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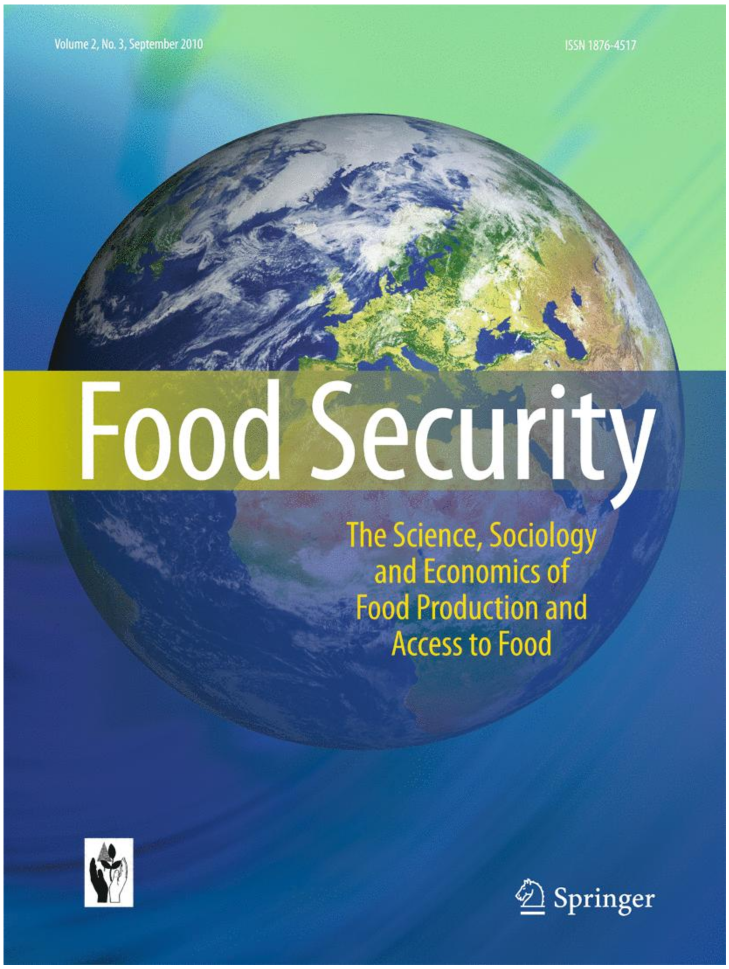

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ORIGINAL PAPER

Evergreen Agriculture: a robust approach to sustainable food security in Africa

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Abstract Producing more food for a growing population in the coming decades, while at the same time combating poverty and hunger, is a huge challenge facing African agriculture. The risks that come with climate change make this task more daunting. However, hundreds of thousands of rain fed smallholder farmers in Zambia, Malawi, Niger, and Burkina Faso have been shifting to farming systems that are restoring exhausted soils and are increasing food crop yields, household food security, and incomes. This article reviews these experiences, and their broader implications for African food security, as manifestations of Evergreen Agriculture, a fresh approach to achieving food security and environmental resilience. Evergreen Agriculture is defined as the integration of particular tree species into annual food crop systems. The intercropped trees sustain a green cover on the land throughout the year to maintain vegetative soil cover, bolster nutrient supply through nitrogen fixation and nutrient cycling, generate greater quantities of organic matter in soil surface residues, improve soil structure and water infiltration, increase greater direct production of food, fodder, fuel, fiber and income from products produced by the intercropped trees, enhance carbon storage both above-ground and below-ground, and induce more effective conservation of above- and below-ground biodiversity. Four national cases are reviewed where farmers are observed to be applying these principles on a major scale. The first case involves the experience of Zambia, where conservation farming programmes include the cultivation of food crops within an agroforest of the fertilizer tree *Faidherbia albida*. The second case is that of the Malawi Agroforestry Food Security Programme, which is integrating fertilizer, fodder, fruit, fuel wood, and timber tree production with food crops on small farms on a national scale. The third case is the dramatic expansion of *Faidherbia albida* agroforests in millet and sorghum production systems throughout Niger via assisted natural regeneration. The fourth case is the development of a unique type of planting pit technology (*zai)* along with farmer-managed natural regeneration of trees on a substantial scale in Burkina Faso. Lastly, we examine the current outlook for Evergreen Agriculture to be further adapted and scaled-up across the African continent.

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The challenge for Africa

Despite accelerating globalization, food security in most of the developing world depends upon local food production (Funk and Brown 2009). Most rural households in developing nations are involved in agriculture and most food is produced and consumed locally (Lamb 2000). Thus, local agricultural production is critical to both food security and economic development among the rural poor, and increasing its productivity remains a central food security issue (Devereux and Maxwell 2001; Schmidhuber and Tubiello 2007).

For the first time in history, there are more than 1 billion undernourished people in the world—increasing the urgency of tackling food insecurity and improving agriculture. The most severe deprivation is increasingly concentrated in sub-Saharan Africa, which is currently home to three-quarters of the world's ultra poor (income less than US$0.50 per person per day) and has experienced a significant increase in the number of ultra-poor since 1990 (Ahmed et al. 2007). Some 218 million people in Africa struggle with hunger daily - about 30% of the continent's total population. The population of Africa is projected to grow from about 796 million in 2005 to 1.8 billion by 2050 (United Nations 2004). Africa experienced considerably faster population growth than any other major geographical area for most of the 1950–2000 period, and the countries with the fastest-growing populations in the next half-century will be mainly in sub-Saharan Africa (United Nations 2004). Despite urban migration, the number of rural dwellers will also continue to grow. However, per capita food production in Africa declined by almost 20% between 1970 and 2000 (Abdulai et al. 2004).

Agriculture contributes around 25% of GDP in Africa and provides jobs for 70% of the labour force, as well as a livelihood for more than 65% of the population. Land holdings have consistently shrunk in size due to rapid population growth rates. Eighty percent of the continent's farms now occupy less than 2 hectares. The dominance of smallholder agriculture means that short- and medium-term agricultural growth and poverty reduction prospects will be closely linked with the successful transformation of this sector.

Crop output in Africa has been increasing, but this is largely driven by the expansion of cultivated land rather than productivity gains (Food and Agriculture Organization of the United Nations 2008). Between 1990 and 2006 the area under cultivation increased by more than 10% annually while cereal yields over the same period were largely stagnant. The average yields of grain crops in sub-Saharan Africa have stayed below 1 t/ha since the 1960s, compared with average cereal yields of 2.5 t/ha in South Asia and 4.5 t/ha in East Asia (Food and Agriculture Organization of the United Nations 2008). The uncertainty of obtaining higher crop yields is further worsened by the prevailing erratic weather conditions and future climate change (Jones and Thornton 2003). Most farmers are forced to grow the same food crops, year after year, on the same plot of land, without adequate fertilization or soil replenishment measures. Fertilizer use by smallholder farmers has remained at the very low levels of about 8–10 kg of nutrients per hectare. Currently, fertilizer prices are double their levels in 2006, and Africa accounts for less than 1% of global fertilizer consumption. The use of fertilizers by smallholders to replenish their soils is often not economically feasible, due to high prices and the risk of drought stress. The consequences are land degradation, low yields, persistent poverty and widespread malnutrition (Lal 2009).

Producing more food for a growing population in the coming decades, while at the same time combating poverty and hunger, is a huge challenge facing African agriculture. Currently, the future picture is dire. Current projections are that higher temperatures and lower rainfall in parts of Africa, combined with a doubling of the population, will lead to a 43% increase in food insecurity, and will induce a 60% increase in food aid expenditures during the next 2 decades (Funk and Brown 2009). These figures are significant because food aid is an indicator of many related problems, including child malnutrition and a decline in health, productivity and economic growth (Food and Agriculture Organization 2007). If the observed 1982–2002 trend continues, the 200 million undernourished sub-Saharan Africans in 2002 will increase to almost 600 million by 2030. The interaction between drought and declining agricultural capacity may be socially explosive, politically dangerous, and costly, with annual aid totals projected to increase by 83% by 2030 (Funk and Brown 2009).

At least a doubling of agricultural yields is required over the coming decades (SEI 2005) in economies where a majority of the populations depend on smallholder rain fed farming. Approximately 65% of agricultural land in SSA is subject to degradation (UNEP/ISRIC 1991; GEF 2003). Reversing the trend of soil fertility depletion in African farming systems has become a major development policy issue on the continent (Scoones and Toulmin 1999). Restoring soil health is often the first entry point for increasing agricultural productivity, because soil nutrient depletion is extreme in most areas where farmers have smallholdings (Sanchez and Swaminathan 2005).

The most urgent need is to increase biomass production in the farming system with richer sources of organic nutrients to complement whatever amounts of inorganic fertilizers that a smallholder farmer can afford to apply. The integration of fertilizer trees into food crop agriculture is a promising, but underappreciated, approach to accomplishing this (Garrity, 2004). This portfolio of options is now referred to as Evergreen Agriculture. The major experiences with Evergreen Agriculture and its broader implications for African food security are reviewed in this article.

What is Evergreen Agriculture?

Evergreen Agriculture is defined as the integration of trees into annual food crop systems. Depending upon which woody species are used, and how they are managed, their incorporation into crop fields and agricultural landscapes may contribute to:

- maintaining vegetative soil cover year-round (Boffa, 1999),
- bolstering nutrient supply through nitrogen fixation and nutrient cycling (Barnes and Fagg, 2003),
- enhanced suppression of insect pests and weeds (Sileshi et al. 2006),
- improved soil structure and water infiltration (Chirwa et al. 2007),
- greater direct production of food, fodder, fuel, fiber and income from products produced by the intercropped trees (Garrity, 2004),
- enhanced carbon storage both above-ground and below-ground (Makumba et al. 2007),
- greater quantities of organic matter in soil surface residues (Akinnifesi et al. 2007),
- more effective conservation of above- and below-ground biodiversity (Scherr and McNeeley, 2009).

About half of all agricultural land in the world now has greater than 10% tree cover (Zomer et al. 2009). In some regions tree cover on farmlands averages over 30%. In many countries the agroforestry area is steadily increasing.

Evergreen farming systems feature both perennial and annual species (trees and food crops). The overall indicator of their effectiveness is that of building a healthy soil and environment to enhance food crop production and increase household income, while increasing the resilience of the farm enterprise to a variety of risks. They are intended to deliver extended growing seasons, increased productivity, better water utilization efficiency, and drought resilience. The overall benefits expected of an evergreen farming system are increased food crop yields and/or overall profitability, lower costs of production, and healthier soils (Garrity, 2004).

The term Evergreen Agriculture denotes that a green cover is maintained on the land throughout the year. It is one of several types of agroforestry, in this case involving the direct and intimate intercropping of trees within annual crop fields (Arnold and Dewees 1995). Thus, it does not encompass agroforestry systems that feature trees maintained on fallow land, trees monocropped on arable land (i.e. farm forests), or combinations of perennial tree species on arable land (e.g. complex agro forests or perennial home gardens (Kumar and Nair, 2006)).

Evergreen Agriculture contributes to integrated soil fertility management (ISFM), which is the application of soil fertility management practices, and the knowledge to adapt these to local conditions, that maximize fertilizer and organic resource use efficiency and crop productivity (Sanginga and Woomer, 2009). It is also compatible with reduced tillage, increased residue retention on the soil surface, and other principles of conservation agriculture in situations where these are feasible and appropriate (see next section). Evergreen Agriculture also broadens the principle of crop rotations to encompass the role of fertilizer trees and/or other cash crop trees to enhance soil fertility more effectively and provide needed biological and income diversity in the farm system (Garrity, 2004). In this respect, the types of intercropped trees may include species whose primary purpose is to provide products or benefits other than soil fertility replenishment alone, such as fodder, fruits, timber, and fuel wood. In such cases the trees are expected to provide an overall value greater than that of the annual crop within the area that they occupy per m^2 in the field.

The principles of Evergreen Agriculture have already been widely applied in Africa, where complexity is a common feature of the agricultural systems. The following sections review the experiences in each of four countries where they have been adapted in a diversity of situations by hundreds of thousands of farmers, often building successfully on proven indigenous farming technologies (Table 1).

Evergreen Agriculture in Zambia

In Zambia, maize production is the foundation of agriculture and the basis for the country's food supply. However, the average maize yield is only 1.1 t/ha. Sixty-nine percent of Zambian smallholders farm without mineral fertilizers. Seventy-three percent 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% of the area under maize in Zambia being abandoned before it was harvested.

Since 1996, a coalition of stakeholders from the private sector, government and donor communities has promoted a package of agronomic practices for smallholders in Zambia based on the principles of conservation farming (Haggblade and Tembo 2003). The effort is spearheaded by the Zambian Conservation Farming Unit (CFU) - (www.conservationagriculture.org). To date, conservation agriculture has been introduced over large areas of the country. The system that is advocated involves:

- Dry-season land preparation using minimum tillage methods (either ox-drawn rip lines or hand-hoe basins laid out in a precise grid);
- Retention of crop residue from the prior harvest rather than burning it in the field;
- Planting and mineral fertilizer input application in fixed planting stations in successive years;

Table 1 Attributes of Evergreen Agriculture in four African countries

Country	Zambia	Malawi	Niger	B Faso
Evergreen Agriculture System	Conservation farming with *Faidherbia* fertilizer trees	Portfolio of agroforestry species including a range of fertilizer trees	Assisted Natural Regeneration of *Faidherbia* + other trees	*Zai* planting pits + ANR[a]
Farming system	Maize, cotton	Maize	Millets, sorghum integrated with livestock	Millets, sorghum
Scaling-up methods	Extension with lead farmer model	Whole-village mobilization	Community-based resource management institutions	Projects & farmer-to-farmer training
Extent of uptake	>160,000 farms	>120,000 farms	>4.8 mha	>200,000 ha

[a] Assisted Natural Regeneration

- Crop rotations that include nitrogen-fixing species; and
- *Faidherbia albida* trees grown in the crop fields as a permanent canopy to increase soil fertility, planted at a density of 100 trees per hectare, and later thinned gradually down to 25 trees per hectare.

This system enables farmers to plant with the first rains when the crop plants will benefit from the initial nitrogen flush in the soil. By breaking pre-existing plow-pan barriers, the planting basins and rip lines are claimed to improve water infiltration, water retention and plant root development. The precise layout of grids and planting lines enables farmers to place any fertilizer and/or organic material in close proximity to the plants, where they will provide the greatest benefits (Haggblade and Tembo, 2003). Aagard (2009) has estimated that more than 160,000 families have adopted the practices.

Results from a survey of 125 farms in Central and Southern provinces during the 2001/2 cropping season indicated that, on average, hand-hoe CF farmers produced 1.5 tons more maize and 460 kg more cotton per hectare than did farmers practicing conventional ox-plow tillage (Haggblade and Tembo 2003). Among maize farmers, 1.1 tons of this increase was estimated to result from the CF technology, 400 kg from early planting and 700 kg from water harvesting and greater precision in input use in the basins. The remaining 400 kg was attributed to higher doses of fertilizer, lime and high-yielding maize seeds. Cotton farmers use standard packages of seed and pesticides. The observed gains in cotton production with CF came from water harvesting and precision and timeliness of the CF system. CF agriculture enables farmers to prepare their land during the dry season, reduce land preparation costs, and plant as soon as the first rains arrive.

One of the main goals attributed to CF 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: Conventionally, farmers tend to burn them. And it involves the rotation of maize with other crops, particularly cotton and grain legumes, and/or the planting of cover crops such as sun hemp *(Crotalaria juncea).* The additional benefits of CF—including improved soil structure, gains from nitrogen-fixing crop rotations and reduced field preparation labor—occur gradually. Evidence from similar experiences in other parts of Africa suggests that the effectiveness of conservation farming will also vary across regions and across crops, due to variations in soils and rainfall. Therefore, it will be important to establish long-term monitoring efforts for conservation farming and control plots across a broad range of geographic settings, crops and seasons.

The value of conservation farming to Zambian agriculture is well-recognized by the government, and receives strong policy and extension support by the Ministry of Agriculture. Increasingly, the country's key donors (particularly Norway) have invested in the work of the Conservation Farming Unit, supporting the research effort and strengthening the extension system in order to expand its ability to reach more farmers each year.

Achieving Evergreen Agriculture by integrating fertilizer trees into conservation farming

As the Zambian Conservation Farming Unit (CFU) worked to develop solutions to make conservation farming feasible for smallholders, they encountered a problem that defied conventional solutions. More than two-thirds of their smallholder clientele cannot afford inorganic fertilizers, and have little or no access to manure or other nutrient sources. This fundamentally limited smallholder maize yields, and further depleted their soil fertility each year. To address the problem the Zambian CFU investigated the incorporation of *Faidherbia albida* trees into maize production systems.

Faidherbia is a nitrogen-fixing acacia species that is indigenous to Africa and is widespread throughout the continent. What makes it unique is its growth habit, known as 'reverse leaf phenology' (Barnes and Fagg 2003). *Faidherbia* goes dormant and sheds its foliage during the early rainy season, at the time when field crops are being established. Its leaves only regrow at the end of the wet season. This unusual phenology makes it highly compatible with food crops, since it does not compete with them significantly for light, nutrients or water during the growing season. On the contrary, annual crops in the vicinity of *Faidherbia* trees tend to exhibit improved performance and yield (Barnes and Fagg 2003).

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 200% (Barnes and Fagg 2003), depending on the age and density of trees, agronomic practices used and the weather conditions. *Faidherbia*'s effects tend to be most remarkable in conditions of low soil fertility. In Zambia, 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 t/ha, compared to 1.3 t/ha nearby but beyond the tree canopy (Aagard 2009). Similar results were obtained in the 2009 growing season (Fig. 1). The work also drew on observations in Malawi, where maize yields were increased up to 280% in the zone under the tree canopy compared with the zone outside the tree canopy (Saka et al. 1994).

The association between *Faidherbia albida* and increased crop yields is well documented. Barnes and Fagg (2003) noted in their comprehensive monograph on the species that “there has been a huge amount published on the beneficial effect of *Faidherbia albida* on the soil once it is established”. Most of these studies have observed significant increases in yield beneath or near the trees. They observed that the tree is found over a wide range of soils and climates and with varied plant and animal associates, from desert to wet tropical climates. However, it does not tolerate competition from other plant species, and thus does not have invasive tendencies.

Fig. 1 Maize may exhibit dramatic productivity increases in association with *Faidherbia albida*. Note differences in maize growth under the tree versus outside the canopy with the same management practices applied and zero inorganic fertilization. Zambia, 2009. Photo: D Garrity

Fig. 2 *Faidherbia* fertilizer trees in a maize conservation agricultural production system. National recommendations in Malawi and Zambia are to plant *Faidherbia* at 100 trees per ha. Trees are 9 years old. Zambia. 2009. Photo: P Aagard

The Zambian CFU recommends that *Faidherbia* seedlings be planted in a grid pattern at 100 trees per ha. Fields with *Faidherbia*-maize systems managed with such a planting pattern (10 m×10 m) can accommodate full mechanization. The result is a maize farming system under an agroforest of *Faidherbia* trees (Fig. 2). The trees may live for 70–100 years, providing inter-generational benefits for a farm family, with a very modest initial investment. As the trees mature, and develop a spreading canopy, they are gradually thinned down to about 25–30 trees per hectare.

There is increasing recognition of the opportunity to exploit the abilities of *Faidherbia,* and in recent years more concerted efforts have been made to improve and enhance this indigenous African agroforestry system in many parts of the continent (Garrity, 2010). Currently, the departments of agriculture in Zambia and in Malawi are encouraging farmers to establish *Faidherbia* trees in their maize fields, the aim being to increase food production. The Zambian CFU estimates that the tree is now cultivated in conservation farming systems over an area of 300,000 hectares (http://www.new-ag.info/developments/devItem; http://www.agfax.net/radio/detail). The efforts are backed by national policy and supported by the Zambia National Farmers Union (Smith 2009).

Further research is needed to quantify the time stream of benefits on nitrogen fixation and soil fertility of incorporating trees from when they are newly planted. Research is also needed on the genetic variation in *Faidherbia albida* so that strategies can be implemented to safeguard and utilize the species' genetic diversity, and superior germplasm can be made available to farmers.

Planting *Faidherbia* requires some patience on the part of the farmer and development-support institutions. It is one of the fastest-growing acacia species, but its initial growth is slow as it develops a deep root system. It therefore takes a few years before the trees begin to provide substantial leaf biomass and fertility benefits. In a survey of 300 farmers with *Faidherbia* in their maize fields, one-third of the farmers indicated that the trees began to provide significant benefits to their crops in 1 to 3 years. Another 43% related that it took 4 to 6 years before they observed the benefits of planting *Faidherbia* (Phombeya 1999). 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 next section).

The Zambia Agroforestry Project of The World Agroforestry Centre has contributed significantly to the research and development of Evergreen Agriculture practices in Zambia and southern Africa. The maize agroforestry technologies developed include leguminous tree improved fallows. Research on improved fallows began in the late 1980s, and received growing attention in the mid-1990s in Zambia (Mafongoya et al. 2006), following the articulation of biological approaches to soil fertility management (Sanchez 1994). Investigations on the performance of rotational fallows of *Sesbania sesban, Tephrosia vogelii, Tephrosia candida*, pigeon peas (*Cajanus cajan*) and *Crotalaria* spp. have shown that after a 2–3 year fallow, these shrubs provide 100–250 kg of nitrogen per hectare, enhancing the yields of the maize crops that follow (Kwesiga and Coe 1994; Mafongoya et al. 2006). Trials across farmers' fields with maize grown after 2 years of *Sesbania* showed that the yields of unfertilized maize were less than 1 t/ha, while the majority of farmers with improved fallows had yields of more than 4 t/ha (Kwesiga et al. 2003). In addition, improved fallows provide abundant fuel energy for rural households. Between 15 and 21 t/ha of fuel wood were harvested after 2- and 3-year fallows of *Sesbania,* respectively (Kwesiga and Coe 1994).

Research on the intercropping of maize with the coppicing legumes *Gliricidia sepium, Leucaena leucocephala, Calliandra calothyrsus, Senna siamea* and *Flemingia macrophylla* has also been on-going for over a decade in eastern Zambia. In contrast to the short-rotation fallows, intercropping with coppicing species increases grain yields continuously for many years after their establishment. The additional organic inputs are derived each year from the foliage re-growth that is cut and applied to the soil. Results of long-term experiments established in the early 1990s show significant improvement in soil fertility and maize yields (Sileshi and Mafongoya 2006).

The disadvantage of the short-term improved fallow systems is that land is taken out of production for 2 out of every 5 years. Nevertheless, they provide greater aggregate crop production and higher returns on investment than the continuous cropping of unfertilized maize, the farmers' *de facto* practice (Ajayi et al. 2009). Over a 5-year cycle, the net profit from unfertilized maize was US$130/ha compared to US$$269 and US$309/ha for maize grown as an intercrop with *Gliricidia* or in rotation with *Sesbania,* respectively. The agroforestry practices had a benefit to cost ratio (BCR) ranging between 2.77 to 3.13 in contrast to 2.65 with subsidized fertilizer applications, 1.77 in fields with non-subsidized fertilizer, and 2.01 in non-fertilized fields (Ajayi et al. 2009).

One way to assess impact is in terms of food security by determining the number of days of additional food that the practices provide to a household. Assuming an average fallow plot area of 0.20 ha, these systems generate between 57 and 114 extra person days of maize consumption per year (Ajayi et al. 2007). An initial investment in terms of higher labour is involved when farmers move from conventional to Evergreen Agriculture models, but once farmers gain experience with them they manage labour use more efficiently (Tripp 2005). Through learning-by-doing, farmers in eastern Zambia have adapted official recommendations and made innovations with improved fallow practices. Such innovations include the use of bare-rooted seedlings instead of bagged seedlings, combinations of more than one fertilizer tree species, and pruning *Gliricidia* concurrently with weeding. Details of these innovations have been documented by Katanga et al. (2007).

There is evidence that the integration of fertilizer trees into smallholder maize production in Zambia, alone or in combination with conservation farming practices, has resulted in greater productivity, food security, and family income. These practices are, however, knowledge-intensive as opposed to being cash-intensive. Thus, sustained rural advisory services, through the public sector and private sector, are important to ensuring sustained uptake and expansion over the longer term (Kwesiga et al. 2005; Ajayi et al. 2005; Place et al. 2005).

Maize agroforestry in Malawi

The Malawi economy is heavily dependent on agriculture, which contributes 35% to the GDP, and, employs 78% of the national labor force (Republic of Malawi 2008). Ninety-percent of national export earnings come from the sector. Almost all maize is grown under rain fed agriculture during the single rainy season from November to April. The crop is subject to rainfall variability that can be particularly damaging when dry spells occur. Decades of intensive cultivation by smallholders, in the absence of significant fertilizer use, have depleted the soils of nutrients, particularly nitrogen (Sanchez 2002; Carr 1997). National yields of maize have averaged 1.3 t/ha during the past two decades (Denning et al. 2009; Food and Agriculture Organization of the United Nations 2008).

Over half of Malawi's farm households operate below subsistence. Only 20% of maize farmers produce a surplus and sell some of their product, due to low productivity and small farm size. As a result, most households must purchase maize at much higher prices when stocks are exhausted, typically during January to March (Republic of Malawi 2008). During the 2004–2005 maize-growing season, drought had a devastating effect on yields: the national average that year was 0.76 t/ha, 40% below the long-term average. In November 2005, five million Malawians, 38% of the population, needed food aid (Famine Early Warning Systems Network 2007). These circumstances underscore the urgent need to improve smallholder maize productivity and make it more resilient to drought stress.

In the face of this crisis, the Government launched a programme to subsidize agricultural inputs, using discretionary budget funds to import fertilizer and procure improved maize seed for distribution to farmers. The cost of the maize subsidy in 2005–2006 was estimated at approximately US$50 million (Denning et al. 2009). The result was a harvest estimated at 3.44 million tonnes, an all-time national record for Malawi, generating a surplus of about 1.34 million tonnes of maize grain above national requirements.

The key issue now is how to ensure sustained growth in maize production to prepare for the medium-term situation when fertilizer subsidies may have to be scaled back or withdrawn. Agroforestry systems, through the use of nitrogen-fixing trees, are providing options in Malawi that complement and reduce the need for inorganic nitrogen fertilizer. There is a long history of research on suitable fertilizer tree practices in Malawi and in the neighboring countries in Southern Africa (Sileshi et al. 2008). Cultivation of crops under *Faidherbia albida* has been traditionally practiced in Malawi for generations within systems that evolved under smallholder farmers' environmental and socio-economic conditions. Traditionally, some Malawian farmers grew their crops under scattered trees of *Faidherbia albida* (Rhoades 1995).

Formal research on the tree began in Malawi in the 1980s where it was carried out as part of the activities of the Agroforestry Commodity Team under the Government's Department of Agricultural Research and Technical Services (DARTS). Saka et al. (1994) reported 100–400% yield increases of maize under *Faidherbia* trees in the Lakeshore plain of Malawi. Several agencies have been promoting its cultivation in Malawi for the last two decades (Akinnifesi et al. 2008). It is estimated that currently about 500,000 Malawian farmers have *Faidherbia* trees on their farms (Phombeya 2009). The majority of these stands were developed through assisted natural regeneration of seedlings that emerged in farmers' fields (Fig. 3).

Since the early 1990s, the World Agroforestry Centre and its partners in eastern and southern Africa have been developing a range of agroforestry systems that would improve soil quality and significantly boost crop yields, providing high returns on both land and labour. The most popular system in southern Malawi, where landholdings are very small (<0.5 ha), is intercropping maize with nitrogen-fixing tree species of *Gliricidia sepium*, *Sesbania sesban*, *Tephrosia* species and pigeon peas. *Sesbania sesban*, *Tephrosia (T. vogelii* and *T. candida*) and pigeon peas are often relay-intercropped with maize (Snapp et al. 1998; Akinnifesi et al. 2008). In these systems, farmers plant the trees in rows between their crops. *Gliricidia* is pruned back two or three times a year, and the leafy biomass is incorporated into the soil (Fig. 3). A long-term experiment spanning more than a decade, involving the continuous

Fig. 3 Two promising fertilizer tree systems in Malawi: **a**) *Faidherbia* trees intercropped with maize, and **b**) *Gliricidia* managed as a coppice shrub in maize fields Photos: D Garrity

cultivation of maize with *Gliricidia* at Makoka Research Station, Malawi, yielded more than 5 t/ha in good years, and an average of 3.7 t/ha overall, in the absence of mineral fertilizers: that compared with an average of 0.5–1.0 t/ha in control plots without *Gliricidia* or mineral fertilizer (Akinnifesi et al. 2007; Makumba et al. 2006).

Rotational fallows that incorporate nitrogen-fixing trees are also suited to areas where land holdings are somewhat larger (>1 ha). In this case, during the fallow period farmers grow short-lived shrubs such as *Sesbania sesban* and *Tephrosia candida*, rather than the long-lived, intercropped trees like *Gliricidia*. Rotational fallows of *Sesbania sesban* and *Tephrosia candida* have been widely tested in farmer participatory research in Malawi. Results from 152 farms show that agroforestry increased the yield of maize by 54–76% compared to unfertilized sole maize, which is the *de facto* farmer practice (Akinnifesi et al. 2009). When supplemented with inorganic fertilizer, the yield increase over the control was 73–76% across tree species (Akinnifesi et al. 2009)..

In addition to increasing soil fertility and crop yields, these agroforestry systems were observed to suppress weeds (Sileshi et al. 2006), improve water filtration (Chirwa et al. 2007), and increase the amount of soil carbon (Makumba et al. 2007). There is evidence that production systems that incorporate *Gliricidia*, *Tephrosia*, *Faidherbia* and other leguminous cover crops assist rural populations to adapt their agriculture to the adverse effects of climate change. Research results and farmer interviews indicated that these systems increased the grain harvest during serious droughts (Akinnifesi et al. 2010; Sileshi et al. 2010). Farmers obtained at least a modest yield during seasons when farmers not using these practices experienced crop failure.

Malawi launched an Agroforestry Food Security Programme in 2007 based on these results. The programme is managed by the World Agroforestry Centre, the Ministry of Agriculture, the Malawian Farmers' Association (NASFAM), and a number of NGOs. It provides tree seeds, nursery materials, and training for a range of agroforestry species, including fertilizer trees. By mid-2009, over 120,000 farmers had received training and tree materials from the programme. Support from the Government of Ireland has now enabled the programme to expand nationally to 40% of Malawi's districts, involving at least 200,000 families or around 1.3 million of the poorest people.

Malawi's Agroforestry Food Security Programme is also incorporating a diverse range of fruit, timber, fuel wood, and tree cash crops into maize farming systems to enhance enterprise diversity and income generation. It relies on whole-village mobilization, particularly through farmer and women's groups, to accomplish the scale of action targeted. Women and the rural poor are the major beneficiaries. The poor are often observed to adopt agroforestry systems more rapidly than wealthier households (Ajayi et al., 2005; Place et al., 2005; Pye-Smith 2008).

The Malawi Agroforestry Food Security Programme is assisting the uptake of tree types of nitrogen-fixing tree legumes: short-term species such as *Tephrosia candida, Sesbania sesban*, and pigeon peas, which are planted and incorporated within 1 year; medium-term solutions such as *Gliricidia,* which can be continuously pruned for organic fertilizer for 1 to 2 decades; and long-term full canopy trees of *Faidherbia albida,* which provide benefits for many decades. These species are often combined in the same fields. The optimum combinations are being tailored to the range of variation in agroecological conditions and farm circumstances across the country.

Research to date has indicated that such forms of Evergreen Agriculture may generally increase yields from 1 t/ha to 2–3 t/ha, even if farmers cannot afford commercial nitrogen fertilizers. However, with an application of a quarter-dose of mineral fertilizer, maize yields may surpass 4 t/ha (Akinnifesi et al. 2010; Sileshi et al. 2010).

A current opportunity is to link fertilizer subsidies directly to agroforestry investments on the farm in order to provide for long-term sustainability in nutrient supply, and to build up soil health as the basis for sustained yields and improved efficiency of fertilizer response. This can be done in the short-term by combining the provision of limited amounts of subsidized fertilizer with the provision of seed and technical advice to establish fertilizer tree systems. Farmers can thus be further encouraged to produce more of the nitrogen required by their crops on farm, increasing and sustaining their maize yields and improving their soils. This would foster a gradual shift of investments from fertilizer subsidies to sustainable on-farm fertility regeneration. Discussions are underway with the Government of Malawi to map out such a *'subsidy to sustainability'* pathway.

Niger: The case of farmer-managed tree regeneration

The Sahel is the belt of land that stretches across Africa on the southern edge of the Sahara Desert. It is one of the poorest regions in the world, and has long been plagued by droughts. Throughout the Sahel, farmers have for many generations maintained a traditional land-use system known as the agroforestry parklands (Boffa, 1999). It is characterized by the deliberate retention of trees on cultivated land. The trees are an integral part of the agricultural system, providing food, fuel, fodder, medicinals, wood for buildings, cash commodities, as well as contributing to soil fertility, water conservation, and environmental protection. Demographic, economic, environmental and social developments during the past 40 years have put pressure on traditional land-use systems. Modern Sahelian forest laws, and the ways that they are locally enforced, have discouraged farmers from optimum parkland management and led to the degradation of the parklands to a varying extent across the region (Boffa, 1999). This was particularly the case in Niger.

Nigerien farmers had managed their agricultural parklands and village woodlands to produce a continuous harvest of trees and tree products for centuries (Boffa 1999). However, during the 1970s and 1980s they faced massive tree losses from drought and human population pressures, resulting in widespread desertification of the agricultural landscape. Considerable efforts were made to re-establish the vanishing tree cover through conventional reforestation projects. However, these overwhelmingly failed due to the harsh environment and a lack of attention given to the species that farmers preferred, and their reasons for nurturing them on their farms (Tougiani et al. 2009).

Traditionally, farmers had sustained populations of 10–50 trees/ha on their farms, not by planting them, but rather by observing the seedlings of useful species and allowing them to regenerate naturally in their fields. This practice is known as assisted natural regeneration (ANR), or farmer-managed natural regeneration (FMNR). Its success is due to the observation that seeds of useful trees are constantly being distributed by cattle, goats, birds, and wildlife throughout the agricultural environment. Likewise, underneath farmers' cleared fields lay extensive webs of living tree roots and stumps that were continually throwing up new stems. These are an invaluable source of new tree stock.

During the mid-1980s, development projects began to emphasize FMNR as a way to re-establish useful trees in the desertified agroecosystems of southern Niger (Tougiani et al. 2009). Farmers would prune the selected stems to promote their growth and the production of food, fuel, or fodder, while removing new, competing stems as needed. Periodically, they would harvest one of the original stems and choose a newly sprouting stem as a replacement, while growing their food crops between the trees. The techniques were flexible, and farmers adapted them to their own situations and objectives. They generated a range of benefits. The trees produced a supply of dry-season fodder for livestock, and they provided firewood, fruit, and medicinal products that farm households could consume or sell. Moreover, *Faidherbia albida*, one of the most ubiquitous species, enhances fertility by adding nitrogen to the soil (Barnes and Fagg 2003).

The re-greening process in central Niger began when an NGO in the Maradi region initiated a pilot project providing food aid to farmers willing to protect natural regeneration (Tougiani et al. 2009). The practices spread through wider support by other projects. Understanding of the processes, and wider awareness, was further enhanced by research collaboration between the University of Niamey and the World Agroforestry Centre. An evolving coalition of local, national, and international actors is now further enabling large-scale diffusion and continued use of these improved practices. Interest in *Faidherbia* and FMNR was further stimulated in the 1990s when the successful experiences of several pilot projects were shared with government policy-makers. This encouraged the government to relax the restrictive forestry regulations (*Code forestier)* that had severely limited farmer management of their own trees. Farmers were no longer prohibited from cutting down trees on their own farms or fined for pruning their trees. They now had an incentive to farm more intensively with *Faidherbia* and other trees, which they could also cut for timber and fuel wood sales (Dramé and Berti 2008). As a result, communities 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. In 2004, the Government of Niger formally recognized this trend by revising the national forestry laws to eliminate the onerous restrictions on the freedom of farmers to manage the trees that they sustained on their own land. This further accelerated the process of FMNR and extensive tree culture on farmland.

Tree densities and tree cover in Niger have increased over time. Analysis of high-resolution images acquired during 2003 to 2008 show that in the Maradi and Zinder Regions of Niger there are now about 4.8 million hectares of *Faidherbia*-dominated farmlands generated through FMNR (Reij et al. 2009). These landscapes harbor populations of *Faidherbia* of up to 160 trees per hectare (Fig. 4 and 5). Many villages now have 10–20 times more trees than 20 years ago. In 2005–06, a team of researchers from Niger examined the impacts of investments in natural resource management and long-term trends in agriculture and the environment (Adam et al. 2006). The highest tree densities were found in areas of high rural population density. Moreover, many of the trees were young and, thus,

Fig. 4 High-density *Faidherbia* tree intercropping in millet systems in southern Zinder, Niger, dry season, 2006. Photo: M Larwanou

Fig. 5 Millet production landscapes within *Faidherbia* parklands in Niger: a transformed agricultural system. Dry season after millet harvest. Photo: M Larwanou

still increasing in size and ground cover. Today, the agricultural landscapes of southern Niger have considerably more tree cover than they did 30 years ago (Reij et al. 2009). Vast expanses of savanna devoid of vegetation in the early 1980s are now densely studded by trees, shrubs, and crops (WRI 2008).

Reij et al. (2009) estimated that this transformation has resulted in an average of at least 500,000 additional tonnes of food produced per year. This additional production covers the requirements of 2.5 million people out of a total population of about 15 million in 2009. Despite a near-doubling of the population since 1980, Niger has been able to maintain per capita production of millet and sorghum, which make up more than 90% of the typical villager's diet. Per capita production remained at approximately 285 kg between 1980 and 2006. FMNR has also had an indirect impact on food security through the tree products that farmers harvest and sell in local markets, particularly fuel wood and timber (Dramé and Berti 2008). In recent years, the changed landscape has also been critical in managing crises. Between 2004 and 2006, when much of Niger was facing a food crisis caused by drought compounded by other factors, including the export of cereals to the urban markets of northern Nigeria, villages that had protected and managed natural regeneration were much less affected by the food shortages than villages that had not (Reij et al. 2009).

Millet and sorghum production in combination with *Faidherbia* in these areas is accompanied by non-inversion tillage methods. The majority of Nigerien farmers do not use the plow or the hoe for land preparation on their typically sandy soils. Rather they use a hand tool for loosening the soil and undercutting weeds, that is passed just underneath the soil surface without inverting the soil. Thus, Nigerien agriculture is essentially already integrating agroforestry into a minimum tillage conservation farming system. Niger farmers claim that the trees improve their crop yields, and also relate that the foliage and pods provide much-needed fodder for their cattle and goats during the long Sahelian dry season. Larwanou et al. (2006) interviewed about 400 farmers in the Zinder Region individually and in groups about their FMNR practices. According to the farmers interviewed, the trees reduce wind speed and evaporation. In the 1980s, crops had to be replanted three or four times because they were covered by wind-blown sand, but today farmers typically plant only once. Nitrogen-fixing species like *Faidherbia albida* enhance soil fertility, although farmers do not observe these effects with very young trees.

The most common species regenerating naturally and protected by farmers in Niger include *Faidherbia albida* (known as *gao* in Niger), *Combretum glutinosum, Guiera senegalensis, Piliostigma reticulatum*, and *Bauhinia rufescens*. Depending on the location of the village, other species can be important, such as *Adansonia digitata* (baobab) and *Prosopis africana*. Sahelian women have benefited in that FMNR has greatly improved the supply of fuel wood over the past 20 to 30 years, allowing them to reallocate the time once spent on collecting fuelwood to other activities, including producing and preparing food and caring for children.

No study has systematically quantified the impacts of FMNR, but Larwanou and Adam (2008) have made a step in this direction. They calculated that if the number of trees has increased by 40 trees/ha (trees of all ages) on a scale of 5 million ha, then FMNR has added about 200 million new trees to Niger's tree stock (Reij et al. 2009). Larwanou and Adam (2008) assumed that every tree produces an average value of $1.40 per year in the form of improved soil fertility, fodder, fruit, firewood and other produce. This would mean an additional value of at least $56/ha/year, and a total annual production value of $280 million.

Wider research and experience with Faidherbia

Investigations on the properties of *Faidherbia* began over 60 years ago, when scientists observed that farmers throughout the Sahelian region of Africa were retaining the trees in their sorghum and millet fields (Barnes and Fagg 2003). The species has long been an integral part of Sahelian agriculture, where farmers have nurtured and protected the 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 (Boffa 1999). There are many reports of dramatic increases in the grain yield of unfertilized millet grown under *Faidherbia* in West Africa (Barnes and Fagg 2003). 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 (Barnes and Fagg 2003). Other crops that are reported to benefit from association with *Faidherbia* include groundnuts and cotton. Rhoades (1995) reviewed several results in Africa and reported yield increases of 37% for groundnut, and 200% for sorghum in the north-central Senegal, and 115% for sorghum in Burkina Faso. *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 (Hadgu 2008). There 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.

Boffa (1999) reviewed research conducted in various countries on the improvement of soil nutrient content and crop yields under *Faidherbia albida* canopies, compared with controls in the open. Increases in nitrogen content ranged from 15 to 156%, but significant increases were also found in carbon, phosphorus, exchangeable potassium, calcium, and magnesium. The impact on millet yields ranged from 49 to 153% increases; for sorghum, most yield increases ranged from 36 to 169%. In absolute terms, this means, in most cases, an additional cereal yield of 400–500 kg/ha or more. This may explain why farmers in parts of the densely populated southern Zinder Region have created such a high-density agroforest of *Faidherbia albida.*

Encouraged by the experience in Niger, new programmes to promote farmer-managed natural regeneration with *Faidherbia* and other species have been established in other countries across the Sahel. Recently, these efforts have coalesced into the launch of the African Regreening Initiative, an alliance of organizations that seeks to promote awareness and action to multiply and intensify the dramatic successes achieved in Niger (http://www.cis.vu.nl/projects). The work is encouraging more optimal tree densities in areas where agroforestry is already practiced, and propagating the trees in areas where parkland farming systems are not present. This is further enhanced by new knowledge of simple, effective propagation techniques for *Faidherbia* and other species that farmers can use locally (CFU). Farmers in many areas relate that they have been constrained by lack of practical methods to produce their own seedlings of *Faidherbia* and successfully establish them in their crop fields. This knowledge gap has now been overcome.

Burkina Faso: adaptation of conservation farming in an extreme environment

The 1968–73 Sahelian droughts caused an acute human and environmental crisis in Burkina Faso, a Sahelian country adjacent to Niger. The densely populated Yatenga Province on the northern Central Plateau of Burkina Faso was particularly affected. Failure of the agricultural systems prompted massive labor migration and caused social disruption (Monimart 1989). Between 1975 and 1985, some villages lost up to 25% of their population as they migrated south to areas of higher rainfall. In the early 1980s, groundwater levels in the Central Plateau dropped an estimated 0.5–1.0 m per year (Reij 1983). Many wells and boreholes went dry just after the end of the rainy season and had to be deepened.

Average sorghum and millet yields decreased to slightly below 300 kg/ha (Matlon and Spencer 1984; Matlon 1990). As a result, the majority of farm households had annual food deficits of 50% or more (Broekhuyse 1983). Most land was cultivated continuously on shallow lateritic, crusting soils with very low natural fertility, creating extensive areas of barren, unusable land. As the landscape became denuded and exposed to severe water erosion, the land and the people became increasingly vulnerable to drought.

During the 1980s, farmers began experimenting with traditional techniques to reclaim severely degraded farmland that water could not penetrate. They developed variations of the practice of digging a grid of planting pits (*zai*) across their fields. The depth and diameter of the pits was increased, and organic matter added to the basins to regenerate an environment where plants could grow. The pits concentrated nutrients in the plant root zone, and retained water for extended periods of time, allowing crops to better survive dry spells. The pits are prepared during the dry season, enabling early planting for increased yields. The use of new and improved planting pits spread rapidly among farmers with the support of NGOs and the extension service. Another practice that became popular with farmers was the construction of contour stone bunds that reduce surface runoff from the fields.

By 2001, well over 100,000 ha of badly degraded land had been rehabilitated by projects and by farmers on the northern part of the Central Plateau alone (Reij and Thiombiano 2003). Taking into account what has been achieved in this region since then and on other parts of the Central Plateau, it is now estimated that the total area rehabilitated over the past three decades is somewhere between 200,000 and 300,000 ha (Kaboré and C. Reij (2004), Botoni and Reij 2009; Reij et al. 2009). A recent study shows that in villages with a long history of soil and water conservation, 72 to 94% of the cultivated land has been rehabilitated with one or more conservation techniques. In villages with a shorter history, this figure ranges from 9 to 43% (Reij et al. 2009).

Cereal production is estimated to have increased by an average of at least 400 kg/ha, a percentage increase of 40% to more than 100% (Reij et al. 2009). This translates into an annual increase of 80,000 tonnes of grain, enough to provide for 500,000 people. *Zaï* planting pits alone usually have a greater impact on yields than stone bunds alone, but the greatest returns accrue from using both together. The effect of the practices was synergistic with added manure. With these increases, farm households that suffered from food deficits of 6 months or more in a year during the early 1980s have been able to reduce their deficit periods to 2–3 months, or to zero in some cases (Reij et al. 2009).

The *zai* planting pits have been used to intensify cereal production as well as to produce trees, or to combine cereal and tree production in agroforestry systems. By stimulating tree production in combination with planting pits, biomass production is dramatically increased, for soil amelioration as well as livestock fodder (Reij et al., 2009). On the Central Plateau, rehabilitated fields now average 126 trees per hectare, compared with 103 trees per hectare on control plots. The trees on rehabilitated land are larger and represent a wider range of species. These modified traditional agroforestry-, water-, and soil-management practices have transformed barren agricultural landscapes into complex agricultural systems with more vegetation and more varied vegetation (Reij et al. 2009).

Some common indigenous tree species, such as *Combretum glutinosum* and *Piliostigma reticulatum*, can be managed as coppiced stumps at a density of at least several hundred per hectare, under a management system much like the coppiced trees of *Gliricidia* that are integrated into maize systems in Malawi (see previous section). If also combined with full-canopy *Faidherbia* trees, several tonnes of additional biomass can be generated annually per hectare to accelerate soil fertility replenishment, provide additional livestock fodder, and increase yields. These developments have also brought changes in how rural people earn their livelihoods. After the harvest, men once commonly migrated to urban areas for employment, but some indicators suggest that this pattern is changing as more men remain in the villages because they can now earn sufficient incomes from agriculture.

Current research with Burkinabe farmers on these options holds the promise of further increasing ecosystem productivity and land rehabilitation in Burkina Faso. The spread of the *zaï* technique may be accelerated as scientists from Institut de l'Environnement et de Recherches Agricoles (INERA) of Burkina Faso have developed a 'mechanical *zai*' that consists of making the pits mechanically with animal-drawn tools. This reduces by more than 90% the amount of time required for making the pits (Barro et al. 2005). Efforts to adapt and expand these Evergreen Agriculture systems to the western and southern areas of Burkina Faso are now accelerating through the African Regreening Initiative, and through projects involving NGOs such as Catholic Relief Services. These are augmented by the research and capacity-building programmes of the World Agroforestry Centre, the African Conservation Tillage Network, the Food and Agriculture Organization of the United Nations and others. The next stage is anticipated to be a full-scale national programme that will bring together the various efforts into a coordinated campaign throughout the country.

The future of Evergreen Agriculture in Africa

The previous sections reviewed significant advances in the application of the principles and practices of Evergreen Agriculture at a major scale in southern and western Africa. The advances in Malawi and Niger are particularly noteworthy as these countries have suffered mass mortality food crises since 2000 (Devereux 2009). In these areas, where smallholder livelihoods are undiversified, and are dominated by subsistence-oriented food crop production, even a moderate decline in harvests can be devastating for household food security (as in Malawi in 2001–2002 and Niger in 2004–2005). Climate change is likely to make this situation worse, with declining and/or more erratic rainfall resulting in lower aggregate production and more unpredictable harvests in much of Africa (Funk and Brown 2009).

The farming practices embodying the principles of Evergreen Agriculture are unique to each country, but they exhibit important similarities. Each involves the integration of tree species into food crop farming in ways that increase and sustain grain production, and diversify and increase household income. The trees sustain a green cover on the land resulting in higher biomass production that contributes to enhanced soil fertility and increased fodder production. And they have enabled practical ways of reducing soil tillage to improve rainwater-use efficiency, increase soil-carbon accumulation, and improve soil health. In each national case there is evidence that the practices increased household and national food security, and that they have reached a level of adoption that may be sustainable in the long term with adequate farm advisory support. Further, there is evidence in all four cases that governments are deepening their support for the expansion of these Evergreen Agriculture systems throughout their territories.

The experiences of Zambia, Malawi, Niger, and Burkina Faso indicate that the principles of Evergreen Agriculture may be applicable to a much broader range of food crop systems in Africa, if accompanied by adequate research and farmer engagement. Although these countries may be the most advanced large-scale examples of Evergreen Agriculture on the continent, there are also successful examples in many other countries, although many of these are at a more localized scale.

The success of Evergreen Agriculture has prompted vigorous political action at the continental level. In April 2009, at a meeting organized by the African Union in Addis Ababa, the Ministers of Agriculture, Land and Livestock from across the continent published a declaration that committed them to ramping up efforts to increase the number of farmers practicing agroforestry-based conservation agriculture, and they called for increased international support for these efforts. Subsequently, the African Ministers of Environment also endorsed this recommendation during their meeting in Nairobi in May, 2009.

The Comprehensive African Agricultural Development Programme (CAADP) is now recognized as the mechanism for coordinating international and national efforts to spur agricultural growth in Africa. The African Union's New Partnership for Africa's Development (NEPAD) is charged with the development and implementation of a nested set of action plans under CAADP. NEPAD is now finalizing a CAADP Framework for Climate Change and Agriculture to coordinate programmes to link productivity increases with investments, to adapt African agriculture to climate change, and to contribute to the mitigation of carbon emissions. NEPAD has called for a continental effort on Evergreen Agriculture as a flagship programme to address these challenges.

A broad alliance is emerging of governments, international donors, research institutions, and international and local development partners, in order to expand Evergreen Agriculture throughout Africa. The World Agroforestry Centre, the African Conservation Tillage Network, the Zambian Conservation Farming Unit, and CILSS[1] have been asked by NEPAD to work closely with 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 becomes a reality. The regional economic commissions of COMESA[2], ECOWAS[3], and the EAC[4] have been encouraged to actively engage in using their influence to further accelerate this process. For example, COMESA will be investing over $50 million in agroforestry-based conservation farming during the next 5 years, with support from the Government of Norway.

Tanzania and Kenya have recently developed national strategies and work plans to support the expansion of Evergreen Agriculture, drawing on the expertise of the African Conservation Tillage Network, FAO and the World Agroforestry Centre. National alliances are now also being created in Ethiopia, Rwanda, Ghana, Mali, and a number of other countries to develop their own Evergreen Agriculture programmes, building on the experience of Malawi, Zambia, Niger, and Burkina Faso. And the African Regreening Initiative is spearheading the expansion of assisted natural regeneration in the Sahelian zone. The donor community is mobilizing to support these efforts on a much greater and more coordinated scale under the CAADP Framework for Climate Change and Agriculture.

Evergreen Agriculture and climate change

As Lal (2010) has pointed out, addressing the issue of food-insecurity and global warming through the sequestration of carbon in soils and the biota, along with payments to resource-poor farmers for the ecosystem services rendered, would be a timely win-win strategy. Conventional conservation farming systems tend to sequester a maximum of 0.2–0.4 t C $ha^{-1}yr^{-1}$. Evergreen Agriculture systems accumulate carbon both above and below-ground in the range of 2–4 t C $ha^{-1}yr^{-1}$, roughly an order of magnitude higher than with conservation farming alone. This is particularly true for systems incorporating fertilizer trees such as *Faidherbia* or *Gliricidia* (Makumba et al. 2007; Kaonga and Bayliss-Smith 2008). Consequently, there is considerable 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 food crop systems while simultaneously enhancing the livelihoods of smallholders and the environment. These investments will encourage development pathways resulting in higher carbon stocks at a whole landscape scale (Garrity and Verchot 2008).

Most forest conversion to agricultural land in Africa is due to clearing by subsistence farmers. A sustained elevation in smallholder crop productivity through the expansion of Evergreen Agriculture can result in significant co-benefits by providing a basis for reducing the overall rate of deforestation on the continent. The new bio-carbon investment funds, if focused on Evergreen Agriculture, could provide new resources to expand farmers' capacity to contribute to the reduction of global carbon emissions while growing more food and providing other sustainable development benefits. Such investments will assist smallholder food crop agriculture to become more resilient to adverse climate change by reducing yield losses due to drought (Syampungani et al. 2010; Neufeldt et al. 2009; Garrity and Verchot, 2008; Kandji et al. 2006).

Conclusion

Today, Africa is critically threatened by food insecurity, land degradation, and climate change. Smallholder farmers need

[1] Comité Inter-Etate pour la Lutte contre la Sécheresse au Sahel
[2] Common Market for Eastern & Southern Africa
[3] The Economic Community Of West African States
[4] The East African Community

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 accessible and affordable. Evergreen Agriculture embodies new options to better care for the land and to increase smallholder food production. However, the effective targeting of investments to expand Evergreen Agriculture needs to be based on a scientific assessment of land degradation hot spots in each country. The past several years have seen enormous advances in spectroscopic methods for rapid, low cost, high throughput soil and plant analysis (Shepherd and Walsh 2007; Swift and Shepherd 2007). These developments are now being harnessed through the new African Soil Information Service (AfSIS) to enable science-based diagnostic surveillance approaches to agricultural and environmental management on a continental scale.

The recent food price crisis has reawakened world leaders and donor agencies to the necessity of assuring the food security of all nations, and to revitalizing and reinvesting in the agriculture sector. Such investments are urgently needed to promote agricultural growth and reduce poverty. Most African governments have not yet prioritized support for the agricultural sector. And farmers in many parts of the continent (but not all) have remained poorly organized, and have failed to lobby effectively for an adequate share of public resources. Sustained engagement with these stakeholders is required to unlock the potential of Evergreen Agriculture to transform the lives of large numbers of poor households in rural communities across the continent, and to make significant contributions to alleviating the effects of climate change.

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

References

Aagard, P. (2009). Conservation Farming Unit, Lusaka, Zambia. Personal communication

Abdulai, A., Barret, C. B. Hazell, P. (2004). Food aid for market development in sub-Saharan Africa. DSGD discussion paper No. 5. Development Strategy and Governance Division International Food Policy Research Institute (IFPRI). Washington, D.C. 20006 U.S.A. 56 p.

Adam, T., Abdoulaye, T., Larwanou, M., Yamba, B., Reij, C., Tappan, G. (2006). Plus de gens, plus d'arbres: La transformation des systèmes de production au Niger et les impacts des investissements dans la gestion des ressources naturelles. Rapport de Synthèse Etude Sahel Niger. Comité Permanent Inter-Etats de Lutte contre la Sécheresse dans le Sahel and Université de Niamey, Niamey

Ahmed, A., Hill, I., Smith, D., Wisemann, D., Frankernburger, T. (2007). The World's Most Deprived: Characteristics and causes of extreme hunger and poverty (2020) Discussion Paper 43. International Food Policy Research Institute, Washington

Ajayi OC, Place F, Kwesiga P, Mafongoya Franzel S (2005) Impact of Fertilizer Tree Fallows in Eastern Zambia. World Agroforestry Centre, Nairobi, p 28

Ajayi OC, Place F, Kwesiga F, Mafongoya P (2007) Impacts of Improved Tree Fallow Technology in Zambia. In: Waibel H, Zilberman D (eds) International Research on Natural Resource Management: advances in impact assessment CABI Wallingford. UK and Science Council/CGIAR, Rome, pp 147–168

Ajayi CO, Akinnifesi FK, Sileshi G, Kanjipite W (2009) Labour inputs and financial profitability of conventional and agroforestry-based soil fertility management practices in Zambia. Agrekon 48:246–292

Akinnifesi FK, Makumba W, Sileshi G, Ajayi OC, Mweta D (2007) Synergistic effect of inorganic N and P fertilizers and organic inputs from *Gliricidia sepium* on productivity of intercropped maize in Southern Malawi. Plant Soil 294:203–217

Akinnifesi FK, Chirwa PW, Ajayi OC, Sileshi G, Matakala P, Kwesiga FR, Harawa H, Makumba W (2008) Contributions of agroforestry research to livelihood of smallholder farmers in Southern Africa: 1. Taking stock of the adaptation, adoption and impact of fertilizer tree options. Agricultural Journal 3: 58–75

Akinnifesi FK, Sileshi G, Franzel S, Ajayi OC, Harawa R, Makumba W, Chakeredza S, Mng'omba SA, de Wolf J, Chianu J (2009) On-farm assessment of legume fallows and other fertility management options used by smallholder farmers in southern Malawi. Agricultural Journal 4:260–271

Akinnifesi FK, Ajayi OC, Sileshi G, Chirwa PW, Chianu J (2010) Fertilizer tree systems for sustainable food security in the maize-based production systems of East and Southern Africa Region: a review. J Sustain Dev. doi:10.1051/agron/2009058

Arnold JE, Dewees PA (1995) Tree Management in Farmer Strategies: Responses to Agricultural Intensification. Oxford UK: Oxford University Press. 304 p. (Paperback edition, 1997, Farms, Trees, and Farmers: Responses to Agricultural Intensification, London: Earthscan)

Barnes RD, Fagg CW (2003) Faidherbia albida. Monograph and Annotated Bibliography. Tropical Forestry Papers No 41, Oxford Forestry Institute, Oxford, UK. 281 p

Barro A, Zougmoré R, Taonda SJB (2005) Mécanisation de la technique du zaï manuel en zone semi-aride. Cahiers Agricultures 14:549–559

Boffa, J. M. (1999). Agroforestry Parklands in sub-Saharan Africa. FAO Conservation Guide 34, Food & Agriculture Organization, Rome. 254 p.

Botoni, E. Reij, C. (2009). *La transformation silencieuse de l'environnement et des systèmes de production au Sahel: L'impacts des investissements publics et privés dans la gestion des ressources naturelles*. Amsterdam, the Netherlands: Comité Permanent Inter-Etats de Lutte Contre la Secheresse dans le Sahel (CILSS) and Vrije University Amsterdam. 175 p.

Broekhuyse, J. T. (1983). *Transformatie van Mossi land*. Amsterdam, the Netherlands: Koninklijk Instituut voor de Tropen.

Carr S (1997) A green revolution frustrated: Lessons from the Malawi experience. Afr Crop Sci J 5:93–98

Chirwa PW, Ong CK, Maghembe J, Black CR (2007) Soil water dynamics in intercropping systems containing *Gliricidia sepium*, pigeon pea and maize in southern Malawi. Agroforest Syst 69:29–43

Denning G, Kabambe P, Sanchez P, Malik A, Flor R, Harawa R, Nkhoma P, Zamba C, Banda C, Magombo C, Keating M, Wangila J, Sachs J (2009) Input subsidies to improve smallholder maize productivity in Malawi: toward an African green revolution. PLoS Biology 7:2–10

Devereux S (2009) Why does famine persist in Africa? Food Security 1:25–35

Devereux S, Maxwell S (eds) (2001) Food Security in Sub-Saharan Africa. ITDG, London

Dramé YA, Berti F (2008) Les enjeux socio-économiques autour de l'agroforesterie villageoise à Aguié (Niger). Tropicultura 26:141–149

Famine Early Warning Systems Network (2007) Monthly reports (2005–2007). Available: http://www.fews.net/Pages/country. Accessed 17 December 2008.

Food & Agriculture Organization (2007) The state of food and agriculture. United Nations Food & Agriculture Organization, Rome

Food & Agriculture Organization of the United Nations (2008). FAOSTAT database. Production: Crops. Available: http://faostat.fao.org/site/567/default.aspx. Accessed 18 December 2008.

Funk CC, Brown ME (2009) Declining global per capita agricultural production and warming oceans threaten food security. Food Security 1:271–289

Garrity DP (2004) Agroforestry and the achievement of the millennium development goals. Agroforest Syst 61:5–17

Garrity, D. P. (2010). Hope is Evergreen. Our Planet May: 28–30.

Garrity D, Verchot L (2008) Meeting Challenges of Climate Change and Poverty through Agroforestry. World Agroforestry Centre, Nairobi, p 8

GEF (Global Environment Facility) (2003). What Kind of World? The challenge of land degradation. Global Environment Facility (GEF), p. 4.

Hadgu, K. M. (2008). Temporal and spatial changes in land use patterns and biodiversity in relation to farm productivity at multiple scales in Tigray, Ethiopia. PhD dissertation, Wageningen University, Netherlands. 174 p

Haggblade, S., & Tembo, G. (2003). Early Evidence on Conservation Farming in Zambia. EPTD Discussion Paper 108. Washington DC: International Food Policy Research Institute.

Jones PG, Thornton PK (2003) The potential impacts of climate change in tropical agriculture: the case of maize in Africa and Latin America in 2055. Glob Environ Change 13:51–59

Kaboré, D., Reij, C. (2004). The emergence and spread of an improved traditional soil and water conservation practice in Burkina Faso. Environment and Production Technology Division Working Paper No. 114. Washington, DC: International Food Policy Research Institute. 338 p.

Kandji ST, Verchot L, Mackensen J (2006) Climate change and variability in Southern Africa: impacts and adaptation in the agricultural sector. ICRAF/UNEP, Nairobi, p 36

Kaonga M, Bayliss-Smith TP (2008) Carbon pools in tree biomass and the soil in improved fallows in eastern Zambia. Agroforest Syst 76:37–51

Katanga R, Kabwe G, Kuntashula E, Mafongoya PL, Phiri S (2007) Assessing Farmer Innovations in Agroforestry in Eastern Zambia. J Agr Educ Ext 13:117–129

Kumar BM, Nair PKR (2006) Tropical Homegardens. Springer, Dordrecht, p 377

Kwesiga F, Coe R (1994) Potential of short-rotation Sesbania fallows in eastern Zambia. For Ecol Manage 64:161–170

Kwesiga F, Akinnifesi FK, Mafongoya PL, Mcdermott MH, Agumya A (2003) Agroforestry research and development in southern Africa during 1990s: Review and challenges ahead. Agroforest Syst 53:173–186

Kwesiga, et al. (2005). Improved Fallow Practices in Eastern Zambia. EPTD Discussion Paper No. 130. Washington, DC: International Food Policy Research Institute. 285 p.

Lal R (2009) Soil degradation as a reason for inadequate human nutrition. Food Security 1:45–58

Lal R (2010) Beyond Copenhagen: mitigating climate change and achieving food security through soil carbon sequestration. Food Security 2:169–177

Lamb RL (2000) Food crops, exports, and the short-run policy response of agriculture in Africa. Agr Econ 22:271–298

Larwanou, M., Adam, T. (2008). *Impacts de la régénération naturelle assistée au Niger: Etude de quelques cas dans les Régions de Maradi et Zinder*. Synthèse de 11 mémoires d'étudiants de 3ème cycle de l'Université Abdou Moumouni de Niamey, Niger. Photocopy. 49 p.

Larwanou, M., Abdoulaye, M., Reij, C. (2006). *Etude de la régénération naturelle assistée dans la Région de Zinder (Niger): Une première exploration d'un phénomène spectaculaire*. Washington, D.C.: International Resources Group for the U.S. Agency for International Development. 385 p.

Mafongoya, P. L., Kuntashula, E., Sileshi, G. (2006). Managing soil fertility and nutrient cycles through fertilizer trees in southern Africa. In: Uphoff N, Ball AS, Fernes E, Herren H, Husson O, Liang M, Palm C, Pretty J, Sanchez P, Sanginga N, Thies J (eds). Biological Approaches to Sustainable Soil Systems, Taylor & Francis, (pp 273–289).

Makumba W, Janssen B, Oenema O, Akinnifesi FK, Mweta D, Kwesiga F (2006) The long-term effects of a *Gliricidia*-maize intercropping system in southern Malawi, on *Gliricidia* and maize yields, and soil properties. Agric Ecosyst Environ 116:85–92

Makumba W, Akinnifesi FK, Janssen B, Oenema O (2007) Long-term impact of a *Gliricidia*-maize intercropping system on carbon sequestration in southern Malawi. Agric Ecosyst Environ 118:237–243

Matlon PJ (1990) Improving productivity in sorghum and pearl millet in semi-arid Africa. Food Res Inst Stud 22:1–43

Matlon PJ, Spencer DS (1984) Increasing food production in Sub-Saharan Africa: environmental problems and inadequate technical solutions. Am J of Agric Econ 66:672–676

Monimart M (1989) *Femmes du Sahel: La désertification au quotidien*. Editions Karthala/Organisation for Economic Cooperation and Development Club du Sahel, Paris, p 263

Neufeldt, H., Wilkes, A., Zomer, R. J., Xu, J., Nang'ole, E., Munster, C., Place, F. (2009). Trees on farms: Tackling the triple challenges of mitigation, adaptation and food security. World Agroforestry Centre Policy Brief 07. Nairobi, Kenya: World Agroforestry Centre.

Phombeya, H. S. K. (1999). Nutrient sourcing and recycling by Faidherbia albida trees in Malawi. PhD Dissertation, Wye College, University of London. 219 p

Phombeya H (2009) MAFE Land Resource Centre, Lilongwe. Malawi, Personal Communication

Place, F., Adato, M., Hebinck, P., Omosa, M. (2005). The impact of agroforestry-based soil fertility replenishment practices on the poor in Western Kenya. Research Report 142. Washington, D.C.: International Food Policy Research Institute and World Agroforestry Centre.

Pye-Smith C (2008) Farming Trees, Banishing Hunger: How an agroforestry programme is helping smallholders in Malawi to grow more food and improve their livelihoods. World Agroforestry Centre, Nairobi, p 27

Reij, C. (1983). *L'évolution de la lutte anti-érosive en Haute Volta: Vers une plus grande participation de la population*. Institute for Environmental Studies, Vrije University, Amsterdam, the Netherlands.

Reij C, Thiombiano T (2003) *Développement rural et environnement au Burkina Faso: La réhabilitation de la capacité productive des terroirs sur la partie nord du Plateau Central entre 1980 et 2001*. Ambassade des Pays-Bas, German Agency for Technical Cooperation- PATECORE, and U.S. Agency for International Development, Ouagadougou

Reij, C., Tappan, G., Smale, M. (2009). Agroenvironmental Transformation in the Sahel: Another Kind of "Green Revolution". IFPRI Discussion Paper 00914. Washington DC: International Food Policy Research Institute.

Republic of Malawi (2008). Malawi poverty and vulnerability assessment: Investing in our future. Volume II: June draft for discussion. Lilongwe: Republic of Malawi and World Bank. Available: http://www.aec.msu.edu/fs2/mgt/caadp/malawi_pva_draft_052606_final_draft.pdf. Accessed 17 December 2008.

Rhoades C (1995) Seasonal pattern of nitrogen mineralization and soil moisture beneath *Faidherbia albida* (syn *Acacia albida*) in central Malawi. Agrofor Sys 29:133–145

Saka AR, Bunderson WT, Itimu OA, Phombeya HSK, Mbekeani Y (1994) The effects of Acacia albida on soils and maize grain yields under smallholder farm conditions in Malawi. For Ecol Manag 64:217–230

Sanchez, P. A. (1994). Tropical soil fertility research: Towards the second paradigm. P. 65–88. In Inaugural and state of the art conferences. Transactions 15th World Congress of Soil Science. Acapulco, Mexico.

Sanchez P (2002) Soil fertility and hunger in Africa. Science 295:2019–2020

Sanchez PA, Swaminathan MS (2005) Cutting world hunger in half. Science 307:357–359

Sanginga N, Woomer PL (2009) Integrated soil fertility management in Africa: principles, practices, and developmental processes. TSBF-CIAT, Nairobi, p 263

Scherr S, McNeely J (2009) Farming with Nature: The Science and Practice of Ecoagriculture. Island, Chicago, 473 p.

Schmidhuber J, Tubiello FN (2007) Global food security under climate change. Proc Natl Acad Sci 104:19703–19708

Scoones, I., Toulmin, C. (1999). Policies for soil fertility management in Africa. A report prepared for the Department for International Development (DFID). IDS, Brighton/IIED, Edinburgh. 128 p.

SEI (Stockholm Environment Institute) (2005). Sustainable pathways to attain the millennium development goals—assessing the role of water, energy and sanitation. Research report prepared for the UN World Summit, 14 September, 2005, New York. Stockholm Environment Institute, Stockholm http://www.sei.se/mdg.htm

Shepherd KD, Walsh MD (2007) Infrared spectroscopy – enabling an evidence-based diagnostic surveillance approach to agricultural and environmental management in developing countries. J Near Infrared Spectrosc 15:1–19

Sileshi G, Mafongoya PL (2006) Long-term effect of legume-improved fallows on soil invertebrates and maize yield in eastern Zambia. Agric Ecosyst Environ 115:69–78

Sileshi G, Kuntashula E, Mafongoya PL (2006) Legume improved fallows reduce weed problems in maize in eastern Zambia. Zambian Journal Agric Sci 8:6–12

Sileshi G, Akinnifesi FK, Ajayi OC, Place F (2008) Meta-analysis of maize yield response to woody and herbaceous legumes in the sub-Saharan Africa. Plant Soil 307:1–19

Sileshi G, Akinnifesi FK, Debusho LK, Beedy T, Ajayi OC, Mng'omba S (2010) Variation in maize yield gaps with plant nutrient inputs, soil type and climate across sub-Saharan Africa. Field Crops Res 116:1–13

Smith, G. (2009). http://www.alertnet.org/db/an_art/60167/2009/10/17-113135-1.htm.

Snapp SS, Mafongoya PL, Waddington S (1998) Organic matter technologies for integrated nutrient management in smallholder cropping systems of southern Africa. Agric Ecosyst Environ 71:185–200

Swift, M. J., Shepherd, K. D., (eds). (2007). Saving Africa's Soils: Science and Technology for Improved Soil Management in Africa. Nairobi: World Agroforestry Centre. http://worldagroforestry.org/Library/listdetails.asp?id=49775

Syampungani S, Chirwa PW, Akinnifesi FK, Ajayi OC (2010) The potential of using agroforestry as a win-win solution to climate change mitigation and adaptation and meeting food security challenges in Southern Africa. Agr J 5:80–88

Tougiani A, Guero C, Rinaudo T (2009) Community mobilisation for improved livelihoods through tree crop management in Niger. GeoJournal 74:377–389

Tripp R (2005) The performance of low external input technology in agricultural development: a summary of three case studies. Int J Agric Sustain 3:143–153

UNEP/ISRIC. (1991). World Map of the Status of Human-Induced Soil Degradation (GLASOD). An Explanatory Note (2nd ed.). UNEP, Nairobi, Kenya, and ISRIC, Wageningen, Netherlands

United Nations. (2004). World Population to 2300. Department of Economic and Social Affairs/Population Division, New York: United Nations Secretariat. 254 p.

WRI (World Resources Institute) (2008). Turning back the desert: How farmers have transformed Niger's landscapes and livelihoods. In Roots of resilience: Growing the wealth of the poor. Washington, D.C.: World Resources Institute.

Zomer, R. J., Trabucco, A., Coe, R., Place, F. (2009). Trees on Farm: Analysis of Global Extent and Geographical Patterns of Agroforestry. Nairobi: World Agroforestry Centre, ICRAF Working Paper No 89.

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