CRAFT
Climate resilient value chains for improved livelihoods

Republic of Kenya
Ministry of Agriculture, Livestock, Fisheries and Cooperatives

Climate Smart Dry Bean Guide

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FOREWARD

Beans are the most widely grown pulses in Kenya. These pulses are mainly grown in counties of Eastern, Central, Rift Valley and Western regions. Dry bean Production is very important as it contributes significantly to the achievement of the Big Four Agenda of 100% food and nutrition security in line with various other policy frameworks within the Country; Food and Nutrition Policy, 2012; The Agriculture Sector Transformation and Growth Strategy (2019 -2029) and the Agri-nutrition Implementation Strategy (2020 – 2025) among others. With the rural to urban migration, high population growth and the increasing consumer awareness on health in relation to nutrition, a high majority of the population is consuming bean as a source of protein as most people reduce on animal protein intake. This has contributed to increased demand for beans in addition to what is consumed in the various institutions (Schools, Hospitals and the Hotels) that mainly consume beans as plant protein source; thus the ever rising increase in demand for the bean commodity that has maintained bean prices way above average.

Despite the raising demand for beans and the good market prices; production of beans has been humped by some challenges key among them climate change which has significantly affected production. Due to climate change some parts of the Country experience an increase in average temperature, more frequent heat waves, more stressed water resources and periods of heavy precipitation. The rising temperature would expose millions of people to drought and hunger. This calls for clear measure to be taken in order to deal with these threats.. The adoption of climate smart technologies, innovation and practices will help address these challenges and thus increase productivity per unit area, thus ensuring adequate production to meet market demand.

The Climate Smart Dry Bean manual is meant for use by extension service providers, state and non-state actors, lead farmers, community-based organizations working with farmers of similar interest in dry bean crop value chain. In the preparation of this manual effort has been made to present it simple for use by various stakeholders along the value chain.

The use of the manual by various bean value chain stakeholders will contribute to increased and sustainable bean production and effective marketing information systems. This will contribute towards achieving food and nutrition security, increased incomes, wealth and employment creation, social equality, business development and environmental conservation.

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The State Department for Crop Development and Agricultural Research and the CRAFT Project is providing an opportunity to disseminate the innovative climate smart and environmental friendly pre- and post-harvest integrated crop management (ICM) practices as well as presenting new technologies and innovations to address emerging challenges and opportunities in the bean producing counties of Kenya and beyond.

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ABBREVIATIONS AND ACRONYMS

AFA	Agriculture and Food Authority
CIAT	International Center for Tropical Agriculture
CCAFS	Climate Change, Agriculture and Food Security
CDD	Consecutive Dry Days
CIGs	Common interest groups
CORDEX	Coordinated Regional Climate Downscaling Experiment
CWDs	Consecutive Wet Days
CRAFT	Climate Resilient Agribusiness for Tomorrow
CSVs	Climate-smart villages
CSAT	Climate Smart Agriculture Technique
ETCCDI	Expert Team on Climate Change Detection and Indices
FAOSTAT	Food and Agriculture Organization Statistics
FEWS NET	Famine Early Warning Systems Network
ICHM	Integrated Crop Health Management
ICIPE	International Centre for Insect physiology and Ecology
IPCC	International Panel on Climate Change
LCG	London Capital Group
LGS	Length of the growing spell
KALRO	Kenya Agricultural & Livestock Research Organization
MAM	March-April-May
MoAL&F	Ministry of Agriculture, Livestock and Fisheries
OECD	Organization for Economic Corporation & Development
OND	October-November-December
NCGG	Netherlands Centre for Geodesy and Geo-information
NARS	National Agricultural Research Systems
GCMs	Global Circulation Models
GHG	Greenhouse gas
GDP	Gross Domestic Product
NGOs	Non-governmental organizations
RCP	Representative Concentration Pathway
SNV	Netherlands Development Organization
VMGs	Vulnerable marginalized groups
WHO	World Health Organization
WRSI	Water Requirement Satisfaction Index

1 INTRODUCTION TO COMMON BEAN

1.1 Background information

The common bean crops are differently known worldwide for its short duration in production. These pulses consist of types suitable to specific agro ecological zones; most wet areas, medium and dry regions. This enable adapting beans as suitable for modeling climate smart agriculture in each region since there are varieties fitting in specific different regions. The scientific term *Phaseolus vulgaris* (L.) refers to a series of beans namely: bush beans, climbing beans, semi-climbing beans, common beans, dry beans and dwarf beans while the green types are referred to as field beans, French beans, garden beans, green beans, snap beans or string beans. These are combined with a host of local names for each variety as nearly every community has its own naming. The dry bean is the most important food legume for direct human consumption in the world (WHO 2007). Production occurs in a wide range of cropping systems and environments, spanning regions as diverse as Latin America, Africa, the Middle East, China, Europe, the United States, and Canada. However, the highest per capita consumption in the world occurs in eastern Africa, especially in the Great Lakes Region. They also have a higher level of mineral content compared to other legumes (Karanja et al.2006). They have substantial amounts of micro-nutrients such as iron, zinc, thiamin and folic acid which are deficient in diets among the poor, particularly expectant mothers and children in Africa. Beans are also a major source of nutrients, especially protein, calories and micronutrients (Dwivedi et al., 2012). The legume is an important source of dietary protein in Kenya, Tanzania, Malawi, Uganda, and Zambia (Karanja et al. 2016).

In Kenya three distinct types are recognized namely; dry beans (common beans), French beans (green bean) and runner beans. The immature green pod of the French beans is the main market part and mostly grown by small and large growers mostly for the export market and elite local market. The French bean and runner bean market is tightly controlled by participating private sector entities in Kenya. The dry beans are ranked third, after irish potatoes which is second to maize in importance as major food crops in the country in terms of food security playing an integral part in mitigating climate change and food security approaches.

In Kenya, bean is a small-scale farmer crop given its short growth cycle (about 70 days) which permits production when rainfall is erratic. Common bean is often grown by women farmers mainly for subsistence and markets (Katungi *et al.* 2010). Also, being leguminous, beans harbor *Rhizobium* bacteria which fix free atmospheric nitrogen, thus helping in maintenance of soil fertility. The impact of climate variable crisis continues to present a bleak scenario for crop production, where dry bean productivity is precarious, export on this showing what need to be done on impact of production etc.

1.2. Importance of beans

Kenya is the seventh biggest global producer of common beans and the third leading producer in East Africa after Tanzania and Uganda. Beans are cultivated almost exclusively by about 1.5 million smallholder farmers on about a million hectares, with yields of about 0.72 tones/ha (One Acre Fund 2015; FEWS NET 2018). Agriculture contributes directly 25% and indirectly 27% to Gross Domestic Product (GDP), where dry beans are important as food security staples. The government of Kenya has outlined the importance of agriculture to the national economy, through the Kenya Vision 2030, the National Adaptation Plan (2015-2030) and the Kenya Climate Smart Agriculture Strategy 2017-2026 among other policy documents. The crop is grown in almost all regions in Kenya. However, Eastern, Nyanza, Central, Western and Rift valley are the major bean growing areas. A good number of local traders include beans on their shelves due to the local demand for all types of meals,

As for dietary advantage, recent improved varieties are being recommended to expectant mothers for consumption as they are rich in iron. Women groups knowledgeable of the varieties recommend these varieties to their fellow women. In beans a complete protein-energy and mineral-rich diet is available to low-income households. The whole family, inclusive of women and children benefit fully from beans production in provision of nutritional and food security (Fig. 1). In some communities' bean leaves serve as vegetable.

Figure 1. Women harvest bean leaves as vegetable (Source: 3blmedia.com)

1.3 Dry bean industry in Kenya

In Kenya, dry bean production has averaged 784,800 tons annually between 2015 and 2019 (Economic Review 2020). The major bean production counties are in Eastern, Rift Valley, Western and Central regions (Figure 2). In several counties such as Bomet, Bungoma, Nyeri, Machakos, Nakuru, Laikipia etc, dry bean is considered as an important food crop and is cultivated in over 50% of the total arable land under food crops (140,000 ha) in the two counties (NCG 2018; LCG, 2018). In these counties, bean production is carried out in diverse growing environments ranging from highland, midland and marginal potential zones. The yields are generally low, with an average of 0.72 tones/ha compared to other countries like Ethiopia (1.68) Uganda (1.61), Burundi (1.49) and Tanzania (1.0) (MOAL&F 2015). As a result of the low productivity and high per capita consumption of beans in Kenya, the country imports over 100,000 MT of beans annually mainly from Ethiopia, Tanzania and Uganda.

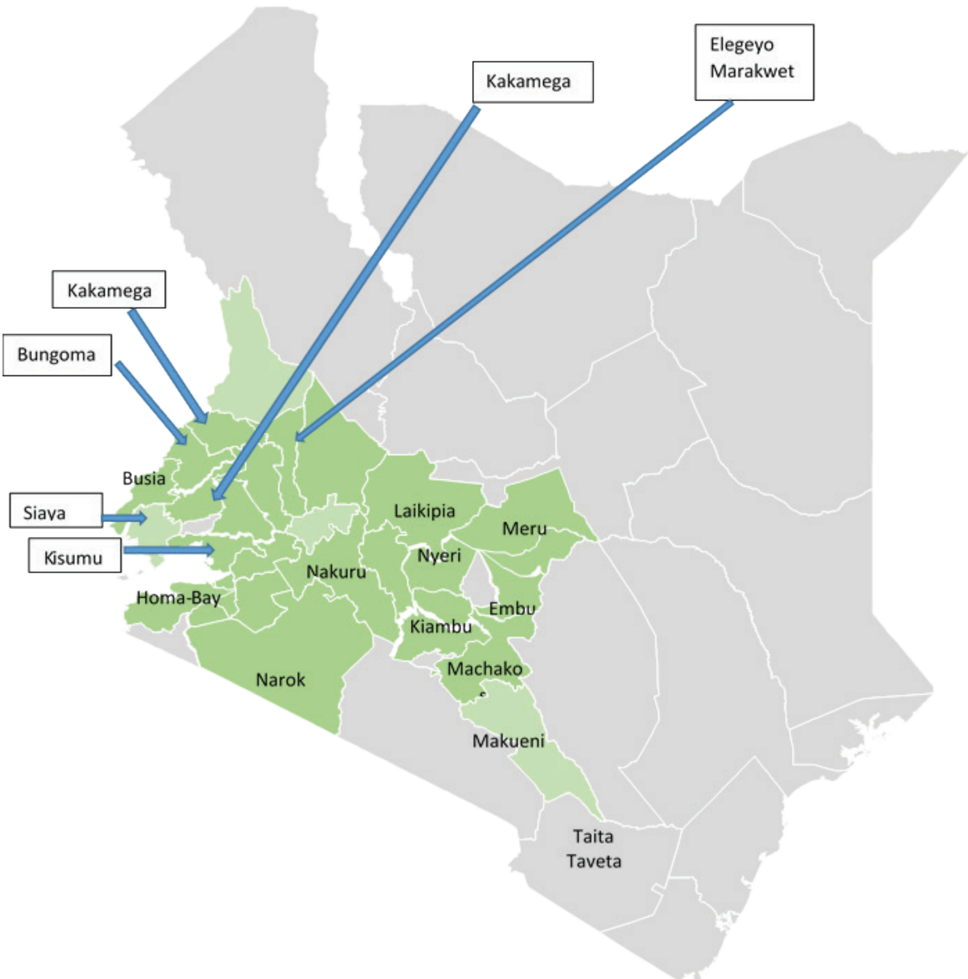


Figure 2: Dry bean production counties of Kenya (Photo: D. Mutisya)

Major constraints of dry bean production are due to increasing moisture stress as a result of climate change, low soil fertility and over cultivation with little addition of soil amendments, poor cultural practices and inadequate bean production technology transfer. Other problems are production of varieties with low genetic potentials, inadequate seed dissemination systems, lack of market information and infestations by arthropod pests and diseases. The National Agricultural Research Systems (NARS) consisting of Universities, Kenya Agricultural and Livestock Research Organization (KALRO) and international agencies like International Centre for Tropical Agriculture (CIAT) have developed various technologies to address these challenges. However, the adoption of these technologies by farmers remains low due to inadequate dissemination of the techniques and information. Overall, there are strong opportunities for bean Value chain in Kenya and beyond even with threats of climate crisis and other factors (Fig. 3).

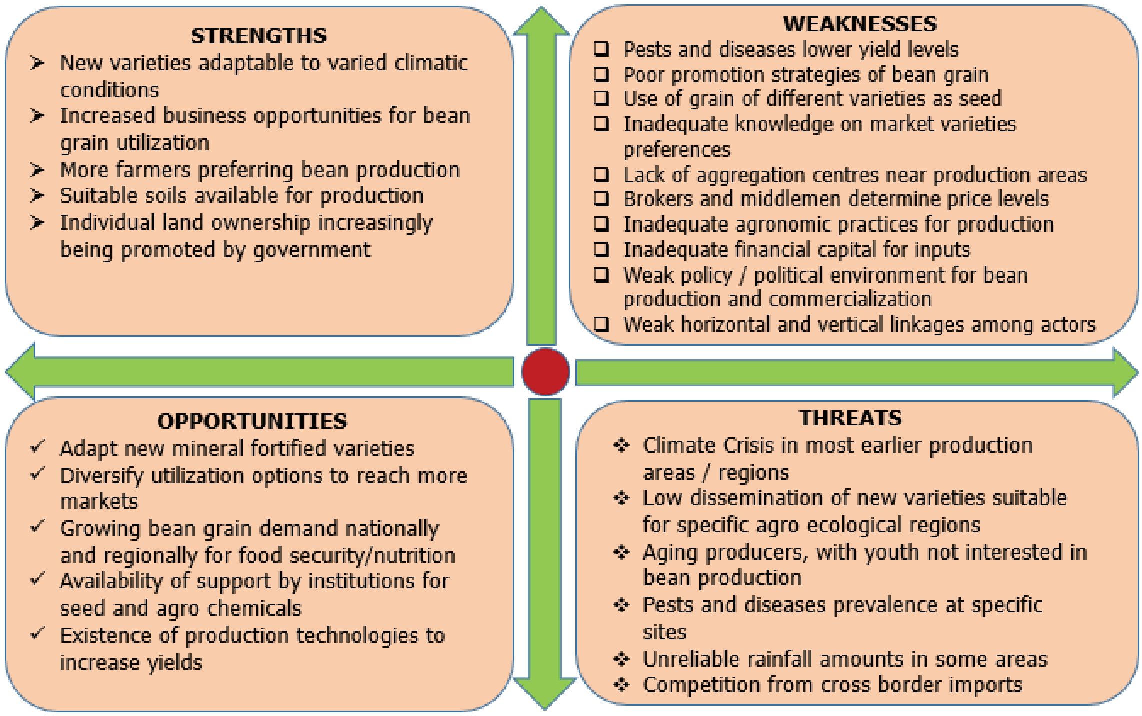


Figure 3: SWOT analysis for common bean crop production

2 CLIMATE CHANGE AND AGRICULTURE

2.1. Impact to dry bean

With the increased unpredictable and unreliable rainfall, occurrence of extreme heat, pest and disease manifestation, crop production and productivity has been declining. Like many crops, dry beans are going to be affected by changes in greenhouse gases, temperature and precipitation, low distribution to demand areas as well as increased diseases and pests at pre- and-post harvest levels.

2.2. Impacts on regional production

Human activities have contributed partly to global climate change leading to huge social and economic costs which demand big environmental inputs to cope with the negative effects (OECD, 2001, IPCC, 2001). Current data demonstrates that climate is changing globally and that human induced greenhouse gas (GHG) emissions, carbon sink are causing an increase in global temperatures that creates changes in the earth's climate. The phenomenon multiplies the challenges of achieving the needed growth and improvements in agricultural systems and its effects are already being felt, in the form of reduced yields and more frequent extreme weather events, affecting crops and livestock productivity alike (PABRA 2010; Willen Bockel 2012).

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

i) Greenhouse gas emissions through burning fossil fuels, cutting down trees and farming activities. This leads to Global warming (The current global average temperature is 1.0ºC higher than it was in the late 19th century (IPCC 2019)). Kenya's total GHG emissions in 2013 were 60.2 million metric tons of carbon dioxide equivalent ($MtCO_2e$), totalling 0.13% of global GHG emissions.

ii) The agriculture sector emitted 62.8% of total emissions, followed by the energy sector (31.2%), industrial processes sector (4.6%), and waste sector (1.4%) in the same period

iii) Deforestation reduces vegetation cover which provides carbon dioxide sink; Kenya forestry cover is less than 10%

iv) Industrialization significantly contributes to burning of fossil fuels which lead to increased emission of greenhouse gases.

These coupled with the expected exponential increase in human population (estimated to be 95 million by 2050), poses a serious threat to Kenya's future development.

2.3. Climate change projection

As part of the Climate Resilient Agri-business for Tomorrow (CRAFT) project in East Africa, a climate projection was performed for Kenya, Uganda and Tanzania using a high-resolution data from the Coordinated Regional Climate Downscaling Experiment (CORDEX). The climate projection work was based on two validated regional climate model data that are dynamically downscaled from four Global Circulation Models (GCMs), which has a reasonable skill in East Africa. The GCMs projections were forced by the Representative Concentration Pathways (RCPs), which are prescribed greenhouse gas concentration pathways (emission) trajectory and subsequent radiative forcing by 2100. The climate projection work in the CRAFT project is based on two RCP scenarios, RCP4.5 and RCP8.5 that are representatives of mid-and high-level of emission scenarios, respectively. The following sections (2.3.1 to 2.3.2.2) summarizes the climate projection work done under the CRAFT project for the common beans growing areas of Kenya.

2.3.1. Temperature changes

Temperature analysis demonstrate change in the last six decades, hence necessitating need to project temperature levels in dry bean production regions in Kenya.

2.3.1.1. Future temperature projections

During both the first March-April-May (MAM) and second October-November-December (OND) rainy seasons, temperature in the 2030s is expected to rise by about 1.4°C to 1.8°C in the common beans growing regions of Kenya (Fig. 5 and 6). However, the projection model shows that temperature in the 2050s is expected to rise by about 1.8°C to 2.8°C in Rift Valley, Central and Western common beans growing areas of the country during the first and second rainy seasons.

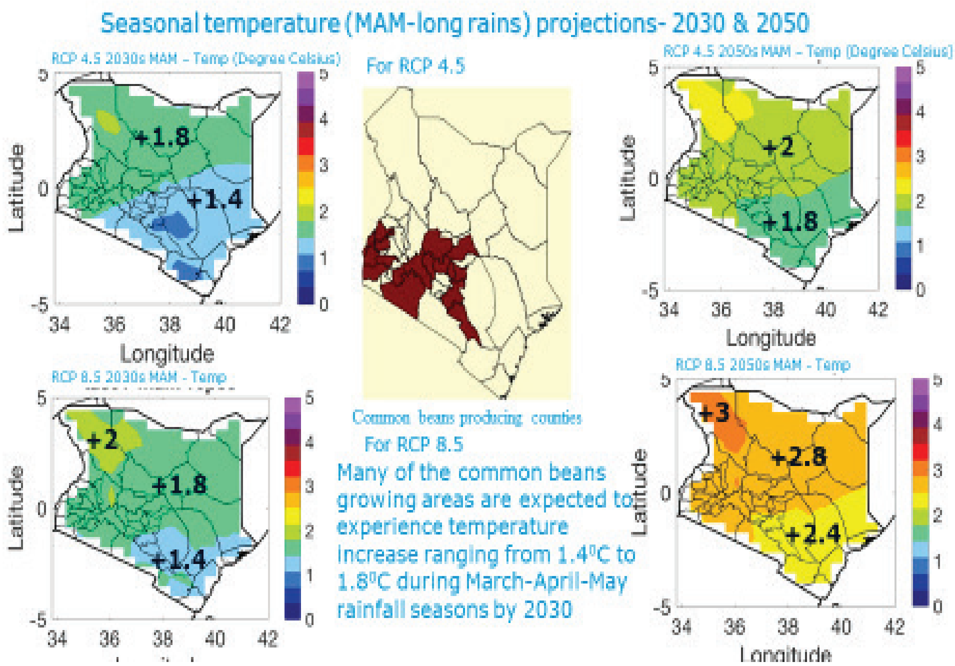


Figure 4: Projected seasonal mean changes in temperature-MAM-long rains- for 2030s (Left) and 2050s (Right) under the RCP 4.5 and RCP 8.5 (Source: CRAFT project 2020)

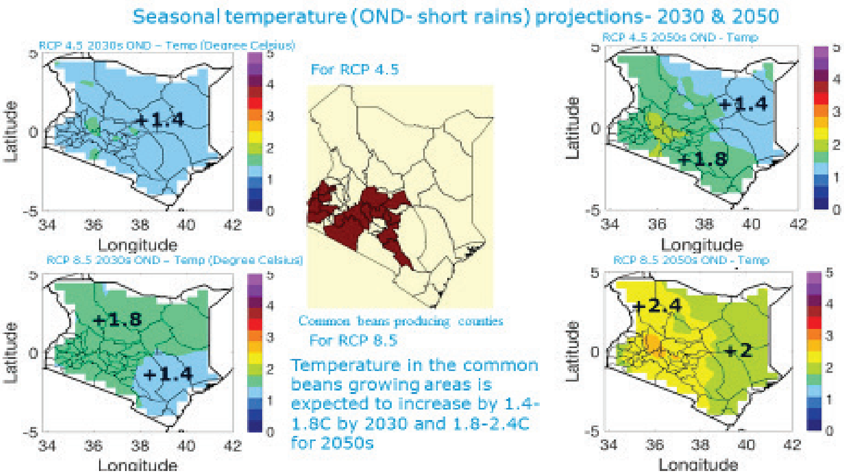


Figure 5: Seasonal temperature projection for the OND- short rain season for 2030 and 2050 under RCP 4.5 and RCP 8.5 (Source: CRAFT project 2020)

2.3.2. Projection for rainfall

The seasonal mean rainfall in the first rainy season of March-April-May (MAM) is projected to slightly decrease in the western, central and south Rift valley regions of the common beans growing areas by about 10% in both scenarios (RCP4.5 and RCP8.5) and for 2030s and 2050s (Fig.6). However, the seasonal rainfall over the south-western (regional map) growing regions is projected to slightly increase by about 20-25%. Overall, no much yield change of beans is expected to the slight decrease in western and Rift Valley by 10% rainfall amount. In the south-western region bean yield will positively increase with the enhanced rainfall amount of 20-25%.

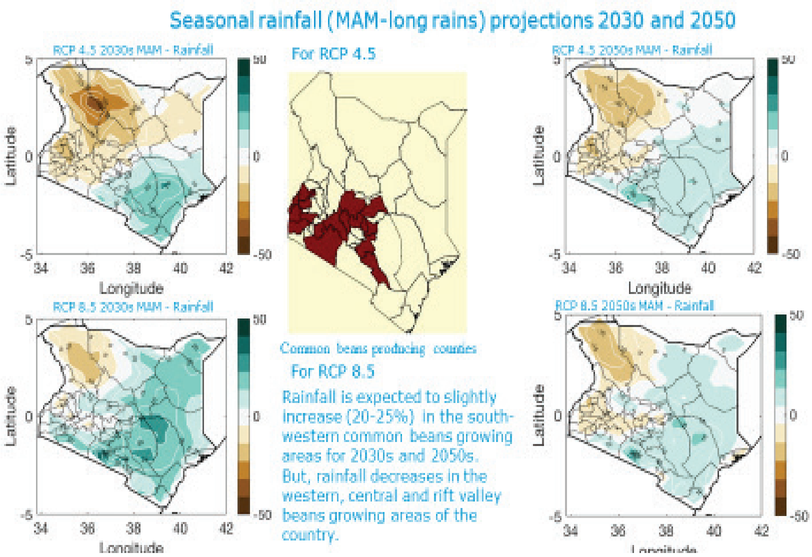


Figure 6: Projected seasonal mean changes in rainfall MAM-long rains -for 2030s (Left) and 2050s (Right) under the RCP 4.5 and RCP 8.5 (Source CRAFT 2020)

On the other hand, the seasonal mean rainfall in the second rainy season of October-November-December (OND) for 2030s and 2050s under RCP4.5 and RCP8.5 show that rainfall is expected to increase by about 20-30% in the south-western growing areas of Kenya, especially during the 2050s (Figure 7). However, the seasonal rainfall in the second rainy season over the western, central and south rift valley common beans growing areas is expected to slightly decrease (5-10 %). The slight rainfall decrease will likely not cause much bean yield reduction these areas receive excess amount of rainfall.

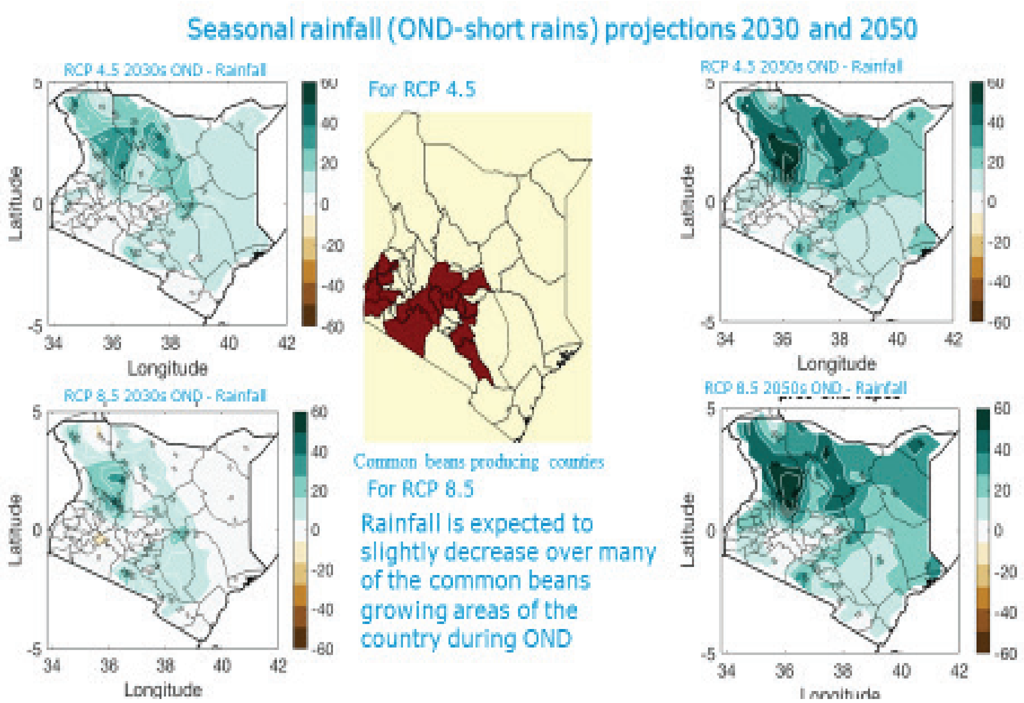


Figure 7: Projected seasonal mean changes in rainfall OND-long rains -for 2030s (Left) and 2050s (Right) under the RCP 4.5 and RCP 8.5 (Source CRAFT 2020)

1.3.2.1. Onset and length of growing spell

The assessment and prediction of the onset and cessation dates, and length of the growing spell of a rainy season is a very crucial element to the agricultural activities in Kenya, whose agriculture is mainly dependent on the distribution and amount of seasonal rainfall. Predictions show that early onset of the seasonal rainfall is expected in most of the south-western common beans growing areas of Kenya by about 10 days (Fig. 8). On the other hand, the onset of rainfall is expected to slightly delay over the western common beans growing areas of the country.

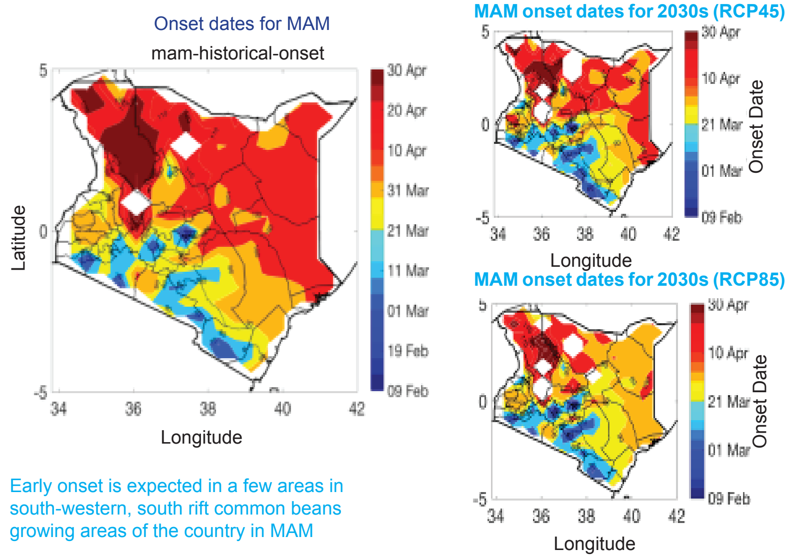


Figure 8: Rainfall onset days for the MAM rainy season for 2030 for RCP 4.5 and 8.5 (Source: CRAFT project 2020)

Similarly, the length of the growing spell in the south-western common beans growing area of Kenya is expected to increase by about 10 days (Fig. 9) suggesting a late cessation for the region. The length of the growing spell over some of the western common beans growing areas of the country is expected to slightly decrease suggesting an early cessation of the season in the region.

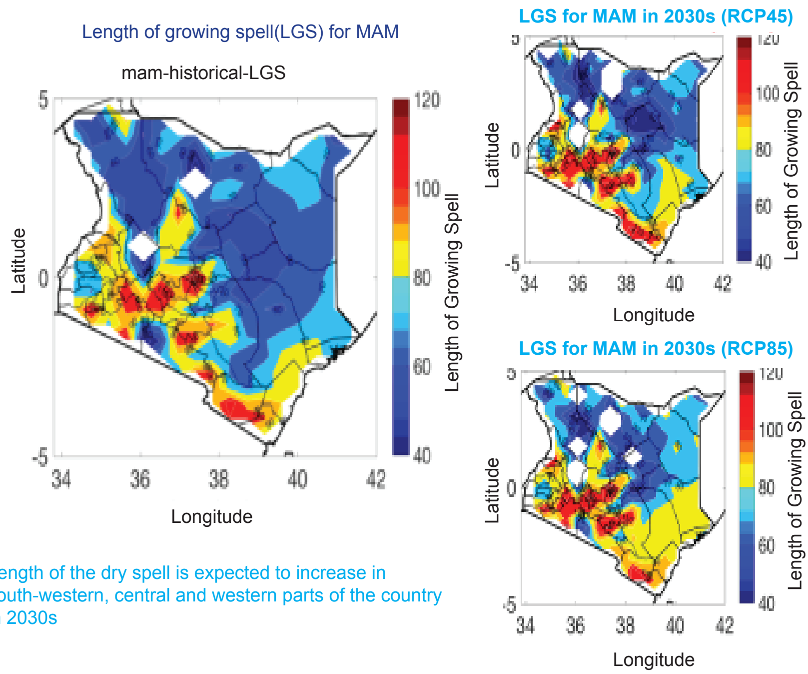


Figure 9: Length of the growing spell (LGS) for the MAM season for 2030 and 2050 (Source: CRAFT project CRA report

2.3.2.2. Projections of extreme rainfall

Precipitation indices such as consecutive dry days (CDD) and consecutive wet days (CWD) are used in the CRAFT project based on the definitions recommended by the Expert Team on Climate Change Detection and Indices (ETCCDI). These indices have been widely used in the detection, attribution, and projection of changes in climate extremes (Duku et al.2020). The CDD has been used as a useful indicator for enhanced dryness and high risk for seasonal drought whereas CWD has been a key indicator of extreme precipitation that could lead to flooding.

The projection of the longest consecutive dry days (CDD) show that dry spells will likely decline in the 2030s and 2050s over the south-west common bean growing areas especially in the second rainy season of the 2050s by about 5 days (Fig.10 and 11). The CDD in the first rainy season for both the 2030s and 2050s is projected with no significant change in the south-west common bean growing areas of the country, signifying the probability of less drought in the region.

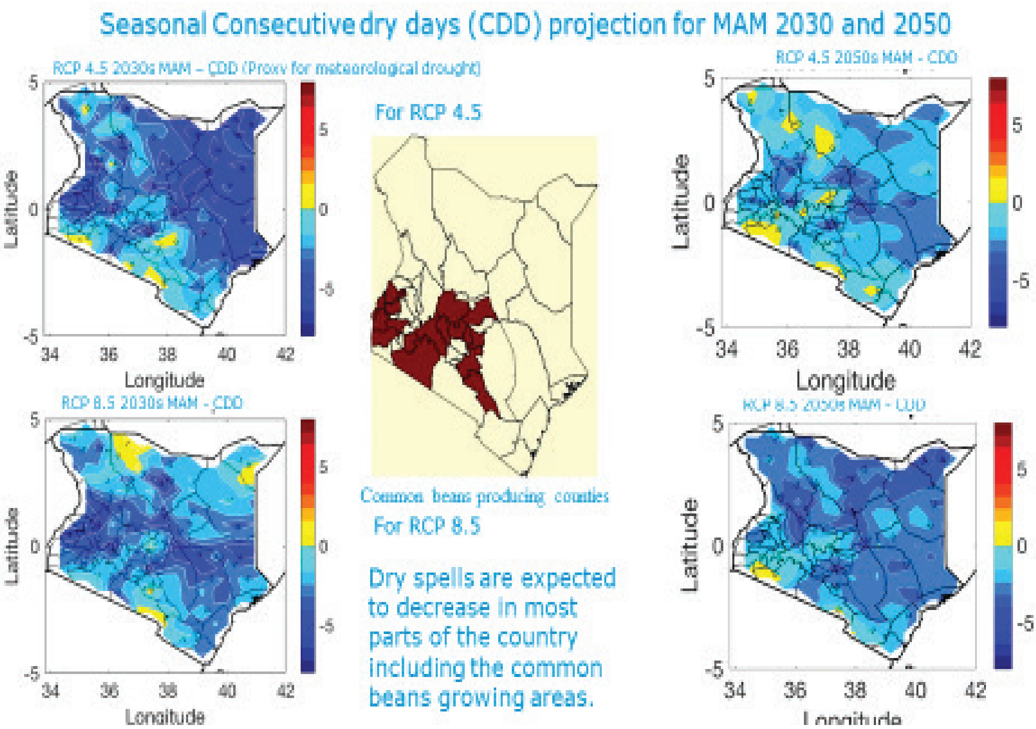


Figure 10: Projected seasonal consecutive dry days for MAM for year 2030 and 2050 in south-western region (Source: CRAFT project 2020)

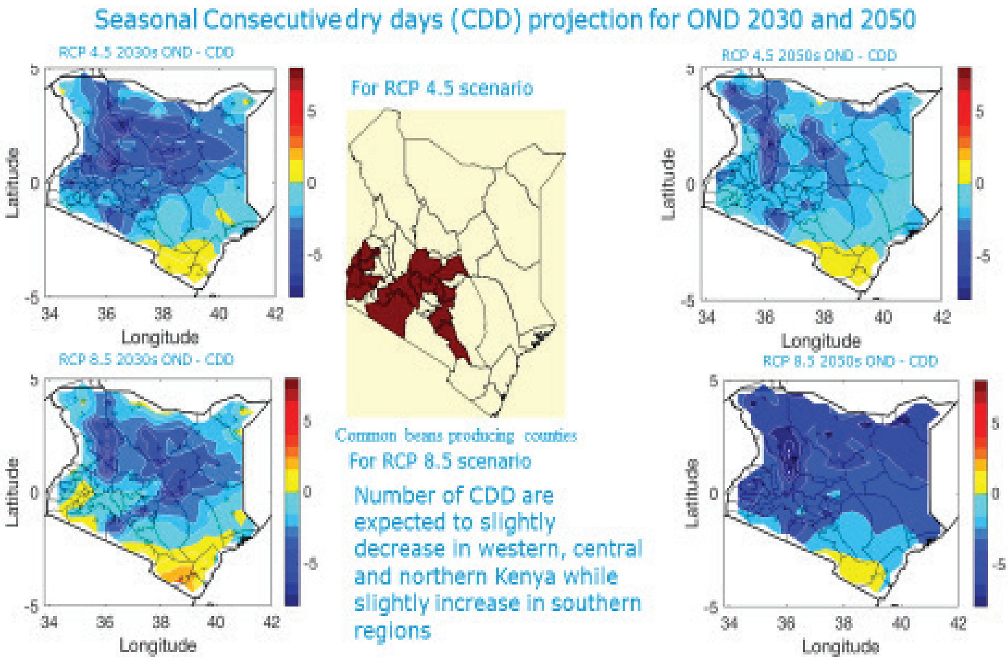


Figure 11: Projected seasonal consecutive dry days for OND for year 2030 and 2050. (Source: CRAFT project 2020)

Figure 12 show projection of wet days during the MAM 2030 and 2050s period will decrease in west-

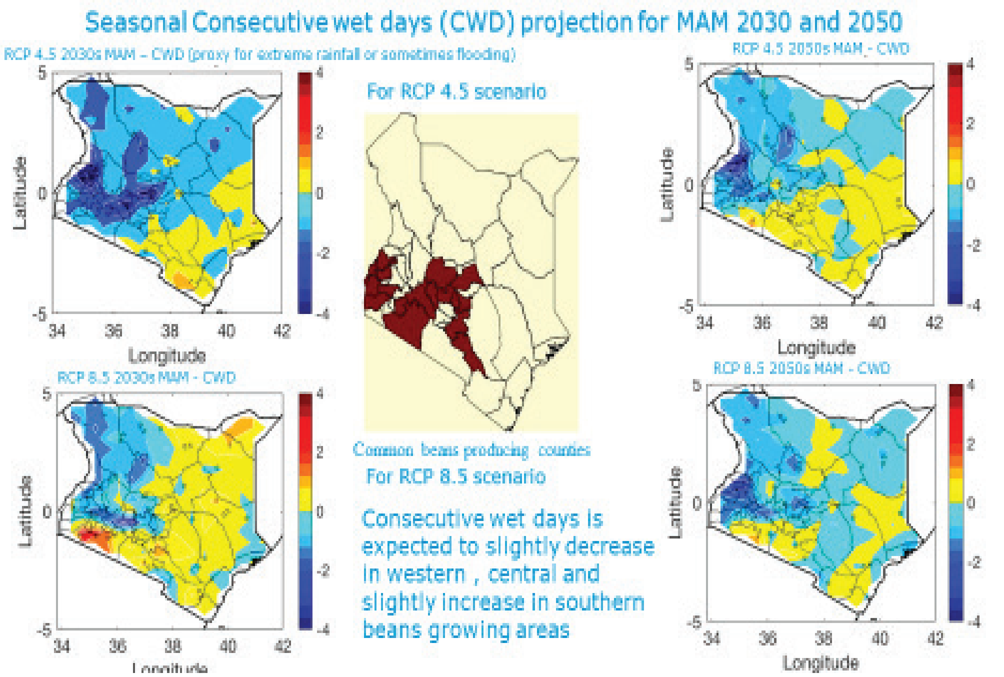


Figure 12: Projected seasonal consecutive wet days for MAM for year 2030 and 2050. (Source: CRAFT project 2020)

Wet days in the OND season will decrease in south-western and south rift by 2030s but increase by 2050s in all the bean areas (Fig.13).

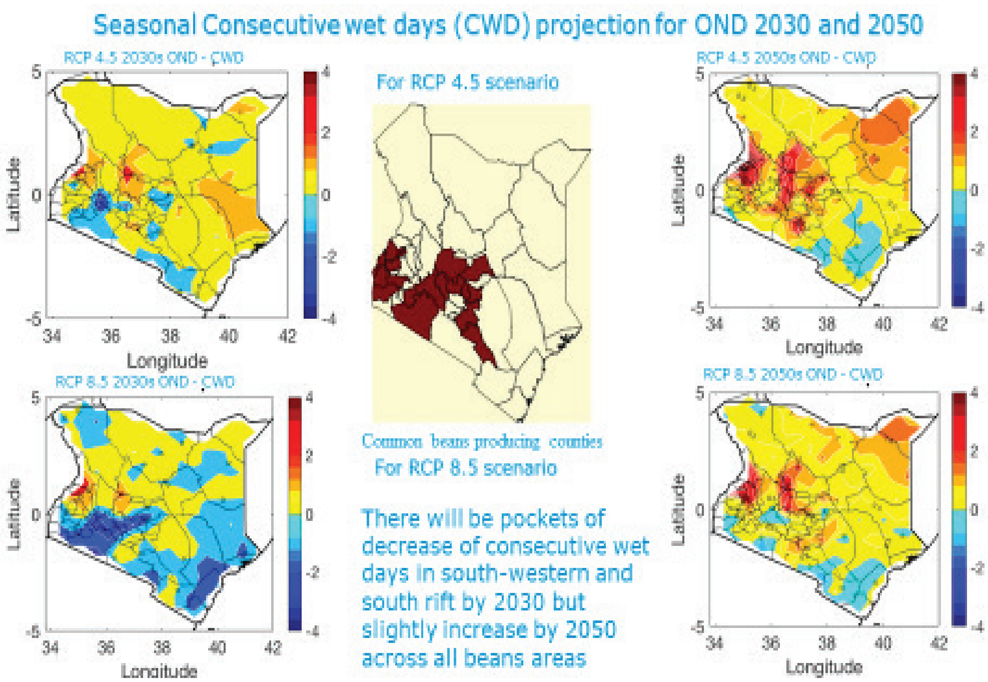


Figure 13: Projected seasonal consecutive wet days for OND for year 2030 and 2050 (Source: CRAFT project 2020)

For the small-scale bean farmers to be able to mitigate and cope with risks and exploit opportunities presented by climate change, it will be critical for extension services providers to:

- Facilitate famers to adapt through use of climate smart practices and technologies
- Incorporate climate information into agricultural extension services
- Engage farmers and the extension services to consider:
    - Climate risks in business planning and decision-making
    - Consider opportunities for managing climate risk – e.g. adaptation investments and climate-oriented insurance for bean production
    - Microclimate management in bean agro ecosystems– as one of the adaptation measures that has mitigation benefits
    - Get skills for general bean crop management; where activities of operations ought to be proactive based on the stage of production or processing. Enquire about when spraying against certain bean pest or disease has to be done and what product is reliable.
    - Plan well on the marketing channel of the bean grain, as this should be done before damage in store and when prices are optimal to get desired returns.

2.4. Climate Change Risks

2.4.1. Risks to chain value players

Bean production risks include lack of right seed, choice of inappropriate varieties for a particular season, insufficient rainfall amount for crop development, poor crop management, floods and lack of suitable marketing channels. Table 1 below shows some risks attributed to various players involved in different value chains of common bean.

Table 1: Risks related to suppliers of inputs, producers/ processors and bean traders

Nodes/ Actors	Risk	Impact
Input dealers	- Heavy rainfall	Impaired mobility to supply areas Floods lead to poor access
Producers	- Drought	Poor germination, stand count loss Some increased pests/diseases Crop failure/ yield loss
Aggregators/ Traders/ off-takers	Heavy rainfall	Logistical challenges to get grain Post-harvest losses
Processors	Heavy rainfall	Disruption of chain supply

Source CRAFT Climate Risk Assessment Report 2019

2.4.2. Climate change projected impact

The impacts of climate change on bean production in the targeted counties is expected to differ depending on the growing season. These impacts were modelled using the Water Requirement Satisfaction Index (WRSI), which is an indicator of crop performance based on the availability of water to the crop during the growing season. The WRSI is directly correlated with yield and changes are indicative of changes in yield. The WRSI results (Fig.14) for beans show that during the MAM season, increasingly less water (rainfall and soil moisture) will be available to meet bean crop water requirements regardless of the climate change scenario in the targeted counties. Water availability for bean production is likely to reduce by up to 10% in large areas under RCP8.5. Similar magnitudes of reduction are expected even under RCP4.5. In other words, irrespective of the climate change scenario, bean water stress is likely to increase and bean yields are likely to decrease correspondingly.

However, for the OND growing season, water availability for bean production as indicated by WRSI is likely to increase in all growing areas. Water availability is likely to increase by up to 20% under RCP8.5 in the targeted areas. Similar magnitudes of increase are likely under RCP4.5 as well. In other words, crop water stress is likely to reduce, and bean yields are likely to increase accordingly during the OND season.

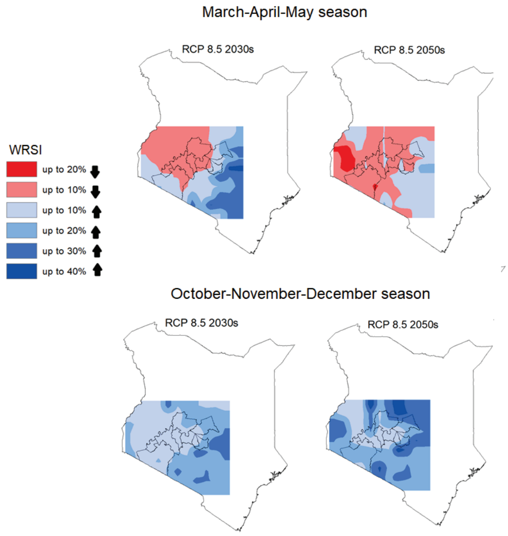


Figure 14: Changes in water availability (WRSI) for common beans production due to climate change (RCP8.5).

2.5 Climate Information

2.5.1. Key Decisions due to Climate Information

For farmers and extension agencies who provide support services in terms of crop management advisories have to consider key decision points impacted by climate information as provided in Table 2.

Table 2: Key decision points impacted by climate information

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

(Source: Madhavan and Rengalakshmi 2015: MoAL&F 2015; Kenya Soil Survey 2019)

The most useful weather forecast information that can assist farmers in making decisions on their bean production is usually based on the following:

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

Bean producers use agro meteorological information for decision-making with a range of scales that can vary from several days to the entire cropping season, or inter-annual time periods. These decisions relate to the choice of bean varieties as for demand in markets; with the choice of cultivar (early or late flowering); pest and disease control options; timing of the harvest; irrigation scheduling; the area planted with a given crop (and/or rotation of fields); timing and amount of tillage and planting rates. Strategic planning and marketing decisions for beans mostly use climate information for the following year to plan early.

3 CLIMATE SMART BEAN PRODUCTION

3.1. Why Climate Smart Agriculture in bean value chain?

With Kenya population being projected to be 95 million by 2050, new production techniques are required to cope with climate change crisis and provide food security to all citizens. Furthermore, land sizes will continue to dwindle resulting to less and less land for cultivation in most areas. In dry bean production, there is an assured reasonable yield for specific regions of optimum rainfall distribution and with adaptable techniques along the crop value chain. Nevertheless, ways of mitigating extremely dry and wet periods need to be addressed

Bean agro ecological requirements are medium rainfall amount of 600-1400mm per season being evenly distributed during the production period. Optimal temperature range is 20-28 °C, with humus rich soil of loam sand to light clay. Soil pH levels requirements are 5.5-8.0 where good drainage is important to prevent root rot. The altitude above sea level is usually in the range of 1000-2100m usually in the midland and the highland regions. Where shortfall occurs, climate smart techniques are adapted to correct and get better crop performance.

3.2 Considerations for Ecological Modification

If the desired ecological suitability is not achievable in an area, climate smart techniques ought to be adapted for better yields. The desirable Climate Smart Agriculture (CSA) practice starts by selecting a suitable bean variety for the prevailing ecological conditions. Unless there is adverse weather conditions a farmer should strive to produce 10 to 18 bags (90Kgs) per acre based on the variety. This production is dependent on the following factors: climate change, choice of seed variety and its ecological suitability (Fig. 15), quality of seed, seed sources, planting site, soil and water conservation techniques, land preparation, planting methods and spacing, weed-pest and disease management, harvesting and processing methods.

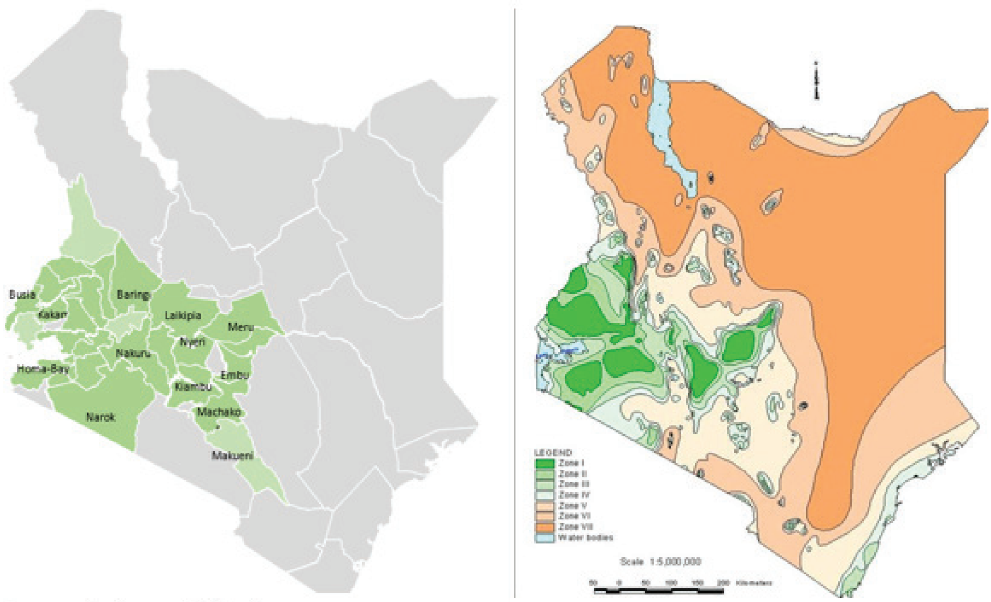
(a) Fewer pods– low productivity **(B) More pods on this plant – higher productivity**

Figure 15: Comparative pod numbers pre-cursor to high yield levels

Various risks associated with bean production occur in each region. In some high altitude areas high amount of rainfall might result to field floods washing away bean crop while in the low midlands drought effects would lead to flower abortion and yield loss (Table 3). Figure 16 shows counties suitable for bean production as well as a map showing the agro-ecological zones in Kenya.

Table 3: Risks associated with bean production in specific regions

Region/ Zones	Risk	Impact	Mitigation CSAT
Highlands (Zone II), Central and Rift Valley regions	Floods	Washing away bean crop	Minimum tillage, drainage channels.
Midlands (Zones III-IV), both western and eastern regions	Floods/ droughts	Either washing of crops by floods or moisture stress by droughts	Floods; drainage channels Droughts; Tied ridge to conserve soil water.
Low lands (Zones V-VI), Eastern regions	Droughts	Moisture stress, yield loss	Tied ridges constructed to conserve soil water Increased manure fertilization.



Bean production counties/ regions

Agro ecological zones in Kenya regions

Figure 16: Guiding agro ecological zones for preparedness with climate smart agriculture techniques for mitigation

(Source D. Mutisya 2021, Kenya Survey 2019)

A quick view of Table 4 below shows which months of the year bean is produced in different regions of Kenya as well as the different crop stages per month, which calls for specific activities

Table 4: Common bean production months in Kenya in varied regions

Region	Season	Bean production period in different regions											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Eastern Kenya	Long Rains			Planting	Planting	Vegetativ	Pod-forming	Grain harvest					
	Short Rains	Pod-forming	Grain harvest								Planting	Planting	Vegetativ
Western	Long Rains												
Central	Long Rains			Planting	Planting	Vegetativ	Vegetativ	Pod-forming	Pod-forming	Grain harvest			
Rift Valley	Long Rains				Planting	Vegetativ	Vegetativ	Pod-forming	Grain harvest	Grain harvest			

Key: Planting, Vegetativ, Pod-forming, Grain harvest

3.3 Selection

Table 5. Trend of bean production in Kenya from 2014 to 2019

From 2014 up to 2019, there has been a steady bean production in the country as shown in the table below

Crop	Area (Hectares)/ Production in Tons	2014	2015	2016	2017	2018	2019
	Area (Hactares)	1,060,645	1,212,758	1,158,071	1,180,784	1,149,985	1,188,678
Beans	Production (Tons)	625,496.9	933,456	722,761.4	778,335.9	765,977.3	770,177.3

Note. Statistics to provide with the projections

3.3 Selection of bean variety

The selection of a bean variety is very critical in mitigating climate change effects and also a determinant of how much a farmer harvest. Some varieties take a short period to mature while others take longer. Farmers from drought prone areas should go for early maturing varieties while those in areas with plenty of rainfall should grow late maturing varieties.

Farmer's also need to ask themselves why they prefer planting particular bean varieties. For subsistence farming, farmers can plant as many varieties as they wish as these will yield differently in times of climate stress and also maintain diverse seed choice in the farming community. Agribusiness farmers will be attracted by high yielding varieties and quality of grain for the market. They will consider how much they will have invested in the bean production and overall profit after subtracting all related costs (see Appendix 1).

3.4 Bean Seed quality and access

Seed is an essential component in agricultural production. Clean seed is a basic resource for crop production and has a direct contribution to harvest attained. A good quality bean seed should have the following characteristics (Fig. 17):

- One colour pattern of seed
- One variety of seed
- Viable and high vigour
- No dis-colouration of seed
- Not shriveled seed
- Disease-free/Clean seed
- Without insect damage on the seed
- Seed not broken/ whole seed
- Without trash, straw, dirt, soil or stones

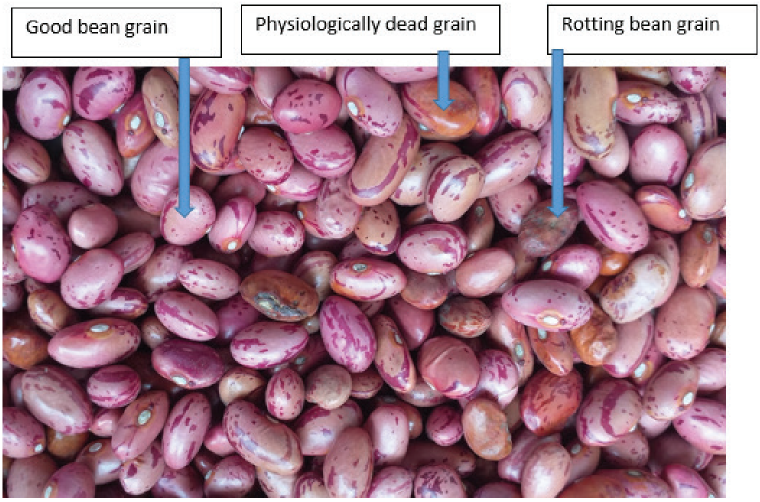


Figure 17: Farmers bean seed with good and bad seed

Bean seed can be sourced from two seed systems a) Informal and b) formal system.

The formal seed system is a framework of institutions linked by their involvement in or influence in breeding, multiplication, processing, marketing and quality control. The framework includes agricultural research institutions, seed companies, regulatory agents and seed stockists.

The informal seed system supplies 90% of most of the open-pollinated varieties seed in the country through the 2 systems namely: assisted informal seed movement and self-driven informal system.

3.4.1 Assisted informal seed movement

The system involves close links between farmers, the Ministry of agriculture extension, research and Non-Governmental organizations (NGOs). Its main targets are resource-poor farmers or farmer groups like common interest groups (CIGs), vulnerable and marginalized groups (VMGs) and farming communities that lack improved open-pollinated varieties seed at planting. Most of the activities revolve around seed bulking. Normally the preferred red varieties are those that fetch good price at the target local market.

3.4.2 Self-driven informal system

FA system where farmers have mechanisms of seed multiplication and transfer which are not organized in any particular way. It has evolved over many years and farmers' initiatives play an important part and include known and unknown seed sources (grain stores). This system involves only one (farmer's) seed type preference which they plant, utilize and trade with.

3.5 Bean Seed Access

Farmers can access seed either through the informal seed system or the formal seed system (Fig.18). There is need to use a combination of informal and formal seed system as in Figure- 18 for a farmer to be climate smart with regard to seed access. A farmer needs to identify a climate smart variety and get initial seed either from a research institution or stockist.

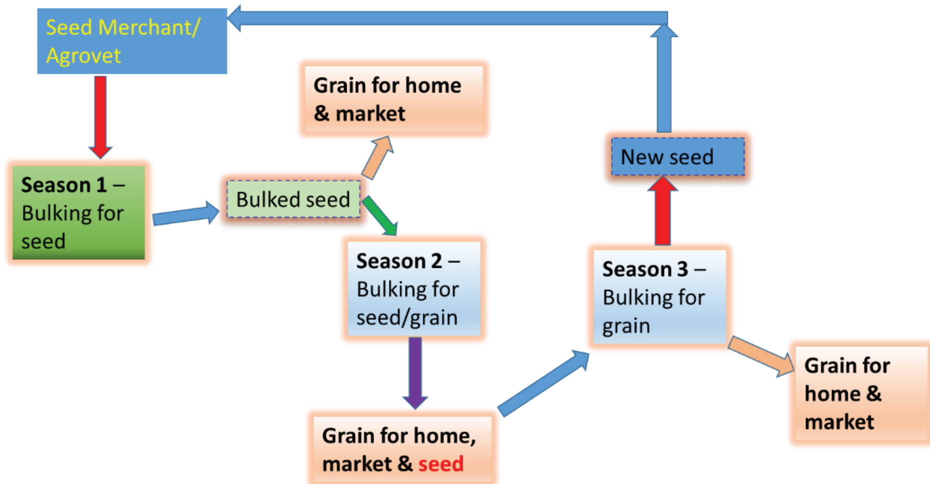


Figure 18: Combining formal and informal seed access (Source: KCSAP community seed bulking manual 2020)

3.6 Bean Varieties

The various bean varieties are classified by their growth habit mainly bush beans, semi-climbers and climbing beans. These are then classified on their growth capability in various agro-ecological zones and in relation to climate challenges. The main classification being drought tolerant beans varieties for medium and high potential areas.

There are several old and new officially released bean varieties. There are also other bean varieties that entered the country through the grain market and have been adopted by farmers for production. This manual concentrates on officially released bean varieties that have a known seed system and farmers can access such seed. Kenya has about 33 bean varieties released in the last 10 ten years with majority not having a defined seed system.

The following section gives a brief description of the various bean varieties and their special attributes with part of the literature adapted from Variety, Characteristics and Production Guidelines of Traditional Food Crops complied by D. Karanja et al 2006.

3.6.1 Bush beans

3.6.1.1 Drought tolerant Beans

In Kenya, some bean growing areas are classified as hot dry lowlands and cold dry highlands and farmers require varieties that would perform very well in these drought prone environments. The following varieties perform well across both environments and arranged in order of official release to farmers with Mwitemania as a pioneer drought tolerant bean released in the 1970s. Farmers may need to test which variety gives them the highest yield and higher gross margin in their region. See attributes of bean varieties in the Table 5 below to choose the best climate compliant variety for their region.

Table 5: Attributes of drought tolerant bush beans

 Mwitemania (GLP92): Pinto	• One of the oldest drought tolerant bean variety • It's a pinto bush bean • Flowers in 30-35days • Flowers are pinkish white • MaturesMatures in 70-90 days • Grain is beige with brown, medium size and elliptic in shape • Potential yields 1200-1500kg/ha (5-7 bags/acre) • Grow in lowlands and medium altitude zones • Seed rate of 30kg per acre
 KATX56	• A red kidney bean • A determinate plant with an average height of 35-40cm • Flowers in 30-35 days • Flowers are pinkish white • Has uniform flowering and maturity • Matures within 60-65 days • Grains are red kidney, medium size and elliptic • Potential yields are 1400-2000kg/ha or 7-10 bags/acre • Has tolerance to rust, charcoal rot, CBMV and tolerance to angular leaf spot/common bean mosaic virus. • Grains cook fast and tastes sweet.
 KAT B9	• A small red bean • A determinate plant with an average height of 35-40cm • Flowers in 30-40 days • Flower colour is white to pink • Has a uniform flowering period. • Matures within 60-65 days • Grain is brilliant red, medium and circular to elliptic • Potential yield is 1400-1900kg/ha or 7-9 bags/acre • Tolerant to common bean mosaic virus and rust; and has field tolerance to several fungal diseases
 KAT B1	• A green yellow bean • A determinate plant with an average height of 35-40cm • Has light pinkish flowers • Flowers within 30-31 days • Matures in 60-65 days • Grain is greenish yellow, medium in size and circular to elliptic in shape • Potential yield 1200-1600 kg/ha or 6-7 bags/acre • Grains are tasty and low flatulence. • Tolerant to rust, common bean mosaic virus (CBMV), angular leaf spot and bacterial blight • Highly tolerant to heat and grows well under tree/banana shades

 KATX69	• A red mottled bean • A determinate plant • Flowers in 30-35 days • Has white flowers • Matures within 60-65 days • Red mottled, medium, elliptic kidney shaped grain • Potential yields are 1400-2000kg/ha or 7-10 bags/acre • It is tolerant to rust common bean mosaic virus (CBMV), angular leaf spot and charcoal rot
 Miezi Mbili (Photo: Simlaw Seed Company)	• A sugar bean • It is a bush variety. • Has pinkish flowers • Flowers in 38-46 days. • Matures in 75-85 days. • Has yellow to beige colouring (red speckled sugar), medium grain type • Yield 650kg-750kg per acre • Seed rate 30kg / acre • Tolerant to floury leaf spot, halo blight, angular leaf spot, anthacnose, bean common mosaic virus and common bacterial blight
 KATRAM (KAT RM01)	• A red mottled bean • Drought tolerant • Has pinkish white flowers • Flowers in 30-40 days • Maturity days in 60-70 days • Red mottled, elliptic grain type • Seed rate of 24-30kg/ acre • Spacing of 50×10cm. • Yields 1500-2000 kg/ha (6-9 bags/acre) • Uniform flowering and maturity • Highly resistant bean Rust (Bean Common Mosaic Virus (BMV) and Bean Common Mosaic and Necrotic Virus (BCMNV)
 Nyota (KAD 02)	• A red mottled bean • A drought tolerant variety • Grow in cold dry highlands • Determinate bush bean • Has pinkish white flowers • Flowers in 30-40 days • Has a uniform flowering period • Matures in 60-70 days • Red mottled, medium, elliptic grain type • Yields 1400-2000 kg per ha (6-9 bags per acre) • Brilliant red mottled grain • High levels of iron and zinc • Tolerant to several diseases rust, CBMV, Angular leaf spot

3.6.1.2 Root rot tolerant beans for medium and high potential areas

The beans in this section are bred to tolerate the root rot disease that is prevalent in medium and high rainfall areas of Western, Northern Rift and Central Kenya.

Table 6: Attributes of root rot tolerant beans

 KK15 (MLB 49/879)	• A black root rot tolerant bean • A semi-climber • Has pinkish white flowers • Flowers in 40-50days • Matures in 80-90 days • Potential yield 1800-2000 kg/ha or 8-9 bags/acre • Black grain that is circular to elliptic shaped • Grain has high zinc levels • Grain is tasty when cooked
 KK Rosecoco 194 (Photo Dr Reuben Otsyula)	• Determinate erect bush type • Has pinkish white flowers • Flowers in 35-40 days • Matures in 75-80 days • Red mottled. Medium, circular to elliptic grain type • Yields: 1800 -2,000 kg per ha (8-9 bags/acre) • Is resistant to *Pythium* root rot and *Fusarium* root rot • Early maturing • Cooks fast, swells, very tasty with no gas
 KK red 16 (Photo: Dr Reuben Otysula)	• Indeterminate bush bean • Flowers about 35 days • Flower colour is pink. • Matures within 75 days • Grain is red, small circular to elliptic • Potential yield is 1800-2000kg/ha or 8-9 bags/acre • Is resistant to *Pythium* root rot and *Fusarium* root rot • Cooks fast, swells, very tasty with no gas

3.6.1.3 Other Beans for medium and high potential areas

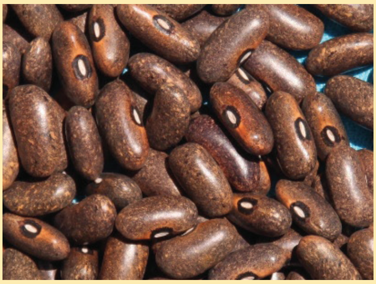
The beans in this section although grown in a range of environments by farmers, don't do well in root rot prone areas or in drought environments. The varieties in Table 7 are arranged from the earliest variety release to the newest and seed is available from the formal seed sector.

Table 7: Attributes of beans for medium and high potential areas

 Wairimu (GLP 585) – Red Haricot	• An indeterminate plant • Flowers in 38-45 days • Flower colour is white. • Matures within 75-90 days • Grain type: Red, small and rectangular elliptic • Potential yield is 1000-1500kg/ha or 5-7 bags/acre • Tolerant to bean mosaic virus and Anthracnose diseases
 Canadian Wonder (GLP 24)	• A red kidney bean • An indeterminate • Vigorous plant growth • Flower is white in colour • Flowers in 35-45 days • Matures 90-100 days • Grain is elliptic kidney shaped, violet in colour. • Potential yield is 1300-1800kg/ha or 6-8 bags/acre • Best in medium and highlands areas. • Moderately resistant to angular leaf spot • Seed rate 30kg /acre
 **KAT B1**(Kathika)  **KAT B9**  **KATX56**  **KATX69**  **KAT B1**(Kathika)  **KAT B9**  **KATX56**  **KATX69** Rosecoco (GLP2)	• A red mottled bean • An indeterminate plant type • Has pinkish white flowers • Flowers in 40-50days • Maturity 80-100days • Red mottled, medium and elliptic grain type • Seed rate of 24-30kg/ acre • Spacing of 50×10cm. • Yields 1600-2000 kg/ha (7-9 bags/acre) • Is resistant to rust • Cooks fast, swells, turns brownish, is sweet

Mwezi Moja (GLP 1004)

- A violet coloured bean
- Determinate plant type
- Flower is white in colour
- Flowers in 30-40 days
- Matures in 60-80 days
- Grain is violet, medium in size and narrow elliptic in shape
- Potential yield 1200 to 1500 kg/ha or 5-7 bags/acre
- Tolerant to bean fly
- Early maturity



New Mwezi Moja (GLP 1127)

- Determinate plant habit
- Has white flowers
- Flowers in 35-40days
- Matures in 75-90 days
- Grain is grey to brown, with white flecks, medium in size and elliptic in shape
- Potential yield 1000 to 1500 kg/ha or 4-7 bags/acre
- Seed rate 30kg /acre
- Best for sowing in short rain.
- Tolerant to bean common mosaic virus and Hallo blight and Anthracnose.

Wairimu Dwarf (Photo: source Sim-law Seeds)

- A red kidney bush bean
- Flowers in 40-50 days
- White flower colour
- Matures in 75-84 days.
- Grain is red, medium in size and circular to elliptic in shape
- Potential yield is 1500-1750kg/ha or 6-8 bags/acre
- Seed rate 30kg /acre.
- Fast cooking with good flavor
- Drought tolerance.

Tasha (Photo: Egerton University seed Unit)

- Determinate erect bush type
- Whitish yellow Flowers
- Flowers in 35-40 days
- Matures in 75-80 days
- Red mottled, medium elliptic grain type
- Yields: 1800 -2,000 kg per ha 8-9 bags /acre
- No acidity and cooks fast
- Self-stripping (sheds leaves in the farm)
- High iron and zinc (37ppm)

 Chelalang (Photo: Egerton University seed Unit)	• Determinate erect bush type • White flowers • Flowers in 40-45 days • Matures in 80-90 days • Red mottled, large, elliptic circular grain type • Yields: 2,000-2,500 kg per ha 10-12 bags /acre • No acidity & cooks fast • Self-stripping (sheds leaves in the farm) • High iron (90ppm) and high zinc (37ppm)
 Ciankui (Photo: Egerton University seed Unit)	• Determinate erect bush type • White flowers • Flowers in 35-40 days • Matures in 75-80 days • Red mottled. Medium, elliptic grain type • Yields: 1800 -2,000 kg per ha 8-9 bags /acre • No acidity & cooks fast • Speckled white-dark-brown • Self-stripping (sheds leaves in the farm) • High iron and zinc (37ppm
 Faida (KMR 13)	• An indeterminate growth • Has white flowers • Flowers in 35-40 days • Matures in 74-84 days • Red-mottled, large, elliptic kidney shaped grain type • Yields of 1400-2000 kg per ha (7-10 bags per acre • Tolerant to Common Bacterial Blight, rust (Uromyces sp.), bean common mosaic virus and angular leaf spot (ALS). • Contains high content of zinc protein, calcium, important vitamins and fibre
 Angaza (KMR 11)	• Has pinkish white flowers. Determinant growth • Flowers in 40-42 days. • Matures in 75-85 days. • Has beige with red speckles and- medium rectangular elliptic grain type, • Yields 6-12 bags per acre. • Sweet grains with low flatulence levels • Tolerant to common bacterial blight (CBB), rust (*Uromyces* sp.), and angular leaf spot (ALS). • Contains high content of iron zinc protein, calcium, important vitamins and fibre.

Bean varieties for specific regions/ zones are shown in Table 8.

Table 8: Bean suitability in Kenya

VARIETIES	OPTIMAL PRODUCTION CONDITIONS	RECOMMENDED GROWING AREAS
Nyota, KATRAM, KATX69, KATX56, KAT B1	ASL and cold dry highlands: Altitude: 900-1,600m Rainfall: 800-1,600mm per year	Machakos, Makueni, Narok, Nakuru, Siaya, Kisumu, Homabay, Kajiado, Laikipia, Nyeri, Embu, Taita Taveta, Kiambu, Muranga, Kirinyaga
KK15, KK Rosecoco 194, KK Red 16,	Medium to high rainfall areas with root rot disease prevalence Altitude: 1,000-2,000m Rainfall: 1,200-2000mm per year	Kakamega, Bungoma, Vihiga, Muranga, Meru, Migpri, Kisii, Uasin Gishu, Transzoia, highlands of Elegeyo Marakwet, Bomet, Kericho, Muranga, Kiambu, Kirinyaga, Meru
Wairimu, Canadian wonder, Rosecoco, Wairimu Dwarf, Mwezi moja, New mwezi moja, Tasha, Ciankui, Chelalang, Faida and Angaza	Medium to high rainfall areas Altitude: 1,400-2,000m Rainfall: 1000-2000mm per year	Kakamega, Bungoma, Vihiga, Muranga, Meru, Migpri, Kisii, Uasin Gishu, Transzoia, highlands of Elegeyo Marakwet, Muranga, Kia,bu, Kirinyaga, Meru, Narok, Bomet, Nakuru

3.6.2 Climbing Beans

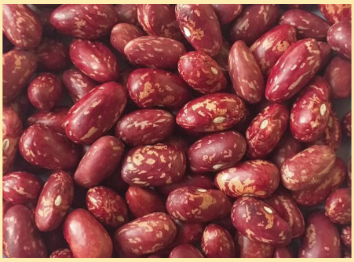
This type of beans is ideal for medium and high rainfall areas where land size is limited. They can also be grown in areas with irrigation. Climbing beans can be a good source of green beans for consumption and some women use the green grain for feeding their children. The bean will require support to climb for full productivity to be achieved (Figure 19). Farmers should plan how to support the beans well in advance before sourcing seed. A farmer can invest in long pole and strings either made of wire, sisal or polythene types, long sticks or long-term metal structures.

a: Using strings as support **b: Using maize as support**

Figure 19: Climbing bean support

Farmers should note that the current released climbing bean varieties in Kenya are aggressive in growth and are suppressing the maize plants as well as enhance plant lodging. Their characteristics are listed in Table 9.

Table 9: Attributes of climbing bean varieties

 Kenya Mavuno (MAC 64)	• Climbing bean growth habit • Flowers are white • Flowers in 40-70days • Grain is red molted (red, beige), large seeded, rectangular elliptic in shape. • Matures in 110-150 days • Potential yield 2000 to 3000 kg/ha or 9-14 bags/acre • Spacing 60cm×10cm by row and plant to plant • Ideal for farmers with small land sizes • Seed rate 30kg per acre
 Kenya Tamu (MAC 34)	• Climbing bean growth habit • Flowers are white • Flowers in 40-60days • Grain is red molted (red, beige), large seeded, elliptic to kidney in shape. • Matures in 110-135 days • Potential yield 2,000 to 2,500 kg/ha or 9-14 bags/acre • Spacing 60cm×10cm • Ideal for farmers with small land sizes • Seed rate 30kg per acre
 Kenya Safi (MAC 13)	• Climbing bean growth habit • Flowers are white to pinkish white • Flowers in 35-60days • Grain is speckled (red, beige), large seeded, elliptic kidney shape. • Matures in 90-120 days • Potential yield 2,000 to 2500 kg/ha or 9-11 bags/acre • Spacing 60cm×10cm • Ideal for farmers with small land sizes • Seed rate 30kg per acre

3.7 Crop establishment

Bean crop establishment starts with the **soil suitability**; where a well-drained soil, is important for germination and crop establishment. Such soil ought to be rich in organic matter, weed free environment and optimum pH of 6.5-7.5. Growth is poor in waterlogged soils in most areas. Farmers ought to consult extension providers on their soil type determination for bean production (Helm et al. 1990). Good land preparation is a pre-requisite before rain onset. Seedbed preparation will depend on amount and type of rainfall pattern. As essential climate smart agriculture (CSA) input is ensuring that for dry areas, seed is planted in a furrow trough while for wetter areas is planted in raised terrace (Figure 20).

Dry areas; Furrow trough (D. Mutisya) *Wet areas; Raised terrace (Kilimo Trust)*

Figure 20: Comparative water troughs to conserve moisture levels

In most cases women use pangas to plant bean crop. Other farmers use jembes, furrow openers or adapted maize of wheat planters. However, planting along rows and planting only 1-2 seeds per plant hole gives options for better management of the crop. Bean crop spacing of 45cmx15 cm or 50cmx10cm has demonstrated proper resource application and maintenance of good agronomic practices (Figure 21).

Figure 21: Sole crop bean spacing (45cm x 15 cm).
Source: nda.agric.za)

In some cases, farmers are also interested in inclusion of a maize crop. The farmers are advised to space their maize crops by planting several rows of beans between the maize plants, as in Figure 22 below.

Figure 22: Bean sole cropping with plots separated by maize crop

In other cropping systems where moisture and fertility are low due to reduced rainfall amount and poor soil nutrient content, bean spacing will be altered to increase area for higher plant population. The result will be sustainable production with limited resources as a CSA approach. In some areas three bean rows of short spacing could be planted before 30cm row spacing. Likewise, where fertility and soil moisture are modest then single row and normal spacing of 30cm x 15 cm is maintained. Otherwise, where low rainfall amount occurs combined with low fertility the spacing is increased to one metre and 15cm for inter-row and intra row spacing respectively as shown in Figure 23 below.

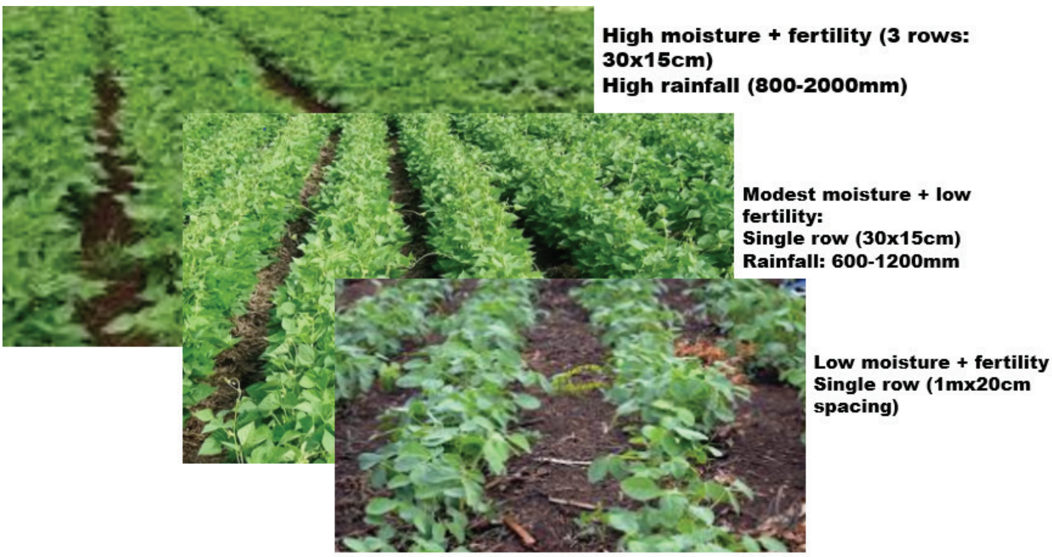


Photo sources: monitor.co.ug; tuko.co.ke; a4gimpact.org, respectively

Figure 23: Different spacing in varied moisture and fertility levels

The bean crop can be intercropped with other cereals like maize. It is not recommended to plant beans and maize in the same hole as is common with some farmers. Planting beans and maize in the same hole promotes competition for water and nutrients. The two crops flower and mature at different times and beans will be a disadvantage. Farmers can use several combinations of beans and maize, e.g. alternating two rows beans to 1 row maize (Fig.24 below):

Figure 24: Bean-maize intercrop alter spacing
(Source: oneacrefund.org)

3.7.1 Growth water requirement

The bean crop requires a well distributed annual rainfall of between 800-2,000mm for the rain fed production. Alternatively, irrigation could be availed if rainfall is inadequate, if not so eminent crop failure occurs.

Needless to say, too much rain or long dry spells are not conducive and reduces yields of bean crop. Excessive rainfall during flowering causes flower abortion and increased disease incidences. Dry weather conditions are needed during harvesting, hence farmer ought to synchronize activities as required for production to maximize yield in the prevailing conditions. The knowledge of the risk factors will enable carrying out mitigation measures on the crop to reduce losses as Figure 25 below show hand watering to safe young bean crop during advance dry conditions.

Figure 25: Supplementary watering of stressed plants

Other CSA practices include planting bean crop in Zai pits (Figure 26) which prevent fast loss of soil moisture, especially with some mulch application added.

Figure 26: Modified Zai pits for bean-maize intercrops

3.7.2 Temperature requirement

Beans can grow optimally in a wide range of temperatures ranging between 15-33 °C (degree centigrade). However, bean crop thrives well in a warm climate optimal temperature of 18-24 °C. Relative high temperatures affect flowering and pod setting processes. The crop is extremely sensitive to frost. Where temperature is greater than 30 degrees use of shades and suitable CSA practices will be essential to prevent yield loss. In areas where temperatures are below 21 °C delay of maturity and seed formation result into empty pods. If temperatures are low, production in greenhouse structures of plastic covers will provide a higher temperature for crop development and better yields

3.8 Crop nutrition and weed management

Even in the marginal areas optimal production requires that the crop is supplied with sufficient nutrients, both macro and micronutrient elements. This is because, if deprived of such nutrients, the crop becomes weak and very susceptible to attack by pathogens. This subsequently leads to reduced yield of grain. During planting, application of DAP fertilizer is recommended at a rate of 1 bag per acre. Considering the amount of organic matter in the soil, manure can also be applied. If soil tests are carried out, other fertilizers can be incorporated either at planting or vegetative crop development as the test results show in most cases (Fig. 27). In choice of organic farming the farmer uses only farm yard and animal manure.

Figure 27: Phosphate and Potassium fertilizers improve yield
(Source: blogs.iita.org)

In weed management, a farmer makes a choice on the method used to control weeds (Fig.28). Hand jembe is the common tool in most farms. Otherwise, where farmers are endowed with capital input, use of herbicide is being adapted from planting to bean crop development stages.

Fig. 28a: Herbicide applied bean plot

Fig.28b: Un-weeded bean crop

Figure 28: Use of herbicide to reduce drudgery in bean production
(Photo D. Mutisya, Farmbuz.org)

The use of such herbicide will be in addition considerations of using products and practices to lower pollutants in the agro ecosystem. Figure 28 above shows what guides the practices of mitigations against the risks of polluting the environment. The goal by the farmer is to get maximum yield in the prevailing conditions. Considerations will be the fertilizers, the pesticides applied not to overuse them and cause ecosystem disruption of pollution or elimination of non-target organisms like bees. Thus as Figure 29 show, the idea is to contribute to reduced greenhouse gas emissions (GHS) from overuse of the pollutants.

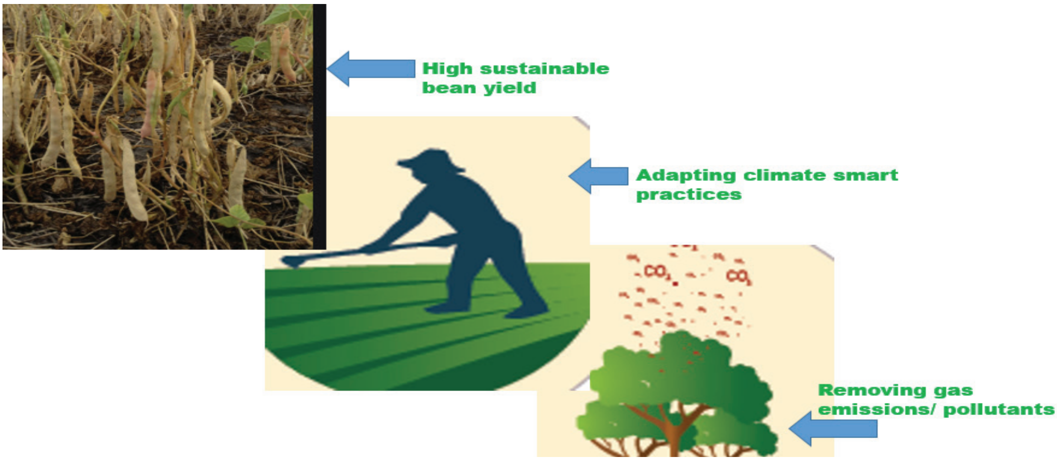


Figure 29: Consideration for not to pollute the agro ecosystem with pesticides and fertilizers; towards reduced greenhouse gas emissions reduction

4 BEAN PESTS AND DISEASES

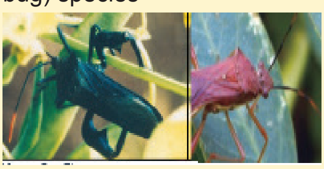
4.1. Bean Pests' Management

Pests and diseases significantly reduce the yield of beans. Pests like cutworms and bean fly occur at crop establishment and need to be managed early to prevent about 30% yield loss. At vegetative stage, diseases become the major risk of yield reduction and could result to over 20% loss, thus their management is critical (Buruchara et al. 2010; Kamunzo et al. 2018). At flowering and pod formation stage, the blister beetles and pod borers like bollworm and other caterpillars have to be managed to reduce yield loss by 40%. Table 10 below displays a list of pests occurring in beans and management options. Pest scouting is carried out each morning (7:30 to 9:30am) to determine need to control the injurious organisms before their numbers cause damage. Bean pests increase with increase of rainfall and temperature. Climate change increasing the two parameters will increase various pests on bean crop.

Table 10: Pest types, symptoms and control options

Type of Pest	Symptoms	Control Methods
Seedling and crop establishment		
  *Photos: A.M. Varela (ICIPE)*	• Several beans in field plot appear wilting or drop • On checking the wilted plants one notices stems are cut just below soil base • A scratch of the stem base bears presence of caterpillar; black or white depending on the species.	• Scout for the presence of the pest in bean plots by visiting plots before midday • Preventive approach provides better results by dressing the seeds with insecticide just before planting • Avoid use of slurry manure; animal or plant manure not fully decomposed as this source of alternative food for cutworms • Where population is high and threatening, the caterpillars can be baited and eliminated with carbaryl insecticide baited in molasses and mixed in the soil where seeds are planted.

Type of Pest	Symptoms	Control Methods
Bean Fly Fly maggots causing swelling of bean stem around soil base. This is as a result of the fly having inserted eggs on the young bean stem.  *Photo source: CIAT 2010*	• Attacked plants appear wilting and drooping • Dry weather lead to symptoms appearing on most plants. • Severe infestations can lead to death of seedling in dry environment. • It has been observed that crops are at a greater risk for 3-4 weeks after emergence.	• Consideration for prevention start with seed dressing with Imidacloprid insecticide at planting • The insecticides group classes of carbaryl, cyfluthrin and permethrin are among new emerging pesticides which have medium to long term residual effects and the trade mark brands keep on changing. Use neem-based insecticide and spray close to plant base to stop development of larval stage of the pest • Uproot pest infested plants and burn to destroy habitat of the pest in the next planting season • Rotate field plot with none-leguminous crop types.
Vegetative and flowering crop stage		
Thrips Are plant juice suckers on leaves and growing buds. 	• Attacks plant petioles and leaves • Leaves have tiny holes surrounded by discoloured areas.	• Plough and harrow before planting. It can reduce subsequent thrips attacks by killing pupae in the soil. • Conserve natural enemies' e.g. predatory bugs (Orius spp. and Anthocoris spp.) and predatory thrips. • Spray with bio-pesticides (e.g. Spinosad) or other insecticides (e.g. Endosulfan, lufenuron, Lambda-cyhalothrin)
Red spider mites These pests are minor and only build to cause wilting of leaves. Where heavy rains fall, they are washed away from plants and do not warrant any control measure. 	• Attacked plants have brown leaf blotches which have webs top and underside parts • Wilting leaves will dry and drop down during dry weather • Increased numbers of the pest will cause crop death especially in greenhouse.	• In dry weather conditions, spray of Abamectin based miticide/ acaricide (30-50ml/20L) eliminates all pest stages. • Alternating Abamectin spray with neem-based products prevents resurgence of pest.

Type of Pest	Symptoms	Control Methods
Aphids The aphids are soft bodied, green, black or brown insects which suck plant sap from various crops including beans. 	• Infested leaves curl and crinkle reducing leaf photosynthetic area. • As they feed, aphids excrete honeydew which encourages the development of sooty mold which reduces photosynthetic area further.	• Control is considered when aphid populations increase and black sooty symptoms occur. • Application of Lambda cyhalothrin 50g/L, alternating with Thiamethoxam 141g/L • To remove sooty mold use horticultural oils.
Pre-harvest and post-harvest		
	• Feeds on leaf buds and bores into the young pods to eat seeds • Damaged flower buds and flowers lead to low yield and dis-figured seed, opening way for pathogens attack.	• Dry grains to 12% moisture content (MC) prior to storage • Use improved storage structures • Spray with Imidacloprid, alternating with botanicals like neem-based products.
The Spotted pod borer, *Maruca vitrata* These are caterpillars of a moth on flowers and young plant pods. 	• The caterpillar damage growing and reproductive organs of beans. • Damaged pods mean poor yield.	• Alternating Imidacloprid and Pyrethrin and neem-based products ensures no pest resurgence.
Pod sucking bugs Giant coreid bug, green stink bug) species 	• These bugs cause necrosis, pod malformation, premature drying, formation of empty pods and shrivelling of seeds.	• Apply any recommended systematic insecticide, as most are effective against these plant bugs, but alternating synthetic with biological ones prevent resistance to certain molecules.

Type of Pest	Symptoms	Control Methods
Bruchids These are beetles which cause stored grain damage, e.g. the legume bruchid, *Acanthoscelides obtectus.* 	• Beetle life stage are found on the grain as generations overlap • Damaged grain bore a lot of dust in the store • Damaged grain bore a lot of heat if one puts hand in the grain feels it • Other moths are attracted to the grain when bruchids are present, hence increased pest load.	• Apply Pirimiphos-methyl 16g/kg +Permethrin dusts which are effective against heavy infestation with grain moisture level at 12%. • Do grain sunning if only a few beetles have not penetrated into the grain in store. Sunning is less effective if some juvenile life stages are already in the seed feeding. • Use hermetic bags where care is taken to make sure live beetles are excluded at the initial storage part.

4.2. Bean Diseases

When temperatures drop below 20°C, increase of disease incidences are observable in bean plots. With onset of weather conditions getting colder due to change of lowering of temperature, mostly fungal and bacterial diseases are the common ones. Nevertheless, other seed borne diseases do occur. The various bean diseases, symptoms and control measures are in Table 11 below.

Table 11: Bean diseases and control

Type of Disease	Symptoms	Control Measures
Powdery mildew A fungal disease occurring when cold at any growth stage of beans. 	• White patches appear on leaves and other green parts, which later become dull coloured. • Infected plants have a greyish-white powdery growth on the surface of leaves, stems and pods • Caused by fungus *Podosphaera fusca* which is a major disease of beans predisposed by cold environment causing severe yield loss.	• Sowing of resistant or moderately resistant varieties where available • Improve aeration in the field by thinning or pruning some of the foliage • Spray neem-based products from stockists@ 50 g/L or neem oil @ 20 ml/L or water soluble sulphur 80 WP @ 4 g/L or carbendazim 50 WP @ 1 g/L twice at 10 days' interval from initial disease appearance
		• Apply good agronomic practices such as control of volunteer seedlings and other host crops and weeds prior to crop establishment.

Type of Disease	Symptoms	Control Measures
Bean yellow mosaic virus A viral disease spread by white-flies 	• The leaves are mottled with yellow, white and light and dark green spots, which appear to be elevated. This gives the leaves a blister-like appearance. • Small yellow specks along the vein-lets of leaves which spread over the lamina to produce yellow mosaic symptoms. The pods become thin and curl upwards.	• Plant resistant varieties • Spray with Copper Oxychloride fungicide • Diseased plants should be rogued out to prevent further spread of the disease. • Use of disease free seeds • Primarily, spray after every two weeks neem-based products to suppress whiteflies which spread the disease from plant to plant.
Common mosaic virus As the name refers, it is common on beans and is seed borne. 	• Viral disease spread through infected seed and aphids • Cause yield loss of up to 90%. • Favoured by temperature range 20-25 °C • Leaf mottle which would turn as dry patch after tissue dies.	• Use certified seeds to prevent spread of disease • Suppress aphid vectors on the bean by spraying Thiamethoxam 141g/L and alternating neem products to break possible molecule resistance.
Fusarium wilt A fungal disease which lead to plant drooping or wilting depending on the severity. 	• Appearance of wilting is the major symptoms • The roots are usually the area of attack by the pathogen, that is proof of the increasing dead tissue • Death of the vascular bundle tissue lead to drop of the plant.	• Plant resistant varieties if available. • Remove stricken growth from the garden and sterilize pruning clippers. • High nitrogen fertilizers may increase susceptibility to the disease. • Hand pull or spot treat weeds using a biological fungicide that will safely protect crops against wilt caused by Fusarium.

Type of Disease	Symptoms	Control Measures
Rust disease A common problematic fungal disease occurring in most bean fields. 	• Caused by a fungus organism • It appears as circular reddish brown pustules • Less abundant on pods and stem	• Plan to increase spacing of plants to allow for air flow at crop establishment • Prevent unnecessary movement into the field as it will spread more the rust • At planting, select rust-resistant varieties. • If only a few plants are infected pick off, remove and destroy all infected leaves. • Spray fungicides with the following active ingredients: Triadimefon (0.02%), triadimenol (0.1%), hexaconazole, Maneb, Mancozeb+-sulfur and Chlorothalonil.
Bacterial blight The bacterial blight spreads fast during wet weather. 	• Leaves become yellow and fall prematurely • Long wet hours mean fast spread of the disease, leading to leaf rot and loss of photosynthetic area.	• Keep foliage dry and don't touch it when it's wet. • Don't injure the plants by any abrasive movement within the field, as this is how the bacteria get inside. • Keep weeds and pests to a minimum. • Destroy affected plants. • Spray with Metalaxyl to stop spread of pathogens
Anthracnose disease A fungal disease which damages stems, pods and leaf tissue. 	• Starts as rotting irregular leaf patches. • Same wound patches spread to stem and even pods • The damage lead to reduced yield • It becomes seed born once crop matures	• Use either certified seed or seed known to have a long disease-free history. • Carryout crop rotation with non-leguminous crops. • Remove diseased plants, where practical, to help check the spread of disease. • Do not pack tightly diseased pods as anthracnose can develop during transport.

5 BEAN HARVEST AND POST-HARVEST MANAGEMENT

5.1 Variety maturity considerations

Depending on the various varieties, beans are ready for harvesting 70-120 days after sowing. Others take shorter periods. At maturity, the plants leaves turn yellowish to brown or fall from plants. Beans can be harvested green or when dry. While bush beans are collected from the field and uprooted as whole plants, for the climbing types one picks the single pods and are threshed before winnowing.

5.2 Harvesting of beans

In most cases, pods are picked from the plants when completely dry. Right time of picking the pods is important to avoid wastage of grain when left in field for long. However, if they have withered but are still moist, they can be harvested and sun dried. Pods that are completely dry split open, exposing the dried bean grain.

5.3 Threshing and winnowing

Harvested plant pods or whole plant hills are placed on nylon canvas and threshed on clean material to avoid impurities. Winnowing enable separating the grain from the pods. The term winnowing is the blowing of the grain with wind to clean and free it from dirt and plant straw material (Fig.30). Care is taken to make sure the grains are winnowed when it is fairly windy to avoid wastage. In some cases much of the grain end up thrown far away and increasing loss by omission to the storage bag.

Fig. 30a: Harvesting

Source: armbiz.com

Fig. 30b: Winnowing grain

Figure 30: Harvesting dry bean crop and winnowing of grain

Women do most of the tasks of harvesting, threshing and winnowing in Kenya (Figure 31). While in some countries mechanized operations are used to harvest large acreage of bean crop. The process includes hand-picking and heaping together in one place as pods or whole plants. Women and youth do most of the threshing manually. The grains are winnowed in windy times to remove the shaft and clean the grains.

Threshing on canvas | Alternative winnowing | Weighing and bagging grain

Figure 31: Threshing, winnowing and weighing of grain

5.4 Storage of Grain

Dry beans are stored in insecticide treated gunny or air-tight hermetic bags which help to prevent major damages caused by storage pests. In the absence of hermetic bags, it is advisable to use an insecticide dust to prevent damage of grain while in the store. Bags should be placed on pallets, not directly on the floor. Green beans can be refrigerated for 8-10 days to eliminate any bruchids in grain before storage. Dried beans can be stored in a cool, dry place for up to a year or more.

Kindly note that if a farmer will use the bean harvest as seed, they should **NOT** store the proposed seed for planting in hermetic bags, as the bags work on principle of air exclusion. This exclusion of air lead to early death of seed in 4-6months. Such grain will not grow. Thus, insecticide treatment is suitable for seed grain.

6 ECONOMICS OF BEAN PRODUCTION AND MARKET ACCESS

6.1 Theoretical Framework of Economics

Economics is a social science which deals with the allocation of scarce resources to maximize on returns. Economic considerations involves capital, land and labour. With the presence of various agricultural challenges such as climate changes, water scarcity and flooding among other constraints, there is need for appropriate resource allocation.

In order to increase the productivity of the dry bean there is need to know the appropriate planting season, choose the best variety and consider the ideological requirements. Also, these challenges could be dealt with by analysing the existing markets and new market models using other enterprises benchmarks which have been effective.

For optimal resource allocation and management in the economics of bean production, the farmer should incorporate economic practices including; planning, record keeping, enterprise management, gross margin and enterprise analysis, bean product value addition and market-oriented bean production.

6.2 Record Keeping

It is important to keep record because it provides information that aids in planning, helps reduce the occurrence of risks and promotes more informed decision-making by farmers. Through record keeping, farmers are able to derive accurate data on the bean enterprise to calculate the profit and loss of the bean enterprise farming. Other than this, the records could help in the evaluation and monitoring of the progress made on different activities in the enterprise such as identifying changes in the agro-climatic parameters or predictions in the disease outbreaks to assess the preventive measures in future.

6.2.1 Financial Statements and List of Required Records in the Farm

Cash Book and Payment Receipt Record Book: This is a farm accounting record book of all the financial transactions, inclusive of the income and expenditure of the farm. With it, the farmer can make productive decisions, basing them on figures in the record.

Farm Inventory Record: The farm record that shows the list of all the items currently on the farm, for instance, farm building, equipment, and tools. The values of the items are also indicated and the state they are in.

Yield and Production Record: It is the record that indicates the output of the farm. The daily or seasonal production rate is recorded in this record. It is helpful in indicating the success rate of the farm over the production year.

Payroll and Labour Record: The amount and types of labour hired to work on the farm are indicated in this record. The rate and the salary paid are also showcased here.

Profit and Loss Record: This is a very important record as it indicates the economic level of the business. The record aids in determining whether the business is giving back a profit or making a loss.

Farm Input Utilization Record: This record shows all inputs used in the production and also indicates the relevance of every input in the production. The input application level is indicated and with the combination of the output record, it is used in determining resources productivity.

6.3 Marketing of Bean Grain

The dry bean is one commodity that is much traded in Kenya and especially by women. Despite progress in increasing production and productivity, farmers from one end of the region normally complain there is lack of market while in another place traders are decrying lack of bean grain to trade (Poku *et al.,* 2018). These are normal market dynamics.

Reasons for lack of market:

- Inadequate skills/information to get best prices for their bean produce
- Low quality of the bean grain and especially admixtures
- Low negotiating skills especially where contracts are involved
- Low production and marketing knowledge.

Reasons for lack of enough volumes for traders:

- Wrong variety for the prevailing demand
- Competition among the various bean traders
- Low supply of preferred grain/ variety from the production areas
- Low prices offered per bag of bean grain
- Poor gender interaction among the actors along the bean value chain.

To make money, farmers prefer nearest market for their grain. Two types of marketing arrangements are available: spot market transactions and collective marketing.

Spot market transactions is the most preferred marketing channel, probably due to the fact that a farmer transacts his produce privately. It is an informal marketing pathway bringing on board local assemblers, brokers and traders who buy common beans from small scale farmers. On the other hand, collective marketing is a more bidding marketing model for dry beans. It involves smallholders marketing farm produce through farmer organizations, contract farming or out grower schemes to formal institutions. It's a formal relationship in which large buyers such as grain marketing boards, food processors, wholesalers, supermarkets, schools, hospitals, exporters and relief agencies enter into formal or informal agreement (Poku *et al*., 2018). Nevertheless, the two marketing channels depend on demand and supply of a bean variety produce in the target market.

6.4 Agribusiness in Bean Enterprise

Agribusiness is the business of undertaking agricultural production. It earns most or all its revenues from agriculture. This includes agriculture inputs, crops and animal production, distribution, farm machinery, processing as well as marketing and retailing of the products.

In order to succeed in agribusiness of bean farming, the farmers need meet the set grain standards to attract more market players. Farmers in a village or group also need to be discussing with extension providers and to each other on their production plans and choice of varieties so that they can achieve tradable volumes. Low volumes in a village will mean transaction costs are high. Choice of growing one or two varieties, for a specific market will give focus of the bean enterprise. This helps in maintaining the specific bean variety purity and buyers knowing where the supplier is.

To achieve good quality bean grain that can meet the grain standard markets, farmers need to use good agricultural practises and follow as much as possible guidelines in this manual. The current marketing system especially by brokers does not benefit the farmer who has low bargaining power (Albu & Griffith 2006). Hence, structured marketing and collective marketing, ensures profitable sells for the farmer.

One of the procedures to get quality bean produce is cleaning and sorting to meeting high quality purity of grain (Annex 2). These standards are important especially for the bean processing factories. Various bean varieties are used to make various bean products.

As suggested by Wanjala *et al*., (2018), farmers in commercial bean production and collective marketing will need to work with private sector aggregators that employ the warehouse receipt system combined with a payment application.

6.4.1 Agribusiness in Dry Bean Climate Smart Agriculture

Dry Bean Enterprise Management

Common bean enterprise management can be defined as decision making process which affects its profitability. This decision will include what variety of beans to cultivate, to what extent, how to produce it and how to obtain the production resources such as land, labour, capital and management. The common bean enterprise performance will be based on the technical (physical) and economic (monetary) performance indicators.

6.5 Bean Enterprise Analysis

6.5.1 Common bean enterprise analysis

The Nature and the Objectives of an Enterprise Analysis

The analysis of enterprise in this case common beans is a management tool which enables us to evaluate the enterprise's profitability and the reason for it. Such an analysis is most important as a guide in deciding what should be done in order to increase profitability. An enterprise's profitability is determined by both external and internal factors. External factors are those over which the farmer has no influence (at least in the short run), for example, prices or government policies.

6.5.2 Use of Enterprise Analysis

Enterprise analysis is used for the following purposes besides the farm management decisions:

a. Supplying data to public institutions and government, for use by agricultural policy makers.
b. Preparation for enterprise budget.
c. Preparation of whole farm plan.

6.5.3 Performance Indicators

In enterprise analysis, performance indicators are used to show how the enterprise is performing. 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:

6.5.4 Economic (Monetary) Indicators

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

Another group of indicators might include proportions and prices. For example,

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

6.5.5 Technical Indicators

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

In order to evaluate the performance of a specific enterprise (common beans) we may compare it with one of the following criteria:

1. Performance of the common dry bean enterprise in the previous year(s).
2. Planned budget for the common bean enterprise
3. Performance of other farmers
4. Standards or norms
5. Performance of the other enterprises on the farm.

A comparison of 3 & 4 can be made only if some kind of central agency is compiling data on regional or country wide basis. Point five is used whenever we extend our analysis to the consideration of the entire farm. In this case we have to compare the returns made to the limited resources by all enterprise concerned.

When we analyze an enterprise for the first time or a single year, special care must be taken in drawing conclusions. This particular year might be one of exponential prices or growing conditions, weather or insect/disease attacks. A continues analysis of the same enterprise, over the course of a few years can affect the influence of several factors in the analysis of a single year.

6.6 Production Costs

6.6.1 Purposes of Cost Analysis

Any production process can be described as a transformation of inputs to outputs; thus the cost of production is supposed to reflect the value of inputs which are essential for that process.

Cost data can be used for different purposes. Costs may be calculated for the following purposes:

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

The concern should be costs within the context of farm/enterprise planning and comparative enterprise analysis.

6.6.2 Production Costs and Gross Margins

6.6.2.1 Gross Margin

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

In order to calculate the gross margin, one has to classify the costs according to the criteria of being variable (avoidable) or fixed (unavoidable).The classification of costs will be done according to the case under consideration.

Table 12: Gross Margin Analysis for Medium-Scale Farmer of Rose Coco Beans in Trans Nzoia County

Crop: Beans (Rose Coco) Farmer Category: Medium					
ENTERPRISE OUTPUT	Unit	Quantity	Price	Total Revenue	
				Ksh/Acre	Ksh/ Ha
Yield:	90 kg	8	8,000	64,000	158,080
TOTAL VARIABLE COSTS				0	0
Intermediate inputs				0	0
Ploughing	acre	1	3,000	3,000	7,410
Harrowing	acre	1	2,000	2,000	4,940
Seeds	Kgs	30	90	2,700	6,669
Fertilizer DAP	50 Kgs	1	3,000	3,000	7,410
Fertilizer CAN	50 Kgs	1	0	0	0
Insecticides	Litres	1	1,200	1,200	2,964
Fungicides	Litres	1	1,200	1,200	2,964
Sub Total				0	0
Labour Costs				0	0
Plantinq	md	5	300	1,800	3,705
Weeding 1st	md	10	300	3,000	7,410
Weeding 2nd	md	10	300	3,000	7,410
Spraying	md	10	300	3,000	7,410
Harvestinq	md	10	300	3,000	7,410
Sub total				0	0
Marketinq Costs				0	0
Baqs	bag	8	100	800	1,976
Transport	bag	8	so	400	988
Levies	bag	8	so	400	988
Sub Total				0	0
				31,020	76,619
Total Variable Costs				0	0
Total Cost				28,200	69,654
Gross Marqin				35,800	88,426
Total Fixed Costs (Share)				0	0
Net Profit/Loss				35,800	88,426
Average cost per 90 kg gag (KSh.)			2,310		
Gross marqin per 90 kg gag (KSh.)			1,570		
Break-even yield				3.5	
Break-even price				3,525.0	

6.6.2.2 Fixed Costs

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 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 the time span of events in relation to the decision to be made. Table 13 demonstrates this issue.

Table 13: Avoidable costs as related to the decisions' time span. X specifies variable (avoidable) cost

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

6.6.2.3 Opportunity Cost

In some cases, inputs are limited and cannot be bought in the market. Land, labour and some fertilizers are the most common examples. Market prices here are not considered since inputs cannot be bought.

The enterprise according to which the input alternative cost will be calculated is the one which provides the lowest gross margin for that input; it is the marginal enterprise from this point of view.

6.6.2.4 Opportunity Cost Calculation Scenarios

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

Table 14: Various possibilities for opportunity cost calculations

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

Certain kinds of resources face all these kinds of possibilities according to the prevailing conditions. Let us consider labour. When the farmer cannot find any work off the farm, he/she faces condition 1. When he/she has much more work than he/she is able to do, and hired labour is not available condition no 2 obtains. When the possibility exists to hire workers, the farmer should calculate the labour value as in case in 3.

Costs Related to Yield and Break-Even Yield

It is quite often necessary to determine to what extent a particular enterprise is sensitive to a change in one or more elements determining its profitability.

The break-even yield is thus defined as that which covers all relevant costs: a higher yield provides profit and small one a loss.

Break-Even Yield Determination.

Let us define the following variables:

1) Break even yield (ha/kg) –Y
2) Cost not related to yield (Ksh/ha) – C
3) Unit cost related to yield (Ksh/kg) – CR
4) Price of the product (Ksh/kg) - PR

Break-Even Formula.

The breakeven yield (Y) is that yield which satisfies the following formula:

1. Y*PR=Y*CR+C
2. Or $Y = \frac{C}{PR-CR}$

The denominator of the second equation is actually the returns per production unit after deducting the cost related to yield (per output unit). Thus, we need enough units of yield (Y) to cover the cost which is not related to yield (C).

6.7 Access to Market Information

Market outlets actors get, share and use information to negotiate and mediate transactions, enforce rights and contracts and manage competition. Dry bean marketing information will also play an important role in reducing unfair practices to the farmer such as unfairly low prices brought about by lack of information where profit is higher. This reduces transaction costs. Therefore, market information services form an important service in supporting rural farmers engage effectively with markets of bean grain.

Different private service providers who avail market outlet information exist, as Ministry of Agriculture, agribusiness division, local FM radio stations among others. It is important to engage them to get desired information of the market.

6.8 Cost Benefits of Bean Enterprise

To grow a specific bean variety targeting a promising market, the farmer foregoes production of another crop enterprise. Both the production and marketing costs will be analysed to evaluate if the activity has economic advantage. It will start with the farmer getting down to evaluate the breakeven yield required to pay for the inputs applied (Poole *et al*., 2010). The break-even yield is thus defined as that which covers all relevant costs: a higher yield provides profit and small one a loss (Table 15). This is what a farmer will focus on to determine on the choice of engaging in dry bean grain production and what costs to note. As this will be reflected on the overall gross margin attained of the choice of bean variety, the farmer will consider costs of all operations. True profits attained will be revenue from bean grain produce minus all operation costs involved (Table 15). For profits to be realised, the farmer needs to manage the crop well especially if the weather is favourable. Higher farm gate prices of beans may not necessarily lead to profits (Table 15).

Table 15: Gross Margins from Two Zones and Bean Management

Description	Medium Potential	Drought prone zones	Not managed well in medium zone
Variable Costs			
Land preparation	1,949	5,843	5,771
Planting	1,855	1,638	1,439
Seed	2,690	1,150	1,390
Fertilizer	2,123	3,887	3,468
Herbicide	427	0	0
Weeding	3,195	3,419	3,664
Chemical	985	238	289
Chemical application	867	238	462
Harvesting	2,081	1,138	1,099
Post-harvest handling	447	4,806	3,075
Total variable cost (TVC)	**16,619**	**22,357**	**20,656**
Marketing	0	312	49
Yields (kg/acre)	509	173	181
Price/kg	83	100	113
Revenue (R) = (Y*P)	**42,147**	**17,410**	**20,450**
Gross Margin (R-TVC)	**25,528**	**-4,948**	**-206**

Source: Nyota bean survey for pre-cooked bean project 2020

7 BEAN UTILIZATION

7.1 Various common bean recipes

The common dry beans provide an income generating opportunity. Both the grain and leaf are rich in vegetable protein, an excellent source of both soluble and insoluble fibre as well as an excellent source of several minerals and vitamins (PABRA 2010). Bean grains contain 70% carbohydrate, starch (43-45%), protein 23.0 g, and iron 8.2-9.0 mg and small amounts of zinc of about 2.9mg per cup of grain. Currently there are bean varieties in Kenya with levels of iron >70ppm and zinc >35ppm. In Kenya, the dry bean is important for food supply and is derived from leaves, green pods and dry grains. Beans can be prepared for food by mixing with bananas, maize and rice and be powdered to make flour for porridge, chapati and Ugali. Cooking is mainly as steamed green leaves, boiled immature pods and dry grains that are boiled, stewed or mixed with maize, potatoes, sweet potatoes or cassava. Consumption of beans can be divided into 3 categories:

a) On-farm home consumption
b) Unprocessed beans
c) Pre-cooked and processed beans

In Kenya most consumers use beans as a mixture of maize and beans (githeri) or just bean alone either as a stew and a starch like rice or Ugali (Table 13). The following is other food items from beans that consumers can prepare.

Table 14: Bean based recipe preparations

Food Name	Ingredients	Preparation method
 **Beans Kienyeji**	• 100 gm bean • 200 gm maize • 200gm potatoes	• Put the clean beans and maize in a cooking pot • Add in enough water to cover the mixture • Boil to cook • Add peeled potatoes and cook until tender • Drain excess water and add in stinging nettle and salt to taste • Mash until smooth • Serve while hot

Food Name	Ingredients	Preparation method
 **Beans Chapati**	• 100 gm cooked • 250 gm wheat flour • 100mls salad oil • 2 large grated carrots • Salt • Enough water	• Mash the cooked beans to a smooth paste • Add a little water to make it moist • Add in salt, grated carrots and a little of the salad oil to the bean paste and mix well • Add in the wheat flour and knead the mixture into a soft but firm dough • Cut and shape into small balls • Roll the small balls into round flat chapatti shape using a rolling pin • Put on a hot flat flying pan and shallow fry until golden brown • Serve hot or cold
 Bean uji	• 100 gm bean flour • 200 gm maize flour • Sugar to taste	• Mash the cooked beans to a smooth paste • Add a little water to make it moist • add in salt, grated carrots and a little of the salad oil to the bean paste and mix well • Add in the wheat flour and knead the mixture into a soft but firm dough • Cut and shape into small balls • Roll the small balls into round flat chapatti shape using a rolling pin • Put on a hot flat flying pan and shallow fry until golden brown • Serve hot or cold

Food Name	Ingredients	Preparation method
 Bean cake	• 100 gm cooked beans • 400 gm self-raising wheat flour • 250gm margarine • 100gm sugar • 8-10 eggs	• Mash the cooked beans to a smooth paste • Cream the margarine and sugar • Add in the mashed beans and continue creaming • Add in beaten eggs slowly • Fold in the flour slowly until all of it is added • Check the consistence; it should be dropping if lifted with a wooden spoon. If too heavy, add a little milk, eggs or water • Oily the baking sheet and dust with little flour and then pour the mixture on the sheet • Put in a hot oven of 250°C and bake for 30-45 minutes until golden brown and if pierced with a knife it should come out dry. • Remove and leave to cool on a cake rack
 Bean mandazi	• 1 cup bean flour Bean flour • 2 cups cassava flour • 1 cup wheat flour • 2 table spoons Sugar • 500ml cooking oil • table spoons Baking powder • 1 Eggs • ½ table spoon Cinnamon (optional) • A pinch of Salt	• Mix all the flour, baking powder, sugar, salt and Cinnamon. • Rub in 2 table spoons of cooking oil. • Make a well in the centre and add in beaten egg and fold the mixture • Add water and knead into firm dough. • Roll the dough on floured board to a thickness of ¼” • Cut into desired shapes like circles, squares or cubes. • Heat oil and fry till golden on both sides. • Drain and allow to cool before serving

Food Name	Ingredients	Preparation method
 Bean-finger millet cookies	• Bean flour - 1 cup • Finger millet flour - 2 cups • Wheat flour - 1½ cups • Margarine/cooking oil - ½ cup • Brown sugar - ½ cup • Eggs - 2 • Baking powder - 1 tea spoon • Baking soda - ½ tea spoon • Lemon rind - ½ tea spoon	• Sieve flour, baking powder and baking soda together. • Rub in margarine and add the sugar. • Add eggs and lemon juice and mix thoroughly to a soft dough. • Cut the dough into small pieces and shape into balls. • Arrange the balls in a flat baking sheet and leave space for expansion. • Press the balls with a fork to flatten. • Bake at 350°F for 15-20 minutes. • When done remove, cool and serve as a snack with a beverage

Source: KALRO Bean report

7.2. Industrial Bean Use

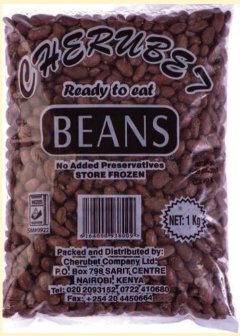
The most common value addition of beans has been products that mostly require refrigeration. These products are mainly for the special niche market and are not accessible to most of the population. These are mainly canned (Figure 31) and frozen beans (Figure 32). Wet beans are processed with a preservative and they don't require refrigeration. Once the container is opened and not all is consumed, remaining will require refrigeration.

7.0.1 Canned and Frozen Grains

Targeting a certain market prior identified by an entrepreneur in the Food Industry, canned and frozen beans are packaged for supermarket outlets (Figures 32 and 33). A choice of suitable variety is the start point for the producers to meet a demand supply in the urban centres or possible export niche.

	Canned bean products • Specific bean grain are sourced from the market or growers • The grain is sorted and cleaned • The grain is cooked, processed and canned in the canning factory

Figure 32: Canned beans



Frozen bean products

- Specific bean grain are sourced from the market or growers
- The grain is sorted and cleaned
- The grain is cooked and vacuum packaged in the factory

Figure 33: Frozen beans

7.2.2 Packaged Grains

Dry bean grain value addition at commercial scale is fairly recent in Kenya and involves sorting and grading a bean variety and packaging mostly for supermarkets (Figure 34). Consumers then purchase the packed bean grain off the supermarket shelves for cooking. Processors have mainly targeted about four varieties in Kenya where Rosecoco and yellow beans lead in the product packaging.

Packaged dry bean grain

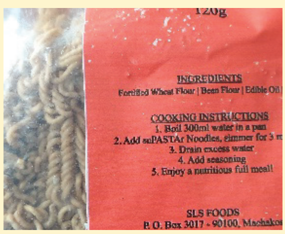
- Market demanded varieties are sourced from farmers or traders
- The grain is sorted and cleaned
- Packaged and distributed to retail outlets

Figure 34: Packaged dry bean grain

The other recent addition to bean value addition is production of pre-cooked bean products (Figure 35). The products are made from certain bean varieties that have been evaluated through research and found out to have good characteristics for industrial processing. These pre-cooked bean products are intended to save time and cooking energy to the consumer while supplying special nutrition to humans. Some of these products don't require refrigeration like the 100% bean flour, bean-based flour products, the quick quacking (15minutes) bean meal, bean based snacks (Keroma) and bean based noodles. Since they don't require refrigeration, they are accessible to a range of consumers in rural, pre-urban and urban areas where trading opportunities exist in marketing of these products.

100% bean flour

15min cooking bean meal



30% bean pasta

60% bean snack with pasta and bean meal

Figure 35: Pre-cooked bean products from the factory

8 GENDER AND SOCIAL INCLUSION IN BEAN VALUE CHAIN

8.1. Introduction to Gender

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. The term is also used more broadly to denote a range of identities that do not correspond to established ideas of male and female. In some cases, male and female youth are considered differently for their roles in an enterprise like bean value chain. 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 bean 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.

Climate change affects men and women, boys, and girls, in different ways. Therefore, it is important to see how interventions can be better designed to address the needs of different actors along the value chain and to overcome existing gender-based discrimination and associated inequalities. Women agricultural producers tend to be more exposed to climate risk compared with men, for many of the same reasons that farm productivity is, on average, lower for female than male farmers: women have less access to, and control over, productive resources and services – including climate information – with fewer employment opportunities, and they are generally less mobile for cultural and economic reasons (FAO, 2011).

8.2. The sources of disempowerment among the farmers in the bean value chain.

In bean value chain, women, men and youth play different roles of socio-economic value needed in production, post-harvest handling and marketing. Key actors in the value chain need to undertake an economic and gender analysis focusing on all domains of women empowerment on decision making on agricultural production, access and decision making over productive resources, control and use over income, leadership and time use) to establish the gains and losses identifying who is affected among men, women and youth in climate smart bean production. The table below shows the sources of disempowerment of men women and youth in each domain.

Table 15: Bean based recipe preparations

Sources of disempowerment	Climate Resilient Agribusiness for Tomorrow	
Control over use of income	women	Women were adequate in this indicator. The women have a say because most of the labour decisions fall in their hands.
	men	Men were adequate in this indicator. As the breadwinners of the family most men have a say in the income from the sale of beans.
	youth	Young men and young women were inadequate
Recommendations		Holding couple/household seminars with men and youth in attendance
Input into productive decisions	women	Senior women were adequate in this because some of the women are left with the responsibility when men go out to urban centres to look for employment.
	men	Senior men were adequate in this indicator. The women have to ask them for their opinion in any decision they have to make.
	youth	Young women were inadequate, there was no youth representation in Nakuru and Machakos counties where the study was conducted.
Recommendation		Sensitize men, women, and youth on the importance of shared decision making at the household level.
Input into marketing decisions	women	Adequate, the women always participate in the informal market.
	men	Inadequate, the men always participate in the formal market and when there is a bumper harvest and there are more surplus beans to sale.
	youth	Inadequate
Recommendations		Establishing bulking centers, access to hermetic bags, etc. Prices.
Ownership of land and other assets	women	Inadequate, women do not own land, they can only access through marriage or renting.
	men	Adequate. Land ownership was highly gendered with a higher percentage of male reported having authority over land as compared to females.
	youth	Inadequate
Recommendations		Gender equality sensitization to all.

Sources of disempowerment	Climate Resilient Agribusiness for Tomorrow	
Access to and decisions on financial services	women	Inadequate Merry go rounds, table banking was the main source of credit for women, which is never enough to buy production inputs.
	men	Inadequate
	youth	Inadequate
Recommendations		Financial literacy training to men, women, and youth
Work balance (fairness in distribution of work between the sexes)	women	Women were inadequate in this, there feeling was that their triple roles (productive, reproductive and community work) add to their workload.
	men	Senior men in all counties felt that the work is distributed fairly.
	youth	The youths were disempowered on this indicator.
Recommendation		Promoting Gender responsive CSA practices and technologies.
Group membership	women	Women were adequate in the group membership and participation though they participants said they are free in women only groups than mixed groups.
	men	Men participation in groups was adequate, especially the men from Machakos who specified that if there are returns to their hard work, they are ready to continue farming.
	youth	young men and young women were inadequate both in group membership and group participation.
Recommendation		Link farmer groups to better markets farmer like engaging in activities that have better returns.

Source: CRAFT Gender mapping 2021.

Among the questions to consider include:

- Can women have more control over the incomes they get as they are empowered economically?
- Are women taking on more workloads with increasing climate smart bean commercialization?
- What is the position of youth in climate smart bean production and commercialization?
- How is commercialization affecting household resource distribution and benefit sharing?
- What is happening to the household consumption patterns/dietary diversity with increased bean commercialization?
- Will the financial empowerment of men, women and youth farmers create spillovers in

reinvestments on farm?

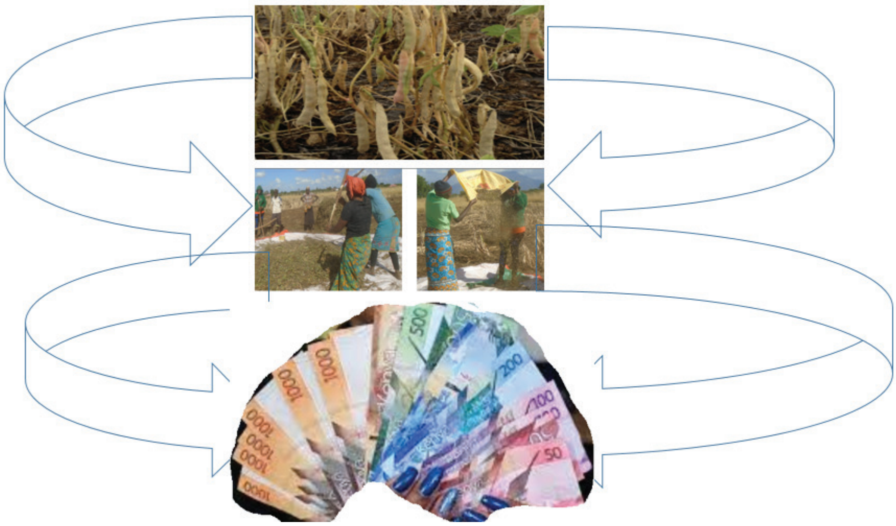


Figure 36: Let women and youth reap benefits of their hard work

The aim is to ensure that the drivers to productivity, nutrition, health, and income from the beans accrued is shared in an equitable manner between women, youth and men (Fig.37). Intersectional factors like religion, ethnicity, and education will be considered to reach and empower the most vulnerable along the urban-rural continuum.

8.3. Men in Climate Smart Bean Value Chain

Men are usually the custodians of land and in extension capital for various production inputs. As head of families they normally monopolize decisions on production acreage and marketing of the bean grain. They fully control the income from the sales of the grain. As a way of liberating the production of beans women and youth need to be empowered to have a say in the initial planning of the enterprise and subsequent revenue utilization. Much effort will be required to bring men into participating in the ways of empowering women and youth, especially on sharing of the benefits. The various choice options to enhance bean production and packaging higher value production as climate smart options will lead increased economic value of the target bean products.

Considering the high importance of beans in household diets and economies, its production is dominated by women. In Kenya, women contribute over 70% of labor used in beans production. Although this has been changing as the crop transforms from just being a subsistence to a commercial crop. This is a clear indication that bean production in Kenya depends largely on women. It is on this basis that, in most of African countries, beans is generally labeled a “woman’s crop”. In addition, decisions relating to these products are also made by women; thus, women know much about these crops. However, because men consider themselves as income providers, then they are in most cases in control over income from beans.

The youth ought to be incentivized in family enterprises where bean value chain activities are carried out from production, value addition and transport to the market. Sharing of the income is what the youth normally does not have much say especially if they do the farming jointly with their parents.

During the CRAFT Gender mapping activity in Bomet, Nakuru and Machakos in 2021, there was no young men representation in Nakuru and Machakos counties. This is to inform the stakeholders and actors in the value chain that much effort needs to be put in place to bring more youth in bean farming. Figure 37 below shows the percentage of gender representation of participants in FGDs during gender mapping exercise.

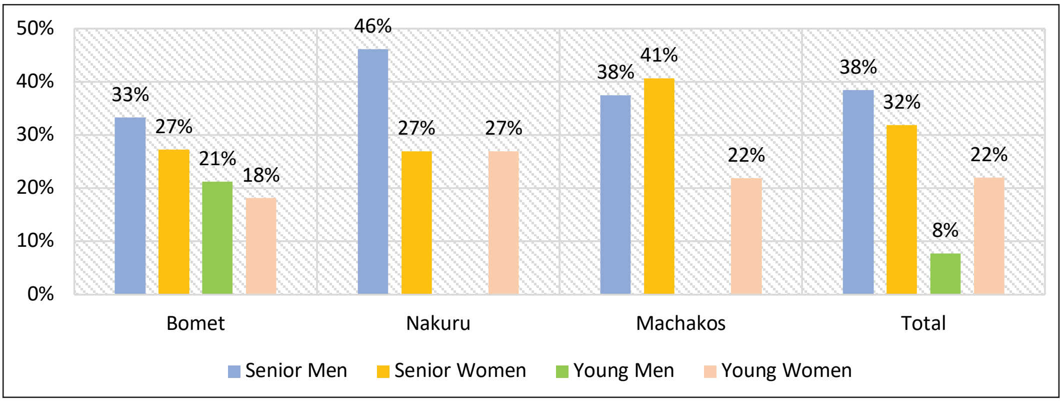


Figure 37: Percentage Gender Representation of Participants in FGD
Source: CRAFT Gender mapping 2021.

8.4. Women Important Roles in Bean Value Chain

In most agro ecosystems, women and the youth have specific roles complementing men as the main decision makers. The impacts of climate change are diverse. Women, in most parts of the world, tend to suffer inequitable access to resources and information, decision-making processes, and benefit sharing. Women tend to be more vulnerable to climate change than men are, because they are more dependent on natural resources. Thus, when dry spells or floods occur it will affect women most due to the negative effects on the bean plot (Fig.38). Loss of the crop and final yield will mean reduced share of the income, unlike men who could have other options.

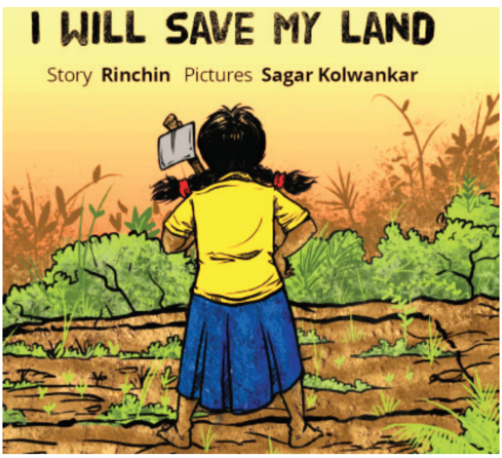


Figure 38: Picture courtesy: niahouse.org

8.5 Youth as Complementary Workers

In most cases the youth ought to be motivated or incentivized in family enterprises where bean value chain activities are carried out. As from production, value addition and transport to the market. Sharing of the income is what the youth normally does not have much say what to use. Of the various tasks of bean value chain, the youth has little said and is instructed by head of the family. After a period, the youth wean into independent player in the bean chain value (Fig.39). Before that how can the youth as young men or women be included in various chain points with accrued income as the attractant item? This would motivate the young as major players in bean value chain.

Figure 39: Youth prepared tasks in bean production.
Picture courtesy: klipartz.com

8.6 Gender responses in procedures

If machines are used it is important to consider machines which are user friendly especially for women. Whether planting beans, weeding and harvesting as well threshing all ought to be women user friendly (Fig.40). Otherwise, most machines are made with men as the end users. To encourage more women in bean production, then machines they will use ought to be suitable to the various tasks to be performed.

Weeding machine

Manual planting in Furrows/ open ridges

Threshing machines

Figure 40: Equipping women with adaptable machines
(Pictures courtesy of Uganda Ministry of Agriculture Animal Industry & Fisheries and Zealyu Machinery).

9 ENABLING POLICY ENVIRONMENT FOR ADOPTION OF CLIMATE-SMART AGRICULTURE APPROACHES

9.1. The Kenya Climate Smart Agriculture Strategy

Climate smart agriculture practices can address the possible impacts of the climate change. Resourceful and transformative approaches are required immediately to help all stakeholders in covering all value chains in the agriculture sector to mitigate against the current and projected effects of climate change. The government of Kenya through the Kenya Climate Smart Agriculture Strategy-2017-2026, provides enabling strategies that have goals and actions points that promote investment in climate smart agriculture. The Kenya Climate Smart Agriculture Strategy-2017-2026, indicates the political, environment, social, and technology, legal and economic factors that affect the implementation of the climate smart agriculture practices. An analysis of these factors will enable us develop of interventions that may be a limitation to climate smart agriculture approaches.

9.1.1 Objectives of the Kenya Climate Smart Agriculture Strategy

The broad objective of the Kenya Climate-Smart Agriculture Strategy (KCSAS) is to adapt to climate change, build resilience of agricultural systems while minimizing emissions for enhanced food and nutritional security and improved livelihoods. The specific objectives of the KCSAS are to (i) enhance adaptive capacity and resilience of farmers, pastoralists and fisher-folk to the adverse impacts of climate change; (ii) develop mechanisms that minimize greenhouse gas emissions from agricultural production systems; (iii) create an enabling regulatory and institutional framework; and (iv) address cross-cutting issues that adversely impact climate-smart agriculture.

The creation and implementation of appropriate policies and an enabling environment is essential for achieving the widespread adoption of climate-smart agriculture (CSA). The wide scale adoption of climate smart agriculture technologies depends on the creation and implementation of appropriate policies. The climate change policies, strategies, actions and plans are coordinated by the National Climate Change Secretariat under the Ministry of Environment and Natural Resources.

In addition, the government recognizes the threats posed by climate change and has taken action to address them through the Kenya National Adaptation Plan 2015-2030.

9.2 Kenya National Adaptation Plan

It is envisioned that the plan will result in reduced climate-induced loss and damage, mainstreamed disaster risk reduction approaches in various sectors, reduced costs of humanitarian aid, and improved knowledge and learning for adaptation and the future protection of the country. The adaptation plan encompasses agriculture and food security plans, development and poverty reduction strategies.

The national adaptation plan includes the policies and strategies of other actors, such as private sector actors and investors, regional and intergovernmental organizations for example *Climate Change for Agriculture and Food Security* (CCAFS), national and international civil society organizations, farmer organizations, and others.

9.2.1. Objectives of the Kenya National Adaptation Plan (2015-2030)

The objective of the plan is to highlight the importance of adaptation and resilience building actions in development; integrate climate change adaptation into national and county level development planning and budgeting processes; enhance the resilience of public and private sector investment in the national transformation, economic and social and pillars of Vision 2030 to climate shocks; enhance synergies between adaptation and mitigation actions in order to attain a low carbon climate resilient economy; and enhance resilience of vulnerable populations to climate shocks through adaptation and disaster risk reduction strategies.

The plan serves as a policy engagement guide and remove components that act as disincentives for adopting climate smart agriculture practices, such as public subsidies, while reallocating resources to programmes that provide incentives for the adoption. Policy tools and instruments, such as rural credit programmes, input and output pricing policies, subsidies, support for investment with public-good benefits, property rights, research and extension services, and safety net programs, can all be used to increase the incentives for farmers to modify production systems and build capacities for climate smart agriculture. The Kenya National Adaptation Plan 2015-2030 encompasses a deeper understanding of the power structure and policy decision-making process on climate change at the national and county levels. Great knowledge on policy formulation is required by policy makers at both national and county governments, particular information is tailored to help in decision-making processes and to ensure a great link between science and policy levels.

Kenya Constitution 2010 Act 43; Every Kenyan has a right to be free from hunger, and have adequate food of acceptable quality

Food and Nutrition Policy (FNSP) 2012 the broad objectives of the FNSP are:

1. To achieve good nutrition for optimum health of all Kenyans.
2. To increase the quantity and quality of food available, accessible and affordable to all Kenyans at all times.
3. To protect vulnerable populations using innovative and cost-effective safety nets linked to long-term development.

Agriculture Sector Transformation and Growth Strategy (ASTGS) 2019- 2029

The Strategy is based on the fact that food security requires a vibrant, commercial and modern agricultural sector that supports Kenya's economic development sustainably.

Specific target outcomes for the first five years follow:

Anchor 1: Increase small-scale farmer, pastoralist and fisher folk incomes

Anchor 2: Increase agricultural output and value add – Expand agricultural GDP from KES2.9 trillion to KES3.9 trillion

Anchor 3: Boost household food resilience

Agri-nutrition Strategy Implementation Strategy; 2020 -2025

The main objective is to contribute towards reduction of high malnutrition levels through coordinated Agri-nutrition action plans by state and non-state actors to empower to produce and consume adequate, safe and nutritious foods.

The strategy is aligned to government commitment of 100% Food and Nutrition security of the Big four Agenda for 2017- 2022 and the SDG –Goal 2 of achieving Zero Hunger by 2030

9.3 Challenges in policy development and creation of enabling environment in sorghum value chain

However, there are some challenges in supporting the development of policy and enabling environments. These include;

- **a)** Ensuring ownership by those responsible for formulation and implementing policies and strategies, and those who are likely to be affected by the policy,
- **b)** Creation of an inter and intra-sectoral approaches and policies that can create integration and coordination among actors,
- **c)** Ensuring effective implementation of plans and strategies at both national and county governments,
- **d)** Finally, it is unfortunate that most policy processes are complex and require high level of commitment.
- **e)** Inadequate funding in policy development, implementation and enforcement

Participatory assessments, multi-stakeholder scenarios and use of simulation models, multi-criteria analysis, participatory power mapping, companion modelling and participatory game design, methods to calculate participatory social returns on investment are some of the tools that can be used in guiding the policy formulation. These can enable development of climate smart agriculture policies for the sorghum value chain that are compatible with the local needs.

10 REFERENCES FOR FURTHER READING

1. Albu, M. and Griffith, A. (2006). Mapping the market: participatory market chain development in practice *Small Enterprise Development* Vol. 17 No.2 http://cdn1.practicalaction.org/m/a/4d92802d-56e0-466f-9ff9-14542e33baf9.pdf

2. Duku C, Groot A, Demissie T, Muhwanga J, Nzoka O, Recha J. 2020. Common beans Kenya: Climate risk assessment. Climate Resilient Agribusiness for Tomorrow (CRAFT). https://hdl.handle.net/10568/107723

3. Dwivedi S. L., Sahrawat K. L., Rai K. N., Blair M. W., Andersson M., Pfieffer W.(2012). Nutritionally enhanced staple food crops. Plant Breed. Rev. 34, 169–262

4. Karanja D. (2016). Pulses crops grown in Ethiopia, Kenya and United Republic of Tanzania for local and Export Market. International Trade Centre, Eastern Africa Grain Council.

5. Karanja D. R., Githunguri C.M., M'Ragwa L., Mulwa D. and Mwiti S. (2006). Variety, Characteristics and Production Guidelines of Traditional Food Crops. KARI Katumani Centre Annual Report.

6. Karanja D. R., Makoani W., Wasike V., Jamoza J., Wasilwa L., Kirigua V. and Malinga J. (2020). Community seed bulking. A model to improve and increase amount of good quality seed to farming communities. KALRO KCSAP

7. Katungi E., Farrow A., Mutuoki T., Gebeyehu S., Karanja D., Alamayehu F., Sperling L., Beebe S., Rubyogo J.C. and Buruchara R. (2010). Improving common bean productivity: An Analysis of socioeconomic factors in Ethiopia and Eastern Kenya. Baseline Report Tropical legumes II. Centro Internacional de Agricultura Tropical - CIAT. Cali, Colombia

8. Famine Early Warning Systems Network (FEWS NET) (2018). East Africa Cross Border Trade Bulletin. Vol.3

9. Helm J. L., Grafton K.F. and Schneiter A.A.(1990). Dry Bean Production Handbook (1990)., North Dakota State University, Fargo, NO 58105.

10. Kamunzo J.K., Mutisya D.L., Muli B.K and Nguluu S. N. (2018). Comparative whitefly vector density and bean disease incidence on local and hybrid varieties in semi-arid Kenya. GSC Biological and Pharmaceutical Sciences, 2018, 05(03), 046–053. https://doi.org/10.30574/gscbps.2018.5.3.0071

11. International Panel on Climate Change (IPCC) (2001). Third Assessment Report.

12. London Capital Group (LCG) 2018. Climate Change Scenarios, London

13. Kenya Soil Survey 2019: Bean Suitability Maps. KALRO Report

14. Madhavan M, Rengalakshmi R (2015) Seasonal climate information for ensuring agricultural sustainability and food security of small holder Rain-fed farmers: experience from India. M.S. Swaminathan Research Foundation, Chennai, India. http://docplayer.net/29188604-Seasonal-climate-information-for-ensuring-agricultural-sustainability-and-food-security-of-small-holder-rainfed-farmers-experience-from-india.html. Accessed 28 Feb 2021

15. Ministry of Agriculture, Livestock & Fisheries (MoAL & F) (2015). Economic Review of Agriculture. Central Planning and Project Monitoring Unit. Retrieved from: http://www.kilimo.go.ke/wp-content/uploads/2015/10/Economic-Review-of-Agriculture_2015-6.pdf.

16. Netherlands Centre for Geodesy and Geo-information (NCGG) 2018.

17. One Acre Fund, 2015. Improved bean seed. Full scale Report.

18. PABRA (2009/2010). Pan-African Bean Research Alliance. Annual Report. 2009/2010

19. Poku, A.; Birner, R.; Gupta, S. (2018). Making Contract Farming Arrangements Work in Africa's Bioeconomy: Evidence from Cassava Outgrower Schemes in Ghana, Sustainability, 2018, 10, 1604.

20. Poole, N.; Freece, A. A. (2010). Review of Existing Organisational Forms of Smallholder Farmers' Associations and their Contractual Relationships with other Market Participants in the East and Southern African ACP Region. Food and Agriculture Organization of the United Nations (FAO). AAACP Paper Series – No. 11. 2010. 12.

21. Buruchara R., Mukankusi C. and Ampofo K. (2010). Bean disease and pest identification and management: Handbook for small-scale seed producers. CIAT Hand book 4.

22. Wanjala S., Karanja, D., Wambua, S., Otiep, G., Odhiambo, C. and Birachi, E. (2018). Marketing Arrangements Used by Small Scale Bean Farmers in Kenya: What Needs to Change for Sustainable Trade Volume 2

23. WillenBockel D. (2012a). Extreme weather events and crop price spikes in a changing climate.

https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=2316&context=usdaarsfacpub

24. Willenbockel D. (2012b). Extreme weather events and crop price spikes in a changing climate: illustrative global simulation scenarios. www.oxfam.org

11 ANNEXES

Annex 1: Bean Grain Standards: EAS 46:2013 – DRY BEANS

S/N	Characteristics	Maximum limits			Method of test
		Grade 1	Grade 2	Grade 3	
	Foreign matter, % m/m	0.5	0.75	1	ISO 605
	Inorganic matter, % m/m	0.1	0.2	0.3	
	Other edible grains, % m/m	0.1	0.2	0.5	
	Pest damaged grains, % m/m	1	2	3	
	Heat damaged grains, % m/m	0.1	0.2	0.5	
	Contrasting varieties %m/m	0.5	1	1.5	
	Broken/split % m/m	1	2	3	
	Discoloured %m/m	1			
	Total defectives grains, % m/m	2	3.5	5.5	
	Filth, % m/m	0.1			
	Moisture, % m/m	14			ISO 24557
	Total aflatoxin (AFB_1+AFB_2+AFG_1 +AFG_2)), ppb	10			ISO 16050
	Aflatoxin B_1, ppb	5			
	Fumonisin ppm	2			AOAC 2001.04

NOTE: The parameter, Total defective grains is not the sum total of the individual defects. It is limited to 70 % of the sum total of individual defects

Annex 2: Roles and responsibilities of stakeholders in bean value chain

Partners	Roles and responsibilities
National Agricultural Research Systems (NARS)	• Development of marketable and preferred bean varieties based on national and regional demands • Production and supply of early generation seeds • Provision of information on new varieties • Support other partners and farmers leaders' skills and knowledge enhancement in improved bean production and collective marketing • Catalyze the development of bean sub sector at county, national and regional levels
State Ministry of Agriculture - policy making	• Promote and enhance bean value chain development • Serve as champion of bean value chain development to other national and county government policy makers • Policy support towards bean research and development • Engage and support private sector investors in the bean value chains
County Governments and Extension Agents	• Support decentralized testing of varieties and provide feedback to researchers • Support decentralized bean grain production and diffusion • Capacity building in bean seed and grain production, quality control • Enhancement of skills in agribusiness management • Mobilize farmers to produce beans and link them to local and export markets • Facilitate linkages with service providers in the bean value chain for example, transporters, cooperatives and researchers • • Facilitate acquisition of basic seeds and other technologies to farmers' groups and individual farmers • Catalyze formation of bean stakeholder platforms
Public and Private Seed Enterprises	• Production and marketing/supply of basic and certified seeds • Business opportunities and capacity building for contracted seed growers, distributors and agro-dealers
Decentralized bean grain producers	• Test new bean varieties with support from extension service, research and other providers • Local community contacts and wider dissemination of information and seeds • Production and marketing of bean grain in local markets and to local organizations • Participate in local bean grain aggregation and marketing
Local Grain Traders	• Purchase of bean grains for local and external markets • Establishment of basic market infrastructure (storage facilities)

Partners	Roles and responsibilities
Bean off takers and exporters	• Testing marketability/suitability of existing and new varieties • Establishment of quality standards and market infrastructure • Purchase and export of quality bean grain (market guarantee) • Training of collectors/traders on grain quality control systems • Members of bean multi-stakeholders' platform
Cooperative Unions/registered farmer groups	• Mobilization of farmers (members) • Provision of agri-inputs (fertilizers, seed) to famers on loan or cash • Purchase of bean grains from the members and other farmers • Establishment of market infrastructure storage, cleaning equipment • Members of bean multi-stakeholders' platform
NGOs	• Support decentralized bean grain production and diffusion • Capacity building in bean seed and grain production, quality control • Enhancement of skills in agribusiness management • Mobilize farmers to produce beans and link them to local and export markets • Facilitate linkages with service providers in the bean value chain for example, transporters, cooperatives and researchers • Facilitate acquisition of basic seeds and other technologies to farmers' groups and individual farmers • Catalyze formation of bean stakeholder platforms
International Research Institutes (CIAT, ICRISAT/ IITA)	• Provision of legume germplasm • Training in seed production and business skills • Support in the design of innovative legume seed systems approaches for wider impact • Support the development of efficient and productive seed multiplication techniques

Note: Adapted from Rubyogo et al. (2010).

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