Food and Agriculture Organization of the United Nations

SAVE AND GROW

A TECHNICAL GUIDE TO AGRICULTURAL PRACTICES IN ZAMBIA

TOWARDS SUSTAINABLE AGRICULTURAL INTENSIFICATION

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FOREWORD

Sustainable crop production systems generate income, protect the environment and create social equity and are therefore of critical importance to achieving the Sustainable Development Goals. Particularly in rural areas where livelihood dependency on agriculture is greatest the promotion of appropriate agronomic practices and associated services is needed to increase production while managing natural resources. Sustainable crop production systems confer resilience to changes in climate and markets to guarantee food security for millions of Zambians.

This technical manual focuses on maize based systems including association with grain legumes such as pigeon pea and is a product of extensive and elaborate consultations between the Government, and all relevant stakeholders in the agriculture sector of Zambia. Practices described in the manual target small-scale farmers to promote sustainable crop intensification. Services such as quality seeds of adapted varieties, cropping system profiles and patterns adapted to different seasons and changes in climate are highlighted. In addition, mechanization services and the role of agri-business hubs to connect farmers to markets and create new employment opportunities are presented.

It is my sincere belief that this technical manual will be a relevant and useful practical guide to facilitate the transition to sustainable crop production in Zambia, and other countries across Sub-Saharan Africa.

Songowayo Zyambo
Permanent Secretary
Ministry of Agriculture

FOREWORD

Crop production must become more efficient to provide sufficient food for an increasing global population while conserving land, natural resources and biodiversity. Optimization of cropping systems with minimization of pesticides and fertilizers for MORE efficient, inclusive, resilient, and sustainable crop production and protection is urgently needed.
The Plant Production and Protection Division of the Food and Agriculture Organization (FAO) of the United Nations actively promotes sustainable crop production: that protects the environment, generates incomes, and creates social equity. Through partnership with the German Ministry of Agriculture, the Government of Zambia, Zambia Agriculture Research Institute, Grassroots Trust, University of Zambia, Conservation Farming Unit, Natural Resource Development College, Kasisi Agricultural Training Centre, Foundations for Farming, Agricultural Knowledge Training Centre, Christian Relief Services, and Golden Valley Research Trust with FAO, practical agronomic options and mechanization strategies have been demonstrated that are sustainable and confer resilience to changing climates for cereals, legumes and cash crops. An enabling environment has been created for agricultural inputs such as quality seed of crop varieties adapted to the varied Zambian agro-ecoregions and combined with traditional knowledge of Zambian farmers, creative extension mechanisms and through the establishment of agri-business hubs to link farmers to markets. Adaptive agricultural research, new science and agronomic practices have been embraced to provide Zambian farmers with options and to avoid stereotyped approaches, such as “traditional” or “intensive” systems.
To ensure coherent guidance and advice, this manual has been developed in a participatory manner with farmers at the core and will be updated regularly to include all relevant practices, technologies and policy recommendations.

Jingyuan Xia

Xia, Jingyuan
Director
Plant Production and Protection Division

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Activities were coordinated by Sebastian Scott (Grassroots Trust) and, from the Food and Agriculture Organization (FAO), Sandra Corsi, Misael Kokwe, Shula Reynolds thanks to the unvaluable support received by colleagues of the FAO Plant Production and Protection Division: Jingyuan Xia (Director), Rémi Nono Womdim (Deputy Director), Fenton Beed (Team Leader), Josef Kienzle (Agricultural Engineer).

The production of this manual would not have been possible without the broad and diverse experience of the contributors, all of whom we would like to acknowledge.

Special thanks to the Ministry of Agriculture of Zambia under its various specialized branches in agronomy, extension, research, mechanization, farming systems, education, and others - whose contributions were critical.

From the Ministry of Agriculture and ZARI, acknowledgments include Handsome Mungalu, Nkumbu Mutwale, Godfrey Mutale, Nathan Phiri, Shadreck Mubanga, Valentine Kilubi, Chanda Bwalya, Morton Mwanza, Kelvin Chinama and Dominic Namanyungu, Katupa Chongo, John Lungu, Gabriel Paundi, Gift Mulenga, Whiteson Kasuba, Chanda Bwalya, Christine Iseki, Daniel Banda, Patricia Kaluba, Professor Sianyenika, Mercy Kabanda, Kalabadya Mambwe, Peter Chilambwe, Kegan Beeendo, Japhet Daka, Meylyn Mweetwa, Brian Iseki, Justine Lupambe, Robert Ntembula and Busuman Banda.

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INTRODUCTORY MODULES

INTRODUCTION

This guide is for extension officers in both the public and the private sector, including those interested in agricultural development in Zambia. It is a tool to allow readers to access up-to-date information about various agricultural practices and their advantages and disadvantages.

This manual is the product of an effort to harmonize the messages farmers receive from those who aim to facilitate positive change in the farming community. Many organizations in Zambia implement programmes aimed at sustainable development in the agriculture sector. These programmes include many different approaches to improving livelihoods and they have good reasons for promoting their specific methods. This manual, however, takes an independent stance and portrays what they each have to offer.

Information is included about new approaches as well as traditional farmer practices and conventional farming methods. The central theme is that there can never be only one way to achieve a goal, given the wide range of conditions found in agriculture. Although there may be some benefit from rigid guidelines for agricultural practices (for example, exact crop spacing, specific tillage methods or precise fertilizer recommendations), such guidelines are often impractical given the economic, social and environmental conditions that affect people's decisions.

Extension methodology

The recognized methodology for adult learning in the agricultural context – indeed, it has become government policy – is the **participatory extension approach (PEA)**:

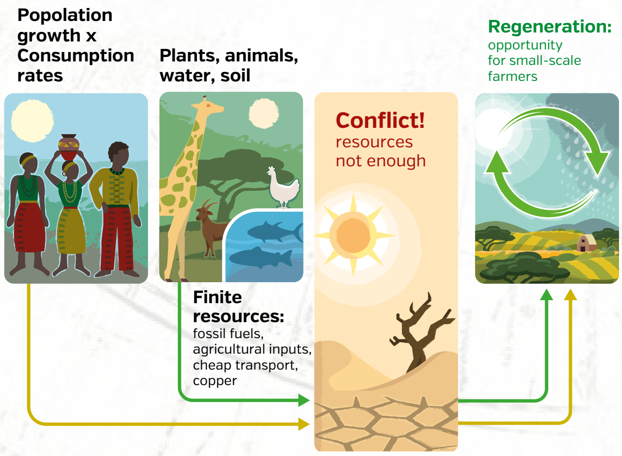
- PEA is a systematic learning process focusing on cumulative joint learning using both indigenous and modern knowledge systems.
- Facilitation is favoured over teaching.
- Adult learning and communication are the foundation principles of extension services in Zambia.
- PEA realizes these principles through farmer commodity study groups, which comprise mainly farmer field schools for the delivery of extension.

MODULE 1

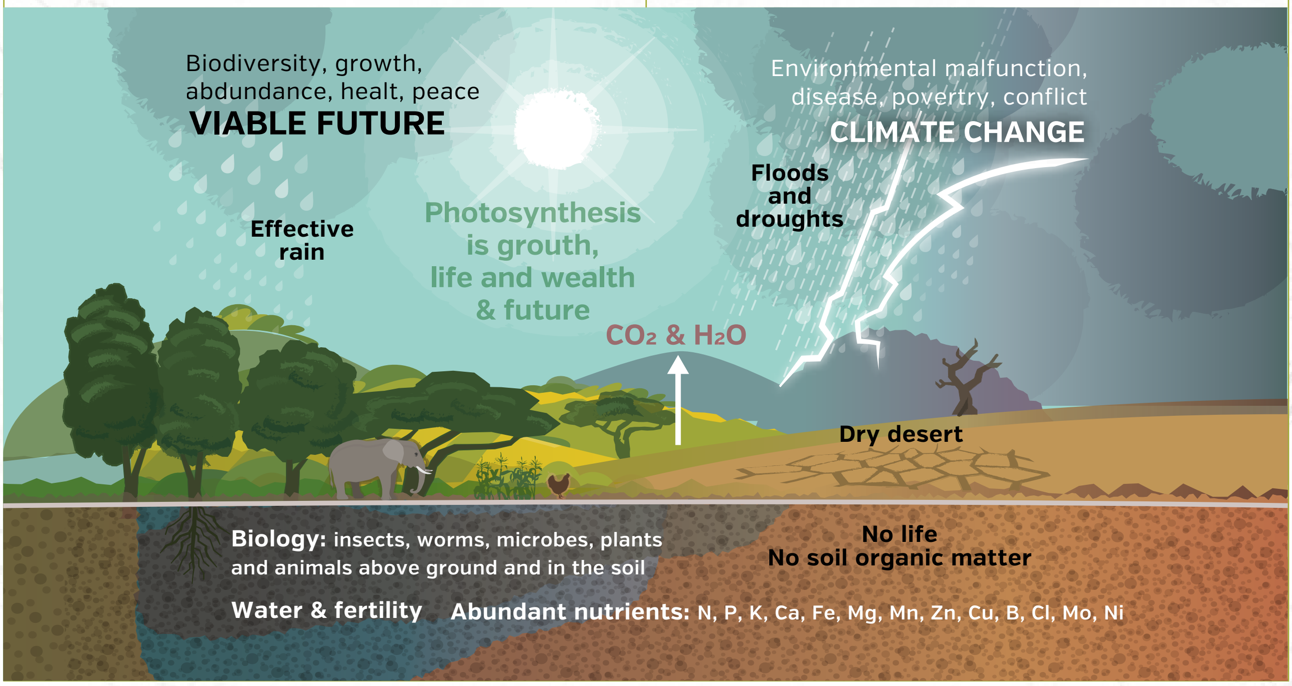
UNDERSTANDING MAJOR FACTORS SURROUNDING FARMING DECISIONS

This module provides farmers with an understanding of the major factors influencing agricultural decisions now and in the near future. The table is based on questions and responses designed to: illustrate these major factors; explain how they influence farmers' decision-making; and guide discussion.

Guiding farm management decision

GUIDING QUESTIONS	KEY FACTS, ANSWERS AND EXAMPLES
The population of Zambia is growing. How will this affect a farmer?	**Social:** • At independence (1964), it was around 3.1 million. • Today (2020), it is 19 million. • The projected population for 2050 is 50 million! **Economic:** • Everyone wants to improve his or her life with more resources. **Discussion:** Can current agricultural management continue to provide the growing population with sufficient food, fibre and energy from the land and water?
What **opportunities** will the increase in population and consumption bring?	**Economic/environmental:** • Increased demand for goods and services, including agricultural produce (crops and livestock) and wild harvest foods (fish, mushrooms, bush-meat etc.). **Discussion:** What do farmers need to do to take advantage of this opportunity?
What **risks** will increasing consumer demand bring to farmers?  	**Socio-economic:** • Reduced access to land for agriculture. • Rising cost of inputs like fertilizer, fuel and chemicals as finite reserves are depleted. • Reduced access to natural resources such as fish, wildlife, and timber and non-timber forest products. • Poor resource management as people rush to make a quick profit. **Discussion:** What needs to be done to ensure more can be produced with less input on less land?

GUIDING QUESTIONS	KEY FACTS, ANSWERS AND EXAMPLES
If we do NOT manage farming land well, what can we expect to happen as the population grows?	**Economic:** • Lower yields – due to reduced fertility and less water. • Reduced income and less profit – due to the rising cost of chemical fertilizers. In 1975, the purchase of one bag of fertilizer was the equivalent of the price of one bag of maize sold. Today a farmer needs to sell approximately five bags of maize to buy one bag of fertilizer. Therefore, yields have to be five times greater to make the same profit. • Declining soil fertility – because soils will become less porous due to loss of soil structure through organic matter loss and erosion. **Social:** • Increasing reliance on common resources such as fish, wildlife and forests to survive – as crop farming becomes less profitable. • Conflict, corruption – resulting from unequal access to resources. **Environmental:** • Increased use of use inorganic fertilizers and agrochemicals – to keep the land productive. • Negative impact on the environment – from overuse of chemical inputs. **Discussion:** What kind of management can increase productivity and profit while reducing input costs?
If we do NOT manage grazing land well, what can we expect to happen as the population grows?	**Environmental:** • Land degradation – with more livestock and less land, plants have less time to recover between grazing. • Decline in productivity and in animal welfare – because pests and diseases will proliferate more. **Social:** • Less vegetation for the whole community (i.e. reduced carrying capacity). **Economic:** • Reduced production, income and profit. **Discussion:** What management is needed to improve habitat growth while also improving health, productivity and profit in livestock?



GUIDING QUESTIONS

What are the **consequences** when many farmers and communities manage their environment without a vision for the future?

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Signs of desertification

Easy to see paterns

- Less biodiversity (plant and animals)
- More bare ground
- More hard soil
- Bigger spaces between grass
- More erosion
- Less moisture in whole ecosystem
  - Less groundwater
  - Springs, streams and dambos drying earlier in season
  - Increased floods
  - Increased droughts

Looking closer

- Less organic matter in the soil
- Less soil - life look for worms, insects and fungi
- Change in plant species towards desert plants
- Sandy soil no longer accepts and hold water
- Less water, fewer plants and animals (biodiversity) in desert

KEY FACTS, ANSWERS AND EXAMPLES

Environmental:

- Degradation of crop fields, pastures and forests over large areas – causing the water cycle to break, leading to bare, hard soils unable to accept or hold water.
- Runoff of rainfall – causing floods downstream and the land to remain dry as the rains fail to infiltrate into the soil.
- Less water in streams, rivers, wells and boreholes – due to the lack of groundwater from reduced infiltration.

Social:

- Disruption of the livelihoods of communities at the local and regional levels.

Economic:

- Lower production of everything – crops, livestock, wildlife, fish, timber and non-timber forest products – due to less available water.
- Lower incomes – as the natural resource base erodes.

Discussion: What management is required to improve production of food, fibre and energy from the land and water while maintaining the environment?

Are the rains decreasing?
Does climate change mean less rain?

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Environmental:

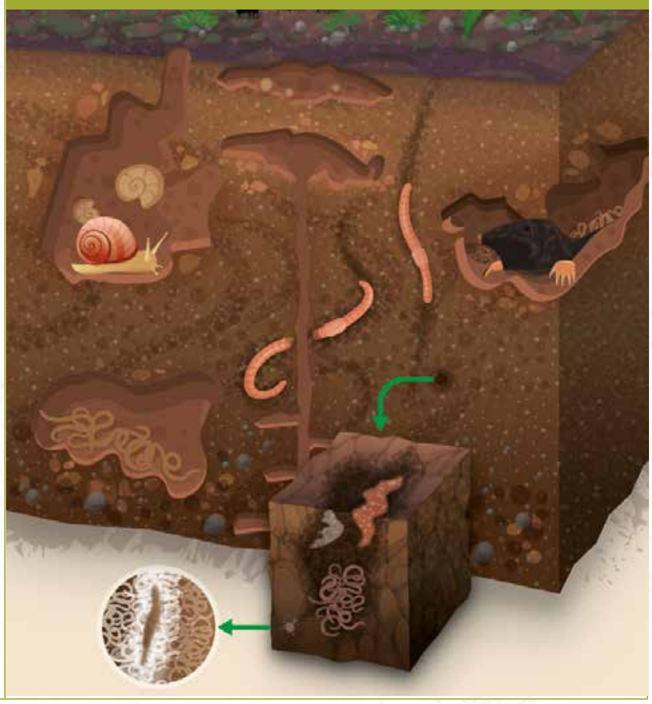
- Long-term studies of rainfall in Zambia show that total rainfall varies greatly from year to year.
- If soils are healthy (i.e. well covered and high in organic matter), more rain will enter the soil. If soils are bare and hard, most of the rain will run off, leaving the land dry.
- Simple demonstration: Take two bottles of water on a hot sunny day. Pour one bottle on bare hard soil and the other on healthy soil covered with grass and leaves. See what happens to the water. Which one runs off more? Which one splashes the soil? Which one dries up quickly?
- Try to imagine heavy rainfall in your catchment. How much rain will enter your land and how much will quickly run off?

Discussion: How can soils be managed to capture as much rainfall as possible?

Partner species:

- Know and understand the plants and animals that will help to improve your land and livelihoods.
- Feed you soli with dead plant matter. This will feed termites, worms and microbes who in turn will feed your plants.
- Reduce chemicals that suppress or kill them, be aware of how they live and what food they need to avoid eating your crops.
- Let nature to do the work so you can reduce of external input costs.

LIVING SOIL



GUIDING QUESTIONS	KEY FACTS, ANSWERS AND EXAMPLES
What do soil health and soil fertility mean? What are the consequences of poor soil health and low soil fertility?	**Soil fertility** refers to the nutrients in the soil. Reduced soil fertility leads to less plant growth as there are fewer nutrients. **Soil health** refers to the balance of physical, chemical and biological aspects of a soil. Healthy soil has a good balance of all these factors. **Environmental:** • Under natural conditions, plant roots take some nutrients from the soil and use them for growth, some plants are eaten by animals, some simply die back. • The organic matter (dead plants and manure) is recycled into the soil to ensure that nutrients are available for new plants and animals. This is the job of the billions of life forms that live in the soil. • If this cycle is broken by burning, deforestation, overgrazing, nutrient mining or overuse of chemicals, the soil becomes increasingly less fertile and less healthy. **Economic:** • Lower production rates – due to poor fertility. • Higher costs – due to expense of chemical fertilizers. **Social:** • Lower standards of living and increased pressure on rural communities to provide their families with what they need to survive. **Discussion:** What management is required to improve soil fertility?
What is soil organic matter?	**Soil organic matter** refers to the organic material that comes from dead plant or animal material that decomposes in the soil. • Soil organic matter has many benefits: - Contains nutrients, which are released and used by plants for growth – reducing costs. - Helps hold the soil together – reducing the negative effects of erosion. - Loosens the soil – allowing rain to enter the soil easily. - Holds water like a sponge, allowing roots to use the water in the soil for longer – reducing impact from dry spells and droughts. - Allows the soil to hold more nutrients, decreasing the need for fertilizer and manure – reducing costs. - Provides food for soil life (worms, bacteria, fungi, termites). These organisms bring nutrients from the soil to the plants and help to reduce soil-borne diseases and pests – reducing costs. • Soil organic matter exists in a flux, as every year: - Old organic matter is used by soil life (worms, termites, bacteria etc.), releasing nutrients into the soil. - New organic matter is added from decomposing leaves, roots, manure etc.
What role does soil organic matter it has in maintaining soil fertility and soil health?	**The soil is like a bank account.** The soil organic matter (SOM) is the 'currency' (money). 1% SOM is approximately 20 tonnes soil organic carbon (SOC) per hectare. SOM can be measured using soil testing with the help of extension staff and usually ranges from 1% to 5% per hectare. • Every year, some nutrients are released from the SOM, this is like a withdrawal and these nutrients are available for use by crops. The nutrients in the SOM are released by soil life like bacteria, fungi, nematodes, protozoa and larger organisms like termites and earthworms. These organisms need food and they use the crop residues both fresh (organic matter) and decomposing (SOM) as a food source to grow. In this way, during the release of nutrients, the SOM is depleted to less than it was before. • If the lost organic matter and SOM are not returned to the soil, the SOM balance will start to diminish. This can happen very quickly in warm weather typical of Zambia during the rainy season. The following example may help us to understand why managing SOM is important: • **Virgin land or very well managed agricultural soil has abundant SOM.** For this example we will say the soil has 5% SOM: - At 5% SOM, the 'bank balance' is very good. - The SOM releases many nutrients. It releases nitrogen at a rate of between 44–176 kg per hectare every year. This amount of nitrogen is enough to harvest between 48 and 180, 50kg-bags of maize from one hectare with no added nitrogen fertilizer. • **If the same agricultural land is used continuously for crop production, for 10 years or more, without using farming practices that increase or maintain SOM:** - The soil now has only 1.5% SOM remaining. The 'bank balance' is now poor. - From this balance, the soil releases nitrogen at a rate of between 13–53 kg per hectare only. This is enough to harvest between 14 and 58, 50kg-bags of maize from one hectare without adding any fertilizer. As you can see from this example, the soil organic matter 'bank' balance can have a big influence on the amount of nutrients released from the soil every year and the potential for good crop growth and yields. As the SOM decreases in the soil, more nutrients need to be added from outside to get good crop yields. Cost of production increases.

<table>
<tr><th>GUIDING QUESTIONS</th><th>KEY FACTS, ANSWERS AND EXAMPLES</th></tr>
<tr><td></td><td>Lesson: The quantity of nutrients released into the soil from the soil organic matter depends on soil health. In the example above, less healthy soil gives only 44 kg N, very healthy soil gives up to 176 kg N.

Soil health improves as SOM increases, but soil health is negatively affected by things like over-cultivation of soil, compacting soil by cultivating when the soil is too wet and the use of certain agricultural chemicals that damage the soil micro-organisms.

What can the farmer do to increase the SOM 'bank balance'?
• When farmers use long fallows (leaving the land to revegetate), the soil organic matter builds up because the roots, leaves, manure etc. enter the soil bank account when they decompose. When this land is brought back into cultivation again, these nutrients become available to the crops as described above.
• Long fallows of at least 10 years are not always possible, but there are other ways to grow crops year after year and increase organic material in the soil.
• The farmer must "feed" the soil to replace lost organic matter and nutrients. This can be achieved by adding manure, compost, crop residues or green manure, or by practicing agroforestry. These practices are covered in detail later in this manual.

What practices reduce the SOM bank balance?
• When farmers use the same field year after year and do not return enough crop residues, green manure or animal manure to the field, the SOM decreases.
• The bank balance cannot be restored with chemical fertilizer, like urea, as it does not contain organic material.
• Tillage affects SOM:

Undisturbed soil retains more organic matter than disturbed soil.
Moving or mixing the soil with a plough, disc or hoe speeds up the loss of SOM, but can also lead to more nutrients being released for crops.
The more the soil is disturbed, the more organic matter the farmer will need to add in order to maintain or increase SOM over time.

How do I know if I am loosing or gaining SOM:
• The only sure way to test if your farming system is leading to increasing or decreasing SOM is to do a soil test with the help of an extension officer.
• Soil that is losing SOM will have a lighter colour and harder texture than a soil with high SOM. This physical test can also help to give a farmer an idea of the direction their production system is taking their soil.</td></tr>
<tr><td>How can we increase the amount of nutrients, organic matter and soil cover in crop fields, pastures and forests?</td><td>• Stop/reduce burning – burning leaves soil bare.
• Plant mixtures of grasses, forbs, shrubs and trees – they produce more organic matter than only one type of vegetation.
• Incorporate deep rooting crops and legumes – to bring more nutrients into the topsoil.
• Leave some trees in the field – to reduce effects of wind and sun.
• Integrate livestock – they help convert plant material into high-value manure.
• Keep livestock moving throughout the year – to give plants time to grow and to prevent animals staying in one place too long and eating all the soil cover leaving soil unprotected from wind and rain.
• Use natural and synthetic fertilizers efficiently.
Discussion: Which of these actions can be done by the individual farmer and which require collective action by the whole community?</td></tr>
<tr><td>So many factors to consider: how to choose the best action?</td><td>• We should now have clear picture of the direction management needs go.
• The desert is dead: management needs to aim for more plants and animals – that is where the money is and that is what will make everyone in the community happy and satisfied.
• Decisions can be tested: will a decision take the farm/community towards or away from the future we want?
Example: Should I remove all the trees to make a crop field?
• Tree removal may seem like the best decision economically in the short term, but many benefits will be lost:
- Decrease in topsoil fertility and water (because trees bring these from deep down) – resulting in aridness and higher fertilizer requirements.
- No places for birds and other predators to perch to hunt the pests in your field – you will be forced to buy insecticides.
- Increased drying effect of direct sun and wind (without the protection of trees) – in drought years there will be no fruits or other forest products for survival.
If a farmer tests the decision holistically and sees all the negative effects of cutting all the trees, they may decide to select the trees and leave only the most useful.</td></tr>
</table>

MODULE 2

MANAGING NATURAL RESOURCES UNDER ZAMBIAN CONDITIONS AND DEVELOPING A VISON FOR THE FUTURE

Zambia's natural resources are managed using a combination of traditional and national laws and by-laws. This module compares past and current management approaches. Farmers are encouraged to consider which practices to adopt in order to best manage natural resources in the future.

Management approaches

PAST MANAGEMENT UNDER TRADITIONAL AUTHORITY (TA)	CURRENT MANAGEMENT	MANAGEMENT REQUIRED TO ACHIEVE A GOOD FUTURE FOR ALL
Everyone shared land and natural resources.	Individuals compete for land and natural resources.	Land and resources accessible to **ALL**.
Everyone managed land and natural resources together with TA.	Individuals – not the community – manage their own land and natural resources.	**Collaboration** in order to improve land and natural resources.
Everyone discussed and agreed on rules and management with TA.	Individuals make own decisions without considering the community.	Learning together to agree on best management practices within the catchment.
TA ensured that everyone received fair share of resources.	Some people get abundant resources, others get few	**Equal access** to resources.
Everyone combined livestock in big herds and planned grazing.	Small herds belonging to individuals compete for grass in communal grazing areas.	**Planning** together to establish grazing based on everyone's needs.
People took few resources/goods (consumption was low).	People need many things (consumption is high).	**Sustainable consumption** of what the environment can produce – not more!
Natural environment was able to flourish (low environmental impact).	People show disregard for the environment (high environmental impact: deficiency of resources, desertification, climate change).	**Regeneration** of the environment, enabling it to produce more resources for a growing population with modern needs.

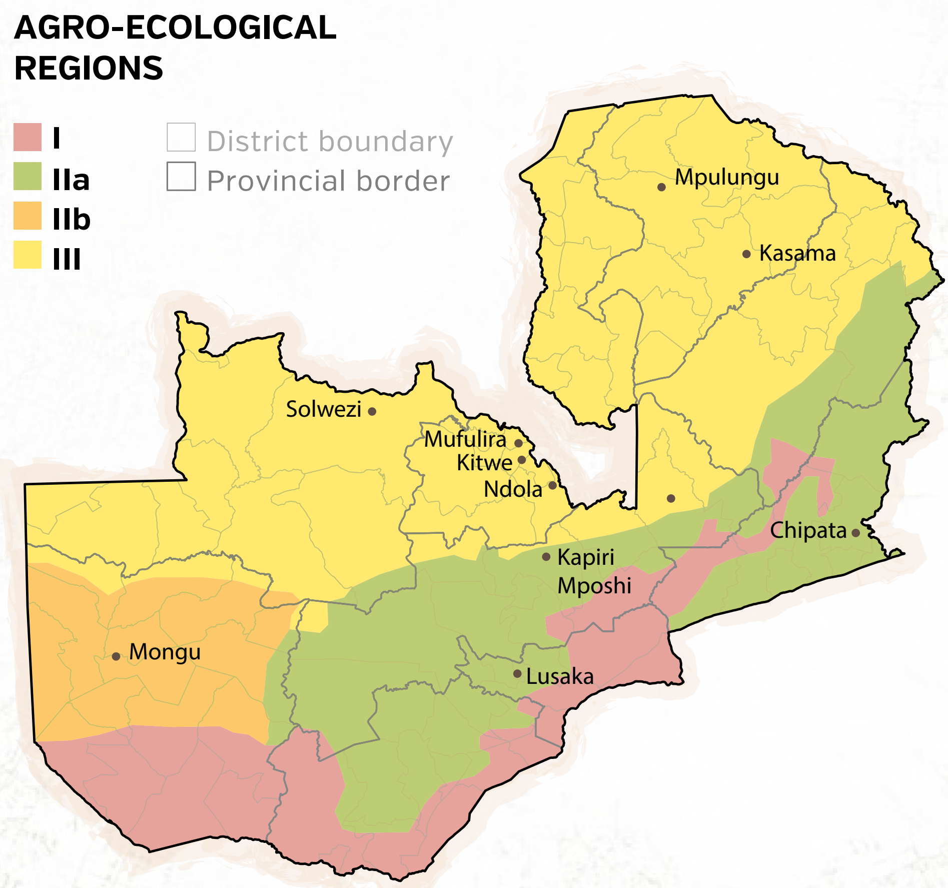
Discussion:

- How do we want our lives to be?
- What practices must we adopt today to ensure land and resources for tomorrow?
- What actions are needed?

MODULE 3

AGRO - ECOLOGICAL REGION AND CURRENT FARMING SYSTEMS IN ZAMBIA

In order to **improve** small- and medium-scale farming systems in Zambia, it is important to **understand** them. This module enables readers to understand the basic dominant production parameters of each of the agro-ecological region (AERs). When working with farmer groups or individuals, it is important to focus on their specific area and the relative AER.



Source: UN. 2020. Map of the World [online]. [Cited 8 March 2021]. http://www.fao.org/geonetwork/srv/en/metadata.show?id=12691

Agro-ecological zones of Zambia

AGRO-ECOLOGICAL ZONE	ATTRIBUTES
AER I	■ **Characteristics:** • Low rainfall (500–800 mm/year) - equivalent of 25–40 20–litre buckets of water on every m2 of land. • Average crop growing season 80–120 days. • Zambezi–Luangwa Rift Valley - solonitzi soils on steep slopes are difficult to manage. • Valley areas. • Semi-arid plains. • Fertile alluvial soils. ■ **Livelihood base:** • Integrated crop and livestock systems dominant. • Maize, sorghum, rice, ruminants, poultry, fishing, wildlife, timber and non-timber forest products, vegetables. ■ **Production challenges:** • Environmental - low and highly variable rainfall, frequent long dry spells, high temperatures, periodic floods, human–wildlife conflict, livestock diseases including Trypanosomiasis spread by tsetse flies, degradation of pastures. • Economic - limited access to input/output markets, low levels of mechanization, long distance to market, poor access to finance. • Social - limited research and extension interventions, poor infrastructure, insufficient access to government services.
AER IIa	■ **Characteristics:** • Medium rainfall (800–1 200 mm/year) - equivalent of 40–60 20-litre buckets of water on every m2 of land. • Relatively stable annual rainfall and temperatures. • Most productive region in Zambia for agricultural crops. • Variable soil types ranging from poor to highly fertile soils. ■ **Livelihood base:** • Integrated crop and livestock systems dominant. • Average crop growing season 120–140 days. • Maize, cassava, groundnut, cotton, rice, beans, ruminants, poultry, fishing, game, timber and non-timber forest products, vegetables, cattle (accounting for 72% of the country's cattle population, one-third of which owned by large ranchers), goats, pigs, chickens. ■ **Production challenges:** • Environmental - erratic rainfall, periodic floods, livestock diseases, human–wildlife conflict, degradation of pastures. • Economic - limited access to input/output markets, low levels of mechanization, long distance to market, poor access to finance. • Social - limited research and extension interventions, poor infrastructure, insufficient access to government services.
AER IIb	**Attributes similar to those of AER IIa. In addition:** ■ **Characteristics:** • Soils very deep, sandy, poor in fertility.. ■ **Production challenges:** • Environmental - sandy soils.

AGRO-ECOLOGICAL ZONE	ATTRIBUTES
AER III	▪ **Characteristics:** • High rainfall (1 000–1 500 mm/year) – equivalent of 50–75 20–litre buckets of water on every m² of land. • Good, stable rainfall distribution. • Lower average temperature than other AERs. ▪ **Livelihood base:** • Growing season 140–155 days. • Cassava, maize, millet, sorghum, groundnut, beans, small ruminants, poultry, fishing, game, timber and non-timber forest products, vegetables. ▪ **Production challenges:** • Environmental – acid soils, leached and infertile soils, human–wildlife conflict, livestock diseases. • Economic – poor access to input/output markets, low levels of mechanization, long distance to market, limited access to finance. • Social – limited research and extension interventions, poor infrastructure, insufficient access to government services.

MODULE 4

MAJOR PRODUCTION CONSTRAINTS IN FARMING SYSTEMS

This module highlights the main production constraints in farming systems in Zambia. Major constraints to production in farming systems are widespread and complex. Farmers should be encouraged to identify them themselves; help should only be provided when they are unable to answer.

Major Production constraints

GUIDING QUESTIONS	CONSTRAINT – CAUSES, CONSEQUENCES, REMEDIES
What happens to soil fertility when crops are grown year after year on the same land?	**Soil nutrient decline** • In areas of intensive production, the repeated cultivation of crops leads to nutrient mining (if nutrients lost at harvest are not replaced, they become depleted in the field). • This is a major problem with crops that take many nutrients (heavy feeders) – e.g. maize and cassava – but it can also happen under other crops.
What is soil erosion?  What are the effects of erosion on soil fertility and productivity?	**Soil erosion** • Water and wind can cause soil to move (erode). • Poor tillage practices remove covering of plants and organic material, leaving the land bare, which exacerbates the effect of water and wind. • The result is the movement and loss of large amounts of fertile topsoil.
What is acidic soil? How does soil become acidic? How can soil acidity be corrected? Has anyone used lime or other remedies for acidic soil?	**Soil acidity** • When the soil has a pH of < 7, it is acidic. The lower the pH, the more acidic the soil is. • Acidic soil has poor availability of nutrients for plants, resulting in poor crop growth. • Repeated use of nitrogenous fertilizers on non-acidic soils can cause acidity. • Many soils are naturally acidic due to leaching of nutrients over long periods of time (thousands of years). • Liming materials: agricultural lime, liquid lime and wood ash. • **Remedy:** Mix a liming material with the topsoil. The quantity applied depends on the type of liming material and how finely it is ground (more finely ground = reduced requirement).
What is soil organic matter? What happens to the soil if soil organic matter is reduced?	**Soil organic matter decline** • Soil organic matter is the organic material that comes from dead plant or animal material that decomposes in the soil. • Decline in soil organic matter leads to reduction in: - soil health; - soil fertility; and - rainwater infiltration and soil water-holding capacity. (Refer to Module 1: "What is soil organic matter?")

GUIDING QUESTIONS	CONSTRAINT – CAUSES, CONSEQUENCES, REMEDIES
Have input costs fallen or risen in the recent past? How does this affect farm income?	■ **Increasing cost of inputs** • The cost of inputs is rising faster than the price of food. • This leads to smaller profits. • Farm income is the revenue from sales minus the cost of production: if the production costs increase, income decreases and vice versa.
Have the prices of agricultural products changed in the recent past? Has demand changed? What effect do these changes have on what you choose to grow?	■ **Erratic markets for agricultural products and limited value addition** • Prices of agricultural products, as well as access to and demand for agricultural products, change depending on: - location of farmers; - local, national and international production; and - government policy. • This makes it difficult for farmers to plan which crops to grow in their farming systems. For example, some areas do not have a stable market for cash crop legumes like soybean. • Smallholders have limited capacity to engage in value addition for produce. • **Remedy:** Plan and know your market before deciding what crop to produce.
Which crops are suitable for crop rotation? Have you encountered difficulties acquiring any of these for cultivation?	■ **Poor/erratic markets for diverse crops for use in agricultural systems** • Lack of suitable crops for diverse crop rotations and mixed cropping (e.g. soybean, groundnut, cowpea, pigeon pea) stifle farm productivity and efficiency.
What causes poor access to animal draft power on a farming business? Have you encountered difficulty acquiring animals for draft power?	■ **Inadequate access to animal draft power** • Pasture degradation reduces available feed and reduces animal performance. • Livestock diseases affect availability of draft animals and production of manure. • Livestock theft is prevalent in many areas of the country. • Poor access to animal draft power and/or reduced animal performance, as well as less manure, have a negative impact on crop productivity.
Do you have access to high-quality farming information? How could you benefit from up-to-date information on improved agricultural practices?	■ **Lack of information on improved farming practices and inefficient provision of agricultural extension** • The development and sharing of new agricultural approaches and technologies is inefficient. • Organizations share the same goal (to improve farmers' livelihoods), but teach different approaches, resulting in mixed messaging. • Extension provision is often limited by resource constraints (current ratio at the national level is approximately one extension agent for over 1 000 farmers). • Extension officers often lack mobility and training resources. • The result is poor service delivery and insufficient information.
Can you name a pest or disease that causes yield losses?	■ **Pests and diseases** • Agricultural pests and diseases can cause significant losses. • Losses can even be of national significance (e.g. African armyworm [*Spodoptera exempta*] caused massive crop losses in 2014 in Zambia). • Even minor pests (e.g. maize stalk borer [*Busseola fusca*] and fall armyworm [*Spodoptera frugiperda*] can cause significant localized losses.

INTRODUCTION TO TECHNICAL MODULES

Modules 5–9 go into detail about the actual farming practices farmers use. By gaining a deeper understanding of the individual practices, readers and their farmers will be better equipped to make decisions.

When working with farmers, focus on the information that is relevant to the specific area concerned. For example, teaching farmers about animal draft power techniques in areas where there are no draft animals could be of interest, but it would not be the best use of time.

MODULE 5

FARMING AS A BUSINESS – UNDERSTANDING SIMPLE FARM BUDGETING

This module presents farm budgeting as a simple way to understand how different practices influence the decisions made on the farm. All farm operations have a cost and this cost can vary according to numerous factors (e.g. labour costs, input costs, distant to market).

- **Direct input costs** – e.g. seed, fertilizer, empty bags, plough, hoe.
- **Indirect costs** – e.g. depreciation of equipment and need to replace parts (e.g. ploughshare, hoe blade/handle, nuts and bolts, tyre for an ox cart).
- **Labour costs** – either the cost of hired labour to do work on the farm or the opportunity cost of the farmer or their family doing the work. The latter concept is easy to understand if you imagine that instead of doing work on farm, you would use the time you had to look for work elsewhere. In this case, the amount you would have been paid needs to be added to the farm costs, as you are not available for paid off-farm work. A good exercise with farmers is to determine the local wage rate according to how much people are paid.

It is useful to draw up a simple budget and cost–benefit table together with farmers. The exercise usually gives only a rough estimate, but it is still indicative of the costs and benefits to farmers.

Step-by-step example:

1. Explain and ascertain “average yield”

In order to make a meaningful comparison, it is necessary to first ascertain the yield of produce from a given area (typically 1 ha or 1 lima) and specify the farming practices or system used.

Begin by asking the farmer or farmer group what **yields** they achieved during the previous season, using what **inputs** and which **production system**. Explain that to ascertain the **area** and thus the **yield**, they can choose from two methods: one based on cultivated area and one on quantity of seed used.

Useful measurements for calculating yield per unit area

SEED TYPE	KG/HA	KG/LIMA[1]	KG/AC[2]
Maize	20–25	5–6.25	8–10
Soybean	60–100	15–25	24–40
Groundnut	60–100	15–25	24–40
Beans (dry)	50	12.5	21

[1] Multiply yield by 4 for equivalent per ha.
[2] Multiply yield by 2.47 for equivalent per ha.

Example:

Soybean seed planted in lima = 40 kg
Yield from 2-lima field = 750 kg
Yield from 1 lima = 375 kg
Multiply by 4: **yield from 1 ha = 1 360 kg**

Farmers usually express yield in bags. Ask the farmers how many bags they harvested. It is then possible to calculate the number of bags per given area. The given area is usually 1 ha or 1 lima; acres are sometimes also used.

Important: ensure that farmers understand that in order to make a comparison, the conversion must be done so that everyone's yield corresponds to the same area (usually 1 ha or 1 lima).

Example:

Five farmers cultivate maize and need to calculate the average yield:
Farmer 1 harvests 45 bags from 20 kg of seed. Yield = 45 bags/ha.
Farmer 2 harvests 10 bags on 1 lima. Yield = 40 bags/ha.
Farmer 3 harvests 50 bags from 30 kg seed. Yield = 33 bags/ha.
Farmer 4 harvests 24 bags on 1 acre. Yield = 60 bags/ha.
Farmer 5 harvests 100 bags from 40 kg seed. Yield = 50 bags/ha.

To calculate the average number of bags per hectare for the five farmers:
45 + 40 + 33 + 60 + 50 = 228/5 = 45.6, rounded up to nearest whole number **= 46 bags/ha.**

The same process is applied to calculate the number of bags of fertilizer used by each farmer and then the average number of bags of fertilizer used per hectare. All other costs (labour, transport, empty bags, weeding etc.) should be treated in the same way to enable a comparison of practices and systems used.

The table presents examples of five different scenarios to assess different farming practices and their impact on farm income.

Such a table is easily replicable at farm level using a school blackboard or portable whiteboard. Everyone in the group needs to understand the aim of the exercise and the process involved. Farm budgeting is a powerful tool for understanding how improvements can be made at the farm level to achieve higher incomes.

Theoretical gross analysis (farm budget) for various farming systems

* Reference land unit: 1 ha * Prices are provided in ZMK * Reference for 2020 1 USD=21 ZMK	Farmer type 1: Mouldboard ploughing, maize only, no rotation with other crops	Farmer type 2: Ripping (minimum tillage), maize only, no rotation with other crops	Farmer type 3: Ripping (minimum tillage), maize in crops rotation with legume (soybean)	Farmer type 4: Ripping (minimum tillage), crop rotation (soybean), manure applied to maize	Farmer type 5: Ripping or plough with crop rotation (soybean), applied manure and use of green manure (pigeon pea)
Average harvest in wieghed 50 kg bags per ha					
Maize	45	50	35	45	55
Soybean	0	0	15	18	15
Pigeon pea (green manure)	0	0	0	0	10
Total bags of produce	45	50	50	63	80
Income in ZMK per ha (Number of bags multiplied by the average price for the produce)					
Maize ZMK 100 per bag	4 500	5 000	3 500	4 500	5 500
Soybean ZMK 250 per bag	0	0	3 750	4 500	3 750
Pigeonpea ZMK 250 per bag	0	0	0	0	2 500
Gross income (before cost) for 1 ha	4 500	5 000	7 250	9 000	11 750
Costs (average or actual)					
Ascertain average labour cost for the area of work. Ask farmers "How much do you pay casual labour for a day's work?" Make an average for all the answers					
Land clearing * ZMK	100	100	100	100	200
Input acquisition - travel to town * ZMK	150	150	150	150	150
Seed – maize	350	350	175	175	175
Seed – soybean			900	900	900
Seed – pigeon pea					200
Fertilizer commercial ZMK 500 per bag	4000	4000	2000	2000	2000
Inoculant (soybean) ZMK 50 per bag	0	0	50	50	50
Land preparation	800	450	450	450	450
Planting (labour)	100	100	100	100	100
Transport of fertilizer ZMK 10 per bag	80	80	40	40	40
Application of fertilizer (basal)	100	100	100	100	100
Purchase of manure ZMK 50 per ox cart delivered to field (4 per ha/maize only)	0	0	0	100	100
Application of manure ZMK 2 per line	0	0	0	111	111
Weed control – mechanical ZMK 550 per ha per weeding	550	1100	1100	1100	550
Purchase of chemicals for pest control control ZMK 250 per application	500	500	500	500	500
Application for chemicals for pest control ZMK 100 per ha	100	100	100	100	100
Harvest – maize ZMK 500 per ha	500	500	250	250	250
Harvest – soybean ZMK 1 000 per ha			500	500	500
Harvest – pigeon pea ZMK 500 per ha					250
Empty bags ZMK 5 per bag	225	250	250	315	400
Transport to market ZMK 10 per bag	450	500	500	630	800
Other...					
Total cost without FISP	8 005	8 280	7 265	7 671	8 276
Total cost with FISP	4 485	4 760	5 505	5 911	6 516
Profit without FISP	- 3 505	- 3 280	- 15	1 329	3 474
Profit with FISP	15	240	1 745	3 089	5 234

Note: FISP – Farmer Input Subsidy Programmes

MODULE 6

FARMING PRACTICES: LAND PREPARATION, CROP ESTABLISHMENT AND WEED MANAGEMENT

Modules 6–9 focus on specific farming practices, highlighting their **advantages** and **disadvantages**.

Notes on mechanization

Farmers the world over have always shifted towards technologies and systems that allow them to do the job better or faster, or both. From the adoption of simple hand tools, farmers moved to the employment of draft animals, and more recently, to the use of motorized equipment like tractors and combine harvesters, which allow a single person to manage hundreds of hectares.

In recent years, the impacts of agriculture on the environment in general and specifically regarding the fossil fuels used, have become much better understood. For this reason, the concept of "sustainable mechanization" has emerged as farming aims to gain the benefits of improved technology without negative effects on the environment.

Farming takes place in a wide range of situations. A farmer with 1 ha does not earn sufficient income from the produce to justify the purchase or maintenance of a large tractor. In contrast, a farmer with 10 ha has no use for a hand hoe. Further, in some areas, a "service provider" may make a tractor available as medium- or large-scale mechanization is used also to service small farmers. A service provider hires out tools and skills that small-scale farmers would otherwise not have access to.

In summary, the cost of energy – be it from mechanical power, animal draft power or human labour – will determine the price of the various tillage operations and it will change according to context.

Soil tillage

PRACTICE	ADVANTAGES	DISADVANTAGES
Conventional tillage: • For land preparation. • For weeding. • With hoe, plough, cultivator, ridger, disk, harrow etc.  	• Can increase mineralization of nutrients from the soil by encouraging bacterial and fungal growth and these organisms speed up decomposition of organic matter and release of nutrients. • Can control certain pests and diseases (e.g. maize stalk borer and maize grey leaf spot) by disrupting their life cycles. • Can protect organic residues from fire and grazing (dry season tillage). • Reduces losses from runoff and volatilization (when tillage is used to bury fertilizer, manure/compost or green manure). • Allows for effective weed control. • Can lead to improved rainfall infiltration (compared with uncultivated soil lacking mulch/residue cover). • Allows for physical drainage in poor draining soils (when ridges are made in high rainfall areas and for susceptible crops over a broad range of conditions). • Can reduce water erosion (by making ridges, bunds, swales, terraces or furrows along the contour of the slope).	• Uses more organic matter (through decomposition) than when the soil is undisturbed. Therefore the farmer has to add more organic material to the soil to replace the amount lost and prevent soil organic matter decline (see Module 4 "Soil organic matter decline"). • Increases potential of soil erosion by wind and water (water erosion becomes more damaging as the slope of the land increases). • Incorporates crop residues into the soil (rather than leaving them on top), leading to soil surface capping, reduced rates of infiltration and higher soil temperatures (which can reduce or damage root growth near the soil surface). • Allows weed seed to come to the surface from deeper layers, increasing weed pressure. • Subsurface soil compaction can occur (hardpan), although usually only when heavy implements (tractors) are used on wet soils.
Minimum or zero tillage and conservation agriculture: • Minimum disturbance of soil – sufficient for planting seeds. • Crop residue retention or mulch.  	• Reduces soil organic matter loss. Therefore, less organic matter needs to be added to the soil to maintain soil organic matter levels and the accompanying benefits (see Module 4 "Soil organic matter decline"). • Increases rainwater infiltration (when rip lines, furrows or pits are made before the rain, they collect rainwater). • Reduces potential for erosion by wind and water by decreasing disturbance of soil (effect is increased if crop residue or mulch is left on the soil surface). • Reduces variations in soil temperature if enough crop residue is kept on the surface, potentially leading to improved growth – especially in dry spells and droughts. • Reduces evaporation from the soil surface (due to layer of residue or mulch), preventing the escape of moisture from the soil. • Encourages various beneficial organisms (as the crop residues provide a suitable habitat), potentially reducing insect damage from certain crops (e.g. fall armyworm).	• Hinders weed control (crop residues prevent efficient use of mechanized implements such as cultivator and ridger), resulting in increased use of herbicides (see section 6.5 for advantages and disadvantages of their use.) • Slows down release of nutrients from the soil in the initial years, which leads to lower yields, resulting in increased use of fertilizers. • Can increase erosion when there are furrows or rip lines not made on the contour, as they can act as drains and create runoff – especially if there are insufficient crop residues or mulch. • Can increase pests and diseases due to crop residues harbouring pests and diseases such as maize stalk borer and maize grey leaf spot, potentially increasing yield losses – especially when crop rotations are not used.

6.1 Land preparation/seeding – hand tools

Key points:

- Hand hoe-based agricultural systems remain dominant in areas of Zambia where draft animals are not available in large numbers, comprising large parts of the Northern, North-Western and Copperbelt provinces.
- The low investment cost of the hand hoe and its versatility make it easily accessible for all who want to grow crops.

Land preparation by hand

PRACTICE	ADVANTAGES	DISADVANTAGES
Hand hoe – ridges: • Conventional. • Widely practised in Northern, North-Western and Eastern Zambia (where there is poor access to animal draft power). Labour requirement: • dry soil: 35 days/ha • wet soil: 22 days/ha 	• Tools cheap and readily available to all. • Low cost where labour is cheap and available. • Can be done before rains, allowing for early planting. • Useful for burying residue/green manure. • Can help with drainage in high rainfall areas. • Can help to capture rainwater if ridges made on contour. • Allows efficient weed control for sensitive crops like groundnut (compared to weeding on flat land). • No need for skilled labour.	• Potentially high cost where labour is expensive. • Can lead to soil organic matter loss if sufficient organic material is not replaced. • Can lead to rapid soil erosion from water where ridges are not formed on contour – especially on fields with steep slopes. • Can lead to early season drought stress when roots are too small to access water. • Cultivated area cultivated limited by high labour requirement, as it is time-consuming. • Labour-intensive.
Hand hoe – flat culture (overall digging): • Not common. Labour requirement: • wet soil: 50–60 days/ha • dry soil: uncertain (only applicable on light soils)	• Tools cheap and readily available to all. • Low cost where labour is cheap and available. • Can be done before the rain in some soils, allowing for early planting.	• Potentially high cost where labour is expensive. • Can lead to soil organic matter loss if sufficient organic material is not replaced. • Can lead to soil capping in certain soils – especially where soil organic matter levels are low. • Potentially time consuming, limiting the land area that can be prepared. • Drudgery.
Hand hoe – minimum tillage (making holes in undisturbed soil after rains begin): • Not common. • CA. Labour requirement: • wet soil: 3–6 days/ha	• Allows for rapid establishment of crops. • Adapted to large areas. • Allows for early planting. • Tools cheap and accessible to all. • Allows farmer to keep crop residues on the surface, reducing erosion and evaporation and increasing rainwater infiltration.	• Increases weed pressure increases, therefore early mechanical weeding or herbicide are required. • Can lead to reduced rainfall infiltration and evaporation where no crop residues or other surface organic matter are present (because the ground will be hard and compacted).
Direct seeding – permanent ridges: • Variation of CA for high rainfall areas with drainage problems. Labour requirement: • depends on seeding method (see specifics for hoe, chaka hoe, dibble stick and jab planter)	• Same advantages as other CA practices. • Allows for better localized drainage – useful in high rainfall areas.	• Same disadvantages as other CA practices.

PRACTICE	ADVANTAGES	DISADVANTAGES
Hand hoe (making planting basins in dry soil before rains begin): • CA. Labour requirement: • basins: 30–80 days/ha (depending on soil type and condition) 	• Can be done before rains, allowing for early planting. • Allows for precise planting populations and fertilizer application due to accurate spacing and permanent stations, potentially leading to increased yields. • Can harvest rainwater in low rainfall years. • Allows farmer to keep crop residues on soil surface, reducing erosion and evaporation and increasing rainwater infiltration.	• High labour requirement. • Increases weed pressure, therefore early mechanical weeding or herbicide are required. • Can lead to reduced rainfall infiltration and evaporation where no crop residues or other surface organic matter are present (because the ground will be hard and compacted).
Dibble stick – direct seeding using pointed stick to make hole big enough for seeds: Labour requirement: • wet: 4 days/ha	• Can plant 1 ha in 1 day with 3 people in good condition. • Simple technology, easily made from wooden pole. • Avoids back pain and reduces drudgery. • Widely applicable. 	• Potentially strenuous – especially if soil is hard. • Specific training required. • Restricted mainly to large seeds with low plant populations (e.g. maize). • Possibility of insect damage and poor germination if holes not covered properly.
Jab planter – direct seeding using machine developed in Brazil: • Option of applying fertilizer at the same time as planting seed. Labour requirement: • 2–4 days/ha	• Saves labour, combining fertilizer and seed operations. • Relatively cheap compared to ox-drawn planters etc. • Easy to understand and use. • Minimal till. • Environmentally friendly – no pollution. 	• Success varies depending on soil and conditions. • If manure is fertilizer of choice, it needs to be applied separately. • Cannot see if seed has been planted. • Not widely available in Zambia. • Relatively high cost. • Some designs weak.

6.2 Land preparation/seeding – animal draft power (ADP)

Key points:

- Animal draft power allows more efficient use of labour than hoe-based systems.
- Increased efficiency translates into increased area cultivated, timeliness of operations and reduced drudgery.
- Cattle and oxen are the most common ADP in Zambia, although a small number of donkeys are also used.
- While ADP represents a low-cost approach towards intensifying agricultural production, the cost of purchasing livestock for families without livestock is substantial and represents a barrier to adoption. This can be overcome to some degree by hiring ADP or using relatives' animals; however, this can result in late planting as relatives and service providers will usually aim to finish their own fields before servicing others.
- The good health and productivity of the livestock are central to the success of ADP. Healthy animals must have access to sufficient good quality food to support their growth and allow them to work.

- Pasture degradation – as a result of poor grazing practices, improper selection of breeds and proliferation of livestock diseases – has reduced the potential of ADP and livestock production in general.
- Farmers' knowledge of livestock husbandry varies greatly across Zambia and is closely related to culture and geography, creating a potential barrier to the use of ADP.
- Keeping cattle provides farmers with the opportunity to multiply their investment by offering hire services, breeding and using manure as an organic fertilizer and soil conditioner.

Land preparation with ADP

PRACTICE	ADVANTAGES	DISADVANTAGES
Mouldboard plough: • Common in all provinces where draft animals are used. • Inverts soil to cover weeds. • Seed and fertilizer/manure applied in furrow and buried by plough on next pass. • Depth depends on seed planted and weed size. • Seeds planted every 1, 2 or 3 furrows depending on crop spacing and speed of animals. Labour requirement: • 10–15 hours/ha	• Cheap and readily available. • Controls early weeds effectively; where seed is covered by plough, planting and weed control can be fast and effective. • Potentially fast if people and animals are well trained. • Large areas can be seeded in short time. • Low labour input as animals do most of the work. • Low maintenance, spare animals easily available. 	• Can lead to severe erosion – especially on hilly land. • Can lead to soil capping in certain soils – especially where soil organic matter levels are low – resulting in higher seeding rates. • Can lead to soil organic matter loss if sufficient organic material is not replaced. • Can lead to non-uniform seeding depth and poor emergence.
Ox-drawn ridge plough/ ridger: • Common in Eastern Zambia. • Ridge plough splits old ridges and forms new ridge in previous year's furrow. • One pass in the field makes one ridge for planting. Labour requirement: • 4–8 hours/ha 	• Cheap and readily available. • Controls early weeds effectively. • Potentially fast if people and animals are well trained. • Large areas can be seeded in short time. • Can be used to bury residue/green manure. • Can help with drainage in high rainfall areas. • Can help to capture rainwater if ridges made on contour.	• Time-consuming as after preparation of ridges, seeding must be done with hoes, sticks or hands. • Can lead to soil organic matter loss if sufficient organic material is not replaced. • Can lead to rapid soil erosion from water where ridges are not formed on contour – especially on fields with steep slopes. • Can lead to early season drought stress when roots are too small to access water. • Can result in soil capping in certain soils – especially where soil organic matter levels are low.

PRACTICE	ADVANTAGES	DISADVANTAGES
Ox-drawn ripper: • CA. • Common in Eastern, Southern and Central provinces. • Pulled through soil to make a furrow for planting. • Often done in wet soil and rarely in dry soil before rain to allow for early planting. Labour requirement: • 4–8 hours/ha	• Widely available. • Rapid establishment of crops. • Effective on larger areas. • Allows for early planting. • Can harvest rainwater in low rainfall years. • Allows farmer to keep crop residues on the soil surface, reducing erosion and evaporation and increasing rainwater infiltration. • Uniform seeding depth that can lead to uniform germination. • Precision application of soil amendments (fertilizer, lime etc.).	• Weed pressure increases, therefore early mechanical weeding or herbicides are required. • Can lead to reduced rainfall infiltration and evaporation where no crop residues or other surface organic matter are present, because the ground will be hard and compacted. • Can lead to erosion and rill/gully formation if rip lines are not on contour. • Requires labour to cover seed by hand or with harrow type implement (tree branch).
ADP-drawn direct seeder: • Uncommon. • Plants seed directly into soil, even in presence of large quantity of crop residues. • Depth, seed rate and fertilizer application adjusted according to crop, spacing and conditions Labour requirement: • 4–8 hours/ha  ©CIMMYT/Thierfelder	• Very rapid establishment of crops. • Effective on larger areas. • Allows for early planting. • Allows farmer to keep crop residues on the soil surface, reducing erosion and evaporation and increasing rainwater infiltration. • Uniform seeding depth that can lead to uniform germination. • Precise application of fertilizer when calibrated properly.	• Weed pressure increases, therefore early mechanical weeding or herbicides are required. • Can lead to reduced rainfall infiltration and evaporation where no crop residues or other surface organic matter are present, because the ground will be hard and compacted. • Difficult to apply manure near crop roots. • Expensive. • Not widely available. • Maintenance can be problematic as expertise is required. • Spares not widely available. • Need for uniform seed size.

6.3 Land preparation/seeding – Motorized tools

Key points:

- Mechanical power (e.g. tractors, combine harvesters, irrigation pumps and threshers) allows agricultural tasks to be carried out easily, rapidly and accurately.
- Mechanization has a high initial investment cost; high interest rates and lack of capital are common in Zambia and this makes borrowing cash for investment even more difficult.
- As labour costs increase and labour availability decreases, mechanization is an increasingly attractive low-cost option for production.
- Mechanization requires skilled labour with a potentially negative effect on rural economies that rely on seasonal agricultural labour to supplement their livelihoods. However, mechanization can open up new and better-paid employment opportunities along the whole of the agricultural machinery supply chain, involving imports, dealership, procurement, spare part supplies, servicing and repair of equipment, training and capacity building; it also provides prospects for youth to become qualified mechanization hire service providers.

Motorized tools

PRACTICE	ADVANTAGES	DISADVANTAGES
Two-wheel tractor double disc: Labour requirement: • 4–8 hours/ha	• Cheaper than 4-wheel tractor. • Controls early weeds effectively. • Potentially fast if operator well trained. • Effective on large areas. • Can be used to bury residue/green manure. • Potentially cheap if hire service is run efficiently.	• Requires additional operation of seeding with hoes, hands or planters after land preparation. • Can lead to soil organic matter loss if sufficient organic material is not replaced. • Can lead to rapid soil erosion from water – especially on fields with steep slopes. • Can result in soil capping in certain soils – especially where soil organic matter levels are low. • High cost of fuel. • Causes air pollution. • Expensive. • Maintenance potentially problematic and requires expertise. • Not widely available. • Potentially difficult to use in fields with trees, stumps and shrubs (clearing fields for tractors can cause increased biodiversity loss).
Two-wheel tractor ripper: Labour requirement: • 4-8 hours/ha  	• Widely available. • Allows for rapid establishment of crops. • Effective on large areas. • Allows for early planting. • Rip lines can harvest rainwater in low rainfall years. • Allows farmer to keep crop residues on the soil surface (reducing erosion and evaporation, increasing rainwater infiltration). • Allows for uniform seeding depth that can lead to uniform germination. • Potentially cheap if hire service is run efficiently (service provision).	• Can result in soil capping in certain soils – especially where soil organic matter levels are low. • High cost of fuel. • Causes air pollution. • More expensive than hoe and oxen. • Maintenance potentially problematic and requires expertise. • Spare parts not widely available. • Can lead to reduced rainfall infiltration and evaporation where no crop residues or other surface organic matter are present (because the ground is hard and compacted). • Can lead to erosion and gully formation if rip lines are not on contour. • Potentially difficult to use in fields with trees, stumps, shrubs (clearing fields for tractors can cause biodiversity loss). • Additional labour required to cover seed by hand or with harrow-type implement.
Two-wheel tractor direct seeder: • single row • double row Labour requirement: • 4-8 hours/ha  	• Allows very rapid establishment of crops. • Effective on large areas. • Allows for early planting. • Allows farmer to keep crop residues on the soil surface (reducing erosion and evaporation, increasing rainwater infiltration). • Allows for uniform seeding depth, leading to uniform germination. • Can plant seed and apply fertilizer at the same time, reducing labour/ time. • Potentially cheap if hire service is run efficiently (service provision).	• Increased weed pressure, resulting in need for early mechanical weeding or herbicides. • Can lead to reduced rainfall infiltration and evaporation where no crop residues or other surface organic matter are present. • High cost of fuel. • Causes air pollution. • Expensive. • Not widely available. • Maintenance potentially problematic and requires expertise. • Spares not widely available. • Difficult to apply manure near crop roots. • Weight of tractor and implement can cause soil compaction and hard pans in some soils. • Potentially difficult to use in fields with trees, stumps, shrubs – clearing fields for tractors can cause biodiversity loss. • Need for uniform seed size.

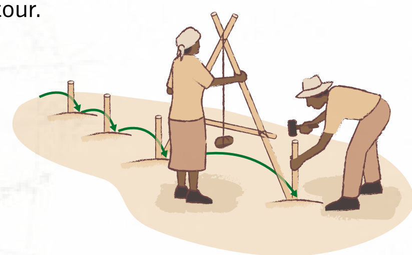
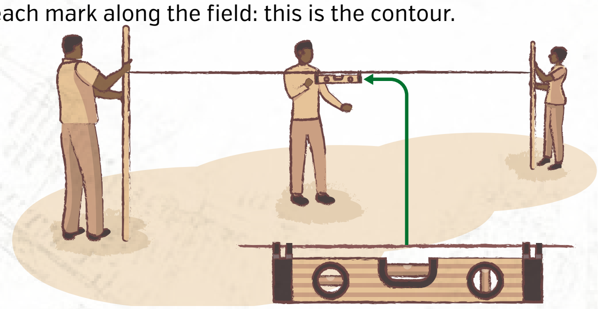
PRACTICE	ADVANTAGES	DISADVANTAGES
Four-wheel tractor-drawn disc: Labour requirement: • 4–8 hours/ha	• Cheaper than direct seeding equipment. • Controls early weeds effectively. • Potentially fast if operator well trained. • Effective on large areas. • Can be used to bury residue/green manure. • Potentially cheap if hire service is run efficiently (service provision). • Can be useful for new land to help level soil and kill grass and other plants.	• Requires additional operation of seeding with hoes, hands or planters after preparation of the ridges, resulting in increased expense. • Can lead to soil organic matter loss if sufficient organic material is not replaced. • Can lead to rapid soil erosion from water – especially on fields with steep slopes. • Can result in soil capping in certain soils – especially where soil organic matter levels are low. • High cost of fuel. • Causes air pollution. • Expensive. • Maintenance potentially problematic and requires expertise. • Spares not widely available. • Weight of tractor and implement can cause soil compaction and hard pans in some soils. • Potentially difficult to use in fields with trees, stumps, shrubs – clearing fields for tractors can cause biodiversity loss.
Four-wheel tractor-drawn ripper: Labour requirement: • 4–8 hours/ha	• Widely available. • Allows rapid establishment of crops. • Effective on large areas. • Allows for early planting. • Can harvest rainwater in low rainfall years. • Allows farmer to keep crop residues on the soil surface (reducing erosion and evaporation, increasing rainwater infiltration) • Allows for uniform seeding depth that can lead to uniform germination. • Easy to apply fertilizer and manure near crop roots.	• Can result in soil capping in rip lines in certain soils – especially where soil organic matter levels are low. • High cost of fuel. • Causes air pollution. • Expensive. • Maintenance potentially problematic and requires expertise. • Spares not widely available. • Weight of tractor and implement can cause soil compaction and hard pans in some soils. • Potentially difficult to use in fields with trees, stumps, shrubs – clearing fields for tractors can cause biodiversity loss. • Additional labour required to cover seed by hand or with harrow-type implement.
Four-wheel tractor-drawn direct seeder: Labour requirement: • 4–8 hours/ha	• Allows very rapid crop establishment. • Effective on very large areas. • Allows for early planting. • Can harvest rainwater in low rainfall years. • Allows farmer to keep crop residues on the soil surface (reduces erosion and evaporation, increasing rainwater infiltration). • Allows for uniform seeding depth that can lead to uniform germination. • Can plant seed and apply fertilizer at the same time, reducing labour/time.	• Increased weed pressure, resulting in need for early mechanical weeding or herbicides. • Can lead to reduced rainfall infiltration and evaporation where no crop residues or other surface organic matter are present. • High cost of fuel. • Causes air pollution. • Expensive. • Not widely available. • Maintenance potentially problematic and requires expertise. • Spares not widely available. • Difficult to apply manure near crop roots. • Weight of tractor and implement can cause soil compaction and hard pans in some soils. • Potentially difficult to use in fields with trees, stumps, shrubs – clearing fields for tractors can cause increased biodiversity loss.

6.4 Soil erosion and contour measurement

Key points:

- Heavy rainfall, long dry seasons and increasingly frequent dry spells result in significant potential for soil erosion due to water movement and wind. Loss of topsoil leads to reduced soil quality, reduced infiltration and use of rainfall, and ultimately, reduced yield potential. The problem is serious even on gentle slopes.
- The solution is to slow the water down, so it can enter the soil to feed the roots and the aquifer, which will feed the groundwater for wells, boreholes, streams and rivers.
- Tillage makes the soil susceptible to movement as a result of rainfall and wind; on the contrary, a covering of living or dead vegetation protects the soil from erosion.
- Whichever system is adopted, crop rows should follow the slope (contour planting) of the land to reduce soil losses from water.
- Where possible, living or dead plant material should be left in the field to reduce soil losses.
- On very steep slopes, permanent strips of grass to catch soil and water can prevent soil losses.
- Contour lines need to be marked on each field, starting from the top of the field: measure the top contour, then move down the slope until the contour is at the eye level of an average adult (approx. 170 cm).
- Where drainage is required, a very gradual slope should carry water slowly and release it into an area that has grass growing on it to reduce soil loss.
- The table describes four different methods for measuring contours. The most appropriate method will depend on the farmers' context.

Contour measurement

PRACTICE	ADVANTAGES	DISADVANTAGES
A-frame: Materials required: • two 1.5-m straight poles • one 75-cm straight pole • 1 m of string or twine • small stone • tyre tube (malegen) • wooden pegs (sufficient number to mark the contour) Method: • Tie three straight sticks firmly together in the shape of an A using malegen or string. • Hang the stone from the tip of the A frame (apex). • Calibrate by placing on level ground, making a mark on the crossbar where the string lies, turning it round and making another mark on the crossbar, and finally marking the midpoint between the two marks. • Begin at one end of the field at the top of the slope. • Place a peg at the foot of the outside leg of the A frame: this is the starting point. • •Adjust the other leg to a position so that the string falls on the centre mark: the ground between these two points is level. • Move the A frame by swinging one leg over the other (checking each time that the ground is level), making a mark every 2 or 3 turns: the pegs mark the contour. 	• Cheap and easy to use.	• Requires care when calibrating. • Slow as distance covered between each move is small. • Low accuracy.
Line level and string: Materials needed: • one line level • two 100-cm poles (cut to exact length) • 5–10 m of string or nylon builders line • wooden pegs (sufficient number to mark the contour) Method: • Stretch the string between the poles. • Place the line level on top of the string. • Move the poles until the level bubble is on centre: the ground between the two points is level. • Peg each mark along the field: this is the contour. 	• Cheap and easy to use.	• Medium accuracy. • Line level not available in some areas.

<table>
<tr><th>PRACTICE</th><th>ADVANTAGES</th><th>DISADVANTAGES</th></tr>
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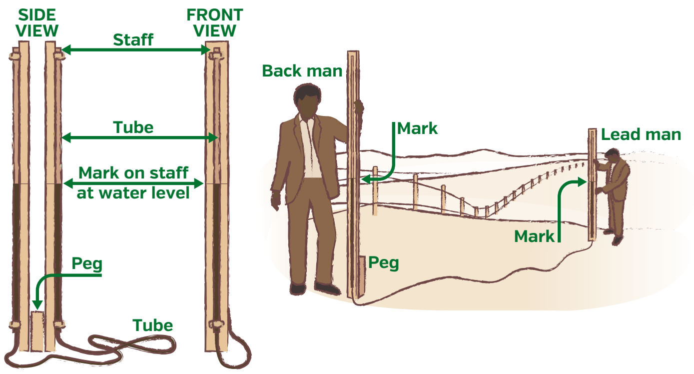
Flexible hose pipe level:

Materials needed:

- two 100-cm poles (cut to exact length)
- 5–10 m of flexible hosepipe without leaks
- rubber tyre tube (malegen)/string
- 10 litres of water
- wooden pegs (sufficient number to mark the contour)

Method:

- Tie the ends of the hosepipe to the top of the poles using malegen or string.
- Fill the hosepipe with water on a slope to ensure there are no air bubbles.
- The person at each pole should have a small bottle of water to top up the water that spills.
- Move the pole positioned lower down the slow upwards until the water does not spill at either pole: the land is level.
- Peg each mark along the field: this is the contour.



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- Very accurate and fast.

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- More expensive than other options.
- Needs water.
- Does not work if hosepipe has holes.
- Flexible hosepipe expensive.

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Dumpy level:

Materials needed:

- dumpy level
- ruler stake

Method:

- Set up the dumpy level at one end of the field.
- Place the ruler stake in front of the dumpy level eye piece and record the exact height.
- One person stays at the dumpy level; the other with the ruler stake moves across the field in the direction of the contour.
- If the height where the ruler stake is placed is the same as the calibration height, the two points are on the same level.
- Peg each mark along the field: this is the contour.

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- Very accurate and fast, even over long distances.

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- Expensive.
- Not readily available.
- Requires knowledge to use.

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6.5 Weed management

Key points:

- Weeds can reduce crop yields to zero, and weed management is therefore essential to efficient agricultural production.
- Weed management is the most labour-intensive field operation.
- **Mechanical** control using tillage to either bury weeds or uproot and expose them to the drying effects of the sun is the most widely used method.
- **Biological** control is also common and involves shading by cash crops or cover crops (e.g. pumpkin or climbing beans), often achieved by intercropping more than one crop in a field. Close row spacing and high plant populations allow crops to shade weeds earlier, thus reducing weed pressure. Surface residue/mulch from cover crops, rotational crops or plants growing outside the field can reduce weed growth if available in sufficient quantity.
- **Chemical** control using herbicides is increasingly widespread and includes various options, from non-selective herbicides that kill all plants, to selective herbicides that kill specific weed species (grasses or broadleaves) only.
- **Integrated weed management** is the combination of all of the above methods of weed control.

Manual weeding

PRACTICE	ADVANTAGES	DISADVANTAGES
Hand pulling	• Can be practised by anyone as no tools needed. • Effective even in very wet weather. • Very effective for weeds growing near established crops or in rows as does not disturb crops. • Effective for certain weeds in early crop establishment.	• Applicable on limited area only because very labour-intensive with high level of drudgery. • Ineffective for young/small weeds, very large weeds/shrubs and weeds with big root systems. • Difficult under dry conditions. • Not very effective in wet conditions as some weeds may not die.
Hand hoe	• Cheap, readily available. • Very effective as allows farmer to weed very close to plants. • Very effective if dry weather follows weeding. • Potentially cheap and applicable on large areas if labour is cheap and abundant. • Light tillage, minimizing negative effects on soil.	• Potentially ineffective in wet soils or if rain follows weeding. • Potentially expensive if cost of labour is high. • Limited use if shortage of labour. • Requires some skill. • May need to be repeated several times.
Grass slasher: • Cutting weeds between crop rows. • Using grass slasher, sickle or motorized grasscutter.	• Potentially fast and effective on upright annual weeds (if < 5 cm in height). • Cheap and easily available. • Effective even in wet weather. 	• Correct tools and knowledge required as grass slasher must be sharp. • Skill needed to avoid cutting crop plants. • Expensive if motorized grasscutter used. • Not effective on low-growing weeds.

PRACTICE	ADVANTAGES	DISADVANTAGES
Intercropping: • Planting cover crops (e.g. pumpkin, bean, sweet potato, cowpea).  © CIMMYT/Thierfelder	• Can provide good late weed control where correct spacing and varieties are used. • Allows farmers to use more sunlight to produce more food/fodder on the same piece of land. • If green manures are used, farmers can improve soils and reduce input costs at the same time as growing traditional cash crops.	• Potential competition between cover crop and main crop if not done properly – especially in dry conditions. • Requires knowledge. • Poses challenges if herbicides are to be used for weed management. • Complicates cultural activities (weed control, planting, spraying insecticide etc.)

Close row spacing:
• Planting high plant populations.
	• Reduced weed growth as cash crops create canopy/shade fast and over long periods.
	• Can reduce costs and labour input for weed control.
		• High plant population that can:
		  • lead to poor yields on low-fertility soils for crops requiring high fertility (e.g. maize);
		  • result in disease problems due to reduced air circulation.
		• Close row spacing that can:
		  • hinder mechanical cultivation as tools are often made for wider rows;
		  • result in more furrows needed at planting, increasing time needed to plant and labour requirement.

Mulch: • Leaving grass/hay/crop residues.  © CIMMYT/Thierfelder	• Can lead to effective weed control for long periods. • Reduces erosion and rainwater runoff. • Increases rainfall infiltration. • Decomposes to form soil organic matter. • Provides habitat for beneficial insects and other organisms. • Can reduce plant diseases by reducing soil splash onto plant leaves and stems. • Moderates soil temperature, leading to improved nutrient cycling.	• Potentially labour-intensive (if mulch is imported to the field from elsewhere), thus limiting the size of the area cultivated and/or increasing the cost of production. • Crop residues may harbour crop pests (e.g. slugs, snails, crickets). • Can lead to increased pest and/or disease damage on crops – especially where crop rotation is not practised.
Hand-held knapsack sprayer: • Spraying herbicides.  © CIMMYT/Thierfelder	• Potentially very fast, covering large areas. • Certain herbicides can kill weeds for long periods in the soil. • Can manage even very stubborn weeds (e.g. kapinga [*Cynodon dactylon*]. • Potentially cheaper than alternatives if applied properly.	• Requires cash outlay and potentially expensive. • Can harm crops if not applied properly. • Requires skill to mix and apply correctly. • Some herbicides can be harmful to human health. • Some herbicides can be harmful to animals, livestock, fish and soil life (insects, bacteria, fungi etc.). • Not suitable for intercropping. • Strenuous work if done on large areas. • Potentially ineffective if weather conditions are not favourable (dry soil, heavy rain following application etc.).

ADP and/or motorized weeding

PRACTICE	ADVANTAGES	DISADVANTAGES
ADP or mechanically drawn mouldboard plough: • Inverts soil to cover weeds. • Passes twice between rows to make ridge on crop row. • Working depth depends on crop and weed size.	• Readily available. • Can be fast and done during seeding (for maize). • Can be done after crop establishment. • Turns weeds over, allowing weeding in moist soils and improving control when rainfall follows weeding. • Can give physical support to the crop stem.	• Can lead to severe erosion – especially on hilly land. • Can lead to soil capping in certain soils – especially where soil organic matter levels are low. • Can lead to soil organic matter loss if sufficient organic material is not replaced. • Can lead to non-uniform seeding depth and poor germination – especially for small-seeded crops or those that have weak germination (e.g. soybean, groundnut, cowpea, beans). • Requires extra labour for hand pulling of weeds and hand hoe in rows.
ADP or mechanically powered ridge plough: • Pushes soil against the row crops. • Passes once between rows to make ridge on crop row. Working depth depends on crop and weed size.	• Readily available. • Fast and saves time as the ridger throws soil both sides, reducing need for multiple passes. • Inverts soil and gives good weed control. • Can give physical support to the crop stem.	• Can lead to soil organic matter loss if sufficient organic material is not replaced. • Can lead to rapid soil erosion from water where ridges are not formed on contour – especially on fields with steep slopes. • Can lead to soil capping in certain soils – especially where soil organic matter levels are low.
ADP or mechanically drawn spike tooth harrow: • Drags metal spikes through the soil to break clods, beak capped layers and kill small weeds. • Mainly used before crop emergence.	• Readily available. • Fast and can cover large areas. • Helps break surface capping. 	• Needs to be done at the right time before crops start to germinate. • Breaking up of soil into smaller particles can increase soil erosion.
ADP or mechanically powered cultivator: • Adjustable cultivator tines with 3–5 tine models available. • Can work in crops spaced 50–100 cm apart. • Number of passes depends on weather conditions and size of weeds.	• Readily available. • Works well with small weeds on flat land. • Most effective in dry weather. • Light working depth, so less erosion potential than plough or ridge plough.	• Potentially ineffective in wet soils or if rain follows weeding. • Cannot be used where lots of crop residues are in the field as the residue catches the tines and can cause crop damage- • Requires some skill. 
ADP or tractor drawn boom sprayer: • Used for applying herbicide.	• Fastest, enabling large areas to be covered. • Potentially very effective if calibrated properly and mixing done well.	• Not widely available. • Requires cash outlay and can be expensive. • Can harm crops if not applied properly. • Requires skill to mix and apply correctly. • Some herbicides can be harmful to human health. • Some herbicides can be harmful to animals, livestock, fish and soil life (insects, bacteria, fungi etc.). • Not suitable for intercropping. • Strenuous work if done on large areas. • Potentially ineffective if weather conditions are not favourable (e.g. dry soil, heavy rain following application).


ZARI

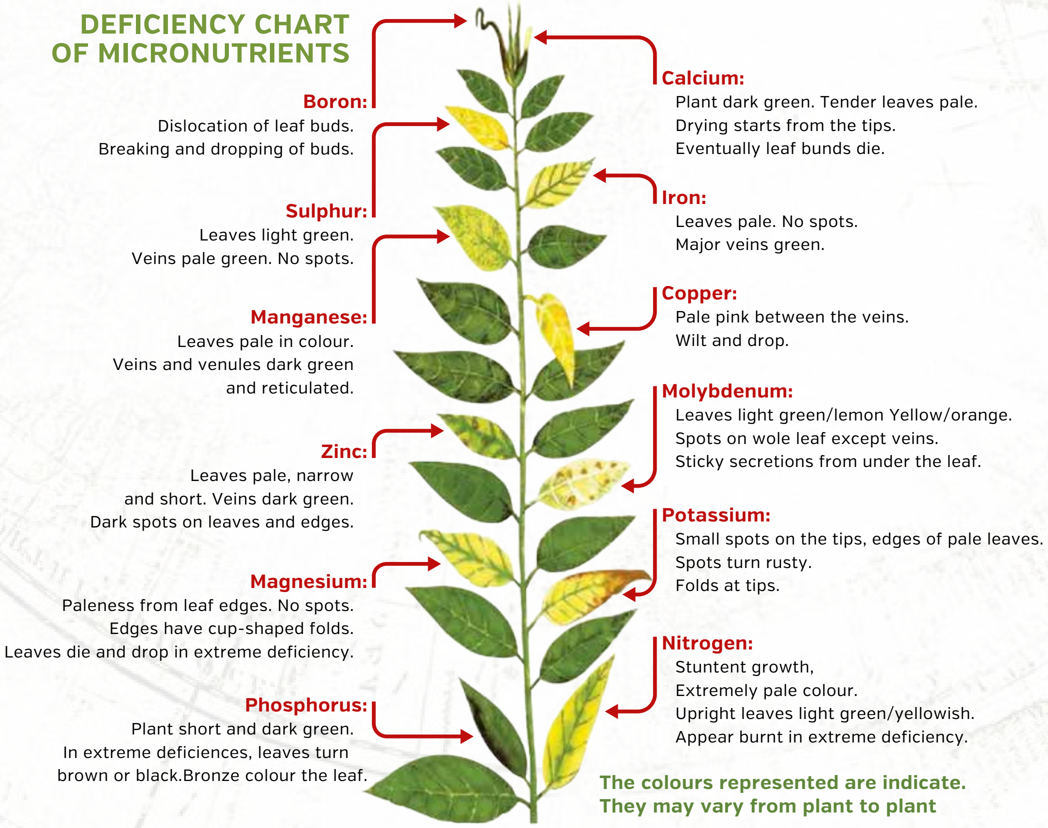
MODULE 7

FARMING PRACTICES – SOIL FERTILITY MANAGEMENT

Soils are complex. Zambia has a range of soil types ranging from fertile to infertile, well drained to poorly drained, sandy to clay, acid to alkaline, high in soil organic matter to low in soil organic matter.

Ideally, soil tests should be performed and interpreted by a qualified soil scientist. This will help farmers understand exactly what and how much to add. With good interpretation, experts can give precise recommendations for specific crops. However, soil testing can be expensive and is often inaccessible to rural farmers.

Different soil types and conditions require different management practices to achieve high crop yields. Moreover, to perform well, plants need to have access to the necessary nutrients. This module covers the advantages and disadvantages of the different practices used by farmers around the country.



Soil fertility management

PRACTICE	ADVANTAGES	DISADVANTAGES
Natural fallow: • Allows natural plants to grow for long periods to improve soil.	• Cheap and low risk. • Low labour requirement – only requires land clearing. • Nutrients brought up to topsoil from deep in the soil by trees, shrubs and grasses. • Nitrogen fixed in soil by legumes. • Soil fertility restored by organic matter from leaves, roots and manure.	• Takes a long time to build soil fertility (10–30 years depending on soil type, amount of rainfall, vegetation type and other factors). • Given time required, farmer must use large areas of land. • Process can be slowed down by frequent burning – difficult to control unless strict community by-laws are followed. • Potentially difficult to achieve under communal management of land. • Increasing human population means this practice is becoming less effective due to limited land available for fallow.
Using soil's natural fertility: • Relies on inherent soil fertility (all soils have nutrients in them). • Relevant to continuous use of the same field over time.	• Free. • Can give good yields on fertile soils. • Can be improved through good soil management to ensure that efficient biological action releases locked up nutrients effectively.	• Continuous use of inherent soil nutrients leads to nutrient depletion. • Difficult to know nutrient content and availability given effects of factors such as acidity, soil organic matter level and soil biology.
Shifting kraal: Traditional system in Western Province. Mobile kraal for cattle, sheep and goats is placed in the field – manure and urine is left in situ. As a guide: • One adult cow produces 10 kg fresh manure or 3 kg dry manure per night in the kraal. • In poor soils, aim to apply 50 tonnes/ha or 5 kg/m2 of dry manure. • Therefore, aim for 1 adult animal per m2 for 2 nights. • If the kraal is 100 m2 (10 × 10 m) and there are 25 animals, they have to stay there for ≥ 7 days. • On better soils, less manure is needed. It is recommended to try different rates for the soils available.	• Reduced labour requirement for transport and application – manure applied directly in field where it will be used. • Animals break up and mix manure with soil. • Effective on very sandy or degraded soils – often the only economic way to bring them into production.	• Labour and resources (trees) required to make and transport kraal. • Large number of animals required. • Manure is exposed to sun and rain (nutrients can be lost). • Weed seeds increase in the field. • Standard recommendation unclear – can lead to inefficient use of manure. • Can increase termite damage to crops.

PRACTICE	ADVANTAGES	DISADVANTAGES
Floodplain culture: • Alluvial deposits on small pockets of land near rivers.	• Supplies nutrients quickly. • Easy to measure according to crop and stage of growth. • Easy to apply. • Easy to transport. • Easy to store. • Nutrient content well known. • Subsidies available. • Specific nutrients can be applied as needed (important where major deficiencies occur, e.g. boron).	• High cost and associated risk. • Leads to dependence on external and unmanageable factors (e.g. world markets and energy prices). • Can deplete soil organic matter. • Can cause acidic soil conditions. • Easily leached under high rainfall conditions, with many nutrients potentially lost through volatilization. • Effects are short-term. • Only supplies few major nutrients – can lead to food that is not nutrient dense. • Can lead to runoff into water courses. • Can cause growth imbalance, which can lead to pest and disease issues. • Subsidies are limited to few people and limited to 1 ha per person. • Can burn crop seeds and roots if not practised properly.
Fertilizer (organic): • Manure. • Compost. • Green manure. • Slurry from pigsty.	• Supplies many nutrients. • Cheap. • Easily available in and around farms. • If grazing lands are functioning properly, animals bring nutrients from grazing lands to the farm (nutrient and organic matter harvesting). • Adds organic matter to the soil and increases soil biology/life. • Steady supply of nutrients over long periods. • Improves soil structure, water infiltration and water-holding capacity. • Can help to buffer soil pH. • Can lead to savings on fertilizer costs. • Increases biological activity.	• High labour requirement to transport and apply in the field. • Requires skills, knowledge and planning. • If not well managed, many nutrients can be lost, resulting in very high application rates. • Requires livestock. • Can take time for nutrients to become available to correct deficiencies. • Difficult to know nutrient content. • Limited information available on application rates for different composts, manures, crops and soil types.
Lime: • Mined limestone crushed into powder and applied to soil.	• Cheap. • Provides calcium and magnesium. • Can unlock natural fertility. • Can correct soil acidity. • Can improve soil structure – improved biological activity. • Liquid lime can correct pH more quickly than crushed lime, but does not have long-term effects.	• Bulky/heavy. • High rates of application resulting in high costs for transport and handling. • Soil testing necessary to know soil status – otherwise, may lead to soil compaction due to excessive build-up of soil magnesium. • Additional cost because must be applied and mixed with soil at least 4 weeks before planting to be effective.
Chitemene: • Specific system developed in Northern Zambia. • Heaping trees 1 m deep and burning them.	• Cheap. • Very effective in acid soils for some crops (millet, cassava). • Burns weed seeds and living weeds. • Kills pests and diseases.	• Requires long fallow periods – shorter if done well. • Destroys soil organic matter. • Leads to release of carbon dioxide. • Kills organisms like birds, snakes, insects. • Labour-intensive (cutting and heaping trees). • Causes soil erosion. • Promotes deforestation. • Depletes soil nutrients.

PRACTICE	ADVANTAGES	DISADVANTAGES
Slash and burn: • Cut and burn vegetation without heaping.	• Acidity neutralized by ash. • Cheap and easy way to open up new land for crop production. • Can reduce weed seeds in the topsoil – but depends on the amount of material burned.	• Depletes soil nutrients. • Promotes deforestation. • Causes soil erosion. • Disturbs ecosystems. • Depletes organic matter. • Leads to release of carbon dioxide.
Ash: • Ash from the kitchen fire used as a nutrient and liming material.	• Free – if household wood ash is used. • Effective in pH regulation. • Provides nutrients such as calcium, potassium and other trace elements.	• Risk of deforestation if trees are not managed sustainably. • Application limited to calm days without wind (or most of the ash will be blown away). • Needs to be kept dry (or nutrients will be washed out of the ash).
Biochar: • Charcoal made specifically for application to soils. • Charcoal made into powder and then applied.	• Cheap (can be made from local materials). • Can increase soil nutrient content, water-holding capacity and yield.	• Significant effects only on very light soil. • High labour requirement – to produce sufficient to be effective. • Can lead to competition for use of residues/ wood (soil amendment vs livestock feed vs fuelwood).
Anthill soil application: • Traditional system. • Termite hill soil applied to light soils to improve the water and nutrient holding capacity. • Best applied at planting station or in furrows/rip lines.	• Cheap. • Can improve cation exchange capacity and water-holding capacity in sandy soils.	• Labour-intensive. • Not effective for heavier soils (unless very infertile).
Crop rotation	• If legumes are used as rotational crops, nitrogen may remain in the soil for crops to use (usually only true if all legume residues are left in the field and only for legumes that are known to produce more nitrogen than is taken out in harvest, e.g. groundnut, cowpea and pigeon pea). • Reduces diseases and pests.	• Limited potential – depending on market. • Introducing legumes into a crop rotation does not always lead to increased soil fertility (often more nutrients are lost than fixed). • Can result in less soil organic matter returned to the soil (legumes produce less biomass than cereals).

7.1 Chemical fertilizers and their use

Key points:

- Chemical fertilizer composition is usually clearly marked on the packaging. The number on the bag indicates the percentage of the nutrient content per weight.
- Phosphorous (P) in fertilizer is not elemental, but is in the form of phosphoric acid P_2O_5); potassium (K) is in the form of potassium oxide (KO_2).
- Most other nutrients are expressed in their elemental form, therefore – as with nitrogen and sulphur – there is no need to use a formula to do a conversion. If the nutrients are in a different form, seek advice from local experts or search on the internet.
- These calculations are important when using fertilizer, as each crop requires different amounts of fertilizer depending on the soil and the yield/harvest targets (see Module 9 for details of crop requirements for specific crops).
- The application of fertilizer nutrients in the field is not an exact science: there are many factors to take into consideration, such as existing nutrients in the soil, leaching, runoff, chemical binding of nutrients, volatilization, soil health, soil biology and soil moisture. This section highlights certain chemical fertilizers and their advantages and disadvantages.

Calculating the actual amount of each element in different fertilizers

NUTRIENT	PERCENTAGE IN MIX (IN THIS CASE, D COMPOUND)		NUMBER ELEMENT		MULTIPLY BY THE WEIGHT OF THE BAG (KG)		AMOUNT OF ELEMENT PER 50-KG BAG (KG)
N (nitrogen)	10	*	0.1	*	50	=	5
P_2O_5 (phosphoric acid)	20	*	0.0437	*	50	=	4.37
KO_2 (potassium oxide)	10	*	0.083	*	50	=	4.15
S (sulphur)	7	*	0.1	*	50	=	3.5

Chemical fertilizers

FERTILIZER	ADVANTAGES	DISADVANTAGES
Various compounds (NPK basal dressing): ▪ Some examples: • D – 10:20:10:6 – N:P:K:S • W – 17:17:14:5 – N:P:K:S • WVC – 8:24:20:5 – N:P:K:S • Soya Mix B – 5:20:20 N:P:K + Ca ▪ Some types also contain sulphur S. ▪ More expensive types include trace elements (e.g. boron B, manganese Mn and copper Cu). ▪ Some also contain a small proportion of organic matter (e.g. chicken manure).	• Supply major nutrients (NPK). • Composition well known. • Easy to apply. • Easily available. • Subsidies available for D compound for small-scale farmers (Farmer Input Subsidy Programmes – FISP).	• High cost. • Wash away or easily leached in heavy rain (because nutrients are soluble). • Short-term effect on soils. • Can cause pollution in underground and surface water. • Contain few plant nutrients potentially leading to pest and disease problems.

FERTILIZER	ADVANTAGES	DISADVANTAGES
Single super phosphate (SSP): ▪ 16–18% P_2O_5 + calcium and trace elements **Triple super phosphate (TSP):** ▪ 44–46% P_2O_5 + calcium and trace elements	• Used in legume production. • Can produce high yields with low rate of use. • Small amounts needed.	• High cost. • Not widely available outside Lusaka. • Nutrients are soluble – can be easily washed away in heavy rain. • Short-term effect on soils. • Can cause pollution in ground and surface water. • Can contain heavy metals (e.g. Cadmium) • Harmful to human health.
Mono ammonium phosphate (MAP): ▪ 12:61:0 – N:P:K **Di-ammonium phosphate (DAP):** ▪ 18:46:0 – N:P:K	• Supply phosphate and nitrogen to plant roots.	• High cost. • Soluble, therefore nutrients can be washed out quickly with heavy rain and nitrogen can be lost as fertilizers dry. • Can be locked up easily as very soluble. • Can cause soil acidity.
Urea (N): ▪ 46% N	• Most widely available nitrogen fertilizer in the country. • Cheapest form of synthetic nitrogen fertilizer. • High nitrogen content. • Works quickly. • Subsidies available for small-scale farmers (FISP). • Easy to apply.	• High cost. • Soluble, therefore nutrients can be washed away easily in heavy rain (loss can be reduced if coated fertilizer is used, but can be costly). • Volatilization/nutrient loss to the air can occur – especially during dry weather. • Short-term effect on soils. • Can cause pollution in ground and surface water. • Can cause soil acidity. • Can lead to loss of soil organic matter.
Ammonium nitrate (AN): ▪ 34:0:0 – N:P:K **Calcium ammonium nitrate (CAN):** ▪ 27:0:0 N:P:K + soluble Ca **Ammonium sulphate (AS):** ▪ 21:0:0:24 – N:P:K:S	• Good nitrogen N source for plants (and calcium source in the case of CAN). • Gives more balanced supply of nitrogen to crops than urea. • Nitrate is very fast acting. • Ammonium sulphate provides soluble sulphur.	• Higher cost than urea and is therefore limited to high-value crops. • Soluble, therefore nutrients can be washed away easily in heavy rain. • Short-term effect on soils. • Can cause pollution in ground and surface water. • Can cause soil acidity.
Potassium chloride/muriate of potash (MOP): ▪ 0:0:62 – N:P:K	• Cheapest form of potassium. • Very fast acting.	• High cost (general). • Strong negative effect on soil life as contains 46% chlorine. • Easily leached.
Potassium sulphate (SOP): ▪ 0:0:50:17 – N:P:K:S	• Supplies soluble potassium and sulphur to plants resulting in increased fruit/ grain yield and quality. • Less harmful to soil life than potassium chloride.	• High cost. • Soluble and easily leached under high rainfall conditions.
Liquid fertilizers in form of foliar spray: ▪ Nutrients in liquid form sprayed onto crop. ▪ Nutrients are taken up by the plant through the leaves directly. ▪ Based on organic or chemical nutrients, or both.	• Can help address major and minor nutrient deficiencies very quickly as nutrients are absorbed through leaves. • Many formulations with some specific to crop and stage of growth.	• High cost. • Soluble and easily leached under high rainfall conditions. • Requires knowledge about mixing and application time. • Crops can be adversely affected if not done properly. • Can be expensive if not made on the farm. • Labour-intensive and requires functioning sprayer and clean water.

Rock-based soil conditioners

SOIL CONDITIONER	ADVANTAGES	DISADVANTAGES
Calcitic agricultural lime: • 30–40% calcium Ca, 1-3% magnesium Mg. • White powder.	• Supplies calcium Ca, to plants and soil organisms. • Corrects soil acidity over time.	• High transport cost – especially in areas where limestone deposits are not close to where they need to be applied (i.e. large parts of Northern Zambia). • Not readily available all over the country. • Bulky, difficult to apply in the field – especially on windy days. • Takes time to work into the soil. • Soil tests necessary to see how much to apply.
Dolomitic agricultural lime: • 20–30% calcium Ca, 10% magnesium Mg. • Grey powder.	• Supplies calcium Ca and magnesium Mg to plants and organisms. • Corrects soil acidity.	• High transport cost. • Not readily available all over the country. • Bulky, difficult to apply in the field – especially on windy days. • Takes time to work into the soil. • Soil tests necessary to see how much to apply. • Can lead to excessive magnesium Mg in soils, resulting in compacted soils and poor plant growth and yields (should only be used in low magnesium soils).
Liquid lime	• Works faster than powdered lime. • Can be applied after crops have been established.	• High cost. • Needs sprayer. • Only has short-term effect on soil therefore requires frequent application.
Gypsum (calcium sulphate): • Approx. 23% calcium Ca, 18% sulphur S, plus trace elements. • Either mined as natural rock or a by-product of phosphate fertilizer manufacture.	• Supplies soluble calcium Ca and sulphur S to the soil. • Works well in groundnut at flowering and can reduce pops (caused by Ca deficiency).	• High cost. • Not readily available all over the country. • Does not correct soil acidity and can make soil more acidic. • Can reduce potassium K in soil.

Fertilizer use/application methods

PRACTICE	ADVANTAGES	DISADVANTAGES
Broadcasting: • Common in commercial agriculture.	• Very fast method of application in the field. • Even distribution of nutrients over the field (if done well) – suited to small grains like finger millet.	• Can help weed growth because nutrients are placed far away from plant roots. • Fertilizer can be easily washed away – especially if not covered.
Row/furrow application: • Common for animal draft power.	• Very fast method of application in the field • Evensuited to crops that are planted in rows finger millet.	• Experience required to apply correct rate of fertilizers. • If placed too close to the roots, can burn plants or seedlings – especially during dry spells.
Spot application of basal or top-dressing: • Apply 10–15 cm away from plant stem. • Common in hand hoe farming and for top-dressing in small- and medium-scale farming.	• Increased efficiency because nutrients applied near the roots of the crop. • Allows farmers to use less fertilizer as fewer nutrients are lost. • Fast method. • Fewer nutrients go to weeds than with broadcasting.	• If placed too close to the roots, can burn plants or seedlings – especially during dry spells.

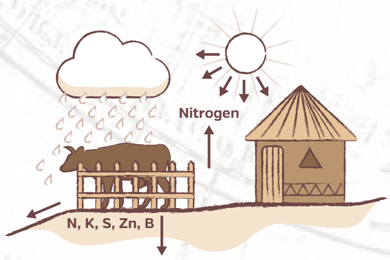
PRACTICE	ADVANTAGES	DISADVANTAGES
Spot application of basal fertilizer before or at planting: • Apply 10 cm away from seed or mix with soil.	• Easy for plants to use nutrients because applied by hand close to the plant roots. • Allows for use of reduced quantity of fertilizer compared to broadcasting or application in row/furrow.	• If placed too close to the roots, can burn plants or seedlings – especially during dry spells. • High labour requirement.
Application of compound fertilizer (basal) after crop germination: • Apply 10–15 cm away from plant.	• Nutrients available to plants as soon as the roots emerge, resulting in high yield as early crop growth determines final crop yield. • Can lead to strong early growth, which helps plants out-compete weeds.	• If crop does not germinate well, nutrients can be washed out of the soil or mixed with the soil during planting of the subsequent crop, leading to loss of expensive fertilizer nutrients.
Application of D compound and urea mixed together after crop germination: • Usually done for maize.	• Farmer has guarantee of fertilizer being used by the crop. • Can help in years when fertilizer is not available during planting.	• Can result in insufficient nutrients during early growth, leading to significant yield losses, as well as poor plant vigour, resulting in less competition by the crop and increased weed growth.
Single application of urea: • 4 weeks after planting.	• Reduces labour requirement for fertilizer application. • Can work well in heavy soils that hold nutrients (clay, not sand) and where soil is sufficiently fertile to allow crops to establish.	• Yield potential (of maize) is determined in the first 3 weeks – if nutrients are low at this time, maize yields can be reduced significantly.
Split application of urea: • 3 weeks and 6 weeks after planting.	• Fast to apply. • Can work well in heavier soils or soils with good organic matter as these soils can hold nutrients for longer than sandy soils.	• Risk of fertilizer loss if heavy rain or dry weather follow application – especially if not covered with soil. • If fertilizer applied all at once, many nutrients may be lost in light soils and acid soils, which cannot hold nutrients well. • Can harm soil organisms if > 100 kg/ha is used at one time. • Can burn stems or roots if dry spell follows application or if applied too close to the plant.
Band or side-dressing: • 4 weeks after planting.	• Increased efficiency and plant use compared to broadcasting – especially when crops are young with limited root size. • Low labour requirement compared to spot application.	• Less efficient than spot application in term of nutrient use by the plant.
Surface application of fertilizer (no covering)	• Can help prevent fertilizer nutrients being lost due to dry spells or heavy rain, resulting in increased yields. • Reduced risk for farmers.	• High labour requirement – especially if applied as spot application and covered with soil.
Covering/mixing fertilizer with soil	• Fast. • Can work well in the right weather conditions. • Helps reduce nutrient losses by reducing the chance of runoff, leaching and drying.	• Heavy rain can wash nutrients away. • If a dry spell follows fertilizer application, many of the plant nutrients will be lost. • High labour requirement if not combined with other cultural practices (e.g. light tillage for weed control).

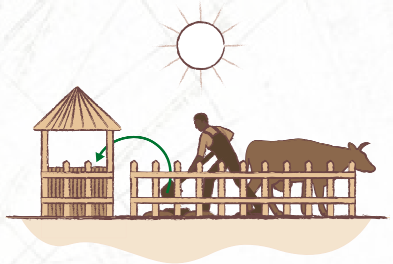
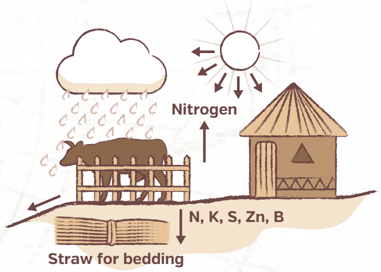
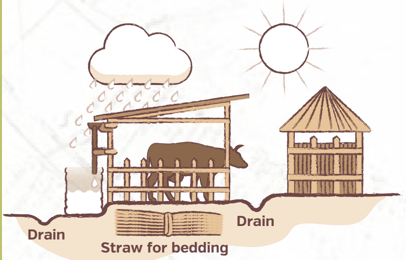
7.2 Management of organic fertilizers and soil conditioners

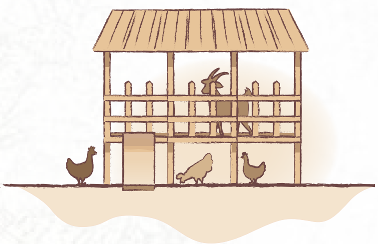
Key points:

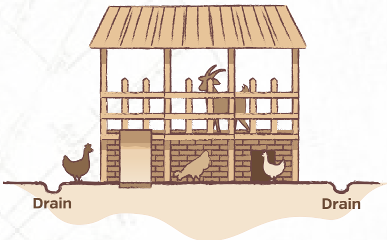
- Manure and compost are valuable resources for farmers. Unlike chemical fertilizers, they contain a large number of the plant nutrients needed for growth. They also contain organic matter, which has a positive impact on soil health, as well as important organisms that contribute to nutrient cycling, plant health and pest and disease control.
- Grazing animals go out in search of food every day and bring nutrients back to the kraal or house in the form of manure and urine. It is a way to bring "free" nutrients (fertilizer) to the farm.
- Manure and compost are also valuable soil improvers, adding nutrients and organic matter to the soil. If regularly applied, the soil becomes loose, allowing rainfall to enter more easily and once it is in the soil, the organic matter acts like a sponge, retaining the water for longer. Farmers are thus better able to survive droughts and dry spells.
- Manure or compost left exposed loses much of its nutrient content, as nutrients are dried out by the sun or washed away by the rain. The farmer then has to use large quantities of manure to improve the soil and feed the crop. Farmers should take steps to protect manure and urine from the sun and rain in order that they may use much less manure over a given area.
- The nutrient content of manure and compost varies and is affected by the quality of the animals' feed, among other factors. The range of figures provided herein serve as a guide only. With experience, the farmer will learn how much needs to be applied for each crop. As with other technologies, experimentation should be encouraged.

Manure and urine

PRACTICE	ADVANTAGES	DISADVANTAGES
CATTLE *Note:* Protection and storage of the manure/compost determine how nutrient-rich the end product is.		
Open kraal – manure left in kraal for 1 year: • Nutrient content 0.05–0.2:0.2:0.3 N:P:K plus minor nutrients.  	• Cheap and easy to construct using local materials. • Manure crushed into powder, making it easy to shovel and spread in the field. • No labour requirement for hauling water and turning the heap.	• Nutrient loss (especially N) because manure left open to the sun (effect of drying) and rain (effect of leaching and runoff). • Large quantities of additional nutrient required for crops, resulting in high labour costs. • Dry, powdered manure contains many weed seeds leading to increased labour requirement for weeding in the field. • Dry manure can burn plant roots or germinating seedlings if placed too close to the plant/seed. • Un-composted (raw powdered) manure can carry plant diseases and pests.

PRACTICE	ADVANTAGES	DISADVANTAGES
Open kraal on soil – collecting raw manure daily and heaping under shelter: • Nutrient content 1–1.7:0.8:1 N:P:K plus minor nutrients. 	• No nutrient loss as a result of rain (washed out) or sun (dried out). • Heat from manure heap kills weed seeds and diseases. • Light and easy to apply in the field. • High nutrient content, therefore fewer additional nutrients need applying in the field, resulting in lower labour requirement. • Improves conditions in kraal, reducing diseases for cattle	• Labour required to collect manure every day before it dries out. • Collection of manure is very difficult during rainy season when animals mix manure with soil. • Collection must take place early, before chickens and pigs scratch the manure around the kraal, hindering collection. • Nutrients in the urine are lost as it soaks into the soil in the kraal. • Labour and investment required given need to cover with a roof of grass, plastic or tin. • Requires skill to ensure the manure is composted properly. • Requires small quantities of water to keep manure wet so it decomposes properly.
Open kraal on soil – adding organic material (e.g. maize stalks, dry grass, soybean waste, dry leaves [deep litter bedding] – then composted): • Uncommon in Zambia. • Nutrient content 1–1.7:0.8:1 N:P:K plus minor nutrients. 	• Cheaper than covered kraal. • In the dry season, manure and urine do not lose nutrients (washed out by rain or dried out by sun). • Heat produced in compost heap is sufficient to kill weeds and potential pests and diseases. • Light and easy to apply in the field. • High nutrient content, therefore fewer additional nutrients need applying in the field, resulting in lower labour requirement. • Use of bedding produces additional compost. • Dry bedding soaks up the urine, catching nutrients that would otherwise soak into the soil and be lost.	• Major nutrient losses due to rain occur during the rainy season. • Labour required to bring dry organic material to the kraal. • Labour required to build compost heap. • Requires skill to ensure the manure is composted properly. • Requires small quantities of water for composting.
Keeping animals under a roofed kraal and adding organic material (e.g. maize stalks, dry grass, soybean waste, dry leaves [deep litter bedding] – then composted): • Uncommon in Zambia. • Nutrient content 0.8–2:0.4–0.8:1 N:P:K plus minor nutrients. 	• Manure and urine do not lose nutrients to rain (washed out) or sun (dried out). • Heat produced in compost heap is sufficient to kill weeds and potential pests and diseases. • Light and easy to apply in the field. • High nutrient content, therefore fewer additional nutrients need applying in the field, resulting in lower labour requirement. • Animals have dry bedding in a shelter during the rainy season – beneficial to their health. • Use of bedding produces additional compost. • Dry bedding soaks up the urine, catching nutrients that would otherwise soak into the soil and be lost.	• Cost of materials (e.g. grass, poles, nails) to put roof on shed. • Labour required to bring dry organic material to the kraal. • Labour required to build compost heap. • Requires skill to make sure the manure is composted properly. • Requires small quantities of water for composting.

PRACTICE	ADVANTAGES	DISADVANTAGES
Shifting kraal: • Traditional system in Western Province. • Mobile kraal for cattle, sheep and goats is placed on the field. • Manure and urine left in situ. • Field then used to plant crops.	• Low labour requirement for transport and application, because manure and urine applied directly in the field where needed. • Animals break up manure and mix it with soil. • Very effective on very low fertility soils due to the addition of large amounts of organic matter and nutrients.	• Labour and resources (trees) required to make and move kraal. • Large number of animals required. • Many nutrients lost when manure is left in the sun and rain. • Manure contains weed seeds. • No clear standard recommendations available (e.g. number of animals, size of kraal), leading to inefficient use of manure/ urine.
GOAT, SHEEP, PIGS, POULTRY *Note:* In general, poultry and pig manure are higher in P and N than ruminant manures. Goat and sheep manure can also be higher in these two nutrients because they derive a greater proportion of their food from trees and shrubs than from nutrient-poor grass. As with cattle manure, the protection and storage of the manure/compost will determine how nutrient-rich the end product is.		
House with mud floor and roof – no bedding	• Low cost. • Low labour requirement. • Protects nutrients in manure from sun and rain.	• Significant loss of urine as it enters the soil. • Animals exposed to worm eggs, potentially leading to poor animal health. • If roof not well made, wet conditions can lead to various diseases for animals. • Expense of building. • Weed seeds, plant pests and diseases are potential problems if material not composted.
House with mud floor and roof – with bedding: • Bedding made from organic material (e.g. maize stalks, dry grass, soybean waste, dry leaves). • Used bedding is composted.	• Urine absorbed into bedding means more nutrients in compost. • Composting process reduces presence of weed seeds, plant pests and diseases. • Manure and urine protected from the sun and rain.	• Goats exposed to worm eggs, leading to potential losses. • If roof not well made, wet conditions can lead to various diseases for goats. • Expense of building. • Labour required to collect organic material. • Labour required to compost properly. • Requires knowledge of composting. • Requires small quantities of water.
Raised house with roof and open bottom: • Manure and urine fall beneath the house. 	• House raised, so goats do not suffer from wet conditions and are not exposed to worm eggs, resulting in better health in general. • Roof provides some protection from sun and rain.	• Chickens scratch manure out into the sun and rain, leading to nutrient losses. • Urine leaches into the soil and its nutrients are lost. • Water can wash manure away if the area under the goat pen is not raised. • Cost of materials.

PRACTICE	ADVANTAGES	DISADVANTAGES
Raised house with roof and closed bottom: • Area under house closed off with grass, unused bricks, sticks, mud etc. • Manure and urine fall into protected area. • Drainage to keep water out of the manure.  	• Manure and urine protected from the sun and the rain – chickens cannot scratch manure into sun and rain • Manure heap absorbs urine. • Low labour requirement, because manure rich in nutrients, therefore less needs to be applied. • Heat from manure heap kills weed seeds, pests and diseases. • Can be taken from the storage area and applied directly in the field as composting takes place year round.	• Requires material to close sides. • Requires skill to make sure material is composted properly. • House needs to be made the right size so that manure forms a sufficiently large heap; if not, the manure and urine will not decompose. • Reduces access for chickens to seeds and insects found in manure (unless door for chickens is made).
Use of bat guano (bat manure): • Cave-dwelling bats are active at night and sleep in caves during the day. • Their manure drops to the ground. • Bat guano is similar to poultry manure (since bats do not urinate), i.e. very rich in N and P.	• Low cost if labour is cheap. • Very good fertilizer. • Best if composted (as for other manures).	• Working in caves can cause serious health problems. • Guano mining illegal in some caves (those protected by the wildlife department or recognized heritage sites).

Storage/composting

PRACTICE	ADVANTAGES	DISADVANTAGES
Leave in the kraal	• Low labour requirement.	• Nutrient losses high from leaching, runoff and volatilization. • Non-composted manure can burn plant roots and reduce seed germination.
Leave in the house (with roof)	• Low labour requirement. • Some decomposition occurs in the house, reducing time required to compost material.	• Non-composted manure can burn plant roots and reduce seed germination. • Nutrient losses can occur if manure is scratched out into the sun and rain by chickens or other fowl.
Compost or manure heap: • Make a heap on flat land with drainage.	• Easy to make drainage to prevent water entering the heap. • Easy to cover with grass or soil to prevent nutrient losses from rain and sun. • Easy to turn compost if need arises.	• Require extra labour to heap, add water and mix until decomposed. • Can dry out easily, so needs to be kept moist – especially on the outside of the heap. • Can be destroyed by cattle and goats climbing onto and digging up the heap – need to provide protection (e.g. thorn tree branches, bricks). • Can take time to decompose (≤ 6 months).
Pit compost: • Dig a pit to place compost materials in.	• Easy to keep wet (does not lose moisture easily in the dry season). • Animals will not disturb compost.	• More labour-intensive than alternatives. • Difficult to turn compost if need arises. • Becomes very wet in rainy season, leading to nutrient losses. • Can take time to decompose (≤ 6 months).

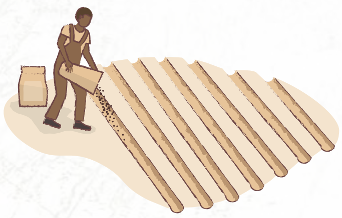
COMPOSTING

Key points:

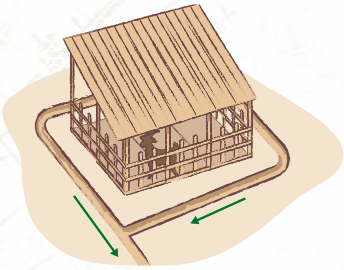
- **What is composting?** Composting of organic material refers to the process of decomposition and relies on the action of microorganisms. Bacteria, fungi and other organisms use the organic material as food. As they consume the food, they multiply. Their waste products make compost.
- **What do I need to add to my compost to make sure it is of good quality?** In order for decomposition to occur, the microorganisms – similar to other organisms – need a balanced food source comprising energy, protein and minerals:
  - energy foods include dry material (e.g. leaves, maize residues, dry grass and woody material).
  - protein rich material includes manure, urine, green leaves and
  - anything with a high nitrogen content.
  - vitamins and minerals are contained in all plant material – the more diverse the material, the more minerals and vitamins. Wood ash and soil are also good sources of vitamins.
- **If I have livestock, how do I mix the materials?** The easiest way to mix the materials together is to use dry material as bedding for the livestock. In this way, animals mix their manure and urine with the bedding.
- **If I have no livestock, how do I mix the materials?** The materials need to be mixed manually and the easiest way to do this is to build a compost heap layer by layer in the following order:
  - 14 cm dry material;
  - 10 cm green material or manure;
  - 1 cm soil or wood ash;
  - continue until the heap reaches ≥ 1.2 m.
- **How big should my heap be?** The heap should be at least 1.5 m wide, 1.2 m high and as long as you have materials for.
- **Do I need to add water?** The decomposition process requires water, without water, there can be no decomposition. To see if the material has enough water, use the moisture test:
  - Take a handful of the composting material and squeeze it.
  - If a drop or two of water comes out, water is sufficient.
  - If the material falls apart and no water comes out, it is too dry – add water.
  - If more than a few drops of water come out, it is too wet – leave the heap to dry out and rebuild once the moisture is correct.

- **How do I know if the ingredients are well balanced?** Temperature is a good indicator of what is going on in the heap. To gauge the temperature, use the **heat test**:
  - Dig into the heap with your hand to test the temperature (wash hands afterwards). Alternatively, insert a wooden pole into the middle of the heap, extract it and touch to see how hot it is.
  - If the heap has been made properly, within 3 days the inside temperature should reach 50–75 °C, i.e. too hot to keep your hand inside the heap.
  - If the heap is not sufficiently hot, it could be due to: insufficient water, insufficient nitrogen-rich material, over-compactness (the heap should never be compacted).
- **Should I cover my compost?** Compost should always be covered for the same reasons as manure. The nutrients in compost can be lost when dried by the sun or left in the rain. Use low-cost materials like thatching grass, a 5-cm layer of soil or a plastic sheet with holes in it. Never use a plastic sheet without holes as the compost will not have enough air and will not decompose properly.
- **Should I mix the compost heap?** Yes, occasional mixing of the compost heap helps mix the ingredients and speeds up the time to maturity. However, mixing also leads to losses of some nutrients. Ideally, compost should be mixed as few times as possible, say, once a month for a good quality compost.
- **How long does compost take to make?** Composting is influenced by many factors (e.g. weather, moisture, number of times it is mixed). In general, a good compost will mature in 3–6 months, although this can be reduced to as little as 2 weeks if it is mixed regularly.
- **How do I know if my compost is ready?** Mature compost looks like fertile soil and does not smell like manure. If the compost still smells of manure or the original material is visible, it is not ready.

Use of manure or compost

PRACTICE	ADVANTAGES	DISADVANTAGES
Undecomposed manure: • Dry or fresh.	• Low labour requirement, because manure used directly without processing. • Can give a strong fertilizing effect on certain crops.	• May contain weed seeds. • May contain plant diseases and pests. • If the manure has a high nutrient content, seeds and plants can be burned by high nitrogen content. • High nitrogen content can lead to imbalanced plant growth, which can lead to pest and disease problems. • If manure has low nutrient content, this may cause stunted growth of plants due to nitrogen lock-up.
Compost or well-rotted manure	• Reduces weed seed content as seeds are made unviable during the heating process that takes place during composting. • Plant nutrients released gradually, resulting in balanced plant growth and fewer plant pests and diseases. • Compost is less bulky than manure and requires less labour to transport to and apply in the field. • Compost contains diverse microorganisms that help to improve soil nutrient cycling.	• Requires labour, water and knowledge. • If not well made, can have the same disadvantages as undecomposed manure.
PRACTICE	**ADVANTAGES**	**DISADVANTAGES**
Broadcasting: • Make heaps in field before rains start and spread with shovels.	• Low labour. • Even spread of compost/manure over the field if done properly.	• Requires large amounts of manure or compost • Can spread weed seeds over field – if not composted • Can supply nutrients to weeds • Can lead to nutrient losses from the sun and rain if not covered with soil immediately (both heaps in the field and when broadcast).
Strip application: • Apply in furrow/rip lines at planting (or just before) using ox cart, buckets or grain bags. 	• Good yields because allows roots to access all nutrients easily. • Manure or compost is covered, resulting in reduced spread of weed seeds and reduced loss of nutrients from sun and rain.	• Needs to be placed on the edges of the field so as not to interfere with field operations (ripping ploughing etc.). • Requires manual labour to apply manure in furrow at the right time. • Raw (undecomposed) manure can kill seedlings if applied too close to the seed.
Spot application: • Apply in planting hole during planting. • Next to or below seed.	• High yields because all nutrients are placed near crop roots. • Easy to measure amount applied. • Reduces spread of weed seeds. • Manure is covered, therefore protected from sun and rain. • Can be applied to the side of the seed to reduce seed rot.	• Labour-intensive. • Raw (undecomposed) manure can kill seedlings if applied too close to the seed (it should be covered or mixed with soil – requiring additional labour).

Use of liquid organic fertilizers

PRACTICE	ADVANTAGES	DISADVANTAGES
Slurry from housed livestock: • Animals kept indoors on a hard surface (e.g. concrete) and the house is cleaned with water: manure + urine + water = slurry. • Used immediately or kept in holding tanks until needed. • Works best when buried with soil. 	• High strength. • Fast-acting.	• Soluble nutrients cause imbalanced growth, potentially leading to pest and disease losses. • If not incorporated into the soil, nutrients can be lost to the air, runoff or leaching. • Needs to be applied soon after being taken out of houses, therefore less practical for farmers growing one crop per year. • Holding tanks are expensive. • Holding slurry in tanks or open-air pits can lead to pollution of surface and underground water and significant nitrogen losses through volatilization. • Transportation is labour-intensive (since most of slurry is water). • Often unpleasant to work with. • Expensive at the commercial level, because large-scale application requires specialized equipment.
Biogas slurry/effluent: • Liquid that comes out of a biogas digester after the methane has been produced.	• As for slurry.	• As for slurry.
Liquid manure (manure tea): • Manure soaked in water for 14–28 days.	• As for slurry.	• As for slurry.
Plant tea: • Plants soaked in water for 14–28 days.	• As for slurry.	• As for slurry.
Effective microorganisms (EMs): • Mixture of beneficial microorganisms that help with nutrient cycling and disease suppression. • Applied to plant roots or as a foliar spray.	• Only small amount required for desired effect. • Cheap and environmentally friendly. • Protects crops from diseases and improves nutrient cycling.	• Not widely available. • Requires knowledge for correct application.
Compost tea: • Compost soaked in water and mixture aerated. • Acts as an inoculant for the soil, reintroducing important microorganisms that may have declined in numbers due to use of chemicals, fertilizers or from lack of sufficient organic matter.	• Introduces beneficial organisms to the soil. • Can suppress diseases as well as improve nutrient cycling in the soil.	• Requires skill to make properly. • Expensive, because requires air pump to keep the tea aerated. • Difficult to know if the compost is of sufficiently high quality.
Foliar sprays: • Nutrients in liquid form sprayed onto crop. • Nutrients are taken up by the plant directly through the leaves. • Based on organic or chemical nutrients, or both.	• Can help address major and minor nutrient deficiencies very quickly, as nutrients are absorbed through the leaves. • Many formulations exist, some of which specific to crop and stage of growth.	• Requires knowledge for mixing and timely application. • If not done correctly, crops can be adversely affected. • Potentially expensive if not made on the farm. • Labour-intensive and requires functioning sprayer and clean water.

7.3 Green manure/agroforestry types

Key points:

- "Green manures" are crops that improve soil fertility by adding nutrients to the soil.
- "Agroforestry" is the integration of tree species into agricultural lands.
- Green manures and agroforestry plants are not limited to soil improvement. They are often multipurpose and have several uses, including food, fodder, medicine, botanical insecticides and firewood.
- When soils are used every year for production of cash crops, they become depleted of nutrients and organic material, leading to poor crop growth. Poor soils need more manure or fertilizer to grow good crops, resulting in higher production costs. Green manures are needed to bring nutrients and organic matter back into the soil and replace natural fallows (high human population = less land for fallow).
- Green manures bring nitrogen from the air into the soil and bring nutrients from deep in the soil up to the surface, thus enriching the soil when they decompose.
- When cash crops/edible legumes (e.g. soybean, groundnut, cowpea, beans) are planted, the seed is harvested and most of the nutrients are therefore taken out of the field. In general, they are not green manures and only have a limited impact on soil fertility improvement.
- When cash crops are mixed with green manure or agroforestry plants, insect pests are disturbed. The additional plants provide a habitat for insects and animals that eat pests, resulting in reduced damage from crop pests.
- Almost all green manures are susceptible to burning and some are susceptible to being eaten by free ranging livestock. Therefore, communities must develop action plans and by-laws to reduce fire damage and regulate livestock grazing/browsing.

Green manure varieties

GREEN MANURE	ADVANTAGES	DISADVANTAGES
Velvet bean (*Mucuna pruriens*): Seed rate: 30–60 kg/ha • When intercropping, plant 3 weeks after maize/sorghum to avoid competition. • Plant in stations or furrows or broadcast. • Cut soon after germination for green manure.  Best varieties: • Black seeded (late maturity) • Black and brown seeded (medium maturity) 	• Used as livestock feed, fodder. • Good for intercropping and crop rotation. • Strong growth and grows in most soils. • Gives good fertilizer effect when seed is left in the field 	• Seed not readily available. • Not edible. • Risk of losing benefits due to fire or livestock if crop is left on the soil surface. • Can become a weed. • Requires knowledge for proper management. • Cannot be grown with small grains or other legumes.
Sunn hemp (*Crotalaria juncea* and *C. ocreoleuca*): Seed rate: 5-20 kg/ha • Grow in-row or between-row. • Black seeded (juncea): plant 2 weeks after planting maize to avoid too much competition. • Red seeded (ocreoleuca): plant same time as maize. 	• Can be eaten/sold (cash crop). • Best in intercropping. • Provides green leaf (= high nitrogen) at the beginning of the rains, when the crops (e.g. maize) need it most. 	• Seed not readily available. • Susceptible to pests. • Low market acceptance. • Not well accepted for food. • Risk of losing benefits due to fire or livestock.  
Pigeon pea (*Cajanus cajan*): Seed rate: 6-15 kg/ha • Can be grown: in alleys 2.5-3.5 m apart; as double rows; or in crop (either between-row or in-row). • Plant at same time as maize, sorghum, pearl millet, groundnut, soybean and 2 weeks before finger millet or cassava. Best varieties: • Mthawajuni • ZPP14 • MPPV 2 	• Can be eaten/sold (cash crop). • Best in intercropping. • Provides green leaf (= high nitrogen) at the beginning of the rains, when the crops (e.g. maize) need it most. 	• Seed not readily available. • Susceptible to pests. • Low market acceptance. • Not well accepted for food. • Risk of losing benefits due to fire or livestock. 
Hyacinth bean (*Lablab purpureus*): Seed rate: 5–10 kg/ha • Grow in-row or between-row. • Plant 2 weeks after maize or sorghum. • Cannot be grown with small grains or other legumes. Varieties: • Highworth (black with white germ) - long season 	• Used as livestock feed, fodder. • Can be grown in intercropping or rotation. • Edible. 	• Seed not readily available. • Risk of losing benefits due to fire or livestock if crop is left on the soil surface. 

GREEN MANURE	ADVANTAGES	DISADVANTAGES
Jack bean (*Canavalia ensiformis*): Seed rate: 15–30 kg/ha • Grow between-row. • Plant at same time or 2 weeks after maize, sorghum, pearl millet, cassava. • Cannot be grown with small grains or other legumes	• Good for intercropping or rotation. • Very drought-tolerant. • Can grow on very degraded soil.	• Seed not readily available. • Dry seed not edible, but can be eaten when very young as green pods. • Risk of losing benefits due to fire or livestock
Silverleaf desmodium (*Desmodium uncinatum*): Seed rate: 5 kg/ha • Grow between-row. • Plant at same time as cash crop. • Can be grown with maize, sorghum, millet, soybean, cassava.	• Best as intercrop. • Good for biological control: repels moths of stalk borers and fall worm and attracts parasitoids; can be used in pull and push, reducing damage caused by these pests. • Fire-tolerant • Used as a fodder crop for livestock. • Only need to plant once with minimum tillage, as it will live for many years (needs to be cut back through the growing season).	• Seed not readily available and expensive. • Not edible for humans.

Trees/agroforestry

TREE	ADVANTAGES	DISADVANTAGES
Gliricidia sepium: Trees/ha: 500–2 500 • Plant in alleys 4–10 m apart on the contour. • Can be grown with all crops if managed by pruning. 	• Very drought-tolerant. • Very good fertilizer effect when green leaves are cut and applied to soil.	• Takes time to start working as soil improver (3–4 years). • Can require expensive nurseries. • Can be killed by fire or termites. • Can require lots of labour for pruning – especially if planted at very high densities.
Faidherbia albida: Trees/ha: 50–100 • Plant on 10 m × 10 m grid on the contour. • Thin every other tree when trees touch. 	• Pods used as livestock feed. • No need for pruning as loses leaves during rainy season. • Deep rooting system, which facilitates nutrient pumping.	• Takes time to start working (10–15 years). • Can require expensive nurseries. • Can be killed by fire or termites. • Can create shade from branches when trees are mature, resulting in reduced yields.
Leucaena leucocephala: Trees/ha: 500–2 500 • Grow in alleys 3–10 m apart on the contour. • Can be grown with all crops if pruned back properly.  	• Used as livestock feed and fodder. • Provides green leaf (= high nitrogen) at the beginning of the rains, when fast-growing grasses like maize or sorghum need it for vigorous vegetative growth.	• Takes time to start working (3-5 years). • Can require expensive nurseries. • Can be killed by fire, termites and livestock. • Can require lots of labour for pruning – especially if planted at very high densities. • Some varieties are susceptible to leaf psyllid, which can considerably reduce the green manure effect.
Sesbania sesban: Trees/ha: 500–2 500 • Grown in alleys 3–10 m apart on the contour. • Can be grown with all crops if pruned back properly.  	• Used as livestock feed and fodder. • Provides green leaf (= high nitrogen) at the beginning of the rains, when fast-growing grasses like maize or sorghum need it for vigorous vegetative growth. • Fastest growing of agroforestry trees. • Can grow well in waterlogged conditions.	• Can require expensive nurseries. • Can be killed by fire, termites and livestock. • Potentially high labour requirement for pruning – especially if planted at very high densities.

7.4 Use of green manure/agroforestry crops

Key points:

- When legumes are grown together with other crops, they do not give significant amounts of nitrogen to their neighbours during growth. The legumes must grow, then be killed or pruned back; when the material decomposes, the nutrients are released to the other plants.
- Annual legumes take the majority of the nitrogen they fix from the air and other nutrients to the seed; if the seed is harvested, most of the nitrogen made by the legumes is taken out of the field (a small amount may be left if all the residues remain in the field). This is not green manure.
- Green legume leaves and stems contain large amounts of nitrogen. As the leaves dry, they lose nitrogen. For this reason, dry legume leaves do not give a strong fertilizer effect on crops grown after legumes. Green leaves give the best fertilizer response and should be added to the soil early in the cropping season for best results.
- If green manure is left on the soil surface, it may lose some nitrogen through drying. Mixing with the soil can reduce nutrient losses, especially in dry areas and seasons with long dry spells.

Green manure/agroforestry practices

PRACTICE	ADVANTAGES	DISADVANTAGES
Growing green manure crops in rotation: • Leave residues on surface or incorporate into soil. 	• Green manure crops grown alone can fix more nitrogen than intercropped green manures. • Easy to manage. • Low labour requirement if managed properly: once for seeding and/or once for weeding. • Helps to clear fields of weeds and diseases for cash crops.	• If seed is harvested, most of the nitrogen fixed in the green manure is lost through harvest. • No cash return, as most green manure seeds do not have a stable market. • If annual green manures are grown (sunn hemp, velvet bean), leaves dry during the dry season and lose most of their nitrogen. • Labour required for land preparation and weeding. • Cost of seed. • If left on surface, there is a risk of fire burning or livestock eating residues, resulting in minimal benefit from green manure. • If green manure is mixed with soil at the end of the growing season, termites will consume green manure and nutrients can become available too soon at the beginning of the next season, leading to poor crop growth later in the season.
Intercropping green manure crops with cash crops 	• No need to take land out of production because green manure is grown in the same field as the cash crop. • Increased food and income from the same field if green manure can be used as a food/cash crop or livestock feed/fodder crop. • Potentially low labour requirement – depending on the system and how the crops are grown together – as both crops seeded and weeded together • Low risk if green manure crop is a cash crop, as many green manure crops can survive droughts better than cash crops.	• Knowledge and skill required for correct planting times, varieties and spacing (see Green manure varieties table above for specific recommendations). • Depending on crop configuration, green manures can reduce cash crop yields (usually by 1–15%); competition can be even greater in dry years. • Cost of seed (usually first year only as most green manure seed can be recycled). • Some green manures are slow to establish and can require extra labour for weeding. • Some green manures are prone to pest problems; these may be more difficult to control in intercropping situations. • Use of herbicides is limited, because grass herbicides may kill legumes.
Growing perennial green manure crops: • Crops that can survive the dry season (pigeon pea, gliricidia, leucaena, sesbania). 	• Strong fertilizer effect and good yields because provides a source green leaf at the beginning of the rainy season. • Plants keep soils protected from erosion by wind and rain during the dry season and the beginning of the rains. • Can produce very large amounts of organic material.	• Best results where leaves are allowed to grow for 2–3 weeks after the first rains; if rains are late, results can be poor. • Must be protected from fire during dry season. • Must be pruned back on time or crop yields will be badly affected. • Can create problems for field operations – especially where animal draft power or mechanical power are used (in this case alley cropping systems are easier to manage than in-row planting of green manure).
Growing self-seeding green manure crops: • For example, velvet bean, jack bean. • Works best in fields with small ridges and furrows – seeds are concentrated in the furrows and crops are planted on the ridges, reducing competition with the crop.	• Strong fertilizer effect, because annual green manures move most of their nitrogen and a lot of other nutrients into their seed. If seed is left in the field over the dry season, allowed to germinate and then killed, the small plants will rot quickly and provide nutrients to the cash crop. • Optimizes growing season because cash crop can be planted early. • Velvet bean and jack bean are not eaten by cattle.	• Green manure seeds left in the field can become weeds in legume crops in the following season (therefore are best suited to continuous cereal/legume intercropping). • Velvet bean and jack bean may be eaten by free ranging pigs and occasionally goats. • Timely control required to avoid competition with the crop and prevent zero crop harvest. 

MODULE 8

FARMING PRACTICES – PEST AND DISEASE MANAGEMENT

Preventing pests and diseases from damaging crops is the foundation of good management. Indeed, the old adage "prevention is better than cure" should be kept in mind when considering pest and disease management: plants grown in healthy soil will grow strong and will suffer less from pests and diseases.

This module describes practices that provide options for both prevention and cure. However, the module covers only the general principles and does not touch on all the vast range of products available on the market. For further advice, it is recommended to communicate with qualified government experts, NGO staff members and/or agrodealers.

Integrated pest management (IPM) is the application of best practices in pest management. It uses prevention and regular monitoring of pest populations to allow the farmer to manage pests in a low-cost and environmentally friendly way.

Cultural management: preventative and curative

PRACTICE	ADVANTAGES	DISADVANTAGES
Use of healthy/fertile soil: • Plants grown in healthy soil will grow strong and will suffer less from pests and diseases.	• Low cost. • Long term. • Low labour requirement.	• Requires knowledge and action to make soil conditions good for plant growth.
Use of pest/disease-tolerant varieties	• Reduced losses from target pests/ diseases. • Widely available for some varieties. • Low cost compared to use of control products.	• Not possible for some pests and diseases. • Varieties limited to specific pests or diseases.
Crop rotation	• Pest and disease control (breaking the pest cycle). • Encourages crop diversification. • Affordable and less complex.	• Limited markets for alternative crops recommended for crop rotation.
Intercropping	• Reduces pest infestations and damage, because crop diversity provides repellents, creates confusion and improves the habitat for beneficial organisms. • Improved nutrient cycling.	• Can lead to competition for water, light and nutrients, potentially resulting in reduced yields from the cash crop. • Limited markets for alternative crops recommended for intercropping.
Improving habitat conservation: • Leaving crop residues, weeds, trees. • No burning in and around fields.	• Provides balanced habitat for beneficial organisms (e.g. wasps, spiders, beetles, lizards, birds) that control insect pests in agricultural crops.	• Requires knowledge. • Requires labour (for fire breaks etc.).
Burning/clearing fields	• Destroys entire pest cycle (egg-larva-pupa-adult). • Cheap. • Controls some pests over large areas.	• Kills also beneficial insects. • Causes pollution. • Destroys organic matter. • Short-term.
Use of fallow	• Pest and disease control by breaking the pest cycle. • Affordable and not complex.	• Requires more land to be able to rotate land for fallow.
Early planting	• Low pest pressure from some pests as crops are established before pest numbers increase (escape), depending on the pest. • Low cost due to limited use of control agents. • Can lead to improved yields.	• Could harbour pests in the absence of other hosts.
Hand picking	• Cheap. • No skills required.	• Labour-intensive. • Contact with some pests (e.g. blister beetle) potentially harmful to humans. • Limited to small areas. • Not effective for all stages of the pest cycle and for all pests.

Biological management: preventative and curative

PRACTICE	ADVANTAGES	DISADVANTAGES
Pheromone traps	• Early warning for pests. • Reduces pest populations.	• Expensive. • Limited effectiveness depending on insect type.
Biological control – bacteria and fungi	• Environmentally friendly. • Very effective. • Some are pest-specific and therefore do not kill beneficial insects or other organisms. • Easy to apply over large areas.	• Requires knowledge and skills. • Limited range of products on market. • Limited to certain pests. • Some also kill beneficial organisms.
Biological control – use of plant extracts: • For example, jatropha, neem, snake bean, chilli, onion, garlic.	• Cheap. • Can be effective depending on type of insect and method of application.	• Requires knowledge. • Not always effective.

Chemical management: preventative and curative

PRACTICE	ADVANTAGES	DISADVANTAGES
Use of chemical seed dressing	• Early control of pest attack. • Long-lasting control measure if systemic chemicals are used. • Cheap.	• Can have long-term harmful effects on the environment/biodiversity and potentially on human health. • Requires extensive skills and knowledge to use safely.
Use of pesticides/fungicides/ bactericides etc.	• Fast action, usually within a few hours. • Precise. • Can be specific or broad in effect. • Widely available. • Covers larger areas. • Low labour requirement.	• High cost. • Harmful to the environment and human health. • Requires extensive skills and knowledge. • Contaminates soils. • Long-term effect, because kills beneficial organisms, often leading to higher pest pressure later in the season. • Pests and diseases develop resistance to pesticides.

MODULE 9

FARMING PRACTICES – SPECIFIC CROPS

There are a diverse range of ways to grow crops in Zambia and this module presents their advantages and disadvantages. However, it serves as a guide only and does not cover the many varieties of each crop. Furthermore, when considering a practice, it is important to take into account the different ways farmers operate – how and why – in different places and circumstances.

There are cases of fake seed on the market. In such cases, the farmer should ask the agrodealer where the seed came from and report it as soon as possible to the Ministry of Agriculture. It is recommended to buy seeds from reputable agrodealers.

When seeds are recycled by farmers, germination tests should be done before the rainy season to avoid poor crop establishment. Where possible, farmers can select open-pollinated varieties for improvement and good performance. In some cases, governmental or non-governmental organizations can help farmers improve their seed-saving systems.

Crop systems

PRACTICE	ADVANTAGES	DISADVANTAGES
Monoculture • Growing the same crop on the same land.onion, garlic.	• Easy to teach/learn. • Easy to weed by hand or with herbicides. • Easy to manage. • High yields in the short term, because there is no plant competition. • High profits if there is no market for intercropped plants.	• No diversity. • High risk of pests and diseases. • More external fertilizer required. • When rotated with green manure crops, cultivated area of crop is reduced, possibly resulting in lower yields. • High risk of crop failure when there is erratic rainfall. • Low economic return per unit area.
Crop rotation • Growing different crops on the same land over several seasons. • Crops can be for cash, consumption, soil fertility improvement or livestock feed/fodder.	• Relatively easy to teach/adopt. • More diversified income, which helps with erratic market prices. • Helps with disease and pest prevention. • Reduces risk of complete crop failure. • Can maintain soil health and fertility, depending on the crops in the rotation.	• Difficult to justify beyond subsistence if markets are not good for rotational crops. • Farmer needs to learn about new crops, which can take several seasons. 
Polyculture/intercropping: • Mixing crops on the same land. • Crops can be for cash, consumption, soil fertility improvement or livestock feed/fodder. 	• Potential multiple benefits due to more efficient utilization of soil nutrients, sunlight and time – if correct crops and crop configurations are used. • Improved pest and disease suppression, because diversity provides habitat for beneficial organisms. • Reduced weed pressure because of shading. • Produces nutrients for feeding plants. • Can increase food security. • Potential for higher profits if there is a market for the intercrop.	• Complex and hard to teach. • Weeding can be more challenging depending on which crops are grown together. • Difficult to harvest using machines. • Difficult to justify beyond subsistence if markets are not good for mixed crops.

9.1 Starch crops

Maize *(Zea mays)*

Key points:

- Maize forms the basis of the Zambian diet.
- Maize has a high yield potential and is relatively easy to grow, weed and harvest.
- Maize needs large amounts of nutrients and water to produce good yields. In the past, soils were more fertile and fertilizers were cheaper. However, growing maize using fertilizer has become more expensive because to get a good crop, more fertilizer needs to be used than before, and the cost of fertilizer is now higher.

Planting

PRACTICE	ADVANTAGES	DISADVANTAGES
Planting depth: 5 cm		
Between-row spacing (in-row spacing adjusted to achieve desired plant population):		
• 80–90 cm	• More space for interplanting/crops. • Fast as few furrows/planting stations need to be made.	• Increased weed pressure due to less canopy.
• 70–80 cm	• Reduced weed pressure (than with 90-cm spacing) because maize canopies faster. • Harvest higher because of higher plant population.	• Increased weed pressure due to less canopy.
• 60–70 cm	• Maize canopies faster, resulting in less weed pressure than with wider spacing.	• More furrows or basins needed. • Less light for intercropping.
Plant population:		
• 30 000–40 000 plants/ha • 7 500–10 000 plants/ lima	• Potentially higher yields with low plant populations when there is lack of nutrients in soil or limited moisture (e.g. during drought or in low rainfall areas), because of less competition during growing period. • Can reduce incidence of fungal disease during wet years and in high rainfall environments – especially for varieties that are susceptible (e.g. local varieties). • Allows more light for growing intercrops. • Requires less seed.	• Crop yields can be lower with lower plant populations when there are sufficient nutrients and moisture.
• 45 000–55 000 plants/ha • 11 500–13 750 plants/ lima	• Potentially higher yields where nutrients and moisture are not limited.	• High costs due to seed requirement. • Can lead to increased fungal damage in wet environments – especially with susceptible varieties.

PRACTICE	ADVANTAGES	DISADVANTAGES
Crop configuration:		
Plant stations • 2–4 seeds per station.	• Low labour requirement for seeding and application of fertilizers/manure/ lime (when done by hand). • Easy to measure number of seeds compared to furrow seeding. • Gives more light for intercrops to grow.	• Reduced yields due to competition for water – especially in dry years.
Single seed • Best suited to furrow/rip line/seeder seeding.	• Fast when furrows are made by draft animals or machines. • Higher yields in dry years, due to less competition for water.	• High labour requirement when done by hand (seeding, fertilizer, manure etc.). • Less light for intercrops.
Time of planting (depends on area and maize variety):		
Dry planting	• High potential yield because allows best use of full growing season with more heat, moisture and sunlight hours for the growing crop. • Affords farmers adequate time to plant.	• Risk of seed rotting due to insufficient moisture for germination. • Potential difficulties in weed management, because crop emerges after or at the same time as weeds. • Difficult due to hard dry soils.
Early planting	• High potential yield because allows best use of full growing season with more heat, moisture and sunlight hours for the growing crop.	• If dry spell hits crop during the growing stage or flowering stage, yields can be drastically reduced. • Potential losses due to damage caused by excessive moisture if heavy late rain occurs.
Medium–late planting: • Best results achieved with medium- and early-maturing varieties.	• Can produce better yields if early-planted maize gets hit by drought or late rain at critical times. • Can allow for green manure growth at the beginning of the season (see sections 7.2–7.4).	• Reduced yield potential as the growing season is shorter. • Can yield poorly if rain stops early. • Can increase pest and disease pressure for later crops. • May require more fertilizer than early-planted maize to produce the same yield.
Varieties:		
Hybrid	• High-yielding. • Drought-tolerant. • Low nitrogen. • Disease resistant/tolerant.	• High cost. • Easily attacked by pests and difficult to store (varieties with soft grain). • Cannot be recycled.
Commercial open-pollinated varieties (OPV)	• Cheaper than hybrids. • Can have higher yields and better disease tolerance than local varieties. • Farmers can save seed successfully. • Can be recycled or replanted for several seasons.	• Medium cost (in year 1). • Lower yields than hybrids.
Local open-pollinated varieties (OPV)	• Cheap as farmers can save own seed. • Often improved taste. • Usually have good storage traits (flint grain). • Can become locally adapted if kept by farmers in one area for long periods.	• Lower yields than hybrids. • Poor germination and declining yields caused by seed-saving problems.
Drought-tolerant and low-nitrogen varieties (hybrid and OPV): • Varieties bred to grow well in dry conditions and with less fertilizer. • PAN 53, SC719, ZM513, Pioneer 30G19w, K2 603, K2 501, ADV 634w.	• Do well in dry spells and where rains finish early. • Do well with less fertilizer.	• High–medium cost. • Requires knowledge of varieties.

Fertility management

- In general, under good growth conditions, maize requires approximately 20 kg of nitrogen, 2.5 kg of phosphorus and 17 kg of potassium to produce 20 bags (1 000 kg) of maize grain.
- For a target yield of 5 tonnes/ha, the crop needs 100 kg of nitrogen, 12.5 kg of phosphorus and 85 kg of potassium, in addition to other minor and trace elements.
- These nutrients can come from the soil and various organic and synthetic sources (see Module 7). Use the "Calculating the actual amount of each element in different fertilizers" table in section 7.1 to calculate the amount of fertilizer for the target yield of the crop

PRACTICE	ADVANTAGES	DISADVANTAGES
Zero use of chemical fertilizer	• Can give high profit if soil is fertile, as fertilizer cost is eliminated. • Low financial risk in case of crop failure. • Works best where manure/compost, agroforestry, green manure and crop rotation with legumes are used together.	• Can lead to very low yield if soil is not fertile and no other soil fertility-improving measure is practised. • Can lead to nutrient mining if soil fertility conservation and/ or replacement strategies are not employed.
Low fertilizer rates: • 50–100 kg/ha D compound and 50–100 kg/ha urea.	• Financial risk is lower than with higher fertilizer rates. • Low impact on environment from leaching, volatilization, damage to soil microorganisms and soil acidification. • Can give good yields where soils are fertile or fertilizer is combined with use of crop rotation, green manure, agroforestry, compost/manure.	• Low yields in less fertile soil with no use of crop rotation, green manure, agroforestry or manure/compost. • Contains enough nutrient for only 1–2 tonnes/ha of maize.
Medium fertilizer rates: • 150–250 kg/ha of both D compound and urea.	• Potentially good yields even on poorer soils and without the use of other soil-improving techniques (e.g. manure, crop rotation, agroforestry).	• Medium to high financial risk. • Potentially detrimental effects on the soil (acidity, organic matter loss, toxic to soil biology), as nutrient losses from leaching and volatilization are increased.
High fertilizer rates: • 250–350 kg/ha of both D compound and urea.	• Very high crop yields due to sufficient supply of nutrients. • Potentially increased levels of nutrients in the soil, which will become available in later seasons – if nutrients not used by the crop.	• Very high financial risk – rainfall, soil fertility and other weather conditions, as well as growing conditions (e.g. weed control, plant spacing), have to be excellent to make a profit. • Detrimental effects on soil (acidity, organic matter loss, toxic to soil biology), as nutrient losses from leaching and volatilization are increased.

Harvesting

PRACTICE	ADVANTAGES	DISADVANTAGES
Stooking: • Putting together in heaps standing up).	• Reduced losses when severe lodging occurs due to wind, termites or rain. • Easy to harvest. • Crop dries off earlier, leading to improved crop quality.	• Double labour requirement. • Residues concentrated in one area rather than spread over the field.
Harvesting standing crop: • No heaping.	• Low labour requirement. • Even distribution of crop residue.	• Increased losses (compared with stoking) when heavy rain or lodging occur.
Dehusking during harvest	• Allows farmers to grade for quality at harvest time.	• Labour-intensive.
Harvesting cobs with sheath	• Low labour requirement where mechanical shelling equipment is available.	• Potentially low quality of grain if cob rot incidence is high and farmers need to regrade grain.

Post-harvest

PRACTICE	ADVANTAGES	DISADVANTAGES
Raised drying bins (chimpaka)	• Reduces losses from rotting and pest attacks (when grain dried to 12%). • Chemical-free drying.	• Can be expensive if building materials are not locally available and if crop harvests are large.
Drying on the ground: • Chemical applied to the soil to reduce termite damage.	• Reduces the need for building material. • Low labour requirement. • Can be used for large quantities of grain.	• Cost of chemicals. • Chemicals are harmful to the environment and humans.
Hand threshing	• Cheap where labour is cheap. • Provides cash income for community members.	• Labour-intensive and time-consuming.
Mechanical thresher	• Very fast. • No need for de-sheathing (some models).	• Expensive to buy. • Requires fuel. • Environmental impact.
PICS bags (grain): • Hermetic sealing (modified atmosphere). • Eliminates oxygen for pests.	• Can be used for 3 seasons if kept properly. • Kills all pests without chemical control. • Allows farmer to know exactly how many bags (kg) they have.	• Expensive. • If not kept well (perforated), will not work. • Requires protection from rats.
Use of biological/botanical agents: • For example, neem, manure, tephrosia (applied separately).	• Cheap. • Non-toxic/environmentally friendly (in some cases).	• Requires knowledge. • Can be harmful to health if not treated properly (tephrosia has been linked to several human diseases when consumed).
Silos metal, polythene and brick and plaster	• Can store large quantities. • No need for bags. • Reduced health problems because grain can be stored without use of harmful chemicals if combined with either oxygen elimination or atmosphere modification (80% improvement over standard grain storage).	• Initial cost of construction. • Difficult to know how much grain is left. • Can lead to significant losses if not built properly. • Can lead to grain spoiling if grain not dry when loaded.

Spacing guide – maize

			Between-row (cm) 1 seed/station			Between-row (cm) 2 seeds/station			Between-row (cm) 3 seed/station		
			90	75	60	90	75	60	90	75	60
Conditions	Plant population per ha (10 000 m²)	Plant population per lima (2 500 m²)	Between-station (cm)			Between-station (cm)			Between-station (cm)		
Low fertility and/or rainfall	33 000	8 250	34	40	51	67	81	101	101	121	152
Medium fertility and/or rainfall	44 000	11 000	25	30	38	51	61	76	76	91	114
High fertility and/or rainfall	55 000	13 750	20	24	30	40	48	61	61	73	91

Fertilizer and manure/compost application rate guide – maize

	RATE OF FERTILIZER (kg/ha)			RATE OF MANURE/COMPOST APPLICATION (kg/ha)		
	100	200	300	3 000	6 000	10 000
Plant population per ha	Spot application (g/plant)[1]			Spot application (g/plant)[1]		
33 000	3.0	6.1	9.1	91	182	303
44 000	2.3	4.5	6.8	68	136	227
55 000	1.8	3.6	5.5	55	109	182
Between-row (cm)	Amount applied evenly per 1 m of row/ furrow (g)			Amount applied evenly per 1 m of row/furrow (g)		
90	9	18	27	270	540	810
75	7.5	15	22.5	225	450	675
60	6	12	18	180	360	540

[1] *Figures are for g per plant: for 2 plants per station, double the amount; for 3 plants per station, triple the amount.*

Cassava (*Manihot esculenta*)

Key points:

- Cassava is the second most important starch crop in Zambia.
- Cassava has the ability to perform well under adverse soil and climatic conditions such as acidic soil (low pH), low nutrient status and moisture stress.
- Cassava is traditionally grown without any fertilizer, making it a low-cost and low-risk option. Furthermore, the roots are sequentially harvested on demand, reducing the need for storage facilities and storage losses.
- Cassava has a 12–36-month growth cycle and grows during the dry season. For this reason, it is traditionally grown in areas that do not have high populations of free ranging ruminants.
- The vegetative part of the plant is readily consumed by goats, cattle, pigs (who also eat the roots) and chickens. This is the main reason cassava plantations are limited to protected gardens and fields in agropastoral areas of Zambia (AER I, IIa, IIb and parts of III).

Planting

PRACTICE	ADVANTAGES	DISADVANTAGES
Planting material:		
Chopped stakes: • 30–45 cm	• Sufficient material to plant larger area. • Easier to transport. • Faster to plant. • Easier to handle during planting. • Easier to achieve correct planting.	• Dries faster than whole stakes when exposed to light or when dry spell follows planting. • Difficult to observe polarity when planting. • Termite damage can kill cuttings more easily than whole stakes.
Whole stake:	• Sprouts faster. • Appropriate for dry planting. • Easier to identify polarity at planting. • Longer storage period of planting materials. • Ease of transportation. • More appropriate for seed multiplication.	• Can plant a smaller area. • Wastage of planting materials. • Higher seed rate. • Expensive. • Yields often less than planting of cuttings.
90° planting	• Gives better yields than 45° planting.	
Culture:		
Ridges	• Concentration of soil organic matter. • Facilitates drainage. • Facilitates root formation and penetration. • Facilitates harvesting of roots.	• Labour-intensive. • May not be suitable for drier conditions. • Slows down the process of weeding.
Flat	• Less labour-intensive at land preparation. • Enables planting of larger area. • Faster weeding.	• Limits root growth and penetration depending on soil conditions. • Prone to waterlogging depending on soil conditions. • Difficult to harvest. • Appropriate to only some areas (sandy soils)
Mounds	• Less labour-intensive. • Enables planting of larger area. • Relatively fast weeding. • Facilitates root formation and penetration. • Facilitates harvesting of roots.	• Easily collapse with excessive rain. • Relatively low plant population.
Land preparation and crop spacing:		
1 m × 1 m	• Ideal for cassava monocropping. • Room for root penetration. • Ease of management (weeding, pest and disease management). • Facilitates disease and pest scouting. • Results in high plant population.	• May not be suitable for some varieties with higher vegetative growth. • Difficult to intercrop in 2nd year as plant stand is dense. • Requires many cuttings.
1 m × 3–4 m (under intercropping)	• Allows for intercrops/diversification. • Higher income/unit area (depending on intercrop). • Facilitates implementation of agronomic practices (e.g. scouting for pests and diseases).	• Low yield resulting from low plant population. • Requires large production area.
Random planting (traditional practice)	• Simple and easy to plant. • Maximizes space if objective is to harvest both roots and leaves.	• Land wastage if objective is to harvest roots. • Hinders implementation of agronomic practices. • Low yield.
Varieties:		
Local	• High adaptation to environment. • Easily accessible.	• Low yield. • Disease susceptibility. • Low nutritional content.
Improved	• High-yielding. • Some varieties are sweet (due to low cyanide content in tuber). • Disease-resistant.	• Not easily available. • Expensive (for first growing season). • Sweet varieties susceptible to insect and pest attack during growth and storage.

Fertility management

- In general, under good growth conditions, cassava requires approximately 3 kg of nitrogen, 0.2 kg of phosphorus and 3 kg of potassium to produce 1 000 kg of fresh tubers.
- For a target yield of 30 tonnes/ha, the crop needs 90 kg of nitrogen, 6 kg of phosphorus and 90 kg of potassium, in addition to other minor and trace elements.
- These nutrients can come from various sources (see Module 7). Use the "Calculating the actual amount of each element in different fertilizers" table in section 7.1 to calculate the amount of fertilizer for the target yield of the crop.

PRACTICE	ADVANTAGES	DISADVANTAGES
Zero fertilization	• High income. • Cheaper than systems where fertilizer is applied.	• Yields can be low if soils are very poor. • Nutrient mining may occur where sufficient nutrients are not replaced.
Some fertilizer, compost, green manure, chitemene	• Higher yields than with zero fertilization approach.	• Fertilizer response low in traditional varieties.

Harvesting

PRACTICE	ADVANTAGES	DISADVANTAGES
Sequential harvesting: • Tubers	• Reduces need for post-harvest storage.	• Can reduce yield if roots are disturbed. • Difficult to measure harvest. • Pest problems can occur. • Crops can mature beyond usable/saleable harvest (nutritional content can be compromised).
Single harvest: • Whole field	• Allows other crops to be planted over the whole field area.	• Ready market and transport required to sell product after harvest.

Post-harvest

PRACTICE	ADVANTAGES	DISADVANTAGES
Fermenting peeled cassava roots	• Eliminates bitterness and cyanide from bitter varieties. • Improves taste of roots. • Improves texture of roots to facilitate roasting. • Facilitates pounding with mortar and pestle.	• Resulting odour undesirable for some consumers. • Some nutrients lost during fermentation. • Prone to pest attack in storage.
Chopped dry cassava pieces	• Suitable for milling into high-quality cassava flour for bakery products if sweet varieties are used. • Preferred for industrial uses (e.g. starch, feed and paper production).	• Not preferred for Nshima. • Not suitable for roasting. • Requires additional labour.

Sorghum *(Sorghum bicolor)*

Key points:

- Sorghum has a high yield potential and is easy to cultivate.
- Sorghum can be used as a substitute for maize and other cereals in both human and livestock diets.
- Sorghum is also grown without the use of commercial fertilizers, but maximum yields cannot be achieved. Alternatives to using chemical fertilizers include practising the system of shifting cultivation, adopting cereal–legume crop rotations, applying compost/manure or using green manure.
- An indigenous Zambian cereal, sorghum is highly drought-tolerant and can withstand periods of low rainfall, doing well in dry conditions. Its drought-tolerant attributes include:
  - an extensive root system compared to other cereals, enabling sorghum to access more water in the soil profile;
  - a smaller leaf surface area than maize and a waxy coat which reduces water loss through evapotranspiration; and
  - the ability to stay dormant and halt most metabolic processes until favourable conditions return.

Planting

PRACTICE	ADVANTAGES	DISADVANTAGES
Planting depth: 5 cm	• Allows seedling to emerge from soil easily.	• Easy for birds to dig up (especially kwale).
Between-row spacing (in-row spacing adjusted to achieve desired plant population):		
• 80–90 cm	• More space for interplanting/crops. • Ideal for tall varieties (≥ 2.5 m). • Reduced etiolation. • Less competition for soil nutrients – especially if no fertilizer is applied.	• Low plant population. • Low yields. • Higher water loss due to less canopy cover if shorter varieties are used.
• 70–80 cm (recommended spacing for sorghum)	• Ideal for medium varieties (1.5–2.5 m). • Ideal plant population. • Ideal spacing for potential yield.	
• 60–70 cm	• Ideal for short varieties (≤ 1.5 m). • Higher yields for short varieties. • Less evapotranspiration because of more canopy cover.	• High plant population not suitable for tall varieties. • More labour required for thinning to achieve correct plant spacing. • Less space for intercropping.

PRACTICE	ADVANTAGES	DISADVANTAGES
Plant population:		
• 80–90 cm between-row • 15–10 cm in-row • (75 000–126 000 plants/ha)	• Can reduce fungal disease incidence during wet years and in high rainfall environments – especially for susceptible varieties (e.g. local varieties). • Allows more light to grow intercrops. • Requires less seed.	• Increased competition for nutrients – if using tall varieties. • Etiolation – if using tall varieties. • Lower yields – if using tall varieties.
• 70–80 cm between-row • 15–10 cm in-row • (84 000–144 000 plants/ha)	• Ideal spacing for best use of nutrients and water to attain more filled grains and larger heads (e.g. during drought or in low rainfall areas) – if using short varieties.	• Can produce lower yields in high fertility conditions.
• 60–70 cm between-row • 15–10 cm in-row • (96 000–168 000 p lants/ha)	• More plants per hectare. • Higher yields – if using short varieties. • Fewer problems with weeds. • Lower evapotranspiration.	• Increased competition for nutrients – if using tall varieties. • Etiolation – if using tall varieties. • Lower yields – if using tall varieties.
• 210 000–370 000 plants/ha	• Ideal for forage sorghums, where the leaves and stalks are harvested as green chop, hay or silage.	• High cost due to increased seed requirement. • Weed management can become difficult.
Crop configuration:		
Broadcasting: • Scattering seed across the field.	• Low labour requirement.	• No plant population control. • Difficult to manage weeds or apply top-dressing. • Waste of resources (fertilizer, manure, compost, seed). • Difficult to harvest.
Plant stations: • 8–10 seeds per station.	• Less labour required for seeding and application of fertilizers/manure/lime (when done by hand). • Easy to measure number of seeds (compared to furrow seeding). • Gives more light for intercrops to grow.	• Potentially reduced yields due to competition for water – especially in dry years. • Higher evapotranspiration rates.
Furrow/rip line	• Fast when furrows are made by draft animals or machines. • Produces higher yields in dry years as there is less competition for water.	• High labour requirement when done by hand (seeding, fertilizer, manure etc.). • Less light available for intercrops. • Possibility of wasted seed, as inexperienced labourers may drop too much.
Thinning (3 weeks after planting):		
Broadcasting	• Zero labour requirement as thinning not usually done.	• Thinning very difficult – if not impossible.
Plant stations: • Retain 3–4 plants per station. • In very dry areas, retain 2–3 plants per station.	• Allows for increased yields as each plant receives adequate nutrients and moisture. • Thinned out plants can be transplanted to fill out gaps or for planting in a new field on wet days.	• High labour requirement if too much seed planted.
Furrow/rip line	• Allows for increased yields as each plant receives adequate nutrients and moisture. • Thinned out plants can be transplanted to fill out gaps or for planting in a new field on wet days.	• High labour requirement if too much seed planted.

PRACTICE	ADVANTAGES	DISADVANTAGES
Time of planting (depends on area and sorghum variety):		
Dry planting	• Highest potential yield because allows best use of full growing season with more heat, moisture and sunlight hours for the growing crop. • Affords farmers adequate time to plant.	• Risk of seed rotting due to insufficient moisture for germination. • Difficulties in weed management if crop emerges after or at the same time as weeds. • Emergence difficult due to hard dry soils.
Early planting	• Highest potential yield because allows best use of full growing season with more heat, moisture and sunlight hours for the growing crop.	• Drastically reduced yields if dry spell hits crop during growing or flowering stage. • Potential yield losses caused by crop damage due to excessive moisture if heavy late rain occurs.
Late planting	• Best results with medium and late planting are achieved with medium- and early-maturing varieties. • Can allow for green manure growth at the beginning of the season (see sections 7.2–7.4).	• Can result in poor yields if gets hit by drought or poor rains at critical times. • Reduced yield potential as growing season is shorter. • Increased pest and disease pressure for later crops – especially sorghum midge and shoot fly.
Germplasm (hybrids/varieties):		
Hybrid	• Higher yields. • Drought tolerance. • Disease resistance/tolerance. • Short hybrids are suited to harvest by combine.	• High cost. • Cannot be recycled.
Commercial open-pollinated varieties (OPV)	• Cheaper than hybrids. • Can have higher yields and better disease tolerance than local varieties. • Farmers can save seed successfully. • Can be recycled or replanted for several seasons.	• Lower yields than with hybrids.
Local open-pollinated varieties (OPV)	• Cheap as farmers can save their own seed. • Usually has good storage traits. • Can become locally adapted, if kept in one area for long periods.	• Lower yields than with improved varieties. • Poor germination and declining yields due to seed-saving problems.

Fertility management

- In general, under good growth conditions, sorghum requires approximately 22 kg of nitrogen, 4.5 kg of phosphorus and 17 kg of potassium to produce 20 bags (1 000 kg) of sorghum grain.
- For a target yield of 5 tonnes/ha, the crop needs 110 kg of nitrogen, 22.5 kg of phosphorus and 85 kg of potassium, in addition to other minor and trace elements.
- These nutrients can come from the soil and various organic and synthetic sources (see Module 7). Use the "Calculating the actual amount of each element in different fertilizers" table in section 7.1 to calculate the amount of fertilizer for the target yield of the crop.

PRACTICE	ADVANTAGES	DISADVANTAGES
Zero use of chemical fertilizer	• Can give high profits if soil is fertile, as fertilizer cost is eliminated. • Low financial risk in case of crop failure. • Works best where manure/compost, agroforestry, green manure and crop rotation with legumes are used together.	• Potentially very low yields if soil is not fertile and no other soil fertility-improving measures are adopted. • Can lead to nutrient mining if soil fertility conservation and/ or replacement strategies are not employed.
Reduced fertilizer rates: • 50 kg/ha D compound. • 25 kg/ha urea.	• Financial risk lower than with higher fertilizer rates. • Low impact on environment from leaching, volatilization, damage to soil microorganisms and soil acidification. • Can give good yields where soils are fertile or if fertilizer is combined with use of crop rotation, green manure, agroforestry and compost/manure.	• Low yields in less fertile soil without use of crop rotation, green manure, agroforestry and manure/compost. • Potentially reduced yields in marginal soils.
Normal fertilizer rates: • 200 kg/ha D compound. • 100 kg/ha urea.	• Can produce good yields even on poorer soils and without the use of other soil-improving techniques (e.g. manure, crop rotation, agroforestry).	• Medium to high financial risk (high production costs). • Potentially detrimental effects on soil (acidity, organic matter loss, toxic to soil biology), with increased nutrient losses due to leaching and volatilization. • Eutrophication of surface water bodies.
High fertilizer rates: • > 200 kg/ha D compound. • > 100 kg/ha urea.	• Vigorous crop growth.	• Potentially lower yields due to excessive uptake of nitrogen. • Late maturity due to vegetative growth. • Very high financial risk (diminishing returns). • Detrimental effects on soil (acidity, organic matter loss, toxic to soil biology), with increased nutrient losses due to leaching and volatilization.

Harvesting

PRACTICE	ADVANTAGES	DISADVANTAGES
Hand harvesting: • Grain	• Easy if sorghum is short.	• Very labour-intensive for taller varieties.
Chopping stalks: • Forage sorghum	• Helps regulate feeding of livestock. • Allows for the making of hay and silage.	• Labour-intensive.
Free grazing: • Forage sorghum	• Not labour-intensive.	• Difficult to control how much animals consume. • Risk of cyanide and nitrate poisoning if crop grows under stressful conditions.

Post-harvest

PRACTICE	ADVANTAGES	DISADVANTAGES
Drying on the ground: • Chemical applied to the soil to reduce termite damage.	• Reduces need for building material. • Reduced labour requirement. • Can be used for large quantities of grain.	• High cost of chemicals. • Chemicals are harmful to the environment and humans. • Loss of grain that cannot be swept up. • Contamination of grain with dust and sand particles making it harder to clean.
Drying on the ground: • On tent or concrete floor.	• Reduced labour requirement. • Can be used for large quantities of grain. • Reduces loss of grain and contamination with sand particles.	• Investment required for strong tents. • Maintenance required for concrete floor and tents.
Hand threshing	• Cheap where labour is readily available. • Provides cash income for community members.	• Labour-intensive and time-consuming. • High loss of grain when not properly separated from chaff.
Mechanical thresher	• Very fast. • Reduced labour cost, as one person can work alone depending on thresher model.	• Expensive to buy. • Cost of fuel or electricity. • Labour required for maintenance for wear and tear. • Environmental impact.
PICS bags (grain): • For grain. • Hermetic sealing (modified atmosphere). • Eliminate oxygen for pests.	• Can be used for 3 seasons if kept properly. • Kills all pests without chemical control. • Allows farmer to know exactly how many bags (kg) they have.	• Expensive. • Ineffective if not kept well (perforated). • Need to be kept safe from rats.
Chemical pest control agents	• Can be cheap depending on chemicals applied. • Can be used to protect a large quantity of grain against pest damage for extended periods.	• Requires knowledge on safe use of chemicals. • Grain can still be damaged by pests if agents applied too late or in insufficient quantities, leading to financial loss (grain) and wastage (chemicals). • Can be harmful to health (leading even to death) if not treated properly. • Some chemicals prevent the grain from being consumed when needed.
Silos metal, polythene and brick and plaster	• Can store large quantities. • No need for bags. • Reduced health problems because no need for harmful chemicals in storage if combined with oxygen elimination or atmosphere modification (80% improvement over standard grain storage).	• Initial cost of construction. • Difficult to know how much grain is left. • Can lead to significant losses if not built properly. • Can lead to grain spoiling if grain not dry when loaded.

Spacing guide – sorghum

Conditions	Plant population per ha (100 000 m²)	Plant population per lima (2 500 m²)	Between-row (cm) 1 seed/station			Between-row (cm) 2 seeds/station			Between-row (cm) 3 seed/station		
			90	75	60	90	75	60	90	75	60
			Between-station (cm)			Between-station (cm)			Between-station (cm)		
Low fertility and/or rainfall	120 000	30 000	20	25	30	40	50	60	60	75	90
Medium fertility and/or rainfall	160 000	40 000	10	15	25	20	30	50	30	45	75
High fertility and/or rainfall	180 000	45 000	10	15	20	20	30	40	30	45	60

Fertilizer and manure/compost application rate guide – sorghum

	RATE OF FERTILIZER (kg/ha)			RATE OF MANURE/COMPOST APPLICATION (kg/ha)		
	100	200	300	3 000	6 000	10 000
Plant population per ha	Spot application[1]			Spot application[1]		
120 000	0.8	1.7	2.5	25	50	83
160 000	0.6	1.5	1.9	19	38	63
180 000	0.5	1.1	1.6	17	34	56
Between-row (cm)	Amount applied evenly per 1 m of row/furrow (g)			Amount applied evenly per 1 m of row/furrow (g)		
90	9	18	27	270	540	810
75	7.5	15	22.5	225	450	675
60	6	12	18	180	360	540

[1] *Figures are for g per plant: for 2 plants per station, double the amount; for 3 plants per station, triple the amount.*

Rice *(Oryza sativa)*

Key points:

- Rice is a potentially important starch crop of diversification in Zambia.
- Zambia imports large quantities of rice. Local and regional demand have been increasing in recent years and remain high.
- Specific guidelines need to be followed for good production.
- Rice is a water-loving plant; it is, therefore, advisable to grow rainfed upland rice in dambos if production is not possible under irrigation or with supplementary irrigation.

Planting

PRACTICE	ADVANTAGES	DISADVANTAGES
Direct seeding (upland rice cultivation):		
Planting depth: 2–3 cm	• Good emergence. • Increased yields.	• More space for interplanting/crops.
Shallow planting	• Can reduce weed competition due to rapid crop establishment.	• Risk of drought and bird damage.
Deep planting		• Poor germination. • Delayed maturity.
Broadcasting onto tilled land	• Less labour at planting time, as no nursery is necessary. • Potentially increased yields because allows for early planting.	• Potentially poor yield if plant spacing is uneven and suboptimal. • Requires high seeding rates (compared to row planting and nursery culture). • Seeds may be exposed to runoff or bird attack because they are shallow planted. • Poor yields. • Difficult to perform agronomic practices (e.g. weeding, fertilizer application). • Patches of very high plant population can lead to reduced airflow and sunlight penetration, potentially resulting in increased disease incidence and poor plant health. • Harvest complicated by grains ripening at different times.
Row seeding using furrow: • Made by hand or using a line marker. • Draft power or mechanical power (50 seeds/m).	• Faster and less labour-intensive at planting time than nursery culture and direct seeding by dibbling. • Line marker is faster than making lines by hand as need to use ropes for spacing and make lines one by one. • Requires little experience (compared to nursery planting).	• Often poor plant population leading to suboptimal plant population. • Often requires thinning and gapping if not well done. • Harvest complicated by grains ripening at different times.
Row seeding using planter: • After tillage.	• Allows rapid and precise planting (compared to broadcasting and row planting in furrows).	• Requires experience. • Not very common and may be expensive. • Harvest complicated by grains ripening at different times.
Row seeding using direct seeding/zero tillage	• Allows rapid and precise planting (compared to broadcasting and row planting in furrows). • Less time and labour required, as land is not tilled.	• Requires expensive machinery. • Machinery not widely available. • Method not well known in Zambia. • Harvest complicated by grains ripening at different times.
Dibbling method: • 3–4 seeds per station.	• Crop emergence is faster.	• Labour-intensive. • May require thinning if > 3 seeds per station. • Harvest complicated by grains ripening at different times.

PRACTICE	ADVANTAGES	DISADVANTAGES
Nursery culture (lowland rice cultivation):		
Planting depth: 3–4 cm	• Increased tillering and crop vigour. • Promotes high yields. • Results in even plant growth.	
Shallow planting	• Low labour requirement for making furrows/holes.	• Can easily be washed away. • May result in poor yields and establishment. • Uneven plant growth.
Deep planting		• Time-consuming. • Results in fewer tillers or poor tillering. • Uneven plant growth.
Broadcasting by hand	• Increased plant population. • One person can do the work.	• Labour-intensive and time-consuming. • Poor yields. • Difficult to perform agronomic practices (e.g. weeding, fertilizer application). • May result in high disease incidence due to lower air circulation that causes humid microclimate.
System of Rice Intensification (SRI): • Organic matter.	• Uses less seed than other methods. • Precise spacing optimizes yields. • Addition of organic matter to the soil improves crop health and yield at lower cost. • Reduces nitrogen losses because of alternate wetting and drying of the soil.	• Higher labour requirement than broadcasting or direct seeding. • Additional labour required for compost making.
1 plant per station: • In lines by hand using a guide rope.	• Promotes tillering. • Recommended for seed maintenance. • Handling easier because all plants mature at the same time.	• Labour-intensive and low yielding. • May result in low plant population if seedlings die. • Establishment sometimes difficult. • Requires experience. • Requires more than one person to handle. • Labour-intensive (compared to using planters).
3 plants per station: • In lines by hand using a guide rope.	• Produces high yields. • Easy to manage. • Increased plant population.	• Requires experience. • Needs more than one person to handle the rope and plant at the same time.
Row planting using planters	• Precise and fast. • Higher yields and less wastage (compared to planting by hand)	• Requires experience. • Expensive and not widely available.

PRACTICE	ADVANTAGES	DISADVANTAGES
Varieties:		
Upland: ▪ NERICA 4: • Non-aromatic. • High-yielding. • Medium-maturing (133 DTM). ▪ NERICA 1: • Aromatic. • Early-maturing (126 DTM).	• Good performance with low rainfall, thus adapted to climate change (compared to lowland varieties). • High yields with reduced rainfall.	• Maturity not uniform. • Not as high-yielding as lowland varieties.
Lowland: ▪ Super MG: • Aromatic. • Very late-maturing (200 DTM). ▪ Kilombero: • Aromatic. • Very late-maturing (207 DTM). ▪ ITA 230: • Non-aromatic. • High-yielding. • Early-maturing (160 DTM). • Not very common in Zambia.	• Very high-yielding. • Preferred by Zambian consumers because aromatic.	• Requires either supplementary irrigation or sufficient rainfall (low rainfall results in poor crop growth and low yields). • High requirement for time and management because very late-maturing.

Note: DTM – days to maturity.

Fertility management

- In general, under good growth conditions, rice requires approximately 15–20 kg of nitrogen, 2–3 kg of phosphorus and 15–20 kg of potassium to produce 1 000 kg of dry grain.
- For a target yield of 5 tonnes/ha, the crop needs 75–100 kg of nitrogen, 15 kg of phosphorus and 75–100 kg of potassium, in addition to other minor and trace elements.
- These nutrients can come from various sources (see Module 7). Use the “Calculating the actual amount of each element in different fertilizers” table in section 7.1 to calculate the amount of fertilizer for the target yield of the crop.

PRACTICE	ADVANTAGES	DISADVANTAGES
Zero fertilization	• Cheap. • Low risk.	• Poor yield if soil has insufficient nutrients.
Reduced fertilizer rates: • 100–150 kg D compound.	• In poor soils, yields can increase.	• Additional risk due to high cost. • Single super phosphate not widely available.
Medium fertilizer rates: • 150–250 kg/ha of both D compound and urea.	• Good yields can be achieved even on poorer soils and without the use of other soil-improving techniques (e.g. manure, crop rotation, agroforestry).	• Medium to high financial risk. • Potentially detrimental effects on soil (acidity, organic matter loss, toxic to soil biology), with increased nutrient losses from leaching and volatilization.
High fertilizer rates: • 250–350 kg/ha of both D compound and urea.	• Supplies enough nutrients for very high crop yields.	• Very high financial risk – growing conditions (i.e. rainfall, soil fertility and other weather conditions) need to be excellent to make a profit. • Detrimental effects on soil (acidity, organic matter loss, toxic to soil biology), with increased nutrient losses from leaching and volatilization.

Harvesting

- Harvesting should be done when 80–85% of the grains have turned golden yellow or brown and the grains on the lower part of the panicle are in the hard dough stage.
- Delay in harvesting results in lower quality of milled rice.

PRACTICE	ADVANTAGES	DISADVANTAGES
Cutting with sickle	• Allows harvest over longer period if labour is limited. • Faster than a knife. • Facilitates threshing with a threshing stand.	• Time-consuming (compared to harvester). • Requires experience.
Cutting with a knife	• Reduces amount of chaff.	• Labour-intensive. • Makes threshing by hand thresher practically impossible. • Time-consuming.
Threshing with sticks	• Lower cost.	• Increased breakages. • Labour-intensive. • Time-consuming.
Threshing using threshing stand	• Cheaper than peddle thresher. • Faster than sticks. • Fewer breakages.	• Moderately labour-intensive. • Requires experience and know-how.
Threshing by peddle thresher	• Cheaper than machine threshers • Faster than threshing stand and sticks. • Fewer breakages.	• Requires technical knowledge and experience. • Somewhat expensive.
Machine threshers	• Fast and efficient.	• Expensive. • Technical know-how required.
Threshing in field	• Does not require transport of stems. • Residue remains in field for soil fertility.	• Losses due to termites if heaped rice left for prolonged periods. • Risk of fire/theft. • Potential losses due to rotting if heaps not covered when late rains occur.
Transporting to the homestead for threshing	• Heaped rice can be more easily protected from rain, termites and fire. • Residues can be fed to livestock and/or used as bedding for livestock housing.	• Additional time required to haul bulky material to the homestead.

Post-harvest

PRACTICE	ADVANTAGES	DISADVANTAGES
Fast drying: • Prolonged exposure to sunlight.	• Not very labour-intensive.	• Increased breakages. • Poor rice quality or grade. • Reduced milling percentage.
Slow drying: • Frequent turning.	• Results in high-quality rice. • Fewer breakages during milling. • Increased milling percentage and better returns.	• Labour-intensive. • Requires experience.
Storage in grain bags or silos	• Stores well without insect prevention for short periods (if stored for prolonged periods, pest attack is common).	• Requires protection from rats and moisture to avoid significant damage. • Germination can be reduced if grain bags dropped.

9.2 Legume crops

Soybean *(Glycine max)*

Key points:

- Soybean production has a potentially important role in diversification on dryland farms in Zambia.
- New markets for soybean have opened up potential to scale up production of soybean in Zambia.
- In order to achieve good production, specific guidelines need to be followed.
- Some varieties of soybean do not produce nitrogen without inoculant, while others do. This is especially important in the first years of soybean cultivation, because without nitrogen, the harvests will be very poor. After the first years, the nitrogen-fixing bacteria that soybean needs build up in the soil, thus reducing the importance of variety selection.

Planting

PRACTICE	ADVANTAGES	DISADVANTAGES
Spacing/culture:		
Planting depth: 2–3 cm		
Close row spacing: • 37.5–50 cm • In-row 5–7 cm between seeds (14–19 plants/m furrow).	• Early canopy closure. • Weed suppression. • Can lead to nutrient-use efficiency improvements. • High biomass production. • Reduces water runoff and evaporation. • Reduces excessive soil temperature.	• Potential lodging of large-frame varieties. • Can have increased disease incidence in prolonged rainfall. • More difficult to do between-row cultivation. • Slow land preparation and planting, because of need to make many furrows.
Wide row spacing: • 60–90 cm • In-row 3–4.5 cm between seeds (23–35 seeds/m furrow).	• Fast as fewer furrows needed. • Between-row cultivation easier. • Best suited to large-frame plants (e.g. Dina). • Can reduce certain fungal diseases due to improved airflow through the canopy.	• Between-row spaces not covered by small-frame plants. • Weed pressure higher than in close row spacing as shading by soybean comes later.
Double row on ridge: • 75 cm apart. • 20 cm between rows on top of ridge. • 10 cm between stations. • 2 seeds/station	• Reduced weeding because of early canopy closure in rows. • Potential yield benefit. • Precise as seeds planted by hand. • Allows for mechanical weeding between rows.	• Labour-intensive. • Difficult to weed between close rows.
Furrow planting	• Very fast if ADP or mechanical power used. • Water harvesting in dry years.	• Potential drainage problems, leading to diseases, because must be on flat.
Ridge planting: • 2–3 seeds/station.	• Precise spacing. • Good drainage. • Easy weed control. • Concentration of nutrients and organic matter in the ridge.	• Slow and labour-intensive, because done individually by hand. • Potentially poor results in dry spells – especially with young plants with small root systems. • Negative effects of soil disturbance.

PRACTICE	ADVANTAGES	DISADVANTAGES
Varieties:		
Promiscuous varieties: • Self-nodulating. *For example, Lukanga, Magoye, Kafue, Mwembeshi, Kaleya.*	• Perform better than non-promiscuous varieties – especially where no inoculant is used or land not used for soybean in the previous 3 years. • Seed is relatively cheap.	• Yield may not be as high as non-promiscuous varieties (where inoculant is used).
Specific/non-promiscuous varieties: *For example, Dina, Safari, Semeki, Satellite, Spike, Saturn, PAN 1867.*	• High yield potential under good management – especially for inoculant. • Seed cost higher than for promiscuous varieties.	• Very poor yields if not inoculated.
Varieties susceptible to shattering: *For example, Hernon, Magoye.*	• Can have good characteristics (self-nodulating). • Potentially good yield.	• Very high potential losses from shattering.
Inoculant use	• Cheap compared to return. • Can give high yields if managed properly. • Remains in soil for ≥ 3 years.	• Not always available. • Needs to be kept cool in storage throughout the producer–supplier–farmer supply chain. • Variable quality and few quality controls in place. • Knowledge required to use effectively. • Cash cost.
Planting windows:		
Early planting: • Before 7 Dec.	• Can lead to increased yields if late-maturing varieties (e.g. Dina, Serenade) used.	• Heavy yield losses due to seed rot, lodging and shattering if wrong varieties are used.
Medium planting: • 7–21 Dec.	• Ideal for medium-maturing varieties as the crop will mature as the rains finish.	• Potentially poor yield due to insufficient rainfall or seed rot, lodging and shattering if short- or long-season varieties are used.
Late planting: • 21 Dec. – 7 Jan.	• Potentially good results if early-maturing varieties are used in low rainfall areas.	• Poor yield if rainfall ends early. • oor yield when varieties are day-length sensitive.

Fertility management

- In general, under good growth conditions, soybean requires approximately 75 kg of nitrogen, 20 kg of phosphorus and 85 kg of potassium to produce 1 000 kg of dry grain.
- For a target yield of 2 tonnes/ha, the crop needs 150 kg of nitrogen, 40 kg of phosphorus and 170 kg of potassium, in addition to other minor and trace elements.
- These nutrients can come from various sources (see Module 7). Use the "Calculating the actual amount of each element in different fertilizers" table in section 7.1 to calculate the amount of fertilizer for the target yield of the crop.
- If the legume is able to fix nitrogen efficiently, some or all of the nitrogen required can be produced by nitrogen-fixing bacteria.

PRACTICE	ADVANTAGES	DISADVANTAGES
Zero fertilization	• Potentially good yields if nutrients were applied to the previous crop as manure or fertilizer. • Cheap. • Low risk.	• Poor yield in some soils with insufficient nutrients – especially where no fertilizer or manure was used on the previous crop.
Some fertilizer – recommended rates: • 50–100 kg/ha D compound or 50 kg/ha single super phosphate.	• Yields can increase in poor soils.	• Increased risk due to high cost. • Single super phosphate not commonly available.

Lime – recommended rate: • 250–2 000kg/ha (depending on soil pH).	• Can improve yields and reduce soil acidity.	• High cost, depending on location, due to need for transport. • Additional cost because must be applied and mixed with soil 4 weeks before planting to be effective. • Soil test required to ensure application of correct rate.

Harvesting

PRACTICE	ADVANTAGES	DISADVANTAGES
Waiting until stems can be pulled easily out of the ground by hand	• Fast. • Low labour requirement.	• Potential losses from shattering if sufficient labour not available to harvest quickly in large fields.
Cutting with sickle	• Allows harvest over longer period if labour is limiting.	• Requires tools. • Time-consuming/drudgery.
Threshing in field	• Does not require transport of stems. • Residue remains in field for soil fertility.	• Losses due to termites if heaped soybean left for prolonged periods. • Risk of fire/theft. • Potential losses due to rotting when heaps not covered if late rains occur.
Transporting to the homestead for threshing	• Heaped soybean can be easily protected from rain, termites and fire. • Residues can be fed to livestock and/or used as bedding for livestock housing.	• Takes additional time to haul bulky material to the homestead.

Post-harvest

PRACTICE	ADVANTAGES	DISADVANTAGES
Storage in grain bags or silos	• Soybean stores well without insect prevention or treatment due to its anti-nutritional enzymes.	• Requires protection from rats and moisture to avoid significant damage. • Reduced germination if grain bags dropped.

Spacing guide – soybean

		Between-row (cm)					Between-row (cm)				
		90	75	60	45	37.5	90	75	60	45	37.5
Plant population per ha (100 000 m^2)	Plant population per lima (2 500 m^2)	Between-station (cm)[1]					Number of seeds planted per linear metre[2]				
250 000	62 500	5	6	7	9	11	19	16	15	11	9
300 000	75 000	4	5	6	7	9	23	19	18	14	11
350 000	87 500	4	5	5	6	8	26	22	21	16	13
400 000	100 000	3	4	4	6	7	30	25	24	18	15

[1] If planting stations are used, multiply the figure by the number of seeds per station (i.e. 2 or 3).

[2] Add 20% to allow for poor germination.

Groundnut *(Arachis hypogaea)*

Key points:

- Groundnut is a drought-tolerant food legume that can grow in marginal soils.
- There are two main types of groundnut: the "bunching" type and the "running" type. Both have many varieties.
- Groundnut commands high prices on the open market for both domestic and export sales.

Planting

PRACTICE	ADVANTAGES	DISADVANTAGES
Spacing/culture:		
Planting depth: 5 cm		
Close row spacing: • 37.5–50 cm on flat/small ridges. • Late-/medium-maturing: in-row 18–13 cm (6–8 seeds/m furrow). • Early-maturing: in-row 13-10 cm (5–7 seeds/m furrow).	• Reduced weed pressure because of early canopy closure. • Can lead to nutrient-use efficiency improvements due to more roots in the ground. • High yield and biomass production. • Reduces water runoff and evaporation. • Reduces excessive soil temperature. • Reduces groundnut mosaic virus.	• Can have increased leaf disease incidence in prolonged rainfall. • Hinders between-row cultivation. • Slow because of need to make many furrows.
Wide single row spacing: • 60–90 cm on flat/ridges. • Late-/medium-maturing: in-row 7–11 cm (9–14 seeds/m furrow). • Best suited to large-frame plants.	• Fast because needs fewer furrows. • Between-row cultivation easier. • Potential for intercropping with maize, sorghum, sunflower.	• Small-frame plants will not form a complete canopy. • Increased weed pressure.
Random planting: • Hand planting after cultivation. • Population dependent on variety and length of growing season. • Best suited to creeping Spanish types.	• Early canopy. • High population.	• Unknown plant population. • Disease problems. • Difficult to do mechanical weeding. • Limited to small areas. • Harvest can take time – especially where soil is not moist.
Double row planting on ridges • 75 cm between ridges. • 20 cm between double rows. • Late-/medium-maturing: 18 cm between planting stations, 1 seed/station. • Early-maturing: 13 cm between planting stations, 1 seed/station.	• Precise spacing. • Improved drainage. • Concentration of nutrients/organic matter (in ridge). • Easy to harvest. • Early canopy closure, resulting in less weeding. • Can be combined with mechanical weeding. • Can reduce mosaic virus infection.	• Time-consuming. • Weeding can be difficult between close row double spacing. • Possible erosion or carbon loss due to soil disturbance.
Single row planting on ridges: • 60–75cm • Late-/medium-maturing: 11–9 cm between planting stations, 1 seed/station. • Early-maturing: 8–7 cm between planting stations, 1 seed/station.	• Precise spacing. • Good drainage. • Easy weed control. • Concentration of nutrients. • Easy harvest. • Early canopy. • Can easily be combined with mechanical weeding (ridging).	• Can produce low yield – especially if small-frame varieties are used. • Can increase incidence of mosaic virus.

PRACTICE	ADVANTAGES	DISADVANTAGES
Furrow planting	• Very fast. • Allows for water harvesting.	• Potential drainage problems resulting in diseases, because must be on flat. • Harvesting can be difficult – especially if soils are heavy or dry.
Mound planting	• Good drainage. • Easy to harvest.	• Land wastage because not all land is utilized.
Varieties:		
Bunching/high-yielding disease-resistant varieties: *For example, MGV-4,5,6,7, Wamusanga, Chishango, Natal common, Comet.* • Lower plant populations (10–15/m²).	• High yield potential. • Easy to harvest. • Some varieties have good disease resistance. • Readily available from seed supplier. • Both early and late maturity.	• Some varieties less acceptable on the market (important to check first).
Spreading/running varieties	• Both early and late maturity. • Produce more biomass than bunching types.	• Can be difficult to harvest. • Some varieties less acceptable on the market (important to check first).

Fertility management

- In general, under good growth conditions, groundnut requires approximately 85 kg of nitrogen, 6 kg of phosphorus and 30 kg of potassium to produce 1 000 kg of dry grain.
- For a target yield of 2 tonnes/ha, the crop needs 170 kg of nitrogen, 12 kg of phosphorus and 60 kg of potassium, in addition to other minor and trace elements.
- These nutrients can come from various sources (see Module 7). Use the "Calculating the actual amount of each element in different fertilizers" table in section 7.1 to calculate the amount of fertilizer for the target yield of the crop.
- If the legume is able to fix nitrogen efficiently, some or all of the nitrogen required can be produced by nitrogen-fixing bacteria.

PRACTICE	ADVANTAGES	DISADVANTAGES
Zero fertilization	• Cheap. • Low risk.	• Poor yields in some soils due to insufficient nutrients.
Some fertilizer/manure: • 50–100 kg/ha D compound or 50 kg/ha single super phosphate. • 1–2 tonnes/ha good compost.	• In poor soils, yields can increase. • Can help in early years when number of nitrogen-fixing bacteria are low. • Medium risk.	• Increased risk because of high cost. • Single super phosphate not widely available in the country.
Lime: • 250–2 000 kg/ha • Apply on day with less wind.	• Can improve yields and reduce soil acidity. • Reduces empty pods (pops).	• High cost (mainly for transport). • Additional cost because must be applied and mixed with soil 4 weeks before planting to be effective.
Gypsum applied at first flowering: • 200 kg/ha • Apply on day with less wind.	• Reduces pops as provides soluble calcium to the roots. • Works fast.	• Not widely available. • High cost.
Wood ash at first flowering: • 200 kg/ha • Apply on day with less wind.	• Reduces pops as provides soluble calcium to the roots. • Works fast. • Cheap.	• Variable nutrient content. • Must be stored and protected from rain until needed.

Harvesting

PRACTICE	ADVANTAGES	DISADVANTAGES
Hand pulling: • Groundnut.	• Can be fast in some soils, depending on soil moisture and crop variety. • Easier on ridges and in basins.	• Potential loss of harvest due to availability of limited window (if soil is dry or heavy, or if an inappropriate variety is planted).
Hoe: • Groundnut	• Most pods can be removed. • Useful in dry or heavy soils. • Easily accessible.	• Potentially time-consuming and labour-intensive.
Plough/ridger: • Groundnut	• Fast. • Effective on ridges with bunching types (not Spanish creeping types).	• Loss of organic matter through soil disturbance. • Requires tools, well-trained animals and skilled labour.

Post-harvest

PRACTICE	ADVANTAGES	DISADVANTAGES
Heaping whole plants on the ground in the field	• Low labour requirement. • No need for transportation (while still wet, groundnuts are heavy). • Residue remains in fields for livestock feed and soil fertility/ground cover.	• Possible high levels of aflatoxin due to moisture in leaves and soil (dangerous to human health and can limit sales to domestic and export markets). • Possible losses due to theft.
Heaping whole plants on drying racks in the field	• Reduces drying time. • Reduces risk of aflatoxin on nuts.	• Requires additional labour and materials to construct racks.
Plucking pods when plants are still fresh and drying on drying racks or plastic tent	• Allows nuts to dry very quickly. • Reduces aflatoxin and improves seed germination rates if seed is saved or sold. • Provides high-quality green material that can be dried in the shade for use as high-quality livestock fodder, green manure or compost.	• Time-consuming and high labour requirement (although raking the pods can improve efficiency).
Plucking pods when material is dry	• Low labour and time requirement.	• Possible build-up of aflatoxin due to moisture in green material. • Reduced protein content because a large proportion of nitrogen is lost as foliage dries in the sun.
Hand shelling (without adding water)	• Good quality grain. • High germination percentage. • Less aflatoxin than with wet shelling.	• Labour-intensive.
Hand shelling (after applying water)	• Less labour than with dry shelling.	• Increases aflatoxin. • Reduces quality and germination percentage.
Hand or mechanical sheller	• Very fast. • Low labour requirement. • Reduces aflatoxin as shelling is done dry.	• Grain quality and seed germination can be low. • Needs to be regraded once shelled for broken and rotten nuts.
Stored in shell in raised storage bins	• Reduces insect damage. • Increases germination percentage.	• High labour requirement.
Stored in grain bags raised off the floor in dry location	• Harvest is weighed and known to the farmer.	• May require treatment to reduce insect damage if nuts kept in bags for long periods. • Requires protection from rats and moisture to avoid significant damage. • Reduced germination if grain bags dropped.

Common bean (*Phaseolus vulgaris*) / cowpea (*Vigna unguiculata*)

Key points:

- Common bean production is usually limited to cooler areas with stable rainfall. This is because common bean is sensitive to moisture stress and high night temperatures. Both of these conditions cause flowers and fruit to abort and this in turn leads to low yields.

Planting

PRACTICE	ADVANTAGES	DISADVANTAGES
Planting depth: 3-4 cm		
Spacing:		
• 50–75 cm between-row. • 7–15 cm between stations. • 1 seed/station.	• Ideal for monocropping. • Easy to manage (weeding, pest and disease management). • High plant population.	• Difficult to intercrop.
Random planting	• Allows for intercrops/diversification. • High income per unit area (depending on intercrop).	• Low yield due to low plant population. • Requires large land area for economic production. • Leads to land wastage. • Hinders implementation of agronomic practices. • Low yield.
Intercropping (maize) between-row: • Erect cowpea: Lutembwe, Bubebe, Musandile. • Plant 10–14 days after planting maize. • 10 cm between plants in row.	• Can have fast canopy closure and weed suppression. • Increases nutritional yield from the field over monocrop due to the presence of cowpea. • Reduces insect pests compared to monocropping.	• Maize suffers from competition if planted too early. • Cowpea yield poor if planted too late. • Potentially labour-intensive, because cowpea may need to be dried as it matures faster than maize and often needs to be harvested in the rainy season; therefore, best applied to small areas for home consumption. • Short planting window – potentially complicated if there is a dry spell.
Intercropping (maize) in-row: • Spreading or climbing cowpea/bean. • Either planted at the same time as maize or ≤ 2 weeks later, depending on maize maturity and bean maturity.	• Potentially high yields, increasing food production and income per hectare. • Nutritional benefit from leaves and seeds/pods. • Insect pests reduced (compared to monocropping)	• Labour-intensive (harvesting beans and cowpeas that climb up maize). • Correct timing is vital to avoid competition, which reduces yield of one crop or both. • Requires knowledge about both variety of maize and variety of bean/cowpea.
Early planting (Nov.–Dec.)	• Opportunity to grow two bean crops in one season in areas with long growing seasons.	• Not possible in hot areas or areas that experience regular drought in the early season (beans do not grow and produce well in hot weather). • Poor yields due to flower and fruit abortion caused by night temperatures > 22 °C and dry weather; therefore, not recommended in areas with short seasons/low rainfall and high temperatures.
Late planting (Jan.–Feb.)	• Increased chances of good yields due to low night temperatures and good rainfall in Jan./Feb, therefore good strategy for hot areas. • Fewer pests.	• Can be increased disease pressure due to high humidity.

PRACTICE	ADVANTAGES	DISADVANTAGES
Varieties:		
Improved: • Bean: Mbereshi, Mweru. • Cowpea: Lutembwe, Bubebe, Musandile.	• High-yielding. • Good tolerance to some diseases that local landraces are not tolerant to.	• Highly susceptible to pests and diseases. • Market acceptance not good in some cases. • Requires fertilization for best results.
Local: • Bean: Kabulangeti, Solwezi red, Mbala, Lusaka. • Cowpea: Running type: Sudan. • Erect or semi-erect.	• Some are tolerant to diseases and pests. • Good adaptation.	• Low yield. • Late maturity. • Low response to fertilization. • Some varieties susceptible to pest and diseases.

Fertility management

Common bean:

- In general, under good growth conditions, common bean requires approximately 36 kg of nitrogen, 8 kg of phosphorus and 18 kg of potassium to produce 1 000 kg of dry grain.
- For a target yield of 2 tonnes/ha, the crop needs 72 kg of nitrogen, 16 kg of phosphorus and 36 kg of potassium, in addition to other minor and trace elements.
- These nutrients can come from various sources (see Module 7). Use the "Calculating the actual amount of each element in different fertilizers" table in section 7.1 to calculate the amount of fertilizer for the target yield of the crop.
- If the legume is able to fix nitrogen efficiently, some or all of the nitrogen required can be produced by nitrogen-fixing bacteria. In general, beans are not efficient at fixing nitrogen and this element needs to be supplied.

Cowpea:

- In general, under good growth conditions, cowpea requires approximately 38 kg of nitrogen, 5 kg of phosphorus and 11 kg of potassium to produce 1 000 kg of dry grain.
- For a target yield of 2 tonnes/ha, the crop needs 76 kg of nitrogen, 10 kg of phosphorus and 22 kg of potassium, in addition to other minor and trace elements.
- These nutrients can come from various sources (see Module 7). Use the "Calculating the actual amount of each element in different fertilizers" table in section 7.1 to calculate the amount of fertilizer for the target yield of the crop.
- If the legume is able to fix nitrogen efficiently, some or all of the nitrogen required can be produced by nitrogen-fixing bacteria.

PRACTICE	ADVANTAGES	DISADVANTAGES
Zero fertilization	• Cheap. • Low risk.	• In some soils, poor yield due to insufficient nutrients.
Some fertilizer: • 50–100 kg/ha D compound or 50 kg/ha single super phosphate.	• Yields can increase in poor soils.	• Increased risk because of high cost. • Single super phosphate not widely available in the country.
Lime: • 250–2 000 kg/ha (depending on soil pH).	• Can improve yields. • Can reduce soil acidity.	• High cost, mainly for transport. • Additional cost because must be applied and mixed with soil 4 weeks before planting to be effective. • Soil test necessary to apply correct rate.

Post-harvest

PRACTICE	ADVANTAGES	DISADVANTAGES
Storage in grain bags	• Easy to handle.	• Treatment required to reduce insect damage if seed kept in bags for long periods. • Protection required from rats and moisture to avoid significant damage. • Reduced germination if grain bags dropped.
Storage in PICS bags	• Can be used for 3 seasons if kept properly. • Kills all pests without the need for chemical control. • Allows farmer to know exactly how many bags (kg) they have. • Easy to handle.	• Expensive. • Must be kept well (perforated) in order to work. • Requires protection from rats.
Silos metal, polythene and brick and plaster	• Can store large quantities without need for bags. • Reduced health problems associated with pesticide use and exposure, because no need for harmful chemicals if combined with either oxygen elimination or atmosphere modification (80% improvement over standard grain storage).	• Initial cost of construction. • Difficult to know how much grain is left. • Can lead to large losses if not built properly. • Can lead to grain spoiling if grain not dry when loaded.

Varieties

VARIETY	DAYS TO MATURITY	POTENTIAL YIELD (kg/ha)	OTHER CHARACTERISTICS
Kabulangeti	80–85	1 000 –1 500	Purple, medium size Highly marketable in Zambia
Kipisha	75–80	1 000–1 500	Khaki, medium size
Pan 148	100–200	1 000–2 500	Red-specked Resistant to rust and angular leaf spot
Kabale	80–85	1 500–2 000	Red, medium size
Kalungu	75–80	1 500–2 000	White, medium size
Lyambai	85–90	1 500–2 000	Red mottled, medium size
Lukupa	75–80	1 500–2 000	Cream mottled, medium size
Kalambo	80–85	1 500–2 000	Cream mottled, medium size
Chambeshi	85–95	1 500–2 000	Khaki, large size
Mbereshi	80–85	1 500–2 000	Red mottled, medium size High in iron and zinc
Lungwe-bunga	85–90	1 500–2 000	Bush type, cream mottled Resistant to angular leaf spot, anthracnose, rust and common beans mosaic virus
Lunga	85–90	1 500–2 000	Purple, large size Resistant to anthracnose, rust, angular leaf spot and bean common mosaic virus
Lwangeni	90–95	2 000–2 500	White, small size Good for canning
Sadzu	80–85	2 000–2 500	Red mottled, medium size Climber

9.3 Cash crops

Cotton *(Gossypium hirsutum)*

Key points:

- Cotton is an important cash crop for smallholders in Eastern, Southern, Central and valley areas of Zambia.

Planting

PRACTICE	ADVANTAGES	DISADVANTAGES
Planting depth: 1–2 cm	• Excellent crop stand since emergence is higher than when planted deeper.	• Poor emergence due to seed rot if there is insufficient rainfall/moisture.
Spacing:		
• 80–90 cm between rows	• Fast as few furrows or planting stations required. • Weeding and spraying easy due to wide spacing.	• Increased weed pressure due to less canopy. • Reduced yield due to low plant population if poorly managed.
• 70–80 cm	• Reduced weed pressure because cotton canopies quick to grow. • Increased income from higher yield due to plant population.	• High labour requirement if ripper used, as more furrows required at planting. • Difficulty accessing plants for cultural practices (e.g. weeding and spraying for pests).
Plant population:		
• 60 000–70 000 plants/ha • 15 000–17 500 plants per lima	• Potentially higher yields with low plant populations when there is lack of nutrients in soil or limited moisture (e.g. during drought or in low rainfall areas), because of less competition during growing period. • Can reduce fungal disease incidence during wet years and in high rainfall environments – especially for varieties that are susceptible (e.g. local varieties). • Allows more light to grow intercrops. • Requires less seed.	• Crop yields can be lower with lower plant populations when there are sufficient nutrients and moisture.
Crop configuration		
Plant stations: • 2 seeds/station	• Less labour for seeding and application of fertilizers/manure/lime (when done by hand). • Easy to measure number of seeds (compared to furrow seeding). • Gives more light for intercrops to grow. • No labour needed for thinning.	• Potentially reduced yields due to competition for water – especially in dry years. • Low emergence, which can affect plant population. • Additional labour or cash may be required for gapping when
Single seed: • Best suited to furrow/rip line/seeder seeding.	• Fast when furrows are made by draft animals or machines. • Higher yield in dry years as there is less water competition.	• High labour requirement when done by hand (seeding, fertilizer, manure etc.). • Less light available for intercrops.

PRACTICE	ADVANTAGES	DISADVANTAGES
Time of planting (depending on area and maize variety):		
Dry planting	• Highest potential yield because allows best use of full growing season with more heat, moisture and sunlight hours.	• Poor crop stand can occur if light showers are insufficient to germinate seed.
Early planting	• Highest potential yield because allows best use of full growing season with more heat, moisture and sunlight hours. • Yield higher than with late planting in high rainfall areas	• Can result in drastically reduced yields if dry spell hits crop during growing or flowering stage.
Medium-late planting: • Best results achieved with the medium- and early-maturing varieties.	• Can yield better if early-planted cotton gets hit by drought or late rain at critical times.	• Reduced yield potential as growing season is shorter. • Can produce poor yields if rain stops early. • Can result in increased pest and disease pressure. • May require more fertilizer than earlier planted cotton to give the same yield.
Varieties:		
Commercial OPV: • Supplied by cotton companies.	• Cheaper than hybrids. • Can have good yields and better disease tolerance than local varieties.	• Medium cost (in first year).
Local recycled seed	• Cheap or free.	• Lower yields than hybrids. • Seed-saving problems leading to declining yields.

Fertility management

- In general, under good growth conditions, cotton requires approximately 120 kg of nitrogen, 42 kg of phosphorus and 84 kg of potassium to produce 1 000 kg of cotton lint.
- For a target yield of 2 tonnes/ha, the crop needs 120 kg of nitrogen, 40 kg of phosphorus and 110 kg of potassium, in addition to other minor and trace elements.
- These nutrients can come from various sources (see Module 7). Use the "Calculating the actual amount of each element in different fertilizers" table in section 7.1 to calculate the amount of fertilizer for the target yield of the crop.

PRACTICE	ADVANTAGES	DISADVANTAGES
Zero use of chemical fertilizer: • Cotton rarely fertilized.	• Can give high profit if soil is fertile, as fertilizer cost is eliminated. • Low financial risk in case of crop failure or erratic commodity pricing. • Works best where manure/compost use, agroforestry, green manure and crop rotation with legumes are used together.	• Can lead to very low yield if soil is not fertile and no other soil fertility-improving measure is practised.
Low fertilizer rates: • 50–100 kg/ha of both D compound and 50–100 kg/ha urea.	• Financial risk lower than with higher fertilizer rates. • Low impact on environment from leaching, volatilization, damage to soil microorganisms and soil acidification. • Can give good yields where soils are fertile or fertilizer is combined with use of crop rotation, green manure, agroforestry, compost/manure.	• Low cotton yield in less fertile soil without use of crop rotation, green manure, agroforestry and manure/compost. • Contains enough nutrient for only 1 000–2 000 kg/ha cotton.
Medium fertilizer rates: • 150–250 kg/ha of both D compound and urea.	• Can produce good yields even on poorer soils and without use of other soil-improving techniques (e.g. manure, crop rotation, agroforestry).	• Medium to high financial risk. • Can have detrimental effects on the soil (acidity, organic matter loss, toxic to soil biology), with increased nutrient losses from leaching and volatilization.
Solubor (boron)	• Reduces losses due to boron deficiencies.	• Not always available. • Can damage plant or reduce yield if not mixed and applied correctly.

References

Lugo A. E. , Brown S., 1993. *Management of tropical soils as sinks or sources of atmospheric carbon.* PLANT SOIL

Bispo A., Andersen L., Angers D. A., Bernoux M., Brossard M., Cécillon L., Comans r. N. J., Harmsen J., Jonassen K., Lamé F., Lhuillery C., Maly S., Martin E., Mcelnea A. E., Sakai H., Watabe Y., Eglin T. K., 2017. *Accounting for carbon stocks in soils and measuring GHGs emission fluxes from soils: Do we have the necessary standards?* Frontiers in Environmental Science, 5 (41). https://doi.org/10.3389/fenvs.2017.00041

Chidumayo E., 1987. *A shifting cultivation system under population pressure in Zambia.* AGROFOREST SYST

Demenois J., Torquebiau E., Arnoult M.H., Eglin T., Masse D., Assouma M. H., Blanfort V., Chenu C., Chapuis-Lardy L., Medoc J.M., Nourou Sall S., 2020. *Barriers and Strategies to Boost Soil Carbon Sequestration in Agriculture.* Front. Sustain. Food Syst. https://doi.org/10.3389/fsufs.2020.00037

FAO, 2018. *A preliminary review of agriculture-related activities in the Green Climate Fund portfolio.* Rome, Italie, FAO, 6 p. Téléchargeable: www.fao.org/3/CA2698EN/ca2698en.pdf

Fujisaki K., Chevallier T., Chapuislardy l., Albrecht A., Razafimbelo T., Masse D., Ndour Y. B., Chotte J.-l., 2018. *A Soil carbon stock changes in tropical croplands are mainly driven by carbon inputs: A synthesis.* Agriculture Ecosystems & Environment, 259 : 147-158

Giller K., 2001. *Nitrogen fixation in tropical cropping systems.* 2nd edition. CABI

IAPRI, 2016. *Rural Agricultural Livelihoods Survey 2015.*

Kjell B. E., 2017. *Water Infiltration and Moisture in Soils under Conservation and Conventional Agriculture in Agro-Ecological Zone IIa, Zambia.* MDPI

Mutiro K., Murwira H.K., 2004. *The Profitability of Manure Use on Maize in the Smallholder Sector of Zimbabwe.* CGIAR

Nguyen H, Craddock G. R., Adams F., 1986. *Effect of Organic Acids on Aluminum Toxicity in Subsoils1.* SOIL SCI SOC AM J

Palm C. A., Giller K.E., Paramu L. M., Swift M.J,. 2001. *Management of organic matter in the tropics: translating theory into practice.* Kluwer

Roose E., Zougmore R., Stroosnijder L. P. D., Bouzou-Moussa I., 2017. *Techniques traditionnelles de restauration de la productivité des sols dégradés en régions semi-arides d'Afrique occidentale.* In Roose E. (éd.): Restauration de la productivité des sols tropicaux et méditerranéens. Contribution à l'agro-écologie, Marseille, France, IRD Éditions : 491-517

Snijders P., Onduru D., Wouters B., Gachimbi L., Zake J., Ebanyat P., Ergano K., Abduke K., van Keulen H., 2009. *Cattle manure management in East Africa: Review of manure quality and nutrient losses and scenarios for cattle and manure management.* Wageningen UR Livestock Research

Rusinamhodzia L., Makokob B., Sariahc J., 2017. *Ratooning pigeonpea in maize-pigeonpea intercropping: Productivity and seed cost reduction in eastern Tanzania.* Elsevier

Thierfelder C., Chivenge P., Mupangwa W., Rosenstoc T. S., Lamanna C., Eyre X. J., 2017. *How climate-smart is conservation agriculture (CA)? – its potential to deliver on adaptation, mitigation and productivity on smallholder farms in southern Africa.* Springer

Vanlauwe *et. al.,* 2010. *Agronomic use efficiency of N fertilizer in maize-based systems in sub-Saharan Africa within the context of integrated soil fertility management.* SpringerLink

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