FARMING-SYSTEM SPECIFIC EXTENSION CONTENT FOR ENHANCING CLIMATE CHANGE ADAPTATION AND RESILIENT FOOD SYSTEMS IN SORGHUM-BASED DRYLAND FARMING SYSTEMS OF TANZANIA AND BURKINA FASO

DR. SAID N. SILIM
SEED AND AGRICULTURAL DEVELOPMENT EXPERT

P. O. BOX 10305
NJIRO, ARUSHA, TANZANIA
TELEPHONE: +255 688 186 030
E-MAIL: saidsilim@gmail.com

22nd December 2022

1 INTRODUCTION

1.1 WHAT IS THE CONTENT IN THIS PUBLICATION INTENDED FOR?

The content in this publication is intended to provide information and tips to agricultural extension and advisory services (AEAS) providers who work directly with farmers in the sorghum-based dryland farming systems of Burkina Faso and Tanzania. The content may also be used in other African countries with similar conditions and farming systems. If this is done, there may be a need to make some context-specific modifications.

1.2 WHAT ARE THE COMMON PILLARS?

This publication is built on two common pillars. First is that, in general, agricultural extension agents need to package the advice they give to farmers in the context of food system resilience and the practice of climate-smart agriculture (CSA) based on the crops that they grow. Second is that the CSA services have to rely on robust climate services.

According to the World Bank[1] CSA aims to simultaneously achieve three outcomes:

1. **Increased productivity:** Produce more and better food to improve nutrition security and boost incomes, especially for the poor who live in rural areas and mainly rely on agriculture for their livelihoods;
2. **Enhanced resilience:** Reduce vulnerability to drought, pests, diseases and other climate-related risks and shocks; and improve capacity to adapt and grow in the face of longer-term stresses like shortened seasons and erratic weather patterns;
3. **Reduced emissions:** Pursue lower emissions for each calorie or kilo of food produced, avoid deforestation from agriculture and identify ways to absorb carbon out of the atmosphere.

The focus on food system resilience, emphasises the aspect of food (not just production and productivity) in advising farmers. The Food and Agricultural Organisation (FAO) of the United Nations gives a comprehensive description and discussion of agrifood system resilience[2]. Put simply for the context of agricultural extension agents supporting rural African farmers, resilience of agrifood systems encompasses primary agricultural production of food and non-food products (from crops, livestock, fisheries, forestry and aquaculture), the food supply chain from producer to consumer and the final consumer of food. A truly resilient agrifood system must have a robust capacity to prevent, anticipate, absorb, adapt and transform in the face of any disruption, with the functional goal of ensuring food security and nutrition for all and decent livelihoods and incomes for agrifood systems' actors. Such resilience addresses all dimensions of food security but focuses specifically on the stability of access and sustainability, which ensure food security in both the short and the long term.

[1] https://www.worldbank.org/en/topic/climate-smart-agriculture

[2] FAO (2021): The state of food and agriculture 2021 - Making agrifood systems more resilient to shocks and stresses. https://www.fao.org/3/cb4476en/online/cb4476en.html#chapter-executive_summary

For the above reasons, all the topics addressed in this publication are prefaced by clearly articulating the climate change and food system resilience issue being addressed and the essential technical knowledge needed.

Climate services provide climate information to assist decision-making. They are overarching since all the CSA operations must be based on scientifically credible climate information and expertise, and require appropriate engagement between the users and providers. Hence, they are treated as a standalone topic for advisory service provision.

1.3 WHO ARE THE TARGETED USERS OF THIS PUBLICATION?

The content is explicitly intended for potential use by village-based advisors (VBAs) and other extension service providers in the countries targeted by Alliance for a Green Revolution in Africa (AGRA). It is assumed that the VBAs and other extension workers are knowledgeable about the agro-ecologies they are working in and that they are fully integrated with agricultural research staff who are developing, testing and releasing the technologies. This is necessary for them to be continuously aware of the new proven technologies as they become available. They are also assumed to have the knowledge and skills to use a range of extension methods for engaging with individuals or groups of farmers and other actors. In the case of AGRA this should include the approaches promoted through the AGRA Extension Strategy[3], namely: *"Mother-Baby-Demonstrations (M&B)"* and extension message delivery through *"ICT4Ag"*. Capacity development in the use of these approaches may therefore be a necessary precursor for using this content. The capacity development could embrace other extension approaches such as:

- **The Value-Chain Extension (VEC) Model** model being implemented by Sasakawa Africa Association (SAA);
- **The "*Twigire Muhinzi Extension (TME)"* model** - a 'home-grown solution' and adaptation of various extension approaches to ensure that all farmers in Rwanda have access to advisory services;
- The **Innovation platforms (IP)** model championed by CGIAR;
- **The Farmer Field Schools (FFS)** model championed by FAO;
- **Field days and demonstrations** that are classically used in agricultural extension.

1.4 WHAT ARE THE TARGETED FARMING SYSTEMS AND LOCALES?

The AGRA commissioned the production of the content in this publication for use in the Sahelian sorghum-millet-agro pastoral subsystem in Burkina Faso and the East African sorghum-based arid and semi arid lands (ASAL) subsystem in Tanzania. These are equated to the agro-pastoral farming systems described by Dixon et.al. (2015) and depicted graphically in Figure 1)

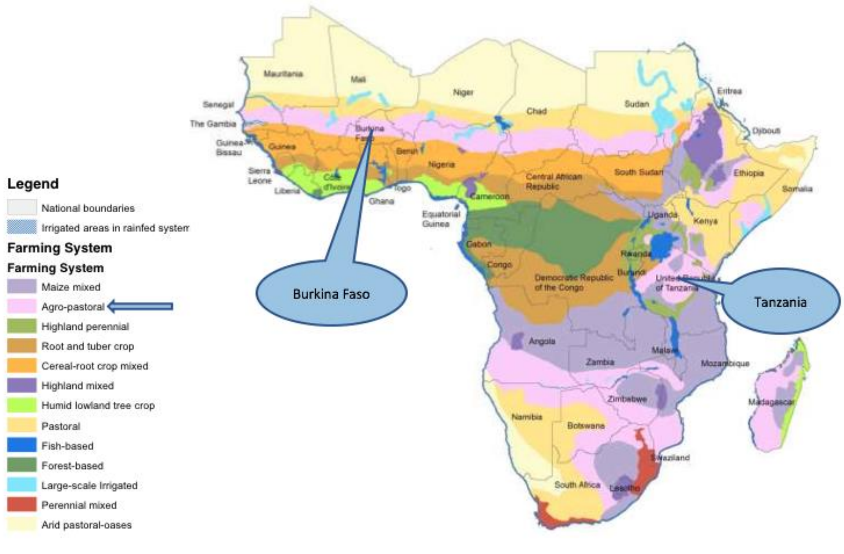
In general the agro-pastoral systems are dominated by sorghum, millet and livestock (cattle, sheep, goats). Other livelihood sources include pulses, sesame, poultry and off-farm work (Dixon et.al 2015). The rural people in these systems derive their livelihoods and food security

[3] https://agra.org/extension-capacity-building/

from crop and livestock production activities and natural resources while also supplying food to urban populations. For centuries they have adapted their farming and livelihood activities to the uncertainties of the local environment. Rainfall variability has pronounced effects on plants and animal production leading to recurrent food insecurity. A strong characteristic of the system is the diversity of crop and livestock production systems based on differences in farmer access to land and livestock capital ranging from specialized cropping systems with a small animal husbandry component to increasingly sedentary mixed systems. Another key factor of this production system is the low land productivity, except in riverine areas where soil fertility and water availability are sufficient to allow production of other crops (rice, vegetables, etc.). This system also has inclusions of small and microscale irrigation areas. New or longer standing challenges that include high population growth rates, climate change, land and resource access and tenure constraints, environmental concerns, institutional change, and global market changes have had major impacts on the agro-pastoral farming system.

In Burkina Faso the agro-ecological setting of sorghum based systems is typified by ancient, weathered soils, drifting sands from the Sahara and climatic pattern is remarkably steady, stretching across a vast west-to east belt (Figure 1). This pattern is characterized by a rainfall gradient that ranges from very dry in the northern Sahelian ecozone to the wetter Guinea savanna ecozone that lies further south. The sorghum-based system lies between the northern Sahelian and the wetter Guinea Savanna in the south.

In Tanzania, sorghum-based systems are found in the central regions. Agro-ecologically the systems are more complex than the other regions of the country because of a wider range of geological, soil morphological, altitude, latitude and climatic attributes (temperature and rainfall).



Reference: Farming Systems and Food Security in Sub-Saharan Africa Priorities for science and policy under global change. Edited by John Dixon, Dennis Garrity, Jean-Marc Boffa, Tim Williams, Tilahun Amede with Christopher Auricht, Rosemary Lott and George Mburathi (2015). https://www.researchgate.net/profile/Amir-Kassam/publication/340370072_The_cereal-root_crop_mixed_farming_system/links/5fe61f11299bf1408843ef4b/The-cereal-root-crop-mixed-farming-system.pdf

Figure 1: Agro-pastoral farming systems described by Dixon et.al. (2015)

1.5 HOW WAS THE NEED FOR THE CONTENT DETERMINED?

The content in this publication is based on the needs that were identified through literature reviews as well as key informant interviews and focus group discussions involving stakeholders working in the sorghum-based farming systems in Tanzania and Burkina Faso. The needs identified by different stakeholder categories in Tanzania are presented in Table 1 below. In Burkina Faso, needs were obtained from The Institut de l'Environnement et de Recherches Agricoles (INERA) and Government Extension Services.

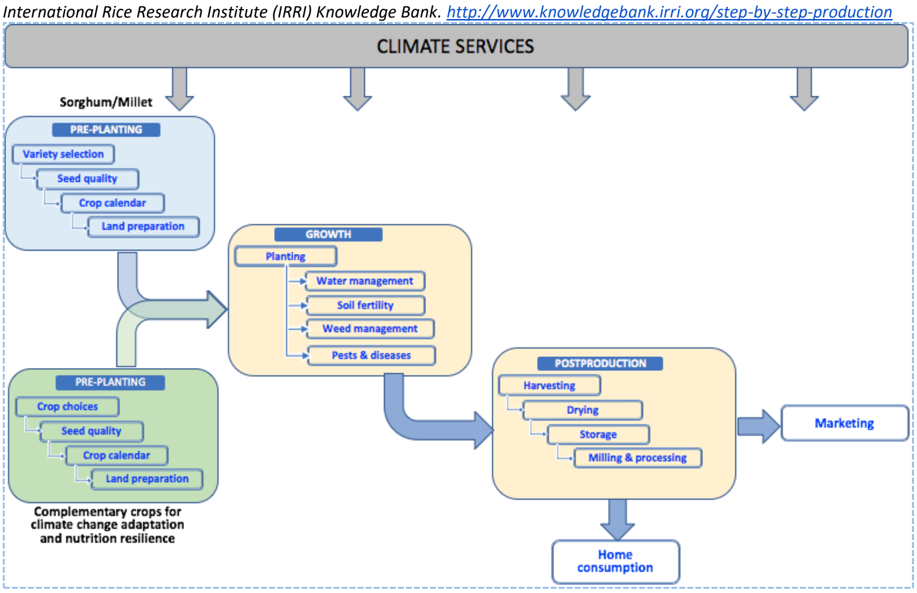
Table 1. Identified extension content needs by different stakeholder groups

Derived content needs	TANZANIA					BURKINA FASO	
	Ministry of Agric.	Agro-dealers	NGOs	Govt. extension	Farmers	Ministry	Research
Good agricultural practices/ recommendations for sorghum production	x	x	x	x	x	x	x
Suitable/improved varieties available and their recommended agronomic practices - especially for different environmental and climatic risk conditions		x	x	x	x	x	x
Inputs/ chemical fertilisers use for sorghum production	x		x		x		
Post-harvest management for sorghum		x	x	x			x
Post-harvest management for pearl millet		x		x			
Quality declared seed production (QDS)				x	x	x	
Markets and market linkages	x				x		
Improved delivery of extension/ extension approaches	x	x					
Recommendations on improved varieties of pearl millet				x		x	x
Recommendations for use of chemical fertilizer on pearl millet				x			
Recommendations on use of chemical fertilizers alongside yard manure.				x			
Irrigation	x						
Mechanisation	x					x	x
Soil and water management		x					
In-situ water harvesting			x			x	x
Use of tie and ridge, pts and bunds					x		
Extension recommendation on the use of PICSs bags for long term storage;				x			x
Resilience and coping with climate change,		x					
Farming as a business		x					
How to produce/ package content for extension		x				x	
A combination tillage practices, CA, fertilizer micro-dosing and use of farm yard manure,			x			x	
Pest and disease control for sorghum			x			x	x
Good agricultural practices/ recommendations for horticultural crop production (mainly tomatoes, okra and leafy vegetables)				x		x	
Pest and disease control for horticultural crops				x		x	
Varietal testing and promotion			x			x	x
Institutional and organizational development					x	x	

1.6 HOW IS THE CONTENT INTENDED TO BE USED?

The content is structured in a way that the AEAS providers can use it to engage with farmers on a "journey" that can start from identifying and selecting the varieties of sorghum and other crops that they can grow, all the way to marketing or consuming the produce. This "journey" is depicted graphically in Figure 2.

Figure 2: Generic extension content domains for crop production *(Adapted from "Step-by-step production" International Rice Research Institute (IRRI) Knowledge Bank. http://www.knowledgebank.irri.org/step-by-step-production*



Ideally, the AEAS provider can use the content to work with groups of farmers on this journey. However, this ideal condition rarely prevails. The AEAS provider may have to work with individual farmers/households who have already started on the journey and may not even wish to be taken the whole way. In these cases, the content can be used to give the farmers a "lift" from where they are to where they want to go. Whatever the case, the AEAS provider should ensure that the advice s/he provides is wholesome from the perspective of integrating other considerations needed for sustainable farming system livelihood strategies based on diversified crop and livestock production.

2 CLIMATE SERVICES

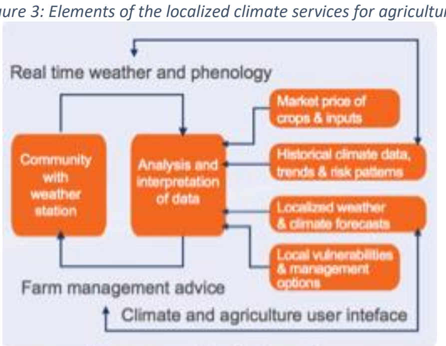
2.1 CLIMATE CHANGE AND RESILIENT FOOD SYSTEM ISSUES

Climate variability and change place significant stress on food production and availability. Highly variable seasonal rainfall, increasing trends of temperature and extreme climate events together with growing demand for food and energy places additional pressure on the food systems and natural resources. The climate impacts are location specific implying a need for localized climate services. Extension agents are a critical link in a localized climate service at decentralized levels. Their role in the service is to bridge the gap between the climate information providers and the information users. The issue is how to enable them to play this role.

2.2 ESSENTIAL TECHNICAL INFORMATION

The Food and Agricultural Organisation (FAO, https://www.fao.org/3/az620e/az620e.pdf) identifies the four main elements of the localized climate services for agriculture as being: (i) collection and synthesis of data on local weather, climate, crop and market price of crops and inputs; (ii) use of weather and climate forecasts; (iii) analysis and development of impact outlooks and management options; (iv) and communicating to end-users. These elements are cyclic as illustrated in the Figure below:

Figure 3: Elements of the localized climate services for agriculture



Source: Climate services for food and agriculture. FAO, https://www.fao.org/3/az620e/az620e.pdf

Both Burkina Faso and Tanzania are implementing national frameworks for climate services to improve the availability and use of tailored weather and climate services necessary to strengthen resilience to climate change and extreme weather. In Tanzania implementation of the framework is led by the Tanzania Meteorological Agency while in Burkina Faso implementation is led by the General Directorate of Meteorology. In both cases, different sectors of government and society are embraced in order to increase coordination and facilitate cross-cutting action and informed decisions.

2.3 FACILITATING CLIMATE SERVICES FOR FARMERS

Localized climate services consider community perceptions, traditional knowledge, livelihood patterns, gender and reliable communication channels. It also promotes community participation and enhances two-way feedback. Hence the extension agents and farmers should play a part in the cyclic identification, analysis and prioritization of the current and future vulnerabilities and climate risks and design management strategies to promote proactive decision-making. This should become more effective as communities are acquire local weather stations.

The extension agents should facilitate the farmers to play their (farmers') role in implementing the national frameworks for climate processes by linking them to the following processes:

A. **Monitoring, data, tools and methods:**
- Acquisition and dissemination of climate data
- Down-scaling climate change scenarios
- Crop monitoring and forecasting
- Climate change impact assessment
- Estimating local climate for regions where coverage of weather stations is scarce

B. **Managing risks of climate variability and change**
- Assessing local risks and variabilities
- Provision of customized weather and climate forecasts for agricultural management
- Provision of need-based advisories to farmers for proactive decision making
- Promoting local coping and improved adaptation strategies to build resilience of food systems

C. **Managing food systems and their resources**
- Land use planning and agro-ecological zoning
- Planning and design of water conservation strategies and enhancing water productivity
- Designing cropping patterns conditioned on climate variation and change
- Supporting agricultural research to develop new crop types tolerant to stresses
- Monitoring ecosystems and biodiversity hotspots

D. **Advancing payment for environmental services and risk transfer mechanisms**
- Defining resource conservation practices
- Promoting economic incentives to farmers for managing ecosystems
- Protecting livelihoods through weather-based insurance mechanisms

E. **Contributing to food security information and emergency response**
- Analysing food security and information on livelihoods
- Food insecurity and vulnerability information
- Providing advance information about impending food crises
- Facilitating disaster risk management in agriculture
- Monitoring crop and livestock pests and diseases

3 VARIETY SELECTION

3.1 CLIMATE CHANGE AND RESILIENT FOOD SYSTEM ISSUES

At the pre-planting stage a major aspect that the extension agents need to be able to advise farmers on is the selection of varieties of the diverse crops of their choice that have the highest potential for achieving the CSA outcomes.

3.2 ESSENTIAL TECHNICAL INFORMATION

In Burkina Faso - as in the rest of the West and Central Africa sorghum-based farming system - the highest proportion of subsistence-oriented smallholder farm households that depend mainly on sorghum and pearl millet, groundnut and cowpea. Livestock is important in the system.

The Central Tanzania sorghum-based system is similar to that of West Africa except that pearl millet is relatively unimportant but pigeonpea is added to the mix as well as sunflower which is promoted by the Government as part of an effort to become self-sufficient in cooking oil.

The agro-ecologies of sorghum-based systems are characterized by high and increasing temperatures, low and variable rainfall and degraded soils. The crops are used for home consumption and markets and straw is for livestock feed.

3.3 FACILITATING VARIETY SELECTION

3.3.1 Generic desired attributes of varieties

Varieties selected should be tolerant to drought, resistant to diseases and pests, high yielding, early maturing and preferred by end users. In both countries, varieties are available from research that are drought and heat-resistant, making them suitable to climatic conditions in the areas. Available pigeonpea, groundnut and cowpea varieties are drought tolerant and improve soil fertility through nitrogen fixation. Sunflower in Tanzania is a drought-resistant crop promoted by the Government in an effort to become self-sufficient in cooking oil. Also in Tanzania, sorghum is increasingly being used in the brewing industry and white grain is the preferred trait hence varieties grown should be white-seeded

3.3.2 Available varieties of the major crops in the Tanzania sorghum-based system

In Tanzania, the Tanzania Agricultural Research Institute (TARI) - Hombolo which is dedicated to the drylands and is being converted into the Centre for Climate Resilient Crop Research, has developed the following varieties that can be demonstrated to farmers for selection:

1. **Sorghum** – research has led to release of a number of varieties (Macia, Wahu, Hakika, Pato, Tegemeo) and by Private sectors (Namburi: Naco Mtama 1 and two hybrids - Naco SH 1 and 2; Advante has two varieties Pac 501 and 537)
2. **Pearl millet** released varieties are Okoa and Shibe
3. **Finger millet** varieties released are P224, U15 and TARI Finger millet 1
4. **Groundnut** - more than 7 varieties have been released
5. **Sunflower** - released varieties include Record and Kenya Feather and four hybrids released by the private sector.

6. **Green gram** - two varieties released, Imara and Nuru
7. **Cowpea varieties** released are: Fahari, Tumaini, Vuli 1, Vuli 2, Vuli Ar 1, Vuli Ar, Raha 1, Raha 2
8. **Pigeonpea -** grown in Kongwa and Kiteto using varieties Ilonga 14-M1 and Ilonga 14–M2

3.3.3 Available varieties of the major crops in the Burkina Faso sorghum-based system

In Burkina Faso, the research systems have developed the following varieties that can be demonstrated to farmers for selection:

i. **Sorghum** – IRAT 204, E 35-1, FRAMIDA, ICSV 1049, Sariaso 10, Sariaso 13, Sariaso 14
ii. **Pearl millet** - CMV-IS 88102, IKMP 1, IKMP 2, IKMP 8201, SOSAT-C88, IKMP 18001, IKMP 18002IKMP 18004
iii. **Groundnut** – CGV 86082, NAFA 1, LOKRE, MIOU, TOUINWA, BEEDA, SOUKEBA
iv. **Cowpea**: a number of varieties are grown but for rotation, it is local indeterminate landraces.

4 ENHANCING THE USE OF IMPROVED/ QUALITY SEED

4.1 CLIMATE CHANGE ADAPTATION AND RESILIENT FOOD SYSTEMS ISSUES

Using quality seed of all crops is a determinant of food system resilience and has to be taken into consideration at the pre-planting stage. Yet, for the dryland crops such as sorghum and millet, there is limited research focus by national public research institutes despite the fact that they are critical for resilience and livelihoods in these agro-ecologies - being sources of food, nutritional security and income security, especially rural communities living in drylands and farming areas prone to drought under climate change. The varieties availed to farmers, therefore, need to produce good yields under these conditions. The issues that have to be overcome by the extension agent are:

- For farmers to adopt improved varieties the seeds should be available (physical presence) and accessible (affordability or the power to buy);
- The adoption of quality seed should have a proven return on investment;
- The private sector should be incentivized or motivated to invest in seed production and dissemination;
- Getting farmers to exert a demand for public research institutes to undertake research on improving the crops.

4.2 ESSENTIAL TECHNICAL INFORMATION

The major seed production systems in operation in all the farming systems are:

i. **The informal seed system.** This represents farming households and communities producing, saving, selling or exchanging uncertified seed of improved varieties and local landraces. The International Fund for Agricultural Development (IFAD[4]) (2018) estimates that these are the main sources for more than 90 per cent of seed for smallholder farmers in the developing world. This is commonly the case for staple crops or underutilised crops that are not profitable for the private sector and where governments no longer have the money to invest in seed multiplication. This system retains genetic diversity since landraces can differ even over short distances, depending on the local agroecology.

ii. **The formal seed system** represents certified/commercial seed production and marketing, usually by seed companies and sometimes by governments, and includes the importation of seed under the supervision of a national seed service. This seed is sold to farming households through, for example, agro-dealers, seed companies, government agencies and non-governmental organizations (NGOs). The process of enhancing the use of improved seed through the formal system is dependent on the development of improved varieties. This is done through the following steps:
   a. Conducting a survey to determine the constraints farmers face regarding the status of the available varieties;
   b. Determining what farmers and markets want and taking into consideration the growing environment;

[4] https://www.ifad.org/documents/38714170/40250597/Seeds_Teaser.pdf/28586c43-1305-446e-9b21-26160502d550

c. Developing the varieties and evaluating them in a number of locations by researchers, farmers and end users to determine their suitability in terms of adaptation to the environments, yield and grain traits preferred by end-users;
d. The official release of the varieties with information on how they should be grown;
e. Demonstration of varietal performance;
f. Seed production for scaling out the varieties.

iii. **The Quality declared seed (QDS) system** is a seed-producer implemented system for production of seed that meets at least a minimum standard of quality but does not entail formal inspection by the official seed certification system. The seed producers are trained farmers or farmer groups who are in the villages. They produce seed of released varieties and are allowed to sell in their localities.

4.3 THE ROLE OF THE EXTENSION AGENTS IN ENHANCING THE USE OF IMPROVED SEED

Extension agents are involved in both the informal and formal seed production processes;

i. In the informal seed production systems, the extension agent advises farmers on taking into consideration climate change adaptation and food system resilience when:
   - Saving seed from the previous harvest to plant the following season;
   - Facilitating the creation of social networks (seed clubs) for sourcing or exchanging seed;
   - Buying seed from the local markets.

ii. In the formal seed production systems, the extension agents play a role in all the stages of the development of varieties. Their main role is to provide the linkages between the farmers and the researchers as well as the QDS producers. They should therefore proactively prepare and seek to engage and participate in the processes.

   Once the varieties are released, the extension agents should:
   - Take the lead in exposing and creating demand for the seed using the extension methods used by the agricultural development agencies that they are associated with. Whatever the methods used, researchers, seed producers, agro-dealers, agricultural-based NGOs and farmers should be involved. The objectives of the extension activities for enhancing use of quality seed are to demonstrate the superiority of improved varieties in terms of yield, tolerance to climatic conditions, disease and pest stresses and having grain traits preferred by the market;
   - They should create a knowledge base on the varieties so that they can provide answers to questions from farmers and/ or relay the questions to the researchers;
   - They should monitor the performance of the seed on farmers' fields after demonstrations and give feedback to the researchers and agro-dealers;

NOTE:
Agro-dealers are regarded as front-line extension agents when it comes to provision of certified seed and agricultural inputs to farmers. To play this role, one should be trained in provision of extension content e.g. which variety to grow when expecting drought, seeding rate and crop management.

5 CROP CALENDAR

5.1 CLIMATE CHANGE ADAPTATION AND RESILIENT FOOD SYSTEMS ISSUE

A cropping calendar is a schedule of the crop growing season from the fallow period and land preparation, to crop establishment and maintenance, to harvest and storage. In the context of climate change adaptation and food system resilience the issues are:

- How to develop a crop calendar for multiple commodities
- How to accommodate the uncertainties in climate

5.2 ESSENTIAL TECHNICAL INFORMATION

Using a crop calendar allows better planning of all farm activities and the cost of production. A cropping calendar is a schedule of the crop growing season from the fallow period and land preparation, to crop establishment and maintenance, to harvest and storage. The crop calendar allows a farmer to:

- plan for input purchase and use
- develop cash flow budget for year
- determine need credit and period requirement
- determine labor requirements and plan for peak usage times
- organize contractors for land preparation and harvesting

The crop calendars for different crops are provided by the national and local government departments responsible for agriculture hence the need for the extension workers to be directly or indirectly linked to these departments.

Given the climate uncertainties, it is not sufficient to engage with farmers to develop a crop calendar for the year. It is also essential to monitor, review and adjust the calendar during the year. This is or the purpose of detecting any change in the calendar associated with main crops due to changing agro-climatic conditions. Overall, the four major types of climate information needed by farmers are:

a. Before the beginning of the season, the interpretation of the agrometeorological crop risk analysis to assess the suitability of sorghum cultivation based on its water requirements and other agrometeorological analysis.
b. Before the beginning of the season, the interpretation of the statistical analysis of rainfall for the determination of the optimum planting date(s);
c. Before the beginning and the end of season, seasonal climate outlooks in order to adapt to the various situations due to the uncertainty inherent in the seasonal climate forecasts.
d. Throughout the season, seven-day weather forecasts for rainfall and temperature (with a focus on forecasts of weather extreme events such as drought, heavy rains and strong winds) and 10- day agrometeorological advice on better adaptation of farmers' practices.

5.3 FACILITATING THE CREATION AND IMPLEMENTATION OF A CROP CALENDAR

The extension agent should facilitate the farmers - preferably in groups - to undertake the following:

a. Determine the best date to plant. This information can be gathered from local experience, agricultural advisors and leading farmers in the district.
b. Determine the time the variety takes from planting to harvest. The length of time from establishment to harvest is known for each variety. It may vary a little depending on the growing conditions, especially water availability and solar radiation. Normally short duration varieties take 100−120 days, medium duration 120−140 days, and long duration 160 days plus. Most varieties take 60−65 days from panicle initiation to harvest.
c. Mark on the calendar the date of planting and then when each other operation needs to be done (plowing, weeding, fertilizing, harvesting).
d. Then determine how much labor, equipment and finance will be required at each step during the growing period.
e. Pin the calendar in a prominent place to remind you when things need to be done.

6 LAND PREPARATION USING THE NO-TILLAGE METHOD

6.1 CLIMATE CHANGE ADAPTATION AND RESILIENT FOOD SYSTEMS ISSUE

Sorghum-based farming systems in semi-arid regions or areas are characterised by eroded and degraded soils. Traditionally, people are used to growing crops first by tilling the soil through digging, stirring and turning it over. Through tilling, the soil is turned over to a certain depth, thereby killing unwanted plants and burying mulch, leaving behind barren soil. This may lead to soil erosion and lower productivity - hence threatening the resilience of the food systems.

6.2 ESSENTIAL TECHNICAL INFORMATION

Land preparation before planting is done for several reasons including allowing water infiltration, allowing greater root development, weed and pest control and ensuring ease of planting. In the sorghum-based systems, farmers traditionally use hand hoes or ox-drawn ploughs which have a higher risk of leading to solid erosion in addition to being expensive to implement and/or demand intensive labour input, especially by the women. The alternative methods that have been developed and tested involve “No-tillage” and “Reduced/ minimum tillage”.

What is “no-Tillage” and “minimum tillage” Farming?

- No-tillage is generally defined as planting crops into soil that has remained untilled after the harvest of the previous crop.
- Minimum tillage refers to those tillage practices whereby minimum or no disturbance is effected on the soil for purposes of crop production.

How Does “no-tillage” and “minimum tillage” Farming Work?

In both systems the residue from the previous harvest is left on top of the field for the next planting season. The reason for this is to preserve the fertile soil, which may be completely lost if farmers continue to till the soil and use tilling practices that do not build and restore soil organic matter.

In the “no tillage” system all that has to be done is spread the harvest’s residue on the field and await the planting season. The soil will be left unharmed by the weather and useful soil microorganisms will find a place to thrive in, thereby making it possible for the soil structure to stay intact.

In the “minimum tillage” system furrows or holes where seed is planted are made and the rest of the field remains undisturbed and crop residue is left on the surface. Only the necessary operations to optimise soil conditions for seed germination and crop establishment and growth are performed, minimize human and machine traffic and thus avoid soil compaction and destruction of soil structure, to avoid soil erosion; to conserve soil moisture, and to use less labour and mechanical energy.

What are the advantages of “no-tillage” and “minimum tillage” Farming?

a. **It Saves Time and Money For a Farmer**: Where a farmer chooses to use no-till farming, they skip the ploughing step each year. It means they will not endure labor or fuel costs associated with ploughing.

b. **It Improves the Soil Structure**: Tilling disrupts the natural structure of the soil, especially if it is done repeatedly. The disruption releases some carbon, which is essential for the growth and development of soil organisms;
c. **It Reduces the Amount of Water Needed to Grow Crops**: Because all the crop residues are left on the surface of the field, they absorb or help the field absorb water more easily, reduce evaporation, and it also helps limit the amount of runoff that occurs;
d. **Beneficial Microbes and Insects Increase:** Because the soil is not turned over the soil microbes and insects are not exposed to the harsh environmental conditions;
e. **It Helps Prevent Soil Erosion:** Ploughing loosens the top-soil and makes it lose moisture as well as vulnerable to winds that blow it away. If floods or heavy rains fall on the land at such a time, they could erode a lot of the soil.
f. **It Fits in the Agenda of Combating Climate Change**: No-tillage farming can play a significant role in reducing greenhouse gas emissions by minimizing soil disturbance. When soil is ploughed, it exposes the carbon components to oxygen in the atmosphere in turn reacting to form carbon dioxide that becomes part of the greenhouse gas emissions that contribute to global warming;
g. **It reduces Soil Compaction**: No-till technology significantly reduces the amount of equipment used, and as such, reduces soil compaction or hardpan formation.

What are the disadvantages of no-tillage and minimum tillage farming?

a. **Formation of Gullies**: Practising no-tilling for a long time may lead to pre-existing gullies to deepen;
b. **Increased Use of Chemicals**: While no-tillage and minimum tillage farming might actually help curb fast-growing weeds, most types of weeds continue to grow and require the use of herbicides to be eliminated;
c. T**he Risk of Carrying Over Diseases**: Without tilling, there is the risk of carrying over diseases when the crop residue is not incorporated into the soil after harvest. As such, the land will act as a host for diseases and will infect subsequent crops.
d. **Some Soil Types Might Not Support it**: No-tillage does not work well on badly drained soils or if soils suffer from water-logging;
e. **The Fields Cannot be Used For Other Purposes**: When a farmer chooses to use the no-tilling farming method, they cannot utilize their fields for livestock benefits or creating grass crops.

6.3 FACILITATING THE PRACTICE OF NO-TILLAGE LAND PREPARATION

Facilitating farmers to practice no-tillage farming can be done on its own but it is commonly part of the package for facilitation conservation agriculture (CA). The components of the CA package are described in section 7.3 further below.

The approach to developing capacity of farmers to adopt the no-tillage practices is determined by extension methodologies employed by the extension agents. In the case of AGRA the method used is the aforementioned mother-baby demonstrations.

In general, before adoption of the “no-tillage” or “minimum tillage” system the following factors must be considered:

i. Farmers must improve their knowledge about the system (especially weed control) before trying the technology on their farms
ii. The change to no-tillage should be planned at least one year before implementation

iii. Plan to acquire no-till implements (direct seeders) and obtain proper orientation on their utilization. The implements so acquired should match the available farm power.
iv. It is advisable to start with a small portion/section and advance with time (e.g. 10% of the farm)
v. If possible, soil tests should be done and nutrient deficiencies corrected with the aim of attaining a balanced nutrient and soil acidity status. If soils are acidic, farmers should apply small quantities of lime each year (instead of large amounts only once)
vi. Avoid soils with bad drainage. It is known that no-tillage does not work on badly drained soils or if soils suffer from water-logging
vii. Level the soil surface, as uneven surfaces make exact seeding impossible
viii. Eliminate soil compaction
ix. Use crop rotations and green manure crops, these are essential in no-tillage system
x. Include green manure cover crops in the rotation. Crop residues and green manures must be left on the soil surface, being incorporated biologically into the soil as they decompose
xi. Buy a no-till seeding (planter) only after having met all requirements mentioned above
xii. Learn constantly and stay up to date with new developments

7 PLANTING/ SEEDING

7.1 CLIMATE CHANGE ADAPTATION AND RESILIENT FOOD SYSTEMS ISSUE

The climate change and food system resilience concerns related to planting are the same as those for land preparation.

7.2 ESSENTIAL TECHNICAL INFORMATION

Planting refers to the precise placing of large seeds (maize and beans for example); whereas seeding usually refers to a continuous flow of seed as in the case of small cereals (sorghum and millet for example). The planting/ seeding equipment penetrates the soil cover, opens a seeding slot and places the seed into that slot. When seeding is associated with the no-tillage/ minimum tillage method of land preparation, the size of the seed slot and the associated movement of soil are kept at the absolute minimum possible. Ideally the seed slot is completely covered by mulch again after seeding and no loose soil should be visible on the surface.

In the case of vegetables, the seedling is placed in a shallow hole while covering the root section with soil.

7.3 EXTENSION ADVICE FOR PLANTING

General advice on planting

Based on their experience of the surrounding environment farmers may choose between two types of planting: (i) dry planting referring to the sowing of the seed before the rains– anticipating that the rain will fall soon, or (ii) immediately after it has rained. The key advice is that planting long after the onset of the rains–like two weeks can adversely affect productivity and production.

It is recommended to plant/ seed in rows following the recommended practice for the respective crop. This is important because it contributes to optimizing the plant population per unit area and therefore contributing to high yields and production and ease of management such as weed and pest control, and harvesting. Whereas broadcasting is less labor demanding it is potentially wasteful in terms of less than optimal plant population or too crowded plant population leading to plants competing for nutrients, water and air in a small area resulting in low yields.

Planting of vegetables in wet valley bottoms is more flexible in terms of time because there is more assurance of moisture availability.

Advice on equipment for no-tillage

When starting planting practices with no-tillage/ minimum tillage practices, a farmer needs tools such as hand hoes for making planting basins, ropes to ensure that planting lines are straight, and a tape to measure the distance from one planting station to the next and from one row to the next. But using these tools can be time-consuming. It takes a long time to complete a plot of planting basins, and the heavy work discourages some farmers from practicing conservation agriculture on a large area. In these cases, the advice to farmers is to migrate to using rippers or power tiller rippers described below.

Advice on equipment for minimum-tillage system:

1. **Dibble stick planting**: Planting stick or machete can be used to create holes to plant the seed in an un-ploughed field with stubble/crop residue. The cut hardwood stick from the bush is sharpened at one end and used to make planting holes. The holes are made in lines at evenly spaced intervals that make it easier to weed and apply fertiliser or manure.
2. **Disc-plant (stubble-harrowing)**: This tool is used to loosen the soil, chop up crop residues and cut weeds. Afterwards planting is done without further soil disturbance and the crop residues are left on the surface
3. **Strip and spot tillage**: This involves scraping out shallow planting holes in un-ploughed soil, sowing the seed in the holes, then covering. The only equipment needed is the hand hoe (Jjembe) and a planting stick. You can plant in the dry or just after the rains. The following are the steps involved:
   - Dig small shallow holes at the correct distance from each other. Make the holes just deep enough to plant the seeds.
   - Put the correct number of seeds in the hole, and cover them with soil.
   - About 2 weeks after the crop emerges, use a stick to make a hole about 10 cm away from each plant. Put fertiliser into the hole.
4. **Tillage and planting using rippers:** A ripper is a chisel-shaped implement pulled by animals or a tractor. It breaks up surface crusts and opens a narrow slot or furrow in the soil, about 5 - 10 cm deep. Hence the soil between the planting rows is not disturbed. The ripper should cut regular lines to facilitate subsequent weeding with ox-drawn weeders. Planting is usually done at the same time as ripping. The distance between the furrows depends on the recommended spacing for the crop.

   The ripper is faster than ploughing, as tillage is limited to only a thin opening for planting. Because of this narrow working width, pulling a ripper requires about half the draught force of that needed for pulling a conventional single-furrow plough. The ripper is smaller and lighter than a plough, and is easier to operate. The farmer can also use smaller animals, or animals that may be weaker at the end of the dry season. The ripper is also cheaper to buy and cheaper to maintain. As a result of these advantages, the farmer can work larger acreages each season, and achieve timeliness in operations, thus taking advantage of the early rains. This is important, especially in seasons of lower-than-normal rains or, generally, for marginal-rainfall zones. The weed problem can be serious in a rip tillage system. Therefore, action should be taken to lessen the problem over the longer term. The ripper (e.g. the Magoye ripper) is a useful weeding tool.

   Advantages

   - Ripper attachments fit on a normal plough beam hence cheaper than complete implements.
   - Can be used to make planting slots in dry soil allowing early planting.
   - Disturbs the soil less than ploughing hence reduces soil erosion and encourages water infiltration into the soil.

   Disadvantages

   - Difficult if there is a lot of residue on the surface because the residue wraps around the ripper shaft.
   - Disturbs up to 30% of the soil surface.
   - Quite difficult to use on fields with tree stamps.

8 SOIL FERTILITY ENHANCEMENT

8.1 FERTILIZER MICRO-DOSING

8.1.1 Climate change adaptation and resilient food systems issue

Poor soil fertility is the single biggest cause of hunger in Africa. However, smallholder farmers use very little manure, and less so, the recommended inorganic fertilizers. For the latter there are no location specific fertilizer recommendations which results in either over utilization, under-utilization or application of an inappropriate fertilizer. Because most of these are resource poor, wasteful or inappropriate fertilizer utilization makes these farmers worse off. In drier regions, farmers are also concerned about application risks.

8.1.2 Essential technical information

Poor soil fertility is the single biggest cause of hunger in Africa, however, smallholder farmers use very little manure, and less so, the recommended inorganic fertilizers. This is largely due to the inappropriateness of the fertilizer recommendations which are very high and unaffordable to the majority of smallholders. In drier regions, farmers are also concerned about application risks. The fertilizer micro-dosing technology deals with the application of small quantities of fertilizers in the planting hole, about 10 kg N per hectare which results in increasing fertilizer use efficiency and yields while minimizing input costs. Combining micro-dose fertilizer with animal manure in the same hole improves further crop productivity. In drought years, micro-dosing also performs well, because larger root systems are more efficient at finding water, and it hastens crop maturity, avoiding terminal drought. Recent research found that solving the soil fertility problem unleashes the yield potential of dryland cereals.

As a result of previous projects carried out by ICRISAT and partners such as the Alliance for a Green Revolution in Africa (AGRA) Microdose Project, some 25,000 smallholder farmers in Mali, Burkina Faso and Niger obtained 44-120% more yield in sorghum and millet, along with a 30% increase in family incomes. As a result, many farmers and producers agree that fertilizer micro dosing is relevant and profitable. However, a major constraint in using the technology is that it is labor-intensive and time-consuming making its use unsustainable for some smallholders.

The high cost of inorganic fertilizer relative to the income of small-scale farmers and the risk associated with its application in drought-prone areas are the major constraining factors for fertilizer use in sorghum-based farming systems, justifies the need for small amounts of fertilizer as opposed to high dosage which would have been the case for more conducive environments.

8.1.3 Extension advice on micro-dosing

Figure 4 illustrates very well the advice on micro-dosing from the International Crops Research Institute for Semi-Arid Tropics (ICRISAT).

Figure 4. Steps in the application of fertiliser micro-dosing. (*Adopted from ICRISAT*)

How to Use Small Quantities of Nitrogen Fertilizer

You received 25kg of Nitrogen fertilizer for use during this cropping season.

This pamphlet describes the best way to use this fertilizer.

Why apply nitrogen fertilizer?

- It makes crops grow and mature faster
- It reduces the effects of late planting
- It increases grain yields

Which crops should be fertilized?

- You can apply fertilizer to any crop. The best is to put it on your main cereal crop, ie maize, sorghum, or pearl millet.
- Fertilizer can be applied on any field, whether or not you have applied basal fertilizer, manure or anthill soil.

When to apply fertilizer?

- Apply nitrogen fertilizer when the crop is at 5 or 6 leaf stage. At this stage plants will be about knee height to an adult.
- You can apply even slightly later, but it **must** be applied before flowering.

How to apply fertilizer?

- Take a beer bottle cap and fill it with fertilizer. This is a very small quantity, but it is still enough for 2 to 3 plants.
- Do not broadcast the fertilizer –apply it carefully near the base of each plant, as shown in the picture. In this way, all the fertilizer goes directly to the plant and nothing is wasted.

Should you apply fertilizer on dry soil?

- No—if you apply fertilizer to very dry soil, it will not work properly. Wait until there is some rain and the soil is wet.

Should you use manure?

- Manure and fertilizer, both are important.
- If you have already applied manure or anthill soil, and later you apply fertilizer as well, yield will be even higher.

What type of fertilizer to use?

- There are different types of nitrogen fertilizer, eg Ammonium nitrate (AN), Calcium ammonium nitrate (CAN), and Lime ammonium nitrate (LAN).
- All three are very similar, and should be applied in the same way. Only the quantities will be slightly different, as shown in the table below.
- Urea is another type of nitrogen fertilizer. After applying urea, you **must** add soil on top, to cover it. Covering is not required for AN, LAN, or CAN.

Application rate for different fertilizers

	AN	LAN / CAN	Urea *
Nitrogen content	34%	28%	46%
Application rate	1/3 beer cap per plant	1/2 beer cap per plant	1/4 beer cap per plant

* Cover with soil after applying urea

This pamphlet was developed by ICRISAT after testing the microdosing method extensively with farmers in several districts.

For more information, consult your local AREX officer

This activity was funded by the Department for International Development, UK (DFID) under their Protracted Relief Programme

ICRISAT

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)
Matopos Research Station, PO Box 776, Bulawayo

DFID Department for International Development

8.2 MANURE COMPOSTING AND USE

8.2.1 Climate change adaptation and resilient food systems issue

Chemical fertilizers are costly for the majority of farmers in the sorghum-based farming systems. Their use may be unsustainable. In addition they can lower the fertility of the soil if used regularly and, if not used properly, they can also damage the crops and make them unhealthy for consumption.

8.2.2 Essential technical information

Manure adds nutrients to the soil without affecting its fertility. It does not damage crops and produces healthy plants. The benefical effects of manure on the soil are; as the soil absorbs manure, nutrients are released which in turn helps the plants as fertilizer, conditions the soil and improves soil's ability to retain moisture and reduces runoff and leaching of nitrates in the soil.

What is manure?

Manure is the decomposed form of dead plants and animals, which is applied to the soil to increase production. It is a natural form of fertilizer and is cost-effective. The human and animal excreta is also used as manure.

What is composting? Compost?

Composting is a controlled, aerobic (oxygen-required) process that converts manure and other organic materials into a nutrient-rich soil amendment or mulch through natural decomposition.

Hence compost is organic residues, mostly manures (animal manure) that has been piled, mixed and moistened to undergo decomposition.

What are the benefits of manure compost?

Composting manure is a great way of improving soil structure, fertility and water holding capacity. Compost is rich in organic matter and improves soil health. As the soil absorbs manure, nutrients are released. This enriches the soil, which in turn helps the plants.

The most important benefit of using manure in the garden is its ability to condition the soil. For instance, mixing manure with sandy soils helps to retain moisture levels. Adding manure to compacted soil helps loosen the soil. Manure produces increased soil carbon, which is an important source of energy that makes nutrients available to plants. Other benefits of manure include reduced runoff and leaching of nitrates in the soil.

In order to maximize the benefits of manure compost in the garden, proper application is vital. One of the best ways to use manure as plant fertilizer is by mixing it in with compost. Composting manure eliminates the possibility of burning the plants. So plenty of time has to be allowed for the manure to break down, eliminating the threat of burning plants in the garden. Well-aged manure on its own also makes a great fertilizer for garden plants.

Nearly any kind of manure can be used. Generally, cow and chicken manure are the most commonly used for manure fertilizer. Some people also use sheep and rabbit manure. However, it is not recommended that anyone use cat or dog manure. These types of manures are unsuitable for the garden or the compost pile, as these are likely to carry parasites

Composted manure can also be used as mulch. Because manure is considered a slow-release plant fertilizer, it provides small amounts of nutrients over an extended period. This makes it an acceptable form of mulch for plants. However, the farmer should make certain it is not fresh manure. Fresh manure is too strong for plants, as it contains excessive amounts of nitrogen, which can burn the plants. In addition, some manure fertilizer consists of urine as well, which is also high in nitrogen. Too much nitrogen on plants can be detrimental for them.

Can compost completely remove the need for chemical fertilisers?

While manure compost improves soil physical and chemical condition, and is a source of fertilizer for crop production, much of the nitrogen is tied up in complex organic compounds and is not ready for uptake by plants. Use of compost should therefore go hand-in-hand with use of commercial fertilisers. The compost should be applied using a spreader or in holes during micro-dosing which will ensure that proper amount is applied in the required area.

8.2.3 Advice to farmers on how to make manure compost

a. Manure should be piled (be in a mound), and the mound should have 50% of the pore space filled with water and the pile should be aerobic/ aerated;
b. The pile at the bottom is generally about 3.0 to 3.7 m wide at the bottom and 1.2 to 1.8 m high.
c. Microorganisms have a C/N ratio of 5 to 1 to 10 to 1.
d. Water management is critical in manure compost management because 40 to 65% of the pore space in composting materials should be water. To feel moisture content, squeeze the compost. If water drips out, then it is too wet and if the compost feels like wrung out wet rug, then the compost has sufficient moisture content.
e. To compost manure well, turn the pile when temperature drops below 43^{0}C. After turning compost 3-5 times, the manure must be composted (plant material within has broken down).

The extension agents may need training on how to train farmers on manure composting. The guide published by the World Vegetable Center on: *"How to conduct a compost-making workshop: A course for trainers" (Suzanne Neave, 2011)* may be a useful resource. It can be downloaded from here: https://avrdc.org/download/publications/manuals/eb0161.pdf

8.3 CONSERVATION AGRICULTURE

8.3.1 Climate change adaptation and resilient food systems issue

- Protecting soils from erosion and compaction, conserve/retain moisture and reduce production costs;
- Improving soil properties and the soil capacity to promote an increased biodiversity in the agro-ecosystem;
- Improving soil productivity while sustaining soil microorganisms and soil structure while also reducing the buildup of pests.

8.3.2 Essential technical information

Conservation agriculture (CA) is a means to protect soils from erosion and compaction, conserve/retain moisture and reduce production costs. It comprises of the simultaneous application of the following three agronomic principles:

- **Minimal mechanical soil disturbance** (also referred to as minimum tillage, no-till farming, zero tillage, no-tillage, direct drilling, direct seeding). The practice is described under land preparation in section 5 above.
- **Maintenance of permanent soil cover with organic mulch:** Keeping the soil covered is a fundamental principle of conservation agriculture (CA) - alongside crop rotation and minimum soil tillage. Crop residues are left on the soil surface, but cover crops may be needed if the gap is too long between harvesting one crop and establishing the next. Cover crops improve the stability of the CA system, not only on the improvement of soil properties but also for their capacity to promote an increased biodiversity in the agro-ecosystem. While commercial crops have a market value, cover crops are mainly grown for their effect on soil fertility or as livestock fodder. In regions where smaller amounts of biomass are produced, such as the sorghum-based farming systems in semi-arid regions or areas of eroded and degraded soils, cover crops are beneficial as they:
    - ➔ Protect the soil during fallow periods.
    - ➔ Mobilize and recycle nutrients.
    - ➔ Improve the soil structure and break compacted layers and hard pans.
    - ➔ Permit a rotation in a monoculture.
    - ➔ Can be used to control weeds and pests.

    Cover crops are useful for:
    - ➔ Protecting the soil, when it does not have a crop.
    - ➔ Providing an additional source of organic matter to improve soil structure.
    - ➔ Recycling nutrients (especially P_2O_5 and K_2O) and mobilizing them in the soil profile in order to make them more readily available to the following crops.
    - ➔ Provide "biological tillage" of the soil; the roots of some crops, especially cruciferous crops, like oil radish are pivotal and able to penetrate compacted or very dense layers, increasing water percolation capacity of the soil.
    - ➔ Utilizing easily leached nutrients (especially N).

Different plants, with diverse rooting systems, explore different soil depths within the profile. They may also have the ability to absorb different quantities of nutrients and produce distinct root exudates (organic acids) resulting in benefits both for the soil and for the organisms. As different cover crops produce different amount of biomass, the density of the residues varies with different crops and thus the ability to increase water infiltration.

Vegetative cover is important in CA for the protection of the soil against the impacts of raindrops; to keep the soil shaded; and maintain the highest possible moisture content. In addition to nutrient recycling (outlined above) they also have a physical and, perhaps, an allelopathic effect on weeds, depressing their incidence and leading to a reduction in agrochemical use and thus in production costs

The presence of a mulch layer (of dead vegetation) in conservation agriculture inhibits the evaporation of soil moisture, yet leads to greater water infiltration into the soil profile. The percentage of rainwater that infiltrates the soil depends on the amount of soil cover provided. Straw residues function as a cushion that reduces the pressure on the soil under wheels and hooves and so they play an important role in reducing soil compaction.

- **Diversification into legume-based crop rotations or intercropping:** Growing the same crop year after year on the same land upsets the natural balance of soils. Too many of the same plant species in one field area rob the soil of its nutrients, resulting in decreasing varieties of bacteria and microorganisms that are needed to maintain fertility of the soil. One species of crop means that only one type of root will be available to trap moisture and prevent soil erosion. This work typically requires multiple types of roots. In monoculture, the root systems are not sufficient to maintain soil structure around the plants, leading to erosion and loss of water uptake.

  Including legumes in the cereal-based system through rotation or intercropping has been demonstrated to improve soil productivity through nitrogen fixation, additional carbon inputs, improve soil structure and by conserving nutrients. Crop rotation interrupts pest build up.

  The rotation of crops is not only necessary to offer a diverse "diet" to the soil microorganisms, but as they root at different soil depths, they are capable of exploring different soil layers for nutrients. Nutrients that have been leached to deeper layers and that are no longer available for the commercial crop, can be "recycled" by the crops in rotation. This way the rotation crops function as biological pumps.

  Furthermore, a diversity of crops in rotation leads to a diverse soil flora and fauna, as the roots excrete different organic substances that attract different types of bacteria and fungi, which in turn, play an important role in the transformation of these substances into plant available nutrients. Crop rotation also has an important phytosanitary function as it prevents the carry-over of crop-specific pests and diseases from one crop to the next.

  The effects of crop rotation:
    - Higher diversity in plant production and thus in human and livestock nutrition.

- Reduction and reduced risk of pest and weed infestations.
- Greater distribution of channels or biopores created by diverse roots (various forms, sizes and depths).
- Better distribution of water and nutrients through the soil profile.
- Exploration for nutrients and water of diverse strata of the soil profile by roots of many different plant species resulting in a greater use of the available nutrients and water.
- Increased nitrogen fixation through certain plant-soil biota symbionts and improved balance of N/P/K from both organic and mineral sources.
- Increased humus formation.

8.3.3 Facilitating the practicing of conservation agriculture

1.1. Minimum tillage

Land preparation for seeding or planting under no-tillage involves slashing or rolling the weeds, previous crop residues or cover crops; or spraying herbicides for weed control, and seeding/ planting directly through the mulch. Planting refers to the precise placing of large seeds (maize and beans for example); whereas seeding usually refers to a continuous flow of seed as in the case of small cereals (sorghum and millet for example). The planting/ seeding equipment penetrates the soil cover, opens a seeding slot and places the seed into that slot. The size of the seed slot and the associated movement of soil are kept at the absolute minimum possible. Ideally the seed slot is completely covered by mulch again after seeding and no loose soil should be visible on the surface

Crop residues are retained either completely or to a suitable amount to guarantee the complete soil cover, and fertilizer and amendments are either broadcast on the soil surface or applied during seeding.

1.2. Maintenance of soil organic cover

- In Burkina Faso the recommended cover crops are cowpea indeterminate type and groundnut for the targeted locales in Burkina Faso;
- In Tanzania the recommended cover crops are cowpea, green gram, groundnut and pigeonpea.

Cover crops are grown during fallow periods, between harvest and planting of the main crop hence utilizing the residual soil moisture or in alternative years. Their growth is interrupted either before the next crop is sown, or after sowing the next crop, but before competition between the two crops starts. Cover crops energize crop production, but they also present some challenges.

1.3. Crop Rotations

In general, design and implementation of crop rotations according to the various objectives: food and fodder production (grain, leaf, stalks); residue production; pest and weed control; nutrient uptake and biological subsurface mixing/cultivation, etc. Use of appropriate/ improved seeds for high yields as well as high residue production of above-ground and below-ground parts, given the soil and climate conditions.

In the drylands of Tanzania after growing adapted and released varieties of sorghum or pearl millet, this should be followed in the second year by groundnut, cowpea or green gram. Alternatively intercrop with pigeonpea where two-to-three rows of cereal are followed by one row of pigeonpea.

In Burkina Faso after cereals this should be followed in the second year by groundnut and cowpea.

The selection of the varieties for intercropping is done in the same way and following the same considerations as those for the selection of the varieties of sorghum (Section 2)

9 WATER MANAGEMENT

9.1 BUNDS ALONG THE CONTOURS AND SPILLWAYS FOR DIRECTING WATER TO PONDS

9.1.1 Climate change adaptation and resilient food systems issue

How to overcome water loss through evaporation and runoff and also mitigate the effects of insufficient and erratic rainfall

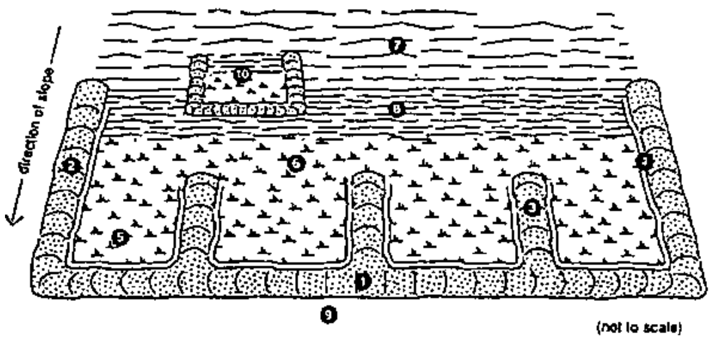
9.1.2 Essential technical information

Earthen bunds are one of the options for overcoming the above issues

1.1. What are earthen bunds?

Earthen bunds are essentially an external catchment, long slope technique of water harvesting. Typically, a u-shaped structure of earthen bunds which farmers build on their cultivated lands to harvest runoff from adjacent upslope catchments, this technique usually collects rainwater and, sometimes, floodwaters (Figure 1).

Figure 5: Typical element of the *teras* water harvesting structure (van Dijk, 1995).



1. Base contour bund	4. Shallow channel	8. Internal catchment
2. Outer collection arm	5. Basin 6. Cultivated area	9. 'Mother' (main structure)
3. Inner collection arm	7. External catchment	10. 'Child'

1.2. Effectiveness of the Technology

The technique allows the production of a crop of millet or sorghum. Based on data from Sudan, yields may reach 750 kg/ha in a good year. Quick maturing sorghum or millet should be planted immediately after the water from a storm has subsided. This crop grows and matures in about 80 days.

1.3. Environmental Benefits

Use of this technology reduces land degradation and improves water infiltration.

1.4. Suitability

This technology is appropriate for areas of the sorghum-based farming system where the foothills reinforce high intensity and short duration rainfall, with 150 to 400 mm rainfall, annually.

1.5. Advantages

The technology is entirely farmer managed and, therefore, not subject to the organizational problems of other soil and water conservation techniques. Socio economic surveys have indicated that application of soil and water conservation practices contributed about an additional 75% to the total household crop production income in the 1980s and 1990s.

Commented [1]: Given the way it has been phrased, it attracts the need to know the place this happened.

1.6. Disadvantages

The lack of a spillway can result in breached bunds.

9.1.3 How to use the earthen bund technology

1.7. How are earthen bunds constructed?

The base bund approximately follows the contour line and impounds the runoff. Two outer arms fulfil the same function and also act as conveyance structures which direct water to the cultivated lands. Sometimes, shorter inner arms are added which divide the land into smaller basins and improve the spread of captured runoff. A shallow channel is left on the inside of the bund to support the conveyance and circulation of runoff. Excess water is normally drained along the tips of the outer arms which are reinforced with materials such as stones, brushwood or old tyres. Bunds are usually 0.5 m high and 2 m deep at the base, but these dimensions can vary greatly depending on both the slope and the amount of runoff expected in the area. The base can be between 50 to 300 m long, while the arms are usually 20 to 100 m long. The size of the cultivated area serviced by such a structure is 0.2 to 3 ha.

1.8. Operation and Maintenance

This is a labour-intensive technique. Generally, between 3 and 18 days/ha of work is required to ensure that the system runs efficiently. However, breaches of the bunds will require additional work to effect repairs. The local dynamics of a drainage system may also require that the conservation structures be continuously adjusted for best performance.

1.9. Level of Involvement

Entirely traditional and farmer-managed, earthen bunds may be built by hand using simple tools, although the use of hired tractors is becoming more common.

9.2 ZAI PITS

9.2.1 Climate change adaptation and resilient food systems issue

How to overcome water loss through evaporation and runoff, encourage infiltration at the crop base and also mitigate the effects of insufficient and erratic rainfall

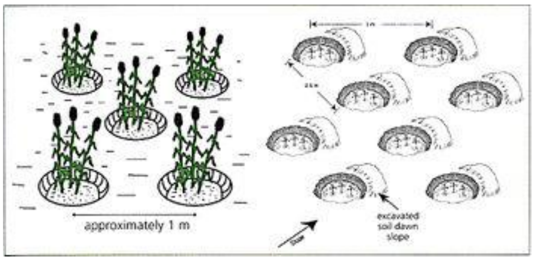
9.2.2 Essential technical information

Zai pits are also known as planting pits, planting basins, micro pits, or small water harvesting pits. They measure 20-30 cm in width, 10-20 cm deep, and spaced 60-80 cm apart. Benefits of Zai pits include:

- Increase the amount of water stored in the soil profile by trapping rain water. It retains moisture thus allowing it to infiltrate.
- Increased yield due to more water and nutrients available
- Protects seeds and organic matter from being washed away
- Reduction in water runoff and evaporation
- Possible increased termite activity, which leads to a higher water infiltration when it rains.
- Can collect more than 25% or more of run-off water
- The pits also retain moisture for a long period of time because of the crop residues at the bottom of the pit.
- The approach ensures improved water and small quantities of fertilizer and manure are targeted to the crop; the result is improved productivity.
- It can work with other techniques such as stone contours and hand dug trenches
- Improved soil fertility and agricultural productivity of several crops
- Pits are sometimes dug during the dry season, which alleviates the labour burden for land preparation at the onset of the rains
- Because of labour times (especially because pits are created during dry and warm season), it is most effective if the measure is undertaken by groups of farmers together, instead of individuals.
- The construction of planting pits can be done with machines.
- Zai pits are even more efficient when combined with other interventions such as organic and inorganic soil inputs such as mulching.

9.2.3 HOW TO IMPLEMENT ZAI PITS

Figure 6: Zai Pit implementation



i. Plough the land along the contour;
ii. Dig the Zai pits (holes) with diameter of 15-20 cm and depth of 10-15 cm or more, distance between each other from 70 to 80 cm apart, resulting in about 10 000 pits per ha. Make sure they are dug perpendicularly to the slope and put the soil from the hole on the direction of the downslope (so as to create a small soil wall/bund to keep the water in the hole)

iii. Apply well-decomposed manure and fertiliser microdose in the Zai pits and slightly mix with soil.
iv. Plant seeds in the pits

Figure 7: Implemented Zai Pits

9.3 TIE AND RIDGE

9.3.1 Climate change adaptation and resilient food systems issue

The sorghum-based ecosystem is characterized by low rainfall and poor soils with low moisture retention potential. Thus, the little rainwater must be conserved as much as possible so that its use by the plants can be maximized. Through this, the system can be made more resilient and its capacity to adapt to climate change can become more enhanced.

9.3.2 Essential technical information

Tied-ridging is a technology to create ridge furrows that are blocked with soil to create basins that retain surface runoff within the field. Ridge-tillage allows for increased water infiltration and reduced runoff, as well as less evaporation resulting in more water being available to the plants.

This strategy aims at conserving rainwater in-situ where it falls within the root-zone. Increased soil moisture storage reduces runoff, which leads to increased efficiency of rainwater utilization.

Figure 8: Tie Ridge in pracice

9.3.3 How to implement the tie and ridge technology

Plough the land and make planting furrows along the contour preferably with ox-drawn plough and make tied ridges. Apply well-decomposed manure and/or fertiliser in the tied ridges and slightly mix with soil. Plant the seeds in the furrows and cover the seeds lightly leaving a furrow to harvest water. Tied-ridges offer good potential for water conservation. Tying the furrows allows in-situ water harvesting with increased water infiltration into the soil and reduced runoff. Make tied-ridges after the first weeding by tying (blocking) the furrows at 4-5 m intervals or 2-3 m in more sandy soils using a hoe.

The following are key steps for tie-ridging:

i. Plough the land and make planting furrows along the contour preferably with oxen
ii. Apply well-decomposed manure and/or fertilizer in the furrows and slightly mix with soil
iii. Plant the seeds in the furrows and cover the seeds lightly leaving a furrow to harvest water
iv. Tied ridges offer good potential for water conservation
v. Tying the furrows allows in-situ water harvesting with increased water infiltration into the soil and reduced runoff
vi. Weed preferably with well-trained oxen to remove weeds and to make water harvesting furrows
vii. Make tied ridges after the 1st weeding by tying (blocking) the furrows at 4-5 m intervals or 2-3 m in more sandy soils using a hoe

viii. Tied-ridges offer good potential for water conservation
ix. Tying the furrows allows in-situ water harvesting with increased water infiltration into the soil and reduced runoff.

9.4 WATERSHED EX-SITU WATER HARVESTING

9.4.1 Climate change adaptation and resilient food systems issue

How to overcome water loss through evaporation and runoff, encourage infiltration at the cropped area and mitigate the effects of insufficient and erratic rainfall and improve and stabilise productivity.

9.4.2 Essential technical information

Rainfall in the drier environments, in this case sorghum based systems, is generally insufficient to meet basic needs for crop production. As it is poorly distributed over the growing season and often comes in intense bursts, and thus usually unable to support economically viable farming. Even this water is mostly lost in evaporation and runoff, leaving frequent dry periods during the growing season.

Water harvesting is based on the principle of depriving part of the land of its share of rain, which is usually small and non-productive, and adding it to the share of another part which is used for agricultural activities, bringing the amount of water available to the latter area closer to crop water requirements and thereby permitting economic agricultural production.

The main components of water harvesting systems are:

Catchment area: the part of the land that contributes some or all its share of rainwater to a target area outside its boundaries. The catchment area can be as small as a few square meters or as large as several square kilometres. It can be agricultural, rocky or marginal land, or even a rooftop or a paved road.

Storage facility: the place where runoff water is held from the time it is collected until it is used. Storage can be in surface reservoirs, subsurface reservoirs such as cisterns, in the soil profile as soil moisture, and in groundwater aquifers.

Target area: where the harvested water is used. In agricultural production, the target is the plant or the animal, while in domestic use, it is the human being or the enterprise and its needs.

Micro-catchment Systems

Runoff is collected from a small catchment area with mainly sheet flow over a short distance. Runoff water is usually applied to an adjacent agricultural area, where it is either stored in the root zone and used directly by plants, or stored in a small reservoir for later use. The target area may be planted with trees, bushes, or with annual crops. The size of the catchment ranges from a few square meters to around 1000 m2 . Land catchment surfaces may be natural, with their vegetation intact, or cleared and treated in some way to induce runoff, especially when soils are light. Non-land catchment surfaces include the rooftops of buildings, courtyards and similar impermeable structures.

On-Farm Systems

The most important land-based microcatchment or on-farm water-harvesting systems in the dry areas are: Contour ridges, Semi-circular and trapezoidal bunds and Runoff strips

9.4.3 How to implement ex-situ water harvesting

The most important land-based on-farm water-harvesting systems are described below:

Contour ridges

Make bunds or ridges along the contour line, usually spaced between 5 and 20 m apart. The first 1–2 m above the ridge is for cultivation, whereas the rest is the catchment for harvesting water. The height of each ridge varies according to the slope's gradient and the expected depth of the runoff water retained behind it. Reinforce the bunds by stones if necessary. Ridging is a simple technique carried out by farmers. Ridges can be formed manually, with an animal-driven implement, or by tractors with suitable implements. They may be constructed on a wide range of slopes, from 1% to 50%.

On ridges, plant grass e.g Chloris guyana which strengthens the mound.

10 WEED MANAGEMENT

10.1 CLIMATE CHANGE ADAPTATION AND RESILIENT FOOD SYSTEMS ISSUE

In Semi-Arid Tropics (SAT) where rainfall is erratic and mostly low, loss of water due to competition with weeds results in reduction in yield and quality. The little water that is available in this harsh environment must be put under the most beneficial use. It should not be left to go to feed weeds which are by definition unwanted plants.

10.2 ESSENTIAL TECHNICAL INFORMATION

Weed is a plant considered undesirable and troublesome and competes with the crop plants for soil nutrients, space and water and causes lower yields. Reduction in crop yields and production efficiency is a direct effect due to weeds and varies from 34.3% to 89.8% depending upon the crop. A weed is any plant growing where it is not wanted. Another set of weeds are referred to as parasitic plants that attach themselves in this case on sorghum and pearl millet plants sucking nutrients from them. Parasitic weeds include striga species (witch weed). Parasitic weeds cause serious economic losses to cultivated host crops. Chemical exudates from the host plant stimulate germination of the seed and as soon as it germinates the seedlings will attach themselves to the root of the plant's host, deriving assimilates, water and minerals from the host. After some days when green tissue is established they begin to synthesise their assimilates but still depend on the host root for water and water minerals, causing severe loss to the crop.

Figure 9: Sorghum field infested with striga

Figure 10: Striga infested sorghum Plant

10.3 HOW TO IMPLEMENT WEED MANAGEMENT

Control of common weeds: (a) Mechanical weed management involves physical disturbance of the weeds, through activities including pulling weeds, tilling the soil before or after weeds emerge, and mowing. Use of hand hoe to control weeds is a common practice. Ensure the root system of crops is not disturbed. When weeding, ensure roots of weeds are exposed so that they dry (b) Chemical Weed Control involves using herbicides. Many different herbicides, including soil-applied (before weeds or crops germinate) and foliar-applied products (when weeds have germinated), selective (kills certain types of weeds without affecting crops) and non selective products. Every herbicide product commercially available is required by law to have a label. The label provides a great deal of information about the product, including how it is to be applied, where, and in what quantity. Herbicide labels change frequently, so be sure to consult the most current label when using a product. Extension agents should explain to farmers how to use, including safety (use of masks, plastic clothing etc.) and when to apply. Herbicides are sprayed by knapsack.

Control of parasitic weeds: Striga is a root-parasitic plant of the major agricultural cereal crops, including sorghum and millets, in tropical and semi-arid regions of Africa. These plants attach to and penetrate the roots of crops, then feed on nutrients of its host, therefore, stunting host growth. Severe striga attack produces symptoms resembling wilting due to drought. Control methods include creating awareness of the damage it causes, hand pulling before striga flowers and crop rotation with non-host plants in Burkina Faso groundnut and cowpea, and in Tanzania groundnut, sunflower and cowpea.

11 PESTS AND DISEASES MANAGEMENT

11.1 CLIMATE CHANGE ADAPTATION AND RESILIENT FOOD SYSTEMS ISSUE

In SAT where productivity is low due to poor rainfall and poor distribution, stabilizing yield through pest and disease management is essential.

11.2 ESSENTIAL TECHNICAL INFORMATION

Sorghum and pearl millet are important traditional food security crops in drylands , and insect pests and disease are some of the main constraints to small-holder production in Africa. In both countries, farmer knowledge of the key pests and diseases and damage caused are partial.

11.3 HOW TO IMPLEMENT PEST AND DISEASE MANAGEMENT

Cereal pests

Major pests are borer, shoot fly and sorghum midge. While chemical control is possible, however they are costly and are not affordable. Two methods are commonly used to manage pests are varietal resistance/tolerance and low cost cultural practices. In both Burkina Faso and Tanzania, varieties tolerant to insect pests are available. Cultural practices which help to avoid damage from these pests, include early planting, intercropping with legumes, crop rotation and stover management. Cut sorghum/pearl millet stover immediately after harvest and spread or place in trash lines and this will reduce live borer numbers and reduce carry-over of stem borers by up to 90%.

Burkina Faso, sorghum and pearl millet are subject to attack by numerous diseases. The most damaging diseases on sorghum are anthracnose and grain mold caused by a complex of fungi, while on pearl millet, downy mildew is the most important. The most common diseases in sorghum based systems of Tanzania are covered kernel smut, Ergot, Anthracnose and Rust.
Control measures include practicing crop rotation with leguminous crops to break the disease lifecycle, field sanitation where crop residues should be collected and burned before the onset of the rains to remove the primary source of the disease and use of resistant or tolerant varieties.

12 HARVEST AND POST-HARVEST MANAGEMENT

12.1 CLIMATE CHANGE ADAPTATION AND FOOD SYSTEM ISSUES

Yield levels in arid and semi arid environments are low because of chronic water stress and very high temperatures that cause the little available moisture to evaporate into the atmosphere. Conserving the little produced is essential to sustain farm households living in this environment. So the issues targeted by this advisory are:

- How to reduce/ eliminate the losses due to insects without using insecticides?
- How can farmers safely store grains so that they can choose when to sell and/ or have healthy, clean, and insecticide-free food for their families throughout the year?

12.2 ESSENTIAL TECHNICAL INFORMATION

Approximately one-third of the food produced (about 1.3 billion ton), worth about US $1 trillion, is lost globally during postharvest operations every year. According to the World Bank report, sub-Saharan Africa (SSA) alone loses food grains worth about USD 4 billion every year. "Food loss" is defined as food that is available for human consumption but goes unconsumed. Postharvest loss includes the food loss across the food supply chain from harvesting of the crop until its consumption. The losses can broadly be categorized as weight loss due to spoilage, quality loss, nutritional loss, and commercial loss. Insects contribute to these losses. Insecticides are commonly used to reduce the losses they cause. However, they are not sustainably affordable for many rural farmers and - if not properly used - can be harmful to health.

Principally, key technical concerns for which advice has to be given to farmers are:

- Ensuring that the harvested grain has appropriate moisture content. If moisture exceeds the threshold, storage problem may emerge where the grain may grow mould or become more susceptible to insect and fungal damage
- Grain must be stored in cool and dry environment so as to discourage mould growth.

12.3 IMPLEMENTING HARVESTING AND POST-HARVEST PROCESSES

12.3.1 Harvesting

Crop harvesting of dryland cereals is performed manually using hand cutting tools such as sickle, knife, scythe, cutters. A large amount of losses occurs before or during the harvesting operation. Too early harvesting of a crop at high moisture content increases the drying cost, making it susceptible to mould growth, insect infestation, and resulting in a high amount of broken grains and low milling yields. However, leaving the matured crop un-harvested results in high shattering losses, exposure to birds and rodents attack and rain. Ensure crops are mature and dried at harvest.

12.3.2 Threshing, winnowing and cleaning

This is achieved through rubbing, stripping, or impact action, or using a combination of these actions. The operation is performed manually (trampling, beating), using animal power, or mechanical threshers. Grain should fall on a cemented floor or canvas.

Cleaning through winnowing or otherwise is performed to separate whole grains from broken grains and other foreign materials, such as straw, stones, sand, chaff, and weed seed. Winnowing is the most common method used for cleaning in developing countries. Screening/sifting is another common method of cleaning, which can be performed either manually or mechanically. If not cleaned well, it increases chances of insect infestation and mould growth during storage. This area is important both for human health and marketing. A crop product full of stones and other types of dirt is not good for human health. On the other hand, crop markets continue to be sensitive to quality and standards. Thus, contaminated produce is likely to fetch low value in the markets.

12.3.3 Drying

Grains are harvested at high moisture content to minimize the shattering losses in the field. The recommended moisture content for storage is at about 13%. Inadequate drying results in mould growth and significantly high losses during storage and milling. Drying should be performed naturally (sun or shade drying) on cemented floor and canvas or using mechanical dryers.

12.3.4 Storage

High losses happen during storage. There are several storage methods (a) The indigenous storage structures are made of locally available materials (grass, wood, mud etc.) (b) Sacks. For both a and b, there is need to use pesticide properly and requires training and (c) The Purdue Improved Crop Storage (PICS) technology.

This advisory focuses on the PICS technology because it is relatively new.

A PICS bag is made of a triple layer composed of two polyethylene bags and one outer woven polypropylene bag. It minimizes insect storage losses by limiting the supply of oxygen to insects living in stored grain. After PICS bags are closed, insects in stored grain use up much of the oxygen left inside the bag, cease feeding, and stop growing and reproducing and eventually die.

This low-cost technology was developed and initially disseminated for cowpea grain, but it has more recently been found effective for all types of grain and even other products. PICS bags allow farmers to store their grain without the use of insecticides and provides them the flexibility to sell when prices are high, while having chemical-free high-quality food for their families throughout the year.

The bags can be reused for three consecutive seasons and so, they are economically efficient when the benefits are compared with the cost of the bag. The use of PICS bags provides farmers the flexibility to sell their grains when they choose while supplying healthy, clean, and insecticide-free food to their families throughout the year. In addition to the physical bags, low-cost method to store grain and hence improving food availability for millions of farm households.

PICS is one form of integrated pest management (IPM). It is an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through *habitat manipulation* of the pest. This technique fits well with the arid and semi-arid sorghum based farming systems where yields are low because of the low precipitation and where saving the little produced is of paramount importance.

The use of PICS bags follows the following steps:

i. Dry the grain until the moisture content is below or equal to 13 % . An easier and practical way of knowing that the grain is sufficiently dry is to bite it between your teeth and it will break with a sharp loud sound.
ii. Place the grain in a clean and dry PICS bag and knit tightly with a proper needle and string and store the bags in a dry cool place.
iii. Open to remove grain for use and re-knit the partially filled bag carefully without leaving any hole that may let in air which would render the grain liable to insect damage.

Figure 11: PICS bags in use

13 LINKING FARMERS TO MARKETS

13.1 CLIMATE CHANGE ADAPTATION AND AGRIFOOD SYSTEM RESILIENT ISSUES

As climate change negative impacts continue to rage, crops adapted to hostile environments such as sorghum and millets continue to gain importance because they naturally outcompete those that need more moisture and more fertile soils. To get full advantage out of this competitiveness firm linkages to markets of the surplus produce is essential. This is together with identifying and linking farmers to new markets such as the brewing industry, food processing industry, etc.

13.2 ESSENTIAL TECHNICAL INFORMATION

Linking farmers to markets is key to improving the lives of smallholder farmers. Ensuring availability, access and use of production technologies alone will not be enough to lift farmers out of poverty and improve their livelihoods. Facilitating their link to markets is essential so that the surplus that they manage to produce by applying the production technologies finds a vent to markets and in so doing increase their incomes and livelihoods.

Linking farmers to markets is key to agricultural transformation. Often, we have noted piles and piles of onions, citrus fruits, pineapples, tomatoes by the roadside waiting to be eaten by cattle and goats or as they wait to rot. Even on the side of livestock, it is not surprising to come across poultry farmers stuck with eggs from their layers without an easy market to dispose them.

Extension agents must as part of their role facilitate linking small-scale farmers to markets so that they benefit from available lucrative opportunities. This linkage is important because small farmers are limited in knowledge about the market given their socio-economic backgrounds. This limitation reduces their ability to participate in high value market chains.

13.3 THE FOLLOWING STEPS ARE RECOMMENDED FOR EXTENSION AGENTS:

The following steps are recommended for extension agents

Step 1: Not all farmers are interested in growing the same crops because their objective functions are different and indeed quite diverse. Thus, the first step is to categorize famers in production domains such as tomatoes, pigeonpeas, sorghum, pearl millet, etc. A further sub-category can be based on small and medium farmers.

Step 2. Make a list of potential market opportunities by reviewing secondary sources, including reports on consumer trends and opportunities for import substitution, as well as talking to industry experts and NGOs. Create a list of potential opportunities by speaking to supermarkets, hotel operators, schools, local traders and wholesalers, and other key commercial informants. Check secondary sources as well.

Step 3. Carefully, analyze and estimate the quantities that are required by the various sources (potential demand) per season per product

Step 4. Carefully analyze and estimate the strength and capacity of farmers to produce and deliver to meet the various requirements.

Step 5. Do a rough matching linking specific crop farmers to respective market outlets

Step 6. Keep watching the market trends and advise farmers accordingly understanding that markets are dynamic entities and never static.

The above can be done by i) the extension agent organizing value chain meetings, e.g. sorghum, millet, pigeonpeas, pearl millet, tomatoes, etc. ii) Requesting to be slated in Village Assembly Meetings to discuss some of these issues iii) working with some farmer groups who may or may not be crop specific and sometimes with individual farmers. When the latter become successful, they will spread the message to other farmers as well.

14 OVERVIEW OF ADVICE ON CROPS FOR NUTRITIONAL RESILIENCE

14.1 CLIMATE CHANGE ADAPTATION AND RESILIENT FOOD SYSTEMS ISSUES

When addressing the resilience of food systems in sorghum-based, dryland farming systems of Africa, the focus of research and extension is heavily skewed on increasing yields of staple crops through prioritization of climate-smart, drought-tolerant, and pest- and disease-resistant varieties. Relatively little attention is paid to nutrition resilience - more specifically micronutrient resilience, which is the ability to withstand dietary diversity shocks without suffering impaired growth or increased morbidity. Staple foods are typically categorized by nutritionists as important sources of certain macronutrients - especially for the poor - but not of micronutrients, which are given lower priority. This impacts mostly on children as well as pregnant and lactating women. So, the issue is how to ensure that nutritional resilience is addressed when providing advice on enhancing the resilience of the sorghum-based food systems.

14.2 ESSENTIAL TECHNICAL INFORMATION

Dietary diversity is widely accepted as the gold-standard approach to building nutritional resilience in food systems. The overriding focus is on increasing the availability and lowering the cost of higher-micronutrient quality foods such as fruits, vegetables, and animal-source foods, often complemented by nutrition and behavior-change communications targeted at increasing consumption. The impact of COVID-19 has revealed that shocks lead to reduced consumer incomes, which force changes in food consumption patterns. This usually involves shifting consumption from higher-nutrient foods to relatively less expensive, but also less nutritious, staples.

The options for addressing the decline in the nutritional quality of foods include increasing supplementation coverage for micronutrient-vulnerable populations and expanding the coverage of industrial fortification, which increases the micronutrient content of staple grains and oils with additives after harvest and before retail. But these options may not benefit the rural people in a sustainable way. The proven responses to this micronutrient challenge are: (i) enhancing growth and consumption of micronutrient-rich foods - essentially fruits and vegetables, and (ii) is increasing the intrinsic micronutrient content of the staple foods themselves (e.g. golden pearl millet is high in zinc, orange fleshed potato is rich in vitamin A) . This is termed “biofortification”. Biofortification delivers micronutrients to vulnerable rural populations in the foods they grow themselves and eat every day. It also builds their nutritional resilience because the micronutrients come at no extra cost and stay in their crops, harvest after harvest.

14.3 EXTENSION ADVICE ON NUTRITION RESILIENCE

14.3.1 Micronutrient dense vegetables

According to the World Health Organization (WHO), a matured person should consume daily 400 grams of vegetable (excluding potato) to live a healthy life. However, insufficient access to market and seasonal fluctuation of available vegetables makes it difficult to intake sufficient amount of vegetables for rural households. Thus, a home garden in rural Burkina Faso and Tanzania are very essential where people can regularly grow vegetables in small piece of land. However, it is also commonly seen that many rural households do not apply appropriate cultivation techniques, which result in limited production, and frequent occurrences of pest and disease attacks.

The common vegetables are tomato, onions,carrots, okra and leafy gevetables. Tomato, onions,carrots, okra and spinach are what is referred to as international vegetables whose seeds are produced by international seed companies and are imported and stocked by agro-dealers. Local vegetables despite being important, their seeds are not traded but grown from saved or obtained from neighbours.

Off-season vegetables are grown using water harvested or at the bottom of river valleys.

Land preparation: Vegetables are either grown in a nursery or directly seeded. Tomato and onion are sown in the nursery but the rest are directly sown in the field.

Nursery is prepared by cultivating through fine tilth and raised bed. Fine compost and fertilizer, mostly DAP is added. Seeds are drilled at close spacing and covered with soil. The nursery is then irrigated. Shed is built to protect seedlings and regularly irrigated. Once the seedlings are well established, harden before transplanting. This is achieved by removing the shed and reducing the frequency of irrigation.

In all cases, seedlings from the nursery or seed are planted in the field. The fields are prepared well, weeds removed and ridged for irrigation. Crops from the nursery are transplanted in the morning in fertile soil. The other vegetable crops are directly seeded.

Management: Fields should be weed free and top-dressed using 100 kg N/ha pests and diseases controlled. Agro-dealers and extension staff should be aware of appropriate use of chemicals. Tomatoes should either be trained to grow on raised beds or use stakes to trellis them.

Harvest: Tomato is harvested when fruits are turning yellow to red and onions when the leaves are showing signs of wilting. Okra and egg plants when fruits are big but still retain their original colour. Leafy vegetables when leaves are fully grown but not showing signs of ageing. If pesticides have been used waiting for 10 days before harvesting.

14.3.2 Extension advice on fruits

Most common home garden fruit crops are citruses and mango. Citrus is budded and mango is grafted. In both cased obtain planting material from a reputable nursery.

Prepare planting holes of 50 cm deep and a radius of 30 cm. Fill the bottom of the hole with decomposed compost mixed with top soil. The spacing for citrus is 7 by 7 m and for mangoes 9 by 9 m. Plant but ensure that the budded or grafted portion is above soil level. Make a basin around each plant with a diameter of one metre that will be used for irrigation. Feel the soil when drying and irrigating.

Ensure that branches do not grow below the budded point and do not allow the trees to produce fruits during the frst two years. For mangoes, control pests by applying pesticide at flowering, when fruits are young and when half mature. Recommendations are on the labels.

14.3.3 Extension advice on biofortification

Tanzania has National Biofortification Guidelines (United Republic of Tanzania Ministry of Agriculture, 2020). The key messages that the extension agents should be aware of for purposes of advising farmers are given in the Table below. These messages are applicable to Burkina Faso.

STEPS	KEY MESSAGES
Seed Multiplication and Distribution	Proper packaging with appropriate colour code facilitates identification and usage of biofortified seeds. Well-trained agro-dealers are key to ensuring farmers have access to quality seeds and follow good agricultural practices.
Production of Biofortified Crops	Use of genuine biofortified seeds and other recommended agro-inputs together with application of GAP enhance production and yield of biofortified crops.
Post-Harvest Management (PHM)	To maintain intended qualities and quantities of biofortified crops, stakeholders along the value chain must adopt recommended agricultural practices and measures to mitigate Post-Harvest Loss (PHL).
Processing and Marketing of Biofortified Crops	● Processers of biofortified food products should consider that consumer acceptance depends largely on sensory characteristics, nutritional value, keeping qualities and/ or shelf life; ● Promotion of biofortified foods is key to ensure acceptability.
Utilisation of Biofortified Foods	● Observing principles of hygiene and safety is necessary during preparation of biofortified foods to minimize contamination and food borne diseases; ● Mass feeding with bio- fortified foods is useful for wider population coverage to make a substantial impact on reducing micronutrient deficiencies.
Gender	Gender mainstreaming in biofortification initiatives is essential in scaling-up, adoption and consumption of biofortified foods
Social and Be- haviour Change Communication (SBCC)	SBCC messages should target beneficiaries, influencers, enablers and those involved in delivering the interventions to increase use of biofortified foods.
Climate Change	● Development of biofortified varieties with resilience to climate change will ensure sustained production and utilization of biofortified products; ● Many of the developed varieties are resilient to climate change.
HIV/AIDS and Tuberculosis	Promote the use of iron/zinc-rich biofortified foods among people living with HIV/AIDS and TB to increase micronutrient intake.

15 CROP LIVESTOCK SYSTEM

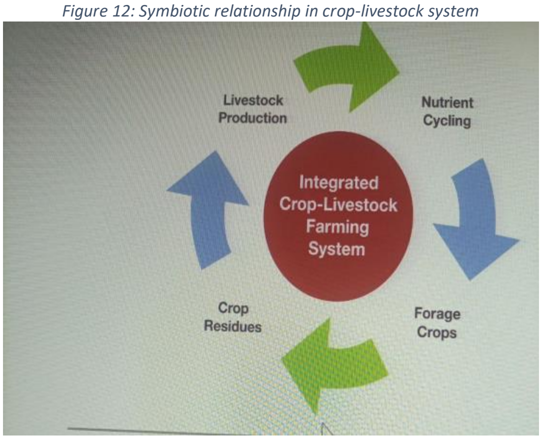
15.1 CLIMATE CHANGE ADAPTATION AND RESILIENT FOOD SYSTEMS ISSUE

While the integrated system that includes livestock provides a productivity buffer against chronic climate stress, in extreme cases it may exacerbate pollution, land degradation and vulnerability to climate extremes.

15.2 ESSENTIAL TECHNICAL INFORMATION

Although primarily most households in the semi-arid and tropics depend on crop production for their livelihood some households in addition to crops keep livestock in the form of cattle, goats, sheep, or chickens. Households in the latter category are more secure because i) existence of a natural symbiotic relationship between crops and livestock whereby the practice of one activity influences the other through its effects on the ecosystem. For example, during the dry season natural forage is in short supply, and the quality is normally very low. The residues of most crops, which are of little or no value to the cultivator, provide a superior diet for the cattle herd. (ii) At the same time, manure deposited on the fields as the cattle graze is beneficial for the subsequent crop. The occurrence of this symbiotic relationship is widespread and varied in its ecological and economic complexity.

Figure 12: Symbiotic relationship in crop-livestock system



Livestock diversify and hedge risks; for example, cattle can move from one grazing area to another to escape drought. Cattle diseases are also less troublesome in dry areas. Livestock are a strategic investment when cash is available, and a cash source when times are hard (sometimes referred to as ‘walking wealth’). In the integrated system, the waste product of one serves as a resource for the other. For example, manure is used to enhance crop production and crop residues and by-products are used as animal feeds, supplementing often inadequate feed supplies.

The integrated crop-livestock system requires farmers to have adequate nutrients to sustain crops and livestock and to maintain soil fertility. Farmers need to be trained in manure management and application but also let them know it is not sufficient for crop requirement.

There is a need for additional sources - fertiliser microdosing and legumes in the system. For livestock, grow fodder legumes as part of rotation to supplement crop residue with a high nutritional value crop. Livestock farmers are not generally connected with veterinary service, as part of the project, the service provider is trained as veterinary agents. Improved livestock management should include water availability throughout the year through water harvesting for animals to drink and growing fodder off season.

Because of these benefits It is recommended to keep some few livestock units on the farm with the number and type being related to the carrying capacity of the available land. The farmer will depend on the advice of the VBA/extension person as it will be among other factors time dependent.

15.3 EXTENSION ADVICE FOR FARMERS

In the semi and arid sorghum-based farming system often controversy occurs between deciding whether the few crop residues should be left on the farm to serve as mulch - especially in conservation agriculture - or be fed to livestock? The choice is usually to go for the latter when the cop residue is very scarce.

16 SILVOPASTORAL SYSTEMS

16.1 CLIMATE CHANGE ADAPTATION AND RESILIENT FOOD SYSTEMS ISSUE

Trees planted are mostly exotic species valued for their nutrition and commercial value, while FMNR was used for subsistence products and environmental services.

16.2 ESSENTIAL TECHNICAL INFORMATION

Trees on farms play an important role in supporting the livelihoods in drylands by providing essential ecosystem goods and services like food, fuel, fodder, medicine, building materials, soil erosion and flood control as well as watershed and biodiversity protection. The role of trees in building resilience of rural livelihoods in drylands should not be underestimated, especially during crop failure due to droughts. In such instances, fodder trees are the main sources of browse for animals and charcoal production is the prevailing coping mechanism

16.3 HOW TO IMPLEMENT TREES ON FARM MANAGEMENT

Prepare areas where trees are to be planted. Dig holes 50 cm deep and a radius of 30 cm. Fill the bottom of the hole with decomposed compost mixed with top soil. Determine the type of trees you need depending on the ultimate goal-timber, charcoal, feeding animals. Buy seedlings from the Department of Forestry. Plant the seedlings in the centre of the holes dug. Seedlings should be planted closely at about 3 by 3 m. There should be a basin around each seedling to harvest water. Once the trees have become big and showing signs of competition, they should be thinned to 6 by 6 m.

Prune by removal of branches from the lower part of the tree crown through side pruning. While pruning a tree, branches are always cut near the stem.

The objectives of pruning in agroforestry are threefold:

- Reduction of shade for crops near the tree
- Improving the quality of the trunk, mainly for timber and poles
- Early harvest of branchwood for fuel or other use.