Soil management in semi-arid savannas

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In Sub-Saharan Africa, 40 percent of the farmland is located in semi-arid and dry sub-humid savannas. These areas are characterised by extreme rainfall variability and high intensity rainstorms. Rainfall ranges from 400 – 900 mm and is concentrated in short 3 – 4 month rainy seasons, when all the crops are grown. It is in these farming systems that most resource poor farmers make their living, and it is here water harvesting can make the largest contribution to livelihood improvements.

Surprisingly, despite the frequent occurrence of water scarcity, in most years there is more than enough water to potentially produce a good crop. The problem is that large volumes of water are lost through surface runoff, soil evaporation and deep percolation, because of a combination of land mismanagement and the intensity of tropical rainfall. On average, 70 – 85 percent of rainfall leaves the farmer's field without contributing to crop growth. In hot and dry tropical climates conventional ploughing, where the soil is turned, contributes strongly to the rapid loss of organic matter, compaction of soil and soil crust formation. Conservation Farming, also known as Conservation Agriculture or Conservation Tillage, may offer an opportunity to reverse this development. This article presents experiences from farmer-driven trials with conservation agriculture techniques in Tanzania.

Minimum or no-till farming systems have now been adopted on a large scale by farmers in Latin America, North America and parts of Asia. These farming systems rely strongly on organic mulch to help maintain infiltration and water holding capacities. This requires an environment that can support considerable biomass growth. In semi-arid savannas, the biomass to secure year-round mulching is simply not available. In these areas, therefore, Conservation Farming takes a different approach. The goal is still to minimise the disturbance of the soil but instead of applying minimum or zero tillage, farmers use rippers and sub-soilers to open parts of the soil for rainfall infiltration. Conservation Farming in this context is a water harvesting system that integrates soil improvement and water conservation.

Farmer-driven technology adaptation

In north-western Tanzania, on the semi-arid savannas of Arusha, Arumeru and Babati districts, decades of ploughing have resulted in severe land degradation and in places even the desertification of previously fertile land. Commercial farmers in the region have adopted Conservation Farming practices over the last decade, abandoning disc ploughing in favour of tractor drawn chisel ploughs, in order to harvest water and to save on diesel costs. However, no affordable conservation tillage options have been available to smallholder farmers. In 1998, the Soil Conservation and Agroforestry Pilot Programme Arusha (SCAPA) established a farmer-extension partnership to introduce, adapt and build capacity on simple low-cost Conservation Farming practices.

Initially, farmers were highly sceptical. Abandoning the plough, the very foundation of farming, was a completely alien idea that seemed very drastic. However, due to the agrarian crisis facing farmers in the area, they were very receptive to new ideas. Sessions were held with farmers to discuss water flow in agriculture and the causes of runoff, with a particular emphasis on the effects of soil compaction and organic matter depletion due to ploughing and removal of crop residue.

Farmers were then introduced to the principles of Conservation Farming. New implements were demonstrated, including an animal drawn ripper (see Figure 1) and a sub-soiler. Conservation Farming was explained and discussed with the farmers, addressing the impacts of Conservation Farming on timing of operations, weeding, fertility management, mulching, cover crops, pest management, harvest and post- harvest management.

The farmers wanted proof that this new farming practice really worked. As a result, the farmers designed a number of Conservation Farming production systems for testing. On-farm experimental plots were set up on 8 – 10 farms, testing three major production systems: (1) Conservation Farming based on animal drawn ripping, using a sub-soiler only the first year on seriously degraded soil; (2) Conservation Farming based on a manual system using hand hoes to dig small planting pits; and (3) conventional animal-drawn mouldboard ploughing (farmers' usual practice).

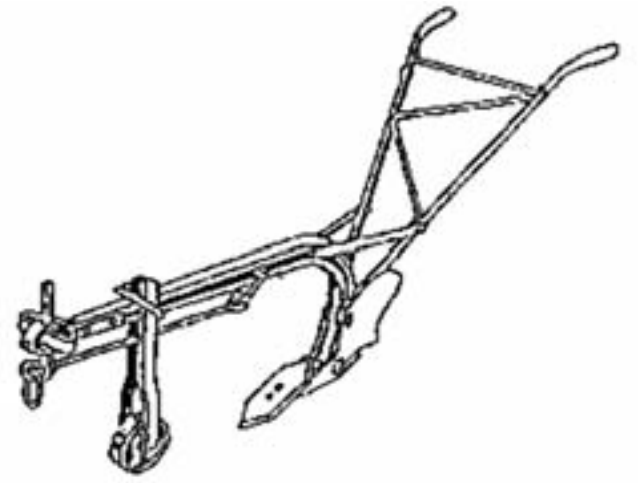

Figure 1: The animal-drawn Magoye Ripper, attached to the normal plough frame used by farmers.

Farmers were very keen on knowing the effect of improved water harvesting through the change in tillage practices, and also the effect of combining water harvesting with soil fertility management, where Conservation Farming enables better spot application of manure and fertilisers along the planting furrows created by the ripper. To do this the farmers decided to test each tillage system (conventional ploughing and Conservation Farming practices) both with and without fertiliser application.

In order to investigate the effects of a cover crop, a Conservation Farming with *Dolicos lablab* trial was added to the experiment. This is a favourite cover crop with farmers and the beans are sold on the markets in Arusha. On the Conservation Farming demonstration farms, rainfall was monitored by the women participating in the trials and labour needs were documented. Because ripping requires less draught animal power, it enables land preparation before the onset of the rains – a critical opportunity in semi-arid regions where 25 percent of a season's rain may fall during the first few rainstorms. Therefore, all the Conservation Farming systems were dry planted. Manure and locally manufactured rock phosphate was applied in the

permanently ripped planting lines. Low amounts of nitrogen fertiliser (30 kg N/ha) were applied twice: once before planting and again as a top dressing 4 – 5 weeks after the crop emerged.

Weeding is a major concern in Conservation Farming systems, in particular during the first years. Without ploughing to suppress the weeds, weed control posed a dilemma for farmers. Weed control was discussed at length, and finally it was agreed that the favoured solution was to add an additional third weeding late in the season in order to avoid weed seeds falling onto the soil. Farmers did not consider using herbicides, which are seen as too expensive.

Yields and water productivity increases

Each season yield results were discussed and analysed with the farmers. Yields were expressed in the number of 90 kg bags produced per acre, which is the yield measure best understood by the farmers in the area. Experiences were shared and adaptations made to the trials. The farmer's conventional practice (ploughing only) resulted in an average yield of 1.6 t/ha, which is actually a higher yield than the 1 t/ha generally experienced in the region by smallholder farmers. Water harvesting alone – where the plough is abandoned in favour of ripping without soil nutrient management – resulted in a 60 percent yield increase to an average of 2.5 t/ha. Interestingly though, water harvesting alone did not give the strongest yield increase, and it was only when soil fertility management was combined with water harvesting that the full effect of Conservation Farming adoption was experienced, with a 240 percent yield increase to an average of 3.9 t/ha. Farmers were very excited about the synergy effect between water and nutrient management. The importance of both factors was clearly shown by the fact that addressing soil fertility alone – ploughing with fertility management – resulted in a roughly similar yield level (2.8 t/ha) to that obtained with water harvesting alone (2.5 t/ha).

Manual pitting resulted in approximately the same average yield as the animal drawn system (3.5 t/ha). To farmers, this was the preferred system. The reason is that manual pitting is cheap, does not require oxen or new implements, and above all gives the farmer full control over the use of precious inputs such as seed, manure and fertilisers, as these can be placed carefully at perfect depth in each planting pit. Farmers agreed though, that the pitting system was very labour intensive compared to the ripping. Ripping saved on average 50 percent of the labour needs compared to conventional ploughing.

More crop per drop

It is clear to the farmers that the primary benefit of Conservation Farming as it is practiced among the pilot farmers in Tanzania, comes from the increased amount of water that reaches the root zone of the crop. Farmers claim that no surface runoff is observed from properly ripped fields, while even in terraced fields (all trials were conducted on fields with good soil conservation measures in place), runoff occurs on ploughed soil. For the farmers Conservation Farming has become the answer to the common concern of "what to do between the terraces" since they experience that despite successful adoption of soil conservation measure, there has been little impact on yields.

The rainwater harvesting effect of Conservation Farming can be quantified by estimating the amount of crop produced per drop of water. Only 2.6 kg of grain is produced per mm of rainfall in the current farming system, based on ploughing and poor soil fertility management, compared to 7.4 kg/mm of rainfall for the Conservation Farming system. This indicates that the crop's capacity to take up water from the soil has increased. It is likely that soil evaporation has also been reduced as a result of a more vigorous crop cover.

Gender sensitive

Improving crop yields and the amount of crop per drop of water is important, but one of the most essential benefits of Conservation Farming is improved timing of operations and the savings in labour achieved. Ripping is only done along permanent planting lines. The 80 cm space in-between the rows is left undisturbed. This translates into a large reduction in the amount of traction needed. Ripping also enables off-season land preparation. The present practice is that farmers wait until the soil is moist before ploughing. This means that essentially all water from the initial rainfall events are lost through evaporation, and that ploughing is done on wet soil, which increases the problem of compaction. Also, this practice hits hard on poverty stricken female-headed households as these farmers do not have their own oxen but rely on neighbours for ploughing. Ploughing is carried out after the owner of the oxen has finished ploughing, which may already be late. The crops of these woman farmers, therefore, have a very late start. Ripping changes things entirely.

Now women farmers can borrow oxen during the dry season, and prepare the land well before the onset of the rains. Dry planting of seed will give the crop an important head start, which may mean the difference between total crop failure and getting a harvest. As the number of female-headed households is increasing rapidly due to the HIV pandemic, this is a significant improvement in farming practices.

Conservation Farming enables planting well ahead of rains and high rainfall infiltration. This is illustrated here by a well-established maize crop under CF practices (to the left) and a late planted conventionally ploughed maize (to the right). Photo: Johan Rockstrom.

Sustainability

The Tanzanian cases presented above show that Conservation Farming is a very important water harvesting strategy in efforts to upgrade semi-arid rain fed farming systems. Similar experiences have been recorded in Kenya and in Zambia. Tractor driven sub-soiling among smallholder farmers in the neighbouring Babati district, south of Arusha, has also shown a progressive increase in yield levels and improved rainwater harvesting over the last decade.

The long-term challenge is to build up soil quality through wise tillage combined with the proper management of cover crops and mulching. At present farmers in the semi-arid savannas of sub-Saharan Africa have great difficulties in securing a mulch cover, due to the combined effect of high competition for crop residues, free post-harvest grazing and the use of residues for

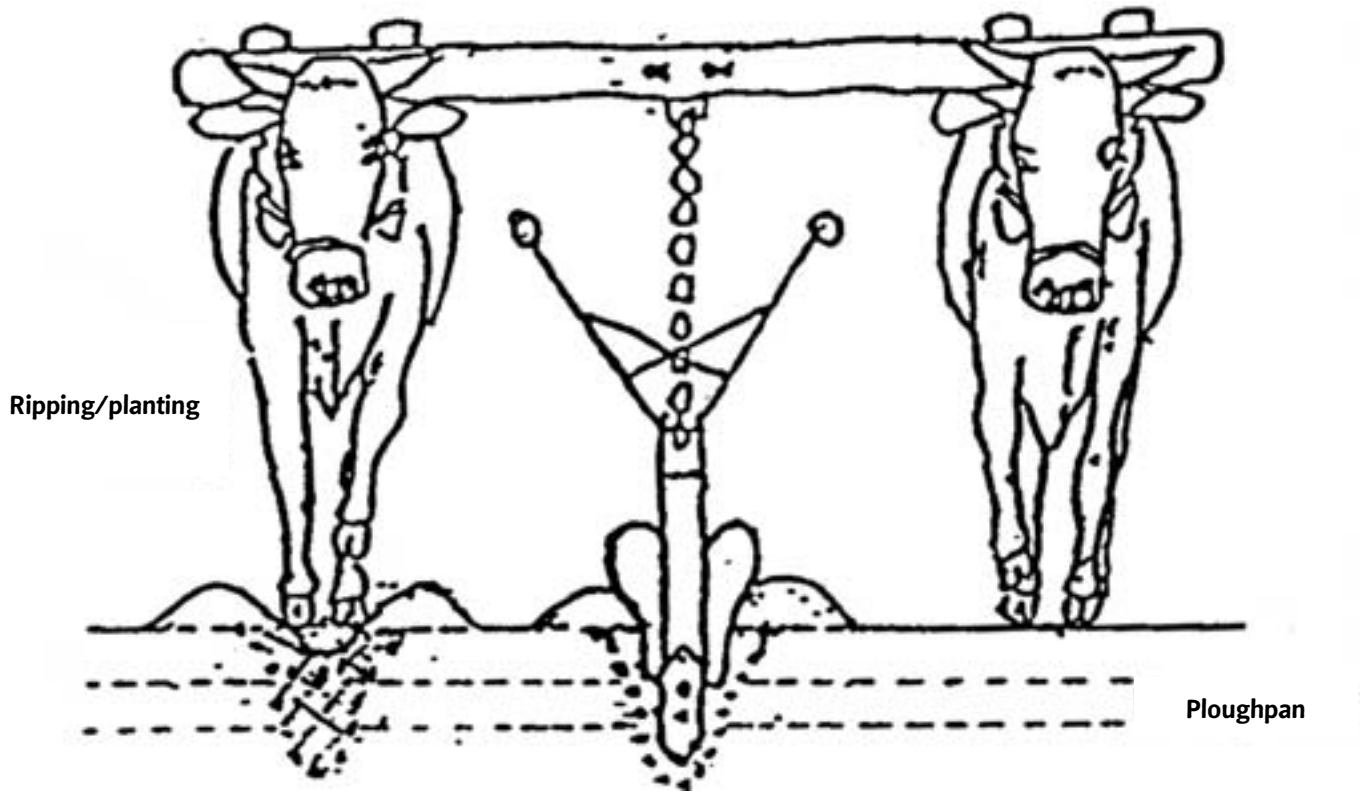

Figure 2: Oxen carrying out ripping.

fuel and construction, low inherent biomass growth, long dry seasons, up to 8 months with no rains, and high termite activity. Still, it is absolutely necessary to try to incorporate a (preferably leguminous) cover crop into the system in order to secure a progressive build-up of soil properties. The mulch is also the key to suppressing weeds and conserving moisture. Weed infestation is one of the major concerns raised by farmers. Animal drawn cultivators have been introduced for weeding and work well but are expensive to buy. So far, it seems clear that persistent weeding during the first 3 – 4 years will be necessary in order to progressively reduce weed infestation.

Conservation Farming is much more than just a change of implements. Abandoning the plough changes every component of the farming system. This is why a systems approach is required where all aspects of water, soil, and crop are addressed. Farmers and extension workers need capacity building in order to deal with the implications of a full shift from present plough-based farming to Conservation Farming. Particular emphasis should be given to training women as most of the critical management aspects of successful Conservation Farming concerns timing, weeding, soil fertility management and the post-harvest management of residue – tasks mostly performed by women. Tillage is important, but a relatively small step. However, it should be noted that a serious effort is needed to train oxen to walk in straight lines during ripping. Ripping is done with a wider yoke than ordinary ploughing in order to secure a line spacing of 75 – 80 cm, which means that oxen do not have a furrow to follow or a neighbour ox to lean on.

Rippers and sub-soilers are new implements that are not readily available on the market. Resource poor farmers need access to not only good quality implements but also affordable ones. This is a major bottleneck at present, even though there are good signs of progress.

In Kenya local *Jua-Kali* implement manufacturers have been trained to produce local Conservation Farming equipment. In Tanzania and Zambia there are several workshops producing implements for commercial purposes. In both Kenya and Uganda, the Food and Agriculture Organisation of the United Nations (FAO) has recently supported two Technical Cooperation Projects to promote manufacturing and to encourage Conservation Farming practices. These are promising developments, which may turn out to be the initial steps in an agricultural revolution for smallholder farmers in Sub-Saharan Africa, and perhaps a major water harvesting development in drought prone savannas. ■

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