Integrated Farming Enhances Rainwater and Soil Productivity

Food security in the entire Volta Basin is under threat. The erratic rainfall pattern and frequent periods of drought cause significant crop damage. Increasing population and livestock pressure and the growing competition over the use of water for generating hydroelectricity have aggravated water stress in the basin. Declining water quantity and quality has become a critical limiting factor for agricultural productivity. Further, inappropriate management practices (e.g., crop residue/bush burning and intensive plowing) degrade the soil and contribute to the deterioration of soil fertility, which consequently results in crop failure.

Water use efficiency holds the key to improving agricultural (Kijne *et al.* 2001) and livestock productivity in the Volta Basin. In the same way, crop yield is a function of soil fertility. Hence, improved agricultural productivity rests on how water and soil are developed and managed.

A research project of the CGIAR Challenge Program on Water and Food (CPWF), led by the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), was designed to address these major constraints encountered by small-scale resource-poor farmers, who rely on rainfed agriculture for their livelihoods.

Broad stretches of the rain-starved Volta Basin could reap the benefits of an innovative land-use system, which is already helping farmers in semi-desert areas of Niger to sustain healthy soil and healthy crops, and even to diversify into higher value produce.

Named the Sahelian Eco-Farm (SEF), the system was developed by scientists and farmers at the Sahelian Center of ICRISAT in Niger. It has been shown to significantly improve the efficiency with which rainwater and soil nutrients are used by crops and retained in the soil, even in periods of extreme water scarcity.

Lessons from the past:

- **Research has shown that only 10% of rainwater is used by crops and the majority of it is lost to evaporation. International and national agricultural research institutions have developed high-yielding cereal and legume varieties that respond to different rainfall regimes.**

- **ICRISAT and its partners have developed and promoted improved varieties of sorghum, millet and groundnut, and soil management technologies adapted to the semi-arid conditions.**

- **The Center for Development Research (ZEF) and the International Water Management Institute (IWMI) are currently developing decision support tools to assist in the management of water in the Volta.**

Development and adaptation

The SEF has now been selected for further development and adaptation for this project. It is using the knowledge gained from these studies to develop 'integrated technology options—solutions that use a systems perspective for improving water and nutrient use efficiencies, while increasing crop productivity. It will also adapt the solutions as necessary for use in different locations.

The SEF was a clear choice for further development in this context. It has as its basis an integrated approach to land management in which an entire farming system is designed with a view to making the best use of the properties of local rainfall, soil and geography, together with those of selected crops and other plants. Its design was successful because it also takes into account—and optimizes—the interactions between these elements.

Package of technologies

The project evaluated and adapted, in partnership with farmers and other stakeholders, technology options that could potentially improve water and nutrient use efficiencies and increase crop productivity. From this consultation, a list of promising technologies was drawn. Four strategic research project sites were chosen along the Volta Basin, namely, Ziga and Saala in Burkina Faso (upstream) and Tamale and Navrongo in Ghana (downstream). Technologies that had shown good performance were chosen: Sahelian Eco-Farms (SEF), fertilizer microdosing, tied ridging, the zai system and stone lines. The yield of crops under these technologies has increased, in some cases by two fold, compared with the usual farmers' practices. These technologies have also brought about improvement in soil, water, nutrient and crop management.

Since the project was started in 2004, CPWF work on the SEF concept has focused on gaining greater understanding of how it works and adapting it for use elsewhere. So far, a total of 35 new SEF trials have been established in countries outside of Niger: 33 in Northern Ghana, divided between the districts of Navrongo and Tamale, and two more in Burkina Faso.

As yet, only preliminary results are available from the pilots, but for the adaptations under trial, farmers are exploring the use of common cereal crops such as millet, sorghum and maize as the base crop, to establish their suitability in various agro-ecological zones.

The Sahelian Eco-Farm concept

A typical SEF comprises a blend of traditional and introduced components selected to work in harmony. An important multi-purpose component is *Acacia colei*, an Australian species of a leguminous tree whose roots fix atmospheric nitrogen and whose leaves remain green during the dry period. Hedges of this species are planted to enrich the soil and improve its fertility and also to act as wind-breakers. Branches pruned from the hedges serve as firewood and mulch; its seeds as poultry feed.

Earth bunds are built in a half-moon shape to create micro-catchments, collecting run off water and protecting the soil against erosion. High-value trees such as the domesticated Indian variety of *Ziziphus mauritania* (or 'Pomme du Sahel') are planted inside these 'demi-lunes'. This variety produces fruit ten times bigger than that of the indigenous tree. Its leaves can be used for forage and mulch and the pruned branches for firewood.

A perennial grass, such as *Andropogon gayanus*, is planted on the earth bunds to strengthen them. Annual crops, like millet and cowpea, are each planted in half or a third of the field in rotation each year. The results are impressive and include increased water use efficiency and soil fertility, drought mitigation, reduced soil erosion, more and better animal feed during the dry season, higher incomes and more diverse sources of income and risk mitigation.

While the SEF is in many ways a self-contained concept, it has great potential for integration with other promising technologies such as conservation tillage, conservation agriculture, micro-dose fertilization (involving the application of small quantities of fertilizers at the plant base) and the Zai method of planting in water-retaining pockets.

Water harvesting (tied ridging), with or without NPK, improved maize grain yield by 20%. Nitrogen-use efficiency (NUE) increased by 45% at 54 kg/kg of nitrogen compared to the recommended rate. In Ghana cowpea and cereal rotation associated with soil and water conservation and trees increased sorghum yield by 42% compared to continuous cropping under the same conditions.

Zai and stone lines with nutrients

Zai and stone lines (water conservation structures) and nutrient source combinations were tested at Ziga and Saala in Burkina Faso. Test crops were sorghum and maize with cowpea being common in both sites.

- **In Ziga, the best yields were obtained with the recommended rate of mineral fertilizer (T2) and intensive fertilization with the addition of Burkina Phosphate (BP) (T4). However, the response of phosphorus appears slightly higher when it is associated with manure (T4).**

- **In Saala, all the technologies had a positive effect on maize yield. The grain yields of maize varied from 300 to 950 kg/ha for the control, compared with 800 to 1500 kg/ha for the improved technologies. T4 gave the best yield. The marginal product obtained from the use of intensive fertilization (T4) was three times greater than that of the simplest technology.**

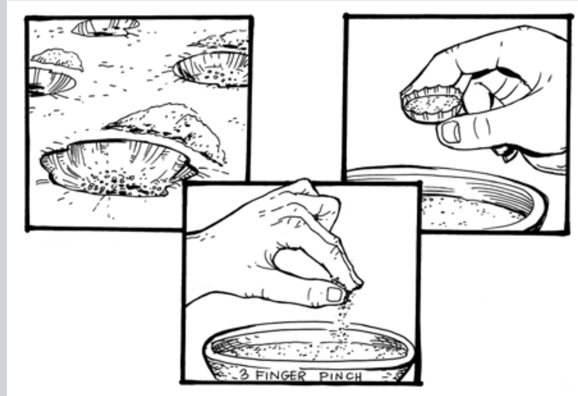
- **All of the technologies, which are a combination of organic fertilizer, mineral fertilizer and BP, produced on average 950 kg/ha of sorghum and 1500 kg/ha of maize when applied with zai and stone lines. Without such structures, the recorded yields were much lower, particularly for maize (500 kg/ha, on average). Overall, the improved technologies performed better than farmers' practices in all years.**

Common to all technologies = stone lines + Zai combined with the following:

Ziga site
T1 = 5 t ha/manure + 50 kg ha/urea
T2 = 100 kg/ha NPK (14:23:14) + 50 kg urea/ha
T3 = 5 t ha/manure + 200 kg/ha BP (26.3% P_2O_5) per + 50 kg ha/urea;
T4 = 5 t ha/manure + 100 kg/ha NPK (14:23:14) + 200 kg Burkina Phosphate/ha + 50 kg urea/ha

Saala site
T1 = 6 t ha/manure + 100 kg ha/urea
T2 = 150 kg/ha NPK (14:23:14) + 100 kg ha/urea
T3 = 6 t ha/manure + 200 kg Burkina Phosphate (BP) (26.3% P2O5) + 50 kg urea/ha
T4 = 6 t ha/manure + 150 kg/ha NPK (14:23:14) + 200 kg ha/BP + 50 kg ha/urea

Fertilizer microdosing: a complementary technology



The micro dose technique was introduced to farmers as an effective and efficient, yet less capital-intensive way of fertilizer application. This field experiment was carried out in Ghana, on-farm in Tamale and Navrongo and on-station in Navrongo.

On-station, the lowest fertilizer rate microdose (25% of recommended rate) almost doubled the yield of the control. Net returns were negative for the no fertilizer treatment and the highest nitrogen use efficiency (NUE) was obtained with the microdose treatment. The sorghum variety used responded poorly to fertilization. However, the microdose treatment out yielded the control.

On-farm, maize yield was nearly four times more than the control treatment. But, with sorghum, microdose fertilizer did not have any advantage over the control for the variety used. NUE was highest for the microdosing treatment (54 kg maize/kg N) compared with the earlier recommended rate (37 kg maize/kg N).

Field trial results: microdosing

Tamale (on-farm)	Navrongo (on-farm)	Navrongo (on-station)
(i) Improved maize variety + 4 g NPK (15-15-15)/hill (6 kg ha/N, 3 kg ha/P, 5 kg ha/K) (ii) Improved maize variety + earlier recommended fertilizer rate of 60 kg ha/N (iii) Local maize variety + earlier recommended fertilizer rate of 60 kg ha/N (iv) Local maize variety + no fertilizer The plot size was 20 x 25 m, with 80 x 40 cm plant spacing and two plants per hill.	(i) Local millet variety + 4 g NPK (15-15-15)/hill (6 kg ha/N, 3 kg ha/P, 5 kg ha/K) (ii) Local millet variety + earlier recommended fertilizer rate of 60 kg ha/N (iii) Local millet variety + no fertilizer The plot size was 20 x 25 m, with 80 x 40 cm plant spacing.	(i) Improved sorghum variety + 4 g NPK (15-15-15)/hill (ii) Improved sorghum variety + earlier recommended fertilizer rate of 60 kg ha/N (iii) Improved sorghum variety + no fertilizer The plot size was 10 x 10 m, with 80 x 40 cm plant spacing. There were three replications.

The AGRA Microdosing Project

Building on the experience of CPWF, the new Alliance for a Green Revolution in Africa (AGRA) microdosing project was aimed at a wider scaling up of the fertilizer microdosing and warrantage system in Burkina Faso, Niger and Mali. This USD 11.5 million project is targeting, on average, a 40% increase in grain yield and will reach several hundreds of households in 3 years.

However, some important research questions emerge. Due to the small amount of fertilizer applied and the increased biomass production resulting from this, a concern was raised about the sustainability of the technology with regard to soil fertility and sustained crop yield. Further work is thus needed to study crop productivity, soil water use, water and nutrient interaction and water and nutrient flows. A watershed approach could be used in such studies.

Warrantage system

One important positive outcome of this project was the warehousing of farm products, called a warrantage or inventory credit system. This system, which is implemented during a period of four to nine months, allowed farmers to benefit from microcredits.

Upon recovery of their products, producers appreciated the warrantage system as an economically profitable operation helping them to make substantial gains and to have remaining products after settlement of their debt. The actual economic grain was 42% at Ziga and 21% at Saala in Burkina Faso compared to the product's price at harvest.

This system helped producers through pledged savings that could be used in the absence of the CPWF project, as personal contributions for future warrantage operations. In addition, they allocated part of the product for family consumption (95% for sorghum at both sites, 100% for millet at Ziga and 78% at Saala and 25% for cowpea at Ziga and 50% of rice at Saala).

Conclusion

Though a lot has been achieved by this project, there is still work to be done in some areas. For example, the issue of water and nutrient interaction needs further study in the context of a changing climate, where water scarcity is becoming more and more apparent. In the analysis, it would be helpful to adopt a watershed management approach in addressing the problems with trying to improve the livelihoods of smallholder farmers in the basin.

The project exposed participating communities to different technology options and allowed them to learn about the importance of proper use of these technologies. Working with farmers in this harsh environment, this project showed that yields of crops can be increased through adoption of improved varieties, in-field rainfall capture and nutrient management, and availing of the productivity benefits by including a legume in the rotation.

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Key Reference

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