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Conservation agriculture

Introduction

What is conservation agriculture?

Conservation agriculture (CA) aims to produce high crop yields while reducing production costs, maintaining the soil fertility and conserving water. It is a way to achieve sustainable agriculture and improve livelihoods.

cropping and Crop rotation

Agroforestry

Processing and Value addition

Energy

Conservation agriculture has three basic principles:

1. Disturb the soil as little as possible. The ideal is to plant direct into the soil, without hoeing or ploughing. Tillage is reduced to ripping planting lines or making holes for planting with a hoe.

2. Keep the soil covered as much as possible. Mulch, special cover crops and/or crop residues left on the field protect the soil from erosion and limit weed growth throughout the year. This is opposed to conventional farming practices, whereby farmers remove, burn crop residues or mixes them into the soil with a plough or hoe. As a consequence, the soil is left bare, so it is easily washed away by rain, or is blown away by the wind.

3. Mix and rotate crops. Planting of the same crop each season - as sometimes practiced in conventional farming is minimized by planting the right mix of crops in the same field, and rotating crops from season to season. This allows a break down of survival and multiplication cycles of pests, diseases and weeds resulting in higher yields and maintenance of soil fertility.

To gain the full benefit of conservation agriculture, all three principles have to be applied at the same time. This ideal is not possible everywhere, but farmers should try to go into that direction as far as possible.

History of conservation agriculture

In the 1930s, soil erosion in the United States reached crisis proportions. The problem was particularly severe in the Midwest, where millions of tons of topsoil were blown away by the wind or washed into rivers, in what came to be known as the 'Great Dust Bowl'. Supported by the government, American farmers started abandoning their traditional practice of ploughing. Instead, they left the crop residues on the soil surface,

and planted the next crop directly into the stubble. Faced with similar problems, farmers in South America also took up conservation agriculture. They sowed cover crops to protect the soil, and rotated crops in order to maintain soil fertility. Because of the benefits, knowledge passed quickly from farmer to farmer.

By the year 2000, conservation agriculture was practised on about 60 million hectares of land worldwide, mainly in North and South America. Government support has been important: in some states in Brazil, conservation agriculture is official policy. In Central America, Costa Rica's Ministry of Agriculture has a Department for Conservation Agriculture. Conservation agriculture is used to cultivate over half the crop land in Paraguay, about one-third of the land in Argentina, one-third in Brazil, and one-sixth in the United States.

The many South American conservation agriculturists are well organized in local and national farmers' associations. They are supported by institutions from North and South America and have links with international agencies such as FAO, GTZ and the World Bank. This support is essential to help farmers to adopt quickly new approaches and technologies that many see as a radical change in the way they farm.

Green Revolution vs No-till or Reduced-till Revolution

The Green Revolution did not provide adequate benefits to resource poor vulnerable farmers without access to external inputs namely fertilizers, hybrid seeds and water. In contrast, Conservation Agriculture can and is beginning to benefit all farmers and communities at large. CA is a silent multi-stakeholder movement driven by an urge to produce more food at less cost, conserve land and water resources and improve environmental quality. Thus CA does easily conform to be an important component of the strategy for food security, poverty alleviation, rural development, enhance

productivity, improve environmental quality and help preserve natural resources at the same time.

Conservation agriculture in Africa

Conservation agriculture has great potential in Africa because it can control erosion, produce stable yields, and reduce labour needs.

The story of conservation agriculture in Africa is not new. Across wide areas of Africa, conservation agriculture principles used to be normal practice, before ploughs were introduced. Farmers would cultivate by hand, often with hoes, rotating crops and fallowing fields for several years. Rising populations and ploughs changed all that. European settlers and colonial regimes introduced ploughs, and they quickly came to dominate farming because they enabled farmers to open up more land quickly and cheaply. But just as in the United States, the plough has gradually eroded Africa's soils. Fertility and yields have fallen, and many countries now face critical food shortages. But not all Africa's farmland was put to the plough, or to the deep-till hoe, and pockets of conservation-friendly farming still remain.

Conservation agriculture emerged in several different places around the same time in Africa. The most dramatic story comes from Zimbabwe and Zambia, where conservation agriculture came to the rescue of the land. Starting on one large-scale commercial estate in Zimbabwe, a combination of zero-tillage and direct planting into deep straw mulch meant a slow but sure recovery for de- graded land. A moderate use of herbicides was needed to kill weeds. By the mid 1990s, nearly 4000 hectares were under conservation agriculture - all on large-scale farms. Efforts are presently being made to transfer this success to some of the many new small-scale farmers in Zimbabwe.

In Zambia around the same time, a dedicated extension unit, supported by donor funds,

spread the message. Here, small-scale farmers found that conservation agriculture worked on their farms too. Currently more than 100,000 small-scale farmers in Zambia have converted to conservation agriculture.

Large-scale farmers in Kenya, South Africa and Namibia also use conservation agriculture practices. In South Africa, no-till farmers' clubs similar to those in South America have been set up. Initiatives by government research and extension agencies, donors and the private sector promote conservation agriculture for smallholder farmers in Cameroon, Ghana, Kenya, Madagascar, Malawi, Namibia, Tanzania, Uganda, Zambia, Zimbabwe, and other countries. Various institutions conduct research on or promote conservation agriculture.

The most important researchers and promoters of conservation agriculture in Africa are farmers themselves. Every farmer is a researcher, who experiments every season on his or her farm. Farmers who find something that works are likely to repeat it the next season, and to tell their friends about it.

Sustainable land management

Sustainable land management (or "land husbandry") is a broad term that includes various types of crop and livestock production that aim to produce good yields year after year, while conserving soil and water resources. It does not necessarily include all three principles of conservation agriculture (don't turn the soil, keep the soil covered, and rotate crops). Conservation agriculture is a type of sustainable land management.

Agroforestry

Agroforestry is a combination of trees and crops (or livestock), and is a form of

'sustainable land management'. Agroforestry promotes soil cover and crop rotation, so may contribute to a conservation agriculture system.
For more information on agroforestry click here

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Why start using conservation agriculture?

You might start using conservation agriculture for many reasons.

- **To improve your yields**

Unlike the rest of the developing world, crop production in Africa is not keeping pace with population growth. Yields in many areas are actually falling. A major cause of this is declining soil fertility, often caused by the way of farming. The rising population has forced farmers to abandon traditional practices that left the land fallow for several years, and to cultivate ever-smaller plots. Intensive tilling and hoeing year after year can produce a hardpan in the soil. That restricts root growth and stunts plants. Rainwater pounds the bare soil, forming a surface crust that the water cannot penetrate. It runs off, taking the valuable topsoil with it. Erosion in some places is so severe that there is little soil left.

To get a good yield, farmers often apply more and more fertilizer. With less moisture in the soil, plants are more vulnerable to drought. They start to wilt after a few days without rain.
Conservation agriculture enables farmers to reverse this trend. It prevents hardpans from forming, protects the soil, increases soil moisture, and restores soil fertility, so

stabilizing yields and improving production over the long term.

- **To reduce your production costs**

Tilling the soil is expensive. Fuel and fertilizer prices and labour costs rise continuously, while market prices of farm products have fallen. Many farmers cannot recoup their production costs by selling what they produce, so they end up making a loss.
Conservation agriculture helps these farmers cut costs while increasing their yields.

- **To overcome shortages of labour and farm power**

Many farm households suffer from a severe lack of labour and farm power. Hunger and malnutrition combine to make people weak, unable to work hard, and vulnerable to disease. Young people are moving out, and HIV/AIDS and malaria create a severe labour shortage. Many draught animals have died because of disease, or their owners have had to sell them to pay for medical treatment and burials. A lack of farm power forces farmers to look for other ways to farm.

Conventional vs conservation

Both conventional farming and conservation agriculture include a very wide range of operations: field preparation, planting, fertilization, weeding, harvesting, and field operations after the harvest. There are, of course, many variations in both 'conventional' and 'conservation' approaches, so the descriptions are simplified and may not depict what happens in a particular area.

Conservation agriculture means less work because it is not necessary to plough the soil

and weed as many times. It suppresses weeds and reduces erosion. It improves the soil structure, ability to retain water, organic matter content and fertility. All these lead to higher and more stable yields.

Organic vs conservation

Organic farming involves growing crops and livestock without using agrochemicals. It is possible to do conservation agriculture in an organic way (without using fertilizers, herbicides or pesticides), but many types of conservation agriculture use these agrochemicals - but in small amounts and with care.

Advocacy of crop rotations to break disease and pest cycles are very complimentary for both organic and conservation agriculture. While conservation agriculture stresses on zero or reduced tillage and maintenance of soil cover, seems not bound by these factors.
For more information on organic farming click here

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How does conservation agriculture work in different types of farms?

The three principles of conservation agriculture (disturb the soil as little as possible, keep the soil covered as much as possible, and mix and rotate crops) can be applied in a wide range of conditions. How farmers put them into practice will vary from place to place, depending on many factors.
Conservation agriculture can be practised on different types of farms, with different combinations of crops and sources of power. Here are some examples:

- **Hoe farming**

Many African farmers cultivate by hand, using hoes. These farmers can practise conservation agriculture by digging small planting holes in lines, at carefully measured distances, leaving the rest of the soil unturned. If hoeing in previous years has produced a hardpan, the holes must be deep enough to break through this hard layer. The farmers can put compost or manure in the holes to raise the soil fertility and the water-holding capacity, then sow maize or beans. They can sow cover crops between the planting holes to protect the soil from erosion and to suppress weeds. They can pull weeds out by hand, or slash them with a machete.
The next season, they can plant different crops in the same holes. It is not necessary to dig through the hardpan again, because the first season?s crop roots will have penetrated deep into the soil and will help water to seep into the soil. So it is necessary to do hard work of digging the pits only once.

- **Small holder farming with draught animals**

Farmers who own (or can hire) oxen or donkeys to pull implements can use a different set of conservation agriculture practices. They can use a subsoiler to break up the hardpan (if there is one). This is usually necessary only in the first year.
If there is no hardpan, the farmers can use an animal-drawn ripper to open up a narrow furrow for planting seed. The soil between these furrows is left alone. It is possible to use rippers and subsoilers that sow seeds and apply fertilizer at the same time, so saving time and work. Before planting the crop, the farmers can use a hoe or knife-roller to kill weeds, or apply herbicide using a sprayer or wiper. They sow a cover crop with the maize crop to smother weeds and to reduce evaporation from the soil surface. When harvesting the main crop, the farmers leave the residues and cover crop on the field. That protects the soil from the sun and rain, and further controls weeds.

- **Mechanized farms**

Farmers with tractors can use conservation agriculture too. They can replace their mouldboard ploughs, disks and harrows with rippers, subsoilers and direct-drill planters.
At the outset of the season, large scale farmers use a knife roller, sometimes in combination with herbicides, to kill the previous season?s cover crop and weeds. In the first season of conservation agriculture, they may need to use a subsoiler to break up ploughpan. They then use a direct drill-drill planter to sow seeds. A post emergence herbicide kills any weeds that come up after planting and before the crop canopy can cover the surface.
After harvest, the crop residues stay in the field. The farmer then sows a cover crop to protect the soil until the next planting season.

Many farmers are able to use a combination of implements and different types of power. For example, a hoe farmer may be able to hire a neighbour with a tractor to subsoil her field. She can then choose among various options so she gets the full benefits of conservation agriculture.

Different situations

Conservation agriculture can be used in all parts of Africa, except where it is too dry to grow crops. It can be applied in various climatic zones and under different conditions, though it may look very different from place to place.

- **In semi-arid lands, conservation agriculture retains water in the soil, keeps the soil temperature even, and protects the land from erosion during heavy downpours. Maintaining soil moisture is the main challenge in these areas, so rainwater harvesting**

methods can be very useful to increase the amount of water available for crops. Crops may be planted with wide spacing, and there may not be enough moisture to grow a cover crop, so farmers may have to rely on mulch or residue to keep the soil covered. Livestock are important in these areas. Farmers may have to restrict grazing on their fields to keep as much soil cover as possible.

- **In sub-humid and humid areas, weeds and erosion are likely to be more of a problem. Crops are planted at closer spacings, and cover crops help suppress weeds and protect the soil.**
- **On slopes, conservation agriculture can be used in association with terraces, contour grass strips and other erosion-control methods. Terraces already exist in many places; conservation agriculture can be used on them.**
- **Where labour is scarce, perhaps because of HIV/AIDS, conservation agriculture enables farmers to produce good yields with less labour.**
- **In densely populated areas, conservation agriculture increases yields on small plots of land under intensive cultivation.**
- **On good soils, conservation agriculture keeps the soil healthy and maintains yields. On poor soils, it is a good way to rebuild soil fertility and enhance water-holding capacity, so increasing production.**

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Challenges for conservation agriculture

Conservation agriculture has the potential to change the face of Africa. But its success is not automatic. It faces various challenges.

Change of mindset. Switching to conservation agriculture involves a fundamental change of mindset. For example, farmers must drop their traditional practice of preparing the land with a hoe or plough, and instead rely on ?biological tillage? by the plant roots and earthworms. The switch also encourages farmers to begin to see their farms as a business rather than merely a way to feed their families.

Conservation agriculture involves radical changes in what extension services do. An effective way to promote conservation agriculture is through farmer field schools and other approaches that put farmers and their needs at the centre, rather than seeing them as mere recipients of advice. Such revolutionary changes require teaching, not only on the farm itself but also within schools and colleges. Extension staff will need intensive training so they can learn the necessary technologies. Field demonstrations and awareness-creation campaigns will also be needed. The mass media must be harnessed to support the campaign.

Crop residues. Keeping the soil covered is important in conservation agriculture. But it can be difficult. Farmers have many uses for crop residues: as fodder, fencing, roofing and fuel. Livestock keepers let their animals graze on stubble. In drier areas, it is impossible to grow a cover crop in the dry season, and crop residues are a vital source of animal feed.
If they are to keep the soil covered, farmers will have to protect their fields and find alternative sources of fuel and fodder. In wetter, sparsely populated areas, this is easy. In drier areas, it is more difficult. Alternatives include fencing animals out, reaching agreements with livestock owners on grazing rights, and growing special plots of fodder and fuelwood.

Land tenure. Farmers can go a long way towards adopting the principles of conservation agriculture with a minimum of investment on their farms. But they may be reluctant to do so if they do not have clear rights to the land they cultivate.
The importance, however, of the land tenure issue varies widely throughout Africa. In some countries, lack of guaranteed tenure impedes all agricultural development.

Adaptation of the "Brazilian" CA to take advantage of indigenous knowledge and different agro-ecological conditions is a process ? uncomfortably long. Other challenges. It can be hard to find seed (particularly of cover crops), inputs such as herbicides, and equipment. Crops such as tef, which has very small seeds, can be difficult to sow without disturbing the soil. And for various reasons, it can be difficult for farmers to work in groups, form organizations or get the support they need to begin practising conservation agriculture.

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Conservation Agriculture and the African Conservation Tillage Network (ACT)

Agricultural growth will play a decisive role in efforts to improve the welfare of the vast majority of Africa's populations. Over half of the continent's populations live in rural areas, and over 60% of Sub-Sahara Africa's populations live off some form of direct exploitation of natural resources, largely through subsistence agriculture. Reductions in the number if increasingly poor people, of the 30% of chronically hungry Africans and vulnerability, therefore, shall depend crucially on sustained and broad-based agricultural growth. This will also lay the

foundation for sustainable socio-economic growth.

Long-term agricultural production trends in Africa have proven disappointing. Africa remains the only region in the world where per capita food production has declined by 13% over the last 35 years. Twenty percent of the natural resource base suffers from water and wind erosion and 70% from moisture stress. Soil fertility is ranked the single, most important food security constraint.
The "Green Revolution" considered by many to be a success story has not only amplified the social inequities, but the resultant deceivingly cheap food is not always healthy and costs a fortune in terms of water, soil and biological diversity on which the future of not only the beneficiaries but all of us depends. Rising world food prices combined with the high costs of energy for transportation pose new opportunities but are simultaneously a catastrophe for the majority who are unable cope. A new paradigm of "producing locally for local consumption is probably in the making".

Conservation agriculture (CA) has the potential to enhance food security through increased and stabilised productivity and sustainable land management (SLM). Building on indigenous, scientific knowledge and innovative equipment designs from Brazil CA is spreading in Africa. More than 14 countries are now practicing the technology. Practicing farmers are able to produce more food more reliably using same rates of fertilizers and using much less labour (up to 50%). Action is needed now to get this promising technology adopted by as many farmers as is possible. But, there are serious challenges to be overcome to make this viable. Experiences of the African Conservation Tillage (ACT) in Enhancing Access to CA Knowledge & Information and Partnerships are summaries in the rest of the discussions.

The ACT is a 'Not for profit', voluntary membership Non Governmental Organisation

registered and with offices in Nairobi Kenya. The organisation has received support from many international organisations including GTZ, FAO, CIRAD and SIDA. The common vision was developed in Harare in 1998. The current membership stands at 1200 Individuals and Institutions from 33 countries. The organisation has regional offices in Nairobi, Harare and the soon to be launched Ouagadougou office.
What is the strategic intervention that will provide the optimal leverage in enhancing adoption and benefits from CA? While being positive to increased productivity and profitability as in the Green Revolution, the technical fix (improved seeds, better distribution of fertilizers, and more research to develop accompanying technologies) is no longer sufficient. Not until we have identified and removed the current hindrances that limit farmers accessing and exploiting the proven and perfected scientific packages. Not until we have answers why farmers enticed into the high external input packages failed to repay loans and reverted back to worse situations when the interventions ended? One key underlining concept that ACT subscribes to is the balancing between input and knowledge based extension interventions; i.e. facilitating the shift from the common "input based approaches" to "farmer knowledge empowerment and input based approaches". ACT believes that farming technologies "will not be transferred from one area to another" but arise from a process were local communities/farmers engage in adaptation of the knowledge/technologies to local circumstances.

Overarching all this is the argument that "accessing and churning knowledge into practice" is probably the last missing mile in this long journey of unlocking millions of poor Africans out of poverty. The interface between farmers and the public/private service providers and the regulatory institutions needs to be more sharpened and focused. As correctly cited by former UN Secretary General Kofi Annan when calling for a "uniquely African" Green revolution, Addis Ababa, 5 July 2004: " Knowledge is not

lacking. The basic policy directions are well established and widely accepted. What is lacking, as ever, is the will to turn this knowledge into practice".

The ACT places networking, knowledge and information management at the core of its functions. Web-based information support to its members is provided under the web site www.act.org.zw, which is now under reconstruction and relocation to www.act-africa.org. Under the web site are available CA databases of equipment suppliers, CA professionals, institutions, farmer organisations and continental/ global experience reference material. Electronic newsletters and special topic forums are being performed. An increasing number of people (extensionist, researchers and policy makers) are accessing e-news, enhancing faster and cost-effective CA /SLM networking.
ACT in collaboration with IIRR and other partners developed a CA reference book for farmers and extension officers. 1500 copies of the manual have been produced and distributed. Also, 8 case studies from 5 African counties have been made and 13,000 books published. Posters, brochures and leaflets are other promotional materials that target smallholder farmers without access to internet.

ACT was co-organiser of the III World Congress on CA in Nairobi in 2005. As a result, some African Governments have prioritized and included CA in countries' development agenda. Another congress outcome is birth of the West African Smallholder Conservation Agriculture Promotion Project (SCAP), a 3 year' pilot project in Niger, Guinea and Burkina Faso. Learning-education and training support has been offered by ACT through FFS curriculum development and adaptation. Local and International tailor made training workshops for research & extension officers for the past 5 years have been offered. The many CA graduates scattered throughout Africa form a good nucleus for CA entry and development. A major challenge is the need to accelerate and address the issue of curriculum reform at a higher national level so that agricultural colleges

stop training "tillage/ploughing" as usual.

The ACT has just embarked on anew phase with a New Thrust. The new impetus revolves around:

- **Broadening the ACT Farmer and Institution membership and subsequently empowering them to actively participate in CA/SLM forums.**
- **Consolidate Knowledge and Information Management Platform to the extent where it becomes a 'bank' for stakeholders to deposit, retrieve, exchange and use. A higher profile will be granted for professional and community-based archiving and assessment of indigenous knowledge and practices.**
- **In recognising farming communities and farmers not only as producers but also managers/ stewards of ecosystems, emphasis will be placed on building the local human capital. Farmers need to be empowered in own on-farm experimentation, monitoring, evaluation and learning. Incentives and other modalities need to be developed for farming communities to demand for services and enhance capacity of researchers to work with local people and their organizations.**
- **Forging strategic partnerships that address medium to long term interventions, geographic concentrated action zones and interventions that will target elevating farmers beyond crop productivity are pertinent. It is clear that even at the maximum possible yields, smallholders constrained by land holdings (of say 1 hectare) cannot eradicate poverty with a single crop in a year. Opportunities need to be explored and exploited on: getting multiple crops in a year, switching to commercial farming with better rewarding crops, diversification to on/off farm enterprises that can utilise and add value to labour saved by CA and value addition enterprises.**
- **Incentives are needed to influence the choices how individuals exploit their natural resources. Issues such as poverty and climate change also require collective agreements on concerted action and governance across limits that go beyond an**

individual?s benefit or liking. Networking farming communities poises utilising the strength of their togetherness to lobby for and tap into existing incentives of CA for environmental services (carbon credits, water, hydro energy generation) insurance and micro credits. Increasing awareness needs also to be made.

- **In conclusion, CA is THE WAY for Africa. Honourable investments have been made by partners such as FAO, GTZ, CIRAD and RELMA to introduce and promote the technology. However, it is not enough. The thrust is too little, the focus is blurred and with too little resources to effect the desired 'uniquely African Green Revolution'. In comparison to the Southern America Models, investments made in kick-starting African CA are too diminutive. National Governments and NEPAD need to take the leading role, supported by Donor organisation, to get widespread adoption and benefits from CA.**

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Information Source Links [informationLinks]

- **African Conservation Tillage Network (ACT). www.act.org.zw**
- **IIRR and ACT (2005). Conservation agriculture: A manual for farmers and extension workers in Africa. International Institute of Rural Reconstruction , Nairobi; African Conservation Tillage Network, Harare. ISBN 9966-9705-9-2.**
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Soil cover

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Introduction

Soil cover refers to live vegetation, crop residue or mulch material found on the surface of the soil.
A permanent soil cover is central to conservation agriculture for the following reasons:

cropping and Crop rotation
Agroforestry
Processing and Value addition
Energy

- It protects the soil from rain, sun, and wind.
- It reduces soil erosion and protects the fertile topsoil hence preventing the silting of rivers and lakes.
- It stops the soil surface from sealing, and reduces the amount of precious rainwater that runs off.
- It suppresses weeds by smothering their growth and reducing the number of weed seeds. This reduces the amount of work needed for weeding.
- It increases the soil fertility and the organic matter content of the soil.
- It increases soil moisture by allowing more water to percolate into the ground and reducing evaporation.
- Decomposing vegetation and the roots of cover crops improve the soil structure and make the clumps and lumps in the soil more stable, making it harder for rain to break them up and wash them away.
- Earthworms and other forms of life can prosper in the cover as well as in the soil.
- Soil cover stimulates the development of roots, which in turn improve the soil structure, allowing more water to soak into the soil, and reduce the amount that runs off.

Types of soil cover

There are two main types of soil cover:

- **Living plant material: crops and cover crops.**
- **Mulch or dead plant material: crop residues and pruning from trees and shrubs.**

You will often use a combination of mulch and living plants to keep the soil covered. To obtain a good soil cover, you should leave crop residues such as maize and sorghum stalks in the field. You might also be able to add mulch from outside the field:

for example, you can cut grass from nearby, or bring in leaves and pruning from trees and shrubs. They will decompose after a while, so you will have to replace them regularly.

In addition, you can plant a cover crop, either during the cropping season (to cover the area in between the crop rows), or afterwards to cover the whole field. During the cropping season itself, the crops themselves act as soil cover.
An intercrop of tall plants (such as maize) and low-growing plants (such as beans) make a good cover.

Living plant material: Cover crops

Cover crops are any crops planted to produce soil cover, protect the soil surface, improve soil fertility and produce food and feed. Cover crops are also grown between orchard trees or on fields between cropping seasons to protect the land from leaching and erosion.

There are many different cover crops in Africa. The type of cover crop used influence the quality and quantity of mulch it provides. Cover crops are divided into four main groups:

- **legumes, e.g. butterfly pea, cowpea, crotalaria, desmodium, mucuna, lucerne (alfalfa), etc**
- **shrubs, e.g. calliandra, gliricidia, sesbania, sunn hemp, etc**
- **grasses, e.g. gamba grass, brachiaria, finger millet, pearl millet, etc.**
- **others, e.g. pumpkin, watermelon**

Characteristics of cover crops

Legumes

Cover crop	Botanical name	Climate	Altitude	Other uses apart from cover	Characteristics
Butterfly pea	*Clitoria ternatea*	Semi-arid to sub-humid	Low to medium	Fodder	Climbing and shrubby legume. Rage of soils. Tolerate salinity and acidity but not flooding.
Centro	*Centrosema pubescens*	Sub-humid to humid	Low to high	Fodder	Trailing legume. Wide range of soils, sandy to clay.
Cow pea	*Vigna unguiculata*	Semi-arid and sub-humid	Low to medium	Food	Legume has both creeping and erect type. Sandy to clayey soil. Long-maturing varieties best for intercropping with cereals.
Crotalaria	*Crotalaria retusa, c. ochroleuca, c.paulina*	Semi-arid to sub-humid	Low to medium	Erect legume. Wide range of soils. Deep roots break	

				compact soil layers. Adapted to infertile soils. C. ochroleuca can be eaten as a vegetable.	
Desmodium	*Desmodium intortum*	Sub-humid to humid	Medium to high	Fodder	Trailing and climbing legume. Wide range of soils
Jack bean	*Canavalia ensiformis*	Semi-arid to humid	Low to high	Food, fodder	Erect legume that can grow to 1m high. Slow growth at first. Draught-tolerant and immune to most pests. Dry before using as fodder. Young pods can be used as food.
Jugo bean, bam bara groundnut	*Vigna subterranea*	Sub-humid to humid	Low to medium	Food	Wide range of soils. Draught resistant. Beans high in protein
Lablab, hyacinth bean	*Dolichos labla*	Semi-arid and sub-humid	Low to medium	Food, fodder	Creeping legume that spreads quickly. Sandy to clayey soils. Suitable for intercropping with

					cereals and sugarcane. High in protein
Lucern, alfalfa	*Medicago sativa*	Semi-arid to sub-humid	Low to medium	Food	Erect legume. Wide range of soils.
Mucuna, velvet bean	*Mucuna pruriens*	Semi-arid and sub-humid	Low to medium	Food	Creeping legume that spreads quickly. Sandy to clayey soils. Suited for intercropping with cereals and sugarcane. More sensitive to fertility than lablab. Excellent soil cover suppresses weeds.
Mungbean, green gram	*Vigna radiata*	Sub-humid to humid	Low to medium	Food, fodder	Wide range of soils. Edible beans and leaves
Pigeonpea	*Cajanus cajan*	Semi-arid to humid (depends on	Low to high	Food, fodder, Firewood	Erect legume. Grows in sandy to clayey. Deep roots break compact soil layer (biological plaugh).

		variety)			**Good at recycling phosphorus. Rich in protein.**
Siratro	***Macroptilium atropurpureum***	**Semi-arid and sub-humid**	**Low to medium**	**Fodder**	**Creeping/trailing legume. Range of soils. Tolerant to draught.**
Stylo	***Stylosanthus guianensis. S. hamata***	**Semi-arid to humid (depends on species)**	**Low to high**	**Fodder**	**Creeping coppicing legume. Does well on coarse textured soils and can tolerate acid soils. Takes 1-2 rainy seasons to cover the soil.**
Tropical kudzu	***Puera phaseoloides***	**Humid**	**Low to high**	**Fodder**	**Creeping/trailing legume that spreads quickly. Wide range of soils. Not draught resistant.**
Wild groundnut, peanut	***Arachis pintoi***	**Semi-arid to sub-humid**	**Low to medium**	**Fodder**	**Coppicing legume. Permanent green cover crop. Does well on coarse textured soils. Takes 1-2 rainy seasons to cover soil.**

Leguminous Shrubs

Cover crop	Botanical name	Climate	Altitude	Other uses apart from cover	Characteristics
Calliandra	*Calliandra spp.*	Semi-arid to sub-humid	Low to medium	Fodder, firewood, mulch	Wide range of soils, often on contours
Gliricidia	*Gliricidia sepium*	Semi-arid to sub-humid	Low to medium	Fodder, firewood, mulch	Coppicing shrub
Sesbania	*Sesbania sesban*	Semi-arid to sub-humid	Low to medium	Fodder, firewood, mulch	Wide range of soils
Sunn hemp	*Crotalaria juncea*	Semi-arid to sub-humid	Low to high	Fodder, firewood	Wide range of soils. Dry before using as fodder
Tephrosia	*Tephrosia candida. T. vogelil*	Sub-humid to humid	Low to high	Fodder, pesticide, firewood	Wide range of soils. Does not tolerate acidity.

Grasses

Cover crop	Botanical name	Climate	Altitude	Other uses apart from cover	Characteristics
Andropogon, gamba grass	*Andropogon gayanus*	Semi-arid to sub-humid	Low to medium	Fodder	Wide range of soils
Brachiaria	*Brachiaria ruziziensis*	Semi-arid to sub-humid	Low to medium	Fodder	Grass with multiple tillers. Wide range of soils
Cenchrus	*Cenchrus ciliaris*	Arid to sub-humid	Low to medium	Fodder	Grass with multiple tillers. Takes time to establish. Wide range of soils
Finger millet	*Eleusine coracana*	Semi-arid to sub-humid	Low to High	Food, fodder, thatch	Grass with multiple tillers. Wide range of soils
Pearl millet	*Pennisetum glaucum*	Arid to semi-arid	Low to medium	Food, fodder, thatch	Grass with multiple tillers. Wide range of soils
Sunn hemp	*Crotalaria*	Semi-arid	Low to	Fodder,	Wide range of soils. Dry

	juncea	**to humid**	**high**	**firewood**	**before using as fodder.**

Other cover crops

Cover crop	Botanical name	Climate	Altitude	Other uses apart from cover	Characteristics
Pumpkin	*Cucurbita spp.*	Semi-arid to humid	Low to high	Food	Creeping edible plant
Watermelon	*Citrullus lunatus*	Semi-arid to sub-humid	Low to medium	Food	Creeping edible plant

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The importance of cover crops in conservation agriculture

Cover crops make up a fundamental component of the stability of the conservation agriculture system, as much for its direct and indirect effects on soil properties as for its capacity to promote an increased biodiversity in the agro-ecosystem.

While commercial crops have a market value, cover crops are mainly grown for their effect on soil fertility or as livestock fodder. In regions where smaller amounts of biomass are produced, like semi arid (dry) areas and eroded soils, cover crops are

beneficial as they:

- **protect the soil during fallow periods**
- **mobilise and recycle nutrients**
- **improve the soil structure and break compacted layers and hard pans**
- **permit a rotation in a monoculture**
- **can be used to control weeds, pests or break soil compaction**

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

Cover crops are suitable for:

- **protecting the soil, when it is not cultivated**
- **providing an additional source of organic matter to improve soil structure and create an**
- **improved topsoil**
- **recycling nutrients and mobilizing them in the soil profile in order to eliminate layers with slow**
- **moving nutrients like phosphorus and potassium**
- **"biological ploughing" of the soil; the roots of some crops, especially cruciferous crops, like oil**
- **radish are pivotal and able to penetrate compacted or very dense layers , increasing water**
- **percolation capacity of the soil**
- **utilising easily leached nutrients**

Different plants, have diverse rooting systems, explore different soil depths, have the ability to absorb different quantities of nutrients and with the production of distinct root exudates (organic acids) result in benefits both for the soil and for the organisms.

The presence of a mulch layer (dead soil cover) contributes to a reduction in evaporation of soil moisture and leads to a higher water infiltration capacity in the soil profile. The percentage of rainwater that infiltrates the soil depends on the amount of soil cover provided. Whether through the effects of pores left by plant roots, earthworms, insects or other soil organisms, or through an improved soil porosity and higher number of bigger aggregates, in both cases it is accumulated organic matter that creates the favourable conditions.
Crop residues left on the soil surface lead to higher soil aggregation, and higher porosity and higher number of macro pores, and thus to a higher trend in infiltration rates. As different cover crops produce different amount of biomass, the density of the residues varies with different crops and thus the ability to increase water infiltration.

Cover crops contribute to the protection of the soil surface and thus to the maintenance and/or improvement of the physical, chemical and biological characteristics of the soil, including adaptation of effective soil depth through their roots. Vegetative cover is essential for conservation agriculture for the protection of the raindrop impacts of raindrops and to keep the soil shaded and with the highest humidity level possible, for utilizing and thus recycling the nutrients, and for its allelopathic and physical effects on weeds leading to a reduction in agrochemical use and thus in production costs.

Increased yield when CA is integrated with agro forestry

© T. Apina, ACT Kenya

CA adopter farmer using cover crop instead of leaving their plots fallow

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Farmers in Mbeere appreciating the effect of biological subsoiling by cover crop

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Cover crops vs green manure

In conservation agriculture the terminology 'green manure' is not used often, although generally the same plant species are used for both practices. Green manure is considered as a crop in rotation with the objective of conserving or restoring the productivity of the land through incorporation of the non-decomposed vegetative matter in the soil. In conservation agriculture this is not desired for two reasons:

- **in conservation agriculture systems the soil is not disturbed, or as little as possible and more important,**
- **when biomass is incorporated in the soil a high microbial activity starts in order to**

decompose the material, resulting in a sudden release of a high quantity of nutrients that can not be captured by the seedlings of the following crop and thus disappear from the system.

The dynamics of residue decomposition depends, amongst others, on the activity of micro organisms but also on soil meso and macro fauna. The macro fauna constitutes mainly of earthworms, beetles, termites, ants, millipedes, spiders, snails and slugs, etc. These organisms promote the integration of the residues into the soil and by doing so, modifying the physical properties through the creation of burrows.

The non incorporation of cover crop and weed residues from the soil surface to deeper layers in the soil is a slow process and depends heavily on the activity of these macro organisms. The activity of micro organisms is regulated by the activity of these macro organisms, because they provide them with 'food' and air through their burrows. In this way, nutrients are released slowly and can provide the following crop with nutrients. At the same time, the soil is covered for a long time and is protected against the impact of rain and sun.

In comparison, when green manure crops are mixed into the soil, a large amount of oxygen and 'food' is worked into the soil that leads to a rapid development of the micro fauna population. This big population can decompose the offered 'food' in a rather quick way but at the moment, the 'food' is finished and the microorganisms die, because they cannot sustain their way of life. At this moment a large amount of nutrients is released, that if not taken up by plant roots it can easily be lost through leaching. The whole time, after incorporation, the soil is not protected by a cover and thus is susceptible to degradation processes, resulting in erosion.

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Commonly used cover crop species

There are various crop alternatives to be used as vegetative cover, like grains, legumes and oil crops. All of them are of great benefit to the soil; however, some crops emphasize certain benefits, which is useful to keep in mind when planning a rotation scheme. It is important to start the first years of conservation agriculture with (cover) crops that leave a lot of residues on the soil surface, which decompose slowly (because of the high C/N ratio). Grasses and cereals are most appropriate for this stage, also because of their rooting system, which need a shorter time to improve the soil. In the following years, when the soil shows a healthier appearance, legumes can be incorporated in the rotation.

Leguminous crops enrich the soil with nitrogen and decompose rapidly because of the low C/N ratio. Later, when the system is stabilized it is possible to include cover crops with an economic function, like livestock fodder. In order to be able to successfully integrate cover crops in a production system, it is crucial to select the plants that are adapted to the different soil and climate conditions and show advantages that fit in the rotation scheme. For this, it is not only necessary to know all the agronomic details of the species, but also all specific conditions of the site where they will be sown (soil and climate) and the anticipated objectives and socio-economic conditions of the farmers.

The selection of cover crops should depend on two main criteria, i.e. the presence of high levels of lignin and phenolic acids, which give the residues a higher resistance to decomposition and thus results in soil protection for a longer period.

Resistance to decomposition

Another determining factor of the dynamics of residue composition is the biochemical composition of the residues. According to species, their chemical components and the time and way of managing them, differences exist in decomposition rates. Grain species show more resistance to decomposition than legumes. The latter has a lower C/N ratio and less lignin content and thus is subject to a rapid decomposition. Because one of the main objectives of a cover crop is the protection of the soil, their resistance to decomposition should be one of the criteria for selection. In addition, for tropical and subtropical cover crops the resistance to decomposition has been researched. Pearl millet followed by pigeon pea, white mucuna and Cratalaria paulina demonstrated higher resistance and left more soil cover for a long period than the other crops.

Therefore, these crops are better suited as a cover crop, especially during the first years of conservation agriculture than other crops.

Generally, the type of crop and the management afterwards determine the quantity of resides produced, the soil cover generated and the time the cover remains on the surface before being decomposed.

Case 1: Effects of various live cover crop types on soil loss - Gatanga Kenya

	no cover crop	Mucuna	Purple vetch	Dolichos
% ground cover	0	43.2	9	11.4
cummulative soil loss tonne/hectare	3.3	0.35	1.83	1.32

Effects of cover crop on water economy:

Water balance

- **Rainfall that enters in soil vs water that is lost through transpiration and evaporation**

Effect of cover

- **Promotes infiltration**
- **Decrease evaporation from the soil surface**
- **3-7% more soil moisture found under soil cover - yield effects of drought**

Effects of cover crop on soil temperature

- **Root extension, soil moisture, soil life nutrient uptake etc.**
- **Upper extreme limit - 30-35 degree Celsius ; lower limit 15-20 degree Celsius . Tropics**
- **Maize - every 1 degree Celsius increase in soil temperature above 30 degree Celsius cause 10% reduction in yields.**
- **Soil cover - reflect sunlight, absorb some radiation (insulate soil). Hence soil under cover receives less heat.**
- **Less heat - less evaporation - increased moisture - cooler soil.**

Effects of cover crop on soil chemical properties

- **Improves soil carbon**
- **Protects and increases soil humus - lignin, wax and fat-like substances form stable humus after decomposition**
- **Improves soils cation exchange capacity - the capacity of the soil to store nutrients**
- **C/N ratio with N immobilization - temporary shortage of N**
- **Adds nutrients to the soil**

How to choose the right cover crop

- **Choose cover crops that fit into your normal cropping system and which has multiple purposes: edible seeds and vegetables, soil fertility, animal fodder, firewood/fencing material, weed suppression, medicines**
- **Select a cover crop that grows well in your area (adapted to soil type, rainfall, temperature and altitude. If you live in an area with little rainfall, select a cover crop that grows quickly, such as desmodium, lablab, lucerne, mucuna or pigeon pea**
- **Select crops that cover the soil quickly and give less work for land preparation, weeding, producing and harvesting the seeds. Species with big pods and grains like pigeon pea and mucuna are easier to deal with than species with small pods such as vetch and grasses.**
- **The cover crop should not interfere with the main crop. Avoid growing a tall cover crop that might shade the main crop. Prevent this by planting the cover crop later**
- **If you can not prevent livestock from getting into your fields, choose a cover crop they do not like to eat, such as sunn hemp (*Crotalaria*) or jack bean (*Canavalia*)**
- **To ensure a lasting soil cover, use a mixture of legumes and grasses. Legumes decompose quicker than grasses. This means that the next crop can use nutrients such as nitrogen from the legumes quickly**

An ideal cover crop should:

- **Grow quickly and produce ground cover rapidly**
- **Be aggressive and be able to compete with weeds**
- **Prevent soil erosion**
- **Have a considerable leaf production and litter fall**
- **Seed freely and produce edible seed and/ or be suitable for use as animal feed**
- **Does not require inoculation with introduced rhizobia**
- **Leave residual N for the following cash or subsistence crops**

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Cover crop and residue management

In conservation agriculture, residues should be manipulated from harvest onwards. An equal distribution of residues provides homogenous temperature and humidity conditions at time of sowing. In case residues are not distributed more or less equally on the soil surface this may cause the following problems:

- **bad placement of the seeds at sowing, resulting in an uneven germination**
- **a cold and humid surroundings of the seeds favours the development of pests and diseases**
- **bringing- about allelopathy**

It is important to choose the precise moment at which the vegetative cover is to be controlled, because most of the species used can regenerate if their growth is interrupted prematurely. Alternatively, mature seeds of the cover crop can germinate if the plants are allowed to mature.

There are, however, species and rotations where cover crops are purposely brought to maturity to establish a seed bank which would allow the cover crop to grow automatically once the cash crop has been harvested.

The best moment to control the majority of cover crop species is at full flowering when they have accumulated maximum biomass. In case of legumes, the pods from the first flowering should be already formed but not yet mature. For oats and rye, the best moment to manage is the milky stage. Forage radishes can be slashed at any growth stage, but in systems of direct sowing and minimum tillage, seeds should be green and

physiologically immature to avoid the germination of new plants.

Both Crotalaria and pigeon pea need to be controlled before flowering due to high re-growth rate and excessive wood development. The most adequate form to manage the cover crops depends on the objective of the cover crop and the possibilities of the farmer. In case the dead mulch should cover the soil as long as possible, the best way to manage the biomass is by using knife roller, chain, sledge or herbicides. When the decomposition process has to start immediately in order to release the nutrients it is recommendable to slash or mow the cover crop. In some cases, it might be necessary to complete this with herbicides. Research shows that the period between slashing/management of the cover crop and seeding of the commercial crop (maize, beans, soya, etc.) defines the production level of the crop. This is related to some of the substances that are released during decomposition of the cover crops. These can harm the germination of the seeds, or sometimes even delay the development of subsequent crops. This is called allelopathy. In general, management of leguminous cover crops ten days before planting of maize gives highest yield responses.

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Inter-cropping/mix cropping

Mixed cropping is not a new agricultural activity; for generations, farmers have grown maize and beans in association and legumes are sown into pastures with the aim of improve the grazing quality of the pasture. Associations of crops have numerous benefits in production systems. Effect on nitrogen availability in proper quantities and adequate moment for subsequent crops and providing soil cover for a longer period are

some of the positive impacts of cover crop mixtures. Crop residues can be an effective source of nitrogen for grain crops, like maize, sorghum and others with a high nitrogen demand, provided that the nutrient release from the residues is synchronized with the demand from the crop.

Therefore, the ideal crop association is the one that offers enough residues to provide a 'pool' of mineral "N" from decomposition to attend to the commercial crop. The strategy for crop associations is to look for species from different families that have different C/N ratios and lignin contents, and that are able to contemplate with both the supply of nutrients and the provision of soil cover for a long time. Mixtures can be made from cereals/grasses and legumes, cereals/grasses and oil crops or even mixing 2-3 or more species that besides presenting an important impact on the improvement of soil properties produce a C/N ratio that favours a gradual nitrogen mineralization. In general, when residues of grass species are mixed with residues of legumes no immobilization of nitrogen will take place and the gradual mineralization favours the availability of nutrient s for absorption by plants.

Commonly used mixtures include:

Millet+sorghum; millet+*Crotalaria juncea*; pigeon pea+sorghum; cowpea+millet; sorghum+ *Crotalaria juncea*.
Mixed cropping is another form of crop mixtures. For instance, maize can be mixed with pigeon pea and Crotalaria juncea both planted when the maize plants have reached a height of 30cm by using the same machine as for planting maize.

In Latin America very common practices include the mixture of maize with Mucuna or Canavalia in both cases planted about 80-100 days after the maize was planted. After the maize harvest these species accelerate their development, completely overgrowing the maize residues. Subsequent crops can include beans, sorghum or sunflower.

When to plant cover crops?

It is important to plant cover crops at the right time if better result is to be realized. Below are explanations under common practices in the planting of cover crops;

Intercropping

This involves planting legume cover crop at the same time as the main crop. This is easy because you can plant both crops at the same time. It is suitable for sub-humid and humid areas. A possible problem is that the cover crop might grow so quickly that it smothers the main crop. Also, you cannot plant a cover crop this way if you are already intercropping a cereal (e.g., maize) with beans.

Relay cropping

This involves planting the legume cover crop when weeding the main crop. This is suitable for sub-humid and humid areas. You can plant the cover crop when you do the first weeding (usually about 4 weeks after planting the main crop). Or if you are intercropping maize and beans, you can plant the cover crop when you harvest the beans.

Sequential planting

This involves planting the legume cover crop after you harvest the main crop. In dry areas, you can plant the cover crop when you harvest the main crop. This prevents the cover crop from competing for moisture with the main crop. You can use the cover crop to provide extra mulch and to produce livestock feed. Harvest water to make sure there is enough moisture to grow the cover crop. If you live in a semi-arid area with only one rainy season, you can plant a drought-tolerant cover crop such as lablab between your

rows of maize. Leave the cover crop in the field after the maize harvest so it covers the soil and suppresses weeds. Before the next season's rains, slash it or roll it, and leave it on the ground as mulch.

How to plant cover crops?

In conservation agriculture, cover crops are planted directly with minimum soil disturbance. You can plant a cover crop as an intercrop (or relay crop) or in a pure stand. For cover crops with large seeds, plant with a hand hoe, jab planters or animal drawn direct planter (for pure stands). You can broadcast cover crops with small seeds (such as finger millet), provided the soil cover is not too thick. If the soil cover is thick, sow the seeds in lines by hand or use a seed drill. The plant spacing and number of seeds per hole depend on several factors.

- **Use a narrower spacing in pure stands, and a wider spacing in mixed (intercropped) stands**
- **Use a wider spacing in drier areas, so the plants don't compete with each other for moisture.**
- **The number of seeds per hole depends on the amount of moisture available: fewer seeds per hole in dry areas; more in wetter areas. In general, plant 2 - 4 seeds per hole.**

How can farmers obtain cover crop seeds?

Varieties of cover crop seeds are available within the supply chain of local agro-stockist, research centres such as Kenya Agricultural Research Institute (KARI), Selian Agricultural Research Institute (SARI), World agro forestry Centre ICRAF and many other similar outlets. The table below provide guidance on the contacts

No	Common name	Scientific name	Where to get it
1	Groundnut	*Arachis hypogaea L.*	Agricultural research centres/Seed companies
2	Wid peanut	*Arachis pintoi Krap. & Greg*	Agricultural research centres/Seed companies
3	Pigeon pea	*Cajanus cajan (L) Millsp.*	Agricultural research centres/Seed companies
4	Calopo	*Calopogonium mucunoides Desv.*	Agricultural research centres/Seed companies
5	Jackbean	*Canavalia ensiformis (L.) DC.*	Agricultural research centres/Seed companies
6	Chick pea	*Cicer arietinum L.*	Agricultural research centres/Seed companies
7	Clitoria	*Litoria ternatea L.*	Agricultural research centres/Seed companies
8	Sunnhemp	*Crotalaria juncea L.*	Agricultural research centres/Seed companies
9	Tanzanian sunnhemp	*Crotalaria ochroleuca*	Agricultural research centres/Seed companies
10	Greenleaf desmodeum	*Desmodeum intortum*	Agricultural research centres/Seed companies
11	Silverleaf esmodeum	*Desmodeum uncinatum*	Agricultural research centres/Seed companies
12	Buckwheat	*Fagopyrum esculentum*	Agricultural research centres/Seed

			companies
13	Soybean	*Glycine max*.	Agricultural research centres/Seed companies
14	Hyacinth bean	*Lablab purpureus*	Agricultural research centres/Seed companies
15	Trefoil	*Lotus corniculatus*	Agricultural research centres/Seed companies
16	Sweet white lupine	Lupinus albus	Agricultural research centres/Seed companies
17	Blue lupine	*Lupinus angustifolius*	Agricultural research centres/Seed companies
18	Yellow lupine	*Lupinus leteus*	Agricultural research centres/Seed companies
19	Siratro	*Macroptilium atropurpureum*	Agricultural research centres/Seed companies
20	Archer Axillaris	Macrotyloma axiilare	Agricultural research centres/Seed companies
21	Horsegram	Macrotyloma uniflorum	Agricultural research centres/Seed companies
22	Lucerne, alfalfa	Medicago sativa	Agricultural research centres/Seed companies
23	Barrel medic	*Medicago truncatula*	Agricultural research centres/Seed companies

24	White sweet clover	*Melilotus alba Medik.*	Agricultural research centres/Seed companies
25	Velvet bean	Mucuna pruriens	Agricultural research centres/Seed companies
26	Glysine	Neontonia wightii	Agricultural research centres/Seed companies
27	Scarlet runner bean	*Phaseolus coccineus*	Agricultural research centres/Seed companies
28	Lima bean	*Phaseolus lunatus*	Agricultural research centres/Seed companies
29	Common bean	Phaseolus vulgaris	Agricultural research centres/Seed companies
30	Pea, field pea	*Pisum sativum*	Agricultural research centres/Seed companies
31	Tropical kudzu	*Pueraria phaseoloides*	Agricultural research centres/Seed companies
32	Stylo	*Stylosanhtes guianensis*	Agricultural research centres/Seed companies
33	Berseem clover	*Trifolium alexandrinum*	Agricultural research centres/Seed companies
34	Rose clover	*Trifolium hirtum*	Agricultural research centres/Seed companies
35	Crimson clover	*Trifolium incarnatum*	Agricultural research centres/Seed companies

36	**Subclover**	***Trifolium subterraneum***	**Agricultural research centres/Seed companies**
37	**Arrowleaf clover**	***Trifolium vesiculosum***	**Agricultural research centres/Seed companies**
38	**Purple vetch**	***Vicia benghalensis***	**Agricultural research centres/Seed companies**
39	**Lana vetch**	***Vicia dasycarpa***	**Agricultural research centres/Seed companies**
40	**Faba bean**	***Vicia faba***	**Agricultural research centres/Seed companies**
41	**Common bean**	***Vicia sativa***	**Agricultural research centres/Seed companies**
42	**Hairy vetch**	***Vicia villosa***	**Agricultural research centres/Seed companies**
43	**Green gram**	***Vigna radiata***	**Agricultural research centres/Seed companies**
44	**Cowpea**	**Vigna unguiculata**	**Agricultural research centres/Seed companies**
45	**Bambara nut**	***Voandzeia subterranean***	**Agricultural research centres/Seed companies**

Do cover crops need weeding?

Yes! You will need to weed cover crops at least once while they are becoming established. Once they have covered the soil well, they will prevent most weeds from

germinating. If you are intercropping or relay cropping your cover crop with maize or sorghum, plan to weed according to the requirements of the cereal crop. Make sure the cover crop does not tangle with the cereal crop.

Controlling pests and diseases

In parts of Kenya and Tanzania, farmers plant lablab as the only cover crop. In some villages, quite large areas are covered with the same crop. Farmers in these villages risk a pest outbreak that may ruin their cover crop. How to reduce the danger of pests and diseases:

- **Rotate the types of crops grown: food, cover and cash crops.**
- **Select cover crops that are unlikely to be attacked by pests.**
- **Plant various different types of cover crops.**
- **Use chemical spray.**

Harvesting and seed storage

Harvest the seeds before you slash a cover crop to make mulch. You may need to harvest the seeds for several reasons: so you can plant the cover crop next season, if you want to use the seeds as food or fodder, or if you want to sell them to other farmers.
Store cover crop seeds well. Here are a few tips on how to handle them:

- **Collect seeds from several plants so you get a range of seeds.**
- **Dry the seeds and treat them with insecticide. If you want to use the seeds for food, make sure that the insecticide is not harmful.**
- **Keep seeds for planting in partly opened bags or in containers in a well ventilated store.**

- **Take the seeds out and dry them again regularly. Throw out any bad seeds.**

Preparing to plant the main crop

At the beginning of the next season, your field may have a cover crop, stalks still standing from the previous main crop, and of course, weeds. You need to prepare the field so you can plant the next main crop. You can do this in several ways: by slashing the cover crop and weeds with a machete or hoe, using a knife roller to bend over and crush the standing vegetation, or by using a herbicide. It may be better to use a knife roller to crush the vegetation rather than slashing it, because equipment such as rippers and planters can easily drag pieces of vegetation along with them.

Case 2:

Cover crop pros and cons

Farmers in northern Tanzania tried various cover crops. Here is what they thought of them.

Cover crop	Advantages	Limiting factors
Lablab *Dolichos lablab*	Grows fast, so covers soil and controls weeds effectively Easy to manage Tolerates drought Fodder for livestock Good market	Farmers not using it as food Needs special management before the next season Susceptible to pests; needs spraying with insecticide
Mucuna *Mucuna pruriens*	Grows fast, so covers soil and controls weeds effectively Easy to manage Dries off in a long dry season, so no need to kill it before planting the next crop Fodder for livestock Produces many seeds, which are easy to collect Some farmers grind seeds and mix with corn bran to feed oxen	Use as food not recommended (under research) Seeds not widely available and fairly expensive Weak market Not seen as a crop, so livestock owners may allow their animals to graze Not liked by cattle
Pigeonpea *Cajanus cajan*	Cash and food crop Protects land from grazing Market available (Asia) Seeds easily available Stems used for firewood	Erect type, so poor weed suppression Little impact on soil erosion
Pumpkin *Cucurbita* spp.	Traditional crop grown with maize Covers soil and suppresses weeds Seeds easily available and affordable	Competes with maize for soil

Source: FAO/IFAD, Case study northern Tanzania, 2001–2

Cover crop pros and cons

© FAO/IFAD

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Mulching

Mulch is dry, vegetative material used to cover the soil. It helps reduce evaporation and retain moisture, reduce soil erosion, suppress weed growth and provide plant nutrients as the material decomposes.

Mulch can be used in fields before and after planting, as well as around young crop plants. It is especially useful for high-valuable vegetable crops, and for growing crops in dry areas, during dry-season cropping, and in places where the soil is easily eroded by heavy rains. Where soil erosion is a problem, slowly decomposing mulch material (low

nitrogen content, high omC/N) will provide a long-term protection compared to quickly decomposing material.

Crop residues

The following are some of the most common mulch mainly from crop residues:

- **Rice husks**
- **Millet stems**
- **Sorghum stems**
- **Maize stover**
- **Wheat stover**
- **Rice straw**
- **Ground nut leaves**
- **Ground nut stems**
- **Cowpea leaves**
- **Cowpea stems**
- **Saw dust**
- **etc**

Case 3: Effect of mulch on average nutrient content of some crop residues (% of dry weight)

Crop part	N	P	K	Ca
Millet stems	0.65	0.09	1.82	0.35
Sorghum stems	0.58	0.10	1.51	0.21

Maize stover	0.70	0.14	1.43	0.36
Wheat stover	0.62	0.12	1.72	0.27
Rice straw	0.58	0.13	1.33	0.20
Ground nut leaves	2.56	0.17	2.11	1.98
Ground nut stems	1.17	0.14	2.20	0.92
Cowpea leaves	1.99	0.19	2.20	3.16
Cowpea stems	1.07	0.14	2.54	0.69

Advantages and disadvantages of mulching

What are the advantages of mulching:

- **Mulch keeps the soil underneath moist longer than bare soil.**
- **Controls soil erosion by cushioning the impact of raindrops and by slowing runoff.**
- **Suppresses weeds by shading them out.**
- **Leads to healthy crop growth.**

What are the disadvantages:

- **Mulching is labour-intensive.**
- **It can introduce new pests and diseases into a field.**
- **Dead plants for use as mulch may not be available.**

How to do it:

1. Carry to the field the material you want to spread as mulch.

2. Spread it on the soil using your hands or a rake. Put a layer of mulch 7-15 cm (3-6 inches) deep all over the bed, or around the growing plants. Do not put on so much

mulch that you bury the plants or shade them out.

Do's and Dont's:

- **Use dry plant material that does not rot quickly.**
- **Don't use wet or green material as mulch.**

Constraints of Mulching

Some organisms can proliferate too much in the moist and protected conditions of the mulch layer. Slugs and snails can multiply very quickly under a mulch layer. Ants or termites which may cause damage to the crops also may find ideal conditions for living. When crop residues are used for mulching, in some cases there is an increased risk of sustaining pests and diseases.

Damaging organisms such as stem borers may survive in the stalks of crops like cotton, corn or sugar cane. Plant material infected with viral or fungal diseases should not be used if there is a risk that the disease might spread to the next crop. Crop rotation is very important to overcome these.

When carbon rich materials such as straw or stalks are used for mulching, nitrogen from the soil may be used by micro organisms for decomposing the material. Thus, nitrogen may be temporarily not available for plant growth (risk of N-immobilization).

Risk of Nitrogen-immobilization:

When organic material is applied to the soil, the decomposing microbes multiply quickly. For growth, they need nutrients, especially nitrogen, like plants do. If the applied plant material does not contain sufficient nitrogen, the micro organisms will take it from the soil. This process is called nitrogen immobilization, as the nitrogen is fixed temporarily in the microbes and released only after some time. During this time, the microbes compete with the plants for nitrogen and the crop may suffer from malnutrition.

How to prevent N-immobilization:

- **Old or rough plant materials should be applied to the soil at least two months before planting or sowing the main crop**
- **nitrogen immobilization can occur when the following materials are applied: straw or grain husks, material containing wood (e.g. twigs, saw dust), half rotten compost**

Case 4: Handle with care! Cover crops can smother
Mr. Anthony Owino Malowa of the Mariwa Farmer Field School and who is practicing conservation agriculture is HIV positive. Although he is weak, he practices conservation agriculture because it requires less labour. He no longer ploughs his field but uses the jab planter to plant directly. Since he adopted conservation agriculture, the weeds in his half-acre field were greatly reduced by intercropping maize with Dolichos lablab. However, in the 2005 long rains his farm, where he intercropped lablab with maize, never gave him any yield because lablab smothered all the maize. He discarded lablab as a cover crop even though it suppresses weeds, calling it a very dangerous weed. Mama Benta Odipo of the Tumaini Farmer Field School decided to plant beans as her main crop during the 2005 short rains. But after two weeks she decided to plant mucuna in between the rows, believing that after a short while, she would harvest her beans and have her soil covered with mucuna. It was a mistake. She

never harvested any beans and there was no sign they had even been planted. This made her rethink using cover crops and she is contemplating leaving it out of her farming.
Source: Kaumbutho, P. and Kienzle, J. (2007)

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Conservation tillage systems

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Description: Conservation tillage embraces one principle of conservation agriculture; "Minimum soil disturbance". It includes practices that keep the disturbance of the soil and loss of organic matter to a minimum, reducing soil and water losses. Mostly, the soil is not turned using ploughs.
Status: For information on conservation tillage systems click here

No tillage or minimum tillage

Conservation agriculture has three basic principles:

1. Disturb the soil as little as possible practising no-tillage or minimum tillage. The ideal is to plant direct into the soil, without hoeing or ploughing. Tillage is reduced to ripping planting lines or making holes for planting with a hoe.

2. Keep the soil covered as much as possible.

3. Mix and rotate crops.

To gain the full benefit of conservation agriculture, all three principles have to be applied at the same time. This ideal is not possible everywhere, but farmers should try to go into that direction as far as possible.

For information on conservation tillage systems click here (Datasheet under Plant Health - Cultural practices)

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Mixed cropping and Crop rotation

Description: Planting the right mix of crops in the same field, and rotating crops from season to season allows a break down of survival and multiplication cycles of pests, diseases and weeds resulting in higher yields and maintenance of soil fertility.

For information on crop rotation click here

For information on Intercropping click here

Mix and rotate crops

Mixed cropping and crop rotation embrace one of the principles of conservation agriculture.

Planting of the same crop each season - as sometimes practiced in conventional farming is minimized by planting the right mix of crops in the same field, and rotating crops from season to season. This allows a break down of survival and multiplication cycles of pests, diseases and weeds resulting in higher yields and maintenance of soil fertility.

cropping and Crop rotation

For information on crop rotation click here
For information on Intercropping click here

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Crop residue used as soil cover

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griculture

Conservation agriculture

rvation agriculture?

agriculture (CA) aims to produce high crop yields while reducing production costs, e soil fertility and conserving water. It is a way to achieve sustainable agriculture and oods.

Processing and Value addition

Energy

agriculture has three basic principles:

soil as little as possible. The ideal is to plant direct into the soil, without hoeing or age is reduced to ripping planting lines or making holes for planting with a hoe.

il covered as much as possible. Mulch, special cover crops and/or crop residues left on the field protect the soil from erosion and limit weed growth throughout the year. This is opposed to conventional farming practices, whereby farmers remove, burn crop residues or mixes them into the soil with a plough or hoe. As a consequence, the soil is left bare, so it is easily washed away by rain, or is blown away by the wind.

3. Mix and rotate crops. Planting of the same crop each season - as sometimes practiced in conventional farming is minimized by planting the right mix of crops in the same field, and rotating crops from season to season. This allows a break down of survival and multiplication cycles of pests, diseases and weeds resulting in higher yields and maintenance of soil fertility.

To gain the full benefit of conservation agriculture, all three principles have to be applied at the same time. This ideal is not possible everywhere, but farmers should try to go into that direction as far as possible.

History of conservation agriculture

In the 1930s, soil erosion in the United States reached crisis proportions. The problem was particularly severe in the Midwest, where millions of tons of topsoil were blown away by the wind or washed into rivers, in what came to be known as the 'Great Dust Bowl'. Supported by the government, American farmers started abandoning their traditional practice of ploughing. Instead, they left the crop residues on the soil surface, and planted the next crop directly into the stubble. Faced with similar problems, farmers in South America also took up conservation agriculture. They sowed cover crops to protect the soil, and rotated crops in order to maintain soil fertility. Because of the benefits, knowledge passed

quickly from farmer to farmer.

By the year 2000, conservation agriculture was practised on about 60 million hectares of land worldwide, mainly in North and South America. Government support has been important: in some states in Brazil, conservation agriculture is official policy. In Central America, Costa Rica's Ministry of Agriculture has a Department for Conservation Agriculture. Conservation agriculture is used to cultivate over half the crop land in Paraguay, about one-third of the land in Argentina, one-third in Brazil, and one-sixth in the United States.

The many South American conservation agriculturists are well organized in local and national farmers' associations. They are supported by institutions from North and South America and have links with international agencies such as FAO, GTZ and the World Bank. This support is essential to help farmers to adopt quickly new approaches and technologies that many see as a radical change in the way they farm.

Green Revolution vs No-till or Reduced-till Revolution

The Green Revolution did not provide adequate benefits to resource poor vulnerable farmers without access to external inputs namely fertilizers, hybrid seeds and water. In contrast, Conservation Agriculture can and is beginning to benefit all farmers and communities at large. CA is a silent multi-stakeholder movement driven by an urge to produce more food at less cost, conserve land and water resources and improve environmental quality. Thus CA does easily conform to be an important component of the strategy for food security, poverty alleviation, rural development, enhance productivity, improve environmental quality and help preserve natural resources at the same time.

Conservation agriculture in Africa

Conservation agriculture has great potential in Africa because it can control erosion, produce stable yields, and reduce labour needs.

The story of conservation agriculture in Africa is not new. Across wide areas of Africa, conservation agriculture principles used to be normal practice, before ploughs were introduced. Farmers would cultivate by hand, often with hoes, rotating crops and fallowing fields for several years. Rising populations and ploughs changed all that. European settlers and colonial regimes introduced ploughs, and they quickly came to dominate farming because they enabled farmers to open up more land quickly and cheaply. But just as in the United States, the plough has gradually eroded Africa's soils. Fertility and yields have fallen, and many countries now face critical food shortages. But not all Africa's farmland was put to the plough, or to the deep-till hoe, and pockets of conservation-friendly farming still remain.

Conservation agriculture emerged in several different places around the same time in Africa. The most dramatic story comes from Zimbabwe and Zambia, where conservation agriculture came to the rescue of the land. Starting on one large-scale commercial estate in Zimbabwe, a combination of zero-tillage and direct planting into deep straw mulch meant a slow but sure recovery for de- graded land. A moderate use of herbicides was needed to kill weeds. By the mid 1990s, nearly 4000 hectares were under conservation agriculture - all on large-scale farms. Efforts are presently being made to transfer this success to some of the many new small-scale farmers in Zimbabwe.

In Zambia around the same time, a dedicated extension unit, supported by donor funds, spread the message. Here, small-scale farmers found that conservation agriculture worked on their farms too. Currently more than 100,000 small-scale farmers in Zambia have converted to conservation agriculture.

Large-scale farmers in Kenya, South Africa and Namibia also use conservation agriculture practices. In South Africa, no-till farmers' clubs similar to those in South America have been set up. Initiatives by government research and extension agencies, donors and the private sector promote conservation agriculture for smallholder farmers in Cameroon, Ghana, Kenya, Madagascar, Malawi, Namibia, Tanzania, Uganda, Zambia, Zimbabwe, and other countries. Various institutions conduct research on or

promote conservation agriculture.

The most important researchers and promoters of conservation agriculture in Africa are farmers themselves. Every farmer is a researcher, who experiments every season on his or her farm. Farmers who find something that works are likely to repeat it the next season, and to tell their friends about it.

Sustainable land management

Sustainable land management (or "land husbandry") is a broad term that includes various types of crop and livestock production that aim to produce good yields year after year, while conserving soil and water resources. It does not necessarily include all three principles of conservation agriculture (don't turn the soil, keep the soil covered, and rotate crops). Conservation agriculture is a type of sustainable land management.

Agroforestry

Agroforestry is a combination of trees and crops (or livestock), and is a form of 'sustainable land management'. Agroforestry promotes soil cover and crop rotation, so may contribute to a conservation agriculture system.
For more information on agroforestry click here

Why start using conservation agriculture?

You might start using conservation agriculture for many reasons.

- **To improve your yields**

Unlike the rest of the developing world, crop production in Africa is not keeping pace with population growth. Yields in many areas are actually falling. A major cause of this is declining soil fertility, often caused by the way of farming. The rising population has forced farmers to abandon traditional practices that left the land fallow for several years, and to cultivate ever-smaller plots. Intensive tilling and hoeing year after year can produce a hardpan in the soil. That restricts root growth and stunts plants. Rainwater pounds the bare soil, forming a surface crust that the water cannot penetrate. It runs off, taking the valuable topsoil with it. Erosion in some places is so severe that there is little soil left.

To get a good yield, farmers often apply more and more fertilizer. With less moisture in the soil, plants are more vulnerable to drought. They start to wilt after a few days without rain.
Conservation agriculture enables farmers to reverse this trend. It prevents hardpans from forming, protects the soil, increases soil moisture, and restores soil fertility, so stabilizing yields and improving production over the long term.

- **To reduce your production costs**

Tilling the soil is expensive. Fuel and fertilizer prices and labour costs rise continuously, while market prices of farm products have fallen. Many farmers cannot recoup their production costs by selling what they produce, so they end up making a loss.
Conservation agriculture helps these farmers cut costs while increasing their yields.

- **To overcome shortages of labour and farm power**

Many farm households suffer from a severe lack of labour and farm power. Hunger and malnutrition combine to make people weak, unable to work hard, and vulnerable to disease. Young people are moving out, and HIV/AIDS and malaria create a severe labour shortage. Many draught animals have died because of disease, or their owners have had to sell them to pay for medical treatment and burials. A lack of farm power forces farmers to look for other ways to farm.

Conventional vs conservation

Both conventional farming and conservation agriculture include a very wide range of operations: field preparation, planting, fertilization, weeding, harvesting, and field operations after the harvest. There are, of course, many variations in both 'conventional' and 'conservation' approaches, so the descriptions are simplified and may not depict what happens in a particular area.

Conservation agriculture means less work because it is not necessary to plough the soil and weed as many times. It suppresses weeds and reduces erosion. It improves the soil structure, ability to retain water, organic matter content and fertility. All these lead to higher and more stable yields.

Organic vs conservation

Organic farming involves growing crops and livestock without using agrochemicals. It is possible to do conservation agriculture in an organic way (without using fertilizers, herbicides or pesticides), but many types of conservation agriculture use these agrochemicals - but in small amounts and with care.

Advocacy of crop rotations to break disease and pest cycles are very complimentary for both organic and conservation agriculture. While conservation agriculture stresses on zero or reduced tillage and maintenance of soil cover, seems not bound by these factors.
For more information on organic farming click here

How does conservation agriculture work in different types of farms?

The three principles of conservation agriculture (disturb the soil as little as possible, keep the soil

covered as much as possible, and mix and rotate crops) can be applied in a wide range of conditions. How farmers put them into practice will vary from place to place, depending on many factors. Conservation agriculture can be practised on different types of farms, with different combinations of crops and sources of power. Here are some examples:

- **Hoe farming**

Many African farmers cultivate by hand, using hoes. These farmers can practise conservation agriculture by digging small planting holes in lines, at carefully measured distances, leaving the rest of the soil unturned. If hoeing in previous years has produced a hardpan, the holes must be deep enough to break through this hard layer.

The farmers can put compost or manure in the holes to raise the soil fertility and the water-holding capacity, then sow maize or beans. They can sow cover crops between the planting holes to protect the soil from erosion and to suppress weeds. They can pull weeds out by hand, or slash them with a machete.

The next season, they can plant different crops in the same holes. It is not necessary to dig through the hardpan again, because the first season?s crop roots will have penetrated deep into the soil and will help water to seep into the soil. So it is necessary to do hard work of digging the pits only once.

- **Small holder farming with draught animals**

Farmers who own (or can hire) oxen or donkeys to pull implements can use a different set of conservation agriculture practices. They can use a subsoiler to break up the hardpan (if there is one). This is usually necessary only in the first year.

If there is no hardpan, the farmers can use an animal-drawn ripper to open up a narrow furrow for planting seed. The soil between these furrows is left alone. It is possible to use rippers and subsoilers that sow seeds and apply fertilizer at the same time, so saving time and work. Before planting the crop, the farmers can use a hoe or knife-roller to kill weeds, or apply herbicide using a sprayer or wiper. They sow a cover crop with the maize crop to smother weeds and to reduce

evaporation from the soil surface. When harvesting the main crop, the farmers leave the residues and cover crop on the field. That protects the soil from the sun and rain, and further controls weeds.

- **Mechanized farms**

Farmers with tractors can use conservation agriculture too. They can replace their mouldboard ploughs, disks and harrows with rippers, subsoilers and direct-drill planters.
At the outset of the season, large scale farmers use a knife roller, sometimes in combination with herbicides, to kill the previous season?s cover crop and weeds. In the first season of conservation agriculture, they may need to use a subsoiler to break up ploughpan. They then use a direct drill-drill planter to sow seeds. A post emergence herbicide kills any weeds that come up after planting and before the crop canopy can cover the surface.
After harvest, the crop residues stay in the field. The farmer then sows a cover crop to protect the soil until the next planting season.

Many farmers are able to use a combination of implements and different types of power. For example, a hoe farmer may be able to hire a neighbour with a tractor to subsoil her field. She can then choose among various options so she gets the full benefits of conservation agriculture.

Different situations

Conservation agriculture can be used in all parts of Africa, except where it is too dry to grow crops. It can be applied in various climatic zones and under different conditions, though it may look very different from place to place.

- **In semi-arid lands, conservation agriculture retains water in the soil, keeps the soil temperature even, and protects the land from erosion during heavy downpours. Maintaining soil moisture is the main challenge in these areas, so rainwater harvesting methods can be very useful to increase the amount of water available for crops. Crops may be planted with wide spacing, and there may not be**

enough moisture to grow a cover crop, so farmers may have to rely on mulch or residue to keep the soil covered. Livestock are important in these areas. Farmers may have to restrict grazing on their fields to keep as much soil cover as possible.

- **In sub-humid and humid areas, weeds and erosion are likely to be more of a problem. Crops are planted at closer spacings, and cover crops help suppress weeds and protect the soil.**
- **On slopes, conservation agriculture can be used in association with terraces, contour grass strips and other erosion-control methods. Terraces already exist in many places; conservation agriculture can be used on them.**
- **Where labour is scarce, perhaps because of HIV/AIDS, conservation agriculture enables farmers to produce good yields with less labour.**
- **In densely populated areas, conservation agriculture increases yields on small plots of land under intensive cultivation.**
- **On good soils, conservation agriculture keeps the soil healthy and maintains yields. On poor soils, it is a good way to rebuild soil fertility and enhance water-holding capacity, so increasing production.**

Challenges for conservation agriculture

Conservation agriculture has the potential to change the face of Africa. But its success is not automatic. It faces various challenges.

Change of mindset. Switching to conservation agriculture involves a fundamental change of mindset. For example, farmers must drop their traditional practice of preparing the land with a hoe or plough, and instead rely on ?biological tillage? by the plant roots and earthworms. The switch also encourages farmers to begin to see their farms as a business rather than merely a way to feed their families.

Conservation agriculture involves radical changes in what extension services do. An effective way to promote conservation agriculture is through farmer field schools and other approaches that put farmers and their needs at the centre, rather than seeing them as mere recipients of advice. Such revolutionary changes require teaching, not only on the farm itself but also within schools and colleges. Extension staff will need intensive training so they can learn the necessary technologies. Field demonstrations and awareness-creation campaigns will also be needed. The mass media must be harnessed to support the campaign.

Crop residues. Keeping the soil covered is important in conservation agriculture. But it can be difficult. Farmers have many uses for crop residues: as fodder, fencing, roofing and fuel. Livestock keepers let their animals graze on stubble. In drier areas, it is impossible to grow a cover crop in the dry season, and crop residues are a vital source of animal feed.
If they are to keep the soil covered, farmers will have to protect their fields and find alternative sources of fuel and fodder. In wetter, sparsely populated areas, this is easy. In drier areas, it is more difficult. Alternatives include fencing animals out, reaching agreements with livestock owners on grazing rights, and growing special plots of fodder and fuelwood.

Land tenure. Farmers can go a long way towards adopting the principles of conservation agriculture with a minimum of investment on their farms. But they may be reluctant to do so if they do not have clear rights to the land they cultivate.
The importance, however, of the land tenure issue varies widely throughout Africa. In some countries, lack of guaranteed tenure impedes all agricultural development.

Adaptation of the "Brazilian" CA to take advantage of indigenous knowledge and different agro-ecological conditions is a process ? uncomfortably long. Other challenges. It can be hard to find seed (particularly of cover crops), inputs such as herbicides, and equipment. Crops such as tef, which has

very small seeds, can be difficult to sow without disturbing the soil. And for various reasons, it can be difficult for farmers to work in groups, form organizations or get the support they need to begin practising conservation agriculture.

Conservation Agriculture and the African Conservation Tillage Network (ACT)

Agricultural growth will play a decisive role in efforts to improve the welfare of the vast majority of Africa's populations. Over half of the continent's populations live in rural areas, and over 60% of Sub-Sahara Africa's populations live off some form of direct exploitation of natural resources, largely through subsistence agriculture. Reductions in the number if increasingly poor people, of the 30% of chronically hungry Africans and vulnerability, therefore, shall depend crucially on sustained and broad-based agricultural growth. This will also lay the foundation for sustainable socio-economic growth.

Long-term agricultural production trends in Africa have proven disappointing. Africa remains the only region in the world where per capita food production has declined by 13% over the last 35 years. Twenty percent of the natural resource base suffers from water and wind erosion and 70% from moisture stress. Soil fertility is ranked the single, most important food security constraint. The "Green Revolution" considered by many to be a success story has not only amplified the social inequities, but the resultant deceivingly cheap food is not always healthy and costs a fortune in terms of water, soil and biological diversity on which the future of not only the beneficiaries but all of us depends. Rising world food prices combined with the high costs of energy for transportation pose new opportunities but are simultaneously a catastrophe for the majority who are unable cope. A new paradigm of "producing locally for local consumption is probably in the making".

Conservation agriculture (CA) has the potential to enhance food security through increased and stabilised productivity and sustainable land management (SLM). Building on indigenous, scientific knowledge and innovative equipment designs from Brazil CA is spreading in Africa. More than 14 countries are now practicing the technology. Practicing farmers are able to produce more food more reliably using same rates of fertilizers and using much less labour (up to 50%). Action is needed now to get this promising technology adopted by as many farmers as is possible. But, there are serious challenges to be overcome to make this viable. Experiences of the African Conservation Tillage (ACT) in Enhancing Access to CA Knowledge & Information and Partnerships are summaries in the rest of the discussions.

The ACT is a 'Not for profit', voluntary membership Non Governmental Organisation registered and with offices in Nairobi Kenya. The organisation has received support from many international organisations including GTZ, FAO, CIRAD and SIDA. The common vision was developed in Harare in 1998. The current membership stands at 1200 Individuals and Institutions from 33 countries. The organisation has regional offices in Nairobi, Harare and the soon to be launched Ouagadougou office.
What is the strategic intervention that will provide the optimal leverage in enhancing adoption and benefits from CA? While being positive to increased productivity and profitability as in the Green Revolution, the technical fix (improved seeds, better distribution of fertilizers, and more research to develop accompanying technologies) is no longer sufficient. Not until we have identified and removed the current hindrances that limit farmers accessing and exploiting the proven and perfected scientific packages. Not until we have answers why farmers enticed into the high external input packages failed to repay loans and reverted back to worse situations when the interventions ended? One key underlining concept that ACT subscribes to is the balancing between input and knowledge based extension interventions; i.e. facilitating the shift from the common "input based approaches" to "farmer knowledge empowerment and input based approaches". ACT believes that farming technologies "will not be transferred from one area to another" but arise from a process were local communities/farmers

engage in adaptation of the knowledge/technologies to local circumstances.

Overarching all this is the argument that "accessing and churning knowledge into practice" is probably the last missing mile in this long journey of unlocking millions of poor Africans out of poverty. The interface between farmers and the public/private service providers and the regulatory institutions needs to be more sharpened and focused. As correctly cited by former UN Secretary General Kofi Annan when calling for a "uniquely African" Green revolution, Addis Ababa, 5 July 2004: " Knowledge is not lacking. The basic policy directions are well established and widely accepted. What is lacking, as ever, is the will to turn this knowledge into practice".

The ACT places networking, knowledge and information management at the core of its functions. Web-based information support to its members is provided under the web site www.act.org.zw, which is now under reconstruction and relocation to www.act-africa.org. Under the web site are available CA databases of equipment suppliers, CA professionals, institutions, farmer organisations and continental/ global experience reference material. Electronic newsletters and special topic forums are being performed. An increasing number of people (extensionist, researchers and policy makers) are accessing e-news, enhancing faster and cost-effective CA /SLM networking.
ACT in collaboration with IIRR and other partners developed a CA reference book for farmers and extension officers. 1500 copies of the manual have been produced and distributed. Also, 8 case studies from 5 African counties have been made and 13,000 books published. Posters, brochures and leaflets are other promotional materials that target smallholder farmers without access to internet.

ACT was co-organiser of the III World Congress on CA in Nairobi in 2005. As a result, some African Governments have prioritized and included CA in countries' development agenda. Another congress outcome is birth of the West African Smallholder Conservation Agriculture Promotion Project (SCAP), a 3 year' pilot project in Niger, Guinea and Burkina Faso. Learning-education and training support has been offered by ACT through FFS curriculum development and adaptation. Local and International tailor

made training workshops for research & extension officers for the past 5 years have been offered. The many CA graduates scattered throughout Africa form a good nucleus for CA entry and development. A major challenge is the need to accelerate and address the issue of curriculum reform at a higher national level so that agricultural colleges stop training "tillage/ploughing" as usual.

The ACT has just embarked on anew phase with a New Thrust. The new impetus revolves around:

- **Broadening the ACT Farmer and Institution membership and subsequently empowering them to actively participate in CA/SLM forums.**
- **Consolidate Knowledge and Information Management Platform to the extent where it becomes a 'bank' for stakeholders to deposit, retrieve, exchange and use. A higher profile will be granted for professional and community-based archiving and assessment of indigenous knowledge and practices.**
- **In recognising farming communities and farmers not only as producers but also managers/ stewards of ecosystems, emphasis will be placed on building the local human capital. Farmers need to be empowered in own on-farm experimentation, monitoring, evaluation and learning. Incentives and other modalities need to be developed for farming communities to demand for services and enhance capacity of researchers to work with local people and their organizations.**
- **Forging strategic partnerships that address medium to long term interventions, geographic concentrated action zones and interventions that will target elevating farmers beyond crop productivity are pertinent. It is clear that even at the maximum possible yields, smallholders constrained by land holdings (of say 1 hectare) cannot eradicate poverty with a single crop in a year. Opportunities need to be explored and exploited on: getting multiple crops in a year, switching to commercial farming with better rewarding crops, diversification to on/off farm enterprises that can utilise and add value to labour saved by CA and value addition enterprises.**
- **Incentives are needed to influence the choices how individuals exploit their natural resources. Issues such as poverty and climate change also require collective agreements on concerted action and governance across limits that go beyond an individual?s benefit or liking. Networking farming**

communities poises utilising the strength of their togetherness to lobby for and tap into existing incentives of CA for environmental services (carbon credits, water, hydro energy generation) insurance and micro credits. Increasing awareness needs also to be made.

- **In conclusion, CA is THE WAY for Africa. Honourable investments have been made by partners such as FAO, GTZ, CIRAD and RELMA to introduce and promote the technology. However, it is not enough. The thrust is too little, the focus is blurred and with too little resources to effect the desired 'uniquely African Green Revolution'. In comparison to the Southern America Models, investments made in kick-starting African CA are too diminutive. National Governments and NEPAD need to take the leading role, supported by Donor organisation, to get widespread adoption and benefits from CA.**

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Soil cover

Soil cover

Introduction

Soil cover refers to live vegetation, crop residue or mulch material found on the surface of the soil. A permanent soil cover is central to conservation agriculture for the following reasons:

- **It protects the soil from rain, sun, and wind.**
- **It reduces soil erosion and protects the fertile topsoil hence preventing the silting of rivers and lakes.**
- **It stops the soil surface from sealing, and reduces the amount of precious rainwater that runs off.**
- **It suppresses weeds by smothering their growth and reducing the number of weed seeds. This reduces the amount of work needed for weeding.**
- **It increases the soil fertility and the organic matter content of the soil.**
- **It increases soil moisture by allowing more water to percolate into the ground and reducing evaporation.**
- **Decomposing vegetation and the roots of cover crops improve the soil structure and make the clumps and lumps in the soil more stable, making it harder for rain to break them up and wash them away.**
- **Earthworms and other forms of life can prosper in the cover as well as in the soil.**
- **Soil cover stimulates the development of roots, which in turn improve the soil structure, allowing more water to soak into the soil, and reduce the amount that runs off.**

Types of soil cover

There are two main types of soil cover:

- **Living plant material: crops and cover crops.**
- **Mulch or dead plant material: crop residues and pruning from trees and shrubs.**

You will often use a combination of mulch and living plants to keep the soil covered.
To obtain a good soil cover, you should leave crop residues such as maize and sorghum stalks in the field. You might also be able to add mulch from outside the field: for example, you can cut grass from nearby, or bring in leaves and pruning from trees and shrubs. They will decompose after a while, so you will have to replace them regularly.

In addition, you can plant a cover crop, either during the cropping season (to cover the area in between the crop rows), or afterwards to cover the whole field. During the cropping season itself, the crops themselves act as soil cover.
An intercrop of tall plants (such as maize) and low-growing plants (such as beans) make a good cover.

Living plant material: Cover crops

Cover crops are any crops planted to produce soil cover, protect the soil surface, improve soil fertility and produce food and feed. Cover crops are also grown between orchard trees or on fields between cropping seasons to protect the land from leaching and erosion.

There are many different cover crops in Africa. The type of cover crop used influence the quality and quantity of mulch it provides. Cover crops are divided into four main groups:

- **legumes, e.g. butterfly pea, cowpea, crotalaria, desmodium, mucuna, lucerne (alfalfa), etc**
- **shrubs, e.g. calliandra, gliricidia, sesbania, sunn hemp, etc**
- **grasses, e.g. gamba grass, brachiaria, finger millet, pearl millet, etc.**

- **others, e.g. pumpkin, watermelon**

Characteristics of cover crops

Legumes

Cover crop	Botanical name	Climate	Altitude	Other uses apart from cover	Characteristics
Butterfly pea	*Clitoria ternatea*	Semi-arid to sub-humid	Low to medium	Fodder	Climbing and shrubby legume. Rage of soils. Tolerate salinity and acidity but not flooding.
Centro	*Centrosema pubescens*	Sub-humid to humid	Low to high	Fodder	Trailing legume. Wide range of soils, sandy to clay.
Cow pea	*Vigna unguiculata*	Semi-arid and sub-humid	Low to medium	Food	Legume has both creeping and erect type. Sandy to clayey soil. Long-maturing varieties best for intercropping with cereals.
Crotalaria	*Crotalaria retusa, c. ochroleuca, c.paulina*	Semi-arid to sub-humid	Low to medium	Erect legume. Wide range of soils. Deep roots break compact soil layers. Adapted to infertile soils. C. ochroleuca can be	

				eaten as a vegetable.	
Desmodium	*Desmodium intortum*	Sub-humid to humid	Medium to high	Fodder	Trailing and climbing legume. Wide range of soils
Jack bean	*Canavalia ensiformis*	Semi-arid to humid	Low to high	Food, fodder	Erect legume that can grow to 1m high. Slow growth at first. Draught-tolerant and immune to most pests. Dry before using as fodder. Young pods can be used as food.
Jugo bean, bam bara groundnut	*Vigna subterranea*	Sub-humid to humid	Low to medium	Food	Wide range of soils. Draught resistant. Beans high in protein
Lablab, hyacinth bean	*Dolichos labla*	Semi-arid and sub-humid	Low to medium	Food, fodder	Creeping legume that spreads quickly. Sandy to clayey soils. Suitable for intercropping with cereals and sugarcane. High in protein
Lucern, alfalfa	*Medicago sativa*	Semi-arid to sub-humid	Low to medium	Food	Erect legume. Wide range of soils.
Mucuna, velvet bean	*Mucuna pruriens*	Semi-arid and sub-	Low to medium	Food	Creeping legume that spreads quickly. Sandy to clayey soils. Suited for intercropping with

		humid			cereals and sugarcane. More sensitive to fertility than lablab. Excellent soil cover suppresses weeds.
Mungbean, green gram	*Vigna radiata*	Sub-humid to humid	Low to medium	Food, fodder	Wide range of soils. Edible beans and leaves
Pigeonpea	*Cajanus cajan*	Semi-arid to humid (depends on variety)	Low to high	Food, fodder, Firewood	Erect legume. Grows in sandy to clayey. Deep roots break compact soil layer (biological plaugh). Good at recycling phosphorus. Rich in protein.
Siratro	*Macroptilium atropurpureum*	Semi-arid and sub-humid	Low to medium	Fodder	Creeping/trailing legume. Range of soils. Tolerant to draught.
Stylo	*Stylosanthus guianensis. S. hamata*	Semi-arid to humid (depends on species)	Low to high	Fodder	Creeping coppicing legume. Does well on coarse textured soils and can tolerate acid soils. Takes 1-2 rainy seasons to cover the soil.
Tropical kudzu	*Puera phaseoloides*	Humid	Low to high	Fodder	Creeping/trailing legume that spreads quickly. Wide range of soils. Not draught resistant.

Wild groundnut, peanut	***Arachis pintoi***	**Semi-arid to sub-humid**	**Low to medium**	**Fodder**	**Coppicing legume. Permanent green cover crop. Does well on coarse textured soils. Takes 1-2 rainy seasons to cover soil.**

Leguminous Shrubs

Cover crop	Botanical name	Climate	Altitude	Other uses apart from cover	Characteristics
Calliandra	***Calliandra spp.***	**Semi-arid to sub-humid**	**Low to medium**	**Fodder, firewood, mulch**	**Wide range of soils, often on contours**
Gliricidia	***Gliricidia sepium***	**Semi-arid to sub-humid**	**Low to medium**	**Fodder, firewood, mulch**	**Coppicing shrub**
Sesbania	***Sesbania sesban***	**Semi-arid to sub-humid**	**Low to medium**	**Fodder, firewood, mulch**	**Wide range of soils**
Sunn hemp	***Crotalaria juncea***	**Semi-arid to sub-**	**Low to high**	**Fodder, firewood**	**Wide range of soils. Dry before using as fodder**

		humid			
Tephrosia	*Tephrosia candida. T. vogelil*	Sub-humid to humid	Low to high	Fodder, pesticide, firewood	Wide range of soils. Does not tolerate acidity.

Grasses

Cover crop	Botanical name	Climate	Altitude	Other uses apart from cover	Characteristics
Andropogon, gamba grass	*Andropogon gayanus*	Semi-arid to sub-humid	Low to medium	Fodder	Wide range of soils
Brachiaria	*Brachiaria ruziziensis*	Semi-arid to sub-humid	Low to medium	Fodder	Grass with multiple tillers. Wide range of soils
Cenchrus	*Cenchrus ciliaris*	Arid to sub-humid	Low to medium	Fodder	Grass with multiple tillers. Takes time to establish. Wide range of soils
Finger millet	*Eleusine coracana*	Semi-arid to sub-humid	Low to High	Food, fodder, thatch	Grass with multiple tillers. Wide range of soils
Pearl millet	*Pennisetum glaucum*	Arid to semi-arid	Low to medium	Food, fodder, thatch	Grass with multiple tillers. Wide range of soils
Sunn hemp	*Crotalaria juncea*	Semi-arid to humid	Low to high	Fodder, firewood	Wide range of soils. Dry before using as fodder.

Other cover crops

Cover crop	Botanical name	Climate	Altitude	Other uses apart from cover	Characteristics
Pumpkin	*Cucurbita spp.*	Semi-arid to humid	Low to high	Food	Creeping edible plant
Watermelon	*Citrullus lunatus*	Semi-arid to sub-humid	Low to medium	Food	Creeping edible plant

The importance of cover crops in conservation agriculture

Cover crops make up a fundamental component of the stability of the conservation agriculture system, as much for its direct and indirect effects on soil properties as for its capacity to promote an increased biodiversity in the agro-ecosystem.

While commercial crops have a market value, cover crops are mainly grown for their effect on soil fertility or as livestock fodder. In regions where smaller amounts of biomass are produced, like semi arid (dry) areas and eroded soils, cover crops are beneficial as they:

- **protect the soil during fallow periods**
- **mobilise and recycle nutrients**
- **improve the soil structure and break compacted layers and hard pans**
- **permit a rotation in a monoculture**
- **can be used to control weeds, pests or break soil compaction**

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

Cover crops are suitable for:

- **protecting the soil, when it is not cultivated**
- **providing an additional source of organic matter to improve soil structure and create an**
- **improved topsoil**
- **recycling nutrients and mobilizing them in the soil profile in order to eliminate layers with slow**
- **moving nutrients like phosphorus and potassium**
- **"biological ploughing" of the soil; the roots of some crops, especially cruciferous crops, like oil**
- **radish are pivotal and able to penetrate compacted or very dense layers , increasing water**
- **percolation capacity of the soil**
- **utilising easily leached nutrients**

Different plants, have diverse rooting systems, explore different soil depths, have the ability to absorb different quantities of nutrients and with the production of distinct root exudates (organic acids) result in benefits both for the soil and for the organisms.

The presence of a mulch layer (dead soil cover) contributes to a reduction in evaporation of soil moisture and leads to a higher water infiltration capacity in the soil profile. The percentage of rainwater that infiltrates the soil depends on the amount of soil cover provided. Whether through the effects of pores left by plant roots, earthworms, insects or other soil organisms, or through an improved soil porosity and higher number of bigger aggregates, in both cases it is accumulated organic matter that creates the favourable conditions.
Crop residues left on the soil surface lead to higher soil aggregation, and higher porosity and higher

number of macro pores, and thus to a higher trend in infiltration rates. As different cover crops produce different amount of biomass, the density of the residues varies with different crops and thus the ability to increase water infiltration.

Cover crops contribute to the protection of the soil surface and thus to the maintenance and/or improvement of the physical, chemical and biological characteristics of the soil, including adaptation of effective soil depth through their roots. Vegetative cover is essential for conservation agriculture for the protection of the raindrop impacts of raindrops and to keep the soil shaded and with the highest humidity level possible, for utilizing and thus recycling the nutrients, and for its allelopathic and physical effects on weeds leading to a reduction in agrochemical use and thus in production costs.

Increased yield when CA is integrated with agro forestry

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CA adopter farmer using cover crop instead of leaving their plots fallow

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Farmers in Mbeere appreciating the effect of biological subsoiling by cover crop

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Cover crops vs green manure

In conservation agriculture the terminology 'green manure' is not used often, although generally the same plant species are used for both practices. Green manure is considered as a crop in rotation with the objective of conserving or restoring the productivity of the land through incorporation of the non-decomposed vegetative matter in the soil. In conservation agriculture this is not desired for two reasons:

- **in conservation agriculture systems the soil is not disturbed, or as little as possible and more important,**
- **when biomass is incorporated in the soil a high microbial activity starts in order to decompose the material, resulting in a sudden release of a high quantity of nutrients that can not be captured by the seedlings of the following crop and thus disappear from the system.**

The dynamics of residue decomposition depends, amongst others, on the activity of micro organisms but also on soil meso and macro fauna. The macro fauna constitutes mainly of earthworms, beetles, termites, ants, millipedes, spiders, snails and slugs, etc. These organisms promote the integration of the residues into the soil and by doing so, modifying the physical properties through the creation of burrows.

The non incorporation of cover crop and weed residues from the soil surface to deeper layers in the soil is a slow process and depends heavily on the activity of these macro organisms. The activity of micro organisms is regulated by the activity of these macro organisms, because they provide them with 'food' and air through their burrows. In this way, nutrients are released slowly and can provide the following crop with nutrients. At the same time, the soil is covered for a long time and is protected against the impact of rain and sun.

In comparison, when green manure crops are mixed into the soil, a large amount of oxygen and 'food' is worked into the soil that leads to a rapid development of the micro fauna population. This big population can decompose the offered 'food' in a rather quick way but at the moment, the 'food' is

finished and the microorganisms die, because they cannot sustain their way of life. At this moment a large amount of nutrients is released, that if not taken up by plant roots it can easily be lost through leaching. The whole time, after incorporation, the soil is not protected by a cover and thus is susceptible to degradation processes, resulting in erosion.

Commonly used cover crop species

There are various crop alternatives to be used as vegetative cover, like grains, legumes and oil crops. All of them are of great benefit to the soil; however, some crops emphasize certain benefits, which is useful to keep in mind when planning a rotation scheme. It is important to start the first years of conservation agriculture with (cover) crops that leave a lot of residues on the soil surface, which decompose slowly (because of the high C/N ratio). Grasses and cereals are most appropriate for this stage, also because of their rooting system, which need a shorter time to improve the soil. In the following years, when the soil shows a healthier appearance, legumes can be incorporated in the rotation.

Leguminous crops enrich the soil with nitrogen and decompose rapidly because of the low C/N ratio. Later, when the system is stabilized it is possible to include cover crops with an economic function, like livestock fodder. In order to be able to successfully integrate cover crops in a production system, it is crucial to select the plants that are adapted to the different soil and climate conditions and show advantages that fit in the rotation scheme. For this, it is not only necessary to know all the agronomic details of the species, but also all specific conditions of the site where they will be sown (soil and climate) and the anticipated objectives and socio-economic conditions of the farmers.

The selection of cover crops should depend on two main criteria, i.e. the presence of high levels of lignin and phenolic acids, which give the residues a higher resistance to decomposition and thus

results in soil protection for a longer period.

Resistance to decomposition

Another determining factor of the dynamics of residue composition is the biochemical composition of the residues. According to species, their chemical components and the time and way of managing them, differences exist in decomposition rates. Grain species show more resistance to decomposition than legumes. The latter has a lower C/N ratio and less lignin content and thus is subject to a rapid decomposition. Because one of the main objectives of a cover crop is the protection of the soil, their resistance to decomposition should be one of the criteria for selection. In addition, for tropical and subtropical cover crops the resistance to decomposition has been researched. Pearl millet followed by pigeon pea, white mucuna and Cratalaria paulina demonstrated higher resistance and left more soil cover for a long period than the other crops.

Therefore, these crops are better suited as a cover crop, especially during the first years of conservation agriculture than other crops.

Generally, the type of crop and the management afterwards determine the quantity of resides produced, the soil cover generated and the time the cover remains on the surface before being decomposed.

Case 1: Effects of various live cover crop types on soil loss - Gatanga Kenya

	no cover crop	Mucuna	Purple vetch	Dolichos
% ground cover	0	43.2	9	11.4
cummulative soil loss tonne/hectare	3.3	0.35	1.83	1.32

Effects of cover crop on water economy:

Water balance

- **Rainfall that enters in soil vs water that is lost through transpiration and evaporation**

Effect of cover

- **Promotes infiltration**
- **Decrease evaporation from the soil surface**
- **3-7% more soil moisture found under soil cover - yield effects of drought**

Effects of cover crop on soil temperature

- **Root extension, soil moisture, soil life nutrient uptake etc.**
- **Upper extreme limit - 30-35 degree Celsius ; lower limit 15-20 degree Celsius . Tropics**
- **Maize - every 1 degree Celsius increase in soil temperature above 30 degree Celsius cause 10% reduction in yields.**
- **Soil cover - reflect sunlight, absorb some radiation (insulate soil). Hence soil under cover receives less heat.**
- **Less heat - less evaporation - increased moisture - cooler soil.**

Effects of cover crop on soil chemical properties

- **Improves soil carbon**
- **Protects and increases soil humus - lignin, wax and fat-like substances form stable humus after decomposition**
- **Improves soils cation exchange capacity - the capacity of the soil to store nutrients**
- **C/N ratio with N immobilization - temporary shortage of N**
- **Adds nutrients to the soil**

How to choose the right cover crop

- **Choose cover crops that fit into your normal cropping system and which has multiple purposes: edible seeds and vegetables, soil fertility, animal fodder, firewood/fencing material, weed suppression, medicines**
- **Select a cover crop that grows well in your area (adapted to soil type, rainfall, temperature and altitude. If you live in an area with little rainfall, select a cover crop that grows quickly, such as desmodium, lablab, lucerne, mucuna or pigeon pea**
- **Select crops that cover the soil quickly and give less work for land preparation, weeding, producing and harvesting the seeds. Species with big pods and grains like pigeon pea and mucuna are easier to deal with than species with small pods such as vetch and grasses.**
- **The cover crop should not interfere with the main crop. Avoid growing a tall cover crop that might shade the main crop. Prevent this by planting the cover crop later**
- **If you can not prevent livestock from getting into your fields, choose a cover crop they do not like to eat, such as sunn hemp (*Crotalaria*) or jack bean (*Canavalia*)**
- **To ensure a lasting soil cover, use a mixture of legumes and grasses. Legumes decompose quicker than grasses. This means that the next crop can use nutrients such as nitrogen from the legumes quickly**

An ideal cover crop should:

- **Grow quickly and produce ground cover rapidly**
- **Be aggressive and be able to compete with weeds**
- **Prevent soil erosion**
- **Have a considerable leaf production and litter fall**
- **Seed freely and produce edible seed and/ or be suitable for use as animal feed**
- **Does not require inoculation with introduced rhizobia**
- **Leave residual N for the following cash or subsistence crops**

Cover crop and residue management

In conservation agriculture, residues should be manipulated from harvest onwards. An equal distribution of residues provides homogenous temperature and humidity conditions at time of sowing. In case residues are not distributed more or less equally on the soil surface this may cause the following problems:

- **bad placement of the seeds at sowing, resulting in an uneven germination**
- **a cold and humid surroundings of the seeds favours the development of pests and diseases**
- **bringing- about allelopathy**

It is important to choose the precise moment at which the vegetative cover is to be controlled, because most of the species used can regenerate if their growth is interrupted prematurely. Alternatively, mature seeds of the cover crop can germinate if the plants are allowed to mature.

There are, however, species and rotations where cover crops are purposely brought to maturity to establish a seed bank which would allow the cover crop to grow automatically once the cash crop has been harvested.

The best moment to control the majority of cover crop species is at full flowering when they have accumulated maximum biomass. In case of legumes, the pods from the first flowering should be already formed but not yet mature. For oats and rye, the best moment to manage is the milky stage. Forage radishes can be slashed at any growth stage, but in systems of direct sowing and minimum tillage, seeds should be green and physiologically immature to avoid the germination of new plants.

Both Crotalaria and pigeon pea need to be controlled before flowering due to high re-growth rate and excessive wood development. The most adequate form to manage the cover crops depends on the objective of the cover crop and the possibilities of the farmer. In case the dead mulch should cover the

soil as long as possible, the best way to manage the biomass is by using knife roller, chain, sledge or herbicides. When the decomposition process has to start immediately in order to release the nutrients it is recommendable to slash or mow the cover crop. In some cases, it might be necessary to complete this with herbicides. Research shows that the period between slashing/management of the cover crop and seeding of the commercial crop (maize, beans, soya, etc.) defines the production level of the crop. This is related to some of the substances that are released during decomposition of the cover crops. These can harm the germination of the seeds, or sometimes even delay the development of subsequent crops. This is called allelopathy. In general, management of leguminous cover crops ten days before planting of maize gives highest yield responses.

Inter-cropping/mix cropping

Mixed cropping is not a new agricultural activity; for generations, farmers have grown maize and beans in association and legumes are sown into pastures with the aim of improve the grazing quality of the pasture. Associations of crops have numerous benefits in production systems. Effect on nitrogen availability in proper quantities and adequate moment for subsequent crops and providing soil cover for a longer period are some of the positive impacts of cover crop mixtures. Crop residues can be an effective source of nitrogen for grain crops, like maize, sorghum and others with a high nitrogen demand, provided that the nutrient release from the residues is synchronized with the demand from the crop.

Therefore, the ideal crop association is the one that offers enough residues to provide a 'pool' of mineral "N" from decomposition to attend to the commercial crop. The strategy for crop associations is to look for species from different families that have different C/N ratios and lignin contents, and that are able to contemplate with both the supply of nutrients and the provision of soil cover for a long time.

Mixtures can be made from cereals/grasses and legumes, cereals/grasses and oil crops or even mixing 2-3 or more species that besides presenting an important impact on the improvement of soil properties produce a C/N ratio that favours a gradual nitrogen mineralization. In general, when residues of grass species are mixed with residues of legumes no immobilization of nitrogen will take place and the gradual mineralization favours the availability of nutrient s for absorption by plants.

Commonly used mixtures include:

Millet+sorghum; millet+*Crotalaria juncea*; pigeon pea+sorghum; cowpea+millet; sorghum+ *Crotalaria juncea*.

Mixed cropping is another form of crop mixtures. For instance, maize can be mixed with pigeon pea and Crotalaria juncea both planted when the maize plants have reached a height of 30cm by using the same machine as for planting maize.

In Latin America very common practices include the mixture of maize with Mucuna or Canavalia in both cases planted about 80-100 days after the maize was planted. After the maize harvest these species accelerate their development, completely overgrowing the maize residues. Subsequent crops can include beans, sorghum or sunflower.

When to plant cover crops?

It is important to plant cover crops at the right time if better result is to be realized. Below are explanations under common practices in the planting of cover crops;

Intercropping

This involves planting legume cover crop at the same time as the main crop. This is easy because you can plant both crops at the same time. It is suitable for sub-humid and humid areas. A possible problem is that the cover crop might grow so quickly that it smothers the main crop. Also, you cannot plant a cover crop this way if you are already intercropping a cereal (e.g., maize) with beans.

Relay cropping

This involves planting the legume cover crop when weeding the main crop. This is suitable for sub-humid and humid areas. You can plant the cover crop when you do the first weeding (usually about 4 weeks after planting the main crop). Or if you are intercropping maize and beans, you can plant the cover crop when you harvest the beans.

Sequential planting

This involves planting the legume cover crop after you harvest the main crop. In dry areas, you can plant the cover crop when you harvest the main crop. This prevents the cover crop from competing for moisture with the main crop. You can use the cover crop to provide extra mulch and to produce livestock feed. Harvest water to make sure there is enough moisture to grow the cover crop. If you live in a semi-arid area with only one rainy season, you can plant a drought-tolerant cover crop such as lablab between your rows of maize. Leave the cover crop in the field after the maize harvest so it covers the soil and suppresses weeds. Before the next season's rains, slash it or roll it, and leave it on the ground as mulch.

How to plant cover crops?

In conservation agriculture, cover crops are planted directly with minimum soil disturbance. You can plant a cover crop as an intercrop (or relay crop) or in a pure stand. For cover crops with large seeds, plant with a hand hoe, jab planters or animal drawn direct planter (for pure stands). You can broadcast cover crops with small seeds (such as finger millet), provided the soil cover is not too thick. If the soil cover is thick, sow the seeds in lines by hand or use a seed drill. The plant spacing and number of seeds per hole depend on several factors.

- **Use a narrower spacing in pure stands, and a wider spacing in mixed (intercropped) stands**
- **Use a wider spacing in drier areas, so the plants don't compete with each other for moisture.**

- **The number of seeds per hole depends on the amount of moisture available: fewer seeds per hole in dry areas; more in wetter areas. In general, plant 2 - 4 seeds per hole.**

How can farmers obtain cover crop seeds?

Varieties of cover crop seeds are available within the supply chain of local agro-stockist, research centres such as Kenya Agricultural Research Institute (KARI), Selian Agricultural Research Institute (SARI), World agro forestry Centre ICRAF and many other similar outlets. The table below provide guidance on the contacts

No	Common name	Scientific name	Where to get it
1	Groundnut	*Arachis hypogaea L.*	Agricultural research centres/Seed companies
2	Wid peanut	*Arachis pintoi Krap. & Greg*	Agricultural research centres/Seed companies
3	Pigeon pea	*Cajanus cajan (L) Millsp.*	Agricultural research centres/Seed companies
4	Calopo	*Calopogonium mucunoides Desv.*	Agricultural research centres/Seed companies
5	Jackbean	*Canavalia ensiformis (L.) DC.*	Agricultural research centres/Seed companies
6	Chick pea	*Cicer arietinum L.*	Agricultural research centres/Seed companies
7	Clitoria	*Litoria ternatea L.*	Agricultural research centres/Seed companies

8	**Sunnhemp**	***Crotalaria juncea L.***	**Agricultural research centres/Seed companies**
9	**Tanzanian sunnhemp**	***Crotalaria ochroleuca***	**Agricultural research centres/Seed companies**
10	**Greenleaf desmodeum**	***Desmodeum intortum***	**Agricultural research centres/Seed companies**
11	**Silverleaf esmodeum**	***Desmodeum uncinatum***	**Agricultural research centres/Seed companies**
12	**Buckwheat**	***Fagopyrum esculentum***	**Agricultural research centres/Seed companies**
13	**Soybean**	***Glycine max.***	**Agricultural research centres/Seed companies**
14	**Hyacinth bean**	***Lablab purpureus***	**Agricultural research centres/Seed companies**
15	**Trefoil**	***Lotus corniculatus***	**Agricultural research centres/Seed companies**
16	**Sweet white lupine**	**Lupinus albus**	**Agricultural research centres/Seed companies**
17	**Blue lupine**	***Lupinus angustifolius***	**Agricultural research centres/Seed companies**
18	**Yellow lupine**	***Lupinus leteus***	**Agricultural research centres/Seed companies**
19	**Siratro**	***Macroptilium atropurpureum***	**Agricultural research centres/Seed companies**

20	**Archer Axillaris**	**Macrotyloma axiilare**	**Agricultural research centres/Seed companies**
21	**Horsegram**	**Macrotyloma uniflorum**	**Agricultural research centres/Seed companies**
22	**Lucerne, alfalfa**	**Medicago sativa**	**Agricultural research centres/Seed companies**
23	**Barrel medic**	***Medicago truncatula***	**Agricultural research centres/Seed companies**
24	**White sweet clover**	***Melilotus alba Medik*.**	**Agricultural research centres/Seed companies**
25	**Velvet bean**	**Mucuna pruriens**	**Agricultural research centres/Seed companies**
26	**Glysine**	**Neontonia wightii**	**Agricultural research centres/Seed companies**
27	**Scarlet runner bean**	***Phaseolus coccineus***	**Agricultural research centres/Seed companies**
28	**Lima bean**	***Phaseolus lunatus***	**Agricultural research centres/Seed companies**
29	**Common bean**	**Phaseolus vulgaris**	**Agricultural research centres/Seed companies**
30	**Pea, field pea**	***Pisum sativum***	**Agricultural research centres/Seed companies**
31	**Tropical kudzu**	***Pueraria phaseoloides***	**Agricultural research centres/Seed**

			companies
32	Stylo	*Stylosanhtes guianensis*	Agricultural research centres/Seed companies
33	Berseem clover	*Trifolium alexandrinum*	Agricultural research centres/Seed companies
34	Rose clover	*Trifolium hirtum*	Agricultural research centres/Seed companies
35	Crimson clover	*Trifolium incarnatum*	Agricultural research centres/Seed companies
36	Subclover	*Trifolium subterraneum*	Agricultural research centres/Seed companies
37	Arrowleaf clover	*Trifolium vesiculosum*	Agricultural research centres/Seed companies
38	Purple vetch	*Vicia benghalensis*	Agricultural research centres/Seed companies
39	Lana vetch	*Vicia dasycarpa*	Agricultural research centres/Seed companies
40	Faba bean	*Vicia faba*	Agricultural research centres/Seed companies
41	Common bean	*Vicia sativa*	Agricultural research centres/Seed companies
42	Hairy vetch	*Vicia villosa*	Agricultural research centres/Seed companies
43	Green gram	*Vigna radiata*	Agricultural research centres/Seed

			companies
44	Cowpea	Vigna unguiculata	Agricultural research centres/Seed companies
45	Bambara nut	*Voandzeia subterranean*	Agricultural research centres/Seed companies

Do cover crops need weeding?

Yes! You will need to weed cover crops at least once while they are becoming established. Once they have covered the soil well, they will prevent most weeds from germinating. If you are intercropping or relay cropping your cover crop with maize or sorghum, plan to weed according to the requirements of the cereal crop. Make sure the cover crop does not tangle with the cereal crop.

Controlling pests and diseases

In parts of Kenya and Tanzania, farmers plant lablab as the only cover crop. In some villages, quite large areas are covered with the same crop. Farmers in these villages risk a pest outbreak that may ruin their cover crop. How to reduce the danger of pests and diseases:

- **Rotate the types of crops grown: food, cover and cash crops.**
- **Select cover crops that are unlikely to be attacked by pests.**
- **Plant various different types of cover crops.**
- **Use chemical spray.**

Harvesting and seed storage

Harvest the seeds before you slash a cover crop to make mulch. You may need to harvest the seeds for several reasons: so you can plant the cover crop next season, if you want to use the seeds as food or fodder, or if you want to sell them to other farmers.

Store cover crop seeds well. Here are a few tips on how to handle them:

- **Collect seeds from several plants so you get a range of seeds.**
- **Dry the seeds and treat them with insecticide. If you want to use the seeds for food, make sure that the insecticide is not harmful.**
- **Keep seeds for planting in partly opened bags or in containers in a well ventilated store.**
- **Take the seeds out and dry them again regularly. Throw out any bad seeds.**

Preparing to plant the main crop

At the beginning of the next season, your field may have a cover crop, stalks still standing from the previous main crop, and of course, weeds. You need to prepare the field so you can plant the next main crop. You can do this in several ways: by slashing the cover crop and weeds with a machete or hoe, using a knife roller to bend over and crush the standing vegetation, or by using a herbicide. It may be better to use a knife roller to crush the vegetation rather than slashing it, because equipment such as rippers and planters can easily drag pieces of vegetation along with them.

Case 2:

Cover crop pros and cons

Farmers in northern Tanzania tried various cover crops. Here is what they thought of them.

Cover crop	Advantages	Limiting factors
Lablab *Dolichos lablab*	Grows fast, so covers soil and controls weeds effectively Easy to manage Tolerates drought Fodder for livestock Good market	Farmers not using it as food Needs special management before the next season Susceptible to pests; needs spraying with insecticide
Mucuna *Mucuna pruriens*	Grows fast, so covers soil and controls weeds effectively Easy to manage Dries off in a long dry season, so no need to kill it before planting the next crop Fodder for livestock Produces many seeds, which are easy to collect Some farmers grind seeds and mix with corn bran to feed oxen	Use as food not recommended (under research) Seeds not widely available and fairly expensive Weak market Not seen as a crop, so livestock owners may allow their animals to graze Not liked by cattle
Pigeon pea *Cajanus cajan*	Cash and food crop Protects land from grazing Market available (Asia) Seeds easily available Stems used for firewood	Erect type, so poor weed suppression Little impact on soil erosion
Pumpkins *Cucurbita* spp.	Traditional food crop intercropped with maize Covers soil and suppresses weeds	Does not fix nitrogen in the soil

Source: FAO/IFAD, Sept. study, Northern Tanzania, 2001-2

Cover crop pros and cons

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Mulching

Mulch is dry, vegetative material used to cover the soil. It helps reduce evaporation and retain moisture, reduce soil erosion, suppress weed growth and provide plant nutrients as the material decomposes.

Mulch can be used in fields before and after planting, as well as around young crop plants. It is

especially useful for high-valuable vegetable crops, and for growing crops in dry areas, during dry-season cropping, and in places where the soil is easily eroded by heavy rains. Where soil erosion is a problem, slowly decomposing mulch material (low nitrogen content, high omC/N) will provide a long-term protection compared to quickly decomposing material.

Crop residues

The following are some of the most common mulch mainly from crop residues:

- **Rice husks**
- **Millet stems**
- **Sorghum stems**
- **Maize stover**
- **Wheat stover**
- **Rice straw**
- **Ground nut leaves**
- **Ground nut stems**
- **Cowpea leaves**
- **Cowpea stems**
- **Saw dust**
- **etc**

Case 3: Effect of mulch on average nutrient content of some crop residues (% of dry weight)

Crop part	N	P	K	Ca
Millet stems	0.65	0.09	1.82	0.35
Sorghum stems	0.58	0.10	1.51	0.21

Maize stover	0.70	0.14	1.43	0.36
Wheat stover	0.62	0.12	1.72	0.27
Rice straw	0.58	0.13	1.33	0.20
Ground nut leaves	2.56	0.17	2.11	1.98
Ground nut stems	1.17	0.14	2.20	0.92
Cowpea leaves	1.99	0.19	2.20	3.16
Cowpea stems	1.07	0.14	2.54	0.69

Advantages and disadvantages of mulching

What are the advantages of mulching:

- **Mulch keeps the soil underneath moist longer than bare soil.**
- **Controls soil erosion by cushioning the impact of raindrops and by slowing runoff.**
- **Suppresses weeds by shading them out.**
- **Leads to healthy crop growth.**

What are the disadvantages:

- **Mulching is labour-intensive.**
- **It can introduce new pests and diseases into a field.**
- **Dead plants for use as mulch may not be available.**

How to do it:

1. Carry to the field the material you want to spread as mulch.

2. Spread it on the soil using your hands or a rake. Put a layer of mulch 7-15 cm (3-6 inches) deep all over the bed, or around the growing plants. Do not put on so much mulch that you bury the plants or shade them out.

Do's and Dont's:

- **Use dry plant material that does not rot quickly.**
- **Don't use wet or green material as mulch.**

Constraints of Mulching

Some organisms can proliferate too much in the moist and protected conditions of the mulch layer. Slugs and snails can multiply very quickly under a mulch layer. Ants or termites which may cause damage to the crops also may find ideal conditions for living. When crop residues are used for mulching, in some cases there is an increased risk of sustaining pests and diseases.

Damaging organisms such as stem borers may survive in the stalks of crops like cotton, corn or sugar cane. Plant material infected with viral or fungal diseases should not be used if there is a risk that the disease might spread to the next crop. Crop rotation is very important to overcome these.

When carbon rich materials such as straw or stalks are used for mulching, nitrogen from the soil may be used by micro organisms for decomposing the material. Thus, nitrogen may be temporarily not available for plant growth (risk of N-immobilization).

Risk of Nitrogen-immobilization:

When organic material is applied to the soil, the decomposing microbes multiply quickly. For growth, they need nutrients, especially nitrogen, like plants do. If the applied plant material does not contain sufficient nitrogen, the micro organisms will take it from the soil. This process is called nitrogen immobilization, as the nitrogen is fixed temporarily in the microbes and released only after some time. During this time, the microbes compete with the plants for nitrogen and the crop may suffer from malnutrition.

How to prevent N-immobilization:

- **Old or rough plant materials should be applied to the soil at least two months before planting or sowing the main crop**
- **nitrogen immobilization can occur when the following materials are applied: straw or grain husks, material containing wood (e.g. twigs, saw dust), half rotten compost**

Case 4: Handle with care! Cover crops can smother
Mr. Anthony Owino Malowa of the Mariwa Farmer Field School and who is practicing conservation agriculture is HIV positive. Although he is weak, he practices conservation agriculture because it requires less labour. He no longer ploughs his field but uses the jab planter to plant directly. Since he adopted conservation agriculture, the weeds in his half-acre field were greatly reduced by intercropping maize with Dolichos lablab. However, in the 2005 long rains his farm, where he intercropped lablab with maize, never gave him any yield because lablab smothered all the maize. He discarded lablab as a cover crop even though it suppresses weeds, calling it a very dangerous weed. Mama Benta Odipo of the Tumaini Farmer Field School decided to plant beans as her main crop during the 2005 short rains. But after two weeks she decided to plant mucuna in between the rows, believing that after a short while, she would harvest her beans and have her soil covered with mucuna. It was a mistake. She never harvested any beans and there was no sign they had even been planted. This made her rethink using cover crops and she is contemplating leaving it out of her farming.

Source: Kaumbutho, P. and Kienzle, J. (2007)

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Conservation tillage systems

Conservation tillage systems
Description: Conservation tillage embraces one principle of conservation agriculture; "Minimum soil disturbance". It includes practices that keep the disturbance of the soil and loss of organic matter to a minimum, reducing soil and water losses. Mostly, the soil is not turned using ploughs.
Status: For information on conservation tillage systems click here

No tillage or minimum tillage

Conservation agriculture has three basic principles:

1. Disturb the soil as little as possible practising no-tillage or minimum tillage. The ideal is to plant direct into the soil, without hoeing or ploughing. Tillage is reduced to ripping planting lines or making holes for planting with a hoe.

2. Keep the soil covered as much as possible.

3. Mix and rotate crops.

To gain the full benefit of conservation agriculture, all three principles have to be applied at the same time. This ideal is not possible everywhere, but farmers should try to go into that direction as far as possible.

For information on conservation tillage systems click here (Datasheet under Plant Health - Cultural practices)

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Mixed cropping and Crop rotation

Mixed cropping and
Description: Planting the right mix of crops in the same field, and rotating crops from season to season allows a break down of survival and multiplication cycles of pests, diseases and weeds resulting in higher yields and maintenance of soil fertility.
For information on crop rotation click here
For information on Intercropping click here

Mix and rotate crops

Mixed cropping and crop rotation embrace one of the principles of conservation agriculture. Planting of the same crop each season - as sometimes practiced in conventional farming is minimized

by planting the right mix of crops in the same field, and rotating crops from season to season. This allows a break down of survival and multiplication cycles of pests, diseases and weeds resulting in higher yields and maintenance of soil fertility.

For information on crop rotation click here
For information on Intercropping click here

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Conservation agriculture

Images

Agroforestry

Wocat

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Soil cover

Images

Crop residue used as soil cover

T. Apina, ACT, Kenya

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Conservation tillage systems

Images

Direct planting using Brazilian made animal drawn planter

T. Apina, ACT, 2009

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Mixed cropping and Crop rotation

Images

Intercropping maize with dolichos beans

S. Fontana, Kenya

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Conservation Agriculture

Conservation agriculture

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