CPWF Project Report

Enhancing rainwater and nutrient use efficiency for improved crop productivity, farm income and rural livelihood in the Volta Basin

Project Number 5

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Program Preface:

The Challenge Program on Water and Food (CPWF) contributes to efforts of the international community to ensure global diversions of water to agriculture are maintained at the level of the year 2000. It is a multi-institutional research initiative that aims to increase water productivity for agriculture—that is, to change the way water is managed and used to meet international food security and poverty eradication goals—in order to leave more water for other users and the environment.

The CPWF conducts action-oriented research in nine river basins in Africa, Asia and Latin America, focusing on crop water productivity, fisheries and aquatic ecosystems, community arrangements for sharing water, integrated river basin management, and institutions and policies for successful implementation of developments in the water-food-environment nexus.

Project Preface:

The CPWF project PN5: Enhancing rainwater and nutrient use efficiency for improved crop productivity, farm income and rural livelihood in the Volta Basin.

The CGIAR Challenge Program on Water and Food (CPWF) is an international, multi-institutional research initiative with a strong emphasis on north-south and south-south partnerships. The initiative brings together research scientists, development specialists, and river basin communities in Africa, Asia and Latin America to create and disseminate international public goods (IPGs) that improve the productivity of water in river basins in ways that are pro-poor, gender equitable and environmentally sustainable.

CPWF practices research for development. Ongoing research work exemplifies this emphasis, and illustrates the Challenge Program's mix of site-specificity, scaling up to the basin level, and the production of international public goods. Thus, CPWF funds and conducts research that is a mixture of basic, applied and adaptive research linked to dissemination of results.

The Challenge Program is working towards achieving:

- **Food security** for all at household level
- **Poverty alleviation** through increased sustainable livelihoods in rural and peri-urban areas
- **Improved health** through better nutrition, lower agriculture–related pollution and reduced water-related diseases
- **Environmental security** through improved water quality as well as maintenance of water-related ecosystems and biodiversity

The project entitled "Enhancing rainwater and nutrient use efficiency for improved crop productivity, farm income and rural livelihoods in the Volta basin" is funded by the Challenge Program on Water and Food (CPWF) and led by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). It is designed to address the major constraints that are encountered by small-scale resource-poor farmers in the Volta Basin, who rely on rain fed agriculture for their livelihoods. The overall research hypothesis is that using a systems approach that integrates water use efficiency, soil and nutrient management, and improved germplasm together with market opportunity identification and building rural communities capacity will result in significant benefits to the rural poor and the environment.

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RESEARCH HIGHLIGHTS

In the entire Volta Basin food security is under threat due to the low water availability, increasing soil degradation and poor soil fertility. The majority of the population in the basin is small-scale farmers who rely on rain-fed agriculture for their livelihoods. However, the average rainfall of 1000 mm per year, which seems to be enough for crop production in the region, is very variable and this makes rain-fed agriculture a risky enterprise. The distribution of rain over the growing season has also been noted to be another bottleneck in agricultural production. Especially the onset of the rainy season is very unreliable and the frequent periods of drought within the season (dry spells) cause significant crop damage

The project is designed to address the major constraints that are encountered by small-scale resource-poor farmers in the Volta Basin, who rely on rain fed agriculture for their livelihoods

The project major highlights include:

- Based on the research priorities of the Volta Basin and the expected outputs of the relevant themes, the PN5 partners have been able to identify research and development activities that are being implemented in a participatory manner to address the major constraints to agricultural and water productivity in the Volta Basin.
- A thorough biophysical and socio-economic characterization of the project study sites in Burkina Faso and Ghana
- Improved soil, water, nutrient and crop management including the Sahelian/Savannah Eco-Farm, fertilizer microdosing, tied ridging, zai system and stone lines have showed their good performance in both countries. Yields of crops under these technologies have increased, in some cases two folds, compared to the farmers practices.
- An innovative inventory credit system also referred to as "warrantage" is making his way in the region, particularly in Burkina Faso where farmers' organizations are benefiting from the system in terms of increases in incomes.
- Scientists in the project team have been trained in the use of the Decision Support System for Agrotechnology Transfer (DSSAT). DSSAT was calibrated to adapt to the environment in the project sites and is being used to evaluate technologies and simulate varying scenarios of nutrient and water conditions.
- The CPWF has enabled us to build a diverse and strong partnership between International Agricultural Research Institutes (IARCs), National Agricultural Research and Extension Systems (NARES), Advanced Research Institutes (ARIs), NGOs and rural communities.
- The project enabled the two partner national institutions SARI and INERA to work together on a common subject, even though at community level some differences might exist. This will in the future enable them to put effort together to submit proposals to sustain the synergy created
- Extension services in both countries (MoFA – the ministry of food and Agriculture in Ghana) and the Ministry of the of Agriculture in Burkina Faso were the major links to the communities in this project and where fully involved in the preparation and implementation of the activities
- Financial institutions involved in the rural sector were trained and sensitized about the warrantage system. In fact even though the farmers have their product, financial institutions are reluctant to accept it as grant. It was necessary to make them understand that if necessary measures are taken this product was the most reliable asset. This we succeeded to do in this project as the institutions accepted to make of the warrantage one of their product.

EXECUTIVE SUMMARY

This project was designed to address the major constraints that are encountered by small-scale resource-poor farmers in the Volta Basin, who rely on rain fed agriculture for their livelihoods. Our overall research hypothesis is that using a systems approach that integrates water use efficiency, soil and nutrient management, and improved germplasm together, as well as market opportunity identification and building rural communities capacity, will result in significant benefits to the rural poor and the environment.

The majority of the populations in the Volta basin are small-scale farmers who rely on rain-fed agriculture for their livelihoods. However, although the average rainfall is 1000 mm per year, it is very variable and this makes rain-fed agriculture a risky enterprise. The onset of the rainy season in particular is very unreliable and the frequent periods of drought (10-20 days) within the season cause significant crop yield reduction. In addition, there has been a decrease in rainfall in most of the region since the 1960's when compared to the long-term average. In the entire Volta Basin, therefore, food security is under threat due to variable rainfall, increasing soil degradation and the dwindling farm sizes resulting from demographic growth. Soil degradation has been caused by inappropriate management practices like plowing and intensive hoeing causing surface crusting, soil compaction, decrease in soil organic matter and hard-pan formation.

The methodology of the project draws on and applies principles and approaches of Integrated Natural Resources Management (INRM). The INRM paradigm provides a significant opportunity to conduct research in a different and innovative way, integrating systems research perspectives including germplasm, crop and nutrient and water management together with a focus on marketing, policy and participatory approaches that have the potential to empower farmers.

In order to curtail the problem of low crop yield or crop failure being one of the major constraints to agricultural production in the Volta basin, the project evaluated and adapted, in partnership with farmers, integrated technology options that improve water and nutrient use efficiencies and increase crop productivity,. This started with a biohysical and socio-economic characterization of the four project sites, namely Ziga and Saala in Burkina Faso and Tamale and Navrongo in Ghana. This baseline information provided a reference point against which to measure progress due to the impact of the project. A list of promising technology was drawn in consultation with farmers and other stakeholders and selected technologies such as the tied ridging, zai system and stone lines were evaluated in partnership with farmers. Additional best bet technologies such as fertilizer microdosing and the Sahelian or Savannah Eco-Farm (SEF) were also tested on-station and on-farm. The microdose application of mineral fertilizer increased maize yield 400%, from 0.26 with farmer's practice to 1 t/ha. Sorghum yield increased 100%and millet grain yield 200%. Water use efficiency was improved by 30%. Water harvesting (tied ridging), with or without NPK, improved maize grain yield by 20%. Nitrogen use efficiency 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. In Burkina cowpea grain yield increased by 67% in the SEF compared to the traditional system. Here zai combined with stone lines and various nutrient sources produced higher sorghum, maize and cowpea yield compared to the plots without such structures. Tech4, which is a combination of organic fertilizer, mineral fertilizer and Burkina phosphate 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 the farmers' practices in all years.

The Decision Support System for Agricultural Technology Transfer (DSSAT) was used to analyze the effect of mineral fertilizer in sorghum cultivation in two management systems (Homestead and Bush-farm).The results show that using mineral fertilizer to grow sorghum is feasible in both management systems with higher returns from the homestead. Also, the risk of lower sorghum yield due to variability in rainfall is higher in farms with lower soil organic matter content. Smallholder farmers would be benefit from investing in organic manure to reduce risk associated with variability in rain fall distribution and amounts.
Water use efficiency increased with increase of the rate of mineral N and was higher in Homestead compared to bushfarm (0.8 kg/mm for control-Bushfarm vs 2.5 kg/mm for control-Homestead and 4.8 kg/mm for 120 kg/ha N on bushfarm vs 6.8 kg/mm for the same rate on Homestead). So to ensure future food security in these areas, supplementing rainfall with irrigation is important. It is therefore necessary to explore the means of supplementing rainfall to eliminate crop lost due to

variability in rainfall. This has been clearly demonstrated by the model DSSAT used in the study. The model thus, provides a sound scientific anticipation into yield variations and can serve as an input to policy and decision making.
Several project partners were trained in the use of DSSAT and it is hoped they will use this tool to make their research work more efficient. The training courses enabled project partners from the NAREs opportunities to acquire skills in the use of the Decision Support Tools for evaluating the potential of promising technologies and up-scaling these technologies in the Volta Basin. Scientists from the National Agricultural Research and Extension Systems in Burkina Faso and Ghana benefited from the wide range of information collected during the characterization studies and compilation of promising technologies as this helps them focus their work in their mandate areas in the two countries.

Improving market opportunities for small holder farmers and identifying market institutional innovations that provide incentives for the adoption of improved water, nutrient and crop management technologies is of paramount importance in the context of vicious circle in which farmers are locked. Low selling market price is the major constraint for farmers to invest in soil fertility improvement. To address this problem, the project has tested with the farmers the warehousing of farm product called Warrantage or inventory credit system. This system, which is implemented during a period of four to nine months, allowed farmers to benefit from micro-credits. Upon recovery of their products, producers appreciated the Warrantage system that they perceived as an economically profitable operation helping them to make substantial gains and to have remaining products after settlement of their debt. Actual gain amount 42% at Ziga and 21% at Saala in Burkina Faso compared to the product's price at harvest. They unanimously recognize the benefit the operation helped them to achieve through the 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). Income generating activities during the course of the warehousing is one the major guaranties to the reimbursement of the credit by the farmers, as this allow them to make profit from the credit through sheep fattening for instance or off-season activities such as vegetable growing or small trading activities. At Ziga this was the pre-requisite to get the credit as the Warrantage management committee and the executives of Credit Unions assured that every farmer has his own plan. This was one of the reasons of success at this site. Among the positive outcome of the Warrantage is the creation of input shops. To be able to do this, the system needs to be implemented in a way that assure saving for the group involved in the Warrantage. Another aspect was the difficulty of farmers' linkage with the financial institutions. To address these issues an exchange and training workshop was conducted in Burkina as well as in Ghana that involved 16 participants from four financial institutions in Burkina and 30 participants from eight financial institutions in Ghana. This exchange workshop even though organized at the end of the project laid the basis of those institutions to make of the Warrantage one of their products.

Earlier research and experience in the development process has shown that to be successful in a community, development as well as research and development initiatives must consider the needs of the people. Therefore building the capacities of farmers and rural communities to make effective demands to research and development organizations, and influence policies that promote the adoption of sustainable water and nutrient use technologies was important in this project. A survey was conducted that revealed that women contribute significantly to agricultural production in the target communities in Ghana. Therefore to be truly effective, the development of crop, water and soil management technologies and strategies for their adoption must involve them directly. The analysis has shown that, aside from dry season vegetable production, women in the target communities engage in a wide range of off-farm activities such as shea nut, rice and groundnut processing. Every effort must be made to assess the income generating potential of some of these activities, so that appropriate technologies or interventions can be made to assist them to maximize their earnings.
In both Burkina Faso and Ghana, the project has been able to stimulate and strengthen the farmers based associations and community based organizations to collaborate with researchers and other stakeholders. The research-extension-farmer linkage was strengthened and this is a good foundation for enhancing the adoption of new and promising technologies. Farmers understand better the importance of expressing their needs on their own: identification of needs of technology; identification of partners and project proposals for their villages within the decentralization and rural restructuring scheme.

The promotion and scaling up and out of 'best bet' crop, water, and nutrient management strategies in the Volta Basin through more efficient information, methodology and technology dissemination mechanisms is the way to reach more people in the dissemination of the identified technologies. Strategic alliances were formed between the project team and key stakeholders including NGOs, Government staff, extension units, farmers' organizations, private sectors and other research organizations. This partnership, coupled with frequent exchange visits and meetings reinforces the collaborative work and sets the stage for a wider dissemination and scaling up and out the most promising technologies in the Volta Basin. The study on the perception of the farmers on the project showed three major strengths: i) the technologies (varieties and fertilizers) are adapted to the agro-climatic conditions, which ensures good yields; ii) the technical/field protocols do not constitute anymore a constraint to the adoption of technologies; iii) at the community level, sharing of seeds constitutes a major driver for the increase in agricultural production and dissemination at larger scale

The new AGRA microdosing project, which aims at a wider scaling up of the fertilizer microdosing and Warrantage system in Burkina Faso, Niger and Mali, built on the experience acquired during the course of the CPWF PN5 project. This project of US$11.5 millions is targeting on average 40% grain yield increase and will reach several hundreds of households in three years. This success of the technology does however mask some important research questions. Due to the small amount of fertilizer applied and the increase biomass production resulting from this, concern was raised of the sustainability of the technology with regards to soil fertility and sustained crop yield. In relation to this further work is needed that would study crop productivity, soil water use, water × nutrient interaction, water and nutrient flows. A watershed approach could be used in the studies. Due to work load at planting there is a need to study options that would make the planting process much easier. Seed coating could be among the option to work on.

The project exposed the participating communities to different technology options, which allowed them to learn of the importance of proper use of technologies. Working with farmers in this harsh environment, this project showed that yields of crops can be increased several-fold through adoption of improved varieties, in-field rainfall capture and nutrient management, and the productivity benefits of including a legume in the rotation, evidences which they have seen themselves. Farmers also applied the warehousing system which due to the results obtained in some communities has the greatest impact in the project. Implementation of Warrantage has shown increasing use by farmers associated with a net financial benefit and greater food security. The helped to strengthen existing farmer organization, which would allow them in the future not only to assure that the Warrantage system continuous but also to make demands according to their need. The different exchange visits and meetings organized between the participating institutions laid the basics for future collaboration between these institutions in achieving their research and development objectives.

INTRODUCTION

The Volta Basin covers an area of about 400,000 Km^2 of the semi-arid and sub-humid savanna of West Africa. This basin, which has a main channel of 1400 km, lies mainly in Ghana (42%) and Burkina Faso (43%), with minor parts in Togo, Côte d'Ivoire, Mali, and Benin (Giesen et al., 2000)

The region is poor; with a per capita income around US$ 1100 per year while the population growth rate is almost 3% per year. Although service and mining sectors contribute to the economic growth of most of these states, agriculture is by far the most important sector (Sipkens and Donhauser, 1987). Thus economic growth could be achieved with increased agricultural productivity.

The majority of the population in the basin is small-scale farmers who rely on rain-fed agriculture for their livelihoods. However, the average rainfall of 1000 mm per year, which seems to be enough for crop production in the region, is very variable (Andreini et al., 2000) and this makes rain-fed agriculture a risky enterprise. The distribution of rain over the growing season has also been noted to be another bottleneck in agricultural production. Especially the onset of the rainy season is very unreliable and the frequent periods of drought (10-20 days) within the season cause significant crop damage (Adiku et al., 1997). In addition, there has been a decrease in rainfall in most of the region since the 1960's when compared to the 20th century average (Nicholson, 1998).

Apart from the erratic, low and unpredictable rainfall over the years, other factors contributing to water becoming a scarce resource in the Volta basin are the increasing population and livestock pressure, and growing competition over the use of water for generating hydroelectricity.

A dominating feature on the map of the Volta Basin is Lake Volta, which has the largest area of any man-made lake in the region (Lawson, 1963). The purpose of the lake is hydropower generation at the dams at Akosombo and Kpong which generate a total capacity of 1060 MW. A great limitation to the irrigation projects downstream has been the limited distance between the lake and the ocean.

At the macro-level, a water management issue emerges. Development of water resources for agriculture is needed to develop the poorer rural societies of Ghana and Burkina Faso (Giesen et al., 2000) in the Volta Basin. Such development will have a yet unknown downstream consequence on the availability of water for hydropower. In turn, reduced hydropower generation threatens industrial development in the South. Upstream, Burkina Faso is more interested in irrigation development since they do not profit from hydropower generation and have no alternatives but agriculture. On the other hand, Ghana in the downstream is more interested in electricity as suggested by the on-going preparation for the construction of a third large dam in Bui gorge.

In the entire Volta Basin, thus, food security is under threat due to the low water availability, increasing soil degradation and the dwindling farm sizes (Steiner and Rockstrom, 2003). Crop failure has not been the consequence of only low rainfall but also due to the effect of soil degradation caused by inappropriate management practices like plowing and intensive hoeing causing surface crusting, soil compaction, decrease in soil organic matter and hard-pan formation. All these have contributed to the inefficient use of the precious water available.

Declining water quantity and quality has become a critical limiting factor to agricultural productivity. Water use efficiency holds the key to improving agricultural (Kijne et al., 2001) and livestock productivity in the Volta Basin. The solution to the water crisis could be found in how water is developed and managed to improve its productivity in agriculture. In a broader sense, improving water productivity will mean getting more value from every drop used for either crops, fish, forests or livestock while maintaining or improving ecosystems services (Kijne et al., 2001). More importantly past research have shown that only 10% of the rainwater is used by the crop, the majority of it being lost to evaporation

In the past, international and national agricultural research systems have developed high-yielding cereal and legume varieties that respond to different rainfall regimes. For example, ICRISAT and its National Agricultural Research and Extension Systems (NARES) partners have developed and promoted improved varieties of sorghum, millet and groundnut and soil management technologies adapted to the semi-arid conditions (Bationo et al., 1998; Bationo and Ntare, 2000; Tabo, 1998). Similarly, 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.

However, although it is known that an integrated approach to water, crop and nutrient management is essential for increasing and stabilizing crop production and optimizing inputs use, there is a dearth of empirical studies on such interactions. Furthermore, majority of research has been conducted with little participation of farmers and rural communities who are the ultimate users and beneficiaries of research results. This has largely limited the adoption of agricultural technologies by small scale farmers, especially women who constitute the majority of farming population. We now know that farmers and rural communities are searching for new ways to intensify and diversify their systems to meet their food security needs as well as generating income, and seize upcoming market opportunities. Yet, until recently, agricultural research has not been effective in responding to these challenges. A win-win situation can occur when a systems research integrates germplasm, crop, nutrient, soil and water management, with explicit focus to empowering farmers and rural communities to take advantage of market opportunities to raise their incomes and invest in better management of their resources. New tools such Geographical Information Systems (GIS) and models can be very useful in facilitating the analysis of these integrated systems. The DSSAT-CENTURY (Decision Support for Agro technology Transfer) cropping systems models enables the analysis of how different soil, climatic and land management strategies affect the yield of a range of crops (Tsuji et al., 1994; Gijsman et al., 2002). On the other hand, participatory research approaches have been found very effective in enhancing the adoption of technologies, empowering rural communities and promoting equity.

The project is designed to address the major constraints that are encountered by small-scale resource-poor farmers in the Volta Basin, who rely on rain fed agriculture for their livelihoods. Our overall research hypothesis is that using a systems approach that integrates water use efficiency, soil and nutrient management, and improved germplasm together with market opportunity identification and building rural communities capacity will result in significant benefits to the rural poor and the environment.

PROJECT OBJECTIVES

[**For each objective - Methods, Results, Discussion, Conclusions – *this will be by far the largest section in the report e.g. 20-40 pp); include figures, diagrams and tables in results section]*

1 Objectives

Objective 1*:*
To develop, evaluate and adapt, in partnership with farmers, integrated technology options that improve water and nutrient use efficiencies and increase crop productivity in the Volta Basin.

Methods
Using an integrated natural resource management approach, in close partnership with farmers, promising 'best bet' integrated crop, soil, water and nutrient management technologies are evaluated in key benchmark sites. This is carried out in a participatory mode taking into account both the biophysical and socio-economic conditions of the target areas. Two sites in Ghana (Tamale and Navrongo] and two in Burkina Faso (Ouahigouya and Dano) are used in this project.
Water-related problems in rainfed agriculture in the water-scarcity-prone areas such as the Volta Basin are often related to high-intensity rainfall and large spatial and temporal variability of rainfall, rather than low cumulative volumes of rainfall. Research from several semi-arid tropical regions show, that the occurrence of dry spells (short periods of 2-4 weeks with no rainfall) far exceeds the occurrence of droughts. This indicates therefore that mitigating inter-seasonal dry spells is a key to improved water productivity in rain fed agriculture in semi-arid and dry sub-humid tropical environments. We approached the problem of water scarcity and periods of dry spell using the following innovations:

1. It has been reported that only 10 to 15 % of rainfall is used by the vegetation. Maximization of infiltration can be achieved through conservation tillage, pitting (zai), tied ridges, stone bounding, mulching and sub-soiling in heavily compacted soils. Soil-water-holding capacity, especially in the sandy soils, can be enhanced through the additions of organic fertilizers.
2. Another innovation, which is referred to as the Sahelian Eco-Farm or Savannah Eco-Farm (SEF) was recently developed at the ICRISAT Sahelian Center (ISC) in Niger in collaboration with NARES partners and provides simultaneous solutions to the main constraints for present rain-fed agricultural systems. The SEF combines the use of live hedges of Acacia sp. trees, earth bunds that turn into micro-catchments or half-moons, high value trees such as the domesticated *Ziziphus mauritania* planted inside the half-moons, annual crops, each planted in half or a third of the field in rotation each year.
3. Integrated Soil Fertility Management (ISFM): It is the adoption of a holistic approach to research on soil fertility that embraces the full range of driving factors and consequences - biological, physical, chemical, social, economic and political. The new paradigm in the soil fertility management in the last years it that the holistic approach encompasses nutrient deficiencies, inappropriate germplasm and cropping systems, pest and disease interaction with soil fertility.

These strategies and innovations are evaluated through a series of activities as shown below:

Activities

1.1. Synthesize available knowledge and information on water deficits, nutrient status and socio-economic issues of major importance in the study area.
1.2. Monitor nutrient and water flows and budgets and recommend appropriate adoption strategies for effective and efficient on-farm water and nutrient use strategies
1.3. Carry out field experiments to test, evaluate and adapt efficient soil, water, nutrient and crop management technologies
1.4. Recommend and scale up and out 'best bet' technologies for wider adoption.

In both countries, in order to make technology development and dissemination demand driven, the research team together with extension staff from the Ministry of Food and Agriculture (in Ghana) met with farmers in Saala and Ziga (Burkina Faso – BF) and Navrongo and Tamale zones (Ghana – Gh) to discuss the list of compiled technologies. The meeting was also aimed at assessing farmers' practices within the respective communities with regards to their use of locally available resources for efficient use of water and nutrient and the possibilities of improving upon their crop production practices over time. During the meetings, expectations, strategies and responsibilities were discussed with the partners. It was stressed that participating farmers have to play a vital role in disseminating the technology that emerge from the meetings, and promoting the methodology to other groups. All this will be possible only if they believe the process will be beneficial and are committed to support it.
As a result of the following was done to arrive at technologies that can address farmers' production constraints:

- Listing of production constraints by farmers
- Prioritization of technologies using pair wise ranking
- Listing of farmers' coping strategies for listed production constraints
- Discussion of technologies that can address farmers' production constraints from list of technologies
- Farmers make technology choices to address their production constraints

Farmers' choices were highly considered in the set of technologies to be tested, which are:

Zai Technologies + Nutrients – Burkina Faso
A set of water conservation structures (zai and stone lines) and nutrient sources combinations were testes at both sites with 32 farmers on each site. The test crop was sorghum at Ziga and maize at Saala. Cowpea was common for both sites

Ziga site:

Technology 1 (T1) = Stone lines + Zai + 5 tons manure per ha + 50 kg urea per ha
Technology 2 (T2) = Stone lines + Zai + 100 kg NPK (14:23:14) per ha + 50 kg urea per ha
Technology 3 (T3) = Stone lines + Zai + 5 tons manure per ha + 200 kg Burkina Phosphate (BP) (26.3% P_2O_5) per ha + 50 kg urea per ha;
Technology 4 (T4) = Stone lines + Zai + 5 tons manure per ha + 100 kg NPK (14:23:14) per ha + 200 kg Burkina Phosphate per ha + 50 kg urea per ha;

Saala site :

Technology 1 (T1) = Stone lines + Zai + 6 tons manure per ha + 100 kg urea per ha
Technology 2 (T2) = Stone lines + Zai + 150 kg NPK (14:23:14) per ha + 100 kg urea per ha
Technology 3 (T3) = Stone lines + Zai + 6 tons manure per ha + 200 kg Burkina Phosphate (BP) (26.3% P_2O_5) per ha + 50 kg urea per ha;
Technology 4 (T4) = Stone lines + Zai + 6 tons manure per ha + 150 kg NPK (14:23:14) per ha + 200 kg Burkina Phosphate per ha + 50 kg urea per ha;

Fertilizer micro-dosing – Ghana

This field experiment was carried out on-farm in Tamale and Navrongo and also on-station at Navrongo. Twenty (20) farmers participated in the on-farm trial, seven (7) at Navrongo with millet and 13 at Tamale with Maize. There were four treatments at Tamale comprising (Table 1) (i) Improved variety + 4 g NPK (15-15-15) per hill (6 kg N/ha, 3 kg P/ha, 5 kg K/ha) (ii) Improved variety + earlier recommended fertilizer rate of 60 kg N per ha (iii) Local variety + earlier recommended fertilizer rate of 60 kg N per ha and (iv) Local variety + no fertilizer. The cereals were planted at a spacing of 80 x 40 cm with two plants per hill in 20 x 25 m plots.

At Navrongo, millet was the test crop in the on-farm field trial, with a spacing of 80 x 40 cm. Plot sizes were 20 x 25 m. The treatments were (i) Local variety + 4 g NPK (15-15-15) per hill (6 kg N/ha, 3 kg P/ha, 5 kg K/ha), (ii) Local variety + earlier recommended fertilizer rate of 60 kg N per ha and (iii) Local variety + no fertilizer. On-station trial at Navrongo had three treatments. These were (i) Improved sorghum variety + 4 g NPK (15-15-15) per hill, (ii) Improved sorghum variety + earlier recommended fertilizer rate of 60 kg N per ha and (iii) Improved sorghum variety + no fertilizer. The plot size was 10 x 10 m and the spacing was 80 x 40 cm. There were three replications.

Table 1: Treatment for Microdose trial

Treatment code	NPK/ stand (g)	SA/stand (g)	Nyankpala		Wa	
			NPK/plot (g)	SA/plot (g)	NPK/plot (g)	SA/plot (g)
T1	8	4	625	313	720	360
T2	6	4	469	313	540	360
T3	4	4	313	313	360	360
T4	2	4	156	313	180	360
T5	8	2	625	156	720	180
T6	6	2	469	156	540	180
T7	4	2	313	156	360	180
T8 (microdose)	2	2	156	156	180	180
T9 Control	0	0	0	0	0	0

Tied ridging

There were four treatments : i) Cereal + No tied-ridging with no mineral fertilizer; ii) Cereal + tied ridging at 0.8 m with no mineral fertilizer; iii) Cereal + No tied-ridging + NPK (15:15:15) ; iv) Cereal + tied-ridging at 0.8 m + NPK (15:15:15)

Sahelian / Savannah Eco-Farm (SEF) – BF and Gh

There were 12 treatments (Table 2) comprising: (i) six treatments with soil and water conservation technique + fruit tree (*Ziziphus mauritania*), a leguminous tree for soil fertility improvement (*Acacia tumida*) and cropping system of rotation and continuous cropping using sorghum cowpea and sesame, (ii) 6 treatments with the same components as above but without the trees and the soil and water conservation structures. The half moon in which the Ziziphus trees were planted served to concentrate water around the tree. In Ghana only sorghum and cowpea were tested, therefore 8 treatments were tested. The plot size was 15 x 30 m. The trial was installed in BF at Saala and Ziga in 2005, while in Ghana it was installed at Navrango in 2004.

Farmers Field Schools (FFS)

This approach was adopted in Ghana to demonstrate and facilitate the adoption of the technology of strategic fertilizer application (microdose), the use of mineral fertilizer and the improved varieties.

All the steps required to implement the FFS were observed, which are:

The identification of the demonstration field that must be in the community

The role and responsibilities of the farmers, which are to offer a field for the demonstration trials, carry out all practical agronomic activities during the course of the school, keep records of all what they will learn, maintain a disciplined school free of any violence or conflicts

The role and responsibilities of research which are to: provide resource persons to handle each learning module, provide research inputs such as sorghum seed, fertilizers, pay for cost of land and seedbed preparation and any other related inputs, provide stationery for participants and resource persons, provide meeting supplies such as food and snacks during each training event.

The roles and responsibilities of the Ministry of Food and Agriculture staff were to: organize and sensitize farmers about the Farmer Field School concept, keep records of discussions at each training event, any other duty as the need arises

Community entry and planning of learning modules

At the meeting with the community organized by the Ministry of Food and Agriculture, Farmers were selected based on their willingness, gender, readiness to work in a group and willingness to share experiences acquired with other farmers. A total of twenty farmers initially formed the group and selected their leaders.

A fairly flat land with minimum tree cover was selected for the demonstration was selected with known history and large enough to accommodate the treatments to be evaluated. Thereafter, farmers were given the option to choose a crop of their interest, and sorghum was the crop selected due to its multiple uses in the community for traditional uses but also because of the

interest expressed by Guinness Ghana Limited to use the improved medium maturing sorghum variety, Kapaala in its brewery activities so ready market was also taken into account.
All the processes right from the land preparation to the planting and fertilizer application were carried out with the farmers as learning modules. The farmers were thought of the important of seed treatment was explained to them. The field was taken care of through regular weeding.

Table 2: Treatment combinations in the SEF at the CPWF PN5 sites in Burkina

No	Year one	Year two	Year three
1	"SWC_tech" + One row ziziphus + two rows A. Colei + Millet – continuous	"SWC_tech" + One row ziziphus + two rows A. Colei + Millet – continuous	"SWC_tech" + One row ziziphus + two rows A. Colei + Millet – continuous
2	"SWC_tech" + One row ziziphus + two rows A. Colei + Millet – rotation	"SWC_tech" + One row ziziphus + two rows A. Colei + Sesame – rotation	"SWC_tech" + One row ziziphus + two rows A. Colei + Cowpea – rotation
3	"SWC_tech" + One row ziziphus + two rows A. Colei + Cowpea – continuous	"SWC_tech" + One row ziziphus + two rows A. Colei + Cowpea – continuous	"SWC_tech" + One row ziziphus + two rows A. Colei + Cowpea – continuous
4	"SWC_tech" + One row ziziphus + two rows A. Colei + Cowpea – rotation	"SWC_tech" + One row ziziphus + two rows A. Colei + Millet – rotation	"SWC_tech" + One row ziziphus + two rows A. Colei + Sesame – rotation
5	"SWC_tech" + One row ziziphus + two rows A. Colei + Sesame – continuous	"SWC_tech" + One row ziziphus + two rows A. Colei + Sesame – continuous	"SWC_tech" + One row ziziphus + two rows A. Colei + Sesame – continuous
6	"SWC_tech" + One row ziziphus + two rows A. Colei + Sesame – rotation	"SWC_tech" + One row ziziphus + two rows A. Colei + Cowpea – rotation	"SWC_tech" + One row ziziphus + two rows A. Colei + Millet – rotation
7	No SEF, Millet – continuous	No SEF, Millet – continuous	No SEF, Millet – continuous
8	No SEF, Millet – rotation	No SEF, Sesame – rotation	No SEF, Cowpea – rotation
9	No SEF, Cowpea - continuous	No SEF, Cowpea - continuous	No SEF, Cowpea - continuous
10	No SEF, Cowpea – rotation	No SEF, Millet – rotation	No SEF, Sesame – rotation
11	No SEF, Sesame - continuous	No SEF, Sesame - continuous	No SEF, Sesame - continuous
12	No SEF, Sesame – rotation	No SEF, Cowpea – rotation	No SEF, Millet – rotation

Types of fertilizers and their applications

The micro-dose technique was to be introduced to farmers as an effective and efficient yet less capital intensive way of fertilizer application. Two experts in soil fertility took turns during the basal application and top-dressing dates to explain the technology to farmers. The presentations and farmers' comments are presented below.

The following treatments were tested in the field:

1. Control: No fertilizer
2. Micro dose: 2g NPK and 2g Sulfate of ammonium (21 & N)/hill
3. Recommended rate: 8g NPK and 4g SA/ha.

Farmers field school closing and graduation ceremony at Kandiga - 2007
The Farmer Field Schools ended with formal closing ceremony where participants and resource persons were awarded certificates of participation. Present were members of the Challenge Program 5 Team from Ghana (Dr. Mathias Fosu, Dr. Roger Kanton, and Dr. Saaka S. Buah), Dr. Ramadjita Tabo, Global coordinator of PN5 and Deputy Director of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Sahelian centre, Deputy Regional Director of Agriculture, Upper East Region in the person of Mr. A-R Z Salifu, a representative of the Kassena-Nankana District Director of Ministry of Food and Agriculture, a representative of

TECHNOSERVE an international Non-governmental Organisation in the region, members of the electronic and print media, the Ghana Broadcasting Corporation, the Metro Television, the Ghana News Agency, the Upper Regional Agricultural Development Radio (URA-Radio), a local FM Station Nabina Radio, opinion leaders in the community and people from the nearby communities. The occasion was chaired by Mr. A-R Z. Salifu, Acting Regional Director, MoFA, Upper East Region. The Chairman commended the Savanna Agricultural Research Institute (SARI) and ICRISAT for their foresight in citing the Farmer Field School in the region with funding from the Challenge Programme on Water and Food Project 5 (CPWF 5). Dr. Roger Kanton, coordinator of the FFS briefed the gathering on the concept, approach and objectives of the Farmer Field School (FFS) and highlighted the five main areas of the FFS, as follows: 1) Why the FFS approach was chosen by the research team, 2) The concept of the fertiliser micro dose, 3) The criteria for site and farmer selection, 4) Role sharing by farmers, extension and researchers in the FFS, 4) The climax of the FFS and what was expected of graduates of the school

Award of certificates

Participants and resource persons were awarded certificate of participation. Dr. R. Tabo, the Acting Regional Director of MoFA, Upper East Region and the SARI CP5 team took turns in presenting the certificates

Results and discussions

Burkina Faso

Biophysical and socio-economic characterization of Ziga and Saala benchmark sites

This is a broad overview of socio-economic and biophysical characteristics at the project sites (Ziga and Saala). Emphasis was put on natural resources management, farmer's perception of land degradation and constraints to rural development. An interdisciplinary team consisting of sociologists, socio-economists, geographer, and agronomists has undertaken the surveys, using participatory rural appraisal tools and approaches.

Ziga site

Biophysical environment

The village of Ziga was established in 1704 by Naba Piiga. It is located at 13°42' latitude north and 2°31' longitude west in the Department of Oula (Yatenga Province), approximately. 20 km southeast of Ouahigouya. It covers an area of 50.6 km^2 (0.4% of the province)

Climate

The climate is tropical sudano-sahelian, characterized by a dry season from November to May and a rainy season from June to October. Rainfall is highly variable and erratic (mean annual rainfall (1963-1984) was 582 mm)

Soils

The soils at Ziga site are predominantly tropical ferruginous characterized by a sandy texture, low organic matter content and inherent low soil fertility. Five soil types have been identified (Table 3).

Soils properties are characterized by low fertility, phosphorus deficiency, low organic matter (<1%), low nitrogen, low CEC. Soil resources are limited at Ziga, and the existing soils show increasing signs of degradation due to combined effects of inappropriate agricultural practices, population pressure and climatic variations.

Table 3: Soil types and utilization at Ziga

Soil types	Sandy/gravel "*zinka*"	Sandy/clayey "*biisgou*"	Clayey/sandy "*boolé*"	Clayey "*bagtenga*"	Hydromorphe "*baoga*"
Characteristics	Sensitive to erosion	Sensitive to erosion, relatively fertile, good water retention	Relatively fertile		
Crops	Millet sorghum groundnuts beans sesame	Rosella beans sesame "souchet" groundnuts	Rosella groundnuts sorghum beans sesame	sorghum	Rice beans sorghum

Vegetation
The vegetation falls within the savanna type. It suffers serious degradation due to combined effects of anthropogenic activities and climatic factors variations.

Water resources
There are no surface water resources (streams or dams) in the village. However, hydraulic infrastructures such as wells (2) and forages (10) exist, although some of them are useless (not functioning) because of maintenance problems.

Land degradation
Land degradation is a problem. Land is the most important capital asset for agricultural production; Farmers are conscious of the degradation of their soils. They use various indicators to characterize and assess degradation stages as follows:

- Indicators of land degradation include certain grass species such as *Borria radiate, Eragrostis spp* and *Striga hermonthica*, while species such as *Fimbristilys hispiduula* and *Dactyloctenium aegyptium* are indicators of improved soil fertility. Biological indicators (termites, iules) are used to characterize degradation.
- Causes of land degradation**:** farmers acknowledge that combined anthropogenic and climatic factors are the main causes of the natural environment degradation. Climatic factors include low and erratic rainfall as well as storm effects on soil structure leading to erosion; anthropogenic factors include inappropriate agricultural practices such as deep tillage, reduction of fallow period, deforestation, fire, grazing and overgrazing.

There is general agreement on environmental degradation at Ziga, mainly soil and vegetation degradation. The degradation affects indirectly the livelihood of the poor people through declining crop and livestock productions. To combat land degradation, farmers at Ziga have tested various indigenous and modern technologies of soil and water conservation (SWC), since the drought of 1970. The technologies include stones lines with reforestation, improved zai, half moon, construction of compost pits. Different projects and programs assisted them.

Socio-economic environment

Population
In 2004 the population is estimated at 3922 inhabitants (2027 women and 1895 men). The population density was estimated at 77 inhabitants / km^2, one of the highest in the province. It was 3528 inhabitants in 1996 with a density of 77 inhanbitants / km^2. Three main ethnic groups cohabit in the village: the "*Mossés*", the "*Yarsés*" and the "*Peulhs*" (foulani)

Farming systems

Land tenure and land use rights
Land tenure system is predominantly traditional with three modes of access to the land:

- inheritance (lineage), most dominant
- gift (rare)
- loan with a counterpart

Women and young people do not have rights to the land. Women however exploit small portions of their husband's land, but they do not make huge investments (agricultural inputs and soil and water conservation technologies with high labor demand for example)

Agriculture

- Mainly subsistence-oriented for auto-consumption. Cropping systems include both intercropping and rotation, based on the soil type and potential. Crops are sorghum, millet, beans, and groundnuts.
- Labor force: mostly family members (including children), mutual assistance (voluntary), cash wages laborers
- Agricultural inputs and farm equipments: organic amendments are used to improve soil fertility; the use of inorganic fertilizers is very limited. Animal traction (cattle and donkey) is often used for soil preparation. Land preparation and agricultural activities (sowing, thinning, weeding and plowing) are done using simple manual tools such as machetes, wooden ploughs and harrows.

Livestock

- Cattle, sheep, goat, and poultry breeding
- Semi-intensive
- Crop residues (straw, fodder) are used to feed animals because most of the grazing areas are degraded.
- Diseases and fodder and water shortage (in dry season) are common constraints to livestock production

Farmers' organization

One union of farmer's organizations was established in 1992 with the following components:

- 13 women farmers groups
- 11 men farmers groups
- Naam Association (established in collaboration with the FNGN)
- Association with specific activities (ex. zai construction)

Infrastructures

Social: health center, maternity, 2 primary schools, 2 religious schools, 3 halls for literacy, 2 cereal banks, 10 deep wells (8 functioning and 2 non-functioning), 5 wells (3 functional) and a livestock health office
Economic: market, savings scheme, 3 shops, 3 public phones, 2 mills
Religious: 2 mosques, 1 public place for Islamic feasts, 1 temple, 1 vault, 1 royal cemetery.

Food market survey

A market survey was undertaken in June 2005. The results show:

- 1 market at Ziga (held every three days).
- several other markets in the vicinity of Ziga (Table 4).

Table 4: Markets distribution in Ziga area

Markets	Distance to Ziga (km)	Frequency	Type of market
Ziga	-	Every 3 days	Rural
Yako	70	Permanent	NA
Gourcy	35	Every 3 days	NA
Bougnaam	12	Every 3 days	NA
Kera Doure	10	Every 3 days	NA
Lougouri	15	NA	NA
Youba	30	NA	NA
Ouahigouya	25	Permanent	Urban

Products:

- Cereals and leguminous,

- livestock products (fattening),
- vegetables, and fruits,
- agricultural inputs (seeds and fertilizers)

Transport: Goods and commodities are transported to the markets by means of bicycles, transportation on head, animal traction (donkeys and/or cattle).

Transformation: This traditionally (no modern processing) done by women organized in associations

Prices fluctuations: Seasonality is an important factor to consider in market transaction. It influences transaction costs of supply/demand chain. High prices fluctuations exist between the dry season and at harvest. At harvest, prices are twofold lower than at dry season, which unfortunately is in disadvantage to the farmers.

Saala site

Biophysical environment

Location

Saala site is located in the Dissin Department (approx. 15 km), at 10°56' latitude north and 2°55' longitude west, and approx. 60 km from the capital of the Dano Province.

Climate

The climate is sudanian with two seasons:

- dry season from November to March
- rainy season from April to October. Mean annual rainfall (1995-2005) at Dissin is 979 mm. The rainfall is erratic with frequent drought periods

Soils

Soils are tropical ferruginous. Five soil types have been identified (Table 5)

Soils properties:
- Low organic matter content
- Low nitrogen
- Important drainage
- Runoff

Table 5: Soil types and utilization at Saala

Soil types	Hydromorph *"zi-bapla"*	Sandy/clayey *"zi-biire"*	Gravel *"zi-kusebie"*	Lithosols *"zi-kwalo"*	Clayey/silt *"zi-bataw"*
% area	15	50	10	5	20
Characteristics	Deep, rich in nutrients, fertile, hard to work	High infiltration, relatively fertile	Relatively fertile	Poor fertility	Nutrients-rich
Crops	Rice, cotton, potatoes	Cotton, groundnuts, millet, sorghum, maize	Beans, maize, cotton, groundnuts, sorghum		Sorghum, millet, cotton, maize, groundnuts

Vegetation

The vegetation is a savanna (parkland) with dominance of tree species such as *Butyropernum parkii, Parkia biglobosa, Acacia albida,* and *Tamarindus indica*. The vegetation suffers from degradation because of combined effects of population pressure, deforestation (for firewood), grazing and overgrazing, and droughts, with consequences on soil resources (erosion, degradation, declining soil fertility, etc.).

Water resources

Saala site is located in the valley of the Mouhoun River. No surface water exists; however, there are hydraulic infrastructures such as deep wells (2) and wells (11). Seven (7) pumps (5 in good condition) and 12 wells (7 in good condition) have been inventoried during the participatory rural appraisal. There is a village committee in charge of water (wells) management. Scarcity of water resources in dry season (mid March to May) limits off-season activities (vegetables gardens) for example.

Land degradation

Farmers are aware of land degradation in the village. They use various indicators (biological and physical) to describe and assess degradation stages. Biological indicators are mainly used to characterize soil fertility. Grass species such as *Eragrostis tremula, Striga hermonthica* are used to characterize degraded soils, whereas other species such as *Andropogon pseudapricus, andropogon gayanus* and *Andropogon ascinodis* are characteristics of fertile soils. Physical indicators include low or absence of vegetation cover, disappearance of certain trees, low crop yields.

Land degradation results from natural factors (runoff, droughts, erosion) and human activities (fire, deforestation, grazing and overgrazing, inappropriate clearing). Faced with land degradation, farmers at Saala have tested and adopted various technologies of soil and water conservation (SWC), as well as sustainable agricultural management practices. Technologies of SWC tested and implemented include composting, stone lines and afforestation (tree plantation). Sustainable agricultural practices including tillage, intercropping and rotation are also tested. They received technical assistance from partners such as rural development projects, NGO's, and public services. However, Saala does not have a strong experience of development partnership compared to Ziga.

Socio-economic environment

Population

The village of Saala was established in the 1800s. The population (2004) was estimated at 1142 inhabitants (51% women and 49% men). The main ethnic group is represented by the "*Dagara*". They are also the "*Mossi*" people.

Farming systems

Land tenure and land use rights

Land tenure system is traditional. Three modes of land acquisition are as follows:

- Inheritance (lineage), most dominant
- Gift (rare)
- Loan for a defined time frame with a counterpart (kind or money) to the land owner

Women and young people do not have rights to the land. The land belongs to the household chief who organizes agricultural activities at the household level. Because of this lack of ownership, they do not invest intensively in the land (ex. reforestation or SWC technologies).

Agriculture

- Subsistence-oriented mainly for auto-consumption. It is practiced by most of the population. Cropping systems include intercropping and rotations depending on soil types. Crops include millet, white and red sorghum, maize, groundnuts, cowpea, and soja. Cotton is cultivated with the financial and technical support of the SOFITEX; but farmers are hesitant because of the risks associated with cotton production.
- Labor forces: family members, mutual assistance (voluntary), laborers who work for cash wages.
- Equipments and agricultural inputs: Animal traction is often used for soil preparation, but most of the equipments are traditional (ex. machetes, wooden ploughs and harrows). Agricultural inputs include organic amendments (compost pits), improved ds and mineral fertilizers (in very limited amount), and pesticides

-

Livestock

The population is mainly agro-pastoralists and practice both agriculture and livestock.

- Livestock breeding: small ruminants (sheep, and goat)
- Serves as savings. Animals are destined for specific purposes (sacrifices, rituals), and/or sold to cover certain emergencies (funerals, medical expenses).
- Animals roam freely in dry season, but they are kept in enclosures during the cropping season. Poultry breeding is also practiced.
- Constraints: diseases, grass (fodder) and water shortage, and theft

Farmers' organization

- Farmers are not well organized at Saala.
- No organizations exist.

Food market surveys

No markets exist at Saala. Farmers rely on markets in the vicinity for their economic activities (Table 6).

The main farm products found on these markets are (Table 7):

- Sorghum, maize, rice, cowpea, groundnuts. The demand for sorghum is high all over the year. It is used by women for dolo (traditional beer) preparation. Maize, groundnuts, rice, and cowpea follow sorghum.
- Livestock products: poultry is a source of income (duck for example).
- Cassava and banana are considered as promising food crops for income generation. Banana is exported to Ghana.

Transport to and from markets: bicycles, on the head, animal traction.
Prices fluctuations: high prices fluctuations between harvesting period (high supply) and during the dry season (high demand). No structure or organization to assist farmers in the market chain (production, storage, marketing, and transformation). Partners such as PNGT2, FAARF, SOS Sahel offer micro-credits to women for income-generating activities. However, constraints hinder these activities: lack of competitiveness, high interest rates, and short repayment period.

Table 6: Markets in the surrounding of Saala

Markets	Distance to Saala (km)	Frequency	Type of market
Dissin	8	Once a week	NA
Zambo	15	Once a week	NA
Hameley	33	Once a week	NA
Tovoir	5	Once a week	NA
Nadom*	15	Once a week	NA
Zongo*	35	Once a week	NA
Lora*	45	Once a week	NA
Koutourou*	15	Once a week	NA

* markets in Ghana.

Table 7: Ranking of products based on the profitability, demand level and degree of adoption at Saala

Products	Profitability	Demand		% adoption
		Harvest	Dry season	
Groundnuts	1	1	3	100
Sorghum	2	2	1	100
Rice	3	4	4	75
Maize	4	3	2	100
Potatoes	5	6	6	30
Cowpea	6	5	5	100
Poultry	1	1	2	100
Pig	2	2	1	100
Sheep	3	4	4	50
Goat	4	3	3	30
Cattle	5	5	5	20

Sahelian Eco Farm (SEF) at Ziga and Saala

Two pilot SEF Field Schools were installed from the second year of the project in 2005 at Saala and Ziga, respectively. The experiment is aimed at studying the effects of an improved soil and water conservation technique, cropping systems, soil fertility management on sorghum, maize, sesame and cowpea yield. (SEF/R = SEF rotation, SEF/C = SEF continuous, NSEF/R = No SEF rotation, NSEF/C = No SEF continuous).

Figure 1 report the results of the rainy season 2005. Yields of maize and cowpea were greater under the SEF than with No SEF whereas the yields of sesame were not different. This trend was observed also the following years.

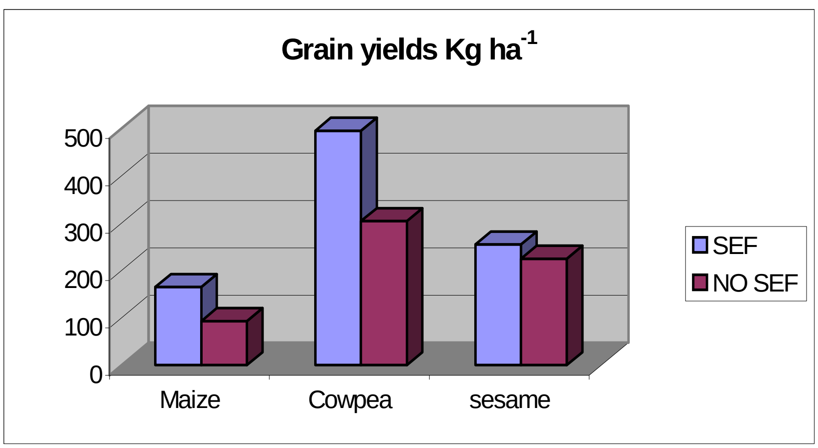


Figure 1: Maize, cowpea and Sesame grain yields under SEF and NO SEF, conditions at Saala. Results of rainy season 2005

Stones lines and Zai combined with various amendment combinations - Ziga

The best yields were obtained with the recommended rate of mineral fertilizer (technology 2) and the intensive fertilization with addition of Burkina Phosphate (technology 4) (Figure 2). However the response of phosphorus appears slightly higher when it is associated with the manure (technologie3). The results reported are from rainy season 2005. However similar trends were observed during the subsequent seasons.

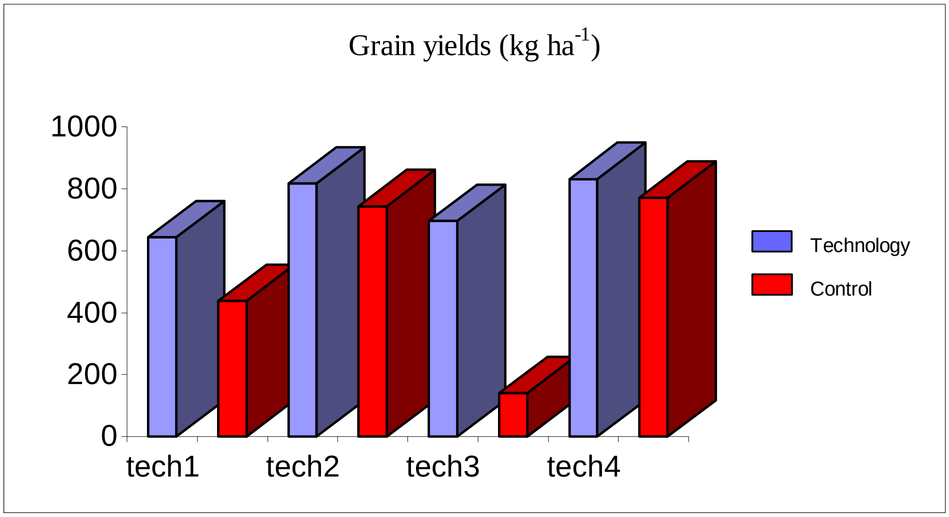


Figure 2: Effects of different combination of fertilizers on sorghum production at Ziga; tech stands for technology; tech1 = Stone lines + Zai + 5 tons manure per ha + 50 kg urea per ha, tech2 = Stone lines + Zai + 100 kg NPK (14:23:14) per ha + 50 kg urea per ha, tech3 = Stone lines + Zai + 5 tons manure per ha + 200 kg Burkina Phosphate (BP) (26.3% P_2O_5) per ha + 50 kg urea per ha, tech4 = Stone lines + Zai + 5 tons manure per ha + 100 kg NPK (14:23:14) per ha + 200 kg Burkina Phosphate per ha + 50 kg urea per ha (data of 2005)

Zai and mineral fertilizer microdose and various amendment combinations - Saala

All the technologies had a positive effect on the yield of maize. The grain yields of maize varied from 300 to 950 kg ha^{-1} for the control compared with 800 to 1500 kg ha^{-1} for the improved technologies (Figure 3). The technology 4, which is a combination of organic fertilizer, mineral fertilizer and Burkina phosphate, gave the best yield. The greatest gross margins are obtained with technology 4 and the technology 1 which is simple combination manure with urea. The margin of production obtained with the technology of intensive fertilization (tech 4) is worth 3 times that obtained with the simplest technology.

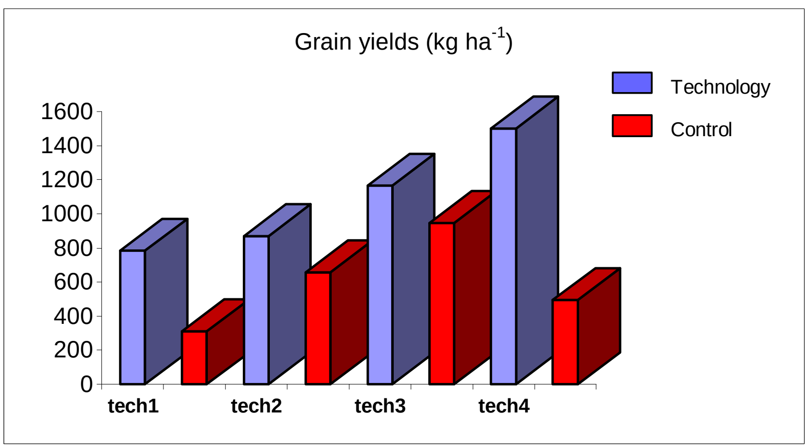


Figure 3: Effects of different combination of fertilizers on Maize production at Saala; tech = technology; tech1 = Stone lines + Zai + 6 tons manure per ha + 100 kg urea per ha, tech2 = Stone lines + Zai + 150 kg NPK (14:23:14) per ha + 100 kg urea per ha, tech3 = Stone lines + Zai + 6 tons manure per ha + 200 kg Burkina Phosphate (BP) (26.3% P_2O_5) per ha + 50 kg urea per ha, tech4 = Stone lines + Zai + 6 tons manure per ha + 150 kg NPK (14:23:14) per ha + 200 kg Burkina Phosphate per ha + 50 kg urea per ha (data of 2005)

For cowpea, the technology 1 that is an organic fertilization with a nitrogen complement seems largely sufficient for the production of cowpea (Figure 4). The rock phosphate is without apparent effect when the performance of productions of technologies 3 and 4 was considered.

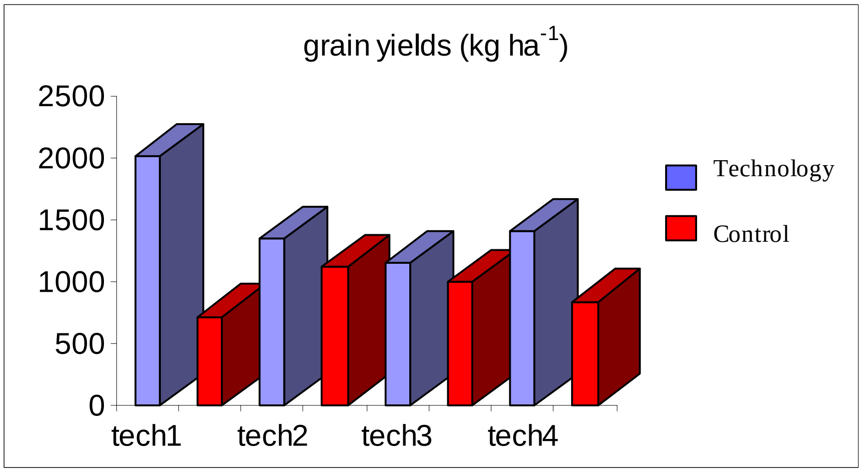


Figure 4: Effects of different combination of fertilizers on cowpea production at Ziga (data of 2005)

Ghana

Synthesis of information on nutrient status and socio-economic issues of Benchmark sites

The benchmark sites that were characterized are Navrongo and Tamale. Information was synthesized from Soil survey report of Soil Research Institute (Adu, 1995), FAO report on soils of the Navrongo-Tono area, Nasia basin and soil characterization report of GLOWA Volta Project (Fosu, 2004; Agyare, 2004).

The major soils of the Navrongo area belong to the Tanchera association and consist mainly of Puga series (Eutric Plintosol), Tanchera series (Endoeutric-Stagnic Plintosol), Pu Series (Eutri Gleyic Regosol), Kupela series (Eutric Gleysol) and Berenyasi series (Gleyic Arenosol). The soils are mainly loamy sand and sandy loam on the surface. Bulk density ranged from 1.7-1.88 Mg m3 and Total Porosity of the top soil was 34-37%. Organic carbon was 0.5-0.7% and Saturated Hydraulic Conductivity at the surface was 4.5 – 9.4 cm hr^{-1}. Surface pH ranged between 5.6 – 7.3, total N (0.02 – 0.1), available P (trace to 12 ppm), K (20 – 120 ppm).

In the Tamale area, the Benchmark soils were classified as Kumayili series (Ferric Acrisol), Kpelsawgu series (Dystric Plinthosol), Lima series (Eutric Gleysol), Luvisols and Leptosols. The soils are developed over Voltain shales, sandstones and quartzite. The soils are clay loam, loam, sandy loam and sandy clays at the surface. Bulk density range from 1.15-1.8 at the surface and 1.2-1.9 in the sub-soil. Organic carbon content ranges between 0.4-1.3% and pH range is 3.7 – 7.3. Total N range is 0.02 – 1%, Available P is 1-12 ppm, K is 9-150 ppm and saturated hydraulic conductivity range is 0.02-17.3 cm/hr. CEC is between 1 and 6 cmol+.

Biophysical and socio-economic characterization

This was carried out in Navrongo and Tamale sites. Four communities in Tamale and 3 communities in Navrongo were covered. The methodology involved preparation and administration of questionnaires and the use of structured interviews.

Compilation and selection of Technologies

The following list of technologies was compiled from annual reports and Journal publications on Northern Ghana: Tied ridging; Contour ridging; Stone bunding, Composting, Crop rotation, Alley cropping/agroforestry, Cover crops, Minimum tillage, Intercropping, Mounding, Manure use, Integrated nutrient management, Nutrient use efficient crop varieties. These technologies were discussed with farmers in all pilot sites

Community Workshop Findings
Navrongo Area
The livelihood activities involving farmers in the Nayagnia and Doba communities included the following:
Livestock production (cattle, pigs, poultry, sheep, goats, donkeys)
Crop production (including dry season gardening)
Migration to southern Ghana to work for cash

The men mainly produced both early and late millet, sorghum, extra-early maize, cowpea bambara groundnut and rice for food. Groundnut is generally valued for cash. Groundnut is widely cultivated by women in Nayagnia. The men ranked the crops they cultivate in order of importance as millet, sorghum, groundnut and rice.
Animals mostly produced by men included poultry, pigs, small ruminants, cattle and donkeys. Poultry, pigs, sheep and goats are mostly raised for cash value. However, poultry may be raised for home consumption. In that case poultry may serve the dual purpose for cash and food in any household food and nutrition security program development.
Problems related to livelihoods of farmers in Nayagnia and Doba communities
Problems related to crop production in the Nayagnia and Doba communities were listed by the farmers as: Declining soil fertility, striga infestation (on maize, sorghum, late millet and groundnut), post harvest losses, erratic rains, lack of market for tomato, lack of suitable tomato varieties with high market value to meet consumer preference, wilting of tomato at fruiting stage, poverty/lack of credit for land preparation and weeding, termite infestation on groundnut, millipede attack on groundnut at podding, wild rice infestation on cultivated rice, groundnut rosette disease (stunted growth – literally termed groundnut leprosy), bird and pests of millet panicles

The farmers at both Nayagnia and Doba prioritized the problems as: declining soil fertility, striga infestation, lack of credit for land preparation and weeding, groundnut diseases, wilting of tomato at fruiting stage.
Based on the above list of constraints the following are identified as potential technologies for improving soil fertility that can be tested: soil fertility management and striga control strategies, composting, cereal-legume rotation (particularly using soybean as a trap crop) or cereal-soybean intercropping to improve soil fertility and reduce striga infestation, integrated striga control strategies, use of nutrient use efficient crops. Soil moisture management strategies included tied ridging, drought tolerant crops, and minimum tillage

The farmers at the Kandiga Community listed the following production constraints: declining soil fertility, insufficient rainfall, soil erosion, labour constraints (especially during land preparation), striga infestation in cereals, soil-borne pests affecting seedlings of all crops, lack of cash to pay for labour and other inputs, lack of irrigation facilities for rice production and lack of grazing grounds during raining season & lack of feed during dry season

Tamale Area
Three communities were covered namely, Kpilo, Nwodua and Mbanayili. The livelihood systems of the farmers in the Mbanayili area are mainly crop and animal production. Major crops grown by farmers in these communities are rice, maize, sorghum, pepper, groundnut, cowpea, cassava and yam. Most the farmers grow their own recycled seed, obtain seed from other farmers or purchase from the open market to plant.
Many of the farmers plant on ridges but the ridges are never tied. Moreover the farmers were of the opinion that rotation of maize planted after a previous crop of pepper often leads to increased maize yields. Although many farmers who were trained on compost production by Savanna Agricultural Research Institute (SARI) are building and using compost, they complained that they are not able to cart larger quantities of compost to their bush farms with bicycles, push carts or women carting it on their heads. Several farmers said they have tried using mucuna and other covers crop for improved fallow management but indicated that due to non-availability of arable land, they did not find the technology feasible.

Table 8 below shows a description of livelihood options, production constraints and potential solutions.

Most farmers in the Mbanayili area said they reduce post harvest losses of grains by treating the grain with shea butter mixed with milled pepper. They also use kerosene to preserve seed. Many farmers also indiscriminately use all sorts of chemicals to store their grain. The project team however advised the farmers to harvest their crops early and dry thoroughly before storage to reduce post harvest infestation of the grain in storage. Additionally, the project team advised the farmers to team up to form recognized farmer based organizations with some guidance from MOFA and the Department of cooperatives in order to access funds that are available for such farmer based organizations.

Table 8: Major Livelihood systems and some solutions in Mbanayili Area

Livelihood	Problems/Constraints	Solutions
Crop Production	Lack of capital for land preparation Lack of early maturing crop varieties Striga infestation Storage pests Shallow soils Insect pests affect seedling establishment Low crop yields Pod sucking pests Groundnut leaf diseases Lack of transport to cart manure and compost to bush farms Lack of market for pepper fruits	Credit Manuring Composting Improved early maturing varieties Inclusion of legumes in cropping systems Pruning of alley crops to mulch soil Drying technologies for pepper Harvest early to reduce infestation in storage
Animal rearing	Theft Diseases/mortality Lack of feed (dry season) Housing	Improved access to veterinary services Planting of Pigeon pea as supplemental animal feed Housing
Pito brewing	Labour intensive Lack of milling facility Buying of pito on credit by consumers Lack of water	Provision of mill Credit Provision of borehole
Shea nut and Dawadawa processing	Labour intensive (fatigue) Price fluctuations Inadequate nuts	Improved processing methods Provision of mill Credit
Charcoal Production	Labour intensive (fatique) Inadequate trees Limited market Low price	Tree planting

In ranking the problems to crop production in the area the farmers thought the most serious constraints in decreasing order were: Soil fertility, lack of transport to cart of compost to bush farms, lack of cash for land preparation, and post harvest losses.
The farmers suggested the following technologies to be tried out: soil moisture conservation (Tied ridging), soil erosion control using Vetiver grass, nutrient use efficient crops, drought tolerant crops, soybean as a trap crop for Striga control in cereal based cropping systems
In the Kpachi, Cheyohi and Cheshegu the following production constraints were listed by farmers : declining soil fertility, insufficient rainfall, high cost of inputs, striga infestation and lack of bullock traction services

Farmers coping strategies in the Kpachi community are presented in table 9.

Selection of potential technologies for testing was based on ex-ante economic analyses and farmer preferences. The most serious crop production problems were those related to declining soil fertility and striga infestation. Most of the farmers expressed interest in trying new varieties that are early maturing, drought tolerant and able to produce reasonable crop yields under low external input levels. Due to the erratic nature of the rains in the two zones, farmers were willing to adopt soil moisture conservation techniques such as tied ridges. Farmers with bullocks are already planting on ridges hence the additional labour required to tie the ridges to conserve soil moisture might be minimal.
In general, farmers indicated their willingness to try out the following technologies in both Navrongo and Tamale: .Soil fertility management and Striga control strategies, composting, cereal-legume rotation (particularly using soybean as a trap crop) or cereal-soybean intercropping to improve soil fertility and reduce striga infestation on striga infested plots, use of nutrient efficient crops, tied ridging, drought tolerant crops, minimum tillage

Table 9: Farmers' coping strategies to listed production constraint in the Kpachi community

Constraint/Problem	Coping Strategies
Declining soil fertility:	- Use manure - Compost household refuse - Crop rotation - Legume production to improve soil fertility
Insufficient rainfall	- Early planting - Forestation - Bounding (in rice production)
High cost of inputs (esp. fertilizer):	- Use animal droppings - Sell animals to buy fertilizer & other inputs, - Access credit from banks
Striga infestation in cereals	- Use groundnut shells as manure, - Regular weeding - Use salt - Plant late millet - Plant crotalaria
Lack of bullock traction services	- Use household labour - Hire labour - Communal labour

Savannah Eco-Farm (SEF)

Tables 10, 11, 12 and 13 show the performance of the Sudanian Eco-Farm (SEF) during 2004 and 2005. Sorghum following cowpea produced higher yield than the continuous sorghum in the SEF but this trend was not observed in the No-SEF. *Acacia colei* had a rapid growth during the rainy season. During the dry season, a number of plants showed die-back from the tip and browning of the leaves along the margins, which could probably due to water stress.

Table 10: Sorghum yield in the Savannah Eco-Farm in Navrongo, 2005

Treatments	Grain(kg/ha)	Panicle(kg/ha)	Stover(kg/ha)
SWC-tech + Ziziphus + Acacia + rotation	1814.7	2388	5854.7
No SEF + rotation	1774.7	2188	5788
No SEF + continuous	1721.3	2334.7	5441.3
SWC-tech + Ziziphus + Acacia + continuous	1281.3	1681.3	3881.3
Lsd (5%)	546.1	764.3	2193.9

Table 11: Cowpea yield in the Savannah Eco-Farm in Navrongo, 2005

Treatments	Grain(kg/ha)	Pod(kg/ha)	Stover(kg/ha)
No SEF + continuous	788	1214.7	1601.3
No SEF + rotation	761.3	1414.7	2228
SWC-tech + Ziziphus + Acacia + rotation	588	1041.3	1334.7
SWC-tech + Ziziphus + Acacia + continuous	548	934.7	1801.3
Lsd (5%)	313.8	369.8	879.6

The sorghum rotated with cowpea out yield the continuous sorghum with or without SEF. Cowpea yield in 2006 was not influenced by cropping system.

Table 12: Sorghum and cowpea yield as affected by cropping system and soil and water conservation methods

Treatments	Sorghum grain yield (kg ha^{-1})	Treatments	Cowpea grain yield (kg ha^{-1})
No SEF + rotation	2147.7a	No SEF + rotation	1088.0a
SWC-tech + Ziziphus + Acacia + rotation	2040.0a	SWC-tech + Ziziphus + Acacia + continuous	1013.3a
No SEF + continuous	1480.0b	No SEF + continuous	981.3a
SWC-tech + Ziziphus + Acacia + continuous	1373.3b	SWC-tech + Ziziphus + Acacia + rotation	810.7a

Table 13: Maize, sorghum and cowpea yield as affected by cropping system and soil and water conservation methods in 2006

Treatment	Maize/cowpea grain yield kg ha^{-1} (Tamale)	Sorghum grain yield kg ha^{-1} (Navrongo)
Maize (R) + SEF	2404.0	1412.5
Maize continuous + SEF	2112.0	1225.0
Maize continuous-SEF	1935.0	1175.0
Cowpea in rotation	786*	-
lsd	ns	161.1

* Cowpea not included in lsd

Microdose

On-station

The least fertilizer rate-microdose (25% of recommended rate) almost doubled the yield of the control (Table 14). Net returns were negative for the no fertilizer treatment and the highest NUE was obtained with the microdose treatment. The sorghum variety used (Kadaga) responded poorly to fertilization. However, the microdose treatment out-yielded the control.

On-farm

Maize yield was nearly quadrupled by microdose over the control treatment but with sorghum, microdose fertilizer did not have any advantage over the control for the Kadaga variety used (Table 15).

Nitrogen Use Efficiency

Nitrogen Use Efficiency (NUE) was highest for the microdosing treatment (54 kg maize/kg N) compared to the earlier recommended rate (37 kg maize/kg N) (Table 16).

Table 14: Response of Maize and Sorghum (var. Kadaga) to different levels of Fertilizers in 2006 at Nyankpala (On-station)

Treatment code	Maize yield (kg/ha)	Sorghum yield (kg/ha)
8g NPK + 4g Urea per stand	2487.5a	1953.1a
6g NPK + 4g Urea per stand	2312.5ab	1703.1ab
4g NPK + 4g Urea per stand	2250.0ab	1703.1ab
2g NPK + 4g Urea per stand	2106.3b	1671.9b
8g NPK + 2g Urea per stand	2009.4b	1671.9b
6g NPK + 2g Urea per stand	1543.8c	1640.6b
4g NPK + 2g Urea per stand	1368.8cd	1640.6b
Microdose (2g NPK + 2g Urea)	1071.9d	1562.5b
T9 – Control	590.6e	1156.3c

Table 15: Response of Maize (Tamale) and Sorghum (var. Kadaga, Navrongo) to different levels of Fertilizers on-farm

Treatment code	Maize kg/ha	Sorghum kg/ha
T2	1774.3a	667.5
T4	1765.6a	647.5
T3	1111.4b	380.0
T1	1096.9b	420.0
T5	256.3c	285.0

T1=Improved (imp) Cereal +microdose, T2=Imp+recommended rate(RR), T3 = Farmer var+microdose, T4=Farmer Var+RR, T5=control

Table 16: Nitrogen Use Efficiency as affected by rates of application in maize at Nyankpala, 2005

Returns	T1	T2	T3	T4	T5	T6	T7	T8	T9
Maize yield (kg/ha)	2,581.20	1,593.70	2,118.70	1,543.70	2,518.70	2,231.20	1,431.20	1,362.50	0
N applied as SA (kg/ha)	31.5	31.5	31.5	31.5	15.75	15.75	15.75	15.75	0
N applied in NPK (kg/ha)	37.5	28.14	18.78	9.36	37.5	28.14	18.78	9.36	0
Total N applied (kg/ha)	69	59.64	50.28	40.86	53.25	43.89	34.53	25.11	0
NUE (Maize)	37.4	26.7	42.1	37.8	47.3	50.8	41.4	54.3	

T1 = 8g NPK + 4g Urea per stand; T2 = 6g NPK + 4g Urea per stand; T3 = 4g NPK + 4g Urea per stand; T4 = 2g NPK + 4g Urea per stand; T5 = 8g NPK + 2g Urea per stand; T6 = 6g NPK + 2g Urea per stand; T7 = 4g NPK + 2g Urea per stand; T8 = 2g NPK + 2g Urea per stand; T9 = Control

Tied-ridging (on-farm)

Tied-ridging increased maize yield above the non-tied ridge but the difference was not statistically significant (Table 17). Fertilizer, however, more than doubled the yield of maize under tied ridging and NPK as compared to zero NPK and tied ridging. This shows the importance of nutrients in these systems even if moisture is adequate.

Table 17: Effect of tied-ridging on maize yield on-farm in 2006 in Tamale

Treatment	Grain Kg/ha	Stover kg/ha
Tied-ridge+NPK	1444.9a	2775.5a
No tied-ridge+NPK	1208.2a	2714.3a
Tied-ridge-NPK	502.0b	1959.2b
No tied-ridge-NPK	412.2b	1857.1b

Tied-ridging (On-station)

Water harvesting increased the yield of maize over no water harvesting when maize is fertilized at Nyankpala at the recommended rate (Table 18). Similarly, manure addition increased the yield of maize with water harvesting compared with no water harvesting with manure addition. Water harvesting did not appear to positively affect cowpea whether manured or fertilized.

Table 18: Effect of tied-ridging and manure on maize yield on-station at Nyankpala, 2006.

Mainplot treatments	Subplot (Kg/ha NPK)	Cob weight (Kg/ha)	Maize grain yield (Kg/ha)
No Water Harvesting - Manure	60-30-30	2084	1709
	30-30-30	1938	1521
No Water harvesting + Manure	60-30-30	2031	1479
	30-30-30	1854	1354
Water harvesting - Manure	60-30-30	1563	1229
	30-30-30	1709	1188
Water harvesting + Manure	60-30-30	2177	1709
	30-30-30	1938	1542
Grand Mean		1912	1466

Further work of the coordination unit to improve the microdosing technology is guided by the fact that due to the small fertilizer applied and the increase biomass production resulting from this, concern was raised of the sustainability of the technology with regards to soil fertility. A long term experiment was installed on station at ICRISAT, with among other objectives study of crop productivity and soil water use. Few results over the last two year will be reported partially. The treatments tested were:

A: Crop variety: Millet crop was tested of which two variety, a local variety – Sadore local (A1), which matures after 120 days and the improved variety HKP (A2) that matures in 90 days

B: Planting density: Three density 5000 (density encountered in some farmers field – B1), 10000 (the recommended density – B2) and 15000 pokets (crops like sorghum are planted at that density – B3) per ha were used.

C: Fertilizer microdose – Three fertilizer application rates and control were used: Control (C1), DAP+1g of Urea at stem elongation (montaison) – C2, NPK at 6g per hill – C3, and NPK at 3g per hill.

In 2008 due to insect attack, which affects mostly the improved variety (Figure 5) grain yield was low on average compared to 2009 (Figure 6). In both years, grain yield increase due to application of microdose (Figure 7). Grain yield was similar for DAP+Urea and NPK. We should underline that 3g per hill gave similar yield as 6g NPK per. This show that to increase adoption by farmers there is still window to reduce the rate applied. However it is important to study the chemical status of the soil to learn more about the effect of this small amount of fertilizer application on the soil in the long term. Soil samples were collected and are still to be analyzed.

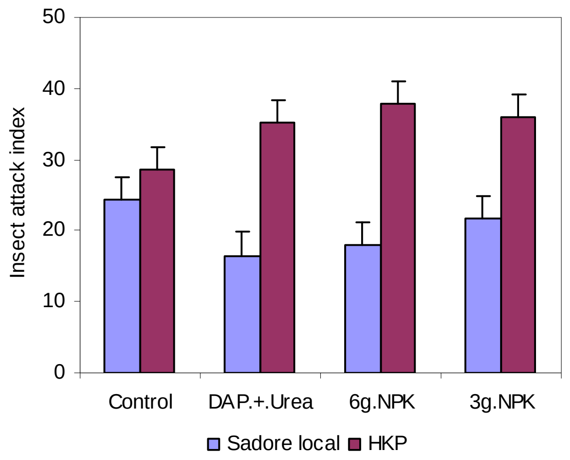


Figure 5: Index of insect attack as affected by variety and fertilizer application. Sadore 2008

Nutrient balance in the whole system is also needed as profuse plant growing due to the fertilizer application may result in plant nutrient uptake that may be higher than the amount applied.

In both years the local variety responded more positively compared to the improved one. Planting density affected all observed parameters as the lowest density produced the least effect however it is important to underline, that the effect of 10000 hill per ha was similar to that of 15000 hills.

Crop water use was monitored in both years but so far we report only results of the first year which shows that in terms of grain production the local variety produced more grain per unit of water when fertilizer was applied as compared to the improved one (Figure 8). As far as total biomass production was concerned, only DAP + Urea increased biomass produced per unit of water used for the improved variety (Figure 9).

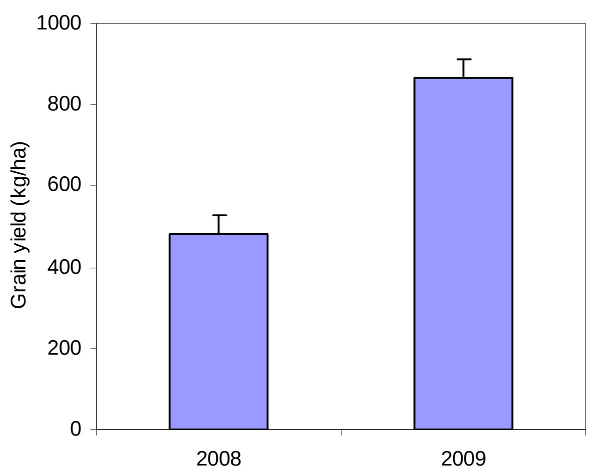


Figure 6: Grain yield in both years averaged over all treatments at Sadore

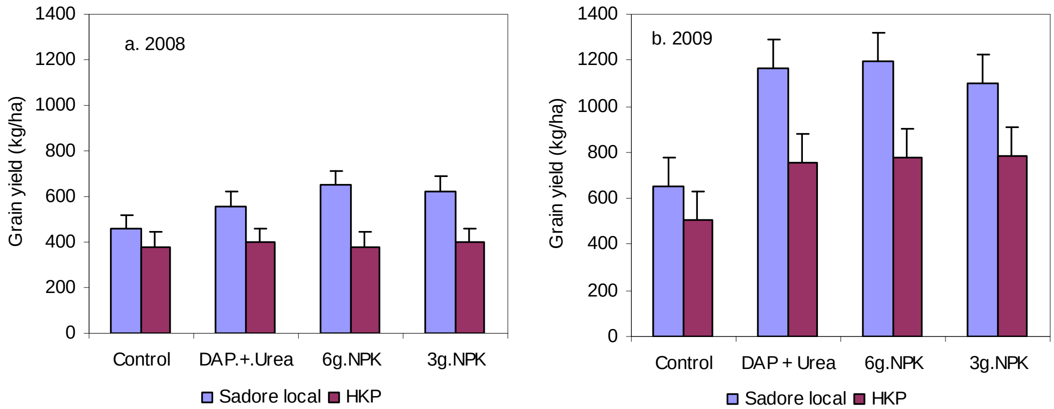


Figure 7: Effect of fertilizer microdose application and variety on millet grain yield; Sadore 2008 and 2009

Application of 3g NPK per hill was even more responsive than 6g per hill and DAP + Urea, which point to the advantage of using this rate as it is smaller, which makes it more attractive from the point of view of it affordability by small holder farmers.

This experiment continues as it will help us answer the many question that are still asked concerning the sustainability of the technology.

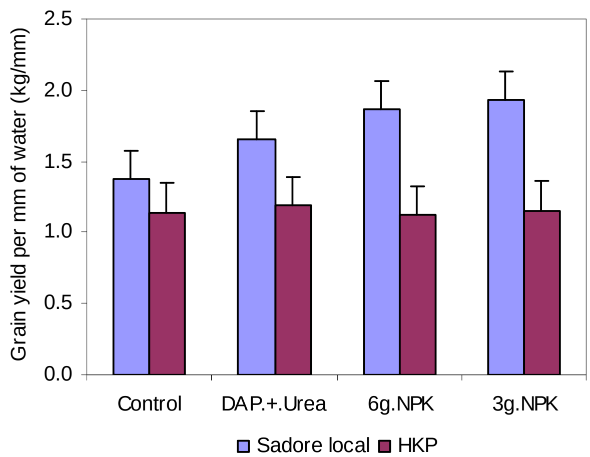


Figure 8: Millet water efficiency as affected by fertilizer microdose application and variety; Sadore 2008

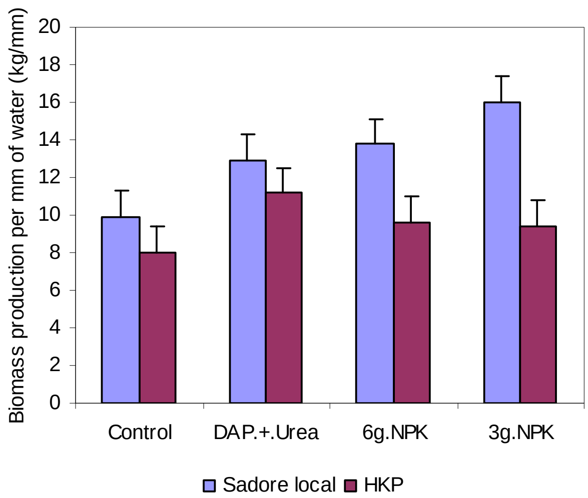


Figure 9: Millet biomass production per unit water as affected by fertilizer microdose application and variety; Sadore 2008

Conclusions

A biophysical and socio-economic characterization of the four project sites, namely Ziga and Saala in Burkina Faso; and Tamale and Navrongo in Ghana was done, which constitute the baseline information that provides a reference point against which we can measure progress due to the impact of the project. A list of promising technology was drawn in consultation with farmers and other stakeholders and a few selected ones such as the tied ridging, zai system and stone lines were evaluated in partnership with farmers. Additional best bet technologies such as fertilizer microdosing and the Sahelian or Sudanian Eco-Farm (SEF) were also tested on-station and on-farm. Overall these improved technologies performed better than the farmers practices*.* The adherence of the farmers involved in the various tests and there participation were sign of the enthusiasm of communities involved to learn and addop the those technologies through the project

Objective 2:
To develop and validate methodologies, approaches and modern tools (GIS, models, farmer participatory approaches) for evaluating and promoting promising water, nutrient and crop management technology options.

Methods
The project uses modeling and GIS tools, combined with participatory approaches that can help develop new production system configurations and evaluate their resilience, sustainability and profitability under different biophysical, social and economic conditions. We use the DSSAT (Decision Support System for Agrotechnology Transfer) and APSIM (Agricultural Production Systems Simulation) for analyzing how different soil, nutrient, climatic and land management strategies affect the performance and yield of a range of crops. DSSAT is a model that is widely used in both developed and developing countries, but with the recent addition of a new soil organic matter (SOM) / residue module (based on the well-known CENTURY model) its applicability to low-input systems, where fertilizer use is modest and most nutrients come from SOM/residue decomposition, has improved considerably (Gijsman et al., 2002). This combined model is referred to as DSSAT-CENTURY.
The latest version 4.5 incorporates more than twenty five crops: maize, wheat, barley, rice, sorghum, millet, dry bean, fababean, soybean, velvet bean, peanut, chickpea, cowpea, pigeon pea, cassava, potato, sugarcane, sunflower, tanier, taro, bell pepper, cabbage, tomato, pineapple and Bahia and Brachiaria grass. DSSAT-CENTURY not only estimates the development and yield of different crop species and cultivars under diverse land management practices concerning fertilization, irrigation, organic applications and crop rotations (including fallow cycles), but also analyzes the long-term sustainability and environmental aspects concerning SOM levels, denitrification and water use by the crop. Presently, the model only deals with the nutrient nitrogen (N), but work is on the way for adding phosphorus (P) and it is expected that this will be available soon. For analyzing the long-term effects of various cropping systems, many years of historical weather data are needed to have a sufficiently wide range of site-specific weather conditions. This is often not available, either because the specific site does not have a weather station or one with no historical data. This limitation will be addressed by using the MarkSim weather generator (Jones and Thornton, 2000), a tool that generates weather data for any point in the tropics by interpolating among several neighboring weather stations. MarkSim produces daily data on maximum and minimum temperature, precipitation and radiation, based on historic data and estimations (mostly radiation).

Activities
Calibrate and adapt the DSSAT-CENTURY and APSIM cropping systems model for the conditions of the Volta Basin

2.1 Collect ground truthing (land use), satellite and weather data and produce long-term weather data with MarkSim
2.2 Calibrate and adapt the DSSAT-Century and APSIM cropping systems models
2.3 Get experience with the WEPP model
2.4 Build scenarios for selected technologies and perform preliminary simulation analyses using DSSAT

Relevant weather data purchased, assembled and shared with research partners

Data were assembled from a total of 22 stations in Northern Ghana spanning a period of 20 to 54 years in collaboration with CPWF PN06. Most of this data has been cleaned and digitized.

Calibrate and adapting DSSAT cropping system model
This work was done in a PhD work carried out during the course of the project but also in the process of three courses on DSSAT cropping system model. As a result of the training, 12 chapters were identified, which are to be published in a book entitled: Improving Soil Fertility Recommendations to Smallholder Farmers in Africa through the Use of Decision Support Tools.

Two experiments were conducted in Ghana. One with the objective of validating fertilizer recommendations for maize in northern Ghana and data was to be used to calibrate DSSAT model and simulate N response for a period of 30 years. The experiment was done in collaboration with University for Development Studies (UDS). Data was collected by a B.Sc. student for his thesis. The levels of the nitrogen were 0-30-60-90-120 kg/ha and for each level except zero, 30 kg/ha P_20_5 and 30 kg/ha K_2O were applied. The data were also used for one of the chapters or the book mentioned above and will be reported on shortly later.

The second experiment was conducted during the 2005 cropping season at Pungu, Navrongo, in the Upper East region of Ghana (bordered by latitude 10° 15” and 11° 10” N and 0° and 1° 0” W) in the semi-arid region (a transition between Guinea and Sudan savanna ecological zones of Ghana. Experimental data used for the calibration of the DSSAT model, were principally generated from two planting date trials conducted in Pungu, in the Upper East portion of the Volta basin (Ghana). The cultivar used was ICSV 111, a pure-line cultivar developed at ICRISAT. Sorghum was cultivated under optimum conditions (no water or N limited growth conditions). The plants were monitored and phenological data which included planting date, date of flowering, date for grain filling date of maturity and date of flag leaf stage. These days were noted when 50 % of plant population attained that stage. Final total biomass and grain yield were also measured from a plot size of 9 m^2 by harvesting aboveground biomass and separating them into the various components according to the procedure described in Hoogenboom et al., 1999. Four different levels (0, 40 80 and 120 kg N ha^{-1}) of mineral N fertilizer in the form of sulphate of ammonia were applied in the homestead farms as well as the bush farms in an experiment set up in a randomized complete block design. The treatments were replicated seven times in the homestead and four times in the bush farms. Sorghum was planted at distances of 70 x 25 cm. Data was collected on final total biomass and grain yield as indicated above.

Model calibration

Soil water balance and soil water holding characteristics

For both experiments, the water content at field capacity or drained upper limit (DUL), lower limit of plants available soil water (LL), saturated upper limit (SAT), saturated hydraulic conductivity (K_{sat}), and root growth factor (RF) for each soil layer were estimated by entering soil particle size distribution, bulk density, organic matter and gravel contents into soil file creation utility (Sbuild).
In the second experiment, soil water dynamics was determines as the method described in the soil water balance sub model and is described in detail in Ritchie (1985). DUL and LL were determined in the laboratory using pressure plate method and SAT also determined by determining soil water contents of core soil samples that have been saturated with water. Bulk density was determined using the core sampling method.

Calibration of Genetic coefficients

The DSSAT Model was calibrated for genetic coefficients of the maize variety Obatampa. As these coefficients were not available, for the maize variety used in the experiment, the medium season maize variety in the cultivar file MZCER040.CUL in the DSSAT v4 model was used as starting point from which to calibrate Obatampa. Genetic coefficients were determined by manipulating model simulation against data. Coefficients for duration from flowering (EM-FL), duration from flowering to seed (FL-SD) and duration from seed to maturity (SD-PM) were adjusted to predict the observed life cycle.

Simulation

The seasonal analysis module of DSSAT v4 was used to simulate performance of nitrogen fertilizer rates for 2006 and 24 years. An economic analysis was carried out to quantify net returns for each treatment, taking yield and prevailing product price into account. After obtaining the distribution of economic returns, strategy analysis was also carried out to determine the most profitable level of N using the mean-Gini stochastic dominance.

In addition to the work conducted in Ghana for the both theses, several attempts were also made as a result of three training workshops organized by the PN5. Some of these studies concerned:
Tillage, rotation and surface residue effect on crop water productivity in Nyabeda, western Kenya, which is on a long-term conservation tillage experiment established in western Kenya in March 2003 to investigate how different tillage systems and residue management under predominant cropping systems affected crop productivity.
Another study was on the effect of integrated soil fertility management technologies on the performance of millet in Niger. Simulation model was used to understanding the processes. This study was conducted on five years data on three sites in Niger (Banizoumbou, Bengou and Karabedji) to understand the performance of millet crop under fertilizer treatments and water stress.
Assessment of maize response to nitrogen fertilization in the northern savannah zone of Ghana using a mechanistic computer simulation model was also done as response of maize to nitrogen in the northern Guinea savanna agro-ecology of Ghana was evaluated using the Seasonal Analysis component of the Decision Support System for Agrotechnoloy Transfer (DSSAT 4.02) - Cropping System Model (CSM). This was an outcome of the BSc work reported earlier.
In a study conducted in Kenya, attempt was made to determine and evaluate the genetic coefficients of dual purpose soybean varieties for the CROPGRO-soybean model using variety screening trials. Model calibration was done using a stepwise procedure to derive the genetic coefficient for individual cultivars required for the CROPGRO model which has never been tested (evaluated) in the Kenyan conditions
Another study on water use and yield of millet under the zai system was also carried out as emphasis was on understanding the processes using simulation. In this study, the effect of three planting techniques (Flat, zai pit of 25cm and zai pit of 50cm diameter) and three fertility management options (control, crop residue, cattle manure) were tested at Damari in 1999 in Niger. Data from that experiment were used to determine if the CERES-Millet model of the Decision Support System for Agrotechnology Transfer (DSSAT) is sufficiently robust to predict yield response to the zai water harvesting system

Results and discussions

Ghana

A quick Bird 8x8 km sub scene was purchased to characterize initial conditions for the Navrongo project 5 sites in Ghana. A professional grade Trimble GeoXM DGPS unit was acquired for field surveys. Land use maps were generated using satellite imagery LANDSAT ETM+

An area 1 x 2 km has been selected and marked at 100m x 100m (grid) interval for soil characterization. An area of about 1 x 2 km was mapped to generate a DEM with 30 m resolution in the Navrongo section of the Volta basin

Modeling work with DSSAT
We will first present the findings of the PhD work on the model calibration using sorghum and then some results from the DSSAT training workshops. Results of DSSAT calibration for N fertilizer using maize are presented in a thesis added in annex to this report.

Results of the PhD work
Grain yields on the homestead fields and bush farms
Grain yield measured from experimental field ranged form 1.43 t ha^{-1} with no inorganic N fertilizer application, to 4.4 t ha^{-1} grain at 120 kg N ha^{-1} application in the homestead fields. In the bush-farm fields, yield ranged from 0.63t ha^{-1} grain in the control to 3.77 t ha^{-1} grains at 120 kg N ha^{-1} application. The very Significant ($p=0.05$) grain yield increases in sorghum cultivation were observed between the homestead and bush farms for all levels of inorganic N fertilizer application. Grain yields were, however, higher at all levels of inorganic N applications on the homestead fields

than on the bush farms. Low yields in the control which is a normal practice of farmers explain their reluctance to crop the bush-farms for sorghum. The yield gaps between the two sites were not compensated by the application of as much as 120 kg N ha^{-1} an indication that inorganic N is not the only yield limiting factors. This means that inorganic fertilizer alone can not solve crop production problems on poor soils with low organic matter content. Yield differences are more likely to be attributed to the differences in the soil organic matter, which in turn affects soil structure and water holding capacity of the soils. This is a property, which is very important in this area due to the erratic nature of rainfall pattern. Thus, for sustainable crop production on the bush farms, inorganic fertilizer must be complemented with measures to increase soil organic matter content.

Model calibration and evaluation

Weather and phenological data for each planting date experiments were used to determine two different sets of genetic coefficients. The radiation use efficiency of 3.2 g plant dry matter/MJ PAR was adjusted to 3.8 as used for sorghum in DSSAT version 3.5 (Ritchie et al., 1998) as the model was under predicting yield. The set genetic coefficient with the lower RMSE was selected as the more appropriate set of genetic coefficients of the cultivar (Table 19).

Table 19: Comparison of predicted and measured total biomass and grain yield from DSSAT model using two planting dates data sets.

Parameter set	Grain (t ha^{-1})	Total biomass (t ha^{-1})
200 C	0.56	0.73
200 D	0.69	0.77

Sorghum grain yield in response to different application of mineral fertilizer was reasonably predicted by the DSSAT – CSM with a RMSE of 0.44 t ha^{-1}. Pair-wise comparisons of observed and simulated values indicate no significant difference ($p = 0.05$). The RMSE measured were also low, 0.65 and 0.60 t ha^{-1} for the bush farm and homestead respectively.

These results are comparable to those of Mavromatis et al., 2001 in their study on developing genetic coefficients for CSM with data set from crop performance trials. Simulations on the homestead were organic manure was applied were better than those on the bush-farms, a probable indication that the model simulates organic fertilizer which is an important source of nutrient for the study region well. Total biomass was generally well predicted (Figures 10) within the standard deviation of measure values, except for the treatment with 40 kg N ha^{-1} were the simulated values were overestimated and out of the range of the standard deviations. The same trend stands for grain yield

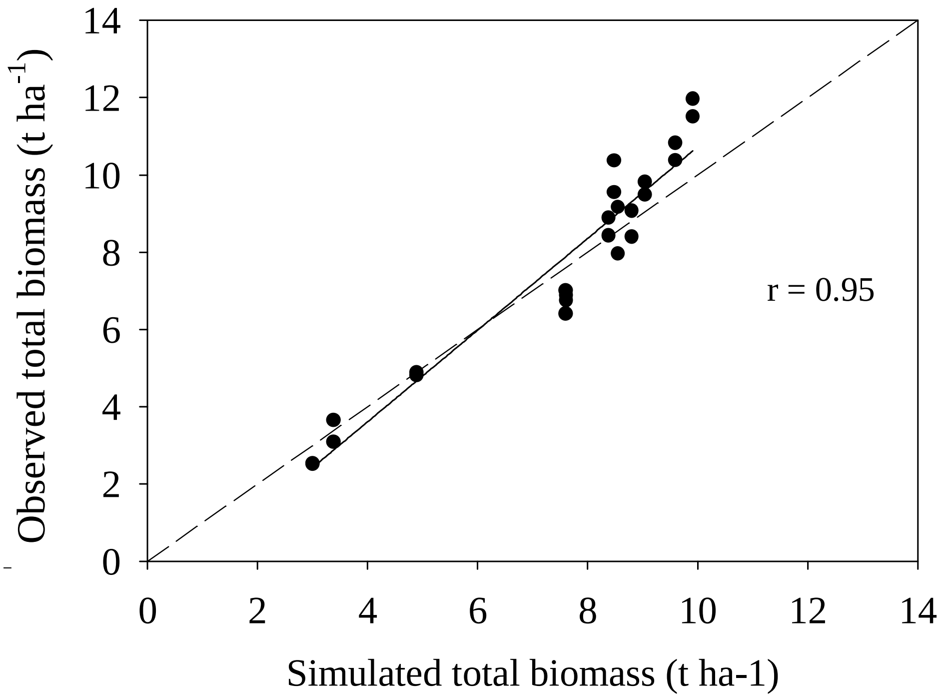


Figure 10: Comparison of measured (mean) total biomass yield of Sorghum and simulated yield values under different rates of inorganic N applications on the homestead and bush farms

Nutrient and water use efficiencies of smallholder systems

Agronomic N use efficiency (AE_N) in the homestead fields Regosol ranged from 25 kg grains kg^{-1} N at 120 kg N ha^{-1} to 34 kg grains kg^{-1} N at 40 kg N ha^{-1}. On the bush farm, the AE_N of sorghum ranged from 26 kg grains kg^{-1} N at 120 kg N ha^{-1} to 45 kg grains kg^{-1} N at 40 kg N ha^{-1}. Thus, AE_N was generally highest at low N application rates in both management systems, a trend which is comparable to that observed by Mushayi et al. (1999) and Zingore et al. (2007). The partial factor, an index of nutrient use efficiency calculated for each management system also indicated a similar trend of decreased nutrient use efficiencies with increasing application of inorganic N fertilizer (Figure 11). Though the homestead fields produced higher yields than the bush-farm fields, the agronomic efficiencies were generally higher in the later due to the higher yields from the control in the homestead compared to lower values for the bush-farms used in the calculations. Agronomic use efficiency is therefore not an appropriate index to compare different management system. The partial factor index provides a better basis for this comparison. It however, does not account for inherent soil N content of the different management systems. Decreasing efficiency of N use with increasing inorganic N fertilizer application in both systems is a situation, typical of poorly managed and depleted sandy soils (Mushayi et al., 1999; Dobermann, 2005; Wopereis et al., 2006). There is therefore, the need to identify the most appropriate level of inorganic fertilizer to be applied, given that it is a limited resource in the study area. The differences in nutrient use efficiencies shown in this study between the different management systems in light of the variable soil fertility conditions and responses to inorganic N applications, provides a basis to discourage the current practice of "blanket" fertilizer recommendations

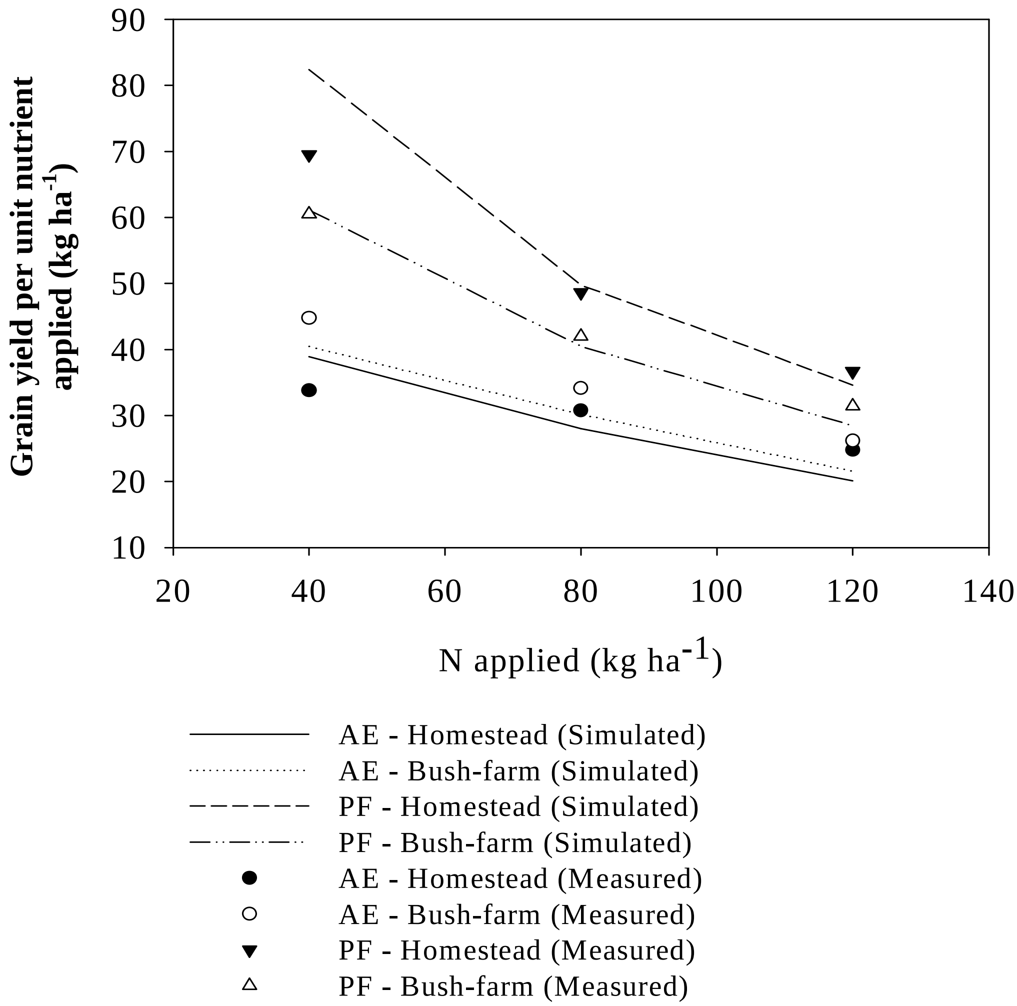


Figure 11: Influence of amount of mineral N applied on the efficiency attained in grain sorghum production in smallholder farming systems

Unlike the efficiency of nutrient use, water productivity increased generally, with increasing application of N fertilizer and was higher in the homestead compared to the bush-farms (Figure 12). It is therefore evident that the supply of adequate water through supplementary irrigation is necessary for efforts towards increasing crop yield to achieve desired objectives and not through only increasing N application.

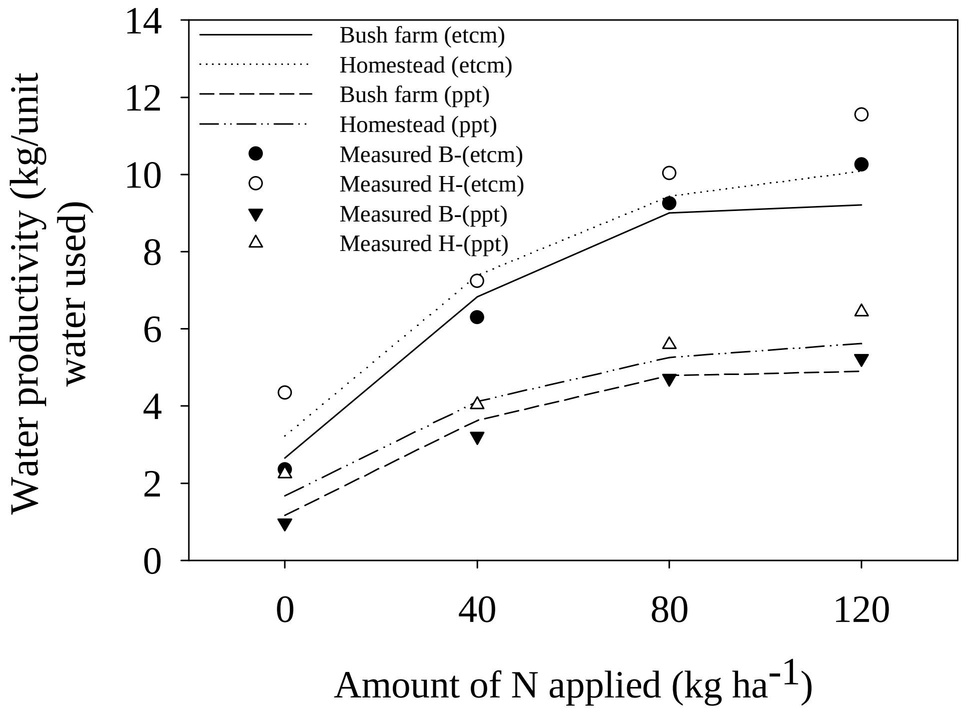


Figure 12: Influence of amount of Nitrogen fertilizer applied on the water productivity of sorghum on both the homestead and bush farms

Model application

Since farm management has much to do with managing risk, and its impact on food security and this risk one main reason for low pace in adopting new technologies (Walker and Ryan, 1990), a value to cost analysis was carried out. A value to cost ratio based on field data, indicated that application of 40 kg N ha^{-1} yielded the highest benefit to farmers on the homestead whilst 80 kg N ha^{-1} yielded the highest value to farmer on the bush farm. Thus mineral fertilizer can be used in both the homestead and bush farms with benefits accrued to farmers.

Sorghum grain yield at 40 kg N ha^{-1} in the homestead were similar to those at 80 kg N ha^{-1} in the bush farm over the projected years (Figure 13). The higher grain yield in the homestead at half the amount of mineral fertilizer applied in the bush farm can be attributed to the multiple benefits provided by the organic manure. Yield projections into 2035, highlighted that, the amount and distribution of rainfall poses a higher risk to efficient use of mineral fertilizer on both management systems, with the risks being higher in the bush farm soil with lower organic matter content as opposed to the homestead soils which are relatively enriched by the application of manure. Grain yield over the simulation period varied within each management system with or without mineral fertilizer application. Variability is however less with the presence of organic matter (homestead compared with bush-farm without fertilizer use). Differences in yield due to organic matter application resulted in 49% increase in grain production without applying inorganic fertilizer. Hence, farmers can improve crop yields through organic matter application. It also reduced the variability in water productivity from 31 % to 13 %. Also, applying inorganic fertilizer reduced the uncertainty of low grain production from 13 % to 7% in the homestead and from 31 to 10 in the bush-farms.

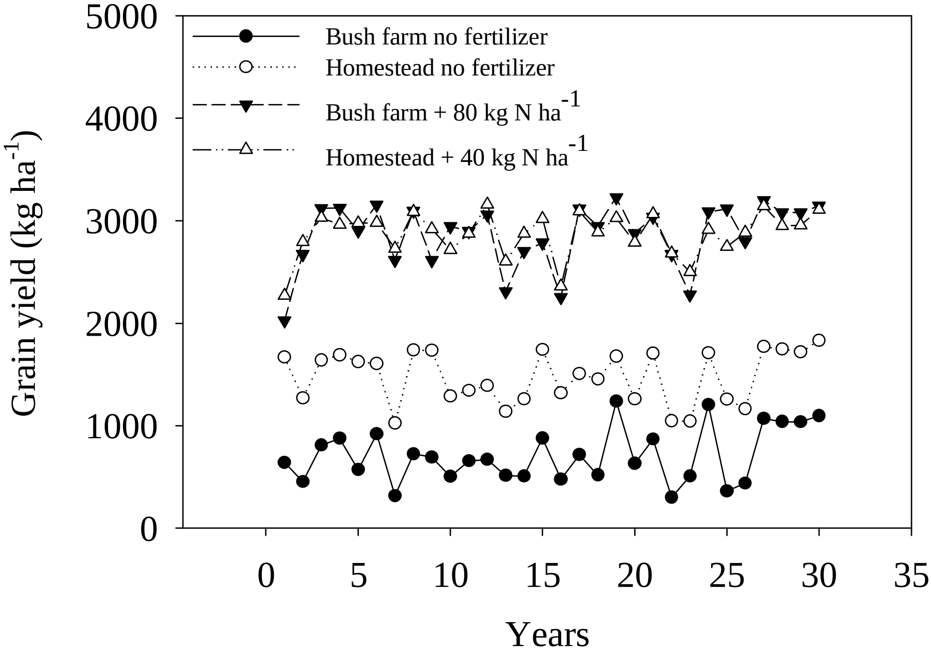


Figure 13: Seasonal dynamics in yield of sorghum under the different scenarios over the simulation period (30 years) in both homestead farms and bush farms as affected by projected weather phenomenon in Navrongo, Ghana.

Some results of the training workshops

The study on tillage, rotation and surface residue effect on crop water productivity in Nyabeda, western Kenya, which is a long-term conservation tillage have shown that phosphorus and nitrogen application had a large effect on crop water productivity (CWP). Under maize-soybean rotation, P application increased CWP by 120% while application of N in plots already receiving P increased CWP by a further 35%. At low rainfall, up to 30% higher yield due to crop residue (CR) application was observed under reduce tillage. However, effectiveness of CR in increasing productivity decreased linearly with increasing rainfall (R^2 ~0.9 to 0.7). Also, organic matter decay was fast (daily % loss of $106e^{-0.019x}$) requiring supplementation of crop residue with seasonal litterfall, achieved when a legume is incorporated. Compared to continuous cereal, rotation system had more simulated extractable soil water for most of the period, and its yield vs extractable water (for the first month) had weaker correlations. Seasonal CWP of maize grain yield ranged between 0.2 and 1.1kg m^{-3} and was negatively correlated with rainfall (R^2=0.57). Without ripping, productivity tended to be lower in reduced tillage compared to conventional tillage.
The predicted yield compared very well with the yields observed from field experimentation. With the right genetic coefficients, DSSAT is an excellent model for simulating production of maize and soybean. Decreasing crop water productivity with season rainfall shows the need for investigating and eliminating obstacles to higher productivity. Crop residue application is necessary to cover the soil surface before plant canopy is optimized. The crop residue should be left as surface mulch to avoid crop nutrient limitation following immobilization in the event of incorporation. Ripping and sub-soiling can enhance productivity within conservation tillage systems. Rotation of maize and soybean increases productivity of maize through conserved soil water. Nitrogen and phosphorus fertilization are necessary to achieve higher crop water productivity.

In the study on the Effect of integrated soil fertility management technologies on the performance of millet in Niger conducted at three sites for five years, it was found that there is always risk in crop management during the rainy season. The simulation has shown that crop under fertilizer treatment are more affected by water stress. During the five years experiment crops have never

been destroyed by water stress and yield was increased with the use of fertilizer. Farmer's practice was not affected by water stress caused by dry spells on other treatments. It means that annual rainfall was enough for millet crops and fertilizer especially P is more limitative since crops yields under fertilizer are improved although some dry spells occurred during the cropping season. It's also shown that only water stress at the grain filling period have affected millet grain yield where as stover production was not affected. Farmer's practice was always deficient with and without water stress.
Water stress affecting crop yield occurred in September corresponding to the end of the rainy season. If we can not control weather, we can adapt our cropping systems to get the maximum benefit from natural resources. If millet production is low in Niger, it's mainly because technologies adapted to the weather conditions are not adopted. Simulations on nitrogen have shown that yields simulated are always better than measured.
Although annual rainfall was sometime higher in the studied sites, yields still lower. Therefore in the context of the Sahel except for water other factors contribute to the low yield and production. DSSAT is a tool that can be used to partition the influence of different factors of crop production especially fertilizer and water

In the study on the assessment of maize response to nitrogen fertilization in the northern savannah zone of Ghana using a mechanistic computer simulation model, a simulation was performed for crop growth, development and yield of maize run for a site at Nyankpala near the University for Development Studies in the northern savanna agro-ecology. A field trial consisting of 5 nitrogen rates (0, 30, 60, 90, 120, kg ha^{-1}) with 30 kg K_2O and 30 kg P_2O_5 ha^{-1} was simulated for 24 years using measured daily weather and soil records for the sites. The results showed that increasing levels of N up to 120 kg/ha increased maize grain yield at a diminishing return. The model accurately simulated maize grain yield up to 90 kg/ha nitrogen application but failed to accurately predict maize grain yield when nitrogen was applied at 120 kg/ha. Excessive water stress induced by high N application negatively affected the growth of maize. Maize production was not profitable at N application rate ≤ 30 kg/ha. DSSAT CSM can be used to accurately predict maize growth, development and yield in Ghana if well calibrated.

The study to determine and evaluate the genetic coefficients of dual purpose soybean varieties for the CROPGRO-soybean model using variety screening trials was conducted in Kakamega in western Kenya. Data were collected on plant development and growth characteristics, soil characteristics, weather and management as required for determining genetic coefficients of a new cultivar. Soybean cultivars (7 improved, 1 local) were grown per site on plots for two years. Receiving 50kg/acre of DAP fertilizer at planting as starter fertilizer. The data was then used for model calibration, using a stepwise procedure to derive the genetic coefficient for individual cultivars required for the CROPGRO model which has never been tested (evaluated) in the Kenyan conditions. The results showed that the derived genetic coefficients provided simulated values of various development and growth parameters that were in good agreement with their corresponding observed values for most parameters. Model evaluation with an independent data set gave similar results. The differences among the cultivars were also expressed through the differences in the derived genetic coefficients. The model can reliably be used for further simulations to gauge the performance of the soybean varieties under different environments in Kenya. It is also possible to use this model for breeding purposes (Banterng et al., 2004) of new improved varieties of soy beans and other legumes. However there is need to include more characteristics in determining the genetic coefficients in order to make it more reliable. Furthermore, it is imperative that, data for more sites be used to validate the model (Piper et al., 1998).

The study on Water use and yield of millet under the zai system was also carried out as emphasis was on understanding the processes using simulation was conducted under conditions that are totally different of those under which the DSSAT model was developed. Therefore it helped stretched it area of application. These conditions are: low and erratic rainfall, its poor distribution within the growing season, prolonged dry spells, lack of adequate water supply due to soil physical degradation (soil crusting) and nutrient shortage. The effect of three planting techniques (Flat, zai pit of 25cm and zai pit of 50cm diameter) and three fertility management options (control, crop residue, cattle manure) were tested at Damari in 1999 in Niger. Soil water was monitored from weekly measurement using Didcot Wallingford neutron probe throughout the growing period.
Data from that experiment were used to determine if the CERES-Millet model of the Decision Support System for Agrotechnology Transfer (DSSAT) is sufficiently robust to predict yield

response to the zai water harvesting system. The model simulated the observed yield response of the control and the manure amended plots with high r-square (0.99), low residual mean error square (340 kg.ha^{-1} for above ground biomass and 94 kg.ha^{-1} for grain yield) and high d-statistic (0.99), but this was not the case for crop residues which was over-predicted. Soil water content and extractable soil water were also well simulated for the control and manure treatments. This evaluation of DSSAT provides a starting point for research to evaluate the performance of these technologies over wider areas in West Africa. The application of models for such studies must be interpreted in the context of limitations of the model to address some constraints. Nevertheless, for the highly variable crop responses due to interacting effects of rainfall, management and adverse soil conditions in this region make this an extremely important approach in planning for technology adoption in an area and in interpreting results from experimental field research.

Conclusions

From the analysis of the results reported earlier, a lot of progresses were achieved in the calibration of the DSSAT model during the course of this project. The model was tested in a wide range of conditions that helped to evaluate its robustness. According to the results in most case the simulated values were similar or closed to the observed one particularly if proper calibration was done. However due to the harsh condition in the semi-arid of Africa more work needs to be done for the model to respond to those conditions. Another limitation in the model is the development of the P model for some important crops in West Africa such as millet. Under sahelian condition where P is the most limiting factor for crop production, developing the P module for this crop would be an important achievement. Some works are being done in this direction and we hope that in the near future a great progress will be achieved

Training

An MSc Student has established an evolution map of land degradation and its rehabilitation in the Ziga region: comparison of 3 periods (1986, 1992 and 2002) using aerial photos (1986) and landsat image (1992, 2002); the 1986 map is completed while the landsat image for land use analysis is still being processed,

A training course on DSSAT (Decision Support System for Agrotechnology Transfer) was held on 23-28 August 2004 in Arusha, Tanzania: Thirty three (33) participants attended the course. Two PN 5 partners from Burkina and three from Ghana were trained. A web page was developed for this workshop. A second Advanced DSSAT4 (Decision Support for Agro-technology Transfer) training Workshop" Assessing Crop Production, Nutrient Management, Climatic Risk" was held on 19-30 October 2005 in Accra, Ghana. A total of forty (40) participants attended the course (4 PN5 members from INERA, Burkina Faso and 3 PN5 members from SARI, Ghana and other scientists/technicians) attended the course. A third advanced DSSAT4 (Decision Support for Agro-technology Transfer) training Workshop" Assessing Crop Production, Nutrient Management, Climatic Risk" was held on May 28 to June 02, 2007 in Mombasa, Kenya.. A total of twenty (20) participants attended the course. The main aim of this advanced workshop was to advance the target scientists' knowledge of the full capabilities of DSSAT through own data simulations and interpretations. Case studies that were developed and presented by the participants at this workshop are being assembled into a special publication. During this training participants spent the entire week working on their data with the help of Jim Jones and Gerrit Hoogenboom. Participants are now writing their scientific papers using the results of the simulation done with DSSAT

A further 10 PN5 partners from Burkina Faso were trained in the use of DSSAT on 10-12 May 2005 in Ouagadougou by participants who attended the Arusha workshop on DSSAT.

Six (6) PN5 partners from Burkina attended a training course on Decision Support Tools i.e. SIMFIS (Simulating Mixed Farming in the Sahel) in Ouagadougou, Burkina in December 2005.

A training workshop on Participatory Research and Scaling-up and out was held in Nairobi, Kenya on 19-30 September 2005. Approximately 38 participants from Burkina, Ghana, Kenya, and Niger attended the course.

INERA and SARI staff trained in DGPS and spatial data collection in Navrongo. This training was conducted in April 2006 at Bolgatanga. Follow up practical training is required to improve skills of scientists.

A training course on land degradation was conducted by UNU-INRA in Accra, Ghana in June 2004: Eighteen (18) participants and project 5 partners from Burkina Faso, Ghana, Togo, Guinea and Nigeria participated in the course;

Objective 3

To improve market opportunities for small holder farmers and identify market institutional innovations that provide incentives for the adoption of improved water, nutrient and crop management technologies.

Methods

The project adapted a methodology for Participatory Market Research (PMR) and Rural Agroenterprise Development (RAeD) developed by CIAT, and other available approaches for gathering market intelligence and assessing market supply and demand chains. PMR and RAeD are based on a territorial or community approach to help rural communities to identify and evaluate market opportunities, select options for both food security and income generation, and develop integrated agro-enterprise for niche markets. A resource-to-consumption approach should assist rural communities in identifying new marketing or post-harvest processing opportunities that increase their income, and returns to land and labour, and provide incentives for investment in efficient water and nutrient use technologies.

The PMR methodology that is used in this project has the following major steps:

- Participatory diagnosis and community planning to identify income generating opportunities
- Collection and systematization of existing market and technical information and detection of gaps
- Market and enterprise visits to collect additional market information and market intelligence
- Characterization of different options, evaluation and selection of options
- Determination of research topics for future options
- Design of integrated agro-enterprise projects

The PMR process aims at: a) encouraging farmers, as part of the participatory learning and action research processes, and with targeted facilitation and capacity building to form marketing lobbies and collective action in marketing; and b) building community business skills and strengthening their entrepreneurship skills; c) providing market information, d) linking the pilot villages to the private commercial sector agro-enterprise business.

The project addresses issues concerned with social and rural development and involves working with government ministries and the private sector to make changes that would improve the efficiency and effectiveness within the supply chain**.** A combination of work at the policy and enterprise levels was used, which aimed to improve supply chain efficiency. Efficiencies achievement was targeted through (i) policy changes that support agro-enterprises, (ii) improving organisational structures within the market supply chain, (iii) developing sustainable support services that deliver useful marketing and technical information to specific sectors (iv) finding ways that enable small and medium-scale enterprises to access fiscal and technical business support tools and advice to improve their decision making. Examples of this work include the provision of market information services, development of ethical trade links for products, and the development of business models to foster more dynamic change events within enterprise clusters. The aim is to improve competitiveness of small scale farming.

This also involves improving input accessibility, focusing on ensuring supply, empowerment, and gender differentiation. To build stakeholders' capacities to secure and manage production factors, emphasis was on the development of efficient and affordable credit and extension systems together with farmers' cooperatives.

Activities

3.1. Facilitate participatory market research to identify and evaluate market opportunities for diversifying crop production and develop sustainable systems for production of high value crops for niche markets

3.2. Improve understanding and knowledge of market systems, market institutional innovations that provide incentives for small-scale farmers to adopt and invest in water and nutrient use efficient technologies
3.3. Link technology development to market opportunities identification and community enterprise development to provide incentives for adoption of improved water and nutrient use efficient technologies
3.4. Identify new market opportunities and market institutional innovations for developing sustainable community agro-enterprise which enhance and promote better water and nutrient management options
3.5. Develop and disseminate market information systems to rural communities and service providers
3.6. Improve input-output marketing systems,

Ghana

Although a general knowledge exists on problems and limitations of food marketing in Ghana, adequate studies and documentation on the specifics of issues affecting commodity marketing in the country are limited. A study was conducted which overall objective was to identify and delineate key agro-enterprises with potential market demand.

Specifically, the study focused on the identification and evaluation of:

- Scarce products of limited supply,
- High demand products,
- Trends of supply, demand and prices, as well as
- Stakeholders of the agricultural commodity trade in the markets and
- The existing savings and credit practices of market operators as well as
- Related problem

The limitation of time and logistics support prevented the estimation of the overall volumes traded annually and the evaluation, selection and training of marketing facilitators and the development of enterprise groups among others.

The collection of primary data involved a Participatory Market Research (PMR) approach with limited questionnaire administration to traders and institutions identified as important players and stakeholders in food marketing. Documentation information on food marketing was also used to supplement data on market storage facilities and procedures of food marketing in Ghana.

For reasons of their importance as major wholesale markets for the sale of grains legumes and cereals in northern Ghana, the Tamale and Bolgatanga regional markets were selected as the major data sources for the survey.

Burkina Faso

Warrantage or inventory credit system

Warrantage is an inventory credit system that is based on storing agricultural products by organized producers in reliable warehouses and the provision of micro-credit from decentralized financial structures. It helps farmers to avoid selling their product at harvest when the prices are low. The amount of the credit depends on the value of stocks at harvest and is used to undertake dry season income generating activities. The producer who stores his harvest receives its worth/value as if he had sold it. After settlement of his credit, 5 to 6 months later, he or she takes possession of his/her harvest for which he can obtain more money with the increase of prices.

The objective of warrantage is essentially to help develop and strengthen community producer organizations by providing micro-credits for income generating activities. The substantial incomes derived are used to acquire inputs, the basis for adopting technologies in order to increase productivity and ensure food security

The warrantage operational framework is as follows:

(i) a functional producer organization with a framework for informing, training and sensitizing partners; (ii) a decentralized financial structure which provides the credit; (iii) a warehouse with a double padlock system (which can only open in the presence of representatives of the producer organization and the financing structure), a joint management which allows the secured storing of products after harvest; (iv) an agricultural input shop (fertilizers, seeds, pesticides, etc.) to ensure availability of inputs in quality and quantity and the supply to producers.

The comparative advantage of warrantage is its flexibility as the stock represents a security for the decentralized finance structure. The producer benefits from his income generating activities at the settlement of his debt and also from the increase in value of his stock sold a few months later. The generated increase is estimated to range between 30 and 50% of the initial value of the secured stock.

Results and discussions

Ghana

Crops and varieties

The study revealed eight crops as the major products of food markets in northern Ghana. The crops, mainly grains, cereals and legumes comprise the following:

- Maize
- Sorghum
- Millet
- Rice
- Groundnuts
- Local beans
- Cowpea, and
- Soya beans

The study revealed different varieties of crops in the markets many of which have local names depicting color and length of maturity (Table 22)

Table 20: Crop varieties identified in order of marketing importance

Crops	Tamale	Bolgatanga
Maize	White maize, Yellow maize	Kayanyanga (white late variety 4 months) white early variety 3 months
Sorghum	Local Red, Local variegated, Agric White and local white	White, Red, Mixed (red and white) variety
Millet	Deep green small grains, White millet, Nara (early millet)	Light green (for porridge and cash), White (for food TZ), Nara (early millet)
Rice	Afifi (White) Madin (mixed) Jekuku (white) Fulana (white), Goma (Red)	Pekega (white 5 months), Mumorega (Red rice 3 months)
Groundnut	Chinese Light Pink, Manipinta (Agric variegated), Simkarigu (late variety)	Chinese (Ndoba 3 months), Sunkara (4 months)
Cowpea	Big Medium and Small (Black eye)	Bonkara (Big black eye), Bonbibehi (small black eye)
Local beans	Sananizie (Red beans) Brown beans, Sanzie purporah mixed color, Black beans (sanze-sablimli), Minpasablia (black eye) Mimpasabenle	No local bens were found
Soya beans	Tule Light yellow (Early maturing), Barigu (Late maturing)	Light yellow early maturing

Examples of the local names are the kayanyanga and the kayandaa white maize in Bolgatanga market. Unlike farmers, traders did not demonstrate sufficient familiarity with the scientific names of crops. In Tamale, market for instance traders separated maize into only two varieties as white and yellow maize instead of Abrotia, Dobidi, Okom asa, etc as farmers normally do.

For traders, only colour seemed to matter for crop differentiation and not scientific characteristics. As such traders were found packaging, storing and selling different crop varieties of similar colour together with a possible generation of pest control consequences.

The implication is a possible training requirement for traders in variety characterization and corresponding storage management.

New produce entrance into markets

Apart from some local early maturing beans which enter Tamale market as early as Mid-May, majority of newly harvested crops come into the market between August and December.

However traders agreed to selling new maize from Techiman as early as May and June before the arrival of the crop from local sources in August/September. Depending on demand requirements, partially dried maize of early maturing varieties from local sources in the Northern Regions enters the Bolgatanga market between in September. However, maize of adequate moisture content starts selling in northern regions from the end of September to October.

Both the quantities of food inflow as well as its peak period into the food markets depend on the rainfall pattern for each year. However market inflow of food crops also depend on various sources in response to individual crop demand at all times. Thus large quantities of some crop produce like cowpea, groundnuts and of late even maize could be brought into the markets by traditional import routes from Burkina Faso, Nigeria, Niger and Mali to fill gaps of shortages. The reverse occurs when shortages occur in these neighboring countries as well.

Food supply to the market during harvest is, however, determined significantly by the quantities harvested and brought into the market from local production sources and any failure of these sources to produce the required quantities creates disturbing gaps in the levels of supply and demand for food in the country.

The study however revealed that in normal years, the peak supply period for most food items like sorghum, millet, rice, groundnuts, soya beans occur between August and December with maize following in February the following year after Christmas festivities.

At this period farmers continue to process and release harvests into the markets in need of money to pay for expenses and for funerals.

Traders explained that many farmers took their time to process maize for the market and rather rushed into selling off rice, groundnuts and beans which are regarded as cash crop before selling maize which is predominantly a subsistence crop in most households of the three northern regions resulting in the delay in the peak period of maize.

High demand period

Traders indicated that purchases by city traders and food processors are highest in the months of high supply. While groundnuts, which is harvested early peaks around November, most of the food crops sell at low prices, and in large quantities around January and February. Many of the customers at this period also have the option to buy directly from villages and thus make it difficult for traders to increase prices.

The large quantity traders from cities take advantage of low prices during this period, resulting from the abundance of food stocks, to buy adequate supplies for storage in the cities of Accra, Kumasi, Takoradi, Cape Coast, Koforidua, Tema, Ho etc. Schools, hospitals, retailers and households which constitute their customers later in the year are not able to stock. Possible avenues exist for the development of agro-enterprise partnerships.

Low Demand High Price Period

When food stocks arriving from villages decline around June and July, prices rise indicating stock-holds of farmers are reducing and farmers stop selling food as security against a possible rain failure in the coming season. At this period, stocks in the market decline as well and prices rise to a peak around June and July as more customers seek fewer quantities of food.

With the high prices, poorer consumers seek cheaper alternatives and depend mostly on food substitutes like dried cassava and local beans for survival. Many farm-gate traders who assemble grains, cereals and legumes in villages to sell to market traders cease to operate and market traders go out to seek supplies for themselves at higher costs. Meanwhile, urban traders take advantage of the situation and increase prices in the cities.

The period of lowest demand however occur during harvesting periods when traders go directly to villages to buy from farmers. This period starts in August to October for maize, millet, sorghum and rice, when farmers are preparing to harvest and start emptying storage structures. New yam, early maize, local beans and vegetables help to cushion hunger and reduce demand for grains and cereals. After stocking groundnuts for cities in October to December, demand for the commodity also reduces by February.

Stakeholders, Credit practices and Problems

Traders listed wholesalers from other regions of the country, especially the big cities of Accra, Kumasi, Takoradi, Tema, Koforidua, Ho and other as their major customers. Following closely were institutions like boarding schools, hospitals, food processors and offices who patronize their goods. The other important groups are retailers who connect wholesalers to households in the country.

Traders depended for trading capital on families, friends and the long time methods of indirect borrowing system in markets. By this system, known trading partners credited goods and paid later after selling. Retailers especially make use of this system to build-up capital for other ventures like wholesaling or farm-gate trading. Traders complained of the inability to access credit from official banking institutions for lack of collateral and because they do not attract assistance from the government the way farmers do.

Problems encountered by traders include:

1. Lack of adequate training from the Ministry of Food and Agriculture (MoFA) on stock management and general marketing issues
2. Lack of credit
3. Poor market infrastructure
4. No exposure to new varieties before release.

Burkina Faso

The warrantage system was implemented from 2005 to 2007 in the Ziga site of the Yatenga province and Saala site of the Ioba province. For this purpose the following steps were adopted (1) literature review/information gathering; (2) sensitization sessions with the target public; (3) joint evaluation of the potential to conduct warrantage ; (4) practical implementation of warrantage ; and (5) setting up of input shops.

1. Information gathering

Participatory Rural Appraisal (PRA) studies were conducted in 2005, which helped to obtain a socio-economic characterization of the Ziga and Saala sites. This also helped to determine the natural, physical, social and economic environment of study villages and to highlight the availability of natural resources, their management, the perception farmers have on land degradation and the organizational constraints that could hinder village development.
The inventory of socio-economic infrastructures and the Venn diagram in the sites contributed to characterize the structures promoting economic and social activities in the villages and how operational they are (PAR study report of CPWF village sites of Ziga and Saala, 2005).

These socioeconomic infrastructures and the Venn diagram helped materialize internal and external relationships between the different village structures and between these structures and development partners.

Market surveys of agro-sylvo-pastoral products
The flow diagram developed in 2005 enabled to understand the commercial exchanges between these two sites and the other markets in the region. The major products providing more income to producers have been identified and characterized according to their various stakeholders. A calendar of production and price fluctuations of income generating products has been developed and the critical production and marketing aspects of these commodities have been established.

Market takes place every three days at Ziga. The Saala village does not have its own market. The nearest market is that of Dissin (8 km) which is held every Sunday. These markets are important venues for the supply and marketing of agro-pastoral and vegetable products, fruits, oilseeds (sesame, groundnut) and other crops like cowpea.

2. Sensitization/animation and training of target public

The sessions started in 2005 through gatherings of target producers in the groups, producer organizations and representatives of decentralized finance structures (Credit Unions). During these animations/sensitization/training sessions the following points were covered: (1) the principles of the warrantage credit system; (2) the major conditions for its implementation and functionality; (3) and warrantage monitoring.

Training sessions were organized in the two sites for the target public on the concept of warrantage and its guidelines (the time to set up security stocks, mode of contribution to security stocks, warrantable products, quantity and quality of products, centralization and proximity of stocks, warehousing conditions and accountability for the stocks, determination of products, provisional trading account for the income generating activities and monitoring the value of secured stocks).

The producers are informed of the major conditions of implementation, which are (1) the warehouse which should have two keys (one for the producer organization and one for the decentralized finance structure); (2) the constitution of stocks; (3) the establishment of a warrantage management committee; (4) the decentralized finance structure that will provide producers with credit to undertake income generating activities; (5) the setting up of an input shop.

The objective of warrantage monitoring is to provide the producer organization with information to help them take the appropriate decisions especially for selling at the best time to obtain the highest prices. Hence, the producer organization and the finance structure should monitor, throughout the credit period, the prices of the secured agricultural products in order to advise the producer organization to settle its debt before term if prices are favorable.

3. Joint evaluation of the potential to conduct warrantage
This joint and participatory evaluation with the producers concerned related to:
The existence of infrastructures essentially warehouses to store agricultural products;
Past experience with agricultural credit;
The dynamism of target stakeholders;
The products generating more income;
Future market opportunities;
The existence of a decentralized finance structure to provide credit;
The identification of economically profitable income generating activities.

4. Warrantage practical implementation
Negotiation meetings with the South-Western and Northern Regional Networks of Credit Unions
After the stock constitution and the establishment of the warrantage management committees, negotiations took place with the South-Western Regional Network of Credit Unions (RCPSO) and the Northern Regional Network of Credit Unions (RCPN), which are the decentralized finance structures, to obtain micro-credits for producers in the Ziga and Saala sites. These negotiations were held at several levels and phases and led to the signing of two tripartite agreement protocols between the Networks of Credit Unions, CPWF and producers. These agreement protocols defined the duties and responsibilities of all parties and the conditions of credit provision with an

alleviation conditions to take into account the living conditions of producers, who, in majority, do not possess the securities required by Credit Unions.

Establishment of warrantage management committees
The various warrantage management committees have been set up and the names of the members of each of the committees are given in Table 23.

Table 21: Composition of warrantage management committees

Site	Credit manager	Stock Manager	Warehouseman/Store keeper
Saala	Monsieur DABIRE Jean-Baptiste	Mme SOME Johana	Monsieur SOMDAH Nestor
Ziga	Mme OUEDRAOGO Elizabeth	Monsieur SAWADOGO Sayouba	Monsieur OUEDRAOGO Souleymane

Constitution of stocks
The first activity in the practical implementation of the warrantage in the sites related to the constitution of stocks. In general, in the two sites, the target populations were very much opened. The guarantee of stocks requires that products be very well conserved; hence some major points on the constitution of stocks of warranted products were treated:
Insecticide products to use;
Celerity in the constitution of stocks;

Warehousing of stocks to be done on pallets.

Table 24. Shows a slight decrease in the number of producers that took part in the 2006-2007 warrantage at Ziga, but an increase of 19 % in the number at Saala.

Table 22: Number of producers that took part in the warrantage at Ziga and Saala.

Site	Warrantage period	Number of registered farmers	Farmers who benefited from the credit
Ziga	2005-2006	32	0
	2006-2007	31	20
Saala	2005-2006	21	0
	2006-2007	25	9

At Ziga, beneficiaries of the credit acted on individual basis. At Saala, however, producers were grouped in order to help those with no accounts at Credit Unions, those without valid (Carte d'Identite Burkine (CIB)) - Burkina Identification card or those with an amount of credit too low to open a file to also benefit of the credit.

The constitution of stocks for the 2005-2006 warrantage took place on 16th January 2006 at Ziga and 21st January 2006 at Saala. For 2006-2007 warrantage, the constitution of stocks took place on 14th December 2006 at Ziga and 29th December 2006 at Saala. The nature and quantities of stored products by site are given in Table 25. It should be noted that at Saala the agricultural products stored in the warrantage warehouse are more varied than at Ziga (Table 25).

Table 23: Nature and quantities of stored products, 2005-2006 and 2006-2007 warrantages.

Site	Year	White Sorghum (kg)	Red Sorghum (kg)	Millet (kg)	Maize (kg)	Rice (kg)	Shelled groundnut (kg)	Cowpea (kg)	Soybean (kg)	Sesame (kg)
Ziga	2005-2006	1509	0	0	0	0	3200	754	0	0
	2006-2007	2429	0	110	0	0	3872	1343	0	0
Saala	2005-2006	0	294	0	1086	37	0	74	0	0
	2006-2007	0	442	0	3790	2870	720	313	37	88

Table 25 shows an introduction of new products like groundnut, soybean and sesame at Saala and millet at Ziga and an increase in stored quantities in 2006-2007 of all products in the two sites.

The products stored in more important quantities during these two years of warrantage are groundnut for Ziga and maize for Saala (Table 25).

Opening of accounts in Credit Unions by producers
The opening of accounts in the Credit Unions (Ziga and Saala) took place in January 2006. Some producers and producer groups already had their bank accounts before this operation.

Provision of credits
Agreement protocols were signed in 2006, but the provision of credits occurred late, three months after the planned period. Since the deadline for the conduct of income generating activities was exceeded, producers in the two sites decided that it was no longer opportune to contract the credit and this did not allow the implementation of the 2005-2006 warrantage.

Credit transfers into producers' accounts by Credit Unions were made on 24th January 2007 for the site of Ziga and from 6th to 28th February 2007 for the site of Saala. The amounts of credit provided and the obligatory pledged savings are presented in Table 26. It is to be noted that pledged savings could not be made that year at Saala.

The planned periods for settling the debts were 6 months at Ziga and 8 months at Saala. These deadlines were not respected in practice; hence, there were early or delayed settlements (Table 26). At the constitution of credit files, each of the producers was to disclose the type of income generating activities he was to conduct. Table 26 shows that these activities were effectively disclosed but unfortunately no producer could conduct his activity.

Table 24: Amounts of credits provided, settlement delays, pledged savings and income generating activities declared by producers, 2006-2007.

Site	Total amount of credit (CFA)	Settlement period (months)	Total amount of pledged savings (3 % of credit) (CFA)	Income generating activities
Ziga	635,809	4 - 5	107,244	Fattening Trade of cereals Trade of cowpea Trade of cowpea snacks Trade of millet snacks Trade of local wine (dolo) Trade of animal skins Trade of animals Trade of condiments
Saala	461,430	5 - 9	0	Pig fattening Goat fattening Butchery Small trade (cereals, cigarettes, batteries, etc.)

Destination of products after withdrawal and economic evaluation of the operation
2005-2006 warrantage
The withdrawal of warehouse stocks was made on 15th May 2006 at Saala and 3rd May 2006 for Ziga. The following observations were made on the state of the stored products a few days before their withdrawal from warehouses:
At Saala, damages were caused by mouses on two bags (1 of maize and 1 of paddy rice), there was also an incipient attack of weevils on the red sorghum that could not be treated at storage at Saala. The two bags of red sorghum on which the attack occurred were taken out of the warehouse to avoid massive infestation.
At Ziga, no conservation problem was observed.
Recorded information on the destination of products after withdrawal at Ziga indicated that:
51.43% of the groundnut stock was intended for consumption, 41.43% for sale and 7.14% for use as seeds.
56.80% of the cowpea stock was intended for consumption and 43.20% for sale.
80% of the sorghum stock was intended for consumption and 20% for sale.
At Saala, the destination of products after withdrawal could not be recorded in 2006.
2006-2007 warrantage
For the 2006-2007 warrantage, stocks were withdrawn on 4th July 2007 for Saala and 4th June 2007 for Ziga. The control of the state of the products at the date of withdrawal showed (1) damages caused by weevils on a few bags of groundnut at Saala, (2) products free from attacks.

Table 27 suggests that at Ziga, the first destination of products after withdrawal is consumption for millet and sorghum and sale for cowpea and groundnut. At Saala, sorghum, maize, groundnut and soybean are meant for consumption, sesame and cowpea for sale and rice for sale and consumption.

Table 25: Destination of agricultural products after warrantage, 2006-2007

Site	Product	Total stock (kg)	Intended for sale (kg)	Intended for consumption (kg)	Intended for seeds (kg)
Ziga	White sorghum	2429	110	2318	0
	Millet	110	0	110	0
	Cowpea	1343	1012	331	0
	Unshelled groundnut	3872	2096	0	1776
Saala	Red sorghum	442	0	436	6
	Maize	3790	822	2968	0
	Rice	2870	1435	1435	0
	Cowpea	313	313	0	0
	Unshelled groundnut	720	288	432	0
	Sesame	88	88	0	0
	Soybean	37	0	37	0

Economic evaluation

As credit was not provided in 2006, the team could not have information to initiate an economic evaluation for that year. With the provision of credit in 2007, the team could attempt to evaluate the potential gains of the warrantage operation by site. This evaluation is done on the basis of the credit effectively provided to producers without the possible margins induced by the income generating activities if they had been conducted. The team also assumed that all stocks related to the credit were sold after withdrawal. Components of this economic evaluation are the following:

- The value of stocks at storage;
- The credit requested;
- The interest paid back (10 % of credit requested);
- The fees to study the files (1000 FCFA per file) and for managing the credit (1 % of credit requested);

- The pledged savings (3 % of the credit requested);
- The storage expenses relating to the upkeep of warehouses, the handling and treatment of vulnerable products (cowpea, sesame, soybean and red sorghum);
- The additional value of products at withdrawal.

Table 28 shows that the gains generated by the 2006-2007 warrantage is around 42 % of the value of stocks (VS) constituted at Ziga and 21 % at Saala. As shown the table, the pledged savings could not be constituted at Saala and this accounts for the poorer gain of 21 % in this site compared to the gain in Ziga. The conduct of income generating activities would have increased this gain.

Table 26: Evaluation of the potential gains of the 2006-2007 warrantage operation in CFA francs

Site	Value at storage (VS)	Credit requested	Present value of stock	Additional value of stock (VA)	Pledged savings (EN)	Interest paid (IR)	Fees for file and credit management (FDC)	Storage expenses (CS) (CFA)	Gain of the operation = [VA + EN]-[IR + FDC + CS]	Gain % compared to VS
Ziga	684320	635 807	928500	244180	107 244	23 398	26 358	12 360	289 308	42,28
Saala	512700	461 430	670800	158100	0	26 761	13 615	9 720	108 004	21,07

5. Setting of input shops

Producers welcomed the CPWF idea to combine the product storage warehouses initiated in 2006 with input shops. In both sites, producers have warehouses somehow reliable for the storage of products before their distribution to beneficiaries. They solicited CPWF to assist them technically to control the quality of the various inputs and their choice in accordance with the recommendations of extension services (dosage, application methods and time, etc.). CPWF contacted some approved suppliers who were ready to convey inputs up to the villages. Producers were to negotiate with these suppliers the partnership conditions with no involvement of CPWF. Unfortunately, these input shops could not be put in place since no supplier accepted to deliver the inputs on credit at a time when producers did not have funds to pay cash. Producers assume they can be financially ready for the launching of these input shops during the 2007-2008 warrantage.

Follow up training

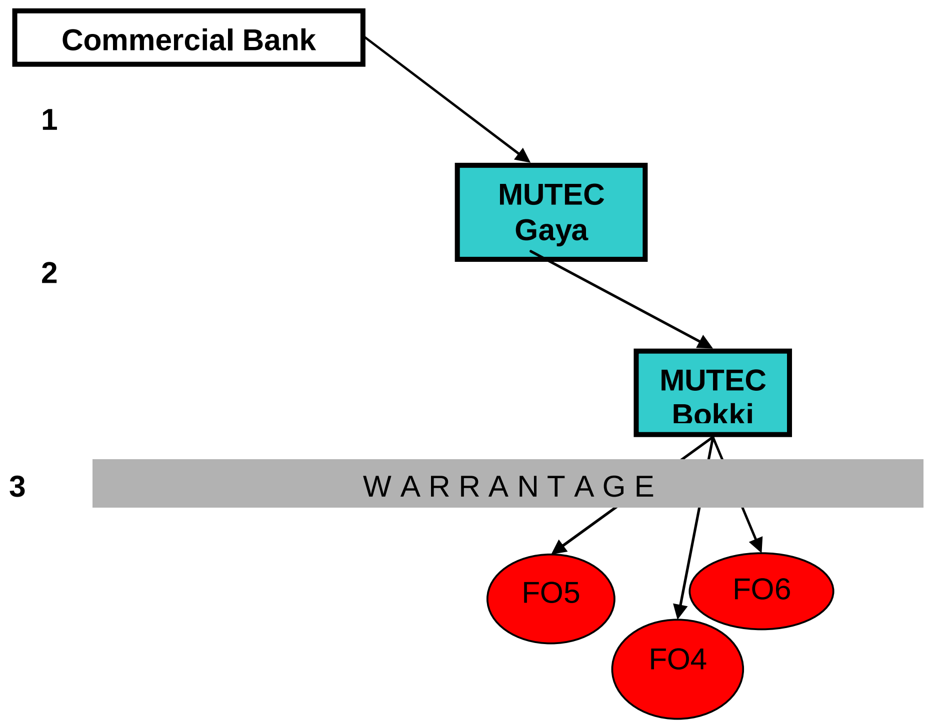
To strengthen the capacity of the warrantage committee, a training was conducted in November 2006 for the "Comité de Warrantage" or inventory credit system in Saala and Ziga, Burkina Faso from 24 to 28 October 2006 (all members of the comité attended to this training) . The main objective of this training was to : i) strengthen the capacity of the committee members to carry out the warrantage activity including the constitution of the stocks of grains, the management of the stores and the sale of the grains; ii) to undertake interactions with the "Caisses Populaires" to facilitate access to credit

As it could be observed some gaps and weaknesses in the implementation of the system in both countries appeals for additional backstopping before the closing of the activities of the project in December 2009. A monitoring trip was therefore organized by the coordination unit of the PN5 to study the state of art of the implementation of the warrantage system at the project sites. Following this trip, exchange and training workshops in warrantage were organized in Burkina and Ghana in November 2009 and early December 2009. The workshops allow addressing the gaps related to the implementation of the warrantage system in Burkina and also reasons for its non-implementation in Ghana in the framework of the CPWF PN5 project. One major gap identified was that the financial institutions don't know much about the system. The training was therefore organized to familiarize these institutions which deal with the rural communities with the system. On 11 November was conducted in Ouagadougou the exchange and training workshop for financial institutions with potential involvement in the warrantage of inventory credit system. This training was conducted by the CPWF PN5 coordination unit at ICRISAT

A total of 16 participants were recorded among whom a strong delegation of the nation wide institution named 'Caisse Populaire' (credit system for the rural population). Another credit institution was the BACB. The NGO SOS Sahel attended in addition to the technical staff of the ministry of Agriculture.
In his welcome note of the Director of INERA in few word point out the importance of the meeting, which according to him would not only allow the financial institution for the first time to understand the essence of the system but also lay the basis for the creation of the necessary link between them and the farmers organizations, that they are supposed to support in their fight for survival. After this the focal point of the PN5 presented the objectives of the meeting. She explained the importance of the workshop even though conducted at the period of the end of project. According to her the meeting would create awereness in the community of the financial institutions which would allow them to consider the warrantage in their activities. This is the only way we can assure the sustainability of the system. The linkage of farmers with these institutions being one of the weaknesses mentioned in all evaluations. A brief history on the system was given followed by few results of the implementation of the system in Burkina. The main part of workshop was on the principles of the system and the link with the financial institutions.

Principles of warrantage.
Considering the audience (the financial institutions) a detailed presentation of the principles of the system was necessary. During this presentation, the different steps of the implementation of the process were covered right from the time the farmers fill their sacs to the credit institutions to get the loan for income generating activities after installing in acceptable condition in the storage warehouse agreed upon by both financial institution and the farmers

Linking farmers to financial institutions
The following presentation was about establishing linkage between the farmer organizations and strong financial institutions. In fact this was among the potential problems as the amount of loan required might be out of reach for the local credit institutions.
Due to the nature of guaranty it is necessary to build the confidence of these banks in the system by creating a system that would avoid direct link of the farmers with the traditional bank. There is a need to of intermediaries, which is show in the following scheme.



The final presentation was about sharing the experience of PICOFA a project that focus on the use of fertilizers to increase agricultural production in Burkina Faso. The warrantage system was one of the components to promote adoption of fertilizer use by farmers.
The discussions focused mainly on the fact that the system needs to be considered as a product in the portfolio of the financial institutions, which idea they agreed to consider in there future plans.

Farmers training in Warrantage system at Saala and Ziga – Burkin Faso
The project's main partners, the farmers at the project sites – Saala and Ziga were also trained. At Saala the training started with a welcome address of the village chief. Two participants of the village who attended the meeting in Ouaga as well as one OP member of the village who visited Niger in during the course of the project were requested to share their experience with the other members. In addition to the farmers from the Saala village with whom the project worked, farmers from neighboring villages also attended this training. Sixty participants attended. One of the lessons learnt during the exchange visit to Niger was the creation of input shops by farmers involved in the warrantage system. The farmers put the question as to how they could succeed in putting in place such infrastructure. Appropriate answer was given to them. At the end a practical training on warehouse management was conducted with the farmers.

On 7th and 8th December 2009, the training in warrantage was conducted on the second site of CPWF PN5 at Ziga. The same procedure as in Saala was adopted. The particularity here is that the office of the caisse populaire is based in the village but farmers involved in the warrantage have individual account. They do the warrantage but on individual basis. Therefore they cannot benefit from all the advantages of the system. Even though they are forced to save money, there is nothing going for the group. It was pointed out that this issue needs to be considered to make their warrantage system work properly, which can lead to the creation of input shops and other advantages. In fact it was emphasized that if the financial institution gives the loan to the group at a given rate, the group should increase 0.5% or whatever rate the group agrees on over the rate of the financial institution. This 0.5% should be kept in the account of the group to serve as common fund that should be used for common need of the group.

Ghana 17 – 20 November 2009

The exchange workshop was organized in Ghana from the 17th to 20th November at Bolgatanga. It was conducted by the CPWF coordination at ICRISAT. The following banks and institutions attended the meeting:

- Agricultural Development Bank – ADB
- Builsa Rural Bank
- Naara Rural Bank
- Bongo Rural Bank
- NIB
- TechnoServe
- MOFA
- UDS

The focal point of the CPWF PN5 focal point in Ghana presented the objective of the meeting after which a brief presentation on the history of warrantage was given. After this, as it was done in Burkina, two presentations on the basics of the system and how to link farmers to the financial institutions were done.
Questions of clarification were asked during a long discussion session. The financial institutions share with the audience ideas on their activities with the farmers. They used to practice a credit system that consists of providing farmers with fund to farm and pay back their loan after harvest. This system was not efficient as they face difficulties to get back their money. According to them farmers think that it is a state's money and are reluctant to pay back. To solve this problem ADB is forced to follow the farmers throughout the whole process up to the market. As it could be expected this procedure requires a lot of investment in time and money. ADB being a state's enterprise the government gives instructions to help farmers. So ADB does it regardless of those constraints. The other institutions just gave up, but they provide fund to small traders who used to buy farm products to sale later. It means that in all this process, the producer is the major looser as he sells his product when the prices are low at harvest and is forced to buy it again at a higher price in the period of scarcity on the market.
The financial institutions recognized that before this exchange workshop, they did not know anything about the system but they agreed to experiment it as a new credit management product.

The farmers' organization of Kandinga, a community where the CPWF PN5 worked were the beneficiaries of this training. About 50 participants were recorded. Opportunity was given to the Naara Rural Bank and the TechnoServe, tow institutions, which mandate were to support farmers by providing them with credit, gave the farmers a feed back on what they learned during the training but also explain to the farmers what they can benefit from working with financial institutions. Additional information was given by the technical staff of MOFA who attended the initial training. After this farmers shared their experience with the rural banks, which showed a lot of constraints.
The ICRISAT training staff tried to file the gaps following the different presentations.
The following day we held an evaluation meeting followed by a demonstration of proper keeping of a warehouse that is meant to be used for warrantage.

This training ended with the feeling that even though it was planned and conducted at the end of the project, we have laid the basis to strengthen the implementation of the warrantage where attempt was made. Where nothing was done the actors may invest time to start. We hope that if a second phase of the CPWF PN5 was financed we already have a strong team ready to continue what we started.

Conclusions

The warehousing of products during these 4 to 9 months allowed farmers to benefit from micro-credits. Upon recovery of their products, producers appreciated the warrantage system that they perceived as an economically profitable operation helping them to make substantial gains and to have remaining products after settlement of their debt. They unanimously recognize the benefit the operation helped them to achieve through the pledged savings that could be used in the absence of the CPWF project, as personal contributions for future warrantage operations. The warrantage management committee, the executives of Credit Unions, the technical heads of CPWF should conjugate their efforts for the effective conduct of these income generating activities.

To help producers who have no accounts at Credit Unions, those with no valid CIB and those whose credit amounts are too low for opening a file, groups of producers have been formed at

Saala. At this level, the head of the Dissin Credit Union proposes that in future, the total amount of the credit be transferred in the account of the group, hence, with a single credit file in the name of the group. Each member of the warrantage could then receive the amount of his credit; reimbursements will be individual but paid in the account of the chairman of the group. This will help reduce the fees related to the credit (fees for file, insurance, credit management, etc.) and facilitate credit management.

Producers called for a strengthening of their capacity through training sessions in simplified accounting and management principles and market prospecting for more success in warrantage operations. They expressed the wish that in the coming years, credits could be made available in November to help them undertake their income generating activities earlier. They also proposed that credit settlement be on a quarterly basis with the peculiarity that with producers undertaking income generating activities like fattening these settlements be done at the end of the 6 months that lasts the credit. These proposals were well received by the executives of the two Credit Unions.

The exchange and training workshop conducted lastly laid the basis we hope for financial institution to get more closely involved into the system as they make a product in their banking system.

Objective 4*:*

To build the capacities of farmers and rural communities to make effective demands to research and development organizations, and influence policies that promote the adoption of sustainable water and nutrient use technologies.

Methods

This objective aims at developing and promoting methodologies, approaches and processes to empower rural communities and creating an enabling environment for combining research and development activities to achieve the above objective. Building social capital in rural communities is an important component of developing and up-scaling knowledge intensive technologies as well as accessing markets and benefiting from market opportunities.

Community-based Participatory Action Research (PAR) methodologies based on mutual learning processes were largely used in the project to empower rural communities and build their capacities to learn about biological and ecological complexities, and to create a sustained, collective capacity for innovation, experimentation and marketing focused on improving livelihoods and the management of natural resources. PLAR approaches were used to ensure that technologies developed are suitable for different categories of farmers, especially women and other marginalized groups. PLAR approaches recognize the importance of transforming communities to foster positive social change in communities and improve people's quality of life as they themselves define it.

Gender and Stakeholder Analysis (GSA**)** methodologies were used to differentiate different categories of small- scale farmers, and to involve them in the research processes as partners and active decision makers. Gender analysis strategies were used to ensure that both men and women are involved in the research processes as active partners and decision makers and actually benefit from improved water and nutrient use efficient technologies and related market opportunities. We make sure the project takes into account different gender roles, needs, perspectives and priorities. Full integration of gender analysis can help to empower women through strengthening their productive capacity, their economic security and social status, as well as contributing to the well-being of their families. A more systematic gender and stakeholder analysis study was undertaken at the beginning of the project to better understand gender issues and dynamics in agriculture, and develop effective strategies to promote gender equity and empower women. Because of the increasing vital role of women in agricultural production, processing and marketing, the project specifically allocated resources to creating gender awareness among local stakeholders and farmers, and facilitated specific activities to empower women to have equal access to technologies, innovations and market opportunities. Participatory approaches to support women's empowerment and leadership at community level were integrated as part of the strategy, creating and facilitating fora where women can discuss their development. The purpose here, in addition to including women in all project activities, is to provide an opportunity for women to identify specific agro-enterprise skills that are innovative, and enable them to use available agricultural technology to their own advantage.

This project focus on ways of strengthening the organizational capacity and social capital of local communities through training and facilitation of leadership skills, group dynamics, consensus building and negotiation skills for managing conflicts, especially as related to natural resources.

Activities:

4.1. Conduct community-based participatory research and development approaches to test, evaluate and disseminate a broad range of options by different categories of farmers, men and women*.*
4.2. Support the development and strengthening of farmer groups or organizations and local institutions to test and evaluate a wide range of options, technologies, approaches and principles.
4.3 Build the capacities of local communities, extension and other services providers to adopt, disseminate and promote integrated nutrient and water use management technologies
Increase flow of information on INM technologies between research, extension, service providers and local communities.
4.4 Implement strategies that enable women to benefit from increased household incomes: Increase the skills of both men and women to promote gender equity, and women's empowerment at the community and household levels.

4.5. A multidisciplinary team of agricultural development professionals conducted a participatory rural appraisal (PRA) in the Kpachi, Cheshegu, Nyanguah and Kologo communities in Ghana and at Ziga and Saala.

Results and discussions

Burkina Faso

Ziga village

A gender analysis was carried out with a focus on access to land, women status and organization, and economic activities in the villages. Methods used: focus group with semi-structured interviews.

Gender-related land acquisition

There are three modes to acquire a piece of land:

- inheritance (lineage): most dominant form of land acquisition
- gift: for strangers who aspire to settle in the village
- loan: for a specific period. In this case, the farmer will give a counterpart of the production (cash or kind) to the owner

In all the three cases, men have rights to own the land whereas women do not have this right.

Labor force

There are three types of labor forces exist:

- Family members (most dominant form). All the family members (men, women, and children) are involved in farm activities.
- Mutual assistance (help from other families members on a voluntary basis)
- Hiring of laborers (wages)

Tables 29 and 30 present a synthesis of gender-related farm activities at Ziga and Saala. These activities are undertaken following a precise yearly farm calendar

Table 27: Gender-related farm activities

Activities	Men	Women	Children
Field preparation			
Sowing			
Weeding, thinning, plowing…			
Livestock keeping			
Harvesting			

- 15 women groups/organizations exist in the village.
- They play important role in farm activities Difficult access to agricultural inputs (seeds and mineral fertilizers) because of their high costs
- Women apply SWC technologies on their small pieces of land (zai, mulching and stones lines). However, they cannot plant trees on the land.
- Agriculture, livestock (sheep and goat fattening), income generating activities are some of the economic activities of women.

Saala site

land tenure

Access to land: three modes:

- inheritance (lineage)
- gift: it was possible in the past; unusual nowadays.
- loan (period basis).

Women do not have rights to the land, even after demise of the husband. Children are those who will inherit the land.

Labor force

Three modes:

- Family members (women, husband and children) are the main labor force.
- Mutual assistance
- Hiring of laborers

Table 28 Gender-related farm activities at Saala

Activities	Men	Women	Children
Field preparation			
Sowing			
Weeding, thinning, plowing…			
Livestock keeping			
Harvesting			

Institutional organizations

Farmers groups/associations at Saala

- men producers of cereals
- women producers of cereals
- men producers of cotton
- women groundnuts producers
- women traditional soap producers
- women pottery producers
-

More specifically 11 women groups/associations exist at Saala. They produce groundnuts. Members use the income generated to cover various expenses (individual).

Results of focus group discussions, transect walks, direct observations and SWOT analysis conducted in the four communities are summarized below.

Ghana

Kpachi community

Location

The Kpachi community is located about 3 km from the Nyankpala township in Tolon/Kumbungu District of the Northern Region. The community shares common borders with the University for Development Studies (UDS), the Savanna Agriculture Research Institute (SARI), and the Cheyohi, Kpalga and Kokpeng communities. The community is home to about 40 households.

Social organization

Like most traditional societies, the Kpachi community is characterized by a strong sense of community with a hierarchical system of control. Traditionally, Kpachi falls within the jurisdiction of the Kumbung-Naa (the paramount chief). The chief of Kpachi pays allegiance to the Kumbung-Naa through the Kpalga-Naa (a sub-chief). The basic social unit of production, which invariably constitutes the unit of consumption in Kpachi and elsewhere in Dagbon is the compound or farm household – a physical entity, usually organized along familial or lineage lines. A typical household consists of a male head of household and his wife or wives, their children and grandchildren. The immediate surroundings of the compound house of the household constitute the compound farms; these are mostly planted to maize. A male member of the household, on attainment of a certain stage in the life-cycle (marriage, for example), may separate from the compound household to set up a new household of his own.

General farming systems information

Although land in the Kpachi community is never privately owned, there are different degrees of tenure security depending on where the rights to control the land come from. A household's claim to land is through membership in one of the several clans in the community. It is generally believed that the size and quality of the land claim depend on the order of arrival of the clan in the community (the largest and best to first comers). Within each household, the land is passed from the father (household head) usually to the eldest son.

The texture of soils in the immediate vicinity of the Kpachi community is moderately silty- gravel; the soil texture changes imperceptibly to silty-gravel, and silty-clay with distance from the community. The soils are generally deficient in organic matter, very shallow and prone to leaching and erosion. Cropping practices have evolved over the years and usually reflect human adaptation to the environment. The principal crops grown include maize, groundnuts, cowpea, yam, rice and assorted vegetables.

Livestock are an integral part of the farming system. Cattle, sheep goats and poultry are found in the community; most households have small ruminants (sheep and goats) and poultry; but few animals are penned. During the cropping season, however, almost all small ruminants are tethered to restrain them from destroying crops on compound farms. Both men and women in the Kpachi community own small ruminants and poultry. However, women defer all important matters pertaining to animal husbandry to the men as a matter of courtesy. Household animals serve as a buffer against the hunger gap; they are sold mostly during the lean season to meet the food and other needs of the household. Farmers in Kpachi who own animals routinely use animal manure as a soil amendment. A dynamic kraaling system, where animals are tethered overnight at different sites is very common in the community. A greater percentage of animal manure and other organic matter generated in the household, end up on the compound farms. Consequently, crop yield on compound farms is reported to be higher than yields obtained from bush farms.

Household labour

Farm labour is provided by male and female members of the household. A calendar of farm and off-farm activities performed by men and women in the Kpachi community is presented in Table 30. It is evident from Table 1 that although both men and women participate in almost all major crop production activities, some gender specialization in the performance of these activities is apparent. Activities such as harvesting, storage, processing, carting and marketing of produce and, in particular, off-farm activities such as groundnut oil processing, shea nut picking and processing, and fuel wood gathering appear to be task specialization of women in the household. In addition, women are responsible for washing, cooking and childcare. By contrast, men are particularly responsible for the initial clearing of land, tillage, and crop management. Weeding is carried out by adult males, females and children. Regardless of gender household members of all age groups participate in crop harvesting activities. It is worth noting however that, although women are actively involved in most farming activities, their rights to the use of land are somewhat restricted. Another important observation made is that yam cultivation is strictly a preserve for men.

Tables 31 and 32 summarize the activity calendar for men and women in the Kpachi community. It is important to emphasize that some activities may start early or delay, according to the onset, and the end of the seasonal rains.

Table 29: Calendar of activities – Kpachi community, Male farmers

Activity	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Crop production activities												
Land preparation												
Seed preparation												
Yam sets preparation												
Yam mound preparation												
Yam field clearing												
Planting -Yam												
-Maize												
-Groundnuts												
-Rice												
-Cowpea												
Nursing pepper												
Tobacco transplanting												
Ridging round tobacco plants												
Yam mulching												
Yam pricking												
Weeding												
Harvesting –Yam												
-Maize												
-Groundnuts												
-Rice												
-Cowpea												
Off-farm activities												
-Groundnut shelling												
-Mat weaving												
-Rope weaving												
-Tobacco harvesting												
-Tobacco curing												
-Tobacco pounding/processing												
-Small ruminant feed hunting												
-Small ruminant tethering												
-Termite harvesting for poultry												

Table 30: Calendar of activities – Kpachi community Female farmers

Activity	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Crop production activities												
Land preparation												
Seed preparation												
Planting -Maize												
-Groundnuts												
-Rice												
-Cowpea												
Weeding												
Harvesting -Maize												
-Groundnuts												
-Rice												
-Cowpea												
Off-farm activities												
-Groundnut shelling												
-Groundnut oil processing												
-Shea nut picking & processing												
-Shea butter processing												
-Fuel wood gathering												

Water Resources

Water resources in the Kpachi community appear to be very limited. Boreholes or pipe-borne water are non-existent. Water for household chores is usually obtained from hand-dug wells, but this is available in sufficient quantities only in the rainy season. Although fetching water for household activities remains an important task specialization of women, both men and men spend considerable amount of time and cover long distances in search of water for household use during the dry season. Therefore, any programme intended to improve the livelihoods of people in the Kpachi community and its environs must of necessity help to address the water supply problem.

Communal activities

Members of the Kpachi community have established a 2 ha community sheanut plantation. There is a sacred grove of mixed trees, which serves as a community shrine, believed to be the home of some traditional deities. Dawadawa, neem, ebony and shea trees are dotted around the community, although the shea tree population is not large enough for women in the community to fully realize the inherent economic potential of this resource. There is a grassland enclave in the community, but it appears to be stunted due to overgrazing.

Community Organizations

Three external organizations (governmental and non-governmental) are very active in the Kpachi community. They are: Sasakawa Global 2000, Ministry of Food and Agriculture and Ghana Cotton Company Ltd. Each of these organizations has facilitated the formation of farmers' groups. Some of the groups are: Crop/Livestock Farmers Association, Small Ruminant Farmers Association, Cotton Farmers Association, Global 2000 Maize Farmers Association, and Groundnut Oil Extraction Women's Group. Activities of some of the organizations will compliment some of the developmental activities envisaged in the project, therefore potential areas of collaboration must be identified and pursued vigorously.

SWOT analysis

Strengths are: Proximity to research and other institutions of higher learning; proximity to valley for rice cultivation

Weaknesses are: Nucleated settlement pattern impinges on sizes of compound farms and small and dwindling land holdings

Opportunities are: Animal/poultry droppings for soil amendments and receptive to development issues due to presence of external organizations

Threats include: Nearness to growing /expanding communities/institutions – land scarcity; lack of adequate water resources and rapidly growing human population

Cheshegu Community
Location

The Cheshegu community is inhabited by about 50 households. It shares a common boarder with several other communities, notably Lemo, Gupanarigu, Kochim, Bognaa-yilli, Kpalga, Cheyohi, Balinkpeng, Nyoring and Tanshegu .

Social organization

The social organization, and for that matter, the agricultural production system in the Cheshegu community is not any different from what pertains in the Kpachi community presented in the preceding pages. Both communities belong to the Dagbon traditional area and so share common cultural practices. Like his counterpart in Kpachi, the chief of Cheshegu derives his authority from the Kumbung-Naa. Compound houses in the community are built close to one another, giving rise to a nucleated type of settlement. Each household has a head (*yilyidana),* who ensures that the entire household 'feeds from the same pot'. Just like in Kpachi, the immediate surroundings of the Cheshegu settlement constitute the community's compound farms.

General farming system information

The topography of Cheshegu is fairly flat. This poses a serious drainage problem in the community and its environs, especially at the peak of the rainy season. The texture of soils in the immediate vicinity of the community can aptly be described as loamy coarse gravel. Farther away from the settlement, the texture changes into silty-clay. In between the two, the texture is medium silty-gravel. These characteristics are locally described or referred to as *Kugchagli*, *Chilchcli* and *Batam* in that order. Continuous cropping is the dominant farming practice in the Cheshegu community. Consequently, the soils are depleted of nutrients because they hardly receive fertilizers in any appreciable quantities, except the compound farms which receive some soil amendments, notably animal manure, crop residue and household refuse. Partly because of this, soils on the compound farms are darker and have better structure than soils on bush farms. Maize is usually planted on the relatively more fertile compound farms. Some farmers interplant tobacco on the maize farms to take advantage of the residual moisture.

The sizes of bush farms are much bigger than compound farms. They are generally planted to a variety of crops including yam, maize, groundnuts, cowpea and sorghum locally referred to as *Kpilnyevili-lana*. In some cases, gourd/calabash is inter-planted with yam to serve as a cover crop to smother or check weeds infestation. Vegetables grown include okra and sabdarifa (bra), which is usually grown as edge plants. Other vegetables grown are pepper and egg plant. The latter is planted as a sole crop and is increasingly becoming attractive to the youth largely because of its high income potential.

Animals commonly reared by members of the community are sheep and goats. Birds including fowls, guinea fowls, doves and ducks and turkeys are also reared for sale and household use. During the rainy season, farmers tether their small ruminants, notably sheep and goats, to prevent them from destroying crops on compound farms (see Plate 5).

Household labour

Adult males in the community specialize in land preparation, which includes bush clearing and tillage. Weeding also tends to be the responsibility of men and adolescent boys, even though women participate in this activity. Both men and women of all age groups participate in planting, except yam, which is a task specialization of men. All age groups and sexes carry out crop harvesting. Women and young girls are responsible for processing and carting as well as sale of farm produce. Household chores such as washing, cooking for the household and childcare are the responsibility of women. However, the sale of birds and animals is the responsibility of the adult males.

A summary of the general activity calendar for male and female members of the Cheshegu community is provided in Tables 33 and 34

Table 31: Calendar of activities –Cheshegu community; Male farmers

Activity	**Jan**	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Crop production activities												
Land preparation												
Seed preparation												
Yam sets preparation												
Yam mound preparation												
Yam field clearing												
Planting -Yam												
-Maize												
-Groundnuts												
-Rice												
-Cowpea												
Planting calabash												
Tobacco transplanting												
Ridging round tobacco plants												
Yam mulching												
Yam pricking												
Weeding												
Harvesting –Yam												
-Maize												
-Groundnuts												
-Rice												
-Cowpea												
Off-farm activities												
-Groundnut shelling												
-Mat weaving												
-Rope weaving												
-Calabash harvesting & processing												
-Tobacco harvesting												
-Tobacco curing												
-Tobacco pounding/processing												
-Small ruminant feed hunting												
-Termite harvesting for poultry												

Table 32: Calendar of activities –Cheshegu community**; Female farmers**

Activity	**Jan**	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Crop production activities												
Land preparation												
Seed preparation												
Planting -Maize												
-Groundnuts												
-Rice												
-Cowpea												
Weeding												
Harvesting -Maize												
-Groundnuts												
-Rice												
-Cowpea												
Off-farm activities												
-Groundnut shelling												
-Groundnut oil processing												
-Shea nut picking & processing												
-Shea butter processing												
-Fuel wood gathering												

Water resources

The Cheshegu community has 5 boreholes, courtesy of the central government and some of the Non-governmental organizations (NGOs) active in the area. The community has no problem with water supply for domestic use. In addition, a dugout has been provided in the community to store drinking water for livestock.

Communal activities

Small pieces of uncultivated land in the community have been reserved as common grazing fields for animals. There is a sacred grove at the outskirts of community, which has greatly enriched the biodiversity of the area. Scattered common tree species include dawadawa, shea, neem, ebony, and kapok. There is a football field in the community for recreation, especially during the dry season when there is not much work to do on the farms.

Community organizations

Two NGOs – the Ghanaian-Danish Community Project (GDCP) and Agriculture and Rural Development (ARD) – are very active in the community. The two organizations and the Ministry of Food and Agriculture have facilitated the formation of farmers' groups within the community. The groups include Suglo-Kongbo Men's Association, Suglo-nbori-bine Men's Association, Tiyumtaba Women's Association and Nangbanyini Women's Association. These groups are involved in food crop production and animal rearing, as well as groundnut and shea butter processing.

SWOT analysis

Strengths include: Appreciable stock of domestic animals/ poultry, regular tethering of animals and the presence of external Non-governmental organizations.

Weaknesses are infertile and erodible soils.

Opportunities include presence of animal/ poultry droppings and community better organized along producer associations.

Threats are high population pressure on arable land.

Location

The Nyanguah community is located about 3 km east of Navrongo, the district capital. The community is bordered by Paga to the north, Telania to the south, and Wusungu to the west. Part of the community has merged into the Navrongo township, especially the area along the main Navrongo-Paga road, towards the Paga airstrip.

Social organization

Households in the Nyanguah community consist of large compound houses headed by male family/clan heads. Within a large compound household, there could be smaller households each with its own head. An aspiring head of household such as a newly-wed who decides to break away from the larger group must always ensure that his compound is not far away from the compound of the clan head. However, the stage at which an aspiring head of household decides to separate from the main clan compound or household is not determined.

General farming systems information

The Nyanguah community has an undulating landscape with granite outcrops here and there. The community territory is within reach of the White Volta River (to the northeast). Two lowlands or valleys divide the community into three distinct 'territories'. However, the lowlands are not wide enough to support commercial farming activities. Soils in the community are sandy, shallow and poor. The presence of striga on several farms in the community lends support to the assertion that the soils are depleted of plant nutrients.

Farmers in the community are aware of the existing soil fertility problems and recognize the need to replenish their soils with organic and inorganic plant nutrients for increased crop productivity. Yet, they hardly use plant nutrients on routine basis, because 'the current cost of inorganic fertilizers is prohibitive'. Instead, farmers have adopted strategies and crop varieties that seem to tolerate the situation. Rice, for example, is grown on bounded plots as sole crop in the lowlands; other plots are cropped with various combinations of crops. The great number of varieties that are mixed on the same plot or farm allows farmers to cope with climatic adversities and sundry parasites. In other words, the farmer's aim may not be necessarily to maximize yields but to achieve a sustained production of complimentary crops while ensuring that he or she does not lose out completely when there is a draught.

Dry season farming of vegetables is also practiced on bounded plots on the lowlands after the rice crop has been harvested, to take advantage of residual moisture. Some farmers use water from hand-dug wells for dry season vegetable gardening. Vegetables that are grown include *vio, kanzaga* (a type of kenaf), pepper, tomato etc. Fencing of the vegetable gardens is routinely done with sorghum and late millet stocks to prevent animals from destroying the crops. Other crops cultivated in the community include groundnut, early and late millet, cowpea and sorghum. However, a few 'daring' farmers, plant maize.

Animals are fully integrated in the farming system. Cattle, sheep, goats, pigs and birds such as fowls, guinea fowls and ducks are also kept. The droppings of these animals are used to fertilize compound farms. Farmers confine the animals in the compound house to facilitate manure accumulation for use on their farms, but this is largely insufficient. Also, decomposed organic matter from domestic rubbish dump sites are used as soil amendments. Animal traction equipment for land preparation is widely used in the community.

Household labour

As shown in Tables 35 and 36, almost all farm operations-- land preparation, weeding, planting, harvesting, carting and sale of farm produce-- are carried out by both men and women. Except in the areas of shea nut picking and processing, and groundnut processing, men and women rub shoulders in off-farm employment activities. It is not uncommon to see men and women working side by side tilling the land. This observation contrasts sharply with what pertains in the Kpachi and Cheshegu communities in the Tolon/Kumbungu district, where some gender division or specialization of agricultural labour seemed apparent. Domestic chores such as cooking, baby-sitting, washing, etc remain the responsibility of women. Subsequent detailed farm-level socioeconomic surveys will capture these differences.

Table 33: Calendar of activities – Nynaguah community; Male farmers

Activity	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Crop production activities												
Land preparation												
Planting -Early millet												
-Late millet												
-Groundnuts												
- Sorghum												
-Rice												
-Sweet/Frafra potato												
-Soybean												
Weeding												
Harvesting –Early millet												
-Late millet												
-Groundnuts												
-Sorghum												
-Rice												
-Sweet/Frafra potato												
-Soybean												
Off-farm activities												
Groundnut shelling												
Processing -Late millet												
-Sorghum												
Dry season gardening												
-Land preparation												
-Seedling nursing												
-Transplanting												
-Harvesting												
Building & repairs of dwellings												

Table 34: Calendar of activities – Nynaguah community; Female farmers

Activity	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Crop production activities												
Land preparation				—	—	—	—					
Planting -Early millet				—	—	—						
-Late millet				—	—	—						
-Groundnuts						—	—					
- Sorghum				—	—	—						
-Rice					—	—	—					
-Sweet/Frafra potato						—	—	—				
-Soybean					—	—	—					
Weeding						—	—	—	—			
Harvesting –Early millet							—	—				
-Late millet									—	—		
-Groundnuts								—	—	—	—	
-Sorghum									—	—		
-Rice									—	—	—	
-Sweet/Frafra potato									—	—	—	
-Soybean									—	—		
Off-farm activities												
Processing -Late millet	—	—								—	—	—
-Sorghum	—	—								—	—	—
Groundnut shelling	—	—	—	—	—	—	—	—	—	—	—	—
Groundnut oil processing	—	—	—	—	—	—	—	—	—	—	—	—
Shea nut picking					—	—	—	—				
Shea nut processing	—	—	—	—	—	—	—	—	—	—	—	—
Rice processing/milling	—	—	—	—	—	—	—	—	—	—	—	—
Building & repairs of dwellings	—	—	—	—							—	—

Other resources

There are many baobab trees in the Nyanguah community. Farmers in Nyanguah use the leaves of the baobab tree to prepare food and export the pulp of the fruit to Burkina Faso where it is used for the preparation of soap. The community has easy access to Navrongo, the district capital, where there is a large market for agricultural produce. Agriculture information and input markets are also available at the district office of the Ministry of Agriculture. The White Volta River is close to the community from which residents obtain sand for building and other construction purposes. Uncultivated land in the community is used for animal grazing, but this appears to be limited.

Community organizations

The Adventist Development and Relief Agency (ADRA), which is very active in the community, has facilitated the formation of two agro-forestry groups).

SWOT analysis

Strengths include the presence of large number of youth, existence of wells for dry season farming and access road to market centers

Weaknesses are low soil fertility, presence of striga on farmer's fields and the presence of hardpan patches on lands in the area

Opportunities include closeness of community to town center and bullocks for animal traction

Threats are high population per unit area and evidence of deforestation.

Kologo Community

Location
The Kologo community lies south of Navrongo, about 10 km from the town centre. It is a relatively large community, spanning over 2 km across. The number of large compound houses in the community is in the range of 60-70. The main north-south Navrongo - Nago road runs through the community. The community has a dam and is quite close to the Tono Irrigation Project..

Social organization

The community falls under the traditional authority of the Navro-pio. Households consist of large compounds headed by male family/clan head. A typical large household may consist of smaller households with independent heads. In effect, the social organization of the Kologo community is not any different from what pertains in the Nyanguah community. However, because household compounds in the Kologo community are farther apart from one another (about 300 metres) compounds farms tend to be a little larger.

General farming systems information

The topography of the Kologo community is undulating with two distinct lowlands used essentially for rice cultivation. The soils in the community are generally sandy and loamy in the lowlands. Other major crops grown in the community aside from rice are sorghum, early and late millet, cowpeas, groundnut and assorted vegetables. Early and late millet and sorghum are the principal cereals. Groundnut and bambara beans are grown essentially on bush farms. Dry season farming of vegetables is carried out in 'basins' near the White Volta River. Tomatoes and water melons are also grown.

Animals raised by farmers in the Kologo community include cattle, sheep, goats and pigs; birds such as chicken, guinea fowls and ducks are also reared. Droppings of these animals and birds are used to fertilize soils in the compound farms. Consequently, yields are reported to be higher on the compound farms than on the bush farms. Animal traction is used mainly for land preparation.

Household labour

Farm labour is provided by family members of all ages and gender. The young ones learn these operations as they alongside the adults on the farm. As was observed in Nyanguah, perhaps except in the area of land preparation which appears to be a task specialization of men, women in Kologo participate in almost all the major activities on the farm (Table 37 and 38). Concerning off-farm work, women in Kologo specialize in shea nut picking and processing as well as rice milling and processing, jut like their counterparts in Nyanguah. Sale of farm produce as well as the performance of domestic chores that include fetching water and fuel wood remains the responsibility of women.

Table 35: Calendar of activities – Kologo community; Male farmers

Activity	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Crop production activities												
Land preparation				—	—	—	—					
Planting -Early millet				—	—	—						
-Late millet				—	—	—						
-Groundnuts						—	—					
- Sorghum				—	—	—						
-Rice					—	—	—					
-Sweet/Frafra potato						—	—	—				
-Soybean					—	—	—					
Weeding						—	—	—	—			
Harvesting –Early millet							—	—				
-Late millet									—	—		
-Groundnuts								—	—	—	—	
-Sorghum									—	—		
-Rice									—	—	—	—
-Sweet/Frafra potato									—	—	—	
-Soybean									—	—		
Off-farm activities												
Groundnut shelling	—	—	—	—	—	—	—	—	—	—	—	—
Processing -Late millet	—	—								—	—	—
-Sorghum	—	—								—	—	—
Building & repairs of dwellings	—	—	—	—							—	—

Table 36: Calendar of activities – Kologo community; Female farmers

Activity	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Crop production activities												
Land preparation												
Planting -Early millet												
-Late millet												
-Groundnuts												
- Sorghum												
-Rice												
-Sweet/Frafra potato												
-Soybean												
Weeding												
Harvesting –Early millet												
-Late millet												
-Groundnuts												
-Sorghum												
-Rice												
-Sweet/Frafra potato												
-Soybean												
Off-farm activities												
Processing -Late millet												
-Sorghum												
Groundnut shelling												
Groundnut oil processing												
Shea nut picking												
Shea nut processing												
Rice processing/milling												
Building & repairs of dwellings												

Other resources

A large tract of land in the community reported to have been leased by the Government of Ghana to the defunct Meat Marketing Board several years ago remains uncultivated, even though there are indications that a private individual has recently acquired it. Currently, the land serves as grazing field for animals owned by people in the community. Women in the community harvest nuts for local processing from the large number of shea trees that grow in and around the community. It is believed that this particular activity significantly adds up to off-farm incomes of women in the community. A dugout constructed in the community provides drinking water for animals.

The community appears to have had a fair share of basic amenities and infrastructure provided by the central government. For example, a yet to be commissioned hospital built by the government is intended to cater for the health needs of the community, while an access road from Navrongo through Kologu to Kpasenkpe will facilitate the carting of farm produce to nearby marketing centres.

Community organizations

Organizations and associations currently active in the community include the Integrated Social Development Center (ISODEC), National Commission on Women and Development (NCWD), World Neighbors, Forestry Commission (FC), International Fund for Agricultural Development (IFAD), Ministry of Food and Agriculture (MoFA), Co-operative League of USA (CLUSA), Rural Women Association (RUWA) and the World Food Programme (WFP) of the United Nations. Interactions with these organizations have helped build the community's capacity in various fields of development. For example, groups such as Akagre Women's group, Asungtaba Women's group, Nayire Nutrition Group, Nayire Afforestation group, Nayire Piggery group, Dijango Women's group, Nayire Soya bean men's group, Kologu Women's group, Dongo KommaWomen's group, Yaaba Pogsi Women's group, and Nayire Disabled group are engaged in activities ranging from crop production and agro-processing, through tree-planting to small trade.

SWOT analysis

Strengths include dispersed settlement pattern, animals confined in compounds, crop residues used as animal bedding and external organizations present in large numbers

Opportunities are large compound farms, large grazing fields around compounds, presence of a dam, closeness to the Tono Irrigation Project and the presence of a large crop storage structure

Weaknesses include poor and rocky fields, soggy animal pens and bedding in compounds during rainy season

Threats are loading and soil erosion

Conclusions

The PRA work and related SWOT analyses indicate that all the four target communities have challenges that need to be addressed as well strengths and opportunities which must be optimized to enhance project success. Prominent among the challenges in the communities are low soil fertility, inadequate water supply for crop production and for human (in two communities) and animal consumption. However, these are some of the basic problems the project has already identified and seeks to address through research. In doing so, however, it is important to identify and collaborate with some of the large number of NGOs that are currently active in the target communities. The extensive experience these NGOs have gained in the communities should be tapped to enhance project success.

Another important asset is farmers' appreciation of the fact that application of organic matter such as animal manure, crop residue and household refuse can improve the fertility of their farmlands to appreciable levels, and thereby increase crop production. It is important however to investigate the reasons why the farmers apply organic matter essentially to compound plots. If it is a question of inadequate supply of organic matter, every effort must be made to help farmers to improve upon their current animal husbandry practices, maximize the production of biomass on their farms, increase the quality of organic matter and even learn to use green manure. The perception that inorganic fertilizers are too expensive and that their continuous use may be detrimental to farmlands is rife in all the four communities visited. Every effort must be made to demonstrate through the on-going farmer participatory research to show that the perception and fear may be unfounded.

It is evident from the calendar of activities that women contribute significantly to agricultural production in the target communities, and to be truly effective, the development of crop, water and soil management technologies and strategies for their adoption must involve them directly. Finally, the analysis has shown that, aside from dry season vegetable production, women in the target communities engage in a wide range of off-farm activities such as shea nut, rice and groundnut processing. Every effort must be made to assess the income generating potential of some of these activities, so that appropriate technologies or interventions can be made to assist them to maximize their earnings.

Objective 5*:*
To promote and scale up and out 'best bet' crop, water, and nutrient management strategies in the Volta Basin through more efficient information, methodology and technology dissemination mechanisms

Methods
The integration of scaling up strategies from the onset of the project will help to strengthen ultimate application of the results through: a) early identification of "demand" for outputs (and of associated documentation & capacity-building needs), and b) involvement of key organizations (scaling up channels) in the learning process**:**

Wider dissemination efforts by strategic partners are critical to achieve impacts. Partnerships and linkages with local stakeholders and service providers will provide the means to share quickly the best technologies and methods to wider areas in the country. Partnership and networking will also provide ready access to a pool of skilled personnel trained through them, and links with multiple partners (NGOs, CBOs, private sector, seed producers, universities, extension agents, traders) who could significantly contribute to wider dissemination efforts. This project will facilitate a coordinated effort to achieve a wide impact, and to scale out profitable proven technologies.

The project will develop a systematic scaling out strategies to expand the benefits to wider geographic areas and to more people. Scaling up strategies will be included in the project planning and implementation framework, and will spell out targets for each year and for different partners, and mechanisms for reaching out more people, more quickly.

The use of innovative social science methodologies (network analysis, collective action, social capital, communication channels, adoption and diffusion pathways, uptake pathways,…) will be necessary to improve understanding of collective action and innovation processes, community and individual decision making processes, communication and dissemination systems that enable resource poor farmers, especially women, to intensify their production systems, access better market opportunities, and adopt and disseminate improved technology options for efficient use of water and nutrient.

Activities

5.1. Identify key stakeholders and develop strategic alliances, partnerships, relationship building and participation to promote inter-institutional partnership between research and development organizations and provide services to farmers in a more integrated manner
5.2. Organize series of training/reflection workshops at different levels (farmers, extension workers, researchers, development agency managers, policymakers) to analyze and learn from experiences and for further action planning
5.3. Facilitate and provide feedback to farmers' communities, research institutions and civil society stakeholders
5.4. Develop, test and document effective alternative dissemination mechanisms to reach a variety of end users and other stakeholders
5.5 Use GIS tools to map suitable areas for efficient water and nutrient use crop varieties, fodder and multipurpose tree crops, and develop recommendation domains for scaling out appropriate technologies.
5.6 Promoting international exchange of experiences and mutual learning on cross-cutting themes through publications, workshops and exchange visits
5.7. Develop and disseminate decision-support tools for policy makers and other stakeholders
5.8. Engage with policy makers and civil society stakeholders in policy advocacy/ development/change to facilitate the exposure of policy makers to INM and water use efficient technologies through field visits, policy briefs, videos, mass media, etc.

Results and discussions

Stakeholders were identified and strategic alliances with these key stakeholders were established and reinforced in Burkina Faso and Ghana.

Several visits were made to the project 5 sites in Burkina Faso and Ghana by ICRISAT and TSBF-CIAT project scientists and research assistants to provide technical backstopping to the partners. Meetings were held between the various partners in Burkina Faso and Ghana and field visits were made to plan activities, exchange experiences, etc. Visits were made to Burkina Faso and Ghana by the Volta Basin Coordinator, the Theme 1 leader, the theme 4 leader, and the Global Coordinator of CPWF. Visit to SARI, Ghana with SAFGRAD for exchange of experience and strengthening of partnership.

Meetings were held between SARI/INERA and SAFGRAD to further elaborate on the collaboration and further define the role and responsibilities of each actor. Aspects of scaling-up and out of the technologies and the associated budget (sharing amongst the partners) were also discussed.

A field Day was organized in Navrongo, Ghana on September 4, 2006 that was attended by one hundred and twenty (120) participants consisting of farmers, Director and Staff of Ministry of Food and Agriculture (UER), District Assembly staff and NGOs attended the field day. The field Day was covered by local FM radio station and proceedings and interviews were broadcasted for 2 days.

A field Day was held at Saala, Burkina Faso on October 3, 2006 that was attended by various stakeholders including farmers from Saala and Ziga, farmers from 5 neigbouring villages, the Director General of CNRST, Directeur of INERA, the Director General of Environnement, Directeur of IRSAT, Provencial Directors, Projects and Associations ; ICRISAT, and UA -SAFGRAD

A Planning and review meeting for PN5 was held in Ouagadougou from 21 to 22 March 2007 and was attended by the PN5 Leader, R. Tabo, and other key PN 5 members (Andre Bationo, Mathias Fosu, Seraphine Sawadogo-Kabore, Saaka Buah, Dilys Kpongor, Konadu Acheampong, Moussa Bonzi, Saidou Koala, Dougbedji Fatondji, Ousmane Hassane, Adamou Abdou, Mahama Ouedraogo, Abebe Haile-Gabriel) the Theme 1 Leader, Dr Liz Humphreys, the Volta Basin Coordinator, Dr Winston Andah, Theme 4 leader, Dr Francis Gichuki, the PES coordinator, Mrs Fredah Maina.

Training course on land degradation was conducted by UNU-INRA in Accra, Ghana in June 2004: Eighteen (18) participants and project 5 partners from Burkina Faso, Ghana, Togo, Guinea and Nigeria participated in the course

JIRCAs scientists visited the benchmark sites in Burkina Faso and Ghana and interacted with partners, developed mechanisms for strengthening collaboration and future joint project proposal development

A comparative study on large scale extension methods used in both countries was conducted and results presented to partners of the project during a workshop organized at SAFGRAD in Burkina Faso in June 2009. The reports of on these studies are join to the completion report on a CD.

Conclusions

Strategic alliances were formed between the project team and key stakeholders including NGOs, Government staff, extension units, farmers' organizations, private sectors and other research organizations. This partnership, coupled with frequent exchange visits and meetings reinforces the collaborative work and sets the stage for a wider dissemination and scaling up and out the most promising technologies in the Volta Basin.

OUTCOMES AND IMPACTS

[**Outcomes and Impacts (3-6 pp.) – *how has this project influenced stakeholders – the people, groups and organizations with whom you are working to effect change (please use the pro-forma below to complete this section and see Participatory Impact Pathways Analysis (PIPA)* http://impactpathways.pbwiki.com)]

2 Proforma

Summary Description of the Project's Main Impact Pathways

Actor or actors who have changed at least partly due to project activities	What is their change in practice? I.e., what are they now doing differently?	What are the changes in knowledge, attitude and skills that helped bring this change about?	What were the project strategies that contributed to the change? What research outputs were involved (if any)?	Please quantify the change(s) as far as possible
Farmers based associations and community based organizations	collaboration with researchers and other stake holders Relations between the communities strengthened	Community leaders and individual men and women farmers who were actively involved in the household surveys have gained significant amount of confidence in interacting with scientists and extension workers These communities became aware of the importance/necessity of joining their forces to enable them get a guarantee with the popular financial schemes, thereby enhancing their access to credit which enables them to engage in income generating activities while waiting for the right time to sell their warranted products	The existing farmers' organizations/associations in the project villages were strengthened in an spirit of community Through the collective storing of products under the warrantage system, the relations between the communities strengthened	
Extension workers and farmers	Working more closely together	research-extension-farmer linkage was strengthened	All the activities of the project were done on participatory basis as all steps were preceded by community meeting.	

MoFA in Ghana	Improved knowledge in field experimentation Improved knowledge in field data collection		In Ghana for instance everything was done with the participation of the ministry of agriculture or it local institutions At all stages of toward and during experiment implementation these MoFA staff on the ground was fully involved. They were also trained in data collection	
Farmers	Understand better the importance of the proper use of technologies Farmers understand better the importance of expressing their needs on their own: identification of needs of technology; identification of partners and project proposals for their villages within the decentralization and rural re-structuration	Zai technology is better used than in the past- mixing organic manure with soil to ensure a better establishment of plant roots Adaptation of the technologies to the biological cotton in Saala observe and study on their own the fluctuation of prices before selling their products that were stored under the warrantage system farmers to become familiar with the variability of rainfall in space and time in a quantitative manner	The monitoring and follow-up of the Sahelian Eco-Farn (SEF) and other technologies in Saala saw an increased involvement of all the farmers during the three years of the project Participatory research was conducted with farmers and development partners: exchanges, meetings and discussions throughout the project period The multi-disciplinary nature of the project enabled a positive interaction between all the disciplines. A new perception of complementarities and participatory research is sustained throughout the project life.	
Financial institutions	They institutions accepted to make of the warrantage one of their product	They understand that if necessary measures are taken the warrantage product was the most reliable asset.	We trained them on warrantage which makes them	
NARS Scientists	The training courses gave project partners from the NARES opportunities to acquire skills in the use of the Decision Support	Scientists from the National Agricultural Research and Extension Systems in Burkina Faso and Ghana benefited from the wide range	Increased research capacity of NARES collaborators achieved during the course of the project	

	Tools for evaluating the potential of promising technologies and up-scaling these technologies in the Volta Basin Close collaboration was establish between SARI and INERA following NARS scientist involved in the project are able to focus their work in their mandate areas in the two countries:	of information collected during the characterization studies and compilation of promising technologies		
Scientific	Working with farmers in this harsh environment, this project also shows that yields of crops such as sorghum and maize can be increased up to several-fold through adoption of improved varieties, in-field rainfall capture and nutrient management, and the productivity benefits of including a legume (e.g. cowpea) in the rotation	Crop yield increase compared to local practices	Demonstration with farmers' participation of soil and water conservation technologies as well as nutrient management technologies (Zai, Half moons NPK, DAP and Rock phosphate)	
Other project partners in both countries	Project partners in both countries have a better understanding of the extent of gender disparity in the allocation of agricultural resources in the target communities. Partners from the national programs have deeper insights into farmers' knowledge and perceptions about constraints to agricultural production in the target communities	Project partners from Burkina Faso and Ghana gained experience in gender analysis and market surveys. Various stakeholders including NGOs, farmers, and scientists		

Of the changes listed above, which have the greatest potential to be adopted and have impact? What might the potential be on the ultimate beneficiaries?

All the technologies used with farmers have the potential to be adopted and particularly smallholder would be the beneficiaries. However some are likely to be more adopted. Among these we can site the warrantage in Burkina at both sites, the application of which continued in the off-season 2009 – 2010. In fact it is even spreading beyond the sites of intervention of the project. For instance the project findings have led to a plan for warrantage systems to be set up in 10 new communities by a new donor, guided by the findings of the PN5 team in Burkina Faso.
The fertilizer microdosing owing to the increase fertilizer use efficiency is another technology that will be continued. The zai technology coupled with the use of NKP and rock phosphate was also adopted at Saala.

What still needs to be done to achieve this potential? Are measures in place (e.g., a new project, on-going commitments) to achieve this potential? Please describe what will happen when the project ends.

So far a lot have been achieved during this project. However, there is still to be done in some areas. For example the issue of water x nutrient interaction need further work in the context of changing climate where water scarcity is become more and more a problem not only due to the total amount of water but also the distribution rain in time. In this regard, no project is actually there to continue what the PN5 have started.
As far as the aspect of fertilizer availability is concerned, it was the bottle neck to the wider adoption of the fertilizer microdose technology. The new AGRA microdosing project that aims at a wider scaling up of the fertilizer microdosing and warrantage system in Burkina Faso, Niger and Mali, which builds on the experience acquired during the course of the CPWF PN5 project is trying to address this problem. This project of 11.5 Millions dollars is targeting on average 40% grain yield increase and will reach several hundreds of households in three years.
From our analysis, it will be necessary to adopt a watershed management approach to address all the problems improving the livelihood of the smallholder farmers in the basin. Owing to the size of the basin and the involvement of many countries this will need a global project that would involve all the countries but not only two of them and on specific questions.
The project has end, however most of the systems and technologies will be used by the farmers particularly the warrantage system which farmers see as way to assure food security and increased income. However the evaluation of this system in the countries of the project have shown that the farmers still need some capacity building and support to master all the processes. In addition in Ghana where the system was not implemented, after the training that we organized the financial institutions were ready to try it with the communities. If opportunities where given to work more with these communities they could be the starting point of the application of the warrantage in Ghana. They call it inventory credit but the way it is implemented in Niger it should not called as such. During the training we understood that they use to give loan to the farmers for farming, which is th opposite of the spirit of the warrantage

Each row of the table above is an impact pathway describing how the project contributed to outcomes in a particular actor or actors.
Which of these impact pathways were unexpected (compared to expectations at the beginning of the project?)

The principal goal of the project was to succeed in improving the livelihood of the communities of the volta basin through the use of best bet technologies in the area of improved water productivity. Most of the impact path ways mentioned was therefore identified.

Why were they unexpected? How was the project able to take advantage of them?

What would you do differently next time to better achieve outcomes (i.e. changes in stakeholder knowledge, attitudes, skills and practice)?

If We were given the opportunity to work for another 4 to 5 years with these communities, from the research point of view we would focus on water x nutrient interaction; we would work on water and nutrient flows and considering the complexity of the systems in basin as whole the watershed approach in all these studies will be targeted. In that regard the problem of payment of environmental services could be addressed fully
From the extension point of view the community base associations that the project helped to strengthen would be monitored to assure that sustainable linkage be built between farmers and extension services
From the policy point of view it was noticed that the major constraints to use of fertilizer are availability and accessibility to farmers. If we were to continue this project effort would be made to assure that through favorable credit schemes, fertilizer is available to them. This should be coupled with the warrantage system one component of which is the input shop. Effort should be made to get the private sector involved in agriculture.

3 International Public Goods

[**International public goods (2 pp.) - *summarize new insights, tools and methodology, data and any other IPG of value beyond the project location/country/basin*]

3.1 Tools and Methodology

The project has published a book entitled "Synthesis of soil, water and nutrient management research in the Volta Basin" by Bationo A., Tabo, R., Waswa, B., Okeyo, J., Kihara, J., Fosu, M., and Kabore, S. Editors. 2008. Ecomedia Ltd. Nairobi, Kenya, 331 pp. ISBN 978-92-9059-220-04 which will be a reference book for students, scientists, development officers from all over the world.

The weather data that are being collected and compiled (long term weather) will be of great use to scientists who will be doing some modeling work in the region and elsewhere.

Several project partners have been trained in the use of new tools like DSSAT that will enable them to add value to their research work. This tool (DSSAT) is being progressively used to run different scenarios under varying water, soil, nutrient and crop management options. It is becoming a good decision support system in PN5.

Participatory approaches for gender analysis and market surveys are used in the project. The activities related to the various socio-economic and gender surveys and analysis are being refined as the work progresses.

African Union / SAFGRAD a partner in the project published two books on a comparative study on large scale extension methods used on the project sites. One in English for Ghana and one in French for Burkina Faso.
A copy of the books will be added as appendix to this report.

4 Partnership Achievements

[**Partnership achievements (1 p) – *what has been the value adding to science, outcomes and impact achieved through new partnerships developed as a result of your participation in CPWF]*

- The CPWF has enabled us to build a diverse and strong partnership between International Agricultural Research Institutes (IARCs), National Agricultural Research and Extension Systems (NARES), Advanced Research Institutes (ARIs), NGOs and rural communities. Based on the research priorities of the Volta Basin and the expected outputs of the relevant themes, the PN5 partners have been able to identify research and development activities that are being implemented in a participatory manner to address the major constraints to agricultural and water productivity in the Volta Basin. A different way of working and interacting with end users is made possible in this project using these laid research priorities of the basin and the alliances that are been formed in the benchmark sites.
- The linkages that are established between PN5 and the projects operating in the project study sites (Desert Margins Program, GLOWA project, AfNET, etc.) are very useful in building synergies and pooling human as well as financial resources together for the common goal.
- Farmers learned how to tie ridges which is their normal seedbed preparation method for enhanced field water harvesting.
- Improving effectiveness and efficiency of fertilizer use e.g. before project implementation, farmers leave fertilizer on soil surface. They also mix NPK and SA which they apply together when crop is 6 weeks old. Now they apply fertilizer at planting and at 6 weeks after planting for efficient plant utilization
- The project enabled the two partner national institutions SARI and INERA to work together on a common subject, even though at community level some differences might exist. This will in the future enable them to put effort together to submit proposals to sustain the synergy created.

5 Recommendations

[**Recommendations (1-2 pp.) – *for research, extension, policy, institutions…]*

For research

- Further work on water x nutrient interaction
- Water and nutrient flows
- Publish findings
- Use watershed approach in studies – recommendation domains

For extension

- Monitor and strengthen Farmers Based Organizations and Community Based Organizations
- Maintain and strengthen extension-farmer-linkage

For Policy

- Make fertilizer available and accessible to farmers through favorable credit schemes
- Price stabilization for agricultural goods
- Stimulate private sector interest in agriculture
- Encourage agro-enterprise and value addition

6 Publications

[**Publications – *a list of project publications and other tangible outputs (e.g. software; training materials; survey materials); include to links to websites where these materials are available]*

Bationo A., Tabo, R., Waswa, B., Okeyo, J., Kihara, J., Fosu, M., and Kabore, S. Editors. 2008. Synthesis of soil, water and nutrient management research in the Volta Basin. Ecomedia Ltd. Nairobi, Kenya, 331 pp. ISBN 978-92-9059-220-04.
(a copy of the chapters to be added in Annex)

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PROJECT PARTICIPANTS

[**Project participants – *list of all participants and their affiliations*]

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Appendix A

[**Appendices – *include copies of Abstracts of all key publications]*

Dilys S. MacCarthy, Rolf Sommer and Paul L.G. Vlek. 2009. Modeling the impacts of contrasting nutrient and residue management practices on grain yield of sorghum (Sorghum bicolor (L.) Moench) in a semi-arid region of Ghana using APSIM. Field Crops Research, Volume 113, Issue 2, Pages 105-115

Abstract:

The cropping systems model APSIM (Agricultural Production Systems sIMulator) was applied to assess the response of sorghum grain yield to inorganic fertilizers applications and residue retention in diverse farmers' management systems (homestead fields and bush farms). The model was parameterized using data collected from experiments under optimum growth conditions (limited water or nutrient stress).
Independent data from field experiments with three levels of P and four levels of N fertilizers conducted at two different locations and soils were used to evaluate the model. Soil water and fertility parameters measured were used for simulations while same starting conditions were assumed for unmeasured parameters for all trials. APSIM predicted the grain yield response of sorghum to both N and P applications with an overall modified internal coefficient of efficiency of 0.64. Following model parameterization, a long-term simulation study was conducted using a stochastic weather data derived from historical weather data to assess the effects of crop residue management on grain production. A gradual decline in sorghum grain yield was simulated over the 30-year simulation period in both the homestead fields and the bush farms, with yields being much lower in the latter under farmers' management practices. Half the amount of mineral N fertilizer used in the bush farms was needed in the homestead fields to produce the average grain yields produced on the bush farm with full fertilization, if crop residues were returned to the fields in the homestead. Year-to-year variability in grain yield was consistently higher with the removal of crop residues, irrespective of management systems. APSIM was responsive to both organic and inorganic fertilizer applications in the study area and also highlighted the essential role of crop residues and inorganic fertilizer in influencing the temporal sorghum grain production and hence the impact of farmers' management practices on food security. This was evident in the rapid decline in soil organic carbon (SOC) accompanied by a decline in grain yield over the 30 years of cropping. The use of inorganic fertilizer and retention of crop residues (SOC) are critical for attaining food security in the study area

D. Fatondji; A. Bationo; R. Tabo; J. W. Jones; A. Adamou; O. Hassane 2009. Water use and yield of millet under the zai system: understanding the processes using simulation. Humphreys, E. and Bayot, R.S. (Editors). 2009. Increasing the productivity and sustainability of rainfed cropping systems of poor smallholder farmers. Proceedings of the CGIAR Challenge Program on Water and Food International Workshop on Rainfed Cropping Systems, Tamale, Ghana, 22-25 September 2008. The CGIAR Challenge Program on Water and Food, Colombo, Sri Lanka. 125 - 146 pp

Abstract:
In the drylands of Africa about 90% of the population are rural and depend on subsistence agriculture for their livelihoods. There is increasing pressure on natural resources due to high population growth, and farmers are forced to cultivate marginal lands due to limited availability of good cropping land, thereby compounding the land degradation problem. Low and erratic rainfall, its poor distribution within the growing season, prolonged dry spells, lack of adequate water infiltration due to soil physical degradation (crusting) and nutrient shortage adversely affect crop growth and yields. To address these problems, indigenous, easy to implement innovations such as the zai system may help increase productivity. The effect of three planting techniques (flat, zai pits of 25cm or 50cm diameter) and three fertility management options (none control, crop residue, cattle manure) were tested at Damari, Niger in 1999. Soil water content was monitored weekly throughout the growing period. Data from that experiment were used to determine the ability of the CERESMillet model of the Decision Support System for Agrotechnology Transfer (DSSAT) to predict yield response to the zai water harvesting system. The model simulated the observed yield response of the control and the manure amended plots with high rsquared (0.99), low residual mean square error (340 kg ha1 for total biomass and 94 kg ha1 for grain yield) and high dstatistic (0.99), but this was not the case for the crop residue treatment where yield was

over-predicted. Soil water content and extractable soil water were also well simulated for the control and manure treatments. This evaluation of DSSAT provides a starting point for research to evaluate the performance of these technologies over wider areas in West Africa. The application of models for such studies must be interpreted in the context of limitations of the model to address constraints related to soil and climate. Nevertheless, the highly variable crop response to technologies in this region due to the interacting effects of rainfall, management and adverse soil conditions make this an extremely important approach in planning for outscaling technology adoption and in interpreting results from experimental field research.

Tabo, R., Bationo, A., Hassane, O., Amadou, B., Fosu, M., Sawadogo Kabore, S., Fatondji, D., Korodjouma, A., Abdou, A., and S. Koala. 2009. Fertilizer microdosing for the prosperity of resource poor farmers: a success story. In: Humphreys, E. and R.S. Bayot (eds.). *Increasing the productivity and sustainability of rainfed cropping systems of poor smallholder farmers.* Proceedings of the CGIAR Challenge Program on Water and Food International Workshop on Rainfed Cropping Systems, Tamale, Ghana, 22-25 September 2008. The CGIAR Challenge Program on Water and Food, Colombo, Sri Lanka. 269 – 277pp

Abstract:

Fertilizer microdosing is the application of tiny doses of fertilizers in the planting hole at sowing, or next to the plant two to three weeks after planting. The technology increases fertilizer use efficiency and yield while minimizing the cost of inputs. The results reported here show that solving the soil fertility problem unleashes the yield potential of improved crop varieties, roughly doubling yield. Two crucial advantages of microdosing are its adoptability and profitability. High rates of fertilizer have been recommended to farmers for a long time to maximize yields, but farmers could not afford to do so. By using much lower rates of fertilizer than the recommended rate, in more efficient ways that deliver economically optimum returns, farmers are much more able and inclined to adopt the practice, and are increasingly doing so. Once fertilizer microdosing is adopted, it establishes a pattern for future productivity as farmers become accustomed to increasing their investments in inputs in order to generate increased returns. Microdosing is thus a strategic first step on a sustainable development pathway, in addition to generating large benefits itself. The microdosing technology has been demonstrated and promoted in Burkina Faso, Mali and Niger during the past few years with very encouraging results. Sorghum and millet yields increased by 45 to 120 % in comparison with farmer practice, while farmers' incomes went up by 50 to 130 %. This paper highlights these outstanding past results and the on-going efforts to further scale-up the technology.

R. Tabo, A. Bationo, S. Sawadogo Kabore, O. Hassane, B. Amadou, P. Siebou, S. Ouedraogo, A. Abdou, D. Fatondji, H. Sigue, S. Koala, M. Fosu and M. Fredah. 2009. Institutional innovation: the potential of the warrantage system to underpin the green revolution in Africa. In: Humphreys, E. and R.S. Bayot (eds.). *Increasing the productivity and sustainability of rainfed cropping systems of poor smallholder farmers.* Proceedings of the CGIAR Challenge Program on Water and Food International Workshop on Rainfed Cropping Systems, Tamale, Ghana, 22-25 September 2008. The CGIAR Challenge Program on Water and Food, Colombo, Sri Lanka. 279 – 291pp

Abstract:
The warrantage or inventory credit system was developed to address the liquidity constraints that farmers encounter while trying to intensify their production systems. The scheme removes barriers to the adoption of soil fertility restoration technologie**s** by ensuring that farmers have access to cash, technical advice, and inputs. Farmers use the credit to purchase external inputs, such as fertilizers and seeds, and to invest in dry season income generating activities, such as fattening of small ruminants, vegetable growing, trading, and groundnut oil extraction. In an earlier study funded by USAID, it was found that the incomes of farmers using the warrantage system, along with use of the fertilizer microdosing technology increased by 52 to 134 %. In a project funded by the Challenge Program on Water and Food (CPWF), farmers are responding positively to the implementation of warrantage in two communities in the villages of Ziga and Saala in Burkina Faso. This scheme is getting increasing support from donors for its wider promotion in Sub-Saharan Africa. The constraints to the development and implementation of warrantage include lack of capital for Decentralized Financial Systems (DFS) to grant loans and for supervising

bodies to provide guarantees, government interference through dumping imported commodities onto the market, lack of infrastructure at the village level, and lack of well□organized farmer associations. An analysis of the constraints to the implementation of the scheme as well as the factors underlining the promotion and use of the warrantage system are also discussed.

Kihara, J. A. Bationo, B. Waswa and J. Okeyo, 2009. Tillage, residue management and fertilizer application effects on crop water productivity in western Kenya. Humphreys E, and Bayot, R.S. (Editors). 2009. Increasing the productivity and sustainability of rainfed cropping systems of poor smallholder farmers. Proceeding of the CGIAR Challenge Program on Water and Food International Workshop on Rainfed Cropping Systems, Tamale, Ghana, 22-25 September 2008. The CGIAR Challenge Program on Water and Food, Colombo, Sri Lanka. pp 55 – 70

Abstract:

A long□term conservation tillage experiment was established in Nyabeda, western Kenya in March 2003 to investigate the effects of tillage and residue management on crop water productivity (CWP, kg grain m^{-3} rain) in continuous maize and maize□legume cropping systems. Seasonal CWP of maize over the first eight cropping seasons ranged from 0.1 to 0.8 kg m□3 of in-season rainfall. For continuous maize, there was a consistent trend for lower CWP with reduced tillage (RT) compared to conventional tillage (CT) for the first few years, for respective residue retained/removed treatments, but with few significant differences. After 5 seasons, CWP was similar with RT and CT, with and without crop residues (CR). There was also a consistent trend for higher CWP of RT with CR than without CR for the first 5 seasons, but with no significant differences. Similar trends in maize CWP occurred in the maize□legume rotation, except in the first year where CR led to reduced yields, presumably due to N immobilization as no N fertilizer was applied. CWP of soybean was not affected by tillage treatment or residue management. With low rainfall, crop residue (CR) application increased yield by up to 30% under RT. The yield advantage of CR (over no CR) decreased with increasing rainfall (R2 = 0.9 for continuous maize and R2 = 0.7 for soybean□maize rotation). CR disappearance was fast (daily % loss of 106 e□0.019x). Phosphorus (P) and nitrogen (N) application had large effects on CWP. In the maize□soybean rotation, P application increased CWP of maize by 120%, while application of N with P increased CWP by a further 35%. Thus fertilizer application is important for increased CWP. The results suggest that RT with mulching gives similar maize CWP in continuous maize and maize□legume rotations. Rotation with soybeans brings further benefits including reduced N fertilizer requirement, while soybean CWP is also maintained in the RT

DOCUMENTS appended to the report:

1. soft copies of the books and publications listed
2. soft copy of the MSc and BSc thesis
3. Final report of the PES study in Ghana
4. Soft copy of the comparative study on scaling up methods conducted in Ghana and Burkina
5. CD of radio emission on CPWF project coordinated by SARI Ghana
6. Soft of the press release in the Accra_Daily_mail about Farmers' adoption of technologies to boost crop yield
7. Copy of women entertainment during warrantage training. NB: this was recorded with a mobile phone and may need adapted software to read it