cost of production will reduce the farmers' profit margins.
- **Government Policies:** There are some existing government policies that may constraint agricultural production. Weak regulatory framework for example may result in the rejection of farmers' produce. Also, the taxation policies for agricultural produce in transit across counties can result in high transaction costs.

Infrastructure: Movement of agricultural produce is dependent on good infrastructural network. In many rural sorghum growing regions, there is poor distribution network for inputs, outputs and roads.

Opportunities and possible solutions to the above challenges include;

- **Promotion**: To solve the problem of inadequate information on markets and knowledge on differentiated products, promotion activities could be done such as advertisement.
- **Policies**: If regulatory framework is a problem, there may be need to lobby for amendment to reduce any unnecessary acts, taxes and non-tariff barriers.
- **Inadequate information on markets:** This could be solved through applying the market growth matrix of market penetration, market development, product development and product diversification.

Learning Exercises

Learning Exercises 4.1: Economics of Sorghum Production and Market Access

Objective

To enlighten participants about the importance of understanding the economics of sorghum production and market access

Method

- Break the participants into groups.
- Provide each group with marker pen and flip charts
- Assign each group to discuss the following issues using the flyer in a question-posing mode, allowing participants to discuss and discover what they represent. The agreed responses should be captured in flip chart for plenary presentation.

Ask participants

- To state the importance of record keeping, types and on how records are kept.
- To discuss about sorghum enterprise management, analysis and its applications
- To calculate sorghum enterprise gross margins and its importance
- To demonstrate understanding of the sorghum profitability and enterprise analysis.
- To outline the performance indicators and to carry out sorghum marketing
- To discuss sorghum farming business
- To list sorghum products and their recipe
- To identify the sorghum market outlets
- To discuss the marketing constraints and opportunities that exist in the sorghum value chain

Afterwards, each group will present to the plenary for discussion on the economics of sorghum production and market access.

Summarize the discussion notes on the economics of sorghum production and market access

5 GENDER AND SOCIAL INCLUSION IN THE SORGHUM VALUE CHAIN

Introduction

This chapter provides links of gender with climate change and agriculture with a major focus on the sorghum value chain. Effective climate-smart agriculture approaches requires understanding the needs, priorities, and challenges of different stakeholders, and the identification of what is appropriate at the local level.

Gender equality refers to the equal access of women and men, not only to social services, but also to livelihood opportunities, production opportunities land and markets.

Learning objectives

The overall objective of this topic is to educate farmers on the importance of gender and social inclusion in the sorghum value chain.
By the end of this session the participants will be able to:

- Understand the importance of gender and social inclusion in the sorghum value chain
- Recognize the opportunities for women and youth
- Develop a gender-responsive approach to climate smart agriculture
- Recognize the gender gaps and social and economic inequities that needs to be addressed
- Understand the levels involved in addressing the gender concerns and stakeholder engagement in climate smart agriculture

Importance of gender and social inclusion in the sorghum value chain

Gender refers to the difference in socially, culturally and politically constructed roles and opportunities associated with being a woman, man and the youth and the interactions and social relations between the different categories. Gender determines what is expected, permitted and valued in a woman, man or youth in a determined context.

Effective climate-smart agriculture approaches require understanding the needs, priorities, and challenges of different stakeholders, and the identification of what is appropriate at the local level. Men, women and youths have different opportunities and challenges that may help or disadvantage them in the implementation of climate smart agriculture technologies in sorghum production. Implementation of climate smart agriculture practices without gender considerations leads to a widening gap of inequalities.

The main purpose of this information is to create awareness of the links of gender with agriculture and climate change, promote mainstreaming and integration of gender in climate change policies, and finally to create responsiveness of existing climate-smart agricultural practices that encourage gender equality and social inclusion.

Opportunities for women and youth in the sorghum value chain

In Kenya, sorghum has traditionally been identified as women's crop in many smallholder- farming communities. However, in the major Agro- ecological zones, the majority of the male-headed households planted sorghum with only 13% of the youth headed household participating in sorghum production.

A gender-sensitive value chain approach to agricultural interventions increases the visibility of men's and women's roles in various nodes and eliminates gender-specific barriers to entry and opportunities for growth in the society.

Women and the youth are an integral part of the agricultural transformation and must be accorded equal opportunities to contribute to the desired sustainable agricultural growth meaningfully. Agricultural Sector Development Strategy (ASDS) notes for instance that to attract the youth to agriculture; there is need for attitude change among the rural communities to perceive agriculture as a business and make it commercially viable. In 2017, the Ministry of Agriculture, Livestock and Fisheries (MoALF) developed the Kenya Youth Agri-business Strategy 2017 - 2021 aimed at addressing the challenges that hinder youth from efficiently participating in the sector and provide new opportunities for the youth in agriculture and its value chains.

Gender gaps and social and economic inequities that needs to be addressed

Factors influencing gender considerations include traditions, rules, norms, customs and practices. The above factors translate into social difference between men and women. Gender further determines the ways in which women, men and the youth participate and benefit from the different interventions.

Impact of climate change on specific gender role

Women are the most affected by climatic change as compared to men mainly because of their socially constructed roles which are mainly dependent on natural resources such as; food production, fetching water, fuel wood, cooking, care of the children and family

Women, in most parts of the world, tend to suffer inequitable access to resources and information, decision-making processes and benefit sharing. The critical role of women in agriculture and sorghum production needs to be clearly understood before designing and initiating any interventions for adaptation and mitigation to climate change

A Gender-responsive approach to Climate-Smart Agriculture

The accepted procedure for addressing the gender gap in agriculture is adopting a gender-responsive approach. In practice, this means that the differentiated needs, priorities, and realities of men and women are recognized and adequately addressed in the design and application of climate-smart agriculture so that both men and women can equally benefit (World Bank, FAO and IFAD, 2015). The ultimate goal of a gender-responsive approach to climate-smart agriculture is to give women and men equal incentives and opportunities to invest in or adopt climate-smart practices.

The fundamental component of a gender-responsive approach is to carry out gender analyses, aimed at developing understanding of specific social and economic contexts and gender-related inequalities. As part of a gender analysis, an assessment is made of women's and men's control of assets such as land, water and other productive resources; income; of the labour involved and the time required until benefits are realized; and of access to information, credit and markets – as well as gender-related vulnerabilities to climate change. The results of such an analysis can reveal the underlying causes of gender inequalities, social and economic barriers and other challenges, including cultural facets that could offer insights that inform solutions.

Gender concerns and stakeholder engagement in climate smart sorghum production

In Kenya, women, men and the youth and all other vulnerable groups have different roles which are less appreciated. In the world, about 40% of the labour in agriculture is provided by women, while in Kenya it approximately 80%. However, women, youth and all other vulnerable groups, suffer lots of barriers that create gender gaps and inequalities.

In the same scale, women farmers face challenges in adopting climate smart agriculture practices, including in access to credit, technology, knowledge and agricultural inputs. Climate change is highly likely to increase these inequalities. Climate-smart agriculture practices and policies will need to take these challenges into justification and develop solutions to address them.

There are three levels in addressing the gender concerns and stakeholder engagement in climate smart agriculture namely' a) policy at both national and county levels, b) community, and c) household/intra-household.

- **Policy level:** In the development of the gender and socially inclusive climate smart agriculture policies, there is a need for all the genders to be included as per the National Policy on Gender and Development (2000).
- **Community level:** Participatory engagements of different stakeholders in the community increases the commitment and adoption of the climate smart agriculture technologies. However, there should be a recognition that the women, men and the youth are not homogenous in the climate smart agriculture initiatives.
- **Household levels:** Appropriate gender sensitive participatory tools are useful in identification of the different existing levels of knowledge, needs, and challenges within the households so as to inform the efforts towards the implementation of the climate smart agriculture practices.

Learning Exercises

Learning Exercise 5.1 Gender and social inclusion in the sorghum value chain

Objective

To educate participants on the importance of gender and social inclusion in the sorghum value chain

Method

- Divide the participants into groups based on their gender.
- Provide each group with marker pen and flip charts
- Assign each group to discuss the following issues using the flyer in a question-posing mode, allowing participants to discuss and discover what they represent. The agreed responses should be captured in flip chart for plenary presentation:
  Ask participants on how they;
- Understand the importance of gender and social inclusion in the sorghum value chain
- Recognize the opportunities for women and youth
- Develop a gender-responsive approach to climate smart agriculture
- Recognize the gender gaps and social and economic inequities that needs to be addressed
- Understand the levels involved in addressing the gender concerns and stakeholder engagement in climate smart agriculture

Afterwards, each group will present to the plenary for discussion based on responses to the different questions above.

Summarize the discussion gender and social inclusion in the sorghum value chain.

ANNEXES

Annex 1: Definition of Terminologies

Term	Explanation/Meaning
Adaptation	Adaptation refers to responses by individuals, groups and governments to actual or expected changes in climatic conditions or their effects.
Adaptive capacity	Adaptive capacity is the ability or potential of a system to respond successfully to climate variability and change, and includes adjustments in both behavior and in resources and technologies.
Agroforestry	Agroforestry is the practice of integration of trees, plants, and animals in conservative, long-term, productive systems.
Cashbook	It records cash in and cash out on daily basis and it serves as source of information for other types of records.
Climate	Climate is statistical information, a synthesis of weather variation focusing on a specific area for a specified interval. Climate is usually based on the weather in one locality averaged for at least 30 years.
Climate change	Climate change is a large-scale, long-term shift in the planet's weather patterns or average temperatures.
Climate variability	Climate variability refers to variations in the mean state and other climate statistics (standard deviations, the occurrence of extremes, etc.) on all temporal and spatial scales beyond those of individual weather events.
Climate-Smart Agriculture	Agriculture that sustainably increases productivity and resilience (adaptation), reduces/removes GHGs (mitigation), and enhances achievements of national food security and development goals.
Compost	Compost is simply controlled decomposition of organic matter (mainly animal manure and plants materials) which can be incorporated easily into the soil.
Conservation Agriculture	Conservation Agriculture (CA) is an approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment.
Deforestation	Is clearing of trees in large scale
Drought	A temporary reduction in moisture availability significantly below the normal for a specified period
Dry Spell	A period of dryness that have no or little effect on soil moisture or water levels.
Farm Inventory	It records the various assets held by the farm and their conditions. This helps to identify items that need replacement
Food Security	Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.

Term	Explanation/Meaning
Gender	Gender refers to the difference in socially, culturally and politically constructed roles and opportunities associated with being a woman, man or a youth, and the interactions and social relations between the different categories.
Labour/Payroll records	It takes care of the various transactions related to labour on the farm including number of labourers, payment for work done as well as pending labour costs among other things as may be relevant to the farm.
Input records	Input records give details of the type and quantity of different input obtained and/or utilized in the farm over a given period.
Marketing	The management of processes through which a product / service, sorghum, is produced and finally delivered to the ultimate buyers.
Mulching	Mulching is the spreading of any organic material to cover the soil surface to conserve soil moisture, and to protect soils from fertility loss and erosion.
Production records	This record measures the productivity of the land, and the success of farming operations generally. It shows how much crop has been harvested or the anticipated level of harvest.
Sales/ Consumption Records	This records the quantity sold and/or consumed by the farmer and his family, or given out to friends and relatives.
Soil erosion	Soil erosion, involves movement of top soil by either wind, water, animal or human activities. It involves 3 distinct activities – detachment of the soil, movement and deposition.
Soil fertility	Soil fertility is the capacity of soil to accumulate, store and transfer nutrients to sustain plant growth. Soil fertility is the component of the general soil productivity, which encompasses its available nutrients and its ability to release nutrients from its reserve and those applied externally for crop production.
Tied ridges	Tied ridges are a series of cross-ridges that block or interrupt the furrows thus preventing flow of water along the furrows, hence allowing trapped water in the rectangular basins to infiltrate into the soil.
Weather	Weather describes the conditions about what is happening outdoors at a specific time over a specific area. It includes the following parameters namely; wind, barometric pressure, precipitation (rain or snow) or temperature.
Zai pits	Zai pits are shallow, wide pits that are dug to collect and retain runoff to allow infiltration into the soil.

Annex 2: Strength, weaknesses, opportunities and threats to sorghum value chain.

Summary of the SWOT Analysis for sorghum value chain

Strengths	Opportunities
• Government of Kenya's commitment to the strengthening of the agriculture sector for increased food and nutrition security • Access to innovations and technology at the farm level, through the Kenya Agricultural and Livestock Research Organization (KALRO)in collaboration with non-governmental organizations, and private sector for improvement of mechanized operations • It can grow well in both high and low potential areas where maize cannot do well. • Good for fodder and silage making because farmers do not need to add molasses as they do when making silage. • Sorghum can do well in areas receiving adequate rainfall	• Stable government policies such Agricultural Sector Transformation and Growth Strategy 2019-2029 (ASTGS), flour blending regulations 2020, regarding socioeconomic and industrial development improving the agricultural sector, and increasing production, productivity and marketability • Reduction in excise duty for sorghum products causing increased demand for sorghum • Public and private sector partnerships between farmers and processors like the East Africa Maltings Limited in promoting sorghum production for blending of flour, malting and brewing of beer • Production of Aflasafe in the Country • Regional integration among the East African Community economies is a major opportunity towards establishment of a common market for consumer population • Availability of new and high yielding stress tolerant varieties • Manufacturing of aflasafe for management of aflatoxin
Weaknesses	**Threats**
• Seed recycling • High cost of production in Kenya makes sorghum products to be less competitive in the international market • Limited choices of available commercial varieties • Lack of information for farmers • Limited support and promotion by county governments • Weak farmer organization and corporative along sorghum value chain • Lean market of sorghum grain • Inadequate access to postharvest handling information	**Theats** • Unpredictable weather patterns due to climate change including; recurrent droughts, flooding, poor precipitation and distribution and high temperatures. • Pricing and marketing policies for sorghum and all other cereal crops are liberalized • Non-tariff trade barriers, such as roadblocks, multiple county access and levies hamper competitiveness domestically and regionally • 25% tariff on sorghum imports into Kenya from Southern Africa Development Community countries and other countries • Maize, rice and the introduction of horticultural crops are growing in popularity thereby taking away the land space that would be for sorghum production • Delays in the East African Community integration of economies by some member countries • High level of tannin reducing suitability for processing • Birds' menace especially the white variety • Agronomic practices practiced by farmers are not updated and followed by farmers. • Reduced sorghum production especially in Eastern region.

Annex 3. Avoidable cost as related to the decisions' time span.

Decision cost item	To be a sorghum farmer or not	To begin growing Sorghum	To keep the sorghum plot for another year
Land rent	X		
Establishment	X	X	
Weeding	X	X	x
Picking	X	X	x
Transport	X	X	x

X specifies variable (avoidable) cost.

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