Creating an Evergreen Agriculture in Africa

World Agroforestry Centre
TRANSFORMING LIVES AND LANDSCAPES

Creating an Evergreen Agriculture in Africa

for food security and environmental resilience

Contents

Introduction: The Challenge for Africa

Since 1970, the population of sub-Saharan Africa has more than doubled. Land holdings have consequently shrunk in size, and many farmers, unable to leave their land fallow, now grow the same food crops, year after year, on the same plot of land. While the use of mineral fertilizers has risen tenfold in East Asia since 1970, it has remained stagnant, at very low levels, in sub-Saharan Africa. For most small farmers the use of fertilizers that could replenish their soils is not economically feasible, due to increasing prices and climatic risks. The result is land degradation, low yields, persistent poverty and widespread malnutrition.

In Africa, cereal yields average about 1 tonne per hectare, compared to average cereal yields of 2.5 tonnes in South Asia and 4.5 tonnes in East Asia. In Zambia, for example, the average maize yield is 1.1 tonnes per hectare. 69 per cent of smallholders farm without mineral fertilizers; 73 per cent fail to produce enough maize to sell in the market. Between 2002 and 2008, a variety of factors, including low soil fertility, drought, and late planting, led to 33 per cent of the area under maize in Zambia being abandoned before it was harvested.

A new approach is needed that makes it possible for farmers to increase and stabilize their crop yields with modest investments.
Photo: World Agroforestry Centre

"Why is Zambia always on a knife-edge, between a small surplus of maize and a deficit?" asks Peter Aagard, the Director of Zambia's Conservation Farming Unit (CFU).

"It's because most smallholders are using unsuitable farming practices."

However, it needn't be like this. Hundreds of thousands of smallholders in Zambia and Malawi have begun to pioneer two farming systems, which are helping to restore exhausted soils and dramatically increase yields and incomes. Combined with one another, and adapted and scaled-up across the African continent, these two systems, conservation agriculture with trees, and maize agroforestry, just might have the potential to foster an 'evergreen agriculture' that could benefit millions more farmers.

A glimpse of the future?

The dirt track that winds its way towards the homestead where Collens Mwinga lives with his wife and 10 children in Zambia's Central Province runs between two fields of maize. Mr Mwinga's maize is almost three metres high; the plants are lush green, their large cobs almost ready to harvest. In stark contrast, his neighbour's maize on the other side of the track is barely knee-high, and many of the withered plants have failed to produce any grain at all.

Mr Mwinga was introduced to conservation agriculture five years ago. By adopting relatively simple farming practices – minimum tillage, crop rotation, early planting – he has transformed his land and his life. Meanwhile his neighbour continues to farm conventionally, mining the soil of its fertility.

"Before I began practicing conservation agriculture," explains Mr Mwinga, "I would use 8 bags of fertilizer a hectare, and I would harvest about 25 bags of maize, or 1.25 tonnes. Now I use half that amount of fertilizer and get over 8 tonnes a hectare." In the past, the Mwinga family had to buy food; now they are self-sufficient, with plenty left over to sell. They have been able to buy oxen, iron roofing sheets, a new kitchen unit and much else.

Mariko Majoni, a smallholder in Malawi, has also increased the productivity of his land by radically changing the way he farms. When he retired from the prison service in the mid-1990s, he used some of his pension to buy mineral fertilizers. But before long the money was gone and he had to manage without fertilizers. His maize yields plummeted. "In the early years, I got 30–40 bags of maize each harvest," he recalls, "but when I stopped using fertilizers, I only got 6– 9 bags."

Mr Majoni got in touch with scientists from the World Agroforestry Centre at the nearby Makoka Research Station and here he learned about the benefits of using ‘fertilizer trees’ – trees that capture atmospheric nitrogen and incorporate it into the soil. He returned home with some *Gliricidia* seeds and planted them between his rows of maize. At first, his yields remained stubbornly low, but after a couple of years they began to improve, and by 2006 he was getting over 70 bags from the same plot of land. “My soil is now very rich and much better at retaining water than it used to be,” he says.

Mr Majoni now has enough maize for himself and his family and some left over to sell, even though he doesn't use a single grain of mineral fertilizer. When he first began planting fertilizer trees, his neighbours thought he was mad. Now, many have begun to adopt the same agroforestry practices.

Since 1996, the Conservation Farming Unit has introduced conservation agriculture over large areas of Zambia, and more than 150,000 families have adopted the practices. Malawi's Agroforestry Food Security Programme, backstopped by the World Agroforestry Centre, is similarly ambitious. It is enabling at least 200,000 families, or around 1.3 million of the poorest people in Malawi, to increase their food production and enhance their nutrition. These two programmes – one funded by the Norwegian government, the other by Irish Aid – were conceived independently.

Mariko Majoni's farm has been doing much better in the past few years thanks to the enriched soil and improved maize yields he's been obtaining from his fertilizer tree system.
Photo: Charlie Pye-Smith

However, those involved now recognise that conservation agriculture with trees, as it is practiced in Zambia, and maize agroforestry, as it is practiced in Malawi, might be combined to further boost performance.

"We suspect that by applying the best of both systems, and carefully testing the new options with farmers in a range of environments, it may be possible to double or even triple smallholder maize yields in many areas, without an overall increase in labour or the need to apply nitrogen fertilizers," says Dennis Garrity, Director General of the World Agroforestry Centre. This booklet describes how this might be done.

Chapter 1: Conservation agriculture with trees in Zambia

In the 1930s, farmers in the American Midwest were forced to abandon 40 million hectares of land. A combination of drought, the loss of natural vegetation, and the ploughing of vast areas of semi-arid prairie land had created a 'dust bowl'. In its wake, farmers and scientists began to explore less destructive methods of cultivation. After decades of research, and the efforts of pioneering farmers, increasing numbers of farmers began to practice 'minimum tillage'. Currently, about 100 million hectares of land are managed, worldwide, under minimum or zero-tillage conservation farming practices, most of it in the United States, Brazil, Argentina, Australia, Canada and Paraguay.[1]

Africa lags far behind, with less than 500,000 hectares of land under minimum tillage. However, recent experience in Zambia and Zimbabwe, and work in many other countries, suggests that conservation agriculture with trees might do much to restore and replenish eroded and impoverished soils throughout the continent.

Principles and practice

There are three main principles for practicing conservation agriculture with trees. First, the soil should be disturbed as little as possible. Second, farmers should aim to keep the soil covered with organic matter, in the form of crops, crop residues and trees that are compatible with crops. And third, they should rotate and diversify their crops, making use, in particular, of leguminous crops such as cowpeas, beans, and pigeon peas, as well as cover crops and trees that generate additional sources of soil fertility replenishment during the off season.

Conservation agriculture with trees helps to protect the soil by reducing disturbance to a minimum. It builds on the indigenous knowledge of minimum-tillage farming techniques, traditionally practiced by many African communities in the past.

[1] See FAO statistics in http://faostat.fao.org.and Conservation agriculture - case studies in Latin America and Africa. http://www.fao.org/DOCREP/003/Y1730E/Y1730E00.HTM

Instead of using a conventional plough, farmers can adopt one of two methods. They can create small, permanent planting basins with a hand hoe, and plant the seeds in these basins each year. Or they can use an ox- or tractor-drawn 'ripper' to create a thin trench into which the seeds are sown. These methods reduce surface soil disturbance to around 12 per cent of the field area.

Conservation farmers apply their animal manure, green manure or mineral fertilizers exactly where they are needed, in their planting basins where the crops are sown. By doing this in the same locations every year, these precious sources of plant nutrition help build up soil fertility over time. Because fertilizer prices in Zambia have doubled since 2007, this is major consideration for smallholders.

Land preparation can commence right after harvest of the previous crop with hoe minimum tillage using planting basins - reducing and spreading out labour inputs.
Photo: Peter Aagard

"I've noticed a big difference since I began using a ripper," explains Collens Mwinga. "Before, when I was using a plough, it used to make a hard pan beneath the soil. The maize roots couldn’t penetrate this hard pan. They were weak and nonproductive, and susceptible to drought. The ripper cuts through the plough pan, and the roots go deeper." Mr Mwinga has found that during a drought his crops don't wilt as quickly as they did when he used a traditional plough.

Good timing is essential, especially when it comes to sowing crops. Research carried out by the CFU during the 2006/7 planting season in Zambia revealed that 70 per cent of farmers planted their maize between 9th and 30th December, rather than between 19th and 20th November, the first effective planting window. Every day of delay matters, reducing maize yields by 1.5 per cent, and cotton yields by 2 per cent. The CFU estimates that the delay during the 2006/7 planting season alone reduced national output from small-scale farms by about 400,000 tonnes, equivalent to 29.5 per cent of the potential maize output.

Since the mid-1980s, when corridor disease wiped out large numbers of cattle, the majority of smallholders in Zambia have had to hire oxen to plough their land. As the land is too hard to plough during the dry season, ploughing begins with the first rains. That’s fine if you own your own oxen and plough; but if you don't, you may have to wait weeks before the hired oxen arrive – with every lost day diminishing your potential harvest.

This is another reason why farmers should consider ripping rather than ploughing. Ripping can be done during the 7-month dry season, enabling farmers to plant their crops as soon as the rains come. Ripping is also much faster than ploughing, and cheaper. It takes approximately 4.5 hours to rip one hectare, compared to 14 hours to plough the same area. The hire charge for a ripper is approximately 100,000 Zambian kwacha (US$20) per hectare, compared to 275,000 kwacha (US$55) for ploughing.

One of the main goals of conservation agriculture with trees is to stimulate biological activity and improve soil structure. To do this, farmers are encouraged to keep the soil covered with organic matter throughout the year. This involves the retention of crop residues – conventional farmers tend to burn them – and the planting of cover crops such as sunn hemp *(Crotolaria juncea)* and *Faidherbia* trees. Farming systems that involve minimum tillage and the retention or addition of crop residues tend to accumulate more carbon than they release. The inclusion of trees in the farming system dramatically increases the potential to store carbon. Conservation agriculture with trees can therefore play a role in the struggle to reduce global warming.

Farmers should also rotate and diversify their cropping system. This helps to reduce the prevalence of diseases and parasites, which tend to build up under mono-cropping systems, and allows farmers to increase soil fertility by planting nitrogen-fixing legumes such as groundnut, cowpea and soya bean, along with cover crops and intercropping with the appropriate species of leguminous trees.

To sum up, conservation agriculture with trees enables farmers to prepare their land during the dry season, reduce land preparation costs, and plant as soon as the first rains arrive. It reduces run-off and soil erosion, and may improve the physical, biological, and chemical properties of the soil. Most importantly of all, where it is suitable to be practiced, it tends to lead to higher and increasing yields and profit margins, and reduced labor inputs. It also helps ensure that farmers can sustainably farm the same plot of land in perpetuity.

Mr Mwinga may be an exception, but farmers that apply the principles of conservation agriculture with trees tend to harvest yields that are considerably above the national average of just over 1 tonne per hectare. After just one year, farmers may increase their yields by 30–100 per cent.[2]

[2] For interesting comparative figures from Zimbabwe, see: ejournal.icrisat.org, December 2008 vol 6: 'Lessons from the field – Zimbabwe's conservation agriculture task force'. CA farmers get cereal yields 50 – 200% higher than convention yields on 40,000 farms.

Chapter 2. African farmers pioneer a new fix for an old problem

There is no getting away from one of the most basic facts of agricultural life. Crops like maize, sorghum, and cotton deplete the soil of its nutrients. For example, a 3.5 tonne per hectare crop of maize removes the equivalent of 275 kilograms per hectare of fertilizer equivalent from the soil. To make up for these losses, farmers must continually supply nutrients to the soil. This can be done by applying mineral fertilizers or livestock manure, and by growing leguminous crops and plants can be used as 'green manures.' But farmers can also establish what Mr Majoni, the Malawian farmer quoted above, calls 'a fertilizer factory in the fields' by planting trees that take nitrogen out of the air and 'fix' it in their leaves, which are subsequently incorporated into the soil.

A tree that shows particular promise for Africa is *Faidherbia albida*, an indigenous acacia-like tree that is widespread throughout the continent. Its pods and leaves are used as protein-rich livestock fodder; its bark as a medicine; and its wood for construction, fuelwood, and charcoal. But what makes it special are its nitrogen-fixing properties, and its unusual habit, known as 'reverse leaf phenology'. *Faidherbia* is unlike virtually all other trees. It goes dormant and sheds its leaves during the early rainy season. Its leaves regrow when the dry season begins. This makes it highly compatible with food crops because it does not compete with them for light, nutrients or water. On the contrary, annual crops in the vicinity of *Faidherbia* trees tend to exhibit improved performance and yield.

Faidherbia is indigenous in most African countries. Photo: Peter Aagard.

Research on the properties of *Faidherbia* began over six decades ago, when scientists observed that farmers throughout the Sahelian region of Africa were retaining the trees in their sorghum and millet fields. Farmers related that this tall, long-lived tree with a broad canopy, improved the performance of the crops planted nearby, and provided nutritious fodder for their livestock during the dry season from the leaves and pods. The scientists realized that *Faidherbia* had long been an integral part of Sahelian agriculture, where farmers have nurtured and protected *Faidherbia* trees growing in their fields for centuries. The trees are a frequent component of the farming systems of Senegal, Mali, Burkina Faso, Niger, Chad, Sudan, and Ethiopia, and in parts of northern Ghana, northern Nigeria, and northern Cameroon[3].

Interest in *Faidherbia* was further stimulated in the 1990s when a remarkable thing happened. The forestry regulations were relaxed in Niger. Farmers were no longer prohibited from cutting down trees on their own farms. They now had an incentive to farm more intensively with *Faidherbia* trees, which they could also cut for timber and fuelwood sales. As a result, farmers dramatically increased their efforts to regenerate and expand the tree populations on their farms. Farmer-managed natural regeneration of *Faidherbia* and other tree species began to accelerate rapidly.

Faidherbia agroforests now cover over 5 million hectares of sorghum & millet farms in Niger. Photo taken in the dry season.
Photo: Mahamane Larwanou

[3] Boffa, JM. 1999. *Agroforestry Parklands in sub-Saharan Africa*. FAO Conservation Guide 34, Food and Agriculture Organization, Rome. This comprehensive publication contains a wealth of information on ***Faidherbia albida*** as managed in the parklands of the Sahelian zone and southern Africa.

Recent satellite data shows that in the Maradi and Zinder Regions of Niger, there are now about 4.8 million hectares of *Faidherbia*-dominated agroecosystems[4]. These landscapes harbor quite dense populations of *Faidherbia* of up to 150 trees per hectare. The Niger farmers claim that the trees improve their crop yields, and protect their crops from dry winds and their land from wind and water erosion. They also relate that the foliage and pods provide much-needed fodder for their cattle and goats during the long Sahelian dry seasons. Encouraged by the experience in Niger, several new programmes to promote farmer-managed natural regeneration of *Faidherbia* and other species have been established in other countries across the Sahel. Those efforts are promoting the more vigorous culture of *Faidherbia* as part of coordinated regional initiatives to re-green the Sahel.

Faidherbia-dominated farmlands in Niger with up to 150 trees per hectare. Trees are black dots on Google image, with a farming village in centre.
Source: Google Earth, 2005

Faidherbia has also been cultivated traditionally by farmers in various parts of Ethiopia, where it enhances cereal production up to 2800 meters elevation in Tigray Province[5]. It is also valued by farmers in southern Africa. It is estimated that about 500,000 farmers in Malawi and the southern highlands of Tanzania maintain *Faidherbia* trees in their maize fields[6].

The association between *Faidherbia albida* and increased crop yields is now well documented in peer-reviewed journals. In their comprehensive review of work on the species, Barnes and Fagg noted that "there has been a huge amount published on the beneficial effect of *Faidherbia albida* - on the soil once it is established"[7]. Most of these studies have observed significant increases in yield beneath or near the trees.

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4 Reij, Chris. Free University of Amsterdam. Personal communication.
5 Hadgu, Kiros M. 2008. PhD dissertation, Wageningen University, Netherlands.
6 Phombeya, H. MAFE Land Resource Centre, Lilongwe, Malawi. Personal Communication.

Maize is the most widely grown crop in Africa, covering some 27 million hectares, and is the basis for food security throughout much of the continent. Numerous published reports have recorded increases in maize grain yield when grown in association with *Faidherbia.* These reports range from increases of 6% to more than 100%[7]. *Faidherbia's* effects tend to be most remarkable in conditions of low soil fertility[3,7].

Maize farming in a Faidherbia agroforest. Southern highlands, Tanzania. 2008.
Photo: Saidi Mkomwa

In Malawi, maize yields were increased up to 280 per cent in the zone under the tree canopy compared with the zone outside the tree canopy[8]. In Zambia, recent unpublished results of 15 sets of observations conducted by the CFU in the 2008 growing season found that unfertilized maize yields in the vicinity of *Faidherbia* trees averaged 4.1 tonnes per hectare, compared to 1.3 tonnes nearby but beyond the tree canopy[9].

The trees provide a natural form of fertilizer free of charge through leaf fall at the beginning of the rains as the crops are planted. All the trees require to thrive is sunshine during the dry season, and sufficient moisture, which they obtain from their very deep root systems during the dry season after the crops are harvested.

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[7] For a comprehensive review of the published literature see Barnes, RD and Fagg, CW. 2003. ***Faidherbia albida. Monograph and Annotated Bibliography.*** Tropical Forestry Papers No 41, Oxford Forestry Institute, Oxford, UK.

[8] Saka, AR, Bunderson, WT, Itimu, OA, Phombeya, HSK, and Mbekeani, Y. 1994. The effects of *Acacia albida* on soils and maize grain yields under smallholder farm conditions in Malawi. Forest Ecology and Management 64, 217-230.

[9] Aagard, Peter. Conservation Farming Unit, Lusaka, Zambia. Personal communication.

There are many reports of dramatic increases in the grain yield of unfertilized millet grown under *Faidherbia* in West Africa[7]. Increases in yield have also been reported for sorghum grown under *Faidherbia* in various parts of Ethiopia, other parts of Africa, and in India. Often, millet and sorghum exhibit no further response to artificial fertilizers beyond that provided by the leaf fall[3]. Other crops that are reported to benefit from association with *Faidherbia* include groundnuts and cotton. But there are some reports of instances where yields were reduced. These cases need to be further examined to guide a better understanding of the limitations.

Comparison of maize and other crops grown under and outside the canopy of Faidherbia in Zambia. Note the dramatic difference in maize growth. February, 2009.
Photo: Dennis Garrity

There is increasing recognition that there are further opportunities to exploit the ability of *Faidherbia.* In recent years, more concerted efforts have been made to improve and enhance this indigenous African agroforestry system. Awareness is growing of the potential to make it an element of a more productive and sustainable evergreen agriculture, that sustains a green cover on the land throughout the year.

Small-scale conservation agriculture with Faidherbia trees in Zambia.
Photo: Dennis Garrity

Currently, the departments of agriculture in both Malawi and Zambia are encouraging farmers to establish *Faidherbia* trees in their maize fields, the aim being to double food production. Agronomists in both of these countries' national programmes recommend that farmers establish 100 *Faidherbia* trees on each hectare of maize field. The seedlings are easy to grow on the farm. They are planted out during the early rainy season. As the trees mature, and develop a spreading canopy, they are gradually thinned down to about 25 trees per hectare. They are planted in a grid pattern to facilitate normal field crop operations. The result is a sustained and productive maize farming system in an agroforest of *Faidherbia* trees. Fields with Faidherbia-maize systems managed with such a planting pattern can accommodate full mechanization. The trees may live to the ripe old age of 70-100 years, providing inter-generational benefits for a farm family, with a very modest initial investment.

By 2011, when the second phase of the CFU's Norwegian-funded project comes to an end, it is expected that over 240,000 hectares of smallholder farmland in Zambia will have been newly planted with *Faidherbia*.

Planting *Faidherbia* does require a bit of patience on the part of the farmer. It is one of the fastest-growing acacia species, but it takes a few years of growth before the trees begin to provide substantial fertility benefits. In a survey of 300 Malawian farmers with *Faidherbia* in their maize fields[10], one-third of the farmers related that the trees began to provide significant benefits to their crops in one to three years. Another forty-three per cent indicated that it took four to six years before they observed the benefits of planting *Faidherbia*.

[10] Phombeya, HSK. 1999. Nutrient sourcing and recycling by *Faidherbia albida* trees in Malawi. PhD Dissertation, Wye College, University of London. 219 p.

However, establishing *Faidherbia* does not preclude planting other nitrogen-fixing trees in the same fields that have a more immediate impact on soil fertility and crop yields (see chapter 3).

Notwithstanding these promising experiences with *Faidherbia, t*here are many questions still to be answered about how to fully exploit the value of this unique agroforestry tree, and how to avoid the use of the species where it might cause unforeseen problems.

Currently, *Faidherbia* trees are found on less than 2% of Africa's maize area, and on less than 13% of its sorghum and millets area. What is the potential for the expansion of coverage? In examining this question, more needs to be known about the water relations of *Faidherbia* farming systems, and how they may influence the behaviour of the water table.

Barnes and Fagg noted that "the tree is found over an incredibly wide range of soils and climates and with varied plant and animal associates, including desert to a wet tropical climate"[7]. However, it is intolerant to competition from other plant species, and thus does not have invasive tendencies. But are there agroecologies where *Faidherbia* should not be recommended, such as on very shallow soils where the tree might compete with food crops? Could there be pest and disease threats when cultivation is more widespread? Will planted *Faidherbia* agroforests exhibit characteristics that differ from those that have already been observed on the extensive naturally-regenerated populations that currently cover millions of hectares in the Sahel and southern Africa? These and many other questions ought to be a basis for the next generation of applied agroforestry science on its role in evolving an evergreen agriculture in Africa.

Chapter 3: Maize Agroforestry in Malawi

"In many parts of Malawi, the soil is so exhausted that it's impossible for small farmers to produce enough food to feed their families without supplying more nutrients," says Festus Akinnifesi, the World Agroforestry Centre's Regional Coordinator for Southern Africa. "Without additional nutrient inputs, they are lucky if they get 1 tonne of maize a hectare, and often much less than that." In the south of the country, the average family holding is just 0.4 hectares, and farmers are not in a position to leave any of their land fallow to allow the soil to recover from cropping. The result, for the majority of farming families without access to fertilizers, is a loss of fertility, declining yields and hunger.

Since the early 1990s, the World Agroforestry Centre and its partners in Eastern and Southern Africa have developed agroforestry systems that improve soil quality and significantly boost crop yields, providing high returns on both land and labour.

The most popular system in areas like southern Malawi, where land holdings are very small, is intercropping with nitrogen-fixing trees like *Gliricidia sepium*, *Calliandra calothyrsus* and *Leucaena* species. "Using this system, farmers can double their yield of maize, or even triple it if they also use a small quantity of mineral fertilizer – about a quarter of the recommended dose," explains Dr Akinnifesi.

Under this system, farmers plant nitrogen-fixing trees in rows between their crops. These are pruned back several times a year, and the leaves and biomass are incorporated into the soil. A long-term experiment spanning more than a decade, involving continuous cultivation of maize with *Gliricidia* at Makoka Research Station, Malawi, yielded more than 5 tonnes per hectare in good years, and an average of 3.7 tonnes per hectare. This was without using any mineral fertilizers. That compares with an average of 0.5 to 1 tonne per hectare in control plots without *Gliricidia* or mineral fertilizer.[11]

[11] Makumba, W.; Janssen, B.; Oenema, O.; Akinnifesi, F.K.; Mweta, D.; Kwesiga, F. World Agroforestry Centre (ICRAF), Zomba (Malawi). SADC-ICRAF Agroforestry Project. 2006. The long-term effects of a gliricidia-maize intercropping system in southern Malawi, on gliricidia and maize yields, and soil properties. Agriculture, Ecosystems and Environment 116(2006) p.85-92. [2006066] ICRAFP

Rotational fallows that incorporate nitrogen-fixing trees are proving popular in areas where land holdings are larger. This system differs from intercropping in that the land is left fallow for up to two years. During the fallow period farmers grow short-lived shrubs such as *Sesbania sesban* and *Tephrosia candida,* rather than long-lived, intercropped trees like *Gliricidia*. Over a two-year period, these shrubs can provide 100–250 kilograms of nitrogen per hectare, giving a valuable boost to the crops which follow.

Malawian farmers intercrop Gliricidia trees with their maize crops to enhance soil fertility and increase yields. Photo: World Agroforestry Centre

A study of five farmers in Zambia, using three different systems – unfertilized maize, fertilized maize and maize grown after two years of *Sesbania* – illustrates the benefits of rotational fallows.[12] Yields of unfertilized maize were little more than 1 tonne per hectare at best, but averaged just under 5 tonnes for fertilized maize. With the rotational fallow system, three of the five farmers had maize yields of more than 4 tonnes per hectare, around four times more than the yields for unfertilized maize.

The disadvantage of the rotational fallow system is that land is taken out of production for two out of every five years. Nevertheless, it still provides more overall crop production and a much better return on investment than the continuous cropping of unfertilized maize, as another study in Zambia has revealed. Over a five-year cycle, the net profit from unfertilized maize was US$130 per hectare, compared to US$269 and US$309 per hectare for maize grown as an intercrop with *Gliricidia* or in rotation with *Sesbania,* respectively. Little wonder, then, that so many farmers in Malawi have began intercropping their maize with fertilizer trees. Besides increasing soil fertility, these

[12] Ref: Kwesiga et al, Agroforestry systems 47: 49-66, 1999

agroforestry systems help to suppress weeds, improve water filtration, and increase the amount of carbon in the soil.

By mid-2009, over 120,000 farmers had benefited from Malawi's Agroforestry Food Security Programme. The programme provides seeds, nursery materials and training for a range of agroforestry practices, including the planting of fertilizer trees. Women and the rural poor are the major beneficiaries, and frequently the most enthusiastic supporters. Economic studies have shown that the poor often adopt agroforestry systems more rapidly than wealthier households, partly because they reduce the burden of land preparation, which has traditionally been the responsibility of women.

"I've seen a big improvement in soil fertility in my field," explains Esnath Chakalamasa, a widow and mother of seven children in Thyolo district, Malawi. Not long ago, her yields were very low as her soils were so exhausted. Then she began intercropping with *Gliricidia* and soon she was getting much higher yields. One of her friends, another widow, has a similar story to tell. "I used to get about 10 bags of maize from my field," explains Mary Sabuloni. "Now I get at least 25 bags." This has made a big difference to her eight children. "In the past, we often went hungry," she says, "but now I can feed my family all year round." She adds that the *Gliricidia* trees also provide her with abundant quantities of fuel wood.

Crop production systems such as these, which incorporate *Gliricidia*, *Faidherbia* and other leguminous cover crops, can help rural populations to adapt their agriculture to the adverse effects of climate change. There is clear evidence from research, as well as from the experience of farmers, that these systems enable farmers to harvest grain during serious droughts, which are becoming more frequent in the sub-humid and semi-arid areas of Africa. With these systems, farmers say they can obtain at least a modest yield during seasons when farmers that have not yet adopted these systems may experience total crop failure.

Chapter 4: The Future: An Evergreen Agriculture?

The maize agroforestry and conservation agriculture with trees discussed above evolved independently in Malawi and Zambia, respectively. Each system has been refined through intensive work with farmers. They are now the basis for national scaling-up programmes in Malawi and Zambia. Maize agroforestry is reaching hundreds of thousands of Malawian farmers through the Malawi Agroforestry Food Security Programme, while conservation agriculture with *Faidherbia* is being extended to hundreds of thousands of farmers in Zambia. The results of these programmes are encouragingly positive.

Each system, however, has unique strengths and weaknesses. Maize agroforestry in Malawi has increased soil fertility and enabled farmers to double or triple their yields. The use of tree legumes also helps to suppress weeds, reducing the drudgery of hand weeding. However, some additional labour is required to establish and maintain the *Gliricidia* trees and other leguminous species. This means that maize agroforestry is generally more labour-intensive than conventional cropping during the initial year or two.

Conservation agriculture with minimum tillage, on the other hand, reduces the labour requirements and costs of land preparation. It encourages timely sowing of food crops, and helps to improve soil conditions, all of which leads to higher crop yields. However, if neither herbicides nor fertilizer trees are used, the labour requirements for hand weeding will increase, at least during first few years of adoption, exceeding the amount of labour used in conventional maize production. Additional nutrient sources at the time of planting are also needed in order to maximize the benefits of minimum tillage. The World Agroforestry Centre and the Conservation Farming Unit in Zambia are carefully observing farmer experiences with these practices, and are designing a new system – an ‘evergreen agriculture’ – that may combine the best of both practices. The intention is to dramatically improve soil conditions and crop yields, while keeping labour requirements to a minimum. "This integrated system is still under development, and will require much more investigation in the coming years. Our hypothesis, however, is that it will increase maize yields and provide greater household food security, while significantly reducing the smallholders' labour and lowering overall investment in maize production," says Dennis Garrity, "We have evidence that it will also improve drought resilience and increase above and below-ground carbon sequestration as well."

The transition from conventional maize production to evergreen agriculture may take about four years. During the first year – the last year of conventional crop production – farmers may intercrop maize with *Tephrosia candida* or other short-term tree legumes. They would also plant *Faidherbia* seedlings every 10 rows in their maize crop. The following year, the first involving minimum tillage, farmers would discontinue tilling the soil. They may then begin sowing their maize seeds in permanent planting basins. The first year's *Tephrosia* plants are removed, their leaves having been incorporated into the soil and the stems cut for firewood, while the subsequent crop of maize is intercropped with alternating rows of *Tephrosia* and *Gliricidia.* This establishes a medium-term fertilizer tree system that also suppresses weeds during the dry season.

In the third year, farmers would continue using the same land preparation methods. During the dry season, the leaves and green stems of the *Tephrosia* and *Gliricidia* are placed in the planting basins, preferably with some animal manure or mineral fertilizer. When the rains come, 3 or 4 maize seeds are planted in each basin. Ideally, farmers also begin rotating their maize with another row crop, such as cowpeas or groundnuts, during the third year.

Intercropped woody annuals and perennials like Tephrosia and Gliricidia cover the crop field after the maize harvest, manufacturing organic nitrogen fertilizer and suppressing weeds during the dry season.
Photo: Dennis Garrity

By the fourth year, the *Gliricidia* soil replenishment system has fully kicked in. From now on the *Gliricidia* bushes are maintained continuously in the field. They suppress weed growth during the late crop season and during the dry season, and their prunings provide nitrogen-rich fertilizer, which is placed in the planting basins prior to the rains each year. During subsequent years, the *Faidherbia* trees also begin adding significant quantities of nutrients during each leaf fall at the beginning of the rains, further enhancing soil fertility. The mature trees will also provide an abundant yield of protein-rich pods that can be used as nutritious livestock fodder.

Research to date has suggested that evergreen agriculture may increase yields from 1 tonne per hectare to at least 2–3 tonnes, even if farmers cannot afford commercial nitrogen fertilizers. However, maize yields may reach up to 4 tonnes per hectare or higher with an application of a quarter-dose of mineral fertilizer. Higher doses, used in tandem with the nitrogen-fixing trees, may raise yields to 5–6 tonnes per hectare.

The complete evergreen agriculture system is still very much under development. It will need to be tested thoroughly across a range of environments and farm conditions. It is expected that the results in some situations will not be as favorable as in others. And more alternative leguminous species are important to ensure diversity in the system. Thus, a vigorous programme of practical research and farmer testing on all aspects of the evergreen agriculture system at the regional, national, and local levels is urgently needed.

From Vision to Reality

In April 2009, at a meeting organized by the African Union in Ethiopia, ministers of agriculture, land and livestock from across the continent committed themselves to ramping up efforts to increase the number of farmers practicing conservation agriculture and agroforestry. The African Ministers of Environment also endorsed this recommendation in their meeting in Nairobi in May. According to Odd Arnesen of the Norwegian Embassy in Lusaka, this represents a turning point for the continent. "With the right type of political thinking and institutional support," he says, "we can strive for at least 2 million more farmers in Africa having access to this technology by 2012 and many more in the years beyond that."

The African Union's New Partnership for Africa's Development (NEPAD) is now building a broad alliance with governments, and international and local partners, to establish evergreen agriculture throughout the region. The World Agroforestry Centre, the African Conservation Tillage Network, and the Zambian Conservation Farming Unit are working closely with NEPAD, other research and development partners, and a growing consortium of supportive donors to develop the evidence base and the capacity on the ground to ensure that this vision may become a reality.

Agroforestry systems tend to sequester much greater quantities of carbon above the ground and below the ground than agricultural systems without trees. This is particularly true for farms with fertilizer trees such as *Faidherbia* or *Gliricidia*.[13] Consequently, there is currently much interest in the creation of bio-carbon investment funds in Africa to channel carbon offset payments from developed countries to stimulate more carbon sequestration in African farming systems.

As the African nations develop their strategies for climate change adaptation and mitigation, there will be opportunities to attract serious investments in carbon offset Payments for smallholder agroforestry development. It is estimated that further

[13] See Makumba, W, Akinnifesi, FK, Janssen, B, Oenema, O. 2007. Long-term impact of a gliricidia-maize intercropping system on carbon sequestration in southern Malawi. Agriculture, Ecosystems and Environment 118: 237–243, and Kaonga, M, Bayliss-Smith, TP. 2008. Carbon pools in tree biomass and the soil in improved fallows in eastern Zambia. Agroforestry Systems 76: 37-51.

Investments in agroforestry over the next fifty years could result in 50 billion tons of additional carbon dioxide being removed from the atmosphere. This alone is a major proportion of the world's total carbon reduction challenge."[14]

These new investment funds, if focused on evergreen agriculture, could provide new sources of funding to expand farmers' capacity to contribute to the reduction of global carbon emissions while growing more food and providing other sustainable development benefits. These investments would tend to make smallholder agriculture more resilient to adverse climate change as well.

Today, Africa is critically threatened by food insecurity, land degradation, and climate change. Smallholder farmers need science-based solutions to increase the efficiency of their crop production systems – solutions that build on the best of local knowledge and practice, and that are truly accessible and affordable. Evergreen agriculture may provide new options to better care for the land and to increase smallholder food production. It is, in short, a concept whose time has come. If so, that would be none too soon.

[14] Garrity, D, Verchot, L. 2008. Meeting the Challenges of Climate Change and Poverty through Agroforestry. World Agroforestry Centre, Nairobi, Kenya. 8 pp.

Further Reading

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Boffa, JM. 1999. ***Agroforestry Parklands in sub-Saharan Africa.*** FAO Conservation Guide 34, Food and Agriculture Organization, Rome. [Accessible without charge on-line through Google Books.]

For updated current information:

World Agroforestry Centre web site: http://www.worldagroforestry.org/af/index.php

African Conservation Tillage Network web site: http://www.act-africa.org

Conservation Farming Unit web site: http://www.conservationagriculture.org/

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