Making Conservation Agriculture ever green

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After decades of research, and the sustained efforts of pioneering farmers, the practice of conservation agriculture (CA) has been steadily increasing globally. Currently, about 117 million hectares of land are now managed under minimum or zero-tillage conservation farming practices. However, the uptake of CA in Africa, and in the rainfed upland areas of Asia, has been modest so far. Why is that?

This paper reviews the key constraints limiting the practice of CA in tropical rainfed agroecologies. It examines evidence from research, and from widespread indigenous practice, that indicates that successful CA systems for tropical smallholders would benefit substantially from the integration of trees. It argues that Conservation Agriculture with Trees (CAWT) addresses a number of the critical constraints to sustained smallholder CA uptake, and notes that there is now clear evidence of its success at scale in several countries in Africa.

There are three long-established principles in conservation farming: Minimum soil disturbance, crop residue retention, and crop rotation. The short-term advantages observed where CA is currently practiced are earlier planting to enable better use of seasonal rainfall, and increased rainwater conservation in the soil to better tide crops over during drought periods (Rockstrom et al 2009). But there are a number of unique constraints to smallholder adoption of CA that are retarding its more rapid uptake. Most important among these are: Competing uses for crop residues where livestock production is common, inadequate biomass accumulation of cover crops in the off-season, increased labor demands for weeding when herbicides are not used, variable yield results across soil types, and the need for greater application of organic and inorganic nutrients.

Giller et al (2009) discussed these constraints. They pointed out that most African smallholders are engaged in both crop and livestock production, and that their available fodder resources are usually very inadequate. Thus, farmers must typically use all of their available crop residues for animal fodder or fuel, and cannot afford to retain these valuable materials as a soil cover. This highlights the imperative to find other ways to increase plant biomass. In addition, more than 75% of African smallholders are not applying any inorganic fertilizers, often because of cash constraints and high climatic risk. Thus, low yields and soil fertility decline in CA are inevitable if greater use of biological nitrogen fixation and more efficient nutrient cycling are not practiced.

How can biomass production be increased to enhance surface cover and to generate greater quantities of organic nutrients to complement whatever amounts of inorganic fertilizers a smallholder farmer can afford to apply? Recently, the CA and agroforestry research and development communities have mutually recognized the value of integrating fertilizer trees and shrubs into CAWT systems (illustrated in Figure 1 and 2) to dramatically enhance both fodder production and soil fertility (eg FAO 2010; FAO 2011). Practical systems for intercropping fertilizer trees in maize farming have been developed and are being extended to hundreds of thousands of farmers in Malawi and Zambia (Ajayi et al 2011). The portfolio of options includes intercropping maize with *Gliricidia sepium*, *Tephrosia candida* or pigeon peas, or using trees such as *Sesbania sesban* as an improved fallow.

One particularly promising system is the integration of the *Faidherbia albida* into crop fields at a 10 m by 10 m spacing. *Faidherbia* is an indigenous African acacia that is widespread on millions of farmer's fields throughout the eastern, western, and southern regions of the continent. It is highly compatible with food crops because it is dormant during the rainy season. It exhibits minimal competition, while enhancing yields and soil health (Barnes and Fagg 2003). Several tons of additional biomass can be generated annually per hectare to accelerate soil fertility replenishment, provide additional livestock fodder. Numerous publications have recorded increases in maize grain yield when it grown in association with *Faidherbia*, ranging from 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 semi-arid cropping systems based on millet and sorghum, double-story production systems with medium-to-high densities of fertilizer trees are now observed across more than five million of hectares in the Sahelian countries (Garrity et al 2010). Depending upon which woody species are used, and how they are managed, their incorporation into CA helps to maintain vegetative soil cover, increase nutrient supply through nitrogen fixation and nutrient cycling, suppress insect pests and weeds, enhance soil structure and water infiltration, increase carbon storage and soil organic matter, and conserve above- and below-ground biodiversity.

Evergreen Agriculture is defined as the incorporation of trees into crop production systems, either in the presence or absence of CA (Garrity et al 2010). Thus, CAWT systems are a type of Evergreen Agriculture. CAWT retains an emphasis on reduced tillage, but it expands on the principle of residue retention to include the integration of trees and shrubs throughout the crop fields to supply increased high-quality residues from tree biomass and other organic sources of nutrients. This broadens the concept of crop rotations to incorporate the role of fertilizer/fodder trees to more effectively enhance soil fertility and provide needed biological and income diversity in the system.

In Niger, millet production in combination with *Faidherbia* is accompanied by non-inversion tillage methods. The majority of Nigerian farmers do not use the plow or the hoe for land preparation on their typically sandy soils. Rather, they use a hand-drawn form of shallow-sweeping implement that is passed just underneath the soil surface, loosening the soil and undercutting the weeds. Thus, agriculture in Niger is now essentially a CAWT system. In Burkina Faso, *zai* cultivation in planting pits is a variation of CAWT. Its practice has been steadily expanding for decades. The pits intensify cereal and tree production in combination. Biomass production in these systems is dramatically increased, for both soil amelioration as well as livestock fodder.

Incorporating trees into crop farming may confer sustainability benefits through ecological intensification. They may increase the resilience of the farm enterprise to climate change through greater drought resilience, and they sequester more carbon. Conventional CA systems tend to sequester a maximum of 0.2–0.4 t C $ha^{-1}yr^{-1}$. CAWT 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 CA alone. This is particularly true for systems incorporating fertilizer trees such as *Faidherbia* or *Gliricidia* (Makumba et al. 2007). Consequently, there is considerable interest in the development of reward systems 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.

CAWT systems should attract much more research and extension attention than has been the case so far. Their success will depend on the use of a wider range of tree species for varied agroecologies, higher quality tree germplasm, better tree seed dissemination systems, and further improvements in tree propagation and establishment methods. The optimum tree densities for different CAWT systems have yet to be fully understood, and the best practices in exploiting the soil fertility synergies between organic and inorganic nutrient sources need to be elucidated. Targeting and scaling-up methodologies deserve particular attention. These need to be supported by work to reverse deleterious policy frameworks in some countries that may discourage farmers from cultivating trees. Also, active farmer organizations have always been instrumental in the development and spread of CA. Thus, the growing interest in Landcare for grassroots mobilization in Africa and Asia can provide a particularly suitable approach for the engagement of farming communities in the refinement and spread of CAWT.

Figure 1. National recommendations for maize conservation farming in Malawi and Zambia include cultivation of 100 *Faidherbia albida* trees/ha at 10 m x 10m spacing.

Figure 2. Smallholder conservation farming in Zambia features the intercropping of *Faidherbia albida* trees to provide additional biomass and enhance soil fertility.

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