KP06
Knowledge Product 06

CCARDESA
Centre for Coordination of Agricultural Research and Development for Southern Africa

DECISION TOOL:
Climate Smart Soil Amendment Options for Maize & Sorghum

CLIMATE SMART AGRICULTURE
KNOWLEDGE PRODUCTS FOR EXTENSION WORKERS
Customised Information Tools for Agricultural Professionals

Audience: Local Level Extension Staff (Government, NGO/Civil Society, Private Sector)

Maize | Sorghum | Decision Point | Gender | Youth | Climate Smart | Practice

Lars Ploughman, 2015

german cooperation
DEUTSCHE ZUSAMMENARBEIT
Implemented by: giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

WHAT IS CLIMATE SMART AGRICULTURE (CSA)?

CSA comprises three interlinked pillars, which need to be addressed to achieve the overall goals of food security and sustainable development:

1. **Productivity:** Sustainably increase productivity and incomes from agriculture, without negative impacts on the environment

2. **Adaptation:** Reduce exposure of farmers to short- term risks, while building capacity to adapt and prosper in the face of shocks and longer-term stresses (resilience). Attention is given to protecting ecosystem services, maintaining productivity and our ability to adapt to climate changes

3. **Mitigation:** Wherever and whenever possible, CSA should help to reduce and/or remove greenhouse gas (GHG) emissions. This implies that we reduce emissions for each unit of agricultural product (e.g. through decreasing use of fossil fuel, improving agricultural productivity and increasing vegetation cover).

CSA = Sustainable Agriculture + Resilience – Emissions.

How is CSA Different?

1. CSA places greater emphasis on **hazard and vulnerability assessments** and **emphasises weather forecasting** (short term) and **climate scenario modelling** (long term) in the decision-making process for new agricultural interventions

2. CSA promotes the **scaling up of approaches** that achieve **triple wins** (increase **production**, increase **resilience** and [if possible] **mitigate GHG emissions**), while at the same time **reducing poverty** and **enhancing ecosystem services**

3. CSA promotes a systematic approach to:

   a. Identifying **best bet** opportunities for agricultural investment

   b. Contextualising **best bet** options to make them **best fit** their specific context through learning and feedback loops

   c. Ensuring the **enabling environment** is in place so that farmers (and other stakeholders) can invest in CSA practices and technologies to catalyse adoption.

Key Messages:

1. Healthy soil is the foundation of climate smart maize and sorghum production:
   Healthy Soil = Healthy and Productive Crops

2. To make climate smart decisions on how to improve your soil, you need to understand:

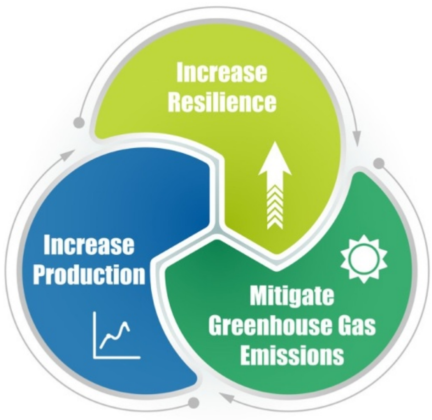
   a. The current status of the soil
   b. Trends in rainfall and temperature
   c. Farmer priorities
   d. Gender dynamics in the farming system

3. Climate smart soil amendments that can improve your soil include:

   a. Compost
   b. Green manure
   c. Biochar
   d. Adding organic + inorganic fertiliser/manure
   e. Adding lime
   f. Integrated Soil Fertility Management (ISFM).

Entry Points for CSA

- CSA practices and technologies
- CSA systems approaches
- Enabling environments for CSA.



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CLIMATE SMART SOIL AMENDMENT OPTIONS FOR MAIZE & SORGHUM

This Decision Tool aims to help field-level extension staff in making climate smart decisions on which soil amendment option best suits their maize and sorghum farmers' context. It focuses on some of the Best Bet Climate Smart Soil Amendment options for Maize and Sorghum production in the Southern African Development Community (SADC) region. These are just some of the many options available. They are listed in no particular order and have been selected as best bet because:

- They are climate smart (see Table 1)
- They are applicable in multiple agro-ecological zones across the region
- They have high potential to address major constraints to maize and sorghum production in the region (Table 1).

These are best bet options. An understanding of the local context and farmer priorities is required in order to make these options the best fit for individual farmer's needs.

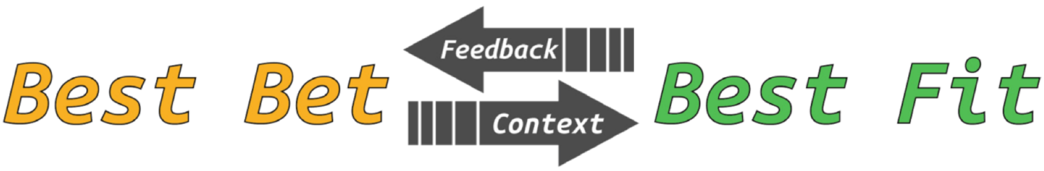

Table 1: Best Bet Climate Smart Soil Amendment Options for Maize & Sorghum that have potential to improve soil health across the SADC region.

Climate Smart Soil Amendment Practice Option	What is it?	3 Pillars of CSA		
		Increase Production	Increase Resilience	Mitigate GHG Emissions if possible
Add Compost	Adding partially decomposed organic material to the soil. There are many types of compost and ways to make it	Adds nutrients to the soil, resulting in healthier more productive plants	Improves water retention and mitigates effects of short -term dry spells	Helps lock more carbon into the soil
Grow Green Manure	Growing a cover crop and either ploughing it back into the soil while still green, or using the green material as a mulch on top of the soil	Adds nutrients to the soil, resulting in healthier more productive plants	Helps prevent erosion and compaction of soil from rainfall. Regulates soil temperatures. Improves water retention and mitigates effects of short -term dry spells	Helps lock more carbon into the soil
Apply Biochar	Essentially this is charcoal, but it does not need to be made from wood. Maize husks will work well	Makes nutrients more available to plants and increases water retention. Can increase pH	Improves water retention. Remains in the soil for a long time	Helps lock more carbon into the soil
Add Organic + Inorganic Inputs	For example, applying compost and fertiliser	Organic matter helps maximise the effect of fertilisers on crop yields	Higher production equals increased food security/income and resilience	Helps lock more carbon into the soil and reduces fertiliser requirements
Integrated Soil Fertility Management	A holistic approach to soil fertility management that includes seed selection, cultivation practices, cropping systems and soil amendments	Improves soil structure Increases soil fertility	Aims at sustainable intensification, and increasing resilience through more predictable production	Maximises the amount of carbon retained in the soil, and aims to maintain this in the long term
Apply Lime	Increases soil pH. Soil pH levels below 5.5 are common across the region, and greatly inhibit plant growth	Trials in Kenya indicate an average increase in yield for maize of 13% at application rates of 0.5 t/ha	Sustainable improvements to soil fertility. Application is not required every year	N/A

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WHICH CLIMATE SMART SOIL AMENDMENT OPTION IS BEST SUITED FOR YOUR FARMER(S)?

- There is no one-size-fits-all package of practices/technologies. A combination of practices will almost always work best
- Some options have multiple benefits – co-benefits – that may make them preferable
- Start with 'best bet' climate smart solutions for the target area, but aim for 'best fit' solutions for individual farmers.

DECISION POINT

Understand context	What type of soil does the farmer have?			
Soil type	Clay soils	Sandy soils	Silty soils (relatively fertile soils)	Loamy soils (gold standard in soils)
Soil amendment goal	Improve drainage, permeability and aeration	Increase moisture-holding capacity Increase nutrient storage/reduce leaching	Reduce possibility for compaction	Maintain soil texture
Possible Climate Smart Soil Amendment Options	Add compost Green manure Vermiculture	Add compost Green manure Biochar	Add organic matter Monitor irrigation closely	Add organic matter

Understanding the local context is critical in any climate smart decision. To make climate smart decisions on soil amendments for maize and sorghum, it is vital to understand the soil type and the soil amendment goals of the farmer.

Swathi Sridharan, 2015

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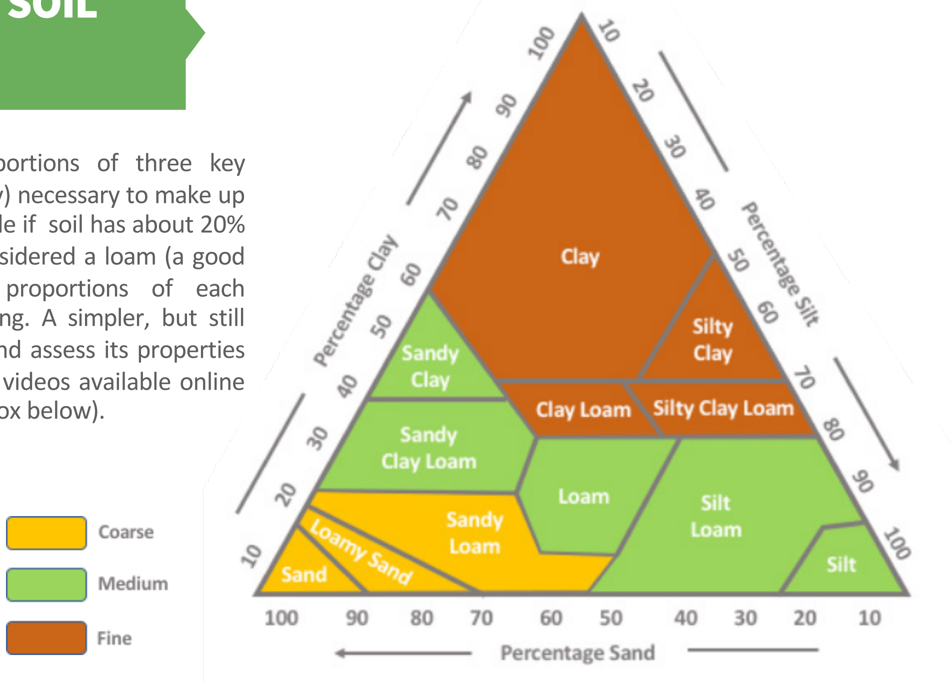
START WITH THE SOIL TRIANGLE

The soil triangle depicts the proportions of three key components of soil (sand, silt and clay) necessary to make up any of the main soil types. For example if soil has about 20% clay, 80% silt and 50% sand, it is considered a loam (a good soil type). Assessing the exact proportions of each component requires laboratory testing. A simpler, but still accurate method is to wet the soil and assess its properties using your fingers. There are several videos available online which show you how to do this (see box below).

Figure 1: The soil texture triangle.



If you are unsure of what type of soil you have, there are lots of videos to help you...

How to test your soil - texture (sand, silt, clay composition)
Central West Local Land Services
June 22, 2014

Soil texture by feel
UCDavisIPO
Sep 1, 2010

UNDERSTAND RAINFALL/ TEMPERATURE TRENDS

The next step is to assess the timing, duration and intensity of rainfall, and periods of high/low temperatures (see KP02 and KP03 on rainfall and temperature requirements for maize and sorghum). If rainfall data is available from a local weather station, this will be very useful. If not, then a discussion with a group of farmers will help provide information to support decision making. It is important to discuss with your farmers how (if) this has changed over the past 5–10 years.

- What do farmers currently do to cope with shortages of rainfall (if anything)?
  - Has this changed over time?
  - How does this affect women and men differently?
  - What are their strategies?

- What do farmers currently do to cope with excessively high/low temperatures during the growing season?
  - Has this changed over time?
  - How does this affect women and men differently?

Understanding the soil type and local climate trends will enable you to make climate smart decisions on what type of soil amendment might be suitable. For example, if the farmer has clay soils and is experiencing more intense rainfall events – resulting in excessive runoff and soil compaction due to limited soil moisture retention – she may want to improve soil aeration and water infiltration (reduce runoff).

Coping with less rainfall or increased heat can severely impact the different daily schedules of men and women, depending on who is in charge of certain tasks such as fetching water, for example.

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DETERMINE SOIL pH

Once we know the soil type and rainfall and temperature trends, the farmers' goals and the coping strategies of men and women, the next step is to analyse soil pH.

Reduced rainfall levels with increased temperatures cause an increase of the soil's pH. Excess rainfall leads to reduced nitrogen and carbon levels, and a more acidic pH.

Ensuring soil pH is at the optimum level for your crop will greatly increase the nutrient-use efficiency of the crop, and will maximise potential yield.

Table 2 lists the optimum soil pH levels for sorghum and maize compared with millet.

Source: FAO

Table 2: Soil pH ranges for maize and sorghum.

Crop	Optimum pH	pH Range*
Maize	6.0 – 7.5	5.5 – 7.5 **
Sorghum	6.0 – 7.5	5.5 – 7.5
Millet	6.0 – 7.0	5.0 – 8.0

** Outside these ranges production is severely impacted*

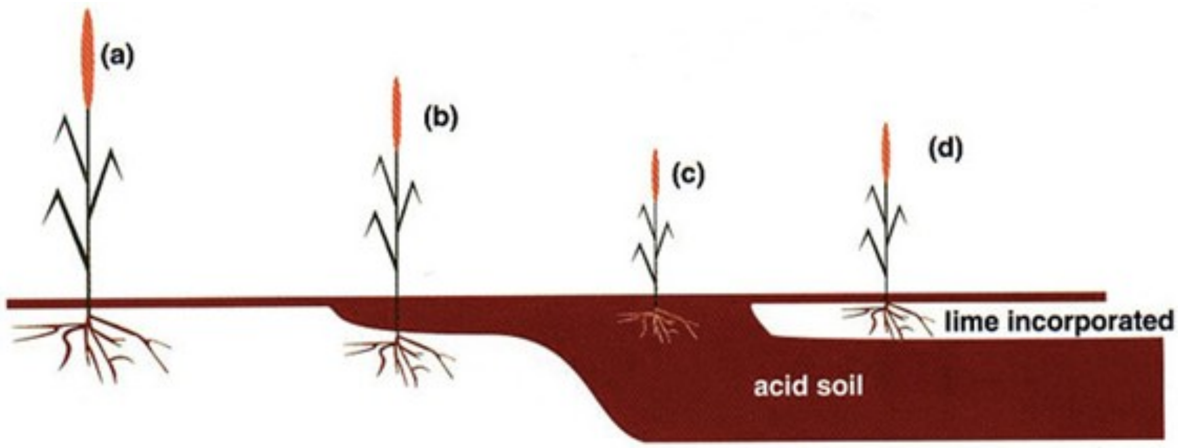
*** Some cultivars may have higher tolerances.*

Testing soil pH is very simple. Litmus paper and a colour chart are most often used and are quite accurate. There are many short videos available online, illustrating how to simply test soil pH in the field or at home (see box below).

FAO: 'How to measure soil pH' video.

Figure 2 illustrates the effect of subsoil acidity on acid-sensitive plants such as maize and sorghum, where (a) has grown well because the soil pH is only slightly acidic; (b) has struggled through an acidic topsoil and is stunted by the time it gets to the subsoil, but should persist; (c) is growing very poorly due to the acidic topsoil and the acidic subsoil and will not be expected to last; and (d) has had lime incorporated and so is establishing itself, but will run into trouble when the roots reach the acidic subsoil.

Figure 2: The effect of subsoil acidity on an acid-sensitive species (e.g. maize or sorghum).



Source: Reproduced from NSW Agriculture Agfact AC19 'Soil Acidity and Liming', 1996

This highlights the importance of knowing both topsoil and subsoil pH levels before making decisions on the application of soil and amendments.

Soil pH levels across the SADC region are often very low. If this is not addressed, the time and money in applying other soil amendments can be wasted. Table 3 illustrates fertiliser use efficiency under different soil pH conditions.

Table 3: Fertiliser use efficiency at different soil pH levels.

Soil Acidity	Nitrogen	Phosphate	Potash	Fertiliser Wasted
Extremely Acid – 4.5 pH	30%	23%	33%	71.34%
Very Strong Acid – 5.0 pH	53%	34%	52%	53.67%
Strongly Acid – 5.5 pH	77%	38%	77%	32.69%
Medium Acid – 6.0 pH	89%	52%	100%	19.67%
Neutral – 7.0 pH	100%	100%	100%	0%

Source: Mosaic Crop Nutrition (http://www.cropnutrition.com/efu-soil-ph)

Adding organic matter to the soil will help raise low pH levels closer to the neutral pH 7.0, and year-on-year application will help stabilise soil pH. However, if pH is particularly low (<5.5) it is advisable to add lime if possible.

Application of lime

Application rates of several tonnes per hectare is often recommended for altering soil pH levels. Even though the cost of lime is generally quite low, its bulk and cost of transportation are often prohibitive for smallholder farmers.

Where it is accessible, it may only be accessible in bulk form, which a smallholder farmer is unlikely to be able to transport on their own.

- To minimise costs, 'spot application' at a rate of about 0.5 tonnes/ha is recommended
  - The farmer can start with a small area of their fields and expand in future seasons
- Lime should be applied about 3 months before planting, to maximise impact in the first growing season
- Application at planting time will save on labour, but the response may be limited in the first season
- Lime needs to be mixed well into the topsoil for maximum efficiency. If the farmer is planting using basins/Zai pits, spot application and mixing into the soil is relatively easy and can be done when applying compost.

The most common method for increasing very low pH levels is to apply lime. Depending on the resources available to your farmer, this may not be an option. Other options are:

- Adding organic matter
- Using crushed seashells if available.

Each type of lime has a different response rate and timeline. The general rule of thumb is that the smaller the 'mesh size' or the finer the grade of lime applied, the quicker it will become available to the crop. It is important that farmers understand this. Where field trials are being conducted, they should span multiple years. This is especially the case if lime is applied at planting time, as its effects may not be felt until the second season. Table 4 illustrates the response rates (%) of crops to the application of different particle sizes of lime after one year and four years. Larger mesh sizes can be cheaper and easier to access but take longer to show results.

Table 4: The response rates (%) of crops to the application of different particle sizes of lime.

Particle Size	Within 1 Year of Application	Within 4 Years of Application
Greater than 8 mesh	5	15
Between 8 and 30	20	45
Between 30 and 60	50	100
Smaller than 60 mesh	100	100

Source: Mosaic Crop Nutrition (http://www.cropnutrition.com/efu-soil-ph)

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DECISION POINT

The influence of soil pH on the selection of climate smart soil amendment options.

Understand Context	Test Soil pH		
pH	<5.5	5.5 - 6.5	>6.5
Climate Smart Soil Amendment Options	Add lime + organic matter	Add organic matter Add lime if you can afford it	Add organic matter and retest every few years

TIP

It is always advisable to test different application rates to find out which is the optimum in the local context. Remember, when establishing farmer trials, to keep all other variables (seed type, time of planting, fertiliser application, weeding etc.) the exact same and to only change the lime application rate. Field trials should be multi-year – especially if lime is applied at planting time – as yield responses in year -one may be minimal. Ensure that new tasks do not conflict or overburden the roles and responsibilities of men and women.

Georgina Smith, CIAT, 2016

SOIL NUTRIENTS

Changes in rainfall and temperature affect the availability of nutrients in the soil. Access to soil testing laboratories is likely to be limited. If this is an option, then it provides a more accurate assessment of the nutrient status of the soil. In the absence of a laboratory soil test, observations of sorghum and maize during their growth stages will assist you in making decisions on which nutrients are required to improve the soil. Figure 3 is a guide to nutrient deficiency symptoms in maize and sorghum.

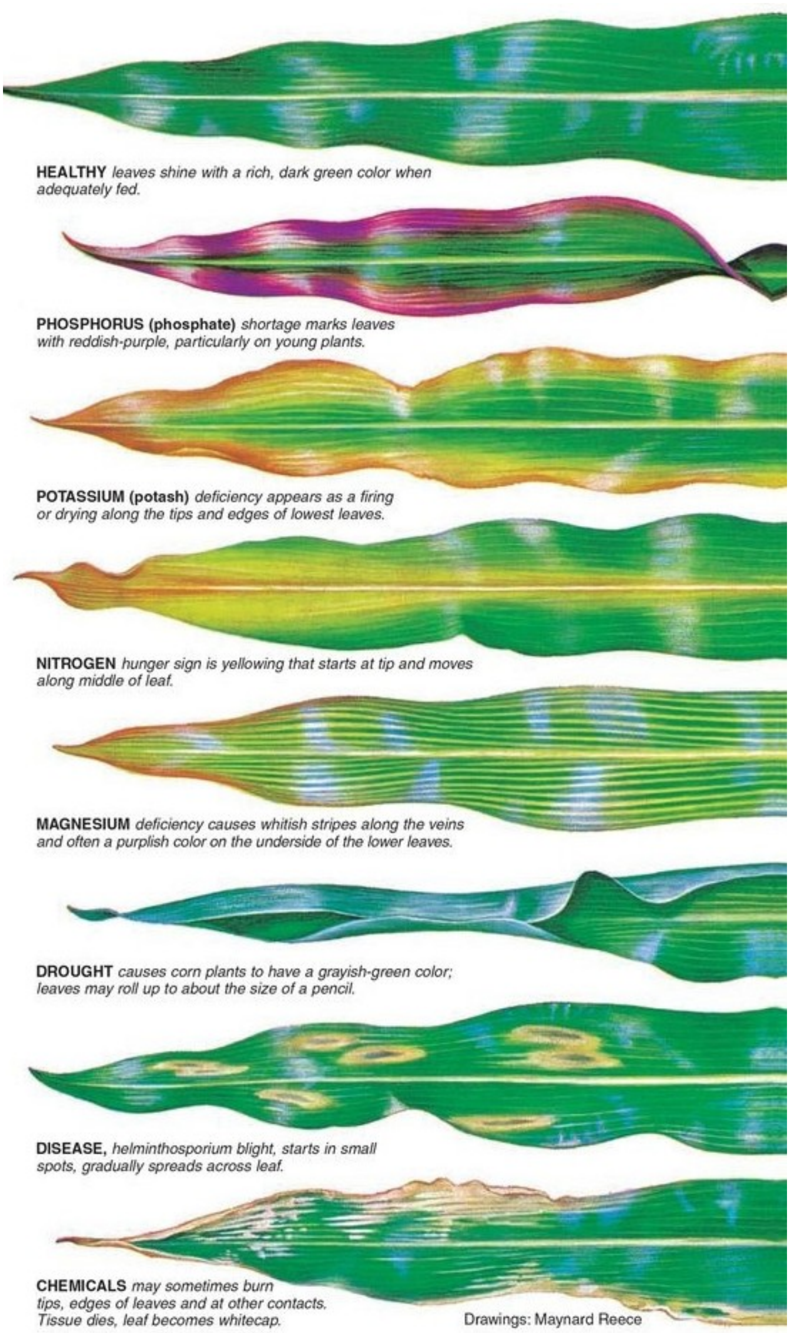

Figure 3: Examples of nutrient deficiencies in maize and sorghum leaves.

Source: www.omafra.gov.on.ca

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If you are unsure about what type of nutrient deficiency your sorghum/maize might have, check out these apps that can be downloaded on your smart phone/tablet. These are just two examples you might find useful. There are many more apps that you might find useful in your day-to-day work. Many of these can be found on a website called Apps4Ag.

Crop Nutrient Removal Calculator
International Plant Nutrition Institute
Free

Crop Nutrient Deficiency Photo Library
International Plant Nutrition Institute
Free

Inorganic fertilisers (also known as compound fertilisers) contain high volumes of the major plant nutrients, the three most common being:

- Urea – high in nitrogen (N)
- CAN – calcium ammonium nitrate; high in N
- NPK – nitrogen/phosphorus/potassium.

Different ratios of all three nutrients are available in different countries, depending on the predominant soil conditions.

Organic soil amendments contain essential plant nutrients and have the added benefits of improving soil structure and increasing microbial activity, which help make nutrients more available to plants. See KP21 for more on climate smart fertiliser application options.

- Green manure
  - Dark green leafy material is high in N
  - Legumes can help fix N in the soil
- Compost
  - Varying amounts of N, P & K depending on ingredients and method used
- Animal manure
  - Chicken manure high in N
  - Protecting manure from sunlight and rainfall will help maintain higher levels of N (See KP16 – Climate Smart Manure Management Options).

Some common organic sources of nutrients (nitrogen, phosphates, potassium and calcium oxides) are detailed in Table 5.

Table 5: Typical nutrient concentrations (%) of animal manures.
(Source: Integrated Soil Fertility Management in Sub-Saharan Africa)

Manure	Water	N	P_2O_5	K_2O	CaO
Farmyard manure	38–54	0.5–2.0	0.4–1.5	1.2–8.4	0.3–2.7
Cattle dung	34–40	1.7–2.0	0.5–3.7	1.3–2.5	0.9–1.1
Sheep and goat droppings	40–52	1.5–1.8	0.9–1.0	1.4–1.7	0.9–1.0
Pig manure	35–50	1.5–2.4	0.9–1.0	1.4–3.8	1.3–1.5
Poultry manure	10–13	2.3–2.5	2.3–3.9	1.0–3.7	0.6–4.0
Compost manure	49–52	0.5–1.7	0.3–0.5	5.0–7.4	4.6–5.4

N=nitrogen, P_2O_5=phosphate; K_2O=potassium oxide; CaO=calcium oxide
Source: (Kaola, 2001)

Organic + Inorganic Inputs (Manure/Compost + Fertiliser)

The multiple benefits of adding organic matter such as compost are that it:

- Feeds microorganisms and macro organisms that maintain a healthy soil food web
- Enriches soil with nutrients for plant growth
- Releases nutrients slowly so they don't leach away
- Promotes drainage and aeration in clay soil
- Enhances moisture and nutrient retention in sandy soil
- Reduces soil compaction
- Inhibits erosion
- Attracts earthworms, nature's best soil builders.

For these reasons, the addition of compost or other organic material is almost always recommended – unless the organic matter content is already high.

If the farmer wants to achieve maximum yields, inorganic fertiliser will likely be required. However, the proportion of fertiliser added that gets used by the plants may be very low if soil conditions are not right. Organic matter in the soil will help increase fertiliser efficiency. For this reason, if maximum yields are required, both organic and inorganic fertiliser are almost always recommended to be applied on the same plot.

Testing different application rates, the types of fertilisers, and combinations of organic and inorganic is recommended. At a minimum, four trial plots should be conducted:

1. Plot with no organic or inorganic amendments
2. Plot with inorganic only
3. Plot with organic only
4. Plot with both organic and inorganic.

You may also wish to trial different types of organic and inorganic applications, but it is advisable to keep the trials simple in the first season and adapt them in later seasons.

DECISION POINT

Analysing soil pH and nutrient deficiencies in the soil will help you make decisions on which climate smart soil amendment option will give the best results for your farmers.

Understand context: What nutrients do you need? Laboratory analysis or field observations

Nutrients required	Low in nitrogen		Low in N, P and K	
Soil pH	<5.5	5.5–7	<5.5	5.5–7.0
Possible Climate Smart Soil Amendment Options	Add lime (if possible) Add compost and or green manure high in N Introduce legumes in rotation	Add compost and/or green manure Introduce legumes in rotation Add Urea or CAN if possible	Add lime (if possible) Add compost and/or green manure Introduce legumes in rotation	Add compost and/or green manure Add compound fertiliser

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Integrated Soil Fertility Management (ISFM)

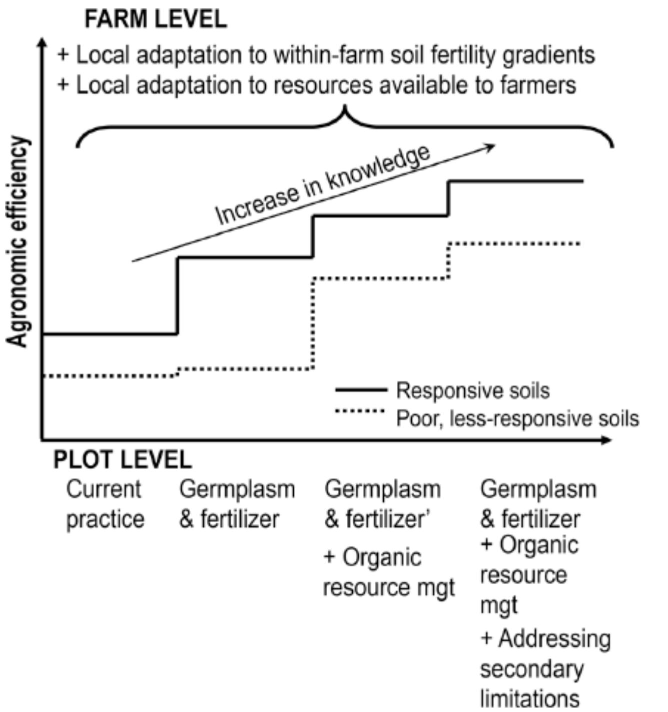
ISFM is a set of soil fertility management practices that includes the use of:

- Fertiliser
- Organic inputs
- Improved germplasm (seeds) adapted to local conditions.

ISFM aims to support the efficient use of fertiliser and organic resources, coupled with other climate smart agronomic practices such as planting improved varieties with appropriate spacing and timing, and good control of weeds, insect pests and diseases. Dynamic crop growth is associated with an extensive and vigorous root system capable of the efficient uptake of soil nutrients and water. The full benefits of ISFM may be achieved in a stepwise fashion, as farmers learn to best adapt and integrate potential components and gain access to financial resources for higher levels of management.

Figure 4 shows how ISFM requires farmers to adapt their practices year-on-year as they gain more understanding of what does and what doesn't work in their own context. Results will be better in responsive soils.

Figure 4: ISFM requires farmers to adapt their practices year-on-year.



ASHC, 2012

TIP

Remember, when establishing farmer trials, to keep all other variables (seed type, time of planting, weeding etc.) exactly the same. The highest possible yield is not always the most profitable for the farmer. Gross Margins should always be calculated to assess the return on investment so that the most profitable option is clear.

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OTHER ON-FARM CONSIDERATIONS

There are a substantial number of variables in the local and household context of the farmer that may affect their ability to implement climate smart soil amendment solutions for their maize and sorghum crops. As an extension provider, it is important to understand these and to work within these constraints.

Some of these might be:

- How many cropping cycles are there on the same piece of land in a year and what, if any, is the rotation?

- Does the farmer own or rent the land?
  - Many farmers, especially those in female-headed households, do not actually own the land they use and may be unwilling to invest in soil amendments that will take several seasons to demonstrate results, or which may result in male relatives coming back to claim the more fertile land

- Does the farmer require an immediate return in terms of production or reduced inputs, or are they willing to wait for the benefits?
  - A food-insecure household aiming for food security may have different priorities to a farmer who is already food secure, and aiming at growing a cash crop

- Is inorganic fertiliser/lime available and accessible locally?
  - Men and women may have different levels of access to these inputs

- What organic materials are available locally to make compost and is there a financial/labour cost in accessing these?

- Is biochar an option if there is already extensive deforestation and crop residues are required for feeding livestock?

- Is there enough residual moisture for green manure crops?

- Are fields left open to grazing animals after harvesting, and how might this effect the planting of green manures?

- Who is responsible for the actual labour involved in each of the climate smart soil amendment options being recommended?
  - Will labour need to be hired?
  - Will additional tasks put a too big a burden on either men or women?
  - Will the solution require children to be kept home from school?

It is vital to obtain a deep understanding of the local agricultural and household context, so that appropriate recommendations can be made. In some instances, it may be recommended to change from maize to sorghum, or even to millet, or another crop altogether depending on local conditions and weather trends over the previous years.

TIP

Improving the soil is almost always going to be a sensible climate smart solution in the medium to long term, but it may not always be the most effective short-term solution. For example, a farmer in a single-headed household with small children that wants to achieve food security for her family by increasing production by 10%, may find the most effective solution to be improving post-harvest storage practices. This might be cheaper (in terms of immediate labour and input costs) than making compost and applying it with micro-dosed fertiliser during land preparation.

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TO SUMMARISE

STEP 1: Consider Your Soil

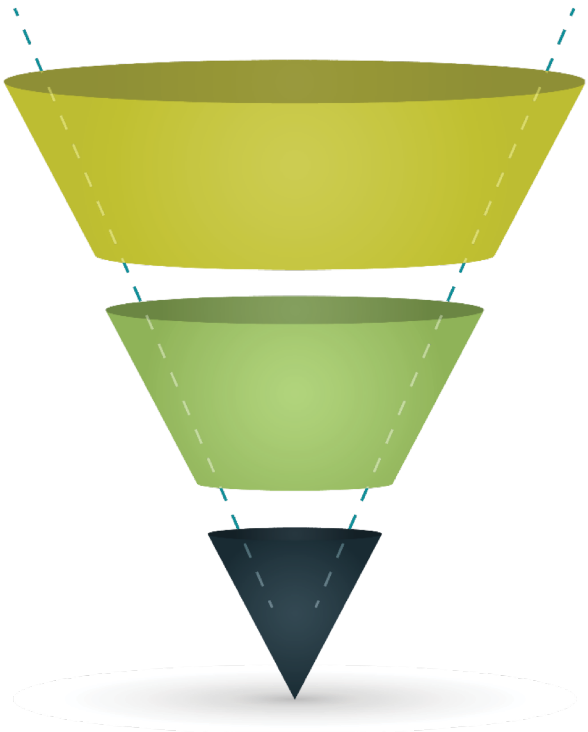
- Texture
- pH
- Nutrient status

STEP 2: Identify the Farmer's Goal

- Food security
- Cash crop
- Grain/fodder

STEP 3: Explore the Local Context

- Availability & accessibility of fertiliser/organic inputs
- Land ownership
- Climatic conditions and seasonal trends.



Always test different climate smart solutions with farmers and let them discuss which one is best suited to their conditions.

WHERE CAN I GET MORE INFORMATION?

The following resources, which were used as reference for the development of this Knowledge Product, provide valuable additional reading on this subject. Please also refer to the CCARDESA website (www.ccardesa.org), the full series of Knowledge Products, and associated Technical Briefs.

- Also refer to CCARDEDSA KPs 7, 8, 9, 10,12, 16 & 19 for more detail on specific climate smart practices and technologies included within Integrated Soil Fertility Management.
- Food and Agriculture Organisation of the United Nations (FAO) – On Farm Composting Methods; Land and Water Discussion Paper 2
  - A detailed guide on how to make different types of compost. Chapter 2 is especially relevant to smallholders
- Institute for Sustainable Development (ISD) – How to Make and Use Compost
  - A detailed practical guide on compost making and use
- FAO – Green manure cover crops and crop rotation in conservation agriculture on small farms: Integrated Crop management Vol 12, 2010
  - Focused on Paraguay and a bit scientific in places, but covers all the principles behind the practices
- African Soil Health Consortium (ASHC) – Handbook For Integrated Soil Fertility Management
  - An excellent resource that every extension officer should have access to
- ASHC – Sorghum and Millet Nutrient Management
  - A very practical resource for anyone growing sorghum or millet
- ASHC – Maize-Legume Cropping Systems
  - A practical guide to growing maize and legumes. Excellent resource for extension staff in the field
- ASHC – Sorghum-Legume and Millet-Legume Cropping Systems
  - A practical guide to growing maize and legumes. An excellent resource for extension staff in the field
- International Centre for Tropical Agriculture (CIAT) – Impact of Conservation Agriculture on Soil Health
  - A very useful infographic/poster that relates to soil health in general, not just conservation agriculture.

Citation: CCARDESA and GIZ 2019. Knowledge Product 06: Climate smart soil amendment options for maize & sorghum. CCARDESA Secretariat, Gaborone, Botswana.