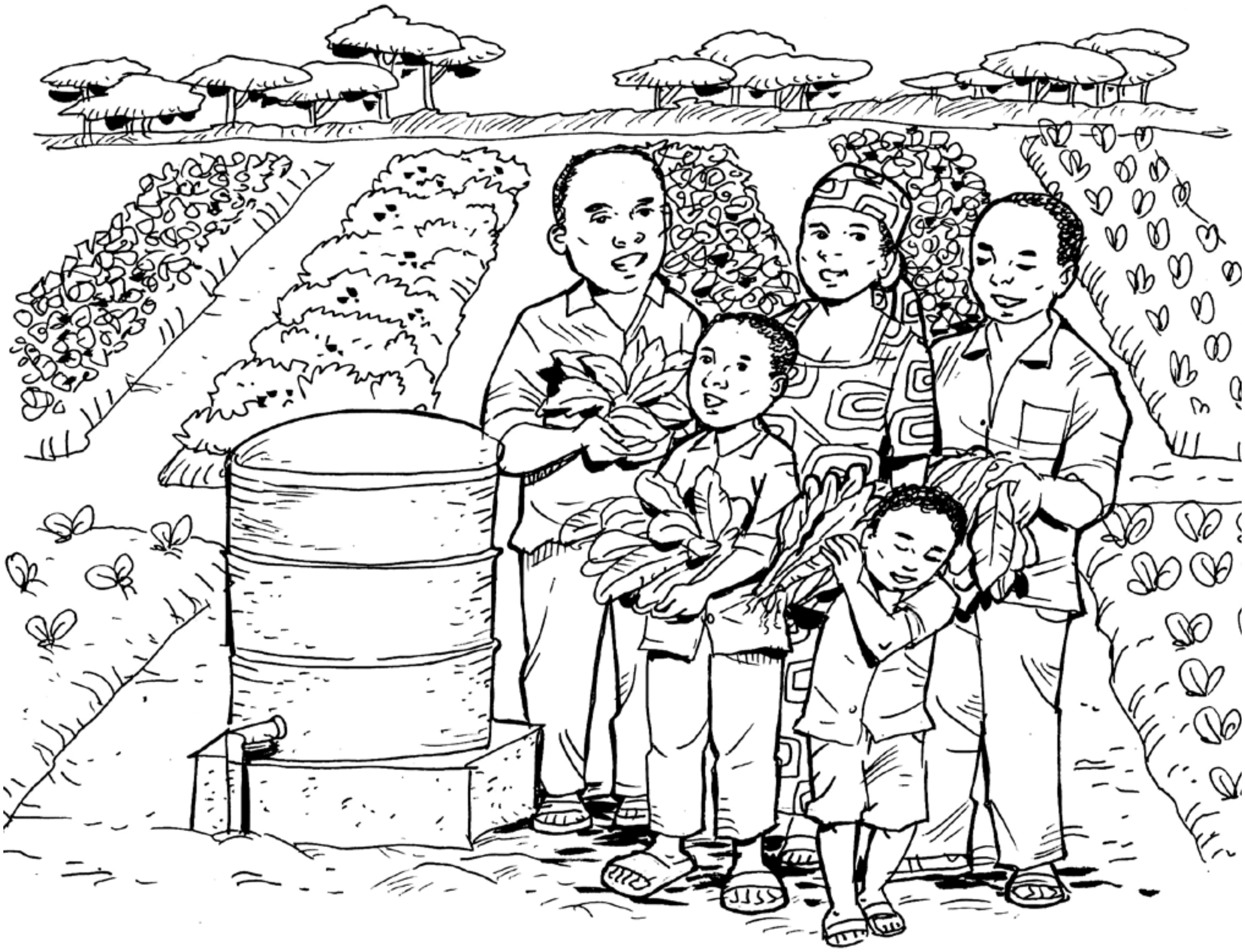
Farmer-Centered Conservation Agriculture Research



A CGIAR Challenge Program on Water and Food (CPWF) project on Integrated Water Resources Management and Rural Livelihoods developed and promoted integrated water resources management (IWRM) to increase the productive use of water flows and manage the risks from drought within the Limpopo Basin. The project, covering the three countries of South Africa, Mozambique, and Zimbabwe, aimed to show that better water management can improve rural livelihoods at both the farmer and basin level.

Research was carried out in three pilot catchments using three approaches: a) farmer field-based action research (FFBAR), which involved the valuation of conservation agriculture (CA), rainwater harvesting and field-testing of different nutrient and soil salinity management regimes; b) water resources research, which modeled precipitation, surface water and groundwater flows; and c) institutional research, which developed institutional models for water governance and strengthened institutions and policies for water productivity and risk mitigation. This article focuses on the farmer-level action research in the area of CA.

Farmer-centered action research approach

This approach addresses the need to develop water management practices employing CA and supplemental irrigation (e.g., drip irrigation) technologies for adoption by smallholder farmers. Better water management is needed to reduce the effects of water scarcity on crops. Although water is limited in semi-arid to arid areas, it is often the distribution of water, rather than a lack of seasonal totals, that affects crop growth and final yields.

Challenges in the Limpopo Basin

Overall

- **Widespread poverty reflected in low income and asset base**
- **Feminization of agriculture affected by low regard for women in society**
- **Agriculture not the main source of livelihood**
- **Absence of strong institutions**
- **Lack of financial resources**

In agriculture and land management

- **Poor soil fertility**
- **Poor access to water resources**
- **Limited infrastructure development**
- **Low crop productivity**

In water resource management

- **Low, unreliable and seasonal rainfall (mean annual rainfall, 530 mm; range, 200-1200 mm)**
- **High evaporation rate, oftentimes more than the mean annual rainfall**
- **Low values of less than 0.20 on the base flow index in most sub-zones, with almost all streams flowing only during the wet season**

Crops use only 36–64% of the seasonal rainfall on average (Barron *et al*. 2003), so there is a large proportion (50%) of non-productive water flow (Nyamadzawo *et al*. 2012). Along with integrated farm system management, which addresses soil fertility and crop management issues, this approach attempts to help increase farm income and water productivity, while also incorporating gender considerations.

This approach is relevant, especially with the general consensus on increasing year-to-year variability in precipitation, due to the effects of ENSO (El Niño/southern oscillation) and climate change, which will lead to an increase in both inter- and intraseasonal drought and flood events and high uncertainty about the onset of the rainy seasons. Yields for staple cereals are predicted to fall sharply with a 1–2^{0}C change in temperature, compounded by more erratic rainfall patterns (Stige *et al*. 2006; IPCC 2007). Current dry spells lasting for more than 14 days in the basin occur every 2 years (Magombeyi and Taigbenu 2008; Mupangwa *et al*. 2011). This is likely to have an impact on the socio-economic and cultural development of poor rural communities.

Conservation agriculture

Conservation agriculture is the application of modern agricultural technologies that collect and store rainwater to improve production, while at the same time, protecting and enhancing the land resources on which production depends. Zero tillage, along with other soil conservation practices, is the cornerstone of CA (Dumanski *et al*. 2006). Positive changes in soil quality, in terms of physical structure, infiltration rates and carbon content as a result of CA, have been reported (Nyamadzawo *et al*. 2012). CA also promotes the optimization of yields and profits: labor demands typically decrease and become more flexible, while the capacity of smallholder farmers to attain family food security increases.

Specifics of CA technologies

1. **Planting basins**. Planting basins are small pits that are usually about 15 cm wide, 30-35 cm long and 15 cm deep—about the size of a man's foot. Instead of cultivating the whole field, a hoe is used to dig basins in the soil where crops are planted. The basins are dug slightly deeper than the depth at which normal hoeing is used to break through the hardpan. Basins made by hand hoes are dug with a spacing of 90 cm between rows, with each basin being 15 cm in length, width, and depth. To be more effective, a micro-fertilizer dose of 10 kg ha/N is added (IIRR and ACT 2005). This modification of CA techniques creates precision conservation agriculture (PCA). A variation of the planting basin is the zai pit.

2. **Ripping**. With stovers still on the field, a ripper is used to open up planting lines about 15 cm deep with 90 cm between rows. A ripper is a chisel-shaped implement, pulled by animals or a tractor, to break up surface crusts and open a narrow slot or furrow in the soil. Plowing is not needed. Seeds are sown along the rip lines. Crop rows are alternately planted between seasons (Mupangwa *et al.* 2007).

3. **Tied ridges**. Tied ridges have a height of 35 cm, are spaced about 75 cm to 1 m apart and are tied at 3- or 6-m intervals. Plants should be spaced every 60 cm within rows. The tie structure or the soil heaps to block the furrow should be reconstructed at weeding to continue harvesting water for the crop.

4. **Mulching**. Mulch is a protective covering, usually of organic matter such as leaves, straw or peat that is placed around plants to prevent root freezing, reduce moisture evaporation and suppress weed growth.

5. **Supplemental irrigation**. Supplemental irrigation involves the application of small amounts of water during times when rainfall fails to provide sufficient moisture for normal plant growth. The amount and timing of supplemental irrigation are adjusted to meet minimum water requirements during the critical stages of crop growth and to bridge dry spells and ensure optimal, instead of maximum, yield.

Lessons learned

Planting basins

- This technology gave the lowest seasonal run-off losses, regardless of soil type and field slope. Despite the below average rainfall of 268-353 mm during the period of study (from 2006 to 2008), planting basins consistently gave the highest soil water content, particularly during the first half of the cropping period. However, this advantage did not necessarily result in higher maize yields in farmers' fields under unevenly distributed rainfall.

- Production risk in the semi-arid conditions of southern Zimbabwe was reduced through the precise application of small doses of N-based fertilizer (10 kg/ha). Yield improvements in planting basins with this level of microdosing can be up to 78, 140 and 250% for low, normal and high rainfall regimes, respectively.

- However, during high-rainfall seasons and depending on soil type and number of days since the last rainfall event (antecedent conditions), waterlogging may occur and adversely affect crop yield under this technology. The effectiveness of this technology depends on rainfall patterns, soil type, crops and other agricultural practices such as soil fertility enhancement, planting dates and density, and mulching. There is a need to identify factors (e.g., rainfall regime, soil type and fertility level) that lead to planting basins being more beneficial and to develop associated crop management guidelines.

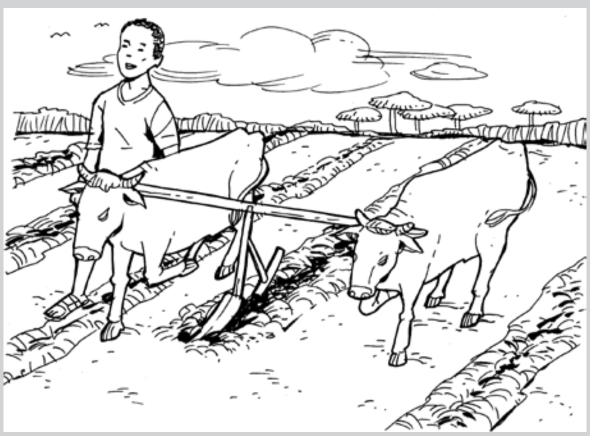
- On average, returns from labor have been higher from planting basins than from conventional practices. Although making the basins requires time and effort, once prepared, the same planting position can be used repeatedly. With each successive season, preparing the basins and weeding become easier.

Double conventional plowing

Though not a CA practice, this tillage technology, combined with the use of N fertilizer, gave better yields than did the other tillage systems, regardless of rainfall pattern during the growing season.

Thus, a majority of the farmers ranked double plowing as the most appropriate tillage system under their conditions, since farmers in the Limpopo Basin consider labor and crop yields to be major factors in the selection of technologies for adoption.

In fact, smallholder farmers who owned draft animals were prepared to continue using double plowing; however, others without similar means were not.



Ripping

- Data from various trials since the 1990s showed that mulch ripping and other minimum tillage practices that reduce draft power requirements consistently increased soil water content and crop yield by up to 50%, compared with traditional plowing.

- Mupangwa *et al*. (2007) reported a decrease of up to 50% in per-hectare yield under clean ripping compared with conventional plowing in the first year. But the yield increased in subsequent years as soil fertility improved.

- Ripping helps reduce up to 50% of sedimentation losses. However, ripping alone did not consistently give higher yields because of weed pressure, which requires timely weeding before weed seeds are spread.

Tied ridges

- Tied ridges increased yields by up to more than 50%, reduced runoff under different soil and rainfall regimes and retained more soil moisture than did conventional plowing.

Mulching

- Maize production was significantly improved by mulching (between 3-6 t/ha) in growing seasons with below average rainfall. Mulch must provide at least 30% of the soil cover. Mulch buffers the soil against extreme temperatures, reduces evaporation and surface runoff (which lead to soil loss), protects the soil from trampling, suppresses weeds through shading and improves soil fertility and biota in subsequent years as the mulch decays (Mupangwa *et al*. 2007, 2012).

Low-head drip irrigation

- Low-cost drip systems can save more than 50% of water use than surface irrigation systems, provided that farmers receive adequate training to operate and maintain the system and there is backup for servicing the drip system.

Conclusion

Access to green water in rainfed farming can be improved through a package of CA techniques. Planting basins help to concentrate rainfall in the field at the root zone and decrease runoff and soil loss. CA methods provide positive results when combined with fertility improvements, such as microdosing with N from organic and/or inorganic sources or with mulching. Supplementary irrigation, such as drip irrigation, along with appropriate water and nutrient management, can further help mitigate the effects of frequent dry spells. While yield increases under CA can be substantial, they depend on local conditions and weather, with considerable year-to-year variation in yield benefits. CA offers the promise of a locally adapted, low-external-input agricultural strategy that can be adopted by resource-constrained farming communities, as well as by those with access to different levels of mechanization and external inputs.

Microdosing in drought-prone areas

Next to drought, poor soil fertility is the single biggest cause of hunger in Africa. The International Crops Research Institute for the Semi-arid Tropics (ICRISAT) in Zimbabwe has been working for the past 10 years to encourage small-scale farmers to increase inorganic fertilizer use as the first step towards Africa's own green revolution. The program of work is founded on promoting small quantities of inorganic N fertilizer (microdosing) in drought-prone cropping regions. Results from initial on-farm trials showed that smallholder farmers could increase yield by 30–100% through application of micro-doses—as little as 10 kg/ha N. The question remained whether these results could be replicated across much larger numbers of farmers. Widespread testing of the microdosing (17 kg/ha N) concept was initiated in 2003/2004, across multiple locations in southern Zimbabwe through relief and recovery programs. Each year, more than 160,000 resource-poor households received at least 25 kg of N fertilizer, and a simple flyer explaining how to apply the fertilizer to a cereal crop. This distribution was accompanied by a series of simple paired-plot demonstrations—with or without fertiliser—hosted by farmers selected by the community, where training was carried out and detailed labor and crop records were kept. Over a 3-year period, more than 2,000 paired-plot trials were established and good-quality data collected from more than 1,200. In addition, experimentation to derive N response curves for maize (_Zea mays_ L.**), sorghum (**_Sorghum bicolor_ **(L.) Moench) and pearl millet (**_Pennisetum glaucum_ **(L.) R. Br.) in these environments under farmer management was conducted. The results consistently showed that microdosing (17 kg/ha N) with N fertilizer can increase grain yield by 30–50% across a broad spectrum of soil, farmer management and seasonal climatic conditions. For a household to make a profit, depending on the season, farmers need to obtain between 4 and 7 kg of grain for every kilogram of N applied. In fact, farmers commonly obtained 15–45 kg of grain per kilogram of N input. This result provides strong evidence that lack of N, rather than lack of rainfall, is the primary constraint to increasing cereal crop yields, and that microdosing has the potential for broad-scale impact on improving food security in these drought-prone regions.**

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Key Reference

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