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Conservation Agriculture:
A Weapon in the Fight against Forest Destruction

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The concept of sustainable crop production intensification (SCPI) arises from the pressing need to increase food production to feed the growing number of people in the world, especially the increasing populations of the urban sector. Initiated in the 1960s, the Green Revolution has been able to double grain yields and reduce hunger, malnutrition and poverty—but at the expense of the natural resource base on which sustainability depends. The SCPI paradigm, promoted by the Food and Agriculture Organization of the United Nations (FAO), is designed to produce more from the same area of land while at the same time fostering the conservation of natural resources, reducing the environmental footprint of agriculture and improving the flow of ecosystem services from the rural sector (FAO, 2011). SCPI endeavours to assist farmers to move from low production on degraded soils (see Figure 1) to higher, more sustainable production on healthy and improving soils (see Figure 2).

Figure 1
Soils that are ploughed or hoed form a plough pan that restricts water infiltration and root development. Crop yield is poor and crops are prone to failure under drought conditions.

Figure 2
Conservation agriculture crops grown on untilled soil with permanent organic mulch and healthy cereal and legume associations and rotations produce healthier crops with higher yields.

Conservation agriculture (CA) forms an integral part of SCPI as it provides the optimum environment for healthy crop root development, maximizes natural soil fertility and eliminates erosion. CA is based on the following three tenets, which, whilst being universally applicable, require adaptation to local conditions:

- **Minimum soil disturbance resulting from tillage.** In practice this means the direct placement of both seeds and fertilizer in the soil profile, at the required depths. Ploughing and cultivation are eliminated.
- **Maintaining organic soil cover.** Soils are kept covered with crop residues and cover crops for as long as possible throughout the year; in this way, they are protected from raindrop energy and insolation.
- **Diversifying species.** Crops, cover crops and associated crop species should be as diverse as possible so that crop rotations and associations (of cereals and legumes, for example) are maintained for both main and cover crops. Tree species, especially legumes, are associated with annual crops in agroforestry systems.

CA was pioneered in Brazil in the 1970s, the result of extreme consternation over the rates of soil lost to erosion following high-energy rainfall on bare cultivated soils. Although no-till was known in previous decades, it was the critical addition of cover crops that produced the complementary mix of CA practices in Brazil. Retaining crop residues and maintaining constant soil cover produces situations comparable to those in humid forests. Forests recycle vegetation through the reincorporation of leaf litter as a result of the action of soil biota (flora, fauna, bacteria and fungi); additional nutrients are supplied through rainfall, as well as bird and animal droppings. Forest soils are often highly leached and mainly serve to anchor the trees, which, once felled, break the cycle and need additional fertilizer input to produce commercial crops continuously.

Practising CA involves the use of farm machinery for direct sowing and the management of cover crops, weeds and harvested residues. Equipment for both large-scale commercial farms and smallholder agriculture is available on the market; meanwhile, research and development activities are underway to provide technical solutions for an ever-widening set of CA scenarios. One example is the development of low-cost direct seeders for two-wheel tractors to replace draft animals. Direct seeders generally have narrow, chisel-tine seed-slot openers or double-disc arrangements for work in heavy-residue conditions. Details of the range of direct seeders available can be found on FAO's CA website (www.fao.org/ag/ca).

While Brazil's policies continue to have a negative impact on the Amazonian rainforest, the damage has been markedly reduced as a result of CA. The Brazilian Cerrado region, in the centre of the country, has been transformed by addressing soil and crop constraints and the use of no-till and cover crop practices (*Economist*, 2010). As a result, pressure on the rainforest is greatly reduced.

In addition to a direct reduction of incursions into rainforest in the search for more agricultural land, CA can have a positive impact on pushing back the tide of desertification, especially when complemented by agroforestry (World Agroforestry Centre, 2009). The incorporation of the 'fertilizer tree' (*Faidherbia albida*) into CA systems is particularly relevant for combatting desert encroachment in Africa's Sahel region.

Cover crops that keep the soil covered—and that grow between the harvesting and the planting of main crops—need to be managed prior to direct seeding. Depending on the species of cover crop, they can be managed mechanically, with machinery such as the knife roller, or with herbicides, such as glyphosate.

Good weed control, which is fundamental to the success of CA, can be achieved by mechanical, biological and chemical means. Mechanical control can be carried out manually, with the use of machetes or surface scraping with sharp hand hoes, or knife rollers powered by draught animals or tractors. Biological weed control is always the favored option and can be achieved with the use of cover crops that can outcompete weed species. The best options are legumes, which are able to cover the soil quickly and prevent weed species from becoming established, while simultaneously fixing atmospheric nitrogen and making it available for cash crops. Legumes widely grown for this purpose are velvet bean (*Mucuna pruriens*) and forage groundnut (*Arachis pintoi*, also known as the pinto peanut), among many other, locally adapted species. Farmers also have the herbicide option available to them, but given that the purchase of chemicals can be prohibitively expensive and in view of potential environmental dangers, this option should always be the last and only used when absolutely necessary.

At crop harvest time with combine harvesters, it is important to spread crop residues as evenly as possible over the ground. This can be achieved with spreaders (either commercial or homemade) fitted to the rear of the combine.

Worldwide adoption of CA currently stands at 1.25 million km^2 (125 million ha)—or 9% of arable land—and is increasing by about 70,000 km^2 (7 million ha) per year (Jat, Sahrawat and Kassam, 2013). Adoption of CA is particularly strong in South and North America, which account for 45% and 32% of the world total, respectively. Australia and New Zealand together have 176,000 km^2 (17.6 million ha) under CA, which constitutes 14% of the world total. Europe and Africa are slow starters, with 1% adoption on each continent. Asia has 4% while Russia and Ukraine account for 3%. The main drivers of adoption are the control of soil and water erosion and drought mitigation, but reducing production costs is what is particularly attractive to individual farmers. Table 1 lists CA-related production cost savings across the board.

Table 1 Indicative figures of production cost savings with CA compared with plough-based production systems

Input	Savings with CA (%)
Fertilizer requirements	30–50
Water requirement	30
Fuel consumption	60
Pesticide applications	20

Throughout the world, the improvement of ecosystem services—especially cleaner water, reduced runoff and sedimentation, and aquifer recharge—is a major driver of promotional efforts.

CA can make a major contribution to the protection of biodiversity and wildlife species. A remarkable programme in eastern Paraguay combines CA with agroforestry and forest management in a very sustainable way (Borsy *et al*., 2013). So successful has the programme been that ecotourism can now be added to profitable livelihoods possibilities, as visitors from neighbouring Brazil are attracted by the natural riches.

The question may be asked, ‘If CA is so beneficial, then why is adoption not universal?’ The answers are many and often site-specific. One factor relates to the issue of mindset. For many generations, ‘good’ agriculture has been associated with clean seedbeds and thoroughly tilled soils. Leaving residues on the surface and relying on Nature to do the subterranean tillage through the action of soil biota is a novel and seemingly strange concept. Giller *et al*. (2009) propose several possible reasons for low adoption rates by smallholders in sub-Saharan Africa. These include: reduced yields in the first seasons after switching to CA; increased labour demand for manual weeding when herbicides are not available; a lack of mulch due to low productivity and demand for livestock feed; the need for more nitrogen fertilizer when ploughing is eliminated; a lack of markets for the legumes grown in rotation; the knowledge-intensive nature of CA; and a need for immediate returns to investment by near-subsistence farmers. Huggins and Reganold (2008) add the important item of the cost of CA machinery as a disincentive.

Many of these points are relevant in particular situations, but most can be overcome if farmers are supported by sound government policies that favour environmentally sensitive crop production, knowledgeable extension personnel who have shed the plough-based mentality, and the formation of CA farmer groups for mutual support and encouragement. The provision of CA mechanisation services through well trained and equipped specialist service providers is another attractive option, which is rapidly gaining ground.

China Case Study

In China's Jiangsu province a major environmental concern has been the annual burn of rice and wheat straw. Smoke from the two harvest seasons pollutes the atmosphere with greenhouse gases and constitutes a serious health hazard (Mousques and Friedrich, 2007). Straw discarded into waterways pollutes rivers and watercourses, blocks irrigation canals and reduces flood discharge capacity. So great was the problem that the Ministry of Agriculture heavily promoted alternative uses for straw, including its incorporation into the soil under a conventional tillage regime and its retention as mulch under CA in a rice–wheat cropping system. Crops are direct-seeded into the residues of the previous harvest or rice is broadcast into the wheat crop before harvest (Figure 3).

Figure 3
Direct planting of rice into wheat straw in Jiangsu province, China.

In the case of rice, as well as undersown wheat, the crop is combine-harvested to leave high stubble and all residues are spread evenly over the land.

Wheat yield was improved under CA, rising from around 6 to 7 tonnes per hectare. Rice yields were better maintained under CA than under traditional, plough-based practice. However, production costs are greatly reduced, mainly because the previous practices of straw management—chopping, spreading and incorporation by rotary cultivation—are no longer needed, and neither is the subsequent ploughing.

Tanzania Case Study

Many smallholder farmers in many sub-Saharan African countries, including Tanzania, find that agricultural machinery is too expensive to purchase; as a consequence, the renting of costly, but infrequently used, machines is increasingly attractive (Kienzle, Ashburner and Sims, 2013). Members of a farmer field school in Arumeru district are CA practitioners and also offer mechanized CA services to neighbouring farmers. These services comprise tracing contour lines with an animal-drawn ripper to encourage infiltration of surface runoff and to guide subsequent planting with manual jab planters (see Figure 4). They also offer a spraying service for the application of glyphosate when weed conditions are severe, prior to or immediately after planting (see Figure 5). Individual farmers manage subsequent weed control through superficial scraping with a hand hoe or hand-roguing.

Figures 4 and 5
Members of a farmer field school in Arumeru district, Tanzania, offer contract CA services, including contour ripping and planting with manual jab planters, and spraying with manually pulled sprayers.

In three years the number of clients rose from 11 to 44 and the gross margin of the enterprise (income minus variable costs) rose from US$119 to US$500. Not a bad record for a budding industry—and indicative of the growing interest in CA in the region.

CA farmers in nearby Karatu district have brought back their land to its original condition, that is, its state before it was ploughed. Reducing labour for land preparation and weed control has meant that children can now attend school more regularly and women can devote more time to vegetable gardening. Moreover, thanks to a reduction in the use of herbicides, net incomes have risen.

Abbreviations

CA	Conservation agriculture
FAO	Food and Agriculture Organization of the United Nations
SCPI	Sustainable crop production intensification

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