

4

Keeping the soil
healthy

Many of Africa's soils are sick. Yields in many places have fallen over the last 20 years. Fields that used to produce 20 bags of maize might now produce less than 10 bags.

Many farmers face crop failure, and their families are hungry. Countries that used to export maize now depend on food aid.

Conservation agriculture can make these soils healthy again. And if the soils are healthy, yields will go up. Farmers will be able to feed their families and have extra to sell.

What makes soils hungry and sick?

Virgin soils under forest, bush or grasslands have a lot of organic matter. This rich, black material has built up over many years. It is very fertile. When farmers clear the natural vegetation, they at first get very good yields.

But ploughing the land and removing the crop residue leaves the land bare. The plant nutrients are washed away. The fine particles, clay and valuable organic matter are eroded first, leaving a poor, hungry soil ([Photo 17](#)).

When the soil is turned, the organic matter decomposes quickly. It turns into lifeless minerals or into carbon dioxide gas, which disappears into the air. Within 10 years after opening virgin land, more than half the organic matter is lost.

Which would you prefer?

Three bags of maize from your acre of land.

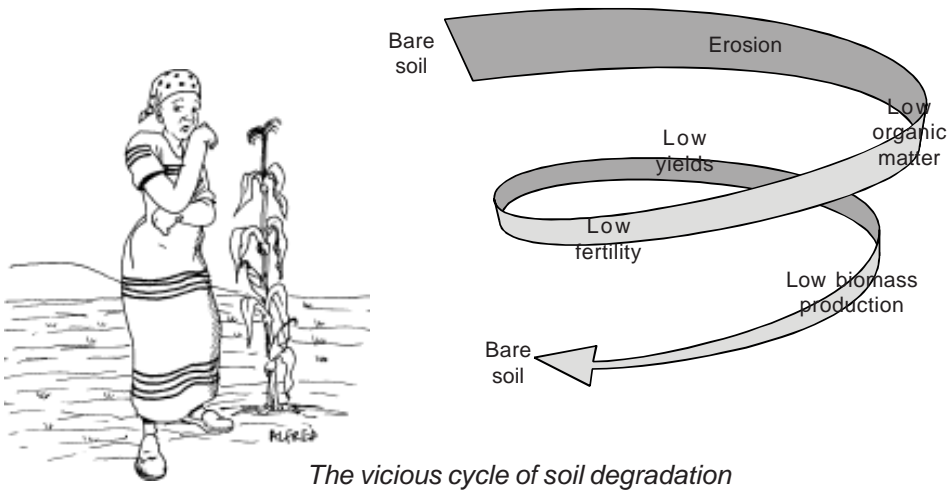
Or 22 bags?

Farmers in Lesotho harvest just three bags of maize per acre: 375 kg per hectare. They plough their fields with oxen or with tractors. They plant the same crop year after year. The soils are poor, compacted and eroded. And three bags are all they can harvest. People are leaving the land because they cannot make a living.

But if they manage their soil well, the same farmers can produce 22 bags of maize per acre – or 4 tons per hectare. By using conservation agriculture – avoiding ploughing, keeping the soil covered, and rotating crops – they can rebuild their soil fertility. The soil will repay them many times over with higher yields, year after year.

Of course, not all farmers can get such dramatic increases – but some can! Worth a try?





Organic matter holds onto water and plant nutrients. Once the organic matter is gone, the water drains away or runs off easily. Nutrients are washed deeper down into the soil, where plant roots cannot reach them.

Earthworms, termites and other tiny animals normally make burrows in the soil and break down the organic matter into simpler forms that plants can use. But they cannot live if there is no organic matter. Without them, the soil becomes hard and lifeless.

Ploughing destroys the soil structure. Below the ploughed layer, a hardpan develops. Crop roots cannot push through this hard layer, so they cannot reach water and nutrients beneath it. The shallow layer above the hardpan dries out quickly during dry spells, so the crops go thirsty too.

The soil has become seriously sick. It has lost its ability to produce a good crop.

What makes a soil sick?

- “Mining agriculture”: farming for many years, taking away nutrients without giving any back to the soil
- Soil erosion
- Loss of organic matter
- Loss of soil life
- Breakdown of soil structure
- Compaction of the soil
- Bare soil exposed to the rain and sun

What effects does a sick soil have?

- Low crop yields
- High levels of inorganic fertilizers needed to produce a good crop
- Crops are short and stunted
- Bare soil
- Yields vary widely from year to year.
- Yields tend to fall year after year

How to tell your soil is sick

You probably already know if your soil is sick. Here are some things to look for:

Organic matter	Is the topsoil colour lighter than it used to be?	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
Soil structure	Does the soil feel hard? If you press a piece of soil in your hand, does it break apart completely?	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
Runoff	Are there rills caused by water on the soil surface? On flat ground, does water take a long time to seep into the soil?	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
Soil moisture	Does the soil get dry quickly after a good rain?	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
Soil life	Do you rarely see earthworms or beetles?	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
Crops	Do the crops look unhealthy? (yellowed leaves, purple stripes, poor growth)	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
Yields	Are your yields falling year after year?	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
Roots	Are the crop roots stunted? Are they shallow? Do the taproots bend sideways rather than going straight down?	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
Weeds	Are there a lot of the type of weeds that like to grow on infertile soil? Especially woody weeds and <i>Striga</i> ?	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>

If you answered **Yes** to any of these questions, your soil may be sick.

Organic matter

A healthy soil has a lot of organic matter. Organic matter provides a home and food for earthworms and other beneficial soil organisms. It binds soil particles together and improves the soil structure. It helps the soil hold water. It improves the soil fertility and leads to higher yields.

*Conservation agriculture
aims to keep the soil alive*

A healthy soil is a living soil. It must be full of earthworms and other soil organisms. These organisms loosen the topsoil better than a hoe or a plough. They break up dead leaves and stalks, carry it down into the soil, and mix it in. They speed up the decomposition of organic matter and release of plant nutrients. They compete with harmful organisms that may cause crop diseases.

How fast the organic matter **breaks down** depends on three things:

- **Soil organisms:** animals (earthworms, beetles, termites, other insects), microorganisms (bacteria and fungi too small to be seen with the naked eye), and plants. (If there are many of these organisms, the organic matter will decompose quickly.)
- **The physical environment:** the soil texture, temperature, moisture and air. (Organic matter decomposes slowly if the soil is dry, for example.)
- **Quality of organic matter:** Woody stems and waxy leaves break down slowly.

The soil can **lose organic matter** in several ways:

- It is broken down into minerals and carbon dioxide gas. This happens quickly if the soil is turned over by ploughing and if it is exposed to the sun and rain.
- Erosion: it is washed away by water, or carried off by wind.
- It is carried out of the field as crops or fodder.

What is a healthy soil?

A healthy soil is a living soil.

- It has many different animals in it: earthworms, beetles, and many tiny animals that are so small they cannot be seen with the naked eye.
- It is high in organic matter.
- It is rich in nutrients that plants can use as food.
- It is deep enough for plant roots to grow properly.
- It has a mixture of fine (clay) soil particles and coarse particles (sand and silt).
- It contains lumps and clumps of different sizes.
- The surface does not seal after rain.



A healthy soil has lots of organic matter, earthworms and other tiny animals in it.

You can do many things to **prevent organic matter from being lost**:

- Don't plough or hoe.
- Use mulch or a cover crop to protect the soil from sun and rain.
- Prevent erosion: plant along the contour, use bunds and microcatchments, etc.
- Don't take the crop residues out of the field. Leave them on the ground.
- Do not allow animals to graze on the field.

You can **add to your organic matter bank** in several ways:

- Leave crop residues in the field.
- Plant cover crops.
- Bring in mulch from outside.
- Add compost and manure.

Making the soil healthy again

Fortunately, it is possible to make a sick soil healthy again. Here are the steps:


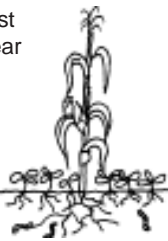

- 1 If your soil has a hardpan, **break it with a subsoiler**. This allows water to sink into the soil, and lets crop roots reach nutrients and water deeper in the soil.
- 2 **Stop ploughing** and hoeing the soil. Instead, you can use a hoe to make planting basins, open planting lines with a ripper, or plant directly using a jab planter.
- 3 **Do not remove crop residues**, and do not allow animals to graze on them. Leave them on the ground so they protect the soil and add to the organic matter.

How to tell if your soil is getting healthier

Here are some things to look for:

Organic matter	Is the soil getting darker?	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
Soil structure	Is the soil getting softer underfoot? Is it easier to work?	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
Runoff	Does rain soak into the soil quickly? Rain infiltrates fast and water does not stay on the surface	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
Soil moisture	Does it stay moist for longer after rain?	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
Soil life	Does the soil have many earthworms? Are there many holes in the soil, and worm casts on the surface?	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
Crops	Do your crops look vigorous and healthy?	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
Yields	Are crop yields improving?	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
Roots	Do the crop roots grow well? Are taproots deep and straight?	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
Weeds	Are there the type of weeds that like to grow on fertile soil?	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>

If you answered Yes to these questions, congratulations! Your soil should be getting healthier.

	Conventional tillage, no cover crop	Conservation agriculture, lablab and maize stover	
Number of worms in 1 m ²	 <p>1 worm</p>	<p>1st year</p>  <p>12 worms</p>	<p>After 3 years</p>  <p>28 worms</p>

Karatu District, northern Tanzania. Source: TFSC/SARI, Arusha

Using conservation agriculture can increase number of earthworms and other small animals in the soil very quickly

- 4 **Keep rainwater in the field** When it runs off, the water carries plant nutrients and organic matter with it. Build microcatchments or bunds along the contour to prevent it from running away.
- 5 **Add organic matter** and plant nutrients: compost, manure, mulch brought in from outside the field, and inorganic fertilizer.
- 6 **Plant cover crops** to protect your soil and produce more organic matter. If your soil is compacted, you can loosen it by planting strong-rooted cover crops such as pigeonpea or sunn hemp ([see Chapter 5](#)).

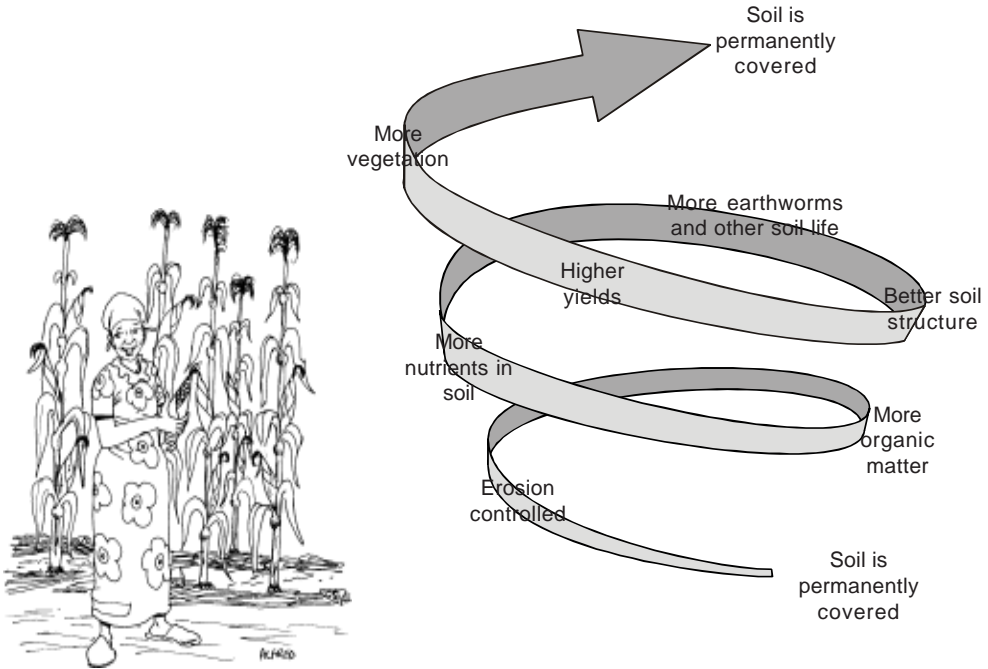
Keeping the soil healthy

It is not enough to apply inorganic fertilizer to keep the soil healthy.

In conventional farming, it is necessary to apply more and more fertilizer to get the same yield.

Conservation agriculture, on the other hand, produces more yield for the same amount of fertilizer. It does this because the soil structure is better and there is more organic matter. Crop roots can go much deeper, and more water can sink into the soil. There are more living organisms to recycle organic matter and make plant nutrients available.

Conservation agriculture keeps the soil healthy. Only a healthy soil can produce a good yield.

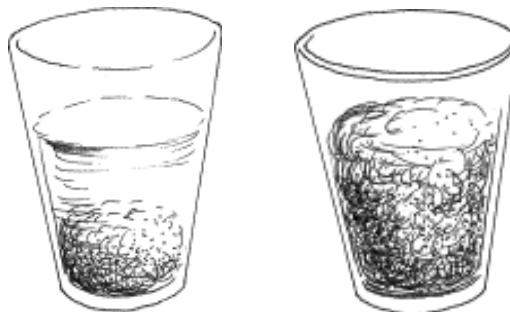


Recycling of organic matter and plant nutrients keeps the soil healthy

How rich is your soil?

Here's one way to check the organic matter in your soil.

- 1 Take a handful of soil from a field that has been ploughed for several years. Put it in a glass of water.
- 2 Now take a handful of the best soil you can find – a soil full of organic matter. Put it in another glass of water.
- 3 Compare what you see in the two glasses.



Many worms make light work

Earthworms are the farmer’s best friend. They break down organic matter into simpler materials that plants can use. They mix organic matter into the soil, and they help bind soil particles together, improving the soil structure. Their burrows allow water and air to get into the soil. They also allow roots to penetrate the soil easily.

Organic matter is food for earthworms. If there is a lot of organic matter, earthworms can multiply. The more worms, the healthier the soil.

Let earthworms till the soil. They do it better than a plough or hoe.

Important plant nutrients

Plants need many different types of nutrients. The most important are nitrogen (N), phosphorus (P) and potassium (K) (see the table below).

Soil nutrients and why they are important

	Nitrogen (N)	Phosphorus (P)	Potassium (K)
Why important	Helps plants grow	Helps plants produce roots, flowers and grain	Helps plants resist disease
Problems caused in maize if not enough of this nutrient	Maize leaves are pale green or yellowish Plant is stunted and leaves are small Tips of leaves are yellow Ears are small and kernels are not filled	Leaves are purplish Roots are few and short Ears are short and twisted, with under-developed kernels	Browning or bronzing and scorching of leaf edges Plant is stunted, with nodes on stem close together Tips of ears are poorly filled
Organic fertilizers with this nutrient	Animal manure Compost Mulch Legumes (intercrops, rotations, cover crop, mulch, compost)	<i>Tithonia diversifolia</i>	
Inorganic fertilizers with this nutrient	Urea Ammonium nitrate Calcium ammonium nitrate (CAN) Ammonium sulphate Diammonium phosphate (DAP) NPK	Single superphosphate (SSP) Triple superphosphate (TSP) Rock phosphate (RP) Diammonium phosphate (DAP) NPK	Muriate of potash (KCl) Sulphate of potash (K ₂ SO ₄) NPK

Organic fertilizers

There are many different types of organic fertilizers:

- **Crop residues**
- **Cover crops**
- **Mulch** brought in from outside
- **Animal manure**
- **Compost**

Only a living and healthy soil can produce a good crop

Organic fertilizers have two big advantages: they add organic matter to the soil directly, and they are free! You can grow or make them yourself. If you have more than you need, you can also sell them to your neighbours.

Unfortunately, most organic fertilizers do not contain much phosphorous. Plants need this nutrient to grow. You can improve the quality of organic fertilizer by adding plants that are high in phosphorus, or by adding phosphate fertilizer ([see page 75](#)).

Crop residues, cover crops and mulch

Keeping a permanent soil cover is a good way to replenish the organic matter in the soil. You can use various types of cover:

- **Crop residues** The stalks and leaves of crops are good as mulch. Stover from maize and sorghum breaks down slowly, so stays on the surface for a long time and protects the soil. The stalks and leaves of legumes are rich in nitrogen and break down quickly, so the nutrients can soon be used by the following crop.
- **Cover crops** Plant these when they fit in your cropping system and allow them to grow and cover the soil. Slash them or kill them with herbicide just before planting the next crop and leave the dead material on the ground as mulch. Leguminous cover crops are especially valuable because they fix nitrogen from the air and make it available for other crops.
- **Grasses and weeds** You can cut grasses and weeds from the edges of the fields or from outside. Spread them on the soil as mulch. Do not bring in vegetation that contains seeds, as you will spread weeds.
- **Prunings from shrubs and trees** You can trim branches and use them as mulch. You can harvest the branches at any time during the year. Leguminous trees and shrubs are high in nitrogen.

Some plants decompose quickly, while others break down more slowly. Try to use several different types of materials to get the best combination of soil cover and decomposing vegetation when you need it.

[See Chapter 5](#) for more information on crop residues, cover crops and mulch.

Animal manure

Animal manure makes good-quality fertilizer. Leave it to decompose before applying it to crops, as it will “burn” the plants if it touches them.

Poultry droppings make the best manure, followed by goat droppings, then sheep and cattle dung.

Animals fed on good-quality feed produce the best-quality manure.

Compost

You can make compost from leaves, weeds, manure, ash, kitchen waste, and any other organic material available.

Try to use materials that rot easily, such as grass and leaves. Woody materials such as tree branches and maize stalks, and shiny leaves such as eucalyptus, do not make good compost.

You can make compost in a pit (best in areas with low or medium rainfall), or in a pile (best in high-rainfall areas).

Nutrients in animal manure and green manure

Type of manure	Kilograms of nutrients in 1 ton of manure		
	Nitrogen (N)	Phosphorus (P)	Potassium (K)
Poultry manure	48	18	18
Goat manure	24	7	14
Sheep manure	13	5	6
Cattle manure	13	2	15
Tithonia (wild sunflower) (dried)	33	2.6	33

Inorganic fertilizers

There are many different types of inorganic fertilizers. They contain nitrogen (N), phosphorus (P) or potassium (K), or some combination of these three nutrients. They may also contain other nutrients that plants need in smaller amounts. If you know what nutrient your soil needs, you can choose the right type of inorganic fertilizer that provides that nutrient ([see the table on page 72](#)).

Making compost, Swazi style

There are many ways to make compost. Here is how farmers in Swaziland do it.

- 1 Choose a shady place under a tree or a thatched roof to protect the compost from the sun and rain.
- 2 Push four sticks (1.5 m long) into the ground, one at each corner of where you want to make your compost pile. Push in a fifth stick in to mark the centre of the pile.
- 3 Start the pile with a layer of sticks or maize stalks, 30 cm thick. This layer lets air circulate in the pile.
- 4 Add a layer of dry grass or other vegetation. Make this layer about 10 cm thick.
- 5 Add a layer of manure, also about 10 cm thick.
- 6 Add a layer of dry straw from legumes, also about 10 cm thick.
- 7 Sprinkle a thin layer of ash on top.
- 8 Add more layers of grass, other vegetation, manure, straw and ash until the pile is about 1.5 m high – as tall as the sticks. A well-made compost pile has almost vertical sides and a flat top.
- 9 Cover the pile with a layer of topsoil.
- 10 Water the pile about three times a week. If it has been raining, you do not need to water it.
- 11 After 4 weeks, turn the pile over to mix the different layers. Do not add any fresh materials. Water the pile for another week, then leave it for 6 weeks.
- 12 After the 6 weeks, the compost is ready for use.

Fortified compost in western Kenya

Some farmers in western Kenya have learned how to make “fortified compost”. They add a little rock phosphate (about 2–5 kg) to the compost pile, or leaves and stems of the wild sunflower (*Tithonia diversifolia*).

Tithonia decomposes very fast. It contains high levels of nitrogen and potassium, and a reasonable amount of phosphorus ([see the table on page 74](#)). It is common in western Kenya, and is found on roadsides and farm boundaries.

Lantana camara, *Vernonia* and *Acanthus* are also good compost fortifiers.

The farmers say that carrying these materials to the compost pile takes some work, and some are hard to harvest because they are thorny.

Compost in conservation agriculture

“In our farm, we practise conservation agriculture. We intercrop maize and beans. We introduced a cover crop by planting lablab between the maize and beans rows. Since lablab forms a big canopy, we plant at a wider spacing. At harvest time, we cut the maize with a *panga*, and spread it low to avoid smothering the cover crop.

My brother and I help my parents make improved compost near our homestead. When the compost is ready, we carry it to the field and spread it evenly without disturbing the soil.

When we plant the crop, we move the crop residue a little to make room for planting.”

Renatha Patrick Allay, Karatu, Arusha, Tanzania

Inorganic fertilizers are much more concentrated than organic fertilizers. A bag of inorganic fertilizer may contain as much nitrogen as a tonne of compost! You need only a small amount of inorganic fertilizer for each plant. That makes inorganic fertilizers easy to use.

Inorganic fertilizers do not contain organic matter themselves. But they do add organic matter to the soil in an indirect way: they help crops grow better, so you will have more crop residues to leave on the soil at the end of the season. They also replenish nutrients (especially phosphorus) that compost and other organic fertilizers have only in small amounts.

Inorganic fertilizer can be expensive and hard to find. If you cannot afford a whole bag of fertilizer, it may be worth getting together with your neighbours to buy a bag between you.

Feed your soil

*If you work your oxen day after day,
but feed them nothing, they will die!*

*If you keep taking from your soil with-
out feeding it, it will die!*

What have you fed your soil lately?

What's in a fertilizer?

Inorganic fertilizers usually contain 3 main elements: nitrogen, phosphorus and potassium. Some have only nitrogen, some have only phosphorus, and some have only potassium.

Some types of inorganic fertilizer have two or all three of these nutrients, and are called "compound fertilizers".

Check the label on the fertilizer bag to see what it contains. A bag of **diammonium phosphate** should say something like this:

NPK 18-46-0

This means that 18% of the fertilizer is nitrogen (N), 46% is phosphorus (P), and there is no potassium (K) (0%).

There are many different combinations of fertilizer. For example:

- **Urea** is 46-0-0 (46% nitrogen, no phosphorus or potassium).
- **TSP** (triple superphosphate) is 0-45-0 (no nitrogen, 45% phosphorus, no potassium).

If possible, get your soil tested to find out what nutrients it needs. Then choose the type of fertilizer that your soil and crop need.

Combining inorganic fertilizers and organic manures

Inorganic fertilizers are expensive, and organics are sometimes poor quality and contain little nitrogen. So it is best to combine inorganic fertilizers with organic manures – perhaps at half the recommended rates of application. This combination also improves the fertilizer use efficiency. You can combine the two types of fertilizers by fortifying compost or by applying them both directly to the field.

How to apply fertilizer

When you apply both organic and inorganic fertilizers, disturb the soil as little as possible, and try not to interfere with the soil cover.

- **Planting basins** Mix the fertilizer with soil before planting. Use bottle caps or cans to measure the amount of fertilizer you put into each basin.
- **Ripped lines** Apply the fertilizer into the ripped lines. Apply DAP, TSP and compound fertilizer in the line before planting. Apply urea as top-dressing to maize and sorghum plants at the tasselling or flowering stage.
- **Cover crop and direct planting** Make a hole with a small hoe or planting stick, and put in the fertilizer by hand. Cover the fertilizer with soil and

Combining inorganic and organic fertilizer

“I used manure and inorganic fertilizer before I learned about conservation agriculture. But I wasn’t using the right amounts, and I didn’t apply them the right way. I was using low-quality manure. I spread it over my whole farm and ploughed it in. Then I made planting holes and put in a very small amount of fertilizer (1 handful of fertilizer for more than 10 holes). I used to get only 5 bags of grain per acre.

I was introduced to conservation agriculture through my farmers group in late 2002. We trained how to do it on a group farm in 2003.

I started practising conservation agriculture on my own farm in 2003. But I didn’t have enough materials: I didn’t use any crop residue, and I didn’t have enough fertilizer. I used the same amounts as I was using before. But I didn’t plough the soil. My maize yield doubled from 5 to 10 bags.

I was well-prepared this year. I left three-quarters of the maize stover in the field as mulch. I cut the top quarter to feed my livestock. I also grew lablab as a cover crop in the field. And I have learned how to make compost to improve the quality of manure.

When I plant maize, I make a row of holes with a hoe. I put a handful of manure and a teaspoonful of fertilizer in each hole. I mix them and put the seed beside the mixture to keep the fertilizer from scorching it.

When the maize is knee-high, I top-dress it with calcium ammonium nitrate (CAN). I apply CAN on the surface when the soil is wet, in a circle around the plants.”

Bernice Kamotho, Kikapu farmer field school, Njoro, Kenya

put the seeds on top. Apply urea to the planting stations, for maize at tasselling, for sorghum at flowering.

- **Using a jab planter or animal-drawn planter** Some planters have two containers: one for seeds, and one for fertilizer. [See page 53](#) for details.

Converting to conservation agriculture

Switching from ploughing or hoeing to direct planting through a soil cover will help degraded soil recover. The fertility will go up. Your soil health will gradually improve from year to year.

But you need to be careful. Many crop residues, especially straw from maize, sorghum and wheat, are low in nitrogen. When they decay, they make soak up nitrogen (and maybe phosphorus) from the soil. So you may have to add

More with less in Brazil

Farmers in Brazil used to have very similar problems to those faced by many African farmers today: heavy rain washed away their fertilizer and eroded their soil. For every kilogram of soybeans harvested in Brazil, 10 kg of precious topsoil was lost.

Frank Dijkstra was one of the first farmers to use conservation agriculture in Brazil. He switched to conservation agriculture in the late 1970s. Twenty years later, his maize yields had doubled, and his soybean yields had risen by 75%.

More inorganic fertilizer?

No. In fact, less. Frank now uses only half the amount of fertilizer on soybean, and two-thirds of the amount on his maize.

With conservation agriculture, he produces much more yield, with much lower inputs, and has stopped erosion.

That's good for the environment, good for the future, and good for his pocket.

More information: Rolf Derpsch, rderpsch@telesurf.com.py

Precision placement with a string

Farmers working with the IMPALA project ([see box on page 110](#)) in western Kenya use a string to sow seeds and apply fertilizer.

The farmers plant leguminous shrubs as part of their crop rotation. These shrubs provide enough nitrogen for their maize crop. But the soil is short of phosphorus.

When they plant maize, beans or legumes, the farmers take a long string with a knot every 25 cm. They make a small hole with a *panga* (large knife) or hoe next to each knot. They put a pinch of TSP fertilizer (the amount that would fit on the tip of a teaspoon) in the hole, followed by two seeds. They then cover the hole with their foot.

This precision placement saves seeds, fertilizers and work.

More information: Anja Boye

extra inorganic fertilizer to make up for this. You should, of course, add nitrogen in other ways too: rotate with legumes, plant leguminous cover crops, leave mulch on the surface, and apply compost or animal manure.

Once the soil is healthy again, you can slowly reduce the amount of fertilizer you apply. In the long run, conservation agriculture can produce higher yields than conventional farming, but needs less inorganic fertilizer.

Over time, the amount of organic matter builds up in the soil. Yields increase steadily over time.

