CPWF Project Report

Empowering Farming Communities in Northern Ghana with Strategic Innovations and Productive Resources in Dryland Farming

Project Number 6

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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 the resilience of social and ecological systems through better water management for food production. Through its broad partnerships, it conducts research that leads to impact on the poor and to policy change.

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:

Empowering Farming Communities in Northern Ghana with Strategic Innovations and Productive Resources in Dryland Farming

The Strategic Innovations in Dryland Farming Project of the Challenge Program for Water and Food is an effort to improve income, labour, land and water productivity for rural households in the Volta Basin in Northern Ghana. The project's outputs were developed, adapted, and improved through pilot site participatory research with farmers in 300 focal households in 16 communities in 8 Districts that fall within the desertification hazard areas in Northern Ghana (EPA, 2002). The pilot site work led by SARI staff and participating farmers, was executed in collaboration with two CGIAR and three local NARES centers. The Project's institutional arrangement capitalized on existing operating procedures of the Research-Extension Linkage Committee (RELC) model of Ghana, such that it provided the platform for ownership by the NGOs, farmer groups and the Agricultural Extension Service. The Project emphasized increasing harvestable crop yield per drop of rainfall by intensifying crop production using varieties improved for enhanced water-use efficiency, soil and water conservation strategies, and analyses of climatic data from the Sudan and Guinea savannah zones of the Volta Basin to refine drought prediction and detection models for selected communities. This participatory technology development approach was underpinned by adoption and impact studies in beneficiary communities that refined project interventions for communities during various stages of the implementation process.

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RESEARCH HIGHLIGHTS

The Savanna Agricultural Research Institute with its research and extension partners have, in collaboration with farming households, developed a suite of technologies that addresses the core of the unsustainable livelihood situation in Northern Ghana. This was the outcome of a five-year research for development project funded through the Challenge Program for Water and Food Project 6 (CP 6). The Project, themed *Strategic innovations in dryland farming* provided outputs in areas of improved staple crop varieties for rainfall-deficit regions, practical options for increasing domestic water availability to engender female empowerment in income generation, and techniques that sustain soil water and fertility improvement of the degraded soils.

By the end of the active Project phase in 2008, four varieties of cowpea were released to farmers. Notable were the attributes of these varieties that they were immediately adopted by farmers who obtained up to 25% yield increments over earlier types. The overall contribution of these varieties to farming system sustainability was demonstrated by their suitability to pre-rice, maize and sorghum cropping where they provide valuable organic matter to the succeeding cereal crop, and dry grains at a time of depleted food stocks. Further, varieties of sorghum and cassava with proven high yields under conditions of drought have enjoyed patronage from farmers over a two-year period that these were put into adaptive trials across Northern Ghana.

The acute household water insecurity situation and its associated negative effects on female income generation were demonstrated to policymakers. To alleviate this burden, the Project introduced the use of a low-cost roof-top water harvesting system in 64 households, directly benefiting some 600 individuals. By the fifth year of the Project, at least 110 additional households have contracted locally trained artisans to install the water harvesting system to provide water during the critical dry months of December to March. At the community level, training on dugout maintenance and fish culture techniques have improved fish harvests by 40% in 22 target dugouts with associated increases in water retention. Women in these beneficiary communities and households having been freed of the burden of water sourcing for domestic needs have ample time to devote to income generation and other livelihood sustaining activities.

Analyses of long-term rainfall data provided information on occurrence, frequency and probability of dry spells. Planting dates that enable the most drought-sensitive growth stage of cereal crops to avoid dry spells were determined. On the basis of soil type, crop type and type of cropping system, farmers adopted an appropriate soil moisture retention and organic matter build-up technique through various participatory trials. These approaches include various field micro-catchment and external water harvesting techniques, and use of several legume species as cover crops.

The adoption and impact studies has shown an 11% increase (over farmers in non-beneficiary communities) in the number of farmers that have access, knowledge and use of the strategic innovations to improve dryland farming conditions in Northern Ghana.

EXECUTIVE SUMMARY

Agricultural activity dominates the livelihoods of the mostly rural inhabitants of the Volta basin in Northern Ghana that is characterized by a relatively short rainy season and longer intervening dry period. This, and conditions of farming methods incompatible with a fragile soil environment, and lack of opportunities for income generation contrive to create one of the most food insecure areas in Ghana. The inadequate capacity to harness the rainfall for domestic, crop and livestock needs; little use of inorganic fertilizer and organic residue management; and reliance on crop varieties and cropping systems that do not adequately match water availability lead to reduced harvestable crop yields and reduced productivity of water.

To mitigate the effects of these productivity constraints and create the pathway to sustainable livelihoods, the project sought to implement strategies that improve food security, ensure sustainable use of the soil resource base and of small reservoirs, and reduce household's vulnerability from the effects of frequent droughts. Central to the Project's approach was the efficient capture, and use of rainfall in the predominantly non-irrigated farming systems.

At the launch of the Project in April 2004 to create awareness about the rationale of the project, and ensure common ownership and mutual responsibility, a participatory problem diagnoses approach was adopted for selecting technology options. This was achieved through formal surveys, dialogue between beneficiary communities, local policymakers, agricultural researchers and extension staff, and field days. The interventions were tested using a systems approach based on five thematic areas designed to reinforce each other. These areas include:

- Genetic improvement of varieties of staple crops water-use efficiency
- Developing predictive tools for drought occurrence and developing mitigation strategies
- Enhanced use of community dugouts for fish culture
- Domestic water harvesting
- Analyses of the socio-economic status of households, and impact of Project's interventions

Integration of molecular techniques offered by ICRISAT and classical breeding by SARI staff led to the development of sorghum lines improved for the stay-green trait. Incorporating the stay-green trait into the genetic backgrounds of the locally-adapted short-duration Kapaala cultivar was expected to enhance its drought tolerance (van Osterom et al., 1996) and the ruminant nutritional quality of the crop residues (Hash et al., 2003). Developed through marker-assisted recurrent selection, BC4F1 lines were entered into adaptive trials across Northern Ghana since 2007. Two of the advanced breeding lines showed promise, with grain yields similar to that of Kapaala under favorable soil moisture conditions, and 10 – 25 % higher under conditions of post-flowering drought stress. Tests on other agronomic and food attributes (sensory and organoleptic properties) of the two lines have been initiated to meet the requirements for formal release of the lines for cultivation in Ghana.

From 2005 to 2007, fourteen advanced breeding cowpea lines developed by SARI and the University of California, Riverside (UCR; Padi and Ehlers, 2008) were entered into participatory multi-location trials following a mother-baby trial methodology (De Groote et al., 2002). Six of the lines were submitted to the National Variety Release Committee of Ghana (NVRC) for assessment. In 2008, four lines were officially released by the

(NVRC) for cultivation as being suitable for pre-rice and main season sole cropping systems, and possessing higher tolerance to major field pests. Currently, these cultivars have assumed prominence among varieties used by cowpea seed producing companies and institutions in Northern Ghana.

Responses from 200 farming households on attributes of preferred cassava cultivars obtained through a formal survey was informative in designing the cassava ideotype for Northern Ghana. Earliness to maturity (less than 12 months), good field storability, food quality of tubers, and plants with large canopies was sought to develop suitable cultivars for Northern Ghana. Six populations developed from seed by the International Institute of Tropical Agriculture (IITA) were evaluated based on the set criteria across Northern Ghana. In the adaptive trials, farmers' choice across the test sites revealed four lines consistently meeting their requirements. Further food quality tests as per the requirements of the NVRC have been commissioned and the outcome will inform on their general suitability for the cassava industry.

Options for soil moisture and soil organic matter accretion were investigated through adaptation of contouring, cover cropping, tied ridging, and contour ridging with vertiver grass integrated to suit particular soil requirements and famers' preferences. In the first two years of the project, farmer training on these methods was done through field days and demonstration plots. Test plots were typically maize or sorghum in mixed stands or with other crops. Fifteen focal farmers' plots across five communities were used as satellite farms for technology dissemination. Tied-ridging has been shown to increase cereal (maize or sorghum) yield by 20%-25%. Under fertilizer application at recommended rates, tied-ridging has been shown to increase cereal yield up to 150% above the control.

We have generated a dry spell distribution map for Northern Ghana based on analyses of long-term rainfall data. Drought frequencies have increased significantly over the past decade compared with frequencies in each of the past four decades. This map is now the basis for commendations on choice of crop for specific regions, and for advice on planting dates particularly for maize.

Primary and secondary fish catch data in community dugouts in the Northern and Upper East Regions of Ghana were analyzed in 2005 to determine the best approach for fish production in these small water bodies. In all the water bodies, a maximum of five species contributed to 90% or more of the catch by weight. Common among the five species were *Clarias gariepinus* and *Tillapia zilli. Oreochromis niloticus* which was used prior to 2004 as stocked material did not contribute significantly to catches. Central to the success of this component of the Project were the formation of fish management committees and their training on various aspects of dugout maintenance and fish culture practices of fingerling production, stocking, fish management, and harvesting. Twenty-two community dugouts which were used as test and training sites recorded up to 40 % increase in fish harvests over previous fish catch data. Three recommendations were developed as critical to the success of fish culture in these community dugouts. First, stocking should be with either 50g size fingerlings of the Nile tilapia, *Oreochromis niloticus* or with mature parent broodstock of O. *niloticus.* Second, stocking needs to be done in mini-cages or hapas in the dugouts rather than directly introducing them into the water. Third, it was deduced that early part of rainy season is most appropriate for enhancing fish stocks of large dugouts not likely to overflow banks at peak of rains. Small dugouts need to be stocked after peak of rainy season to avoid fish escape with possible flooding.

We assessed the water needs of households, existing rainwater harvesting and storage systems, and potential for income generation using stored rainwater in 300 households in six Districts. Households in two communities in each of six Districts were surveyed for information on existing water resources, and water use patterns. Based on average household size of 10 persons, average roof size of 80 m^2, and a rainfall range of 717 to 1500 mm (based on 1992 to 2002 data), a reservoir capacity of 30,000 litres was required to meet household water needs during the critical water-stress months of December to March, if households fill the reservoirs during September and conserve for the dry period. To meet this demand, the Project tested the suitability of a low-cost ferro-cement tank for water storage. Sixty-four households in 16 farming communities were provided with 3 or 4 ferro-cement water reservoirs, each with an estimated capacity of 5,000 litres to test suitability and water use patterns. The water harvesting system was found compatible with households' cultural preferences, and maintained water quality suitable for domestic chores. As the average distance from a household to the most reliable community water source vary from 0.3 km to 8.0 km, we tested the use of the harvested water for compost manufacture or nursing sorghum and millet seedlings with households in closer proximity to community water sources. To facilitate such application of harvested rainwater by households, the agronomic benefits of composting, and of establishing cereal production fields from transplants (rather than by direct seeding) were demonstrated. The benefits of a standardized compost (made from *Gliricidia sepium*, rice husk and cow dung with 1% N) on maize grain yields at 10 sites showed a 12 - 36% yield advantage when applied at 2.0 t/ha plus half the recommended inorganic fertilizer rate over applying inorganic fertilizer alone at the recommended rate. Demonstration of direct seeding and transplanting of sorghum and millet was carried out with 70 participating farmers in 4 communities over a three-year period. The 30 – 74 % yield increment observed in transplanted plots were attributed to earliness to mature, escape from post-flowering drought stress, reduced impact of *Striga hermonthica* attack, and reduced insect pest incidence. Deliberate application of the harvested rainwater for these two on-farm applications by households was, however, not observed as households generally preferred harvested rainwater for domestic chores.

A baseline socio-economic study on livelihood status and options of farm households in Northern Ghana was completed by the end of the second year of the Project. The study revealed a seemingly high level of awareness of the Project interventions, though the level of awareness was below the threshold required to elicit adoption of the innovations. The major determinants of adaptive capacity of farmers to innovations include: knowledge or awareness of farmer on the available innovations, access of farmers to financial services, social network (institutions), household income, availability of innovation (technology) and household size. Adoption and impact studies were conducted within a relatively short period by 2008 from responses obtained from 353 households. Compared to the baseline situation, there were improvements in the proportion of farmers reporting increased availability, access, knowledge, use, participation and consultation. Overall, there is evidence that farmers and farm households are gaining confidence in their own capacity to cope with low productivity or adapt innovations that mitigate the effects of climate variability on farm level productivity.

How much of the benefits of the innovations accrue to the target ecology is determined by the rate of adoption, and spread beyond the immediate project boundary partners. By the end of the Project in 2008, more than twice the number of Project beneficiary households have financed, and installed the water harvesting systems. Other outputs have spread as well (notably sorhum/millet transplanting and tied ridging), albeit to a lesser extent. There is promise that the varieties of staple crops developed during this Project will make a huge contribution to food security as the formal seed distribution systems have started patronising them. The evidence will however await variety adoption studies that will be carried some five years from the dates of official release.

INTRODUCTION

In the predominantly smallholder farming systems of Northern Ghana, livelihoods are directly dependent on harvestable crop yields on seasonal basis. The constraints to sustainable production are the dry spells during the cropping seasons, low fertility of farmlands and farming practices that exacerbate the effects of drought and low soil fertility. The 800-1,000 mm rain per annum is received over a five-month period followed by seven months of dry crop-free periods. Both the onset and cessation of the rains are irregular, and the temporal and spatial variabilities in rainfall are well marked. Even within the humid months of June to September, 10 to 14 days of dry spells are common. Shallow sandy and lateritic soils predominate with a large proportion characterised by presence of iron and magnesium concretions. Declining productivity of the farmlands is associated with a decline in the soil organic matter content. Moreover, households decapitalise their stock of soil fertility through removal of crop residues to feed livestock, or as building materials. The resulting loss of organic matter reduces both soil water holding capacity and use-efficiency of any applied fertiliser, and erosion of the bare soils become intense at the start of the rainy season.

Because of unpredictability in the onset and cessation of rains and high risk of intra-seasonal dry spells, farmers begin planting during late June or early July. This practice leads to reduced water productivity on seasonal basis, as all the rain received earlier is lost as run-off and evapotranspiration from ground surface and weeds. Farm-level yields of less than 30 % of crop potential yield are a defining characteristic of the farming systems in this region. The chief causes relate to lack of technologies and cropping systems suited to dryland agriculture, a degraded natural resource base, poor resources, and extension focussed on high input farming. High surface run-off during the rainy months results in silting up of community dugouts, and high evaporation rates in the dry season lead to rapid drying up of these dugouts.

Majority of farmers in Northern Ghana are small-scale farmers and poor. With rising real prices of farm inputs, there is little use of inorganic fertilisers and improved seed to the extent that the formal seed sector supplies only 15 % of seed requirements. Coupled with their little capacity for soil and water conservation practices and organic residue management, crop yields are declining.

The inadequate capacity to harvest rainwater for domestic, crop and livestock needs; little use of inorganic fertiliser and organic residue management; and reliance on crop varieties and cropping systems that do not adequately match water availability lead to reduced harvestable crop yields and reduced productivity of water. Coupled with a land tenure system in which only male family heads own land and livestock, women are worse affected by the declining yields. The necessity for women to obtain water for domestic chores reduces time available for income generation. Interventions by a systems approach that is gender sensitive and pro-poor are needed to ensure sustained livelihood of the farming communities. The need to increase food production, and sustainable use of the soil and water resources are particularly urgent. The challenge to ensuring food security is to raise land and water productivity in a manner that regenerate the natural resource base for sustained production.
In this non-irrigated agricultural systems, increasing harvestable crop per unit of precipitation is possible by emphasizing the capture, storage and efficient use of rainfall through reduction in surface run-off and evapo-transpiration from ground surface and weeds, diversification and intensification of cropping systems, and reliance on crop varieties whose phenology match the prevailing rainfall pattern or have enhanced water use efficiency.

To achieve this will require domestic, community-based and on-farm water harvesting, informed policy discussions that encourage communities to institute community water governance mechanisms, developing and adopting varieties that enhance seasonal water productivity, crop residue management and soil conservation practices that are congruent with the fragility of the soils of Northern Ghana.

PROJECT OBJECTIVES

Objectives
The basic research premise is that adopting varieties that enhance seasonal water use efficiency of the cropping systems, increased opportunities for domestic, dugout and on-farm water harvesting, and crop residue management for soil fertility amelioration can mitigate the constraints to sustainable crop production in the rainfed smallholder farming systems of Northern Ghana.

Specific objectives

1. Develop varieties of staple crops with high water use-efficiencies
2. Develop drought prediction and mitigation models for staple crops
3. Improve community dugouts to accumulate and retain water for fish culture
4. Assist households to install domestic water collection tanks, and to implement technologies dependent on rainwater harvesting.
5. Analyze the socio-economic status of households, and impact of Project's interventions

Objective 1: **Develop varieties of staple crops with high water use-efficiencies**

Introduction
Because of its high water and nutrient use efficiencies, cassava has gained prominence as one of the important tuber crops in the drylands of Northern Ghana. The objective was to develop varieties that produce high tuber yields of good cooking quality in less than 12 months.

Advanced breeding lines of cowpea developed from crosses between drought tolerant varieties from the University of California, Riverside (UCR) and two varieties released in 2003 by the SARI (Apagbaala and Marfo-Tuya; Padi et al., 2004a, 2004b) were available to the project. The objective was to select lines from these populations that will be compatible with intensified cereal-based systems such as pre-cereal cropping, intercropping as well as sole cowpea cropping systems.

Two sorghum varieties ICSV 111 (released in Ghana as Kapaala; Murty et al., 1998) and IRAT 204 were the most important commercial varieties of sorghum in Ghana. At the start of the project, BC_3F_1 or BC4F1 families heterozygous for at least one of six stay green QTLs in the genetic background of Kapaala were available to ICRISAT. The objective was to develop stay-green derivatives of Kapaala and IRAT 204 to improve upon their tolerance to post-flowering drought stress.

DEVELOPING EARLY BULKING CASSAVA VARIETIES

Methods
To select Districts within which varietal testing will be conducted, we relied on cassava production statistics in 13 Districts in Northern Ghana. These data was analysed for the total acreage, yield per unit area and total production. The type of varieties dominant in these Districts was noted. Data was provided by the Ministry of Food and Agriculture (MoFA)

I. Appraisal of indigenous knowledge of cassava production potential and constraints

Questionnaires were designed and used to obtain responses from 200 farmers in five Districts to document farmers' indigenous knowledge and perceptions of early bulking in cassava. The Districts include Nyankpala in the Tolon-Kumbungu, East Gonja, West Gonja, Nanumba and Yendi. The key information requested included the following:

- Cassava acreages cultivated, yield and production
- Distribution of production by district
- Cassava varieties cultivated and their uses, and constraints to adoption
- Farmgate, retail and wholesale prices received by producers
- Competition for production resources with other crops
- Uses of cassava at the farmer level
- Production goal of farmers
- Production cost per acre
- Estimate of cassava supply and demand
- Cassava production and supply calendar
- Availability of improved cassava planting material

II Identifying plant characters indicative of early bulking

This experiment was designed to identify the key indicators that signal the start of significant assimilate partitioning to roots in cassava. Four genotypes were used, namely 92/0057, TME 225, Afisiafi and Biabasse. The genotype 92/0057, TME 225 and Afisiafi originated from the IITA, Nigeria. 92/0057 has been noted for its mealiness and has a profuse branching habit. TME 225 is among a group of African landraces received from IITA in 1998 and produces tubers with good cooking quality after 8 months after planting. In multi-location trials, it produces high tuber yield, and has it is non-branching. Afisiafi (TMS 30572) originally from IITA is a released variety in Ghana with a medium-branching habit. Biabasse is a favorite local variety in major cassava growing belt in Northern Ghana. At each of five locations, the trial was laid out as a split plot design with genotype as main plot and harvest as sub-plot in 6 replicates. A sub-plot (stage of destructive sampling) measured 2 x 2 m consisting of four plants. A final harvest plot of 4 x 10 m was used to estimate final yield. Destructive sampling started at 1 month after planting (MAP) and thereafter every month. At each sampling period, petioles, leaves, stems, fibrous and tuberous roots were measured, counted, separated and weighed. At three of these locations (Salaga, Damongo and Yendi) the experiment was designed to take account of famers' perception on earliness at each sampling date.

III Multi-location evaluation of cassava families for early bulking

Seeds selected from families known for their high yields were received from the IITA prior to the project. These were established in a seedling nursery in 2003 and evaluated for stem girth, general plant vigor and disease symptom expression. Total of 2,000 cassava seeds from five populations, 03R02, 03R05, 03UYTA12, 03UYTC16 and 03AYTA were planted for assessment. Eight high yielding clones in the on-station evaluation were evaluated in 2007/2008 in multi-location trials with farmers.

Results and Discussion
The statistics on cassava production in 13 Districts within the cassava producing belt of Ghana from 1996 to 2000 is provided (Figure 1 a - b). Choice of District for the project was based on accessibility (roads), total output of the District, acreage and yield. Five Districts namely Bimbilla (Nanumba), Damongo (West Gonja), Salaga (East Gonja), Tolon/Kumbungu and Yendi were selected. In these Districts, the major varieties grown include Afisiafi, Biabase, Buyeduo and Kentenma.

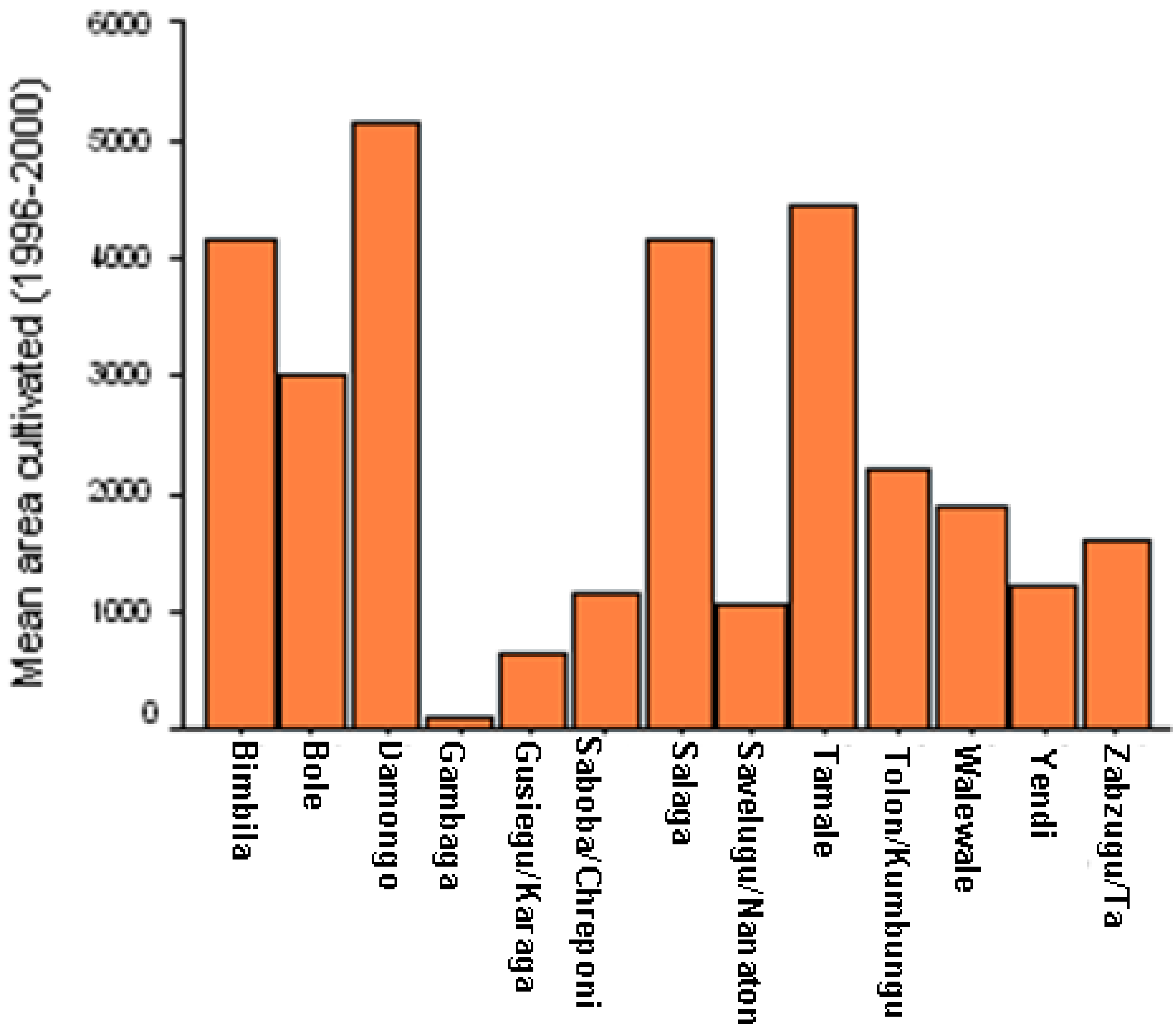


Figure 1a: ***Mean area cultivated (ha) to cassava in 13 Districts in Northern Ghana from 1996 to 2000 (****Source: MoFA****)***

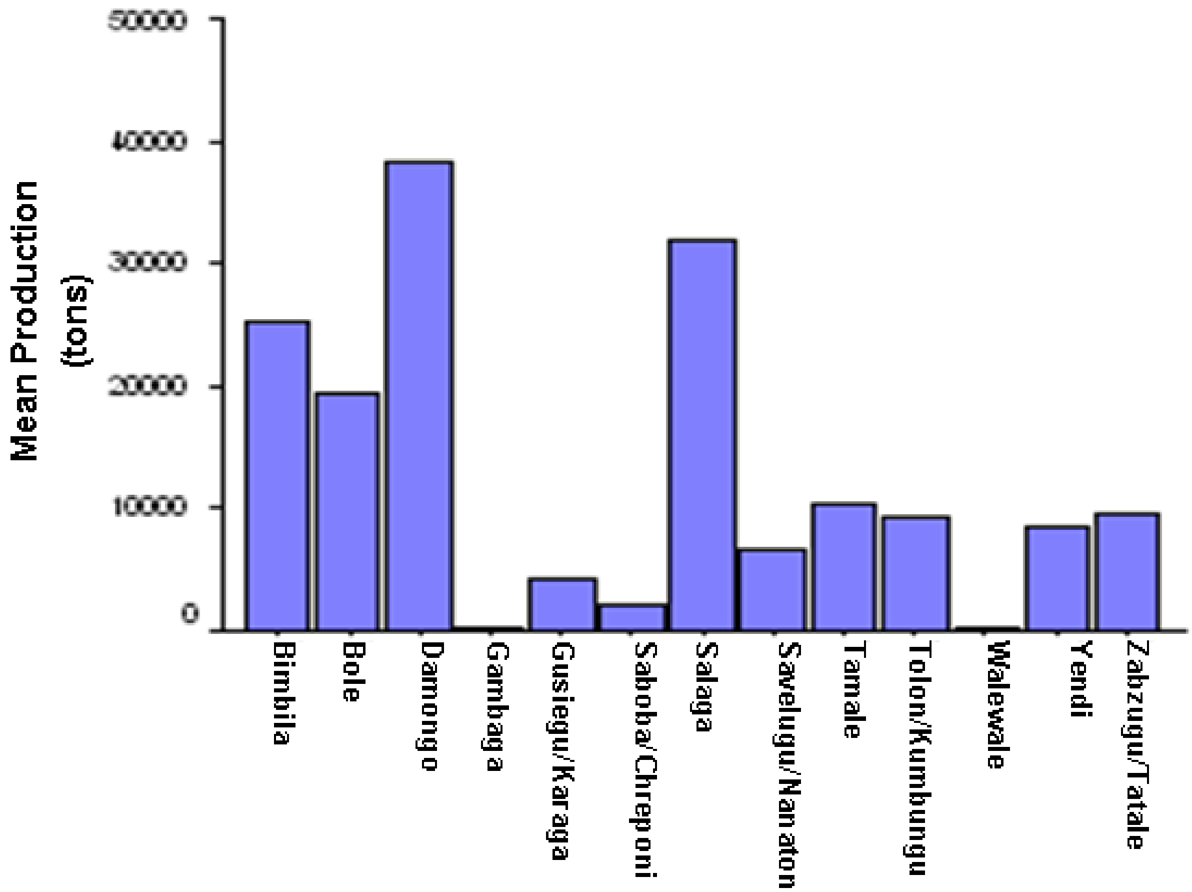


Figure 1b: **Total production of cassava (tons/year) in 13 Districts in Northern Ghana from 1996 to 2000** (*Source: MoFA)*.

I. Appraisal of indigenous knowledge of cassava production potential and constraints

Age of farmers surveyed ranged from 18 to 70 years, with a mean age of 42. Overall, 66% of respondents have between 5 to 20 years experience in cassava production, though with wide differences between Districts. In most households, at least one other person was actively engaged in cassava production. There were only slight differences in the number of varieties cultivated per farmer with a range of 2 to 4. Among the 200 respondents, 97 (48.5%) indicated they presently cultivated fewer number of varieties than in previous years (five years earlier). The frequency distribution of the current number of varieties being grown was similar irrespective of earlier size of holdings or experience. A slightly higher proportion of farmers from the Nanumba District had abandoned a larger number of varieties. Of those who had earlier grown more varieties earlier, various reasons were assigned for curtailing the production. These include low yields (45%; 47 of 97 respondents), late maturity (15%), poor root quality (15%), poor tuber storability (5%) and undesirable cooking and eating qualities (5%). A third of respondents sell 60% of their total produce.

Approximately 80% of respondents indicated that they possess varieties they consider early bulking (harvesting within 12 MAP), with similar proportions across the Districts.

Significantly, from the data collected 70% of farmers harvest their crops by 12 MAP (Figure 2).

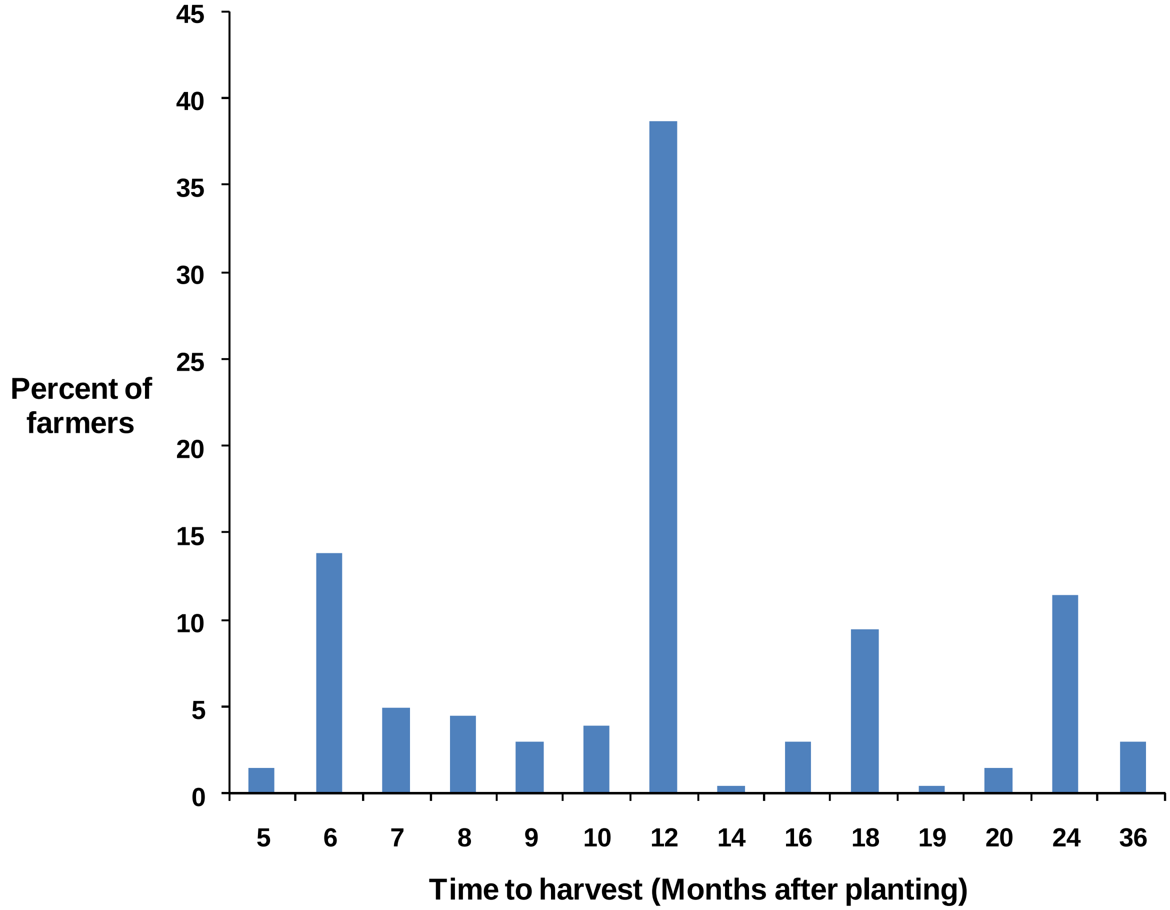


Figure 2: ***Frequency distribution of time to harvest of cassava fields among 200 farmers in the Northern Region of Ghana***.

Farmers provided a total number of 33 varieties as early bulking varieties they cultivate. Of these, 30.5% of respondents cultivate Bosumnsia variety (literally meaning six months). Other varieties with high prevalence among farmers include Afisiafi (9.9%; a recommended variety), Kromaso (7.2%), Buyado (6.6%) and Puriya (5.3%). Surprisingly, the time to harvest was not related to whether a farmer had early maturing varieties or not. Some farmers with early maturing varieties harvested 18 MAP.

When asked whether they can classify varieties as early bulking based on vegetative characters, 55% of respondents indicated that they have the skill to do so. There was little variation among the respondents from the various Districts with or without the skill to select an early bulking variety (Figure 3).

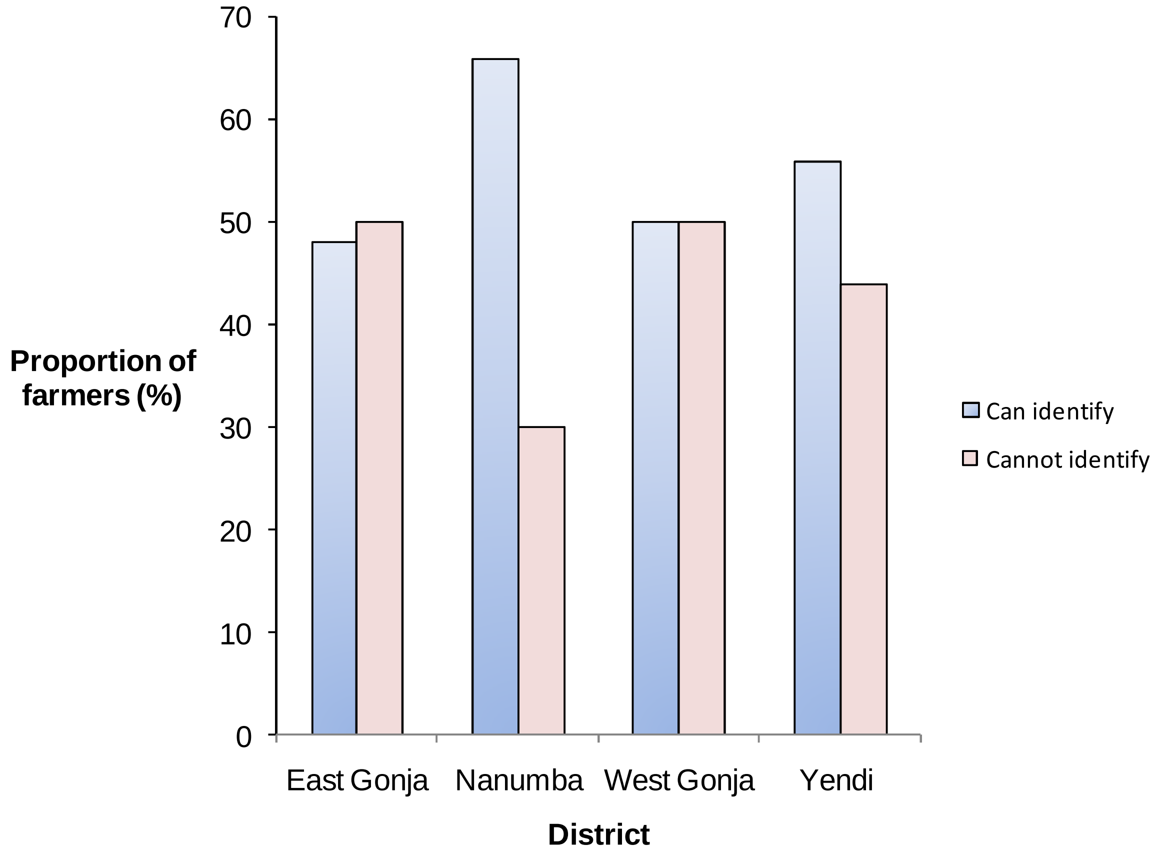


Figure 3: ***Proportion of farmers in each of four cassava growing Districts with or without skill to select for early bulking varieties*.**

Except for East Gonja District where respondents gave a variety of indicators of early bulking, across the Districts stem (34.5% of respondents), leaf (22.6%) and pant size (29.8%) attributes were the indicators of early bulking. For stem attributes, size (thick and short and color (brown, white or red) were the indicators of early bulking (their appearance in relation to the age of the crop). The leaf attributes were time of shedding leaves, and change in color from green to dark green or yellow. Among the plant size attributes, the height and canopy size in relation to age were the key indicators.

Though an overwhelming majority (96%) was eager to adopt an early maturing variety, some constraints to adoption were mentioned. These include poor on-field storability of tubers of early maturing varieties which requires harvesting even if maturity coincides with a time of poor market value. The second most important constraint was the poor canopy development of early varieties which makes them unable to shade out weeds.

II Identifying plant characters indicative of early bulking

Data was collected on various root and shoot characters for the four genotypes used in the study. From the sequential harvests of tuberous roots, an early bulking index (EBI) estimated as root weight at a sampling period over the root weight sampled at 26 weeks after planting (WAP) was computed for each sampling period. The change of EBI over time revealed that the local variety Biabasse was over 70% of its 6 month yield at 18 weeks after planting compared to between 30 and 40% for the three other varieties (Figure 4). In terms of total dry matter accumulation however, Biabasse is the lowest yielding line by 26 WAP.

The results conform to the general performance of crop varieties that show early maturing varieties recording yield penalties for earliness (Mitra, 2001). In spite of low EBI values of genotype 92/0057 up to 18 WAP, rate of dry matter partitioning to roots increased rapidly in this genotype and recorded EBI value similar to Biabasse by 26 WAP. It appears the advantage of the local variety is in rapidly reaching its yield potential, potential avoiding moisture stress that frequently occurs within the sub-region. The actual dry matter accumulation (yield potential) is rather low.

The data obtained at Salaga, sampled at 16 weeks after planting (Table 1) showed the low yield potential of Biabasse is spite of the high EBI associated with the genotype.

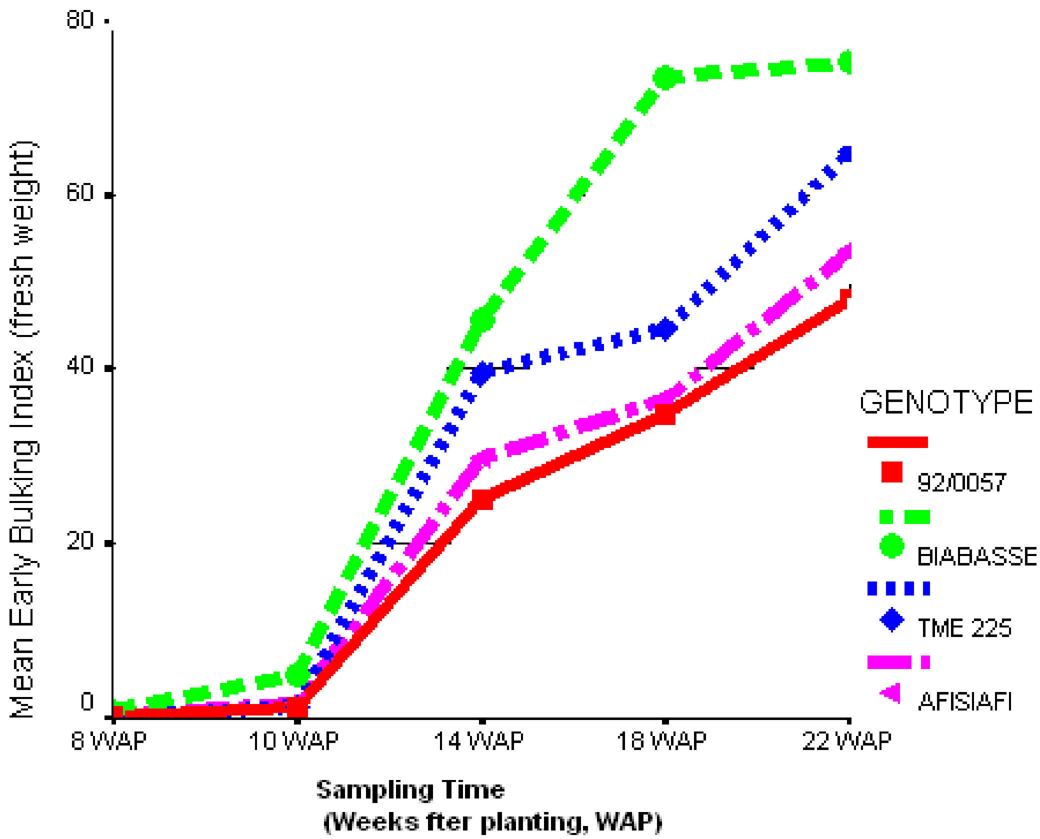


Figure 4: ***Progress in the early bulking index (EBI) of tuberous roots in four genotypes of cassava in Nyankpala, 2004.***

Table 1: Performance of four cassava genotypes at 16 weeks after planting at Salaga

	Number of plant parts (per plant)			**Weight of plant parts (g/plant)**		
Genotype	**Leaf scars**	**Roots**	**Leaves**	**Roots**	**Stem**	**Leaves**
T ME 225	42.0	3.0	35.2	433.3	103.3	76.7
AFISIAFI	44.3	4.2	30.8	520.0	186.7	83.3
BIABASSE	42.5	5.0	41.0	226.7	63.3	30.0
92/0057	63.5	5.2	59.0	496.7	126.7	73.3
$LSD_{0.05}$	**3.45**	**0.63**	**9.1**	**142.5**	**39.8**	**13.6**

In the appraisal of the varieties in relation to early bulking, all farmers who participated indicated their preference for early bulking varieties. Farmers ranked the four genotypes based on either shoot or root characteristics as early and high yielding, early and low yielding, late and high yielding or late and low yielding. In general, the assessment provided by the farmers agreed with the empirical analyses of dry matter partitioning and accumulation in the local variety Biabasse, but not for the genotype 92/0057. For the shoot characteristics, farmers' used such attributes as colour of the stem, branching pattern, size of stem, and appearance of flower buds and flowers. For the root characteristics the main attributes used include cracking of the soil and number and size of tuberous roots.

Table 2: **Categorisation of four cassava varieties by farmers based on shoot or root characteristics at 3 months after planting**

Shoot characteristics				
Attribute	Afisiafi	92/0057	TME 225	BIABASSE
Low yielding and early	29.0	71.0	19.4	41.9
Low yielding and late	0	9.3	16.4	22.6
High yielding and early	61.3	0	19.4	19.4
High yielding and late	0	0	0	0
Root characteristics				
Attribute	Afisiafi	92/0057	TME 225	BIABASSE
Low yielding and early	12.9	41.9	45.2	64.5
Low yielding and late	0	38.7	0	19.4
High yielding and early	80.7	12.9	41.9	3.2
High yielding and late	0	22.6	9.7	3.2

III Multi-location evaluation of cassava families for early bulking

In 2004, seedlings in the six families were evaluated at Nyankpala based on shoot characteristics. The main traits used include seedling vigour (visual rating), number of branches per plant, number of leaves per plant, number of leaf scars per plant, and plant height. The analyses revealed large variation for each trait studied within the families; these variations were highest in three families including 03UYTA12, 03R05 and 03UYTC16 (Table 3). Analysis of variance indicated that significant differences exist among the families in the number of leaves per plant, number of leaf scars per plant, and plant height. Tukey's HSD was used to form homologous groups from the ANOVA. Three families 03UYTC16, 03AYTA20 and 03AYTA60 recorded higher values in the three parameters under study compared to the three other families (Table 4). Similarly, the number of branches per plant 6 MAP was higher for these three families indicating better seedling vigour for these families.

Table 3: Mean performance and variation in three plant characters of six families of cassava in a seedling nursery at Nyankpala, 2004

	Plant height (m)			**No. of leaves plant^{-1}**			**No. of leaf scars plant^{-1}**		
FAMILY	**Mean**	**Std. Dev.**	**CV (%)**	**Mean**	**Std. Dev**	**CV (%)**	**Mean**	**Std. Dev**	**CV (%)**
03AYTA20	0.69	0.24	35.2	29.9	19.8	66.4	23.8	8.1	33.9
03AYTA60	0.78	0.31	39.2	29.4	15.8	54.0	21.7	9.5	43.7
03R02	0.52	0.19	36.5	19.7	9.4	47.7	22.2	7.6	34.4
03R05	0.55	0.22	40.5	20.6	10.8	52.4	20.0	8.0	40.0
03UYTA12	0.61	0.31	50.2	23.3	17.5	75.2	19.2	9.3	48.8
03UYTC16	0.68	0.26	37.4	30.1	19.1	63.6	21.2	9.4	44.1

Table 4. Separation of means (Tukey's HSD) of plant height, leaves plant^{-1} and leaf scars plant^{-1} of six cassava families evaluated at Nyankpala 2004.

	Subset for alpha = .05			
Plant height				
Family	**1**	**2**	**3**	**4**
03R02	0.51			
03RO5	0.55	0.55		
03UYTA12		0.61	0.61	
03UYTC16			0.68	
03AYTA20			0.69	
03AYTA60				0.7848
Sig.	.910	.373	.162	1.000
Number of leaves plant^{-1}				
Family	**1**		**2**	
03R02	19.70			
03RO5	20.57			
03UYTA12	23.29			
03AYTA60			29.35	
03AYTA20			29.85	
03UYTC16			30.08	
Sig.	.503		.999	
Number of leaf scars plant^{-1}				
Family	**1**		**2**	
03UYTA12	19.15			
03R05	19.99			
03UYTC16	21.24		21.24	
03AYTA60	21.74		21.74	
03R02	22.17		22.17	
03AYTA20			23.82	
Sig.	0.064		.172	

Performance of clones in on-farm evaluations

Eight advanced breeding early maturing clones together with two checks were arranged in a randomized complete block design and tested on-station, and at four on-farm locations in 2007/2008. The locations were Kpabi, Kpabya, Nomnayili and Nyangwuripe all in the Guinea savannah zone. Periodic harvestings were done at 3, 6 and 9 months after planting on station. Genotypic differences were established among the different genotypes in terms of tuber initiation and bulking. There was a sharp increase in tuber yield from 3 MAP to 6 MAP. The increase in tuber yield from 6 MAP to 9 MAP was however minimal (Figure 5). Significant location effects on tuber yield were also evident (Table 5), reflecting the huge variability in moisture and soil fertility across the eco-region.

At 3 MAP genotypes 96/1708 and 96/1613 had tuber yields that were higher than the check local check Biabasse though not statistically significant. The least yield of 3.39 t/ha was recorded by 96/1089A (Table 6). At 6 MAP, genotype 96/1613 had the highest tuber yield of 15.5 t/ha which was significantly higher than 96/1089A, 96/1632, I89/02729 and the local check Biabasse. The performance of the lines show that there are five cassava lines with potential for adaptation to drought prone areas as these can be harvested between 6 and 9 months after planting (Figure 5). There is scope to select lines that mature at different dates for farmers in specific locations.

Table 5: Performance of 10 cassava varieties at three months after planting on farmers' fields in five locations across Northern Ghana in 2007/2008

Location	Tuber yield (t/ha)	Weight/tuber (g)	Harvest index	Plant height (cm)	Canopy width (cm)
Nyankpala	4.71	64.3	0.57	55.0	93.7
Nomnayili	1.50	36.8	0.43	47.7	78.5
Nyanguipe	3.84	75.6	0.56	58.2	86.0
Kpabi	6.57	105.7	0.58	80.3	93.8
Kpabya	5.41	118.0	0.60	77.3	95.0
$LSD_{0.05}$	**1.376**	**17.03**	**0.036**	**8.86**	**10.92**
CV (%)	**17.1**	**41.5**	**12.7**	**27.1**	**23.8**

Table 6: Mean tuber yield of 10 cassava lines tested on farmers' fields across five locations in Northern Ghana at two harvesting dates

	Yield (t/ha) at different sampling dates	
Genotypes	**3 Months after planting**	**6 months after planting**
96/0160	4.58	10.93
96/1089A	3.39	10.97
96/1613	5.00	15.51
96/1632	3.83	11.48
96/1708	6.22	12.52
I89/02729	4.66	11.63
TME 419	4.01	11.03
TME 435	3.76	11.54
AFISIAFI	3.96	10.54
BIABASSE	3.95	10.20
$LSD_{0.05}$	**1.95**	**3.29**

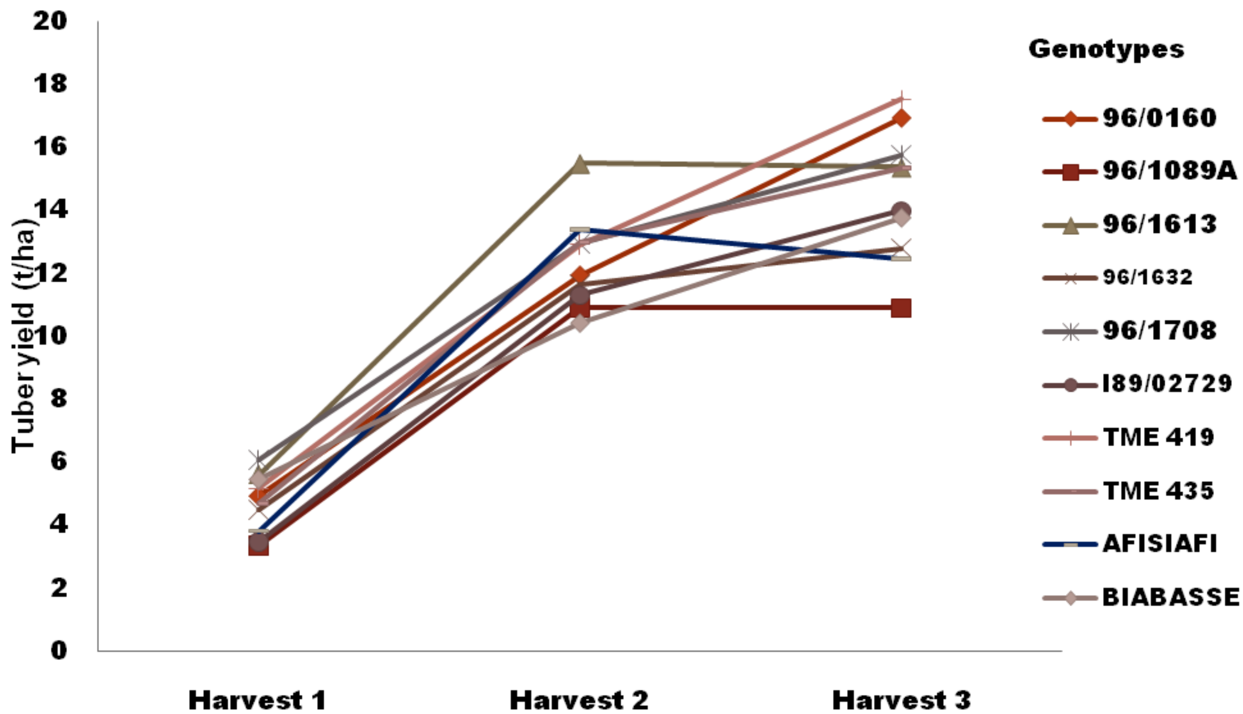


Figure 5: Increase in tuber yields over a nine-month period for 10 test genotypes at Nyankpala in 2007/8 season

IMPROVING COWPEA FOR EARLINESS, AND FOR TOLERANCE TO DROUGHT
Methods

At the start of the Project in 2004, two experiments were initiated. In experiment 1, advanced breeding line obtained from crosses between each of two existing two cowpea cultivars Apagbaala and Marfo-Tuya and exotic lines were put under multi-environment testing to select families that combine high grain yield with earliness. Experiment 2 was focussed on evaluating cowpea families for traits that are associated with water use efficiency.

Experiment 1: Multi-location evaluation of lines for yield, earliness and consumer preference traits
F_3 families ranging in size between 120 and 300 derived from 13 populations were examined at Nyakpala in 2004. Of these, 3 crosses were selected based on the set criteria. These populations include UCR 01-11-52 × Apagbaala, UCR 01-15-52 x Marfo-Tuya and UCR 01-15-127-2 × Marfo-Tuya. $F_{3:4}$ families from these crosses were again evaluated for grain yield in Nyankpala. $F_{3:5}$ families that met a set of criteria are then put into preliminary multu-environment trials within the Sudan and Guinea savannah zones to assess stability of earliness and grain yield.

Replicated yield evaluation of F_5 families was conducted at three locations including Manga (Sudan savanna, latitude 11° 01'), Nyankpala and Yendi (Guinea savanna, latitude 9° 27') all located within the northern sector of Ghana. The number of families evaluated at each location varied depending on the quantity of F_5 seed obtained, but ranged between 91 and 151. A traditional cultivar named SARC-L02, the parental cultivars and three advanced breeding lines including IT 97K-399-35, IT 97K-279-3 and IT 98K-506-1 were included as checks at each location.

Experiment 2: Evaluating the association between traits related to water-use efficiency and grain yield
Six populations derived from crosses between the cultivar Marfo-Tuya, and exotic variety Ein El Gazal and other breeding lines of the UCR were made at the UCR and bulk-harvested F_3 seeds were made available at the start of this project. Ein-El-Ghazal is a cultivar bred for the Sahelian region of Sudan (Elawad and Hall 2002). F_4 families were obtained from the F_3 lines based on a set of criteria to test their adaptation in the Guinea savannah zone of Ghana. Selected $F_{3:5}$ families from two populations were evaluated for variation in some traits known to be related to efficient water use. These include 107 families derived from UCR 01-15-48 × Marfo-Tuya and 102 families derived from UCR 01-15-48 × Ein El Gazal. The traits studied include days to 50 % flowering, leaf succulence, relative water content, specific leaf weight and total ash content of leaves, following standard procedures.

Results and Discussion
Experiment 1: Improving two cowpea cultivars for earliness and consumer acceptability
A total of 390 F_4 families of cowpea belonging to three populations were evaluated under monoculture. In all three populations, significant differences were observed in days to 50% flowering, day to maturity, grain yield and individual grain weight. Yield potential was highest in the population derived from UCR 01-11-52 × Apagbaala compared to the two derived from Marfo-Tuya. For the population derived from Apagbaala, grain yield ranged from 345 to 2000 kg ha^{-1}; the mean grain yield of Apagbaala in this evaluation was 1178 kg ha^{-1} indicating a high percentage of families produced grain yield higher than that of the adapted parent Apagbaala (Figure 6). Hundred-grain weight in this population ranged from 10.5 to 22.8 g, and the 100-grain weight of Apagbaala was 13.1 g. Similar yield superiority of some cowpea families were observed in the two other populations derived from Marfo-Tuya. For example in the population derived from UCR 01-15-127-2 × Marfo-Tuya, grain yield ranged from 423 to 1583 kg ha^{-1}, and mean yield of Marfo-Tuya in these evaluations was 685 kg ha^{-1} (Figure 7). A large proportion of families (42 %) also had higher 100-grain weight. The mean 100-grain weight in this population ranged from 12.3 to 31 g whiles that of Marfo-Tuya was 17 g.

Families that had high grain yields, and had good seed coat characteristics were then put into the multi-location evaluations from 2005 to 2007. Differences between locations and years in rainfall amount and distribution that characterize semiarid regions were recorded during the period of the experiment. In 2003 at Nyankpala where single plant selections were made within and between F_3 families, total rainfall was similar to the long-term mean of 1000 mm for the Guinea savannah agro-ecology. Of this amount, 422.7 mm was received on 32 rainy days during the period of the experiment, and provided very favorable conditions for growth. In 2005, total rainfall in Nyankpala was 16% less than the long-term average with a reduction in rainy days from 75 (long-term average) to 57 in 2005. Total rainfall during the experiment in Nyankpala was therefore only 316.2 mm received on 22 rainy days. In particular, a dry spell lasting 15 days across the Guinea savanna zone in August affected plant growth at this location. Plant growth was less severely affected by drought at Yendi probably due to higher soil organic matter. At Manga in the Sudan savannah agro-ecology, rainfall total and distribution was typical of the eco-region, with 386.1 mm rain received in 32 rainy days. The rainfall distribution and amount coupled with soil fertility characteristics differentiated the locations for crop performance; Yendi being the most favorable and Manga being the least favorable, attributed mainly to a very poor sandy soil at Manga.

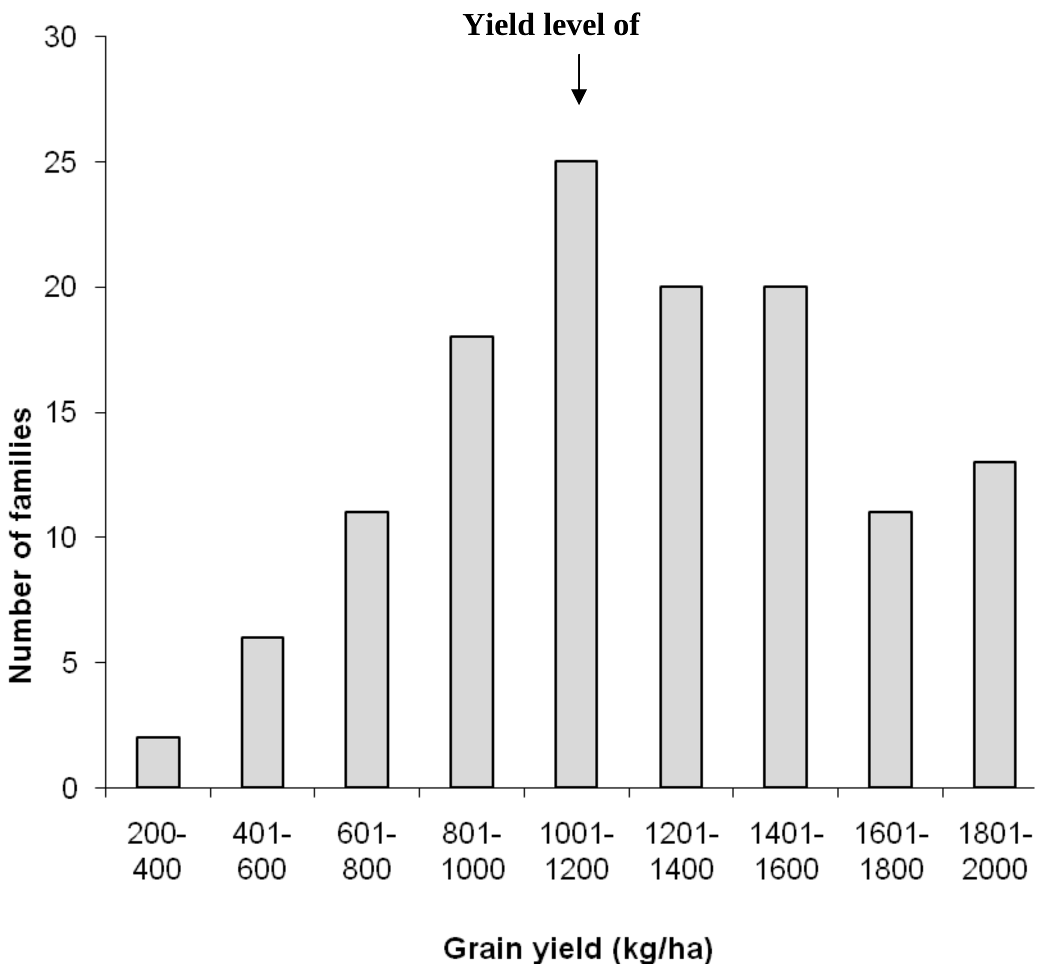


Figure 6: ***Frequency distribution of grain yield among 126 F_4 cowpea families derived from 01-11-52 x Apagbaala.***

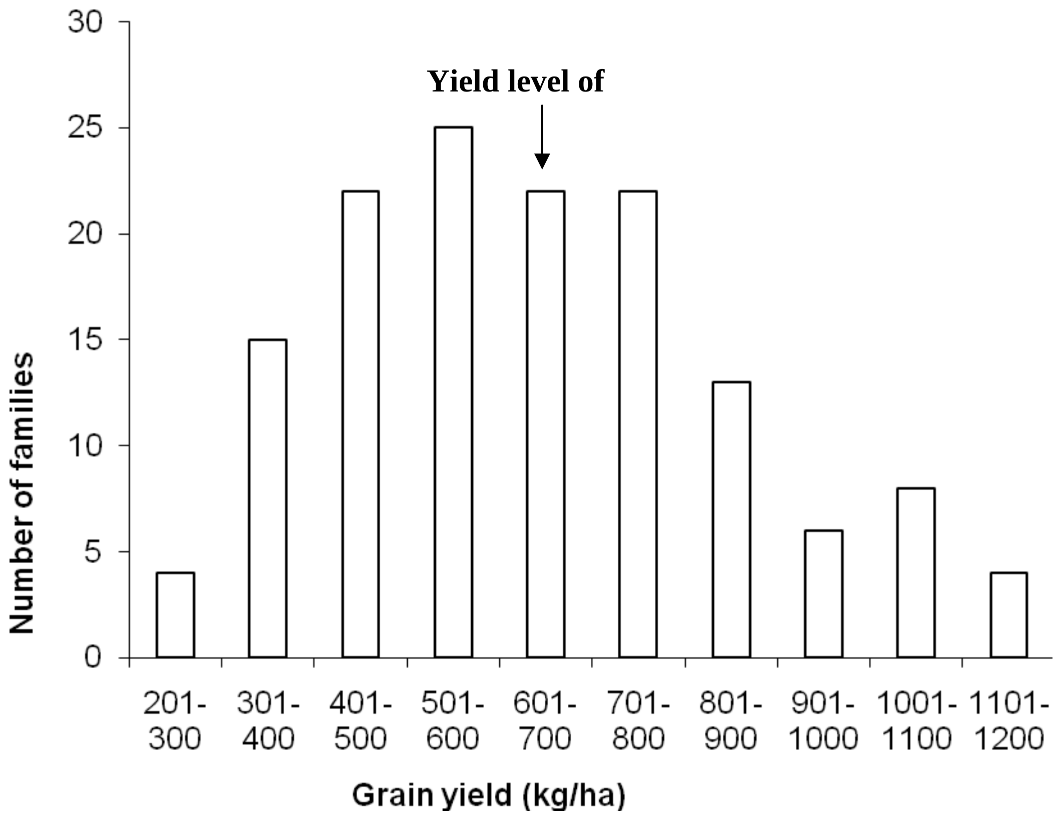


Figure 7: ***Grain yield variation in an F_4 segregating population of 01-15-127-2 x Marfo-Tuya.***

Combined ANOVA of various traits for the genotypes common to the three locations indicated significant effects for genotype (G), location (L) and G × L interaction for all traits studied. Confidence in the grain yield obtained by the elite F_5 families can be judged by comparing with check genotypes that were common to all three locations. These check genotypes includes three advanced breeding lines (prefix 'IT' in Table 7) obtained from the International Institute of Tropical Agriculture, and were the highest yielding genotypes among 60 breeding lines in earlier evaluations conducted across the Guinea and Sudan savanna ecologies (Padi, 2004). In addition, Apagbaala, the adapted parent of the population, SARC L02 were included. The location with the highest mean yield (Yendi) favored late genotypes such that the correlation between days to flowering and grain yield for the subset of lines presented in Table 5 was r = 0.58, P = 0.019. SARC L02 was therefore the highest yielding genotype, although four of the F_5 families had grain yields that were not statistically lower. Apagbaala and the earliest advanced breeding line, IT 98K-506-1, performed relatively poorly. In contrast to genotype performance at Yendi, growth conditions at Manga favored early genotypes, with a significant correlation between days to flowering and grain yield (r = -0.62, P = 0.019). The elite F_5 families generally out-yielded the check genotypes. Irrespective of location characteristics, therefore, significant gains were recorded for grain yield, as it was for seed size. Compared to seed size of 12.0 g per hundred seeds in Apagbaala, F_5 families with seed size exceeding 15.0 g per hundred seeds were obtained at each location. Similarly in the populations derived from Marfo-Tuya, gains in earliness, yield and seed size were observed (Tables 7 & 8).

Based on the performance of the lines based on the set criteria, the desirable lines were selected together with check genotypes to comprise 64 entries. These were tested at Nyankpala and Yendi in 2006. These materials were again tested in 2007 at Damongo, Manga, Nyankpala and Yendi. Among the 64 genotypes, yield varied from 0.66 to 1.44 t/ha at Nyankpala. At Yendi, yield varied from 0.64 to 1.53 t/ha (Figure 8).

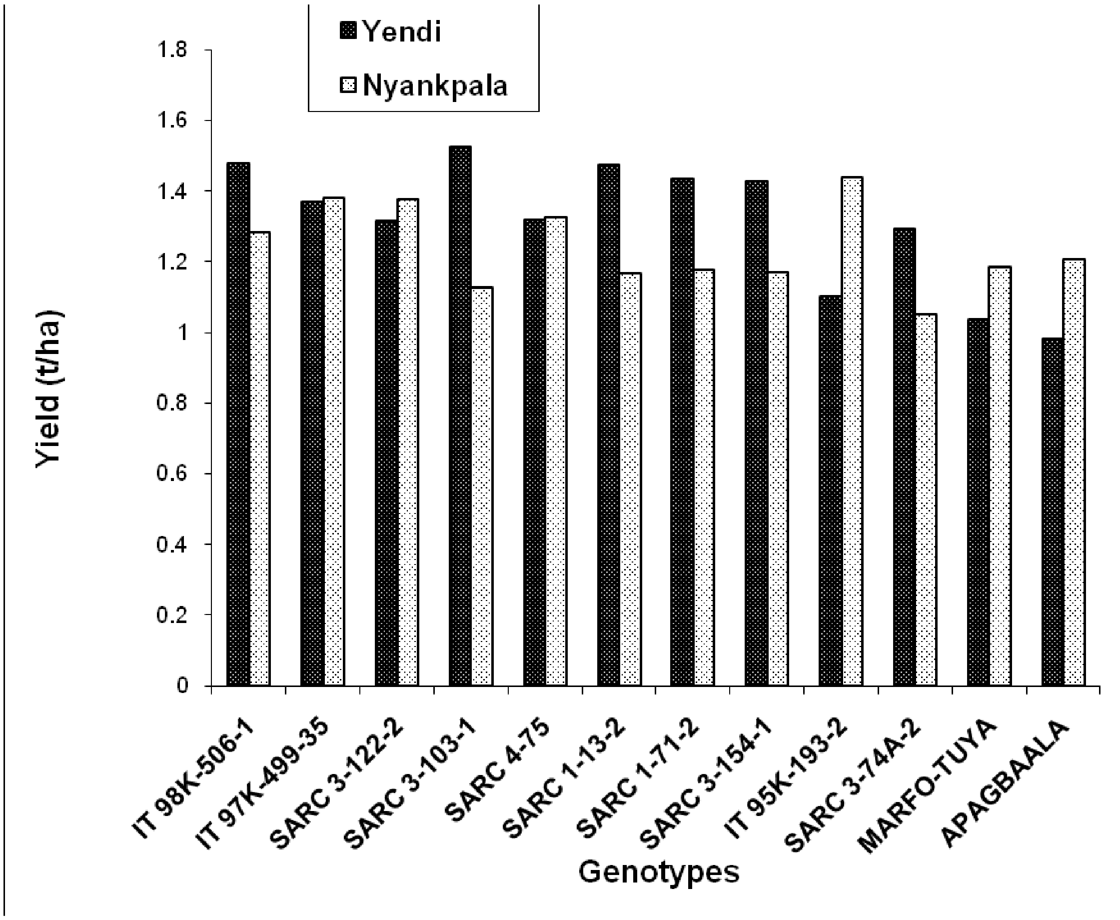


Figure 8: Grain yield of the top yielding lines and check varieties at two locations in the Guinea savannah zone of Ghana in 2006

In 2007, the anova for yield indicated significant differences among locations and among genotypes. The genotype x location effect was significant, but of minimal effect on the ranking of genotypes. Six of the highest yielding lines (in Table 10) were selected for release, and were tested with 8 others on farmers' plots. Some higher yielding varieties were not selected due to poor preference by farmers during field days. For example, for IT 98K-506-1, in spite of high yields and desirable seed quality, this genotype changes its white seed coat to an unattractive white colour in high humidity environments. Also, SARC 3-129-1 does not have an attractive seed coat colour. Similarly, SARC 1-71-2 has seed size of approximately 13.5 g/100 seeds which is not attractive to farmers.

Adaptation to pre-season cropping (pre-rice cropping)
Twenty six farmers tested the suitability of two of the advanced breeding lines and their varieties to pre-season cropping conditions. The varieties tested include SARC 1-94A-2, SARC 3-103-1. They include 10 farmers in the Tamale Metropolis, 8 farmers at Duko and 8 farmers at Kanshegu in the Savelugu-Nanton District. The performance of the varieties

indicated in Table 11 shows that these lines are generally suitable to cropping before the start of the main cropping season.

Performance of varieties in on-farm evaluations, and variety release
To assess the adaptation of the new varieties to farmers' conditions, we tested 14 advanced breeding lines and check cultivar Apagbaala, across the predominant cowpea growing belts in the Upper West, Upper East and Northern Regions of Ghana. Evaluations were done in 2006 and 2007. In all 126 farmers were involved over 12 Districts. Each farmer tested 3 varieties in addition to his currently used variety. The results are indicated in Table 12. Wide variation was evident in the yield of each genotype among farmers in a community, District, and across the 3 regions. The performance of the six proposed varieties was generally higher than Apagbaala and the farmers' varieties. In general farmers appreciated the new varieties for their large, white seeds, earliness to mature and resistance to *Striga gesnerioides*. In almost all farms visited, farmers rated the new varieties better than their current varieties.

In 2008, four of six varieties proposed for release were accepted by the National Variety Release Committee. They were released as Songotra (for IT97K-499-35), Bawutawuta (for IT95K-193-2), Zaayura (for SARC4-75), and Padi Tuya (for SARC 3-122-2).

Table 7: Performance characteristics of the top 10% of F_5 families derived from UCR 01-11-52 x Apagbaala compared to check varieties at three locations in 2005

Genotypes	**Locations**								
	Manga			**Nyankpala**			**Yendi**		
	Yield (kg/ha)	Days to 50% flowering	100 seed weight (g)	Yield (kg/ha)	Days to 50% flowering	100 seed weight (g)	Yield (kg/ha)	Days to 50% flowering	100 seed weight (g)
SARC 1-13-1	-	-		-	-		1792	39	21.2
SARC 1-13-2	-	-		1247	44	20.3	-	-	
SARC 1-14-1	-	-		1033	47	16.4	-	-	
SARC 1-17-1	-	-		1063	45	11.8	-	-	
SARC 1-34-1	-	-		-	-		1678	43	20.5
SARC 1-34-2	1013	44	15.5	-	-		-	-	
SARC 1-35-2	-	-		1109	44	20.4	-	-	
SARC 1-36-2	-	-		1031	46	18.0	-	-	
SARC 1-57-2	-	-		1092	43	19.9	-	-	
SARC 1-68-2	1032	43	15.5	-	-		-	-	
SARC 1-74-2	1073	41	16.4	-	-		-	-	
SARC 1-77-1	-	-		1055	43	15.9	-	-	
SARC 1-82-1	-	-		1053	44	19.2	-	-	
SARC 1-88-1	-	-		1189	44	17.4	-	-	
SARC 1-97-1	-	-		-	-		1797	43	15.2
SARC 1-100-2	-	-		1023	47	19.1	-	-	
SARC 1-102-1	-	-		-	-		1670	39	16.2
SARC 1-119-2	-	-		-	-		1728	42	18.0
SARC 1-125-1	-	-		-	-		1693	41	15.7
SARC 1-146-2	-	-		-	-		1783	43	15.2
SARC 1-71-1	1108	43	17.4	-	-		-	-	
SARC 1-71-2	1326	42	15.7	-	-		1704	43	16.2
SARC 1-132-1	1121	43	16.3	1221	43	16.8	-	-	
SARC 1-136-1	1197	43	16.0	-	-		1667	41	17.0
SARC 1-136-2	1102	42	15.5	1076	43	15.8	1842	41	16.1
SARC 1-91-1	1064	43	18.4	1035	47	18.3	1684	43	18.5
Apagbaala	594	42	11.8	880	44	11.9	1426	42	12.0
IT 98K-506-1	1190	40	17.4	811	40	18.8	1397	38	17.9
IT 97K-499-35	708	41	14.9	1079	41	16.9	1676	41	16.2
IT 98K-279-3	888	48	17.0	832	47	18.5	1715	44	18.6
SARC L02	459	61	20.7	662	50	19.5	2038	47	18.5

LSD (0.05)	**172.7**	**1.8**	**1.29**	**195.3**	**1.3**	**1.12**	**310.6**	**0.9**	**1.11**
CV (%)	**17.6**	**2.6**	**4.9**	**17.1**	**1.7**	**3.9**	**14.5**	**1.4**	**4.0**

Table 8: Performance characteristics of the top 10% of F_5 families derived from UCR 01-15-52 x Marfo-Tuya compared to check varieties in 2005

Genotypes	Yield (t/ha)	Days to 50% flowering	Hundred seed weight (g)
SARC 2-66	0.78	44	22.5
SARC 2-112	0.74	44	23.7
SARC 2-59	0.72	40	23.4
SARC 2-77	0.72	39	17.3
SARC 2-101	0.72	44	19.8
SARC 2-82	0.70	42	17.1
SARC 2-72	0.69	39	19.6
SARC 2-55	0.68	40	21.0
SARC 2-113	0.65	45	20.4
SARC 2-115	0.64	43	23.9
SARC 2-51	0.63	40	21.7
SARC 2-16	0.62	41	17.3
SARC 2-104	0.62	40	20.5
SARC 2-97	0.62	41	26.2
SARC 2-83	0.61	44	18.5
Marfo-Tuya	0.65	42	15.6
$SED_{0.05}$	**0.12**	**1.7**	**1.17**

Table 9: Performance characteristics of the top 10% of F_5 families derived from UCR 01-15-127-2 × Marfo-Tuya compared to check varieties in 2005

Genotypes	Yield (t/ha)	Days to 50% flowering	Hundred seed weight (g)
SARC 3-122	1.52	42	21.9
SARC 3-48	1.38	44	19.0
SARC 3-129	1.37	43	21.1
SARC 3-149	1.36	44	19.3
SARC 3-137	1.34	44	20.0
SARC 3-74A	1.33	45	25.9
SARC 3-146	1.31	42	16.9
SARC 3-148	1.29	42	18.7
SARC 3-68	1.27	44	19.5
SARC 3-56	1.25	43	24.0
SARC 3-35	1.24	43	18.5
SARC 3-134	1.24	44	12.9
SARC 3-63	1.23	43	18.9
Marfo-Tuya	1.30	46	15.8
$SED_{0.05}$	**0.14**	**1.0**	**1.05**

Table 10. Grain yield of 20 advanced breeding lines compared with check cultivars evaluated across Northern Ghana in 2007

GENOTYPES	Damongo	Manga	Nyankpala	Tingoli	Yendi	Mean
IT 95K-193-2	0.907	0.678	1.495	0.989	2.745	1.363
SARC 3-129-2	0.516	0.724	1.237	1.065	1.841	1.077
IT 98K-506-1	0.794	0.444	1.458	0.795	1.556	1.009
IT 97K-499-35	1.028	0.484	1.298	0.652	1.569	1.006
SARC 4-75	0.906	0.617	1.103	0.944	1.460	1.006
SARC 1-71-2	0.856	0.442	1.109	0.759	1.859	1.005
SARC 2-51-1	0.544	0.492	1.357	0.790	1.708	0.978
SARC 3-154-1	0.603	0.363	1.235	1.056	1.483	0.948
SARC 3-90-2	0.524	0.693	1.078	0.751	1.679	0.945
SARC 3-122-2	0.457	0.670	1.158	0.874	1.553	0.943
SARC 1-136-1	0.811	0.525	1.124	0.934	1.314	0.942
SARC 3-103-1	0.833	0.428	0.895	0.626	1.968	0.930
SARC 2-115-1	0.880	0.403	1.137	0.827	1.382	0.926
SARC 1-18-2	0.640	0.426	1.197	0.617	1.658	0.908
SARC 4-51	0.726	0.294	1.048	0.555	1.901	0.905
SARC 3-74A-2	0.562	0.493	1.239	0.771	1.456	0.904
SARC 1-82-1	0.716	0.408	1.109	0.839	1.447	0.904
SARC 1-13-1	0.695	0.627	1.108	0.683	1.386	0.900
SARC 1-71-1	0.899	0.423	1.030	0.749	1.396	0.900
SARC 4-40	0.442	0.336	1.138	0.424	2.158	0.900
MARFO-TUYA	0.429	0.323	1.223	0.608	1.829	0.882
APAGBAALA	0.738	0.218	1.125	0.583	1.141	0.761
[1]Mean	**0.550**	**0.383**	**1.037**	**0.643**	**1.436**	**0.810**
Lsd (5%)	**0.222**	**0.195**	**0.343**	**0.261**	**0.474**	**0.154**

[1]Mean is for all 64 tested genotypes

Table 11. Performance of two advanced breeding lines in pre-rainy season experiments with rice farmers in two Districts in Northern Ghana

	Yield (kg/ha)	
Variety	Savelugu/Nanton District	Tamale Metropolis
SARC 1-94A-2	425	370
SARC 3-103-1	515	480
Farmers' variety	250	Not obtained
Lsd (5%)	152.7	130.3

Table 12. Performance of advanced breeding cowpea lines under on-farm testing in Northern Ghana

Variety	Frequency of test			*Yield (kg/ha)*		Farmers general preference, and comments
	Region	**No. of Districts**	**No. of Farmers**	***Range***	***Mean***	
	Northern	1	16	435 – 845	644	High preference. A lot of pods
Apagbaala	U/West	4	40	150 – 1050	523	High preference
	Northern	3	36	558 – 1250	754	High preference. High yields, Striga resistant.
	U/West	3	30	300 – 1200	711	Early maturing
IT 97K-499-35	U/East	2	20	200 – 1200	668	
IT 95K-193-2	Northern	1	16	655 – 1115	789	Preferred. High yield, but late maturing
	U/East	2	20	342 – 767	521	
SARC 1-13-1	Northern	2	20	457 – 763	542	Moderate preference. Early maturing
SARC 1-132-1	NR, UWR	3	30	290 – 1170	516	Moderate preference. Late maturing
SARC 1-136-2	NR, UWR	6	60	290 – 1170	469	Moderate preference. Early maturing
SARC 1-34-2	NR	3	30	325 – 722	415	Low preference. Late maturing, low yield
SARC 1-36-1	UWR	2	20	320 – 1180	478	No comments obtained
SARC 1-57-2	UWR, UER	4	40	360 – 1130		Attractive seeds, early, preferred.
SARC 3-74A-2	NR, UER	4	20	410 – 975	569	Moderate preference. Average yields, large seeds
SARC 3-103-1	NR, UER	4	20	350 – 1100	668	High preference. High yield, large seeds
SARC 3-122-2	NR, UER	4	24	400 – 1200	709	High preference. High yield, large seeds
SARC 4-75	NR, UER	4	26	467 – 1235	725	High preference. High yield, large seeds
Farmers' Varieties	NR, UER, UWR	All 12 test Districts	126	0 – 1050	435	Low preference. Late maturing or small seeds or unattractive seed colour

Experiment 2: Evaluating the association between traits related to water-use efficiency and grain yield

About 590 lines belonging to 6 populations were evaluated during the main season. Wide variations were observed in days to first flower, and grain yield on per plant basis. Two populations were selected for further studies. A total of 204 lines were studied during the dry season for a number of traits that are known to determine adaptation of cowpea in semi-arid regions. These include specific leaf weight, succulence index and relative water content. Significant variation was observed in all traits measured. Leaf area and relative water content were positively correlated. Similarly, specific leaf weight and succulence index were also positively correlated (Figure 9). No trait associations were observed between other traits measured.

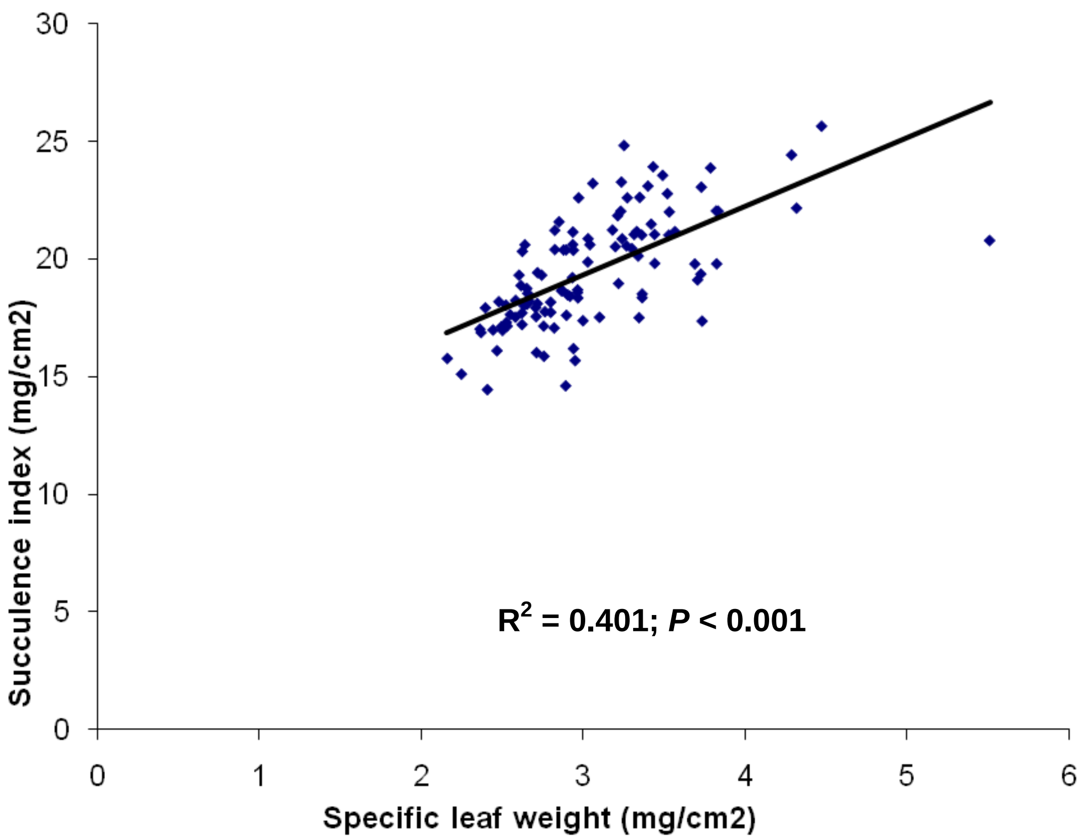


Figure 9: *Relationship between specific leaf weight and succulence index in 108 cowpea lines evaluated under irrigated conditions*

DEVELOPING SORGHUM VARIETIES IMPROVED FOR THE STAY-GREEN TRAIT
Methods
Developing Kapaala derivatives homozygous for the stay-green QTL
In each generation, the elite recurrent parents (IRAT 204 and Kapaala = S 35 = ICSV 111) were sown in multiple sowing dates along with a single sowing date of the BCnF1 progenies segregating for the target QTLs for the stay-green trait from donor parent B35, in order to facilitate backcrossing of selected BCnF1 individuals with pollen from the recurrent parent. Tissue samples were collected from individual BCnF1 plants in each progeny, DNA was isolated from each of the tissue samples, and DNA quality and concentration were then determined for each sample.

In case of recurrent parent Kapaala = ICSV 111 = S35, the following sorghum SSR marker loci were used for foreground selection for the six indicated target stay-green QTLs, based on polymorphisms used on earlier generations of this backcrossing program (information available prior to this project):

Target stay-green QTL	Flanking marker loci
*stg*A	*Xtxp*88, *Xtxp*43, *Xtxp*357
*stg*B	*Xtxp*7, *Xtxp*296, *Xtxp*8
*stg*1	*Xtxp*34, *Xtxp*114
*stg*2	*Xtxp*114, *Xtxp*31, *Xtxp*33
*stg*3	*Xtxp*56, *Xtxp*298
*stg*4	*Xtxp*15, *Xtxp*225, *Xtxp*23

In case of recurrent parent IRAT 204, the following sorghum SSR marker loci were used for foreground selection for the six indicated target stay-green QTLs, based on polymorphisms identified in 2004 during the course of this project activity:

Target stay-green QTL	Flanking marker loci
*stg*A	*Xtxp*32, *Xtxp*88, *Xtxp*149, *Xtxp*43
*stg*B	*Xtxp*7, *Xtxp*207, *Xtxp*296, *Xtxp*8
*stg*1	*Xtxp*34, *Xisp*361, *Xtxp*285, *Xtxp*114, *Xisp3*07
*stg*2	*Xtxp*114, *Xtxp*31
*stg*3	*Xtxp*298, *Xtxp*1, *Xtxp*56, *Xtxp*286
*stg*4	*Xtxp*225

Before flowering, individual BCnF1 segregants identified as heterozygous for alleles from the donor parent B35 at the two-three SSR marker loci flanking a particular target stay-green QTL (listed above) were selected for backcrossing to their respective recurrent parent (IRAT 204 or Kapaala = S 35 = ICSV 111). At the time of panicle emergence, circa 100 florets were emasculated on each selected BCnF1 plant and then crossed with pollen from their recurrent parent. At maturity, these backcrossed plants were scored for simply inherited morphological markers such as grain pericarp color (white vs red or yellow), grain mesocarp thickness (thin vs thick), awns (absent vs present), plant height (2-dwarf vs taller) and foliage color (tan vs non-tan) for background selection to speed recovery of recurrent parent traits (white pericarp, thin mesocarp, awns absent, 2-dwarf plant height, and tan foliage color) at loci that are not linked to specific target stay-green QTLs. In the three instances where a specific stay-green QTL locus is known to be linked to genes controlling one of these morphological markers (*stg*1 with awns present, *stg*2 with red pericarp color, and *stg*3 with thick mesocarp), the morphological markers were used to confirm foreground selection based on the flanking SSR markers. After harvest and threshing, the numbers of seeds obtained by selfing and crossing was noted for the selected plants and the combined information on seed availability, SSR marker genotype, and morphological marker phenotype used to selected backcross progenies to be advanced another generation.

In case of the BC3F1 and BC4F1 progenies in the background of recurrent parent Kapaala = S 35 = ICSV 111 that were grown in the second season of this marker-assisted backcrossing program during 2004, plants selected on the basis of foreground SSR marker genotyping data (at marker loci flanking each of the six individual target stay-green QTLs) were selfed to produce BCnF2 seed and selection of two or three BCnF2 families to be advanced in the first sowing of 2005 was based on phenotypic similarity of their corresponding BCnF1 plants with the recurrent parent.

In the case of target stay-green QTL *stg*4 and recurrent parent IRAT 204, it has not been possible to identify more than one polymorphic SSR marker in the target region so it is was not practical to pursue marker-assisted selection to introgress this stay-green QTL from donor parent B35 into the IRAT 204 genetic background.

Evaluation of stay-green derivatives of Kapaala cultivar in on-station trials
A large number of stay-green derivatives of Kapaala were received in Ghana in 2005, and were put into on-station trials. A total of 363 derivatives and parentals were evaluated from 2005 to 2007. Ten backcross derivatives were selected based on plant type, yield, seed colour, and texture for multi-location yield assessment.

Results and Discussion
Developing Kapaala derivatives homozygous for the stay-green QTL
The following backcross progenies were identified and advanced by a further generation by the end of 2004.
Recurrent parent Kapaala = S 35 = ICSV 111 (BC4F2 seed generation)

Progeny	Target QTLS	BC4F2 seed available
8626 self	*stg*A	28 g (72 seeds advanced)
8640 self	*stg*B	34 g (23 seeds advanced)
8645 self	*stg*B	34 g (23 seeds advanced)
8664 self	*stg*B	34 g (24 seeds advanced)
8683 self	*stg*B	23 g (23 seeds advanced)
8601 self	*stg*3	40 g (18 seeds advanced)
8604 self	*stg*3	35 g (18 seeds advanced)
86__ self	*stg*3	30 g (18 seeds advanced)
8629 self	*stg*3	25 g (19 seeds advanced)
8688 self	*stg*3	23 g (19 seeds advanced)
8605 self	*stg*4	10 g (24 seeds advanced)
8608 self	*stg*4	35 g (24 seeds advanced)
8610 self	*stg*4	47 g (38 seeds advanced)
8625 self	*stg*4	40 g (39 seeds advanced)
8602 self	*stg*A+*stg*3	26 g (36 seeds advanced)
8603 self	*stg*A+*stg*3	34 g (35 seeds advanced)

Recurrent parent Kapaala = S 35 = ICSV 111 (BC3F2 seed generation)

Progeny	Target QTLs	BC3F2 seed available
8701 self	*stg*A	44 g (19 seeds advanced)
8702 self	*stg*A	24 g (19 seeds advanced)
8703 self	*stg*A	86 g (19 seeds advanced)
8711 self	*stg*A	70 g (19 seeds advanced)
8714 self	*stg*A	59 g (19 seeds advanced)
8793 self	*stg*1	41 g (48 seeds advanced)
8729 self	*stg*2	35 g (16 seeds advanced)
8758 self	*stg*2	24 g (16 seeds advanced)
8816 self	*stg*2	14 g (16 seeds advanced)
8717 self	*stg*3	13 g (16 seeds advanced)
8737 self	*stg*3	32 g (16 seeds advanced)
8742 self	*stg*3	18 g (16 seeds advanced)

Recurrent parent IRAT 204 (BC3F1 seed generation)

Progeny	Target QTLs	BC3F1 seeds advanced
8547 x IRAT 204-16	*stg*A+*stg*2	11
8565 x IRAT 204-12	*stg*A	11
8568 x IRAT 204-05	*stg*A	11
8585 x IRAT 204-05	*stg*A	11
8545 x IRAT 204-16	*stg*B	16
8570 x IRAT 204-01	*stg*B+*stg*3	16
8573 x IRAT 204-13	*stg*B	16
8562 x IRAT 204-10	*stg*A+*stg*B	30
8571 x IRAT 204-13	*stg*A+*stg*B+*stg*2	30
8572 x IRAT 204-15	*stg*A+*stg*B	30

In 2005 assessment of SSR marker polymorphism between donor parent B35 and recurrent parents IRAT 204 and Kapaala, continued for loci mapping to appropriate target regions. Advance of BC3F2 and BC4F2 progenies in the genetic background of recurrent parent Kapaala by one generation of selfing while using SSR marker genotyping to identify candidate stay-green QTL introgression homozygotes segregating in these progenies was completed in 2005. This permitted seeds harvested from lines homozygous for the QTLs to be received in Ghana for field testing. Also, it was possible to produce BC3/4F2 lines through marker-assisted backcrossing of stay-green QTLs *stg*A, *stg*B, *stg*1, *stg*2, and *stg*3 from donor parent B35 in the genetic background of recurrent parent IRAT 204.

Evaluation of stay-green derivatives of Kapaala cultivar in on-station trials

The lines homozygous for the stay-green QTL were multiplied in the field in 2005 to enable adequate quantities of seed to be produced for replicated evaluation. Based on preliminary records taken during the seed increase, 11 lines were taken for further testing during the post-rainy season of 2005/6 to assess their response to seedling-stage drought. A box technique (Plate 1) was used to assess drought tolerance. Drought was imposed for 8 days and watering resumed thereafter. In this evaluation, B 35, the donor of the stay-green QTL remained unaffected by the moisture stress. Varying levels of mortality were recorded for Kapaala, IRAT 204 (= Dorado) and the 10 derivatives. Of the various data taken, the root:shoot ratio (Table 13) had the most significant association with seedling vigor or survival under stress.

Ten lines were selected based on field performance in 2006 under rainfed conditions and tested under irrigated conditions in the post-rainy season under post-flowering drought stress. In addition to the stay-green donor, lines 570 IDSG 06102, 2351(S35 x B 35 x S 35) and 2520 (K x B 35 x K) combined ability to withstand drought and high yielding potential.

Plate 1: *Drought evaluation using the box screening technique of sorghum seedlings*

Table 13: Root to shoot ratio for 14 sorghum genotypes tested for seedling drought tolerance

Genotype	Root: shoot ratio
B35	0.2487
IDSG 06117	0.2013
2437 SxBxS	0.1700
2543 KxBxK	0.1563
DORADO	0.1550
IDSG 06102	0.1500
IDSG 0613	0.1263
2455 SxBxS	0.1250
S35	0.1050
2520 KxBxK	0.0963
2351 SxBxS	0.0938
IDSG 06107	0.0850
ICSV 111	0.0812
2343 SxBxS	0.0638
SE	0.0196

Objective 2: Develop predictive tools for drought detection and formulate appropriate mitigation strategies

Introduction

In rainfed agriculture, poor distribution of rain, and variations in the amount and intensity may lead to low levels of moisture within the reach of plant roots. Plant water stress results in reduced quantity and quality of harvestable produce. In Northern Ghana, drought is also associated with the outbreak of some key pests of crops including armyworms. The objectives of the Drought detection and Mitigation component of the project is to reduce the impact of drought on food security by providing information to farmers to guide decisions they make in relation to cropping patterns and cropping cycles.

Methods

Generation of drought probability maps

At the start of the Project in 2004, a survey was conducted to document farmers' perceptions on drought and their coping strategies. Through a designed questionnaire, responses were sought on traditional concepts of drought, drought prediction, mitigation and risk reduction.
Daily rainfall data was obtained for 20 Districts in the Northern and Upper East Regions of Ghana. The data was obtained for 30 to 54 years depending on the availability of the data at the meteorological stations.

Evaluation of drought mitigation strategies

The drought mitigation strategies identified were based on in-field water harvesting techniques and various nutrient management options. The experiments were designed and carried out on farmers' plots. Field days were organized on demonstration plots established in the various communities. The strategies tested include contour ridging, tied ridging with vertiver grass barrier, and cover cropping integrated with inorganic fertilizer application. Test crops used were mainly cereals, and depending on the community sorghum or maize varieties were used in sole or mixed stands.

Results and Discussion

Primary data was generated on traditional concepts, beliefs, prediction and mitigation of drought and drought risk reduction from 11 districts in the Northern, Upper East and Upper West regions. Farmers' perception of changes in climate over time was documented. Indigenous signs of impending drought and traditional beliefs about causes of drought were documented. Problems of combating drought, changes in crop varieties and cropping patterns as coping strategies were recorded. Farmers' perception of the start of rains was also documented. The key finding was that farmers were well aware of declining rainfall totals during the rainy season. Farmer also noted that the length of the dry spells (a period of at least two weeks with less than 4 mm/day precipitation) within the rainy season have increased within the last five years. To cope with the change in the climate, cultivation of most of their preferred long-duration traditional cereal varieties had to be curtailed for short-duration types. In some cases, farmers indicated a change from cultivating maize to groundnuts and sorghum or millet due to the recurrence of crop failure due to drought.

We used Makov's chain probability analysis of the long-term daily rainfall data to generate dry spell probability mapping for selected Districts in Northern Ghana. A dry day was considered as one with less than 4 mm of rainfall. The following maps were generated

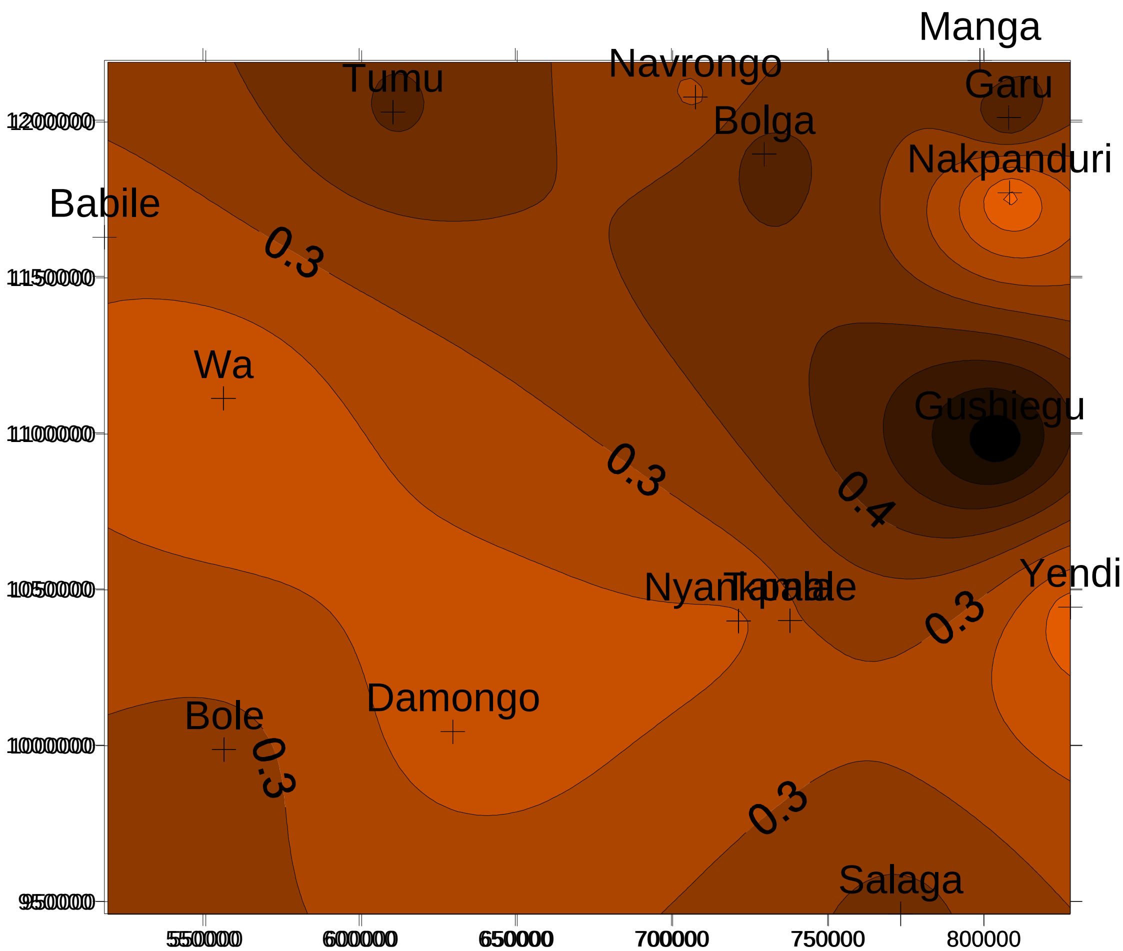


Plate 2: ***Drought spell probability map in June for selected Districts in Northern Ghana***

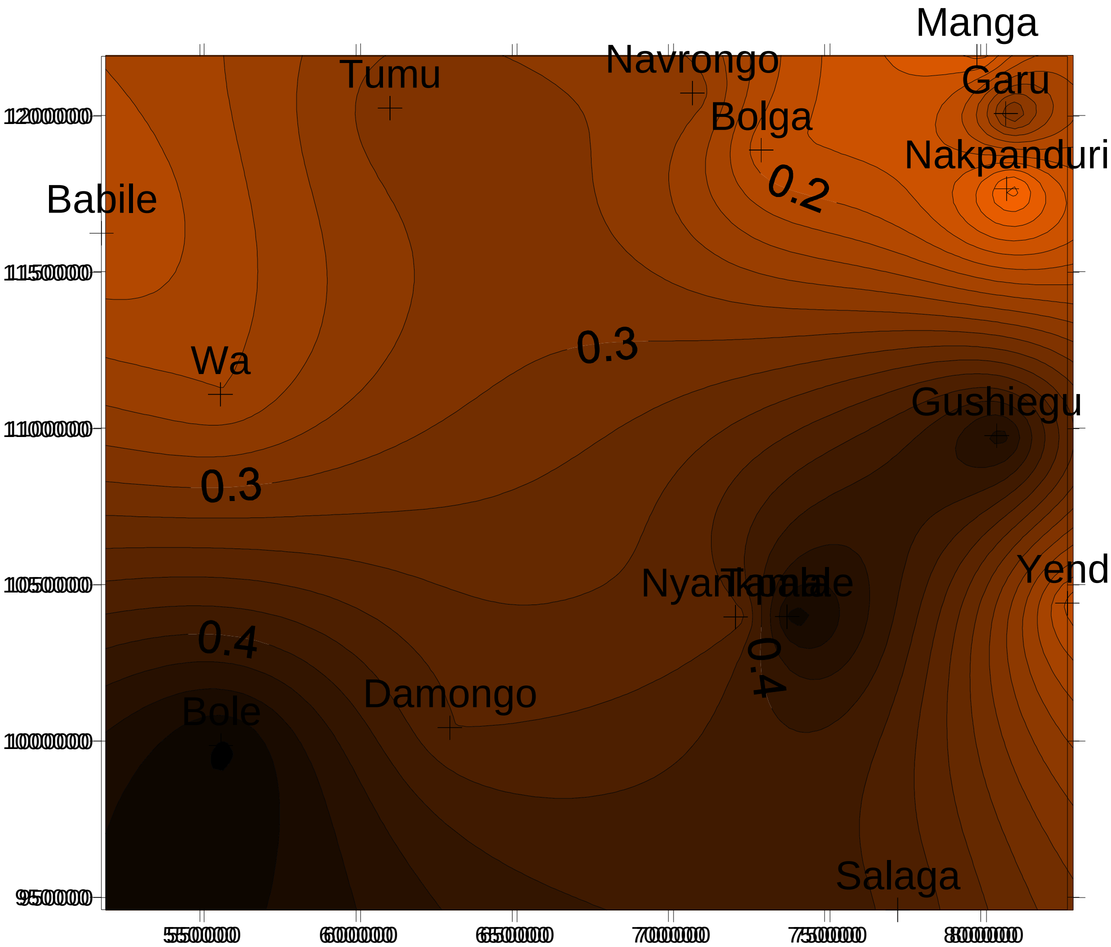


Plate 3: ***Drought spell probability map in July for selected Districts in Northern Ghana***

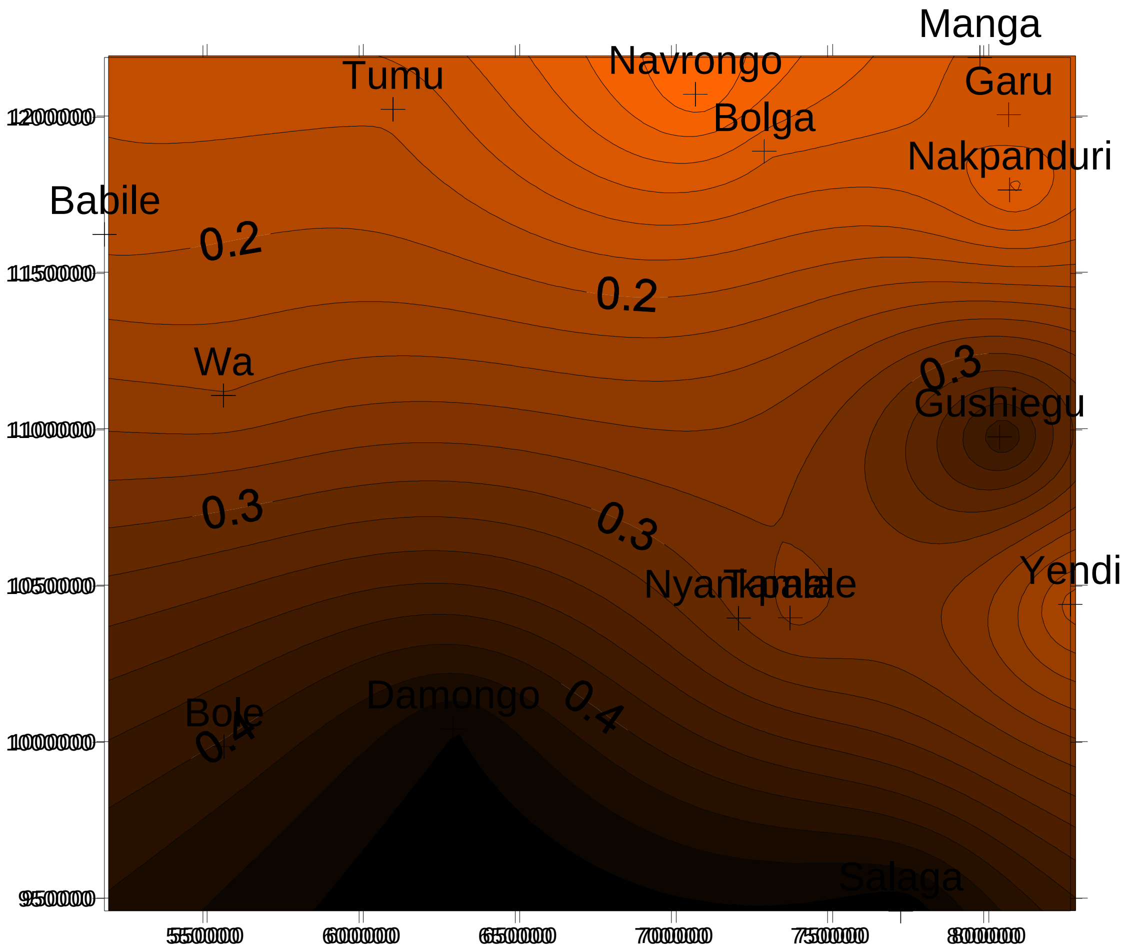


Plate 4: ***Drought spell probability map in August for selected Districts in Northern Ghana***

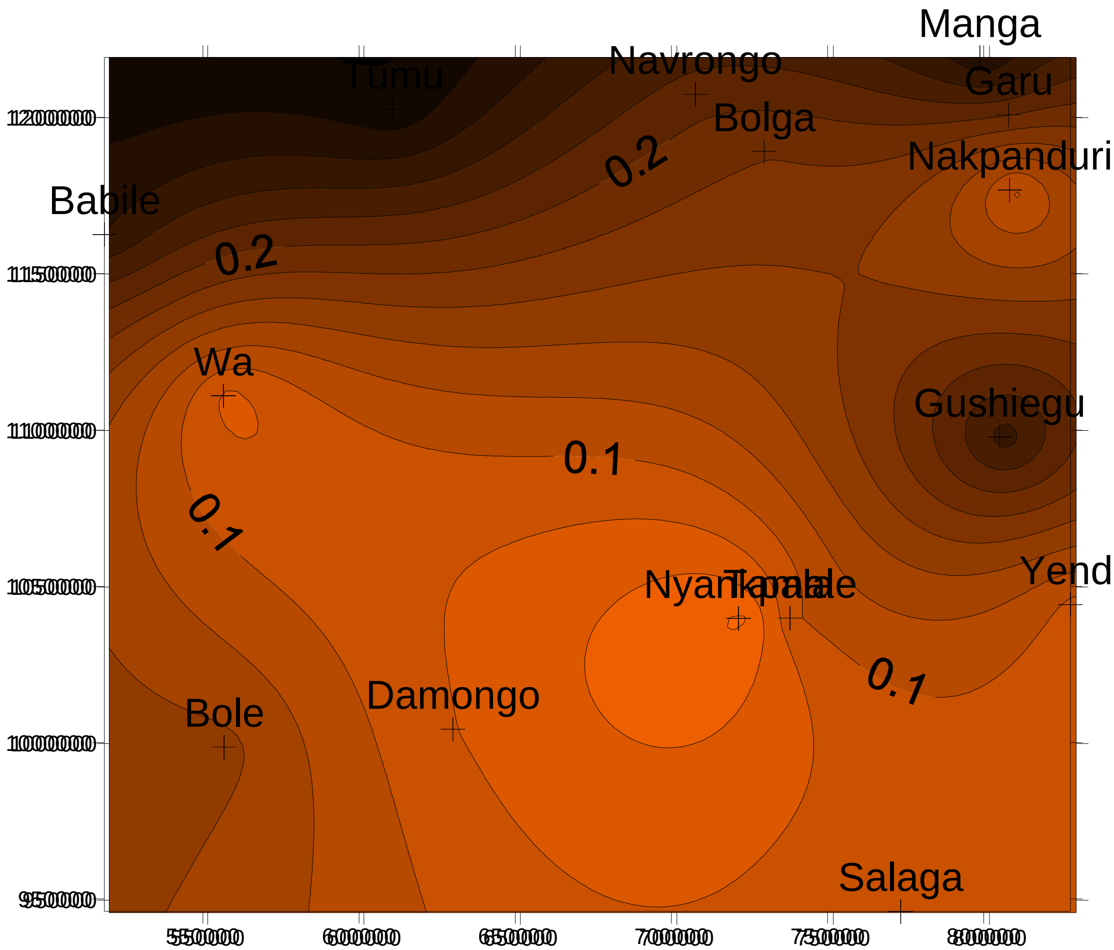


Plate 5: *Drought spell probability map in September for selected Districts in Northern Ghana*

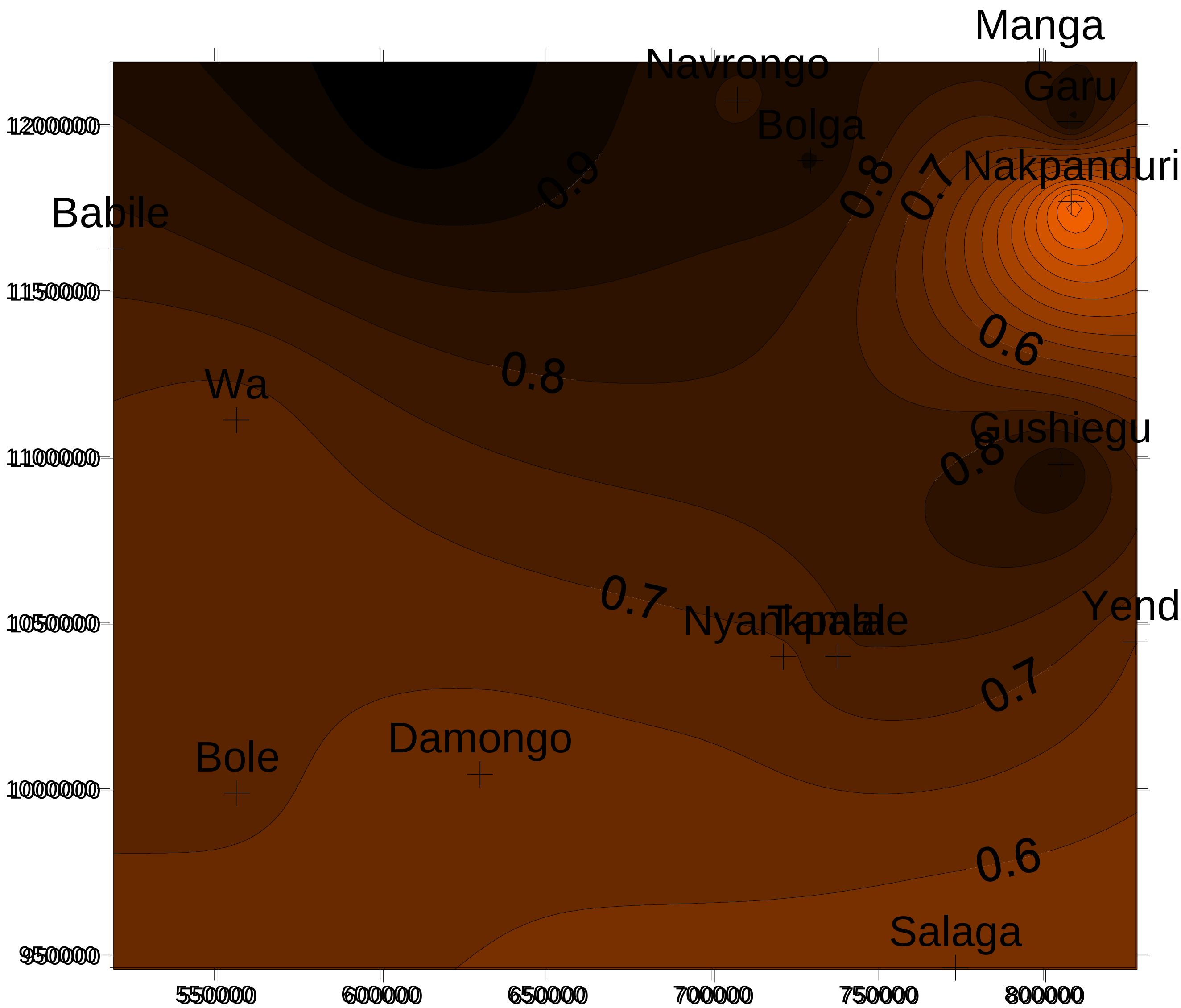


Plate 6: ***Drought spell probability map in October for selected Districts in Northern Ghana***

Evaluation of drought mitigation strategies

Tied-ridging and contour ridging with vertiver grass barrier experiments were conducted with 20 farmers from 8 communities for on-farm water harvesting from 2005 to 2007. Irrespective of the cereal crop used (maize or sorghum) or cropping system (sole or intercropped) water harvesting increased grain and stover yields. The impact was more evident on grain than on stover yields. In individual farmers' plots, Tied-ridging increased sorgum yield by 20%-25% over control when no fertilizer was applied in 2005. The mean grain yields obtained for sorghum under various water harvesting and fertiliser amendments are indicated in Figure 10. Under soil amendment at recommended rate, tied-ridging increased cereal yield by 150-200% above the control. On the average, tied ridging increased water productivity by 36 %, whereas application of NPK fertiliser increased productivity by 200 % (Table 14).

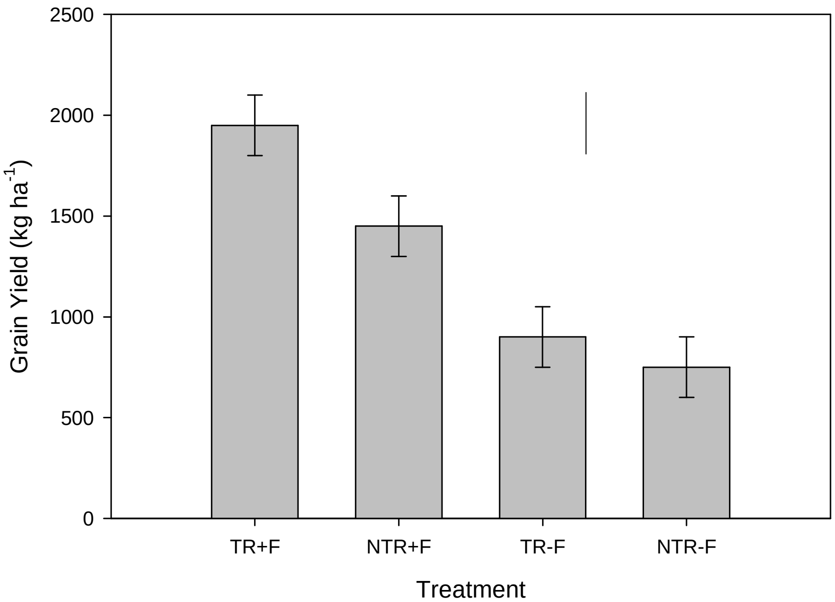


Figure 10: ***Mean grain yield of sorghum from farmers in 20 communities in Northern Ghana practicing various combinations of tied ridging (TR) with or without fertilizer (F) application.***

Table 14: Average cereal yields for 20 farmers practicing water harvesting and fertilizer amendments from 2006 to 2007 in Northern Ghana

Treatments	**Productivity measurements**		
	Grain yield (t/ha)	**Stover (t/ha)**	**Water productivity (kg/mm)**
No tied ridging	0.81	2.3	1.5
Tied ridging	1.1	2.4	2.04 (36% Δ)
$Lsd_{0.05}$	0.14	Ns	
No fertilizer	0.46	1.9	0.80
$N_{60}P_{30}K_{30}$	1.33	2.7	2.4 (200% Δ)
$Lsd_{0.05}$	0.40	0.23	

Fertilizer x water harvesting interaction not significant (P = 0.78)

Objective 3: Enhance use of community dugouts for fish culture
Introduction
Community dugouts in rural Ghana serve various needs including water for domestic chores, livestock watering and fish production. The efficient and continued multiple-use of the dugouts requires the active participation of various user groups in the communities. Moreover, where multiple uses for a community resource exist, it is imperative that mechanisms exist to ensure conflicts over the use of the resource are avoided. This component aims at improving water productivity through adopting better management of dugouts and improved stocking options for fish production. As at 2003, there were approximately 850 and 230 dugouts and small reservoirs in the Northern and upper East regions respectively ranging from less than 0.2 to 5 ha. Together, dugouts and reservoirs covered an area of about 1620 ha and 450 ha in the North and Upper East Regions, respectively.

Methods
Assessment and selection of community dugouts for project activities
Previous fish catch data (2000 to 2004) on dugouts of sizes between 0.5 to 3.0 ha in the Northern and Upper East Regions of Ghana were sourced from the Ministry of Food and Agriculture. The data were analyzed for volume of water retention, and potential for fish production. Twenty-two dugouts were then selected in communities in the Upper East and Northern Regions for project activities. Visits were undertaken to the selected to verify the status of dugouts previously selected and assess the volume of water present in them at the end of the major raining season in 2004 in order to ascertain the suitability of the dugouts.

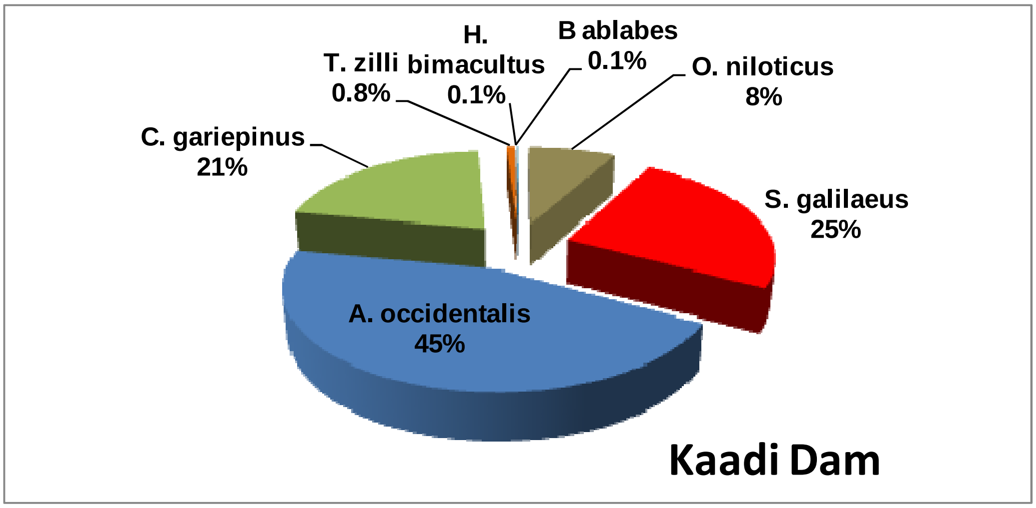
Community sensitization and training sessions
The Project rationale was introduced to riparian communities of selected dugouts for their primary involvement and ownership. The communities were also consulted on options for enhancing water retention and experiences in fish production. In each year of the Project, training sessions were organized for selected in the selected communities on dugout management, fish stocking, nursing and harvesting methods. Water Users' Associations, and Fish Management Committees were established in communities where this did not exist.

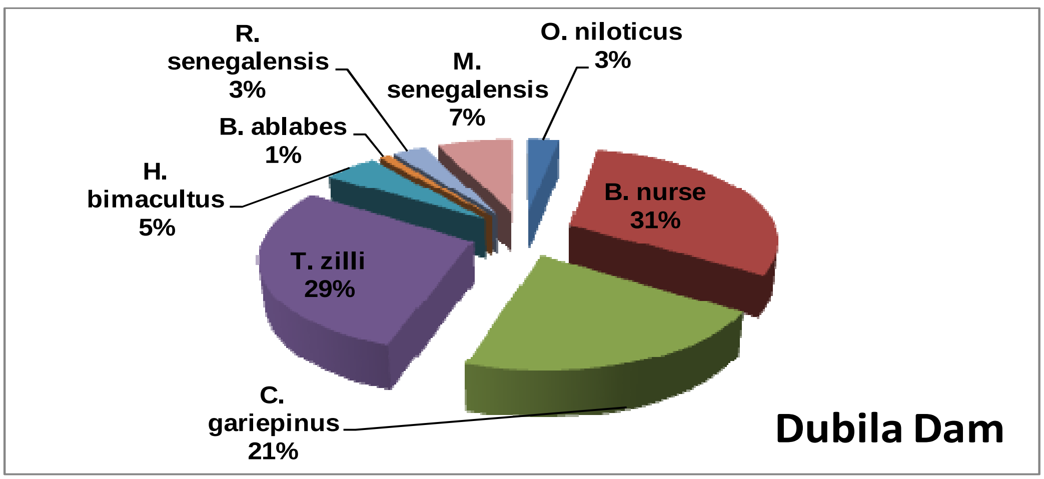
Stocking options of dugouts for fish production
Various stocking options of the dugouts were tested with the communities. Options tested include direct stocking with large number of fingerlings, use of few numbers of broodstock size fish, and stocking in cages.

Results and Discussion
Assessment and selection of community dugouts for project activities
Previous data (obtained from the MoFA) on fishes harvested from dugouts in Northern Ghana shows that a total of 20 fish species were encountered. Whereas two species including *Clarias* and *Sarotherodon galilaeus* were common to the majority of dugouts, six fish groups constituted the major fishes in most of the dugouts. These comprised *Brycinus nurse, Clarias, S. galilaeus, Synodontis* spp and *Labeo senegalensis* and *Hydrocinus forskahlii*. Available fish catch data for some of the small water bodies, particularly in the Upper East Region, although gave indication of their fish species composition, did not provide information on the relative abundance of species. Ten out of a total of eleven fish species found in the area were accepted as food fishes. Three species, the African Catfish (*Clarias gariepinus*.), the Mango tilapia (*Sarotherodon galilaeus*) and the red throat tilapia- *Tilapia zillii* were common

to all the water bodies. Dugouts that were previously stocked with tilapia fingerlings by the Department of fisheries personnel of MoFA did not show the stocked material to have contributed significantly to the catches. The highly represented omnivore/carnivore catfish *Clarias* in catches is considered to have preyed on the tilapia fingerlings. The predation is also exacerbated by uncontrolled fishing by fishermen in dugouts.

Primary fish data was therefore generated for some of the dugouts to verify the secondary data obtained, and obtain actual catch statistics. Species encountered included *Brycinus nurse, Schilbe* intermedius, *Clarias* sp., *Sarotherodon galilaeus* and *Oreochromis niloticus*, which together dominated species composition of the dugouts (Figures 11 and 12). In all dugouts, previously stocked tilapia did not contribute significantly to the catches.





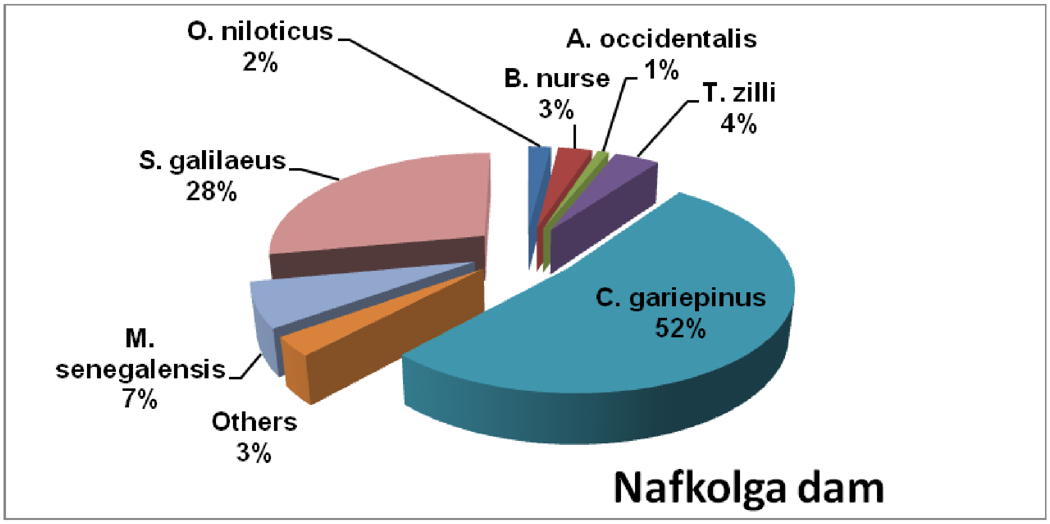
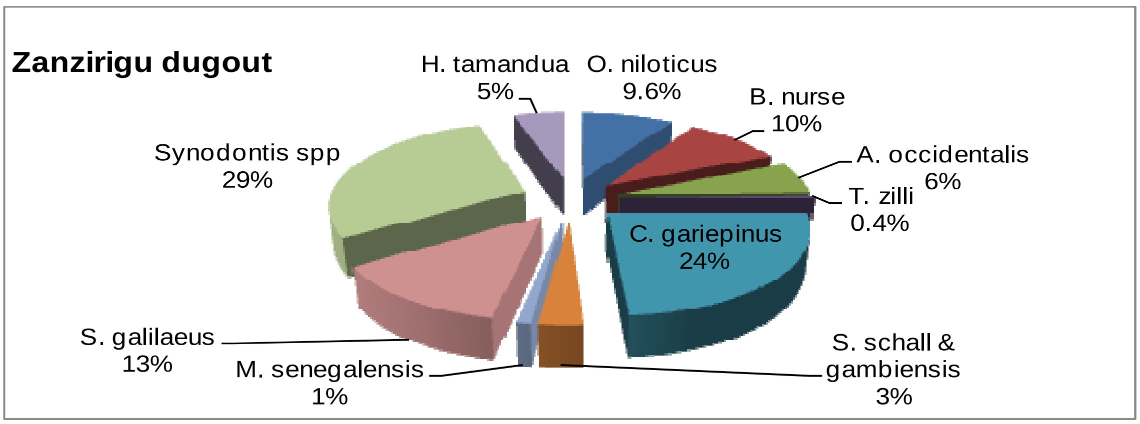
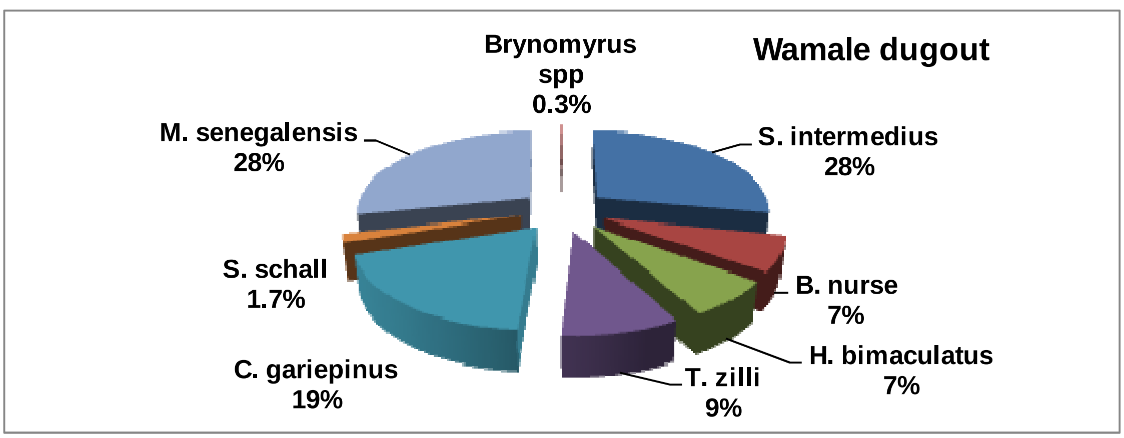


Figure 11: ***Relative abundance of fish harvested from 3 small water bodies in the Upper East Region of Ghana***





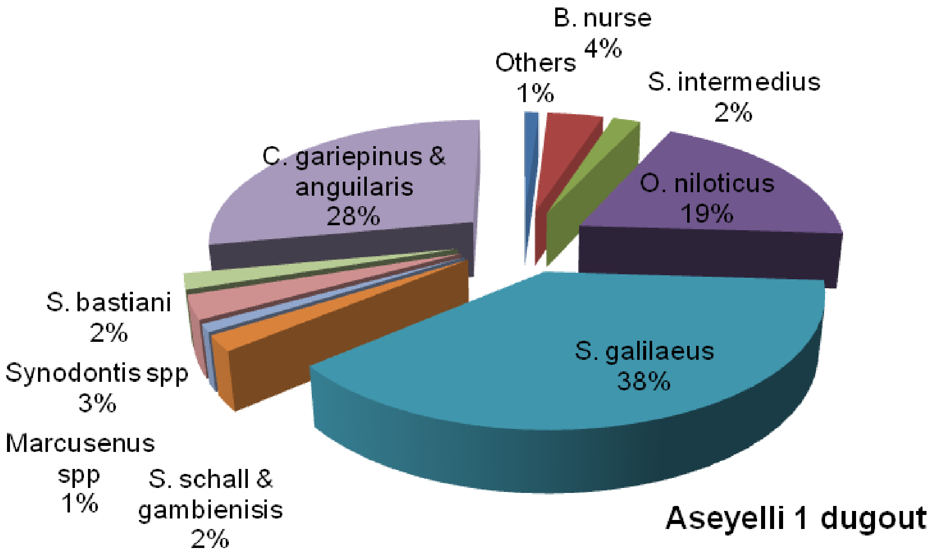
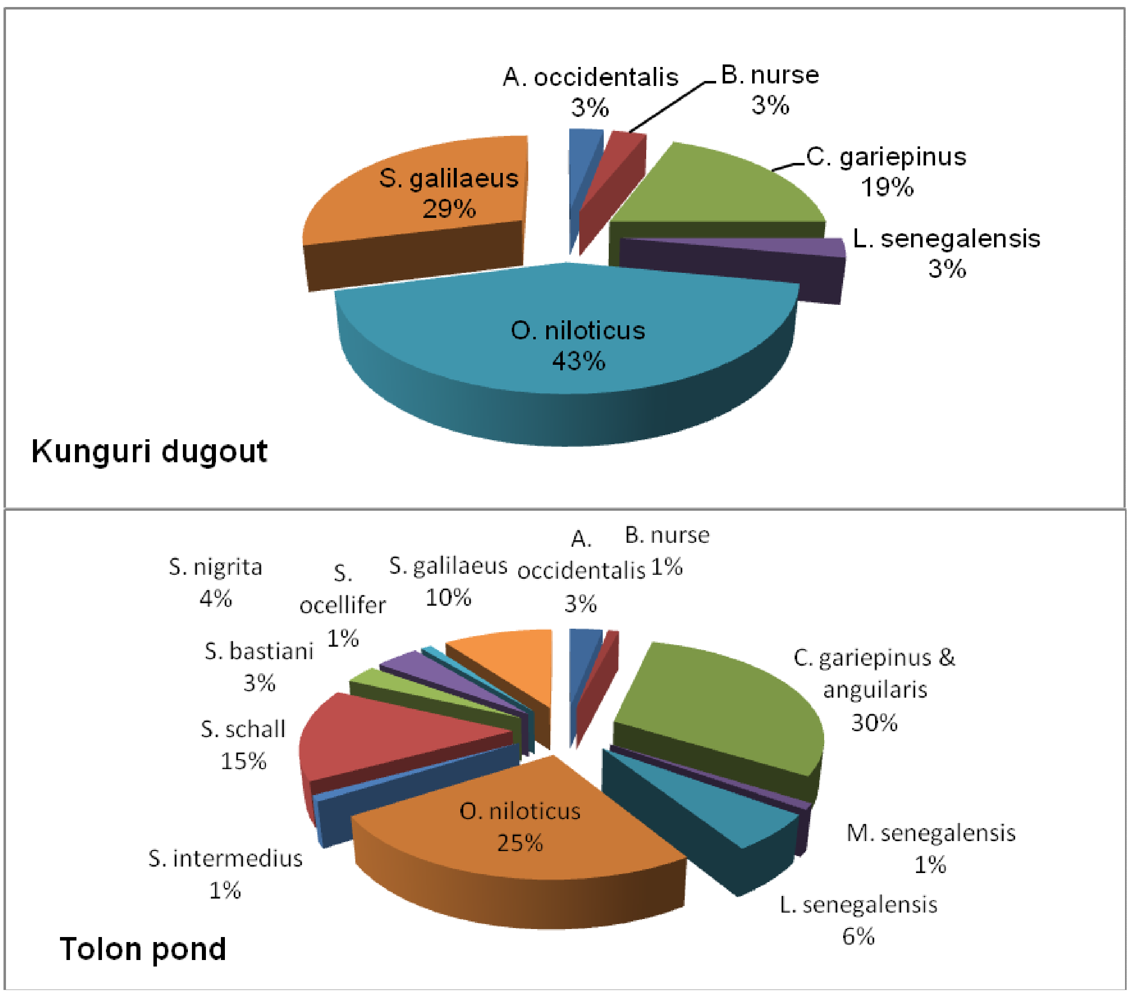


Figure 12a: ***Relative abundance of fish harvested from three community dugouts in the Northern Region of Ghana***



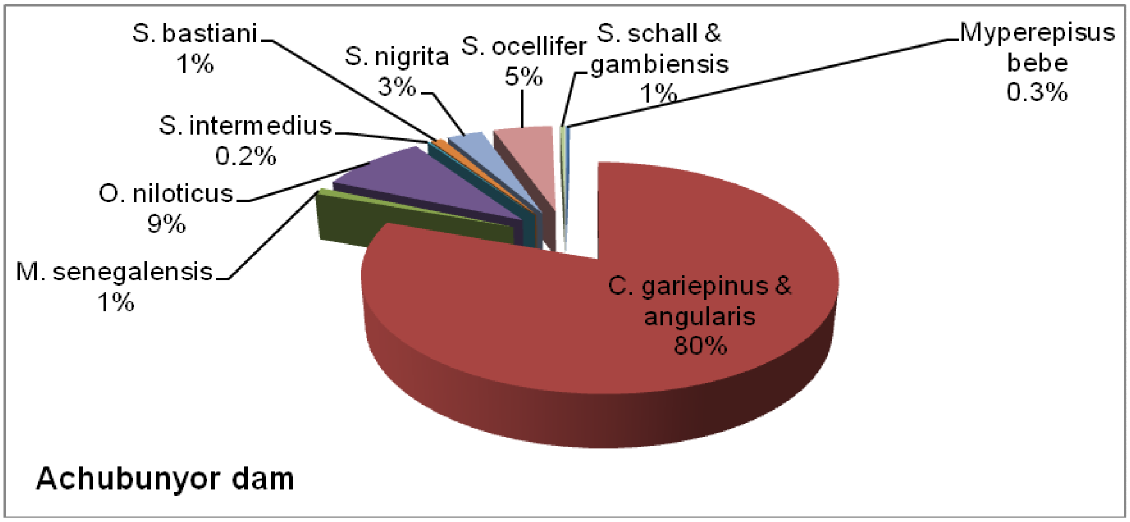


Figure 12b: ***Relative abundance of fish harvested from three small water bodies in the Northern Region of Ghana***

Following the assessment of these dugouts, twenty-two were selected for project activities.

Community sensitization and training sessions
A series of workshops were held each year covering institutional arrangements and training were organized for community representatives in the project districts in the Northern and Upper East Region. Representatives of the project communities, local government or District Assemblies, Technical and Agriculture Extension Agents from the Ministry of food and Agriculture (MOFA), and the Directorate of Fisheries and Non Governmental Organizations attended the workshops. Training workshops on dugout maintenance and fish enhancement as well as others on tilapia fingerling production in hapas and use of *Moringa oleifera* for live fencing dugouts and water treatment were held for Fish Management committee members from the selected small water bodies between August and November in each year.

In the early part of the Project in 2005, the purpose of the stakeholders' workshop was to obtain and collate views of stakeholders towards formulating appropriate guidelines for the implementation of the subproject in the various communities. Specifically, the workshops sought to:

I. To identify common approaches to the implementation of activities under the subproject

II. To identify how best to get community involvement in the project

III. To identify common problems and conflicting use of water resources within the communities of the project area

IV. To identify possible solutions to conflicts in the use of water within the project area to serve as a bases for drawing up guidelines for minimizing conflicts and optimizing use of water resources

V. To identify institutions for collaboration and solicit possible assistance from these institutions towards rehabilitating community dugouts.

Key issues discussed during the discussions:

- Role of community in de-silting dugouts for increased capacity for water storage.
- Conflicting needs for use of water in participating communities
- Specific interventions for conflicting use of water resources in participating communities.
- Ownership of dugouts and harvested fish as well as control of fish resources in the water bodies
- Management options for enhancing fish yield in dugouts
- Record keeping of fish catches from dugouts and dams
- Other benefits to community from fish catches from the dugouts and dams
- Institutional collaborations for maintaining increased productivity of water bodies.

Plate 7: *Participants at a workshop on enhanced fish production In Tamale, 2005*

The following were the outcomes compiled from groups' presentations on issues at the sessions in the two regions.

De-silting of dugouts

- That de-silting of dugout should start with the adoption of preventive measures that avoid or minimize silting of the water bodies. The measures include destructive farming practices such as farming, ridging or ploughing along contours, depletion of vegetative cover and deforestation in the water catchments areas and around dugout.
- Communities should plant trees (live fencing) to shade the water body and grasses on the embarkments to check erosion of soil into the dugouts.
- Create contour bunds or plough across slopes of catchment's area
- Avoid human settlements within dam/catchments areas
- Community Based Fish Management Committees (CBFMC) should be formed to oversee fish enhancement in the dugouts and their maintenance by organizing community members for communal labour to undertake de-silting of the dugouts
- The CBFMCs should dialogue with communities around the dugout to provide labour and in kind contribution to support communal work force in de-silting water body. Recalcitrant members of the community should attract sanctions such as the imposition of a fine.
- Communities should contact other stakeholders working within and outside it. Also seek the support of the District Administration and NGO's through their Assemblyman.
- Contacts are established with other community citizens living or staying outside the community for assistance.

Ownership of dugout and control of harvested fish

Generally, communities own the dugouts but have the chiefs as the custodians. Strict allegiance of the community to the chief and elders most often limit interaction between the traditional authority and the community members. To enhance interaction and understanding between the subjects and the community heads on issues pertaining to the dugouts, the following are recommended

- The management committee should work closely with the chief pertaining to issues on the dugout and reach agreements that will satisfy both parties.
- Community ownership of dam and dugouts should be emphasized from the inception of the project.
- The Fish Management Committee on behalf of the community members should agree with chiefs on the sharing of harvested fish from the dugouts.

- Fish catches should be sold to community members and proceeds used to solve identified problems of the community as well as providing social service support such as schools, latrines, repair of bore holes etc.

Conflicts in the use of water resources

The following sources of conflicts were identified in the use of water from dugout and dams

- Water requirements for domestic purposes such as drinking, washing and cooking relative to cropping and livestock needs
- Prohibition of fishing in dugout/dam at low water level
- Use of water for dry season farming as against water for maintaining fish in the dugouts
- Abstraction of water from dugouts by contractors for constructional purposes leading to early depletion of water resource
- Disorderly watering of livestock in the dugouts at critical periods of the dry season

Suggested interventions to minimize or solve conflicts

- Formation of Management Committees such as Water Users Association to ensure enough that water is available to serve all interest groups for water resource. Emphasis should be placed on following the right channels in the establishing the committees in order to empower the people in all matters.
- Communities should encourage dialogue and co-operation among themselves to agree on a plan for water use from dugouts e.g. prohibition of fishing when water level is critically low (concern of livestock farmers and domestic water users). The Water Users Association should draw this plan.
- Communities should, through the Water Users Association and in consultation with the chiefs, Tidanas and community representatives such as the assemblyman and opinion leaders and the District Assembly, enact and enforce bye-laws to guide water use.
- Provide separate watering spots or source for livestock.
- As far as possible water users association (WUA) should be empowered to handle or resolve conflicts. In the event of conflict becoming complex, its resolution should involve chief, Tindanas and assemblyman.

Management and exploitation of fish resources

- Fish Management Committees (FMC) should be formed to ensure the security and management of fish resources in the drought period. This committee should be a sub-committee of WUA or have representation on it

- The FMC's, working in conjunction with the chief and opinion leaders, should be tasked with enforcement of appropriate fish management practices including the imposition of closed fishing season once a year, restocking of water body and enforcement of approved fishing methods (e.g. use of approved gear and mesh sizes).

- Fish exploitation by fishermen outside the community should not be free but should be done at a fee. The FMC and fishers should resolve the rate of payment, which could be either in kind or in cash.

- The FMC should agree with other users on the water on common inputs such as manure form animals that are left along the shores of the dugout/dams.

Record keeping

- Fish Management Committees should ensure that all fish catches by fishermen outside the community are recorded at all times. Records of fish catches by the community and sales made should be kept by the committee. To facilitate the keeping of proper records, committee members and volunteers should be trained in fish record keeping. This should be undertaken with the assistance of the Ministry of Fisheries, District Assembly and related agencies such as the Water Research Institute.

Other benefits to community arising from fishing

- Participants recognized that enhanced fisheries from the dugouts could empower women economically by providing more fish for value addition through processing. Dealing in processed fish would not only increase preservation of fish products but also reduce post harvest losses and generate additional income.

- Household diets will be improved with the inclusion of fish protein and promotion of healthy family status.

- Promotion of marketing activities around the dam sites.

- Potential reduction in rural-urban migration of community members.

Institutional collaboration

- Participants stressed for the need for the project to seek collaboration with the District Assemblies, Non Governmental Organizations working in the food security sector, MoFA and the traditional authorities, Ghana Irrigation Development Authority (GIDA) and the Water Research Institute (WRI) to complement efforts at improving the water storage capacity of the dugouts and dams.

At the inaugural workshop, it was decided that training of the community members should be an important component of the Project to sustain initiatives of the Project.

Consequently, a total of fifty three participants selected from 25 communities in the Northern and Upper East Regions were respectively given a day's training in Tamale and Bolgatanga. The purpose of the training was to communicate to participants the traditional and major uses of dugouts and dams and their potential for fish production. Additionally the training also equipped the participants with knowledge on stocking the small water bodies with fish and managing the fish till harvest.

Participation

Participants for the training were drawn from the Communities' Fish Management Committees. Each community presented at least three participants for the training. Twenty-eight and twenty-nine participants respectively represented communities from the Northern and Upper East Regions. In all cases female representation was low and was restricted 3 and 4 women for each of the two regions. Also participating in the training were 3 and 5 fisheries agriculture extension agents for the Northern and Upper East Region respectively.

Training modules

Three main subject areas were covered during the training sessions comprising: a) dugouts management for increased fish production and their maintenance; b) sources of stocking materials (fingerlings) for dugouts and their management; and c) recording of fish catches and keeping of records .

Three resource persons handled aspects of subtopics of the main training topics. The following subtopics were treated in participatory interactions.

a. Sources of water and fish in dugouts

b. Management of fish in dugouts for increased production

c. Assumptions, which provide basis for Management of Dugout fish communities for increased production.

d. Sources of fish stocking material for dugouts

e. Hapa production of tilapia fingerlings in dugouts and dams

f. Transport of fingerlings and stocking into dugouts

g. Common available local agro-industrial by-products as feed for fingerlings

h. Live fencing as physical barriers for protection of dugouts from livestock

i. Use of live fencing for shading and creation of microclimatic conditions for reduction of water loss from dugouts

j. Use of Vertiver grass for checking soil erosion on slopes of dugouts and dams

k. The use of seeds from the live fence plant *Moringa oleifera* for clarifying water for domestic use

Training involved interactions with group and presentations during which major ideas were communicated through very slow and patient discussions with interpretations or translations into two dialects; Gonja and Dagbani for the Northern Region and

Kusasi and Frafra for the Upper East Region. Field trips were organized to nearby dugouts for each training session where the planting of *Morienga* seedlings, transport of Tilapia fingerlings and their stocking/release into dugouts, as well as sexing of tilapia broodstock were demonstrated.

Reaction of participants
Participants expressed satisfaction at the end of the training workshop but wanted to know whether communities will be provided with Hapas. The project promised to donate two hapas to each community to enable the communities to construct more hapas from their own resources. Participants were reminded of the project's objective of improving their capacity through training to generate innovative ideas of increasing production from water resources and to do things for themselves. This will require that the communities learn to provide some inputs for the realization of their dreams and not to depend solely on the project.

Training in Tilapia fingerling production
A training session on tilapia fingerling production in hapas was organized for fish committees' members from 7 and 8 communities respectively in the Upper East Region and Northern Region. At the training, members first refreshed their memories by recapping some of the treated topics in the previous sessions especially, those related to fish species composition in the dugouts and the methods for increasing their production. These methods included augmenting the numbers of species of fish existing in the dugouts by adding young fish (fingerlings) that had been either bred in captivity or produced naturally and collected from associated water systems for stocking.

Previously taught topics on stocking dugouts with fish were reinforced by teaching and discussing with the participants specific methods of producing tilapia fry and fingerlings in hapas mounted in the dugouts. The advantages offered by producing tilapia fingerlings in hapas in relation to their direct production in the water body were discussed. Demonstrations on the construction, mounting and installation of the hapas in the dugouts were conducted for the participants who were directed to mount a couple of hapas in the dugouts.

Plate 8: ***Community members attempt to install hapa in the Kajelo Dugout***

In two communities in the Upper East Regions, broodstock of the Nile tilapia *Oreochromis niloticus* was obtained and from associated reservoirs at Kajelo and Dubila. The fish obtained were first sorted by sizes to separate matured specimen whose weight ranged from 80 g to 150 g. Some of the matured fish obtained was used to demonstrate the community members the manual sexing of the fish into males and females using characteristics of the urino-genital papillae and their subsequent stocking into hapas for reproduction. The hapas were stocked with male and female fish at a stocking ratio of 1 male to 3 females and stocking rates of 4 fish/m^2. Feeding of the stocked fish with locally available by-products such as pito waste, maize chaff and wheat and rice bran where available was also demonstrated to the Fish committees. Lastly the participants were taught to inspect hapas for fry at 18 days intervals within which all fry/fingerlings sighted should be transferred into another hapa for nursing.

At the end of the training, 3 Hapas were presented to each community for initiation of the fingerling production experiment and were encouraged to sew more from their resources when needed. Collaboration in fingerling production among closer communities was also stressed, especially in situation were water conditions such as low water levels in the community dugouts may be a disadvantage.

Plate 9: ***Leader of sub-Project presents Hapas and bundles of Hapa materials to representatives of the Tolon-Kunguri-Aseyilli communities after a training session in Tolon***

Hapas provided for the communities were stocked with broodstock of O. niloticus in latter part of November and early December 2005 for commencement of fingerling production.

Live-fencing of dugouts and water clarification using Moringa (*Moringa oleifera*).

In the later part of 2005, training was offered to communities on nursing and transplanting of *Moringa oleifera* seedlings for use as live-fencing material for the

physical protection of community dugouts and dams, and the use of its seed for clarifying water for domestic consumption.
Training sessions were held with the following objectives:

1. To equip the communities with the knowledge and skills on tree production and nurturing of *Moringa*.

2. To show communities the use of *Moringa* seeds to clarify water and improve its quality for domestic use

Approaches
Seeds of *Moringa oleifera* were picked from the wild and distributed to the communities for nursing and onward transplanting when the rains established in June 2005 during a training session. Community representatives were taught nursing procedures and transplanting techniques for *Moringa* to ensures its quick establishment and avoid or minimize wilting. Alongside the direct distribution of the seeds to the communities, a nursery was established at SARI to provide seedlings to supplement the seeds supplied to communities and also for demonstration.

At each community, a demonstration was made of how the seedlings should be planted to facilitate fast growth and development when the seedlings were sent. The community members took turns to practice the transplanting procedure. The procedure was demonstrated to all the community representatives in the Upper East region during the second training workshop held at Bolgatanga.

Concerns on the use of Moringa as life fence
When communities were visited during the post-rainy season, no community had up to twenty percent of their seedlings alive. Reason for the low success rates varied but could be summed up as:

(1) Moringa is not hardy enough for the conditions around the dugouts, eg water logging

(2) People from other communities who know Moringa well stole most of the seedlings

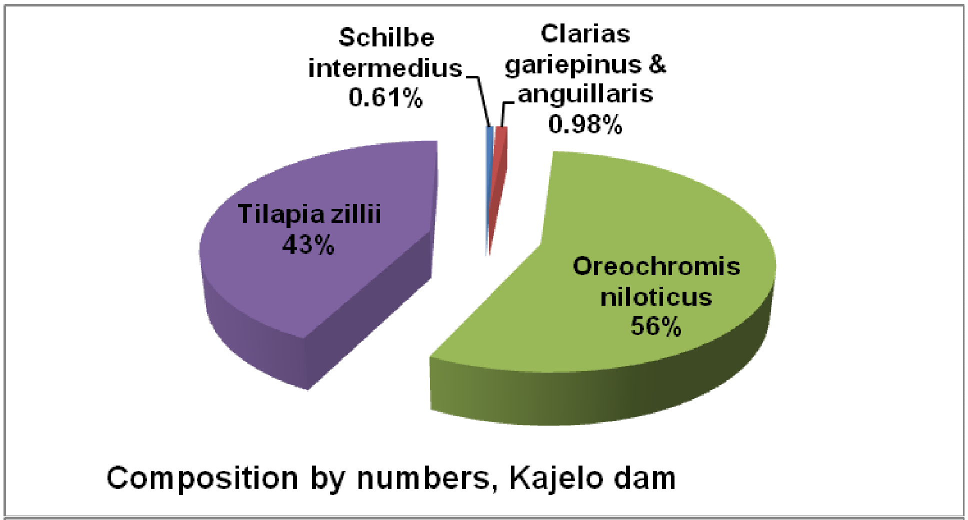
(3) Lack of cohesion between community members and representatives with regards to caring for the plants

(4) Cassia spp and some local tree spp good for the dugouts and Moringa good for backyards

(5) Low rainfall and poor distribution did not favor the plants

It was concluded that though Moringa grows fast conditions around the dugouts was not conducive to the plant. Cassia species and other local species were selected for life fencing since such trees have been sighted at various locations around artificial water bodies where they better serve the live-fencing purpose than Moringa. Seedlings of Cassia spp and some selected local tree spp were multiplied and supplied to the communities.

Evaluating options for stocking dugouts
Obtaining fish catch data from dugouts stocked earlier with tilapia or naturally during the flooding season has not always been easy. In some years, extensive flooding during the first half of the year caused some dams to overflow that lost some stocked fish. The most important reason however was that although the communities were informed through their Fish management committees or traditional heads about the intended harvest date of dugouts, some communities went ahead to harvest their dugouts before the project team could arrive. This they did by renting out the water body to itinerant fishermen who came in to rent the water body and fished for a period in them and shared the produce with the community through head (Tidana) or WUA's.



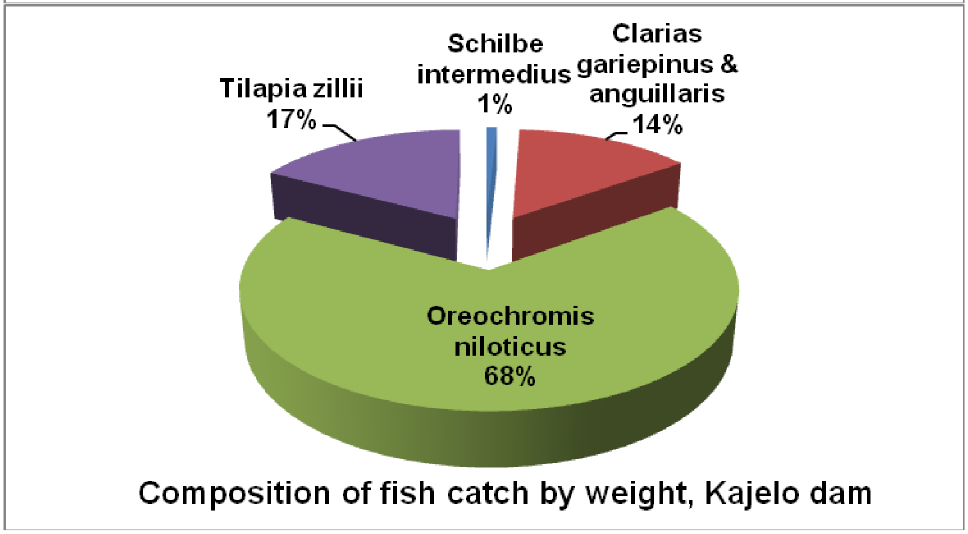


Figure 13a*: Relative abundance by numbers and weight of total fish catch in the Kajelo dugout six months after stocking with Orechromis niloticus broodstock*

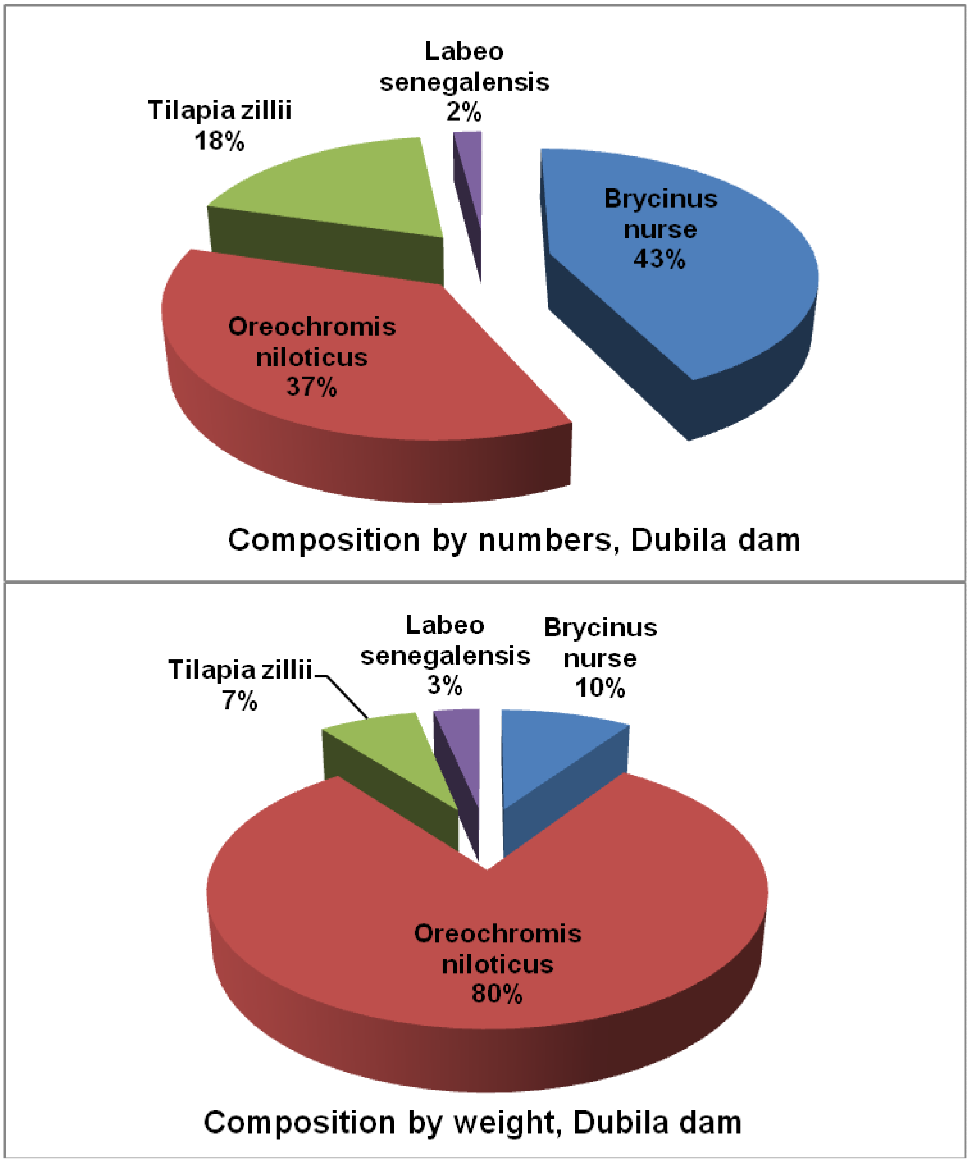
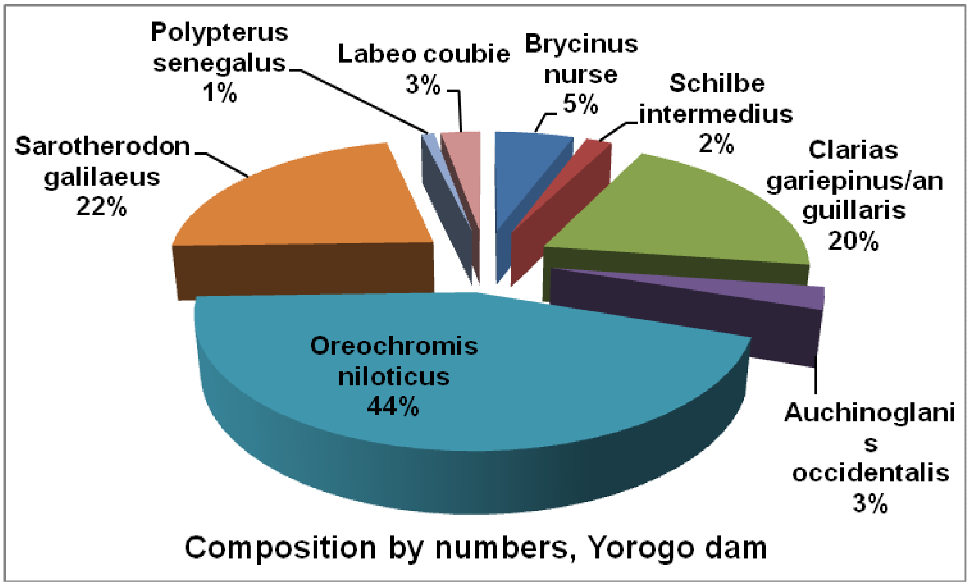


Figure 13b*: Relative abundance by numbers and weight of total fish catch in the Dubila dugout six months after stocking with Orechromis niloticus broodstock*



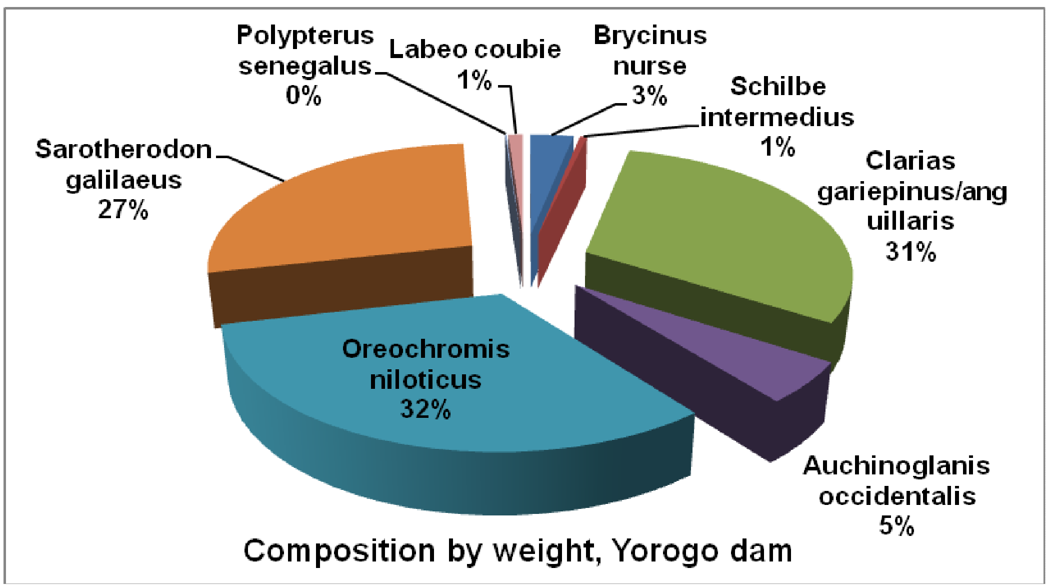


Figure 13c*: Relative abundance by numbers and weight of total fish catch in the Yorogo dugout six months after stocking with Orechromis niloticus broodstock*

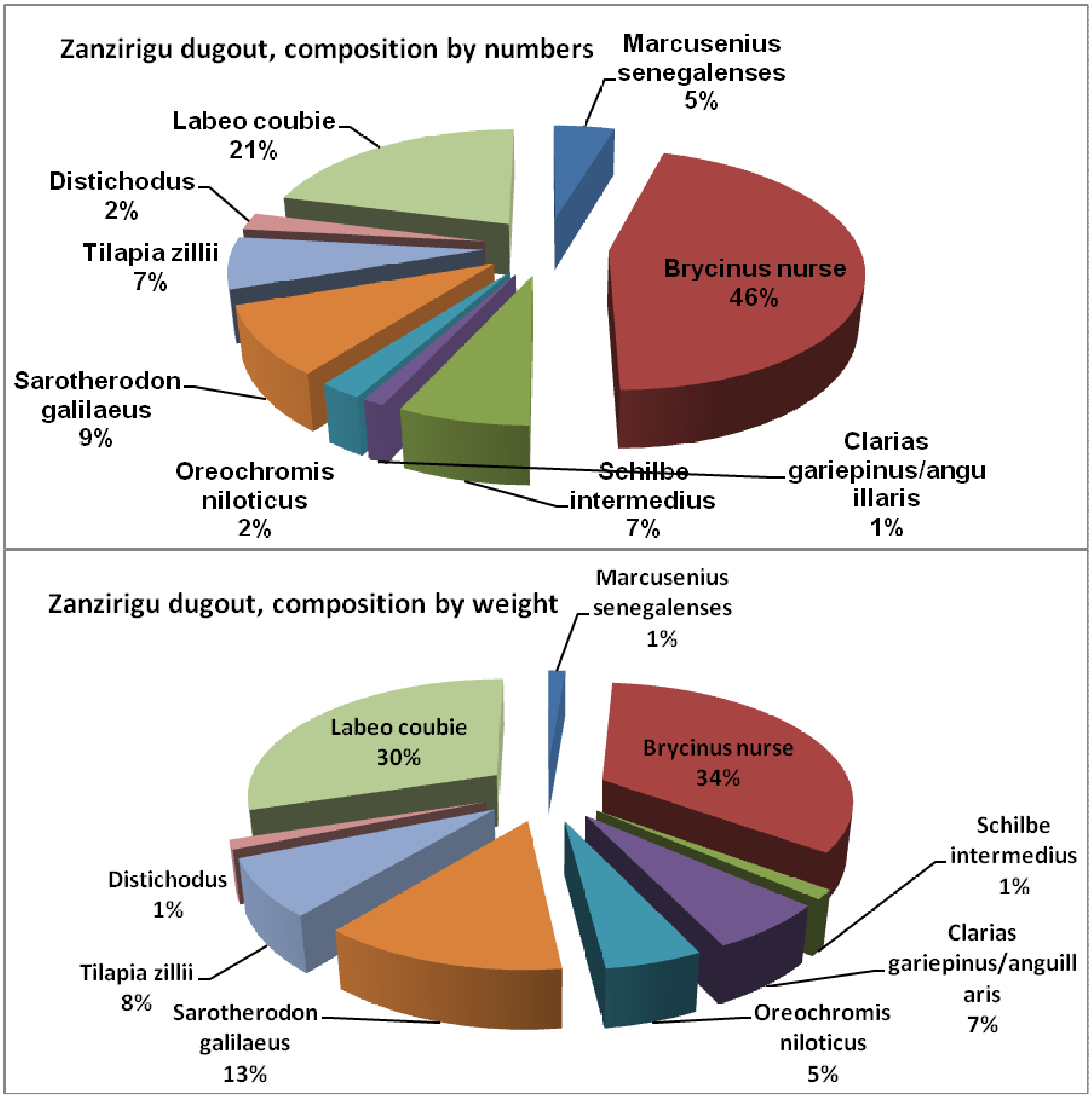
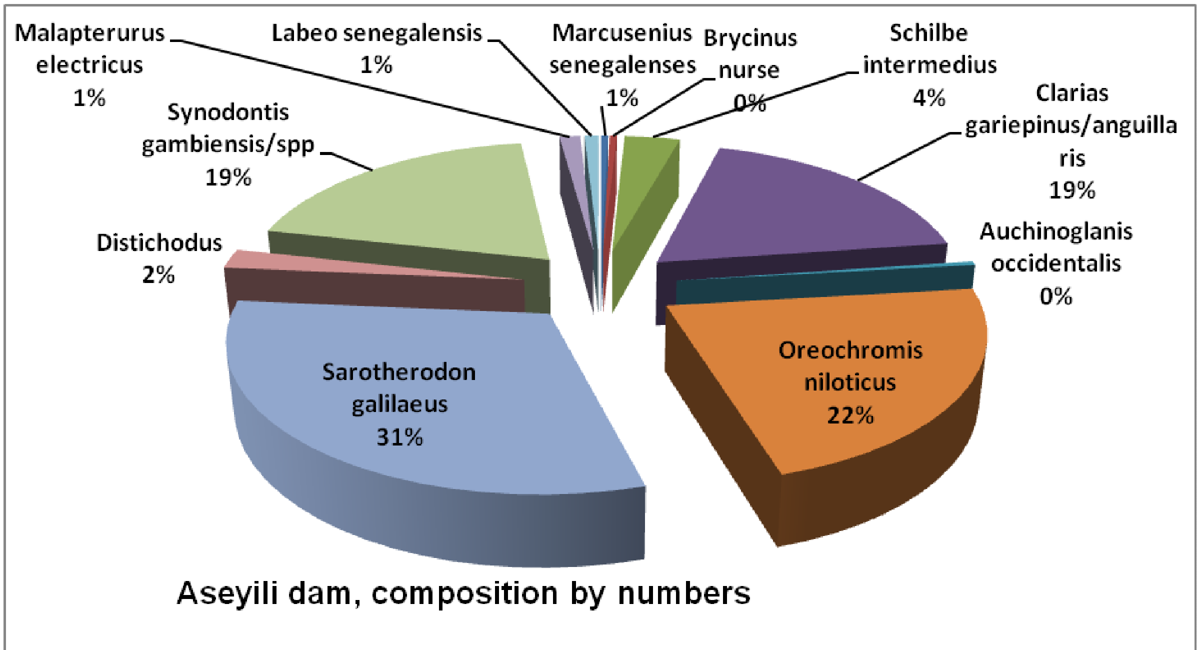


Figure 14a*: Relative abundance by numbers and weight of total fish catch in the Zanzirigu dugout six months after stocking with Orechromis niloticus broodstock*



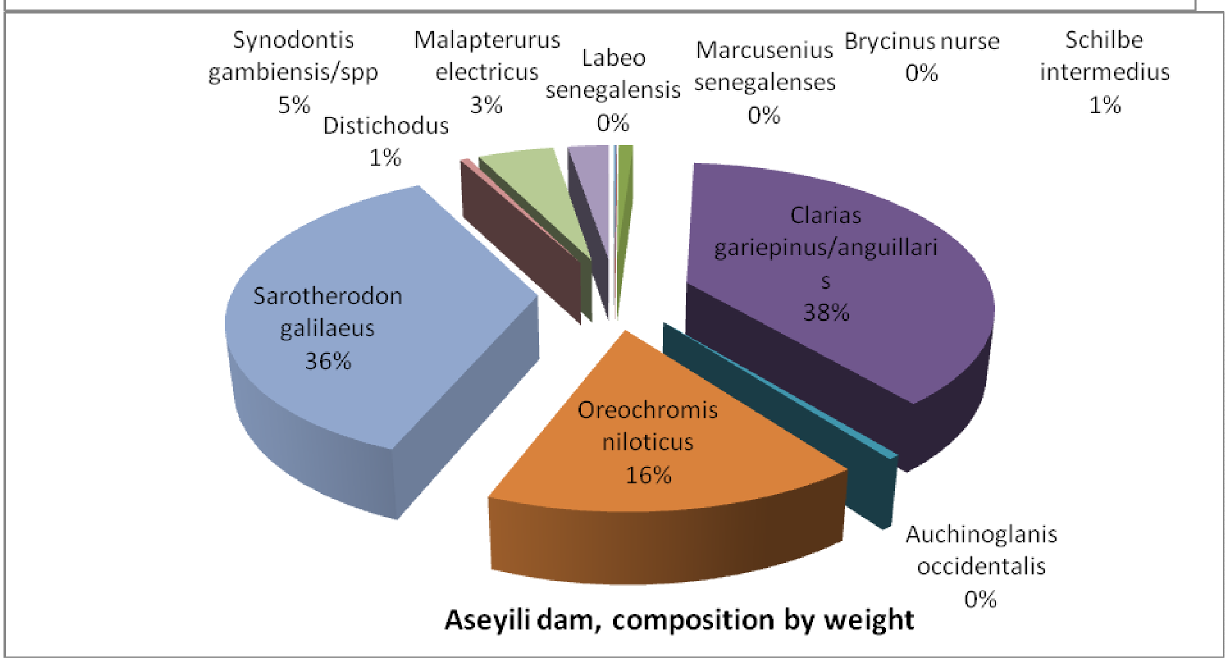
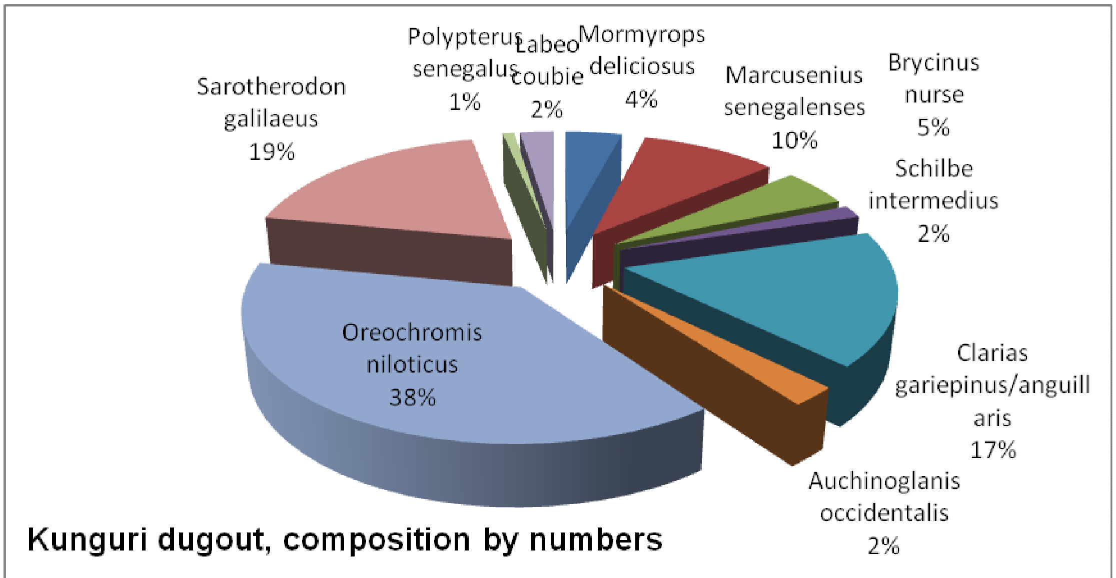


Figure 14b*: Relative abundance by numbers and weight of total fish catch in the Zanzirigu dugout six months after stocking with Orechromis niloticus broodstock*



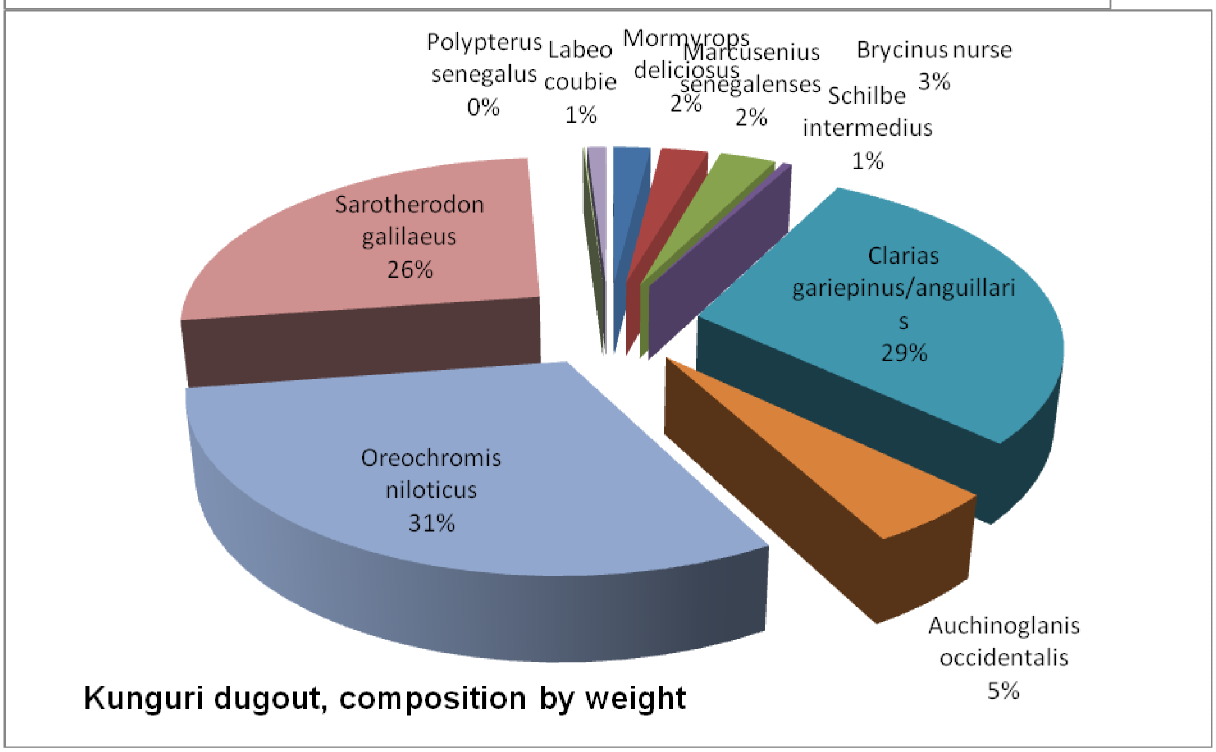
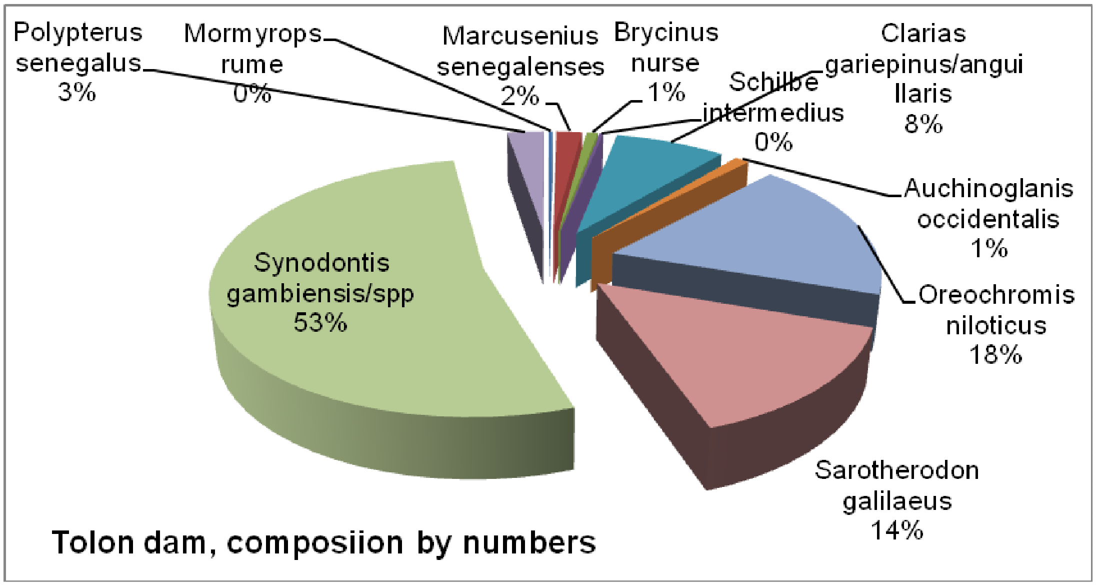


Figure 14c*: Relative abundance by numbers and weight of total fish catch in the Kunguri dugout six months after stocking with Orechromis niloticus broodstock*



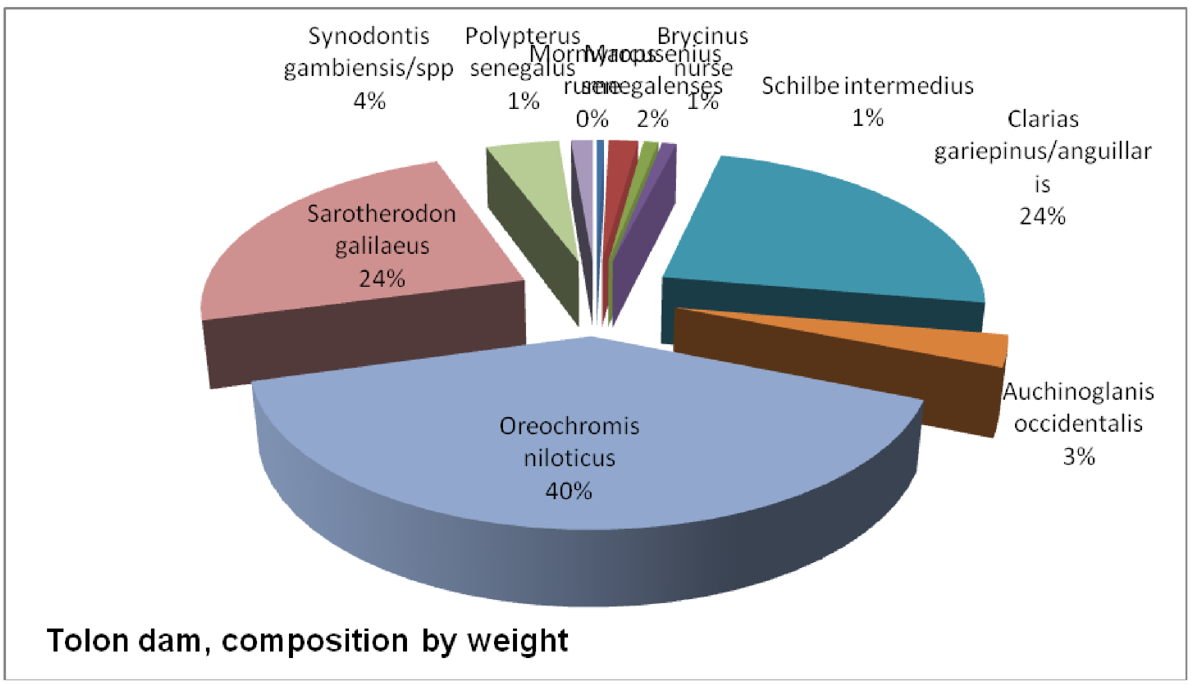


Figure 14d*: Relative abundance by numbers and weight of total fish catch in the Tolon dugout six months after stocking with Orechromis niloticus broodstock*

Catches in dugouts from the Northern Region were higher compared to those of the Upper East Region. Species compositions of harvested dugouts in the Upper East region were few and dominated by the tilapias mainly *O. niloticus* (Figure 13 a-c). This cichlid was followed by the African catfish *Clarias gariepinus*. The percentage compositions by weight for the two species ranged from 18.12 to 52.4% and 6.2 – 38.1 % respectively. The absence of many riverine fishes in dugouts of the UER relative to those of the Northern region (Figure 14 a-d) reflects the limited connectivity of these dugouts in the UER to the major water bodies and the general absence of floods on the plains to encourage fish movement in associated water channels to naturally stock the small water bodies. On the other hand, the prominence of *O. niloticus* in the catches reflects enhancement of yields brought about by the stocking of dugouts with tilapia.

In all, species encountered in the dugouts in Northern Region (Figure 14a-d) ranged from 9 to 11, with the cichlids *O. niloticus*, *S. galilaeus* and *T. zillii* constituting the bulk by weight. Their percentage total weights ranged from 18.42 to 85.03%. This family was followed by the Claridae (6.2-38.09%) and the Bagrid *Synodontis* spp. Nine other lotic species made up the rest of the groups. The Aseyilli dugout proved the most productive among the water bodies yielding 55 kg of fish six months after stocking with O. *niloticus.* Some dugouts such as Kunguri and Aseyilli had been fished previously before the harvesting but catch records were not available to the project so what is reported is a fraction of actual fish yields. Nonetheless, the dominance of the cichlid *Oreochromis niloticus* in the catches would suggest its reflection as the major species stocked and therefore its enhancement of the total catches obtained. In communities where flooding occurred soon after stocking, the contribution of O. *niloticus* (example Zanzirigu dam) was minimal suggesting its susceptibility to predation.

Comparison of the fish catch data in 2005, and after project interventions in 2008 showed remarking improvement in fish yields. Dugouts were stocked either with 50g size fingerlings of the Nile tilapia, *Oreochromis niloticus* or with mature parent broodstock of O. *niloticus*. These stocking strategies are departures from previous efforts with similar objectives that utilized less than 20g fingerlings for stocking. Fish species composition and yield estimates of the dugouts obtained by seining were compared with the primary or secondary fish catch data of the selected dugouts. Stocking dugouts with broodsize fish ensured the stocking material's availability for catch at harvest, and also provided fry and fingerlings to support carnivorous fish species in the dugouts; catch of carnivorous fish further increased fish yield obtained with this stocking strategy. The available data indicate that the proposed fish culture enhancement strategies will increase fish catch yields by 40%, while the desilting and routine maintenance practices significantly increases the volume of water available for domestic needs and livestock watering.

Objective 4: Assist households to install domestic water harvesting system, and to implement technologies dependent on water availability

Introduction

Various development projects in Northern Ghana have provided small dugouts for rainwater harvesting for dry season irrigation and other uses, thereby improving availability. However access to water still remains a challenge. Only 39.4 per cent of households in Northern Ghana have access to potable water. Considerable time is spent by a household to obtain water for domestic needs. The objective of this component of the project is to improve labour productivity by improving domestic water supply, and stimulate the adoption of on-farm technologies that are constrained by water availability.

Methodology, Results and Discussion

At the start of the Project in 2004, we conducted a survey among 300 households to document the extent of domestic water insecurity among communities by analyzing the availability, access and utilization of water available for domestic uses in the Volta basin. Particularly important to us is the possible negative impacts of domestic water scarcity on the livelihood outcomes through reduced labour deployment for dry season gardening and other productive ventures.

Appraisal of village water systems and household water use

We assessed the water needs of households, existing rainwater harvesting and storage systems, and potential for income generation using stored rainwater in 300 households in six Districts in the Upper East and Northern Region of Ghana. Households in two communities in each of six Districts were surveyed for information on existing water resources, and water use patterns.

Water resources

The results indicate that source of water for domestic needs vary significantly between Districts in the two regions surveyed. In general, boreholes supply approximately 47 % of water for a household's needs in Northern Ghana. Wells provide a 25 % of the surveyed group whilst dugouts and dams provided for almost the same proportion of the surveyed sample (Table 15). The data indicate that a larger proportion of households in the Upper East Region rely on boreholes. The average distance from a household to the most reliable community water source vary from 0.3 km in the East Mamprusi District to 8.0 km in the East Gonja District.

Type of reservoirs

In communities where water resources appear adequate, households spend time and energy to fetch water because of inadequate containers/reservoirs in the house. The survey revealed that the predominant water storage reservoir in the households is clay pots. Only 12 out of 300 households indicated they do not use clay pots. These households use large (200 litres) metal drums and aluminium pots. The metal drums were found in Nanumba, Yendi and Mamprusi districts.

Table 15: Sources of domestic water for households in six Districts in Northern Ghana. (*percentages in parenthesis)*

District	Region	Bore hole	Dam	Dugout	Stream	Well	Total respondents
Bawku East	Upper East	36 (72.0)	3 (6.0)	4 (8.0)	1 (2.0)	6 (12.0)	50
Kassena-Nankana	Upper East	50 (100.0)	0	0	0	0	50
East Gonja	Northern	0	1 (2.0)	39 (78.0)	0	10 (20.0)	50
West Mamprusi	Northern	5 (10.0)	0	0	0	45 (90.0)	50
Nanumba	Northern	35 (70.0)	0(0)	0(0)	0(0)	15 (30.0)	50
Yendi	Northern	15 (30.0)	35 (70.0)	0 (0)	0 (0)	0 (0)	50
Total	-	141 (47.0)	39(13.0)	43 (14.3)	1 (0.3)	76 (25.3)	300 (100)

Capacity of water reservoirs and household water use

Responses were obtained from 243 households on capacity of their reservoirs. Approximately 57 % of the households indicated they could store up to 250 litres at a time (Table 16). A further 27% can store between 250 and 500 litres. Ten percent of the respondents indicated they have reservoirs to store water between 500 and 1000 litres. The data did not indicate any tendency towards large households having higher storage capacity. Most households, according to the ranges in Figure 15, have capacities below 400 litres. The average storage capacity per household was estimated at about 360 litres.

Table 16: Volume of household water reservoirs in six Districts in Northern Ghana

Reservoir capacity (litres)	No. of households	% of households
1 – 250	139	57.20
251-500	65	26.75
501 - 750	14	5.76
751-1000	10	4.12
1001-1250	1	0.41
1251-1500	3	1.23
1501 -1750	5	2.06
1751-2000	1	0.41
2001-2250	0	0
2251-2500	1	0.41
2501-2750	1	0.41
2751-3000	2	0.82
3001-3250	1	0.41
Total	243	100

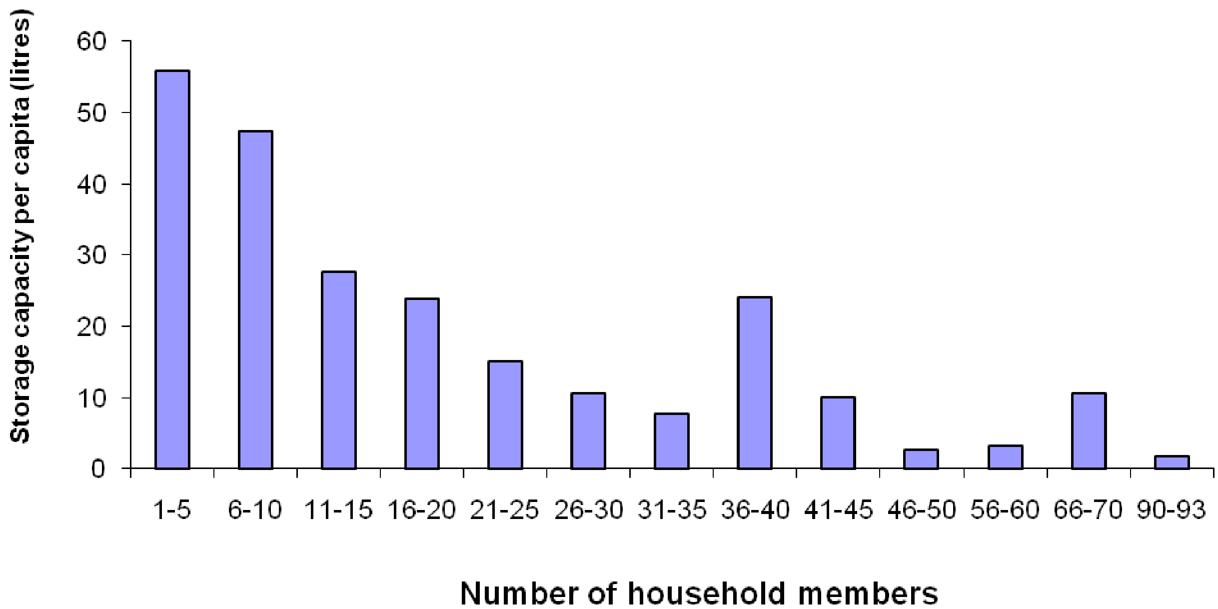


Figure 15: ***Estimated storage capacity per capita in households of different sizes***

The size of households varies from 4.3 to 93, and the majority of households (64 %) comprise 6-15 members. Water usage per day per head is 30 litres, although with very large households (60-90 members) per capita usage is much lower. This decrease in water use per head for larger households is associated with a disproportionately larger number of children in larger households. In general usage per household during the wet season was found to be similar as in the dry season.

Periods of household water shortage
Responses from the survey indicate that most households experience severe water shortage for domestic and livestock needs from March to May (Figure 16). Few of the respondents mentioned July and August, which are in the middle of the rainy season. Only few people also indicated January, which is a month during which the harmattan is severe. A small number of respondents (5.7 %) indicated that they do not experience any water problems.

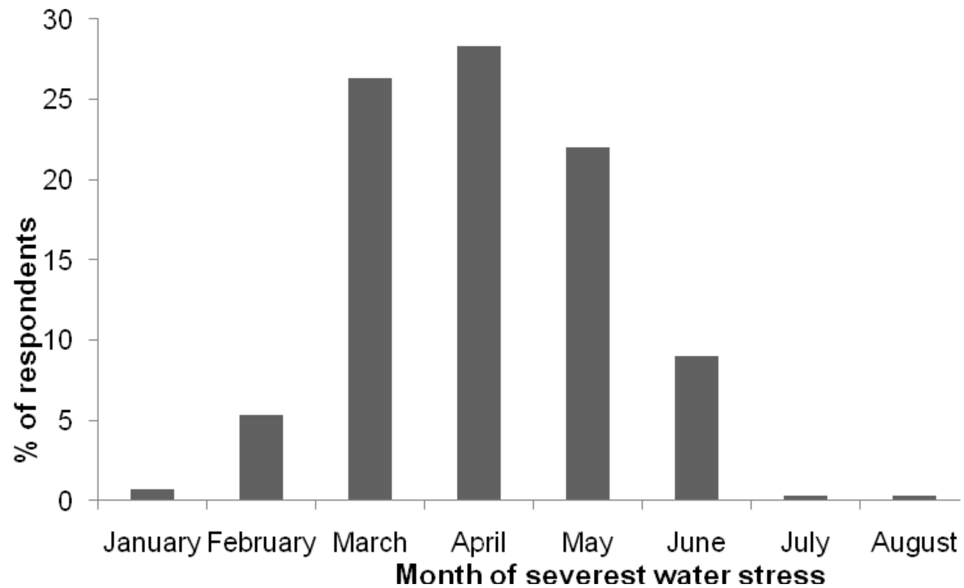


Figure 16*: Period of severe water shortage in households as indicated by households in six districts in Northern Ghana*

epend mainly on the volume of reservoirs available for water storage, and the number of household members available to fetch water from a water source. The data from the survey showed that the households with reservoir volumes less than 251 litres are those who form the bulk of those who indicated earlier and longer periods of severe water shortage (Table 17). Households in this category comprise 46.6%, 71.6%, 61.9% 40.5% and 48.1% of the total number of households experiencing severe water shortage for the months of February, March, April, May and June, respectively.

Table 17. Water storage reservoir capacity of households in relation to months of severe water shortage in Northern Ghana.

Household storage capacity (litres)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Nil	Total
Up to 250	0	7	53	39	15	13	1	1	5	139
250 to 500	1	5	15	11	16	10	0	0	5	65
500 to 7500	1	2	2	3	1	2	0	0	2	14
750 to 1000	0	1	2	2	2	2	0	0	1	10
1000 to 1250	0	0	0	1	0	0	0	0	0	1
1250 to 1500	0	0	1	2	0	0	0	0	0	3
1500 to 1750	0	0	0	3	1	0	0	0	0	5
1750 to 2000	0	0	0	0	0	0	0	0	0	0
2000 to 2250	0	0	0	1	0	0	0	0	0	1
2250 to 2500	0	0	1	0	0	0	0	0	0	1
2500 - 2750	0	0	0	0	1	0	0	0	0	1
2750 to 3000	0	0	0	1	1	0	0	0	0	2
3000 to 3250	0	0	0	0	0	0	0	0	1	1
	2	15	74	63	37	27	1	1	14	243

Household acquisition of water

In Northern Ghana, the burden of water acquisition for a household rests on the women and children. The number of men who fetch water from village reservoirs for (domestic use) is 0.7 (or 1 man) per household , ranging from zero to a maximum of seven (Table 18). On the average, four women undertake this activity, but depending on the size of the household it ranges from 1 to 36. Men are most active in this respect in the Districts in the Upper East Region (Kassena-Nankana and Bawku East) and least active in the Northern Region.

In 207 of the households surveyed (representing 69%) men are not involved in fetching water during the wet season. The corresponding figure for the dry season is 45.6% (Table 19). Only 2 households (0.7%) indicated that women are not involved in fetching water during the dry season.

Table 18: Percent of household members in six Districts in Northern Ghana that undertake trips to fetch water for a household

	Males (n=299)			Females (n=294)		
District	Mean	Min	Max	Mean	Min	Max
Bawku East	0.7	0	7	4.1	1	15
East Gonja	0.3	0	7	3.4	1	11
Kassena-Nankana	1.4	0	7	2.9	1	10
West Mamprusi	1.0	0	6	5.5	1	36
Nanumba	0.1	0	4	4.1	1	24
Yendi	0.4	0	4	3.5	1	10
Total	0.7	0	7	3.9	1	36

n represents number of households surveyed

Table 19. Percentage of household members involved in water acquisition by season, gender and household size

	Wet season		**Dry season**	
Number of household members who fetch water	**Male**	**Female**	**Male**	**Female**
	Percent of respondents			
0	69.23	0	45.64	0.67
1-5	29.43	83.11	50.17	82.83
6-10	1.34	15.54	4.18	15.15
11-15	0	0.68	0	0.34
21-25	0	0.34	0	0.34
36-40	0	0.34	0	0.34
46-50	0	0	0	0.34

Surprisingly, the number of times in a week that a household member involved in water acquisition undertakes a trip for water does not change significantly between the dry and the wet seasons. Members normally undertake a trip or two in the morning and again in the afternoon. Table 20 shows that respondents from East Gonja and Bawku East Districts undertake the most number of trips for water, whilst those in Kassena-Nankana District undertake the least.

Rainwater harvesting from household roofs

The data from the household survey revealed that a high percentage of inhabitants in Northern Ghana do not collect and store rainwater. On the average, only 37.7% (113) of the 300 households indicated they harvest rainwater for domestic use.

Except in the Kassena-Nankana District that 74 % indicated that they harvest and use roof rainwater, the average number of households harvesting rainwater from five other Districts is 30.4 %. Among those households not harvesting rainwater, 66.8% have only thatch roofs. Thus 20.6 % of households surveyed who have aluminium roofed houses do not practice rainwater harvesting. We observed that for households that harvest rainwater, the water is channelled through gutters made of aluminium, and typically not exceeding 1 m in length, or the water is collected from the eaves of the roofs without special spouts constructed.

Table 20: Number of times per week that household members fetch water for domestic use

	Wet season (n=294)			Dry season (n=293)		
District	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max.**
Bawku East	19.1	3	140	19.9	2	149
East Gonja	35.1	2	175	34.1	3	185
Kassena-Nankana	5.1	3	15	13.8	5	14
West Mamprusi	11.5	2	49	12.2	0	49
Nanumba	29.5	3	63	29.4	6	63
Yendi	24.6	2	42	34.1	16	126

n refers to number of households surveyed

Use of stored water for income generating activities

A large proportion of households in Northern Ghana rely on stored water for income generating ventures. Of the households who responded to the survey, 88.4 % in five Districts rely on stored water for a significant proportion of the household's income. The exception was encountered in the East Gonja District where only 30 % of households indicated that water is used in their income generation. Among the economic activities in which water was employed are crop processing (shea nut, rice, groundnuts, *Parkia*), food vending (preparing rice, maize porridge, kenkey, tubani for sale), watering of livestock, gardening, brewing, composting, charcoal production, and building of houses and kraals. The major uses recorded were crop processing, watering of livestock gardening and food vending (Fig 17). A number of households were engaged in combinations of these activities, but we encountered one household engaged in all four major activities. Crop processing and preparation of food for sale is undertaken by women, whereas gardening and livestock watering is the preserve of men.

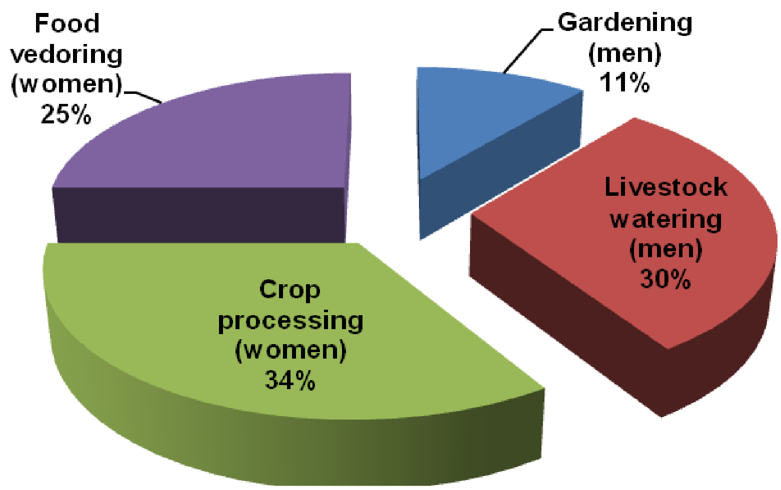


Figure 17: ***Proportion of households in six districts of northern Ghana engaged in various income generating activities that employ stored water***

Perceptions on soil fertility, and soil fertility management

Approximately 98 % of the respondents indicated that fertility of their farmlands is on the decline. Assigning a crop to a particular farmland depends on its importance to a household, with millet, sorghum and maize being placed on the best soils. Groundnut and cowpea were mentioned as secondary crops. Rice, soybeans, sweet potato and cotton are considered minor crops. To increase the yield of their crops, 96 % of the respondents indicated that they apply one form of fertiliser or another. Most households apply inorganic fertilizer, but only in combination with other organic materials (Figure 18). The least popular appear to be plant residue (plant parts in various stages of decomposition) or animal manure applied alone. These soil amendments are applied to millet, sorghum and maize, mainly.

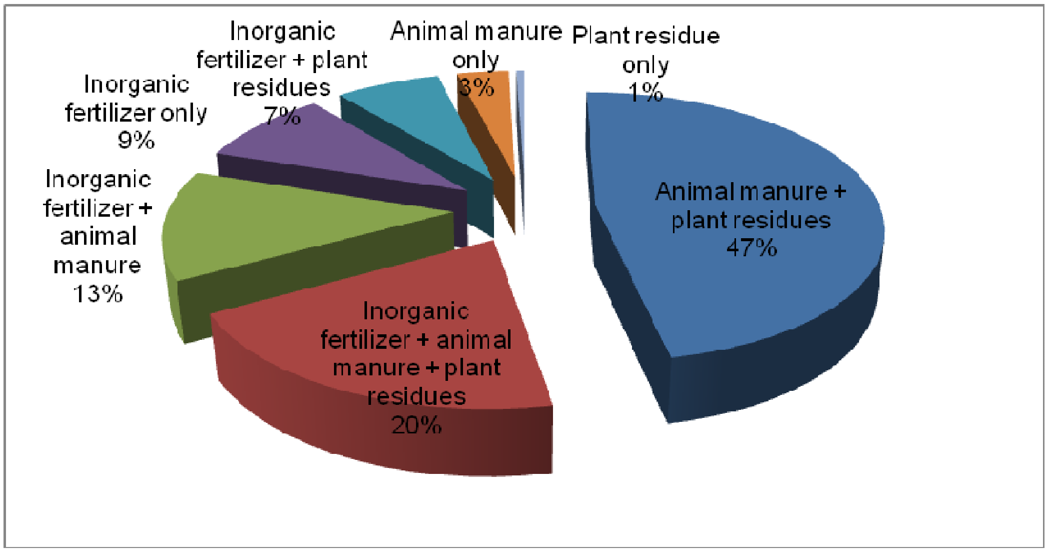


Figure 18: ***Proportion of households indicating use of various soil amendments***

% of respondents indicated that they practice composting. For those not producing compost, the reasons provided include the scarcity of materials, lack of know-how, scarcity of water, lack of transport to cart compost and busy schedule. The materials used in composting, as indicated by the respondents were mainly crop residues, animal manure and wood ash. There were others that received mention by very few farmers. These include neem leaves, grass and topsoil. The crop residues were mainly groundnut vines, and cereal stalks. The farmers mentioned that animal manure was the most limiting raw material. In general, of the households actively producing and using compost 45.2 % indicated that adequacy of raw materials was an important limitation to compost production. Availability of water for composting was the second most important constraint for those producing compost (Figure 19). The respondents indicated various reasons for producing and using compost on their farmlands. These include doubling grain yield as compared with yield from the same area of unfertilized land, faster growth rate of crops, and drought tolerance.

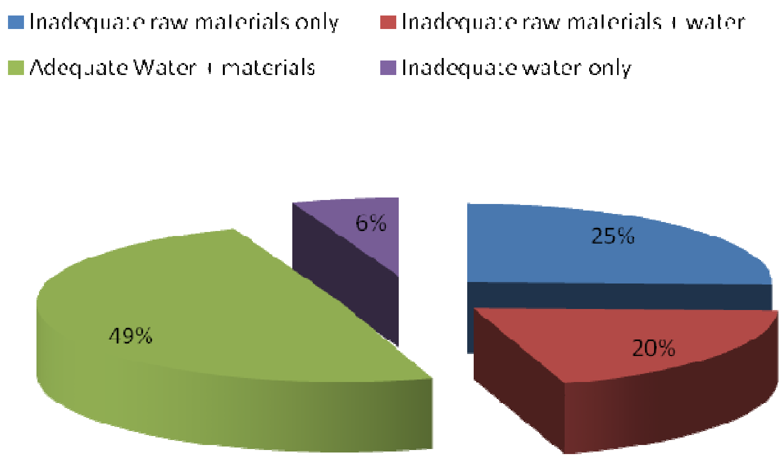


Figure 19: ***Proportion of households indicating constraints of availability of water and raw materials for composting in selected Districts in Northern Ghana***

Provision of domestic rainwater harvesting and storage system

Responses from the survey reinforced our belief that adequate water for domestic needs is a key determinant of the labour available for a household to engage in income generation. To proof this concept that harvesting and storing rainwater will free women and children from the drudgery of long daily trips for water, and offer opportunities for income generation, we have designed and introduced a ferro-cement reservoir in 64 households in 8 Districts across Northern Ghana. In each community each of three households were provided with 4 partially-buried ferro-cement reservoirs, each designed to hold 5,000 litres of water together with a collecting system. This made available 20,000 litres of water to each beneficiary household. This is expected to provide an average household with fixed usage of 150 litres/day with more than 130 days supply of water at the peak of the dry season.

Plate 10: An example of the water harvesting reservoirs

The steps involved an initial removal of earth is removed from the demarcated area such that the excavate area has dimensions of 2 m diameter at the top (soil surface) and 0.8 m diameter at the bottom. Mortar obtained from a blend of river sand and cement is then used to plaster the excavation, providing the base of the pot. Typically each 5,000 litre reservoir requires six 50 kg bags of cement and 2,000 cm^3 of river sand. When the plastering is completed the paper bags from which the cement were poured are used to line the base of the pot, and then filled with earth, in the typical mould of a traditional clay pot, to a height of approximately 1.8 m from the base of the pot. The earth is then plastered with mortar and left for at least 12 hours. The earth is later removed together with the paper lining, and the inner surface of the pot is smoothened with mortar using a hand trowel.

Testing technologies dependent on availability of water

Two activities were planned and tested with communities that were beneficiaries of the domestic water harvesting system. Households in close to community water resources were also included in the tests.

1. Demonstration of potential of compost to reduce application of inorganic fertiliser in maize production

The objective was to provide resources that alleviate the limitations to compost production, and to encourage organic matter build-up in production plots. In 2006, we provided cuttings of *Gliricidia sepium* to each of ten households. These were established on the borders of their farmlands at approximately 110 trees per acre. These provided adequate biomass as a component of materials to make the compost. Two compost troughs, each measuring 2 m x 2 m x 2m were constructed in each of five locations, one each for the 10 satellite households. A standardised compost consisting of Gliricidia foliage, rice husk a d cow dung (containing 1.0% N) was produced with the 10 focal households. Two field days were organised with the larger community during the compost manufacture process. The compost was tested in treatments combined with or without inorganic fertiliser on maize.

Results of the on-farm trials on maize indicated that the standardised compost could replace half the recommended inorganic fertiliser rate ($N_{75}P_{60}K_{60}$), with additional benefit of improved soil moisture. The control treatment (no added fertiliser), half recommended rate from compost and full rate from compost gave less than 1 t ha^{-1}, whereas the inorganic fertiliser at half the recommended rate, at full rate and the combined application gave 1.1, 1.6 and 2.2 t ha^{-1} respectively. The trend was similar in 9 out of 10 farmers. The difference in grain yield between the combined application (of half rate of inorganic fertiliser plus other half provided by the compost) and the full rate inorganic fertiliser was not statistically significant. In the on-station experiment, the combined application of compost and inorganic fertiliser produced maize grain yields 16% higher than the control, but this was not a significant difference, neither was the yield (3.2 t ha^{-1}) significantly different from the inorganic fertiliser treatment at half the recommended rate (4.2 t ha^{-1}) and full rate (4.3 t ha^{-1}).

2. Demonstration of sorghum and millet transplanting innovation

Introduction

Typically, establishment of sorghum or millet production fields is done by direst sowing of seeds following land preparation. Dry spells that occur in the early part of the season shortly after seedling establishment often lead to poor crop growth or complete crop failure. Prior to the initiation of this project, we demonstrated in on-farm participatory trials the advantages of using millet/sorghum nurseries for transplanting compared with farmers' practice of direct seeding (Young et al., 2003). Availability of water to establish the nurseries early in the season was a major obstacle to adoption of the innovation. Creating the opportunity for rainwater harvesting was therefore expected to stimulate adoption. The innovation requires raising a proportion of sorghum and millet crops in nurseries, using small amounts of water before the rainy season, and transplanting seedlings into the field when rains are established thereby reducing the in-field growing period.

Methods

From 2005 to 2007, comparative assessment of direct seeding and transplanting of sorghum and millet was carried out with 150 participating farmers in 7 communities as satellite plots. The communities were Kugur-Nwariko, Kabingo, (Bawku East District), Nanori, Gambaga (East Mamprusi District), Mirigu (Kasena-Nankana District), and Sayoo, Jaabani (West Mamprusi District). Each farmer prepared nurseries measuring 10 x 10 m for their variety of crop species and nursed the seedlings for up to one month using the harvested rainwater or water from a nearby community source. For each farmer, half the production field was planted by direct seeding at the usual time of planting. The other half was established by transplanting when the probability of early season drought was low, later in the season. Field days were held in each community at various stages of crop growth.

Results and Discussion

Generally, transplanted plots had a head-start over direct sown plots and were therefore harvested earlier in the season (Figure 20). This reduced the frequency of dry spells on the transplanted plots as they were cultured over a relatively shorter period in the field. Similarly, grain yields were higher in transplanted fields compared with direct sown plots for each participating farmer (Example, Figure 21). Across the various communities, the average contribution of the direct sown to total grain output of sorghum and millet in the various communities rarely exceeded 40 % (Figure 22).

Reasons for the yield superiority of transplanted fields was further investigated by taking counts of emerged seedlings of the parasite *Striga hermonthica* on each plot in 21 farms in each of two communities in the West Mamprusi and Bawku East Districts. We observed that on transplanted plots, fewer counts of the parasite were recorded compared to directly sown plots (Figure 23).

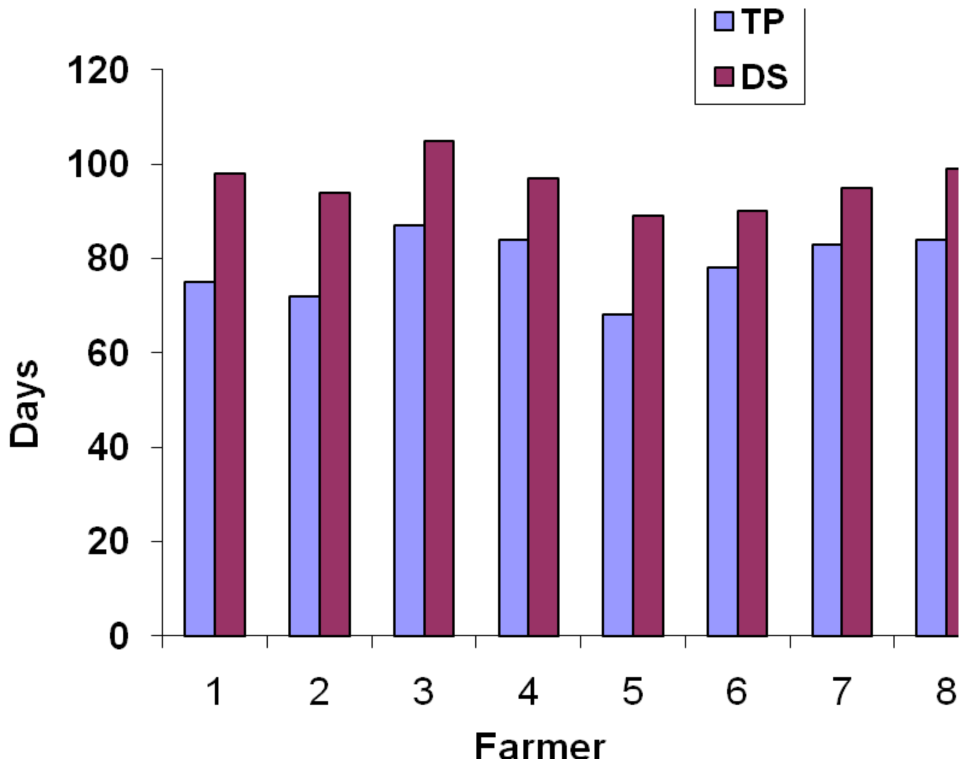


Figure 20: ***Days to maturity of transplanted and direct-sown sorghum at Sayoo, in the Northern Region of Ghana in 2006***

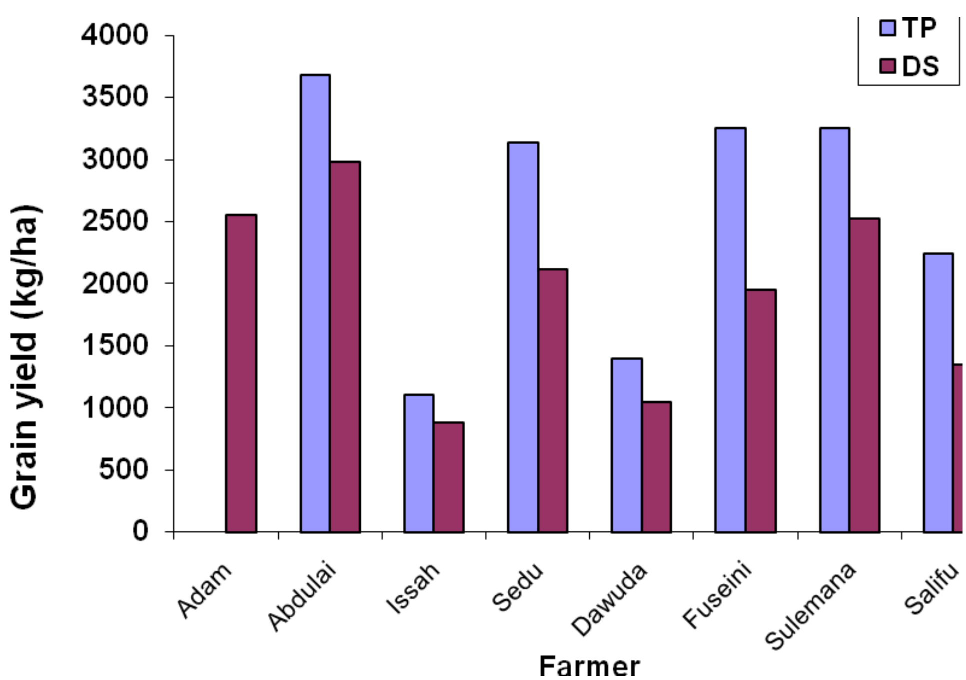


Figure 21: ***Relative grain yields of transplanted and direct-sown sorghum in farmers' plots at Sayoo, 2006. [TP = transplant; DS = direct sown]***

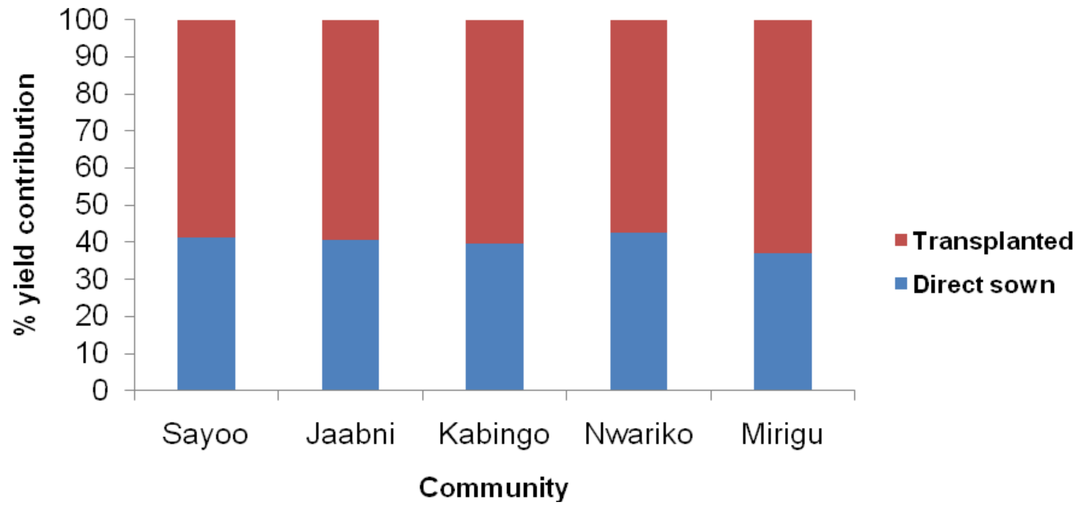


Figure 22: Relative contribution of directly- sown or transplanted plots to total grain yield of sorghum and millet plots in five communities in Northern Ghana, 2005 – 2007.

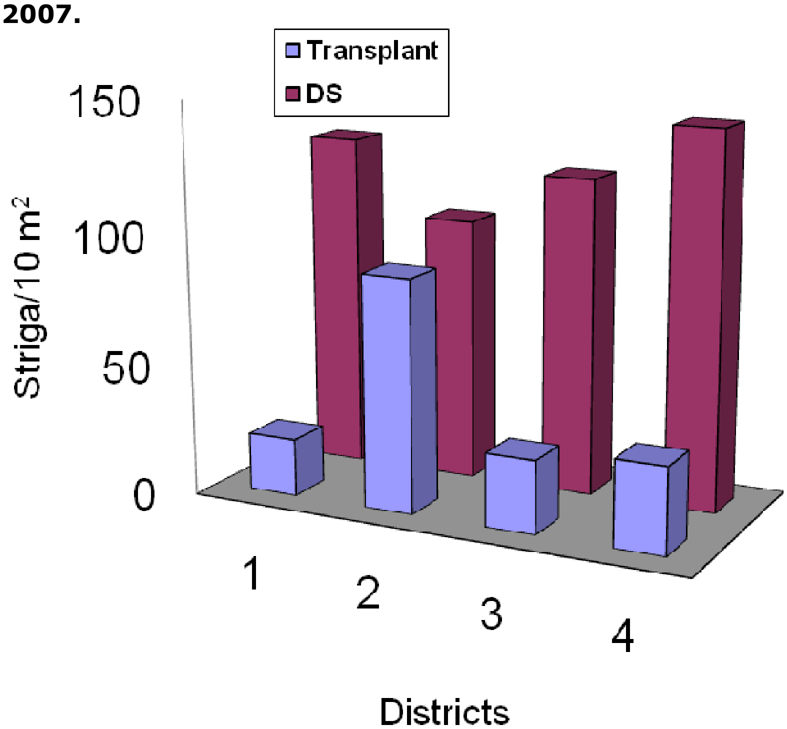


Figure 23: Striga infestations of sorghum plots established by transplanting or direct-sowing in farmers' fields in each of four Districts in Northern Ghana, in 2006

Objective 5: Analyze the socio-economic status of households, and impact of Project's interventions

Introduction

The purpose of understanding livelihood strategies is to shed light on how and when individuals, households, and groups negotiate among themselves, with their communities, markets and society to improve their well being or reduce food insecurity by appropriating the benefits from their assets, activities, and investments. This requires understanding of household strategies; their dynamics through time and identifying which groups of households have the capacity to access information and technologies.

What is largely not known is the capacity of the farmers to adapt and what influences their ability to adapt.

Methods

At the start of the Project in 204, we obtained baseline data on socio-economic situation prevailing in 300 households of the target Regions. This was achieved by administering questionnaires and interviews.

Summary of baseline conditions

The detailed report on baseline conditions in (as at 2004) is submitted separately.

Production is on the decline in the Northern and Upper East Regions of Ghana as a result of decreases in precipitation and rapid water loss due to high mean temperatures. The problem is compounded by huge deterioration in vegetative cover accelerating the rate of soil nutrient and water loss.

Achievement of food security is assessed by the household's ability to meet its food consumption levels on regular basis. Inadequate production levels, income and also food prices are essential in determining the ability of households to experience improvement in their livelihoods. The prolonged and ever increasing hunger periods most especially in the Upper East Region and the high proportions of household who easily run out of own food stock coupled with the fact that cash incomes are very low and are even unavailable during the period of depleted stock; implies that many households are experiencing regular and severe food insecurity.

There exists a seemingly high level of awareness or knowledge of the innovations among farm households; however, they are not easily accessible or available to the farmers. Also it is clear that the level of awareness attained are not enough or did not exceed the threshold required to elicit any reaction from farmers to adapt using them as options. This situation accounts for the low level of adaptive capacity to the strategic innovations. Within the study area, most household and demographic characteristic do not have any significant influence on the adaptive capacity of farmers. The major determinants of adaptive capacity of farmers to innovations include: knowledge or awareness of farmer on the available innovations, access of farmers to financial services, social network (institutions), household income, availability of innovation (technology) and household size.

Summary of report on adoption and impact studies (2008)

Results of the current survey are an improvement over the baseline conducted in 2005 as more respondents answered questions relating to the livelihood system in the current survey, and also more households had a high opinion about the livelihood system. For example while 11 percent scored 'high' for sustainable income in the current survey, it was 2 percent in the baseline survey. Similar observations were made in respect of sustainable food security, increased well being, and sustainable use of natural resources. In addition, above 50 percent of households reported knowing very well about 4 innovations being implemented: diversion of runoff water into cultivated areas (73.6%), use of mulch/ organic matter (74%), and installation of domestic (54%) and community

(51%) water collection tanks. During the baseline survey less than 50% of all the households studied reported knowledge of each innovation.

The capacity of farmers to adapt to three innovations for adapting to the impacts of climate change was assessed, separately, using an ordered logit model. Results showed that farmer's adaptive capacity to the innovation on dugout construction and improvement is determined by educational level of the household head, and availability of technology. While education enhances the probability of adapting for those with low adaptive capacity, technology enhances the probability of adapting for those with high adaptive capacity.

Determinants of a farmer's adaptive capacity to the sorghum/ millet transplanting innovation are availability of technology, educational level of the household head, and access to financial services. Education and access to financial services have similar effects on adaptive capacity being negative at moderate and high adaptive capacities but positive at low adaptive capacities. Two of the variables were significant determinants of the adaptive capacity of farmers to organic matter use and composting, the highest level of education attained by the household head and access to technology. The influence of technology and education on the adaptive capacity of farmers to organic matter use and composting were similar to those observed for the innovation on dugout construction and improvement.

The results obtained from the current survey are encouraging as substantial gains were recorded, in a space of three years, in all project status indicators. There were improvements in the proportion of farmers reporting increased availability, access, knowledge, use, participation and consultation. However, even the improved numbers reported are still low, indicating that there is more room for further improvement. In order to build on the gains made more effort needs to be directed towards promoting the innovations to farm households.

OUTCOMES AND IMPACTS

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
Cowpea Seed Producing companies in Northern Ghana	Now produce seed of four cowpea varieties developed during this project as the major cultivars	Increase yield per unit area of varieties, better resistance to insect pests, and attractive seed characters	Participatory varietal selection, demonstration plots	More than 75% of total seed output of Cowpea Seed Producing companies are of the four released varieties
Farming households in Upper East and Northern Regions of Ghana	Now finance, and construct ferro-cement type of water harvesting system for domestic chores	Suitability of harvesting system to cultural preferences for harvested rainwater over water in streams and ponds; better water quality of harvested rainwater	Demonstration of a low-cost water harvesting system	At least 110 households have finance and installed the water harvesting structures
Farmers of sorghum and millet in 7 communities in Northern Ghana	Now use transplanting rather than direct sowing to establish a portion of total annual acreage	Transplanted sorghum and millet better withstand drought when transplanted. Lower incidence of the parasitic weed in transplanted fields	Demonstration, and field days on the technology. Economic analyses of the innovation with farmers	Difficult to provide estimate of farmers. Communities involved include Kabingo, Nwariko, Sayoo, Jaabni, Mirigu, Naanori and Gambaga
Rural communities with small water bodies in the Upper East and Northern Regions of Ghana	Use fast growing trees to protect community dugouts from drying; use Moringa in domestic water treatment;	Demonstration that increases in fish production is possible through better dugout maintenance and fish stocking options.	Training in fish stocking in small water bodies, demonstration of the use of Moringa parts for water treatment	At least five communities routinely stock their dugouts and have increased fish production compared with before Project

	undertake Tilapia production in water bodies			period

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? **1. The domestic water harvesting system: Improve labour productivity from time saved in sourcing water for domestic chores; reduction in water-borne diseases; better access to water for domestic needs** **2. Cowpea varieties developed: Increase in cowpea grain production**
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. **The domestic water harvesting system is being financed and constructed by households themselves. Little else needs to be done** **Seed producing companies have adopted, and are producing seed of the new cowpea varieties. These varieties are dominating the total acreage under cowpea in Northern Ghana. There is adequate institutional arrangement to supply Breeder seed to Certified seed producing companies.**
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 use of Moringa to treat water for domestic needs, and as leafy vegetable was not expected** Why were they unexpected? How was the project able to take advantage of them? ***Moringa olifera* was introduced in communities as one of fast growing trees to protect community dugouts from silting up, and from evaporation due to direct sunlight. It was found unsuitable for the intended purpose, but communities now grow it around the homestead for water purification and as vegetable.**

What would you do differently next time to better achieve outcomes (i.e. changes in stakeholder knowledge, attitudes, skills and practice)? **Concentrate interventions in a fewer number of communities, and rather increase the number of participating households in a community to better achieve impact.**

International Public goods

1. *Value of stay-green trait to drought tolerance in sorghum established for the Guinea and savannah ecologies*

In multi-location tests of Kapaala cultivar of sorghum and its stay-green derivatives across northern Ghana, we have shown that lines with various combinations of the six QTLs gave higher grain and biomass yields. The stay-green trait was found effective for tolerance to drought not only at the post-flowering stage, but also seedling stage drought. The lines developed will are likely to have a wide adaptation over regions where droughts occur intermittently during the growing season

2. *Varieties of cowpea suitable for intensified cropping systems developed*
We have developed four cowpea varieties that have high yield potentials (1.8 to 2.0 t/ha) under Guinea and Sudan savannah ecological conditions. Within the five-month rainy season that is typical of semi-arid conditions, these varieties can be cropped thrice. Two of the varieties developed were also found compatible with pre-cereal (rice, maize or sorghum) production conditions as they can be harvested before the rains have stabilized to permit cereal planting.

3. *Cassava lines with early bulking characteristics developed*
We have developed five cassava clones that provide up to 150 t/ha of tubers with good cooking quality in less than nine months under Guinea savannah ecological conditions. These clones are therefore suitable for regions with a single rainy season or where environmental conditions restrict the length of the growing season.

4. *Improved labor productivity demonstrated through use of low-cost water harvesting system in semi-arid regions*
For rural households in semi-arid regions where rainfall in the single rainy season is between 700 – 100 mm, and households have an average roof size of 80 m^2, provision of a low-cost water harvesting system can greatly improve labor productivity. Household members whose burden it is to provide water for domestic chores can better contribute to livelihood sustaining activities, particularly during the periods of water scarcity.

1 Partnership Achievements

The project established strong partnership with IWMI and strengthened the partnership between ICRISAT, ISSER and CSIR Institutes. Collaboration between WRI and SARI became strong with common objective of ensuring efficient water usage. The Project has provided a unique opportunity to introduce germplasm of sorghum, cassava and cowpea that were well characterized for their tolerance to drought from elsewhere into the West African Region. Not only were these valuable *per se* as potential for direct cultivation, but has also provided opportunity for further breeding into other genetic backgrounds for local adaptation.
The existing Research-Extension linkage system has been strengthened with more active participation by farmers in project execution afforded by the wide coverage of project activities, and several field days organized.

2 Recommendations

To improve agricultural productivity in semi-arid regions, particularly within sub-Saharan Africa, research and extension efforts should focus largely on improving soil organic matter build-up. Interventions that recognise local opportunities to alleviate the critical constraints to organic matter addition, and reduce soil organic matter decapitalization must be encouraged. In composting for example, the main constraints have been biomass to compost and water at a time when labour is available for the exercise. Extension should focus on ways to encourage planting of fast-growing tree species to provide this biomass. Simple, low-cost water harvesting systems are available that can meet the demands for water for composting. The declining organic matter in production plots has been a major cause for poor nutrient and water use efficiencies in most tropical climates.

3 Publications

Early generation selection for high yielding cowpea genotypes in additive series intercropping systems with sorghum
F.K. Padi
Source: Annals of Applied Biology 151: 391-400
Abstract
Defining appropriate selection strategies for developing cowpea varieties adapted to additive series intercropping systems is an important requirement for cowpea breeders and producers in sub-Saharan Africa. One hundred and forty-three F2:3 cowpea families and their subsequent 99 F3:4 families derived from a cross between a sole bred cultivar, Apagbaala, and a traditional variety, SARC-L02, were evaluated under additive series intercropping with sorghum. Intercropping imposed a strong selection pressure for days to flowering such that 31% of F2:3 families that flowered after 50 days produced too few grains to permit their subsequent evaluation in the F3:4 generation. Narrow-sense heritabilities estimated by parent–offspring regression were high for 100 seed weight and days to flowering, moderate for biomass, low for grain yield and insignificant for branches/plant and pods/plant. Retrospective selection at 40% intensity based on F3 grain yield recovered 5 of the 10 top yielding families in the F4. No significant difference was observed between mean grain yield of selected and rejected families (at the 40% selection intensity) as estimated by a t-test. Sole and intercrop yields produced by six advanced breeding lines included as controls showed poor correlation, and suggests selecting cultivars under the target cropping system will produce better selection response.

Response to selection for grain yield and correlated response for grain size and earliness in cowpea based on early generation testing
F.K. Padi
Source: Annals of Applied Biology 152 (2008) 361–368.
Abstract
Large grain size and earliness to flowering are traits critical to cowpea adoption in the West African savannahs. This study reports on the correlated response to selection in these two traits in the two populations in which selections were made primarily for grain yield potential. Further, the present study reports on the effectiveness of early generation selection for grain yield. Each of the two populations, SARC 2 and SARC 3, was derived from a cross between an adapted parent Marfo-Tuya and an exotic breeding line that has large grain size and early flowering. Replicated yield evaluation of F5 families showed that grain yield of Marfo-Tuya was not different from those of the highest yielding families in each population. Increases in grain size of individual families over Marfo-Tuya were large and, the response to selection averaged 5.3 and 3.9 g/100 seeds in the SARC 2 and SARC 3 populations, respectively. Response to selection in days to flowering averaged 3 days in SARC 3, whereas response to selection was not observed in SARC 2. Retrospective selection in the F3 at 40% intensity was efficient in identifying a high proportion of elite families in each population.

Effectiveness of Early Generation Selection in Cowpea for Grain Yield and Agronomic Characteristics in Semiarid West Africa
Francis K. Padi, and Jeffrey D. Ehlers
Source: Crop Science 48:533–540 (2008)

The effectiveness of early generation selection for grain yield in a cowpea [*Vigna unguiculata* (L.) Walp.] population was examined in the Guinea and Sudan savanna agroecologies of Ghana where genotype × location interaction is known to be large. A set of 131 F3:4 lines were developed from a cross between a local cultivar and an

unadapted source of large grain size. Mild selection was practiced during line development at one location in the Guinea savanna zone to eliminate poorly adapted lines. Unreplicated F3 plant data were collected on all the lines at the one location during the development of the lines. Multilocation trials were conducted with lines formed by bulk harvest of F4 families to assess how effectively the early generation selection protocol was able to generate superior lines for the target agroecology. Genotypic correlation for grain yield between locations was high only between the two locations in the Guinea savanna zone. Narrow-sense heritability estimates were low and not different from zero for grain yield, but heritability estimates for days to flowering and seed size were large. F4 lines derived from the highest 10% performing F3 individuals were no higher yielding than F4 lines derived from the remaining F3 individuals, indicating that early generation selection for yield was ineffective. Single-seed descent (SSD) or bulk breeding methods will be more efficient than pedigree breeding for developing cowpea varieties with high yield potential for this agroecology.

IMPROVING STAPLE CROPS FOR DROUGHT ESCAPE AND TOLERANCE IN A SEMI-ARID ENVIRONMENT. Padi FK[1]., Cecil O[1]., Hash CT[2]., Atokple IDK[1]., Fosu M[1]., Abunyewa AA[1]. and Asante SK[1]*.

[1]Savanna Agricultural Research Institute, Box 52, Tamale-Nyankpala, Ghana
[2]International Crops Research Institute for the Semi-Arid Tropics, India
*Corresponding author: skasante@yahoo.com
Source: Paper presented at the African Project Leaders workshop of the Challenge Program on Water and Food. 28 November – December 1 2005, Entebbe, Uganda

ABSTRACT
Developing varieties with ability to escape or resist drought is important in stabilising yield in semi-arid areas. In efforts at developing superior varieties of sorghum, cassava and cowpea for the semi-arid regions of Ghana, we have used various approaches to produce advanced breeding lines for testing in a range of dry production environments. Marker-assisted backcrossing of six stay-green QTLs from B 35 into the genetic background of Kapaala, a cultivar of commercial importance in Ghana, yielded BC_3F_3 and BC4F3 families homozygous for at least a region of one stay-green QTL. Seeds of these families are being multiplied for evaluation in the Guinea and Sudan savannah regions of Ghana to improve Kapaala for terminal drought tolerance. In cassava, analysis of tuberous root bulking and crop growth components in adapted genotypes is providing clues to the major differences between varieties in relation to dry matter partitioning to roots. Based on secondary traits related to early bulking and high tuber yields, clones are selected from seedling nurseries to develop early bulking lines for areas with short periods of rainfall. Advanced breeding lines of cowpea have been produced that are earlier in maturity than currently grown early-maturing cultivars. Multi-environment testing of these lines is currently ongoing across the savannah regions of northern Ghana. In addition, we are exploiting the use of traits related to efficient water use in plants to develop varieties with potential for higher yields in water-limited environments. The experimental procedures and preliminary results obtained are reported.

Strategic Innovations in Dryland Farming in Northern Ghana.
PN 6 of the Challenge Program on Water and Food. Technical Report 2005. Edited by Stephen K. Asante and Francis K. Padi

Summary
Farmers, agricultural researchers and policy makers in sub-Saharan Africa are aware that food production is well below demand. Among the causes of this situation, one thing

is clear: our agriculture is largely dependent on rainfall, and success in feeding ourselves depends largely on how we manage the rain we receive. The Challenge Program on Water and Food (CPWF) recognized this global concern, and is pioneering new ways of producing food to keep pace with population growth in a safer environment. Project 6 of the CPWF emphasizes increasing harvestable crop yield per unit of rainfall in the semi-arid regions of the Volta basin as a means to sustaining and improving the livelihood of the predominant farming households. To meet this challenge our interventions are designed at improving the capture, storage and efficient use of rainfall for both domestic and on-farm needs of the farming households. We are also devoting a lot of effort to developing varieties of staple crops with phenology that will be suitable to the existing rainfall pattern, or have enhanced water use efficiency. Over the past 12 months we have touched, albeit to different degrees, communities in 8 Districts across northern Ghana with interventions that we believe will make food production more profitable, safer, reliable, and easier with less harm to the environment than we see currently. We have built on the experience from past projects funded by various donors, and have explored collaboration between activities of CPWF PN6 and existing projects. These interventions are based on the simple viewpoint of improving the efficiency with which rainwater is used for food production. Within this reporting year some outputs already can be seen. For example, we have developed advanced breeding lines of sorghum and cowpea with potential for drought tolerance or avoidance; and 44 households in the Project Districts have installed ferro-cement reservoirs to prove the concept that rainwater harvesting can release vital female labour for on-farm and off-farm income generation. This report summarizes the various research activities undertaken (and the findings) with funding under the CPWF Project 6. We have learnt already new ways of interacting with our clients, and with our partners in agricultural development and technology transfer. We owe much of our success to the estimable support of the Directors of Agriculture and their extension Agents in the 8 Districts we are operating. How we progress in the years ahead to improve agriculture from within the pilot communities to a larger part of Volta basin will be determined by the success of our dialogue with our partners and beneficiaries. It is my firm belief that the medium-to-long term benefits of the various innovations we have introduced (or proposed to introduce) in the participating communities will ultimately bring us all closer to our common goal of producing more food in a sustainable manner with less water.

BIBLIOGRAPHY

1. Hash, C. T., A. G. Bhasker Raj, S. Lindup, A. Sharma, C. R. Beniwal, R. T. Folkertsma, V. Mahalakshmi, E. Zerbini and M. Blümmel (2003). Opportunities for marker-assisted selection (MAS) to improve the feed quality of crop residues in pearl millet and sorghum. Field Crops Research, 84: 79-88.

2. De Groote. H., M. Siambi, D. Friesen and A. Diallo 2002. Identifying Farmers' Preferences for new Maize Varieties in Eastern Africa. In Bellon, M.R. and J. Reeves (Eds.) 2002. Quantitative Analysis of Data from Participatory Methods in Plant Breeding. Mexico, DF: CIMMYT.

3. Padi, F. K. 2004. Relationship between stress tolerance and grain yield stability in cowpea. *Journal of Agricultural Science (Cambridge)* 142: 431 – 443.

4. Padi, F. K., N. N. Denwar, F. Z. Kaleem, A. B. Salifu, V. A. Clottey, J. Kombiok, M. Haruna, A. E. Hall, and K. O. Marfo. 2004a. Registration of 'Marfo-Tuya' cowpea. *Crop Science* 44:1486 – 1487

5. Padi, F. K., N. N. Denwar, F. Z. Kaleem, A. B. Salifu, V. A. Clottey, J. Kombiok, M. Haruna, A. E. Hall, and K. O. Marfo. 2004b. Registration of 'Apagbaala' cowpea. *Crop Science* 44:1486.

6. Murty, D. S., C. C. Nwasike, and I. D. K. Atokple (1998). Registration of 'ICSV 111' Sorghum Cultivar. Crop Science 38: 1716-1717

7. Young, E.M. and Mottram, A. (2003) Transplanting sorghum and millet as a means of increasing food security in semi-arid, low income countries. DFID Plant Sciences Research Programme, Final Technical Report Project R7341.

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Appendix A: Table of coordinates for project sites

Location	Latitude	Longitude	Country
Gbung	9° 09' N	0° 36' W	Ghana
Damongo	9° 05' N	0° 48' W	Ghana
Nyankpala	9° 24' N	0° 59' W	Ghana
Yendi	9° 22' N	0° 41' W	Ghana
Demon-Naa-Yili	8° 55' N	0° 00' W	Ghana
Chambuligu	9° 12' N	0° 35' W	Ghana
Kagberishie	9° 12' N	0° 34' W	Ghana
Mazeri	9° 30' N	0° 01' W	Ghana
Walewale	10° 12' N	0° 49' W	Ghana
Kabingo	10° 57' N	0° 06' W	Ghana
Kuguri	10° 57' N	0° 11' W	Ghana
Gambaga	10° 31' N	0° 26' W	Ghana
Mirigu	10° 54' N	0° 59' W	Ghana
Kpabi	8° 53' N	0° 01' E	Ghana
Nanoori	10° 29' N	0° 26' W	Ghana
Manga	11° 01' N	0° 16' W	Ghana
Salaga	08° 33' N	0° 31' W	Ghana