CPWF Project Report

Increased food security and income in the Limpopo Basin through integrated crop, water and soil fertility options and public-private partnerships

Project Number 1

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ICRISAT

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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

The Limpopo River Basin of Southern Africa transcends four countries namely, Botswana, Mozambique, South Africa, and Zimbabwe. The area is characterized by poor and unreliable rainfall, frequent droughts and periodic flooding in some parts. As a result, smallholder farmers living in the basin fail to produce enough food and are perennially food insecure. The basin is also faced with other challenges posed by HIV and AIDS and these factors impact negatively on household labour and well being (ICRISAT, Baseline Survey Report, 2007).

The Challenge Program on Water and Food Project Number One "Increased food security and income in the Limpopo Basin through integrated crop, water and soil fertility options and public-private partnerships" was established in the Limpopo Basin to address problems of food and environmental insecurity. The project intended to achieve this by increasing crop water productivity while saving water for other users and the environment (Mgonja *et al*, 2006). The purpose of the project was to increase sustainable crop and water productivity and market access of smallholder farmers in the Limpopo Basin by developing and promoting technologies through public-private partnerships.

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Farmers in the Limpopo Basin convinced to use water harvesting techniques through training and participatory evaluation

End of project workshops in Zimbabwe confirmed that tied ridges or furrows were a preferred water conservation technology by farmers. Farmers felt that mulching combined with zero tillage also tended to conserve more moisture and reduced the need for weeding. Basins were recommended because they collect more water and contained more than one plant in each basin. It was indicated by farmers that the quantity of fertiliser applied per basin was sufficient for the plants in the basin and yield tended to be higher in basins compared to the other soil water conservation techniques.

Mulching was found to have the added advantage of reducing weeding incidence and hence there no need to weed after mulching; a result which, farmers said eased their workload. However farmers failed to achieve the 30% mulch cover required. Therefore, the sustainability of basins and mulch remained questionable and this left tied ridges as a better option especially for farmers who can use draft animals to make the ridges.

Farmers in the Limpopo Basin acknowledge the superiority of improved crop varieties

The crop species by variety trials carried out with farmers helped farmers identify the best varieties for their respective areas in Mozambique, Zimbabwe and South Africa. Farmers now know that improved varieties of Maize, Sorghum, Pearl Millet and Groundnuts perform better than the local land races in the Limpopo Basin. They are now calling for seed of improved varieties to be readily available for wider adoption in order to increase food availability in the basin.

Extension personnel gain skills in technology evaluation

Ability to layout trials and work closely with farmers was enhanced through training provided to extension staff participating in the PN1 project activities. Exposure to new method of participatory technology dissemination was imparted through training sessions and planning meetings convened each year of the project.

Project partners enhance input and output marketing skills: a case of Progress milling Company in Polokwane-South Africa

The private partnership created between the project and Progress Milling Company in South Africa demonstrated that innovative marketing through small fertilizer packs was a new skill that allowed Progress Milling Company to sell fertilizers in a modest way of small packs as opposed to large fertilizer packs. Bringing the selling points at the closet distance to the farmer reduced the procurement hassles the farmers face and encouraged more farmers to use fertilizer. The assured market of the output also stimulated farmers to produce more maize as it had a ready market.

EXECUTIVE SUMMARY

The biggest challenges facing smallholder farming communities in the Limpopo Basin of southern Africa are food insecurity, poverty and ill-health. Many parts of the basin are routinely food-deficient and rely on food aid. There have been confirmed reports of starvation related deaths in basin areas in both Zimbabwe and Mozambique. The basin's local economies depend on rainfed agricultural systems characterized by low productivity, vulnerability to frequent droughts (and sometimes devastating floods), poor adoption of improved technologies and diminishing farm labor due to out-migration and HIV/AIDS. This is exacerbated by poorly developed input and output markets.

Technologies to raise the water-use efficiency of cereal-based systems, improved varieties of sorghum, pearl millet, groundnut, pigeonpea and cowpea, many of them bred specifically for drought tolerance, have been released. Maize germplasm with tolerance to drought and low soil fertility has been developed. Innovative seed production and distribution mechanisms have been developed and tested in southern Africa, and can be used in the Limpopo Basin (Monyo and Mgonja 2003, Mgonja et al. 2003). However, adoption of these technologies has remained poor in the past, but innovative approaches such as Farmer Field Schools and Participatory Extension are proving successful in enhancing adoption of integrated soil, water and crop management practices (Masendeke 2001). There is also evidence that farmers are more likely to invest in soil and water management if appropriate varieties and markets are available as these will improve the returns to these investments.

A project PN1 was developed as part and parcel of CPWF projects to be implemented in the Limpopo Basin. The goal of the project is to improve food security, incomes and livelihoods of smallholder farmers in the Limpopo Basin. The project built on past collaborative and current research by national programs and the CGIAR on crop-water productivity in drought-prone areas; innovative approaches to participatory technology development and extension; and new institutional arrangements that link public and private sector with the smallholder farmers in appropriate market chains. The specific objectives of the PN 1 project were: 1) To delineate agro-ecological recommendation domains in the smallholder dry-land areas of the Limpopo Basin, based on biophysical and socio-economic factors, 2) To validate and adapt integrated cereal and legume crop variety and soil management practices that are suitable for resource-poor smallholders in a risk-prone environment with the aim to diversify cropping and livelihood options, maximize crop water productivity, and increase incomes from rain-fed farming systems in the basin, 3) To use innovative research and extension methodologies, linked to public-private partnerships, to facilitate promotion and uptake of management options and strengthen linkages to input and product markets and draw lessons from this experience for application to other areas and countries in southern Africa, and 4) To strengthen capacity of farmer and partner institutions to develop and implement innovative research and extension approaches; improve stakeholder participation in agricultural development; and strengthen public-private partnerships that will create income opportunities and improve crop water productivity in the basin.

The approach to project activities included Reconnaissance surveys, Agro-ecological characterization, Base-line surveys, Adaptive trials, Impact assessment studies, Adoption studies and end of project farmer project evaluation and feed back workshops.

The reconnaissance surveys were aimed at identifying crop water productivity enhancing technologies. The Base-line survey was also conducted in order to establish the bench marks on socio- economic status of the smallholder farmers in the Limpopo Basin before project interventions could start. Agro-ecological characterization was dane using available data on ecologies and GIS was used to integrate the information with aim of identifying entry points for project interventions.

Mother – Baby approach was used in the design of the adaptive trials to allow wider farmer participation in the evaluation of the different technologies. Notable of the trials evaluated using the Mother Baby approach include: Water use efficiency, water harvesting by fertilizer, water harvesting by weed management by fertilizer, Species by variety and Species by Nitrogen trials. Participatory crop variety evaluation trials conducted include: Maize, Sorghum, Pearl millet, and groundnut variety evaluation. Although trials were addressing crop water productivity, the treatments were variable across countries. This therefore determined the type of analysis for the data collected. Even within country trials, treatments differed from season to season depending on need and particular socio-economic requirements. For example in Zimbabwe; some sites require sorghum instead of pearl millet while others required pearl millet more than sorghum. Therefore, across season and across country analyses were not done on the data. Therefore, the results have been presented in year by year and country by country.

Results from reconnaissance surveys identified a number of crop water productivity enhancing technologies in the basin. The potential technology options identified in collaboration with extension and farming communities included crop species grown by farmers in the basin such as drought tolerant early maturing varieties of sorghum, maize, groundnuts, cowpeas and pigeon peas, and soil and water management technologies included; pot holing, intercropping, crop rotation, mulching and application of manure /compost and trenches. The agro-ecological characterization resulted in geo-referencing of 40 Progress Milling depots, showing the coordinates of the depots in the Limpopo Province in terms of latitudes and longitudes. This information allowed IMMW to generate several interlinked variables which provided insights to potential investment areas to be undertaken by both government and the private sector to accelerate smallholder development in the Limpopo Province. The information collected was used to identify the sites for on farm testing of crop, soil fertility and water management technologies.

The Base-line surveys found that female headed households in the basin had limited access to both assets and income and as such, they may not be able to produce enough grain to ensure household food security. Activities to be implemented by the WFCP therefore needed to take the female headed households as a special category in which resource constraints threatened the livelihood base of the female headed households. Area cropped by households with chronically ill members was found to be smaller compared to area cropped by households without a burden of the chronically ill members. The survey also found that access to draft resources was the biggest challenge for households in the basin to achieve food security. Ownership of draft resources was positively related to the total area cropped meaning that a cheaper and affordable tractor hire service in South Africa would boost the total area cropped as most households appeared to be depend more on tractor hire service and most households did not own cattle or donkeys which could be used as a substitute for tractors. In Zimbabwe ownership of draft cattle or donkeys was the key determinant of the total area cropped. Limited tillage or zero tillage technologies therefore might be important for the households that do not own any livestock. The WFCP would have to explore ways of improving smallholder farmers' access to information on planting basins and other limited tillage technologies.

Further more a significant proportion of Zimbabwean households were found to be spending more than earnings due to the economic problems experienced since 2002. It appeared that most of the households relied on credits thereby increasing their debt load. The disposal of assets will then be the other option for the households' livelihoods thereby further crippling the households' chances of enhancing livelihoods through asset accumulation. The WFCP would therefore have to explore other livelihood enhancing options for households to raise incomes and limit the disposal of keys assets (cattle, plough, hoes). Droughts and mid-season dry spells were the biggest threat to household food security in the basin. Water harvesting technologies were said to be effective in retaining moisture and boosting crop yields. However, households in the basin were found to have limited access to information on these technologies. Although a significant proportion of households especially in Zimbabwe had information on water harvesting technologies, their adoption remained very low in both countries. Participatory testing of water harvesting technologies would therefore be important in trying to raise crop yields through this project.

The survey results showed that although the 2004/05 season was a poor season, farmers observed that households that applied mineral fertilizer generally had higher yields compared to those households that did not use any. Improving access to fertilizers and also providing information on efficient use of fertilizers therefore remained a possible task for the project to take advantage of the observed better yields from farmers who used fertilizer.

The agro-ecological characterization work ended up geo-referencing of 40 progress Milling depots and which are the market places as input and output market in the Limpopo Province of South Africa. Bench mark sites for technology testing for the project were identified using inter-linked variables achieved through this work.

The four seasons of experimentation under the CPWF project in the Limpopo Basin of Zimbabwe, Mozambique and South Africa resulted in the identification of several strategies for improving crop water productivity from the small-scale farmer's perspective although treatment effects were mostly not statistically significant. Crop water productivity assessed through Water use efficiency; Water harvesting by fertilizer by variety, Water harvesting by weed control by fertilizer showed increase yield from tied ridges, basins and mulch, mulch with fertilizer, basins and Zai-pits and Basins and mulch. Poor rainfall and droughts led to loss of trials or sometimes failure to get grain yield. Quelea birds also were a big challenge in Zimbabwe as they led to loss of grain yield. Crop variety trials gave significant yield difference in different countries. Best yielding varieties were mostly improved varieties. Therefore, better yielding Maize, Sorghum, Perl millet, and Groundnut varieties were identified in the three countries of the Limpopo Basin. The There was generally low response to Nitrogen fertilizer which was attributed to lack of moisture which might have limited crop N uptake in very dry seasons. The higher fertilizer rates generally led to much higher yield gains of the crops concerned signifying the need to use fertilizer in order to increase crop yield in the basin. Row seeding also proved to increase yield compared to broadcasting planting method in Maize and sorghum in South Africa.

The study on use of small fertilizer packs showed that farmers preferred to buy small fertilizer packs compared to large packs. Therefore small fertilizer packs enhance fertilizer use by farmers although some farmers though that the Basin areas can do without additional in organic fertilizer use. Some farmers thought the manure alone could lead to yield increase since the soils were deemed already fertile by some farmers.

During the end of project workshops, Farmers in Zimbabwe as a case study confirmed that water harvesting techniques resulted in increased crop productivity nut expressed worry that some of the water harvesting techniques such as tied ridges/furrows was laborious unless they were mechanized. They said that tied furrows required rebuilding when destroyed by water due to heavy rains.

In terms of recommendations, farmers recommended that the project should continue as noted that some farmers only worked in the project for one season. They also recommended that resident extension staff from the country ministries of agriculture must continue back-stopping farmers even after the end of the project so that the proven technologies to be up-scaled up so that more farmers can adopt the proven technologies. Farmers recommended for more trainings for farmers in terms of use of specialized equipment and record keeping. They also recommended to have more look and learn tours (exchange visits) within the country and across countries to ensure that there is exchange of ideas and sharing of knowledge.

On the part of extension staff recommended that future projects need to build in an incentive package for the increased work load as they also had other assignments from their ministries on top of the project work. They suggested that there is need for transport and fuel, stationery and protective clothing to be provided. They also recommended for intensive training so they become familiar with data collection in future as they note that some of the data to be collected required a full time staff on the project other than extension staff alone because the processes were time demanding e.g. days to flowering assumes that the extension worker is there on farmers' field in almost daily.

On partnership approach to project implementation, it has been recommended that in future, proper stakeholder analysis should be done to make sure that only serious stakeholders are brought on board. The weaker partners in this project determined the failure of some activities as some activities depended on the actions of other institutions. Again the size of the project activities were far too ambitious than required considering the data needed. Such cases led to complicated data collection procedures yet the extension staff had limited expertise with capacity to only collect simple other than complicated data. Such complicated data set should have been collected by students. An example here is the soil data, canopy temperature and soil moisture data all of which extension staff had problems to take in this project. It is therefore recommended that simple and straight forward data should be targeted in future so that even extension staff can be able to collect it from the trials with very little supervision.

It is also recommended that future research on technologies for improving crop water productivity in the Limpopo Basin need to consider uniform design aspects of the trials in older to isolate the best bet options for improving crop water productivity in the Basin.

INTRODUCTION

The Limpopo River basin in southern Africa is shared by four countries – Botswana, Mozambique, South Africa and Zimbabwe. This is a semi-arid area, dependent on rainfed subsistence agriculture on small landholdings. The rainfall pattern is unimodal and erratic (250-600mm) and combined with a high irradiance and heat load (FEWSNET 2003). Water levels in the Limpopo River are often very low except for downstream areas in Mozambique. Coastal areas near the mouth of the Limpopo (Xai Xai) get better rainfall and have diversified smallholder cropping.

Large-scale irrigation is restricted, with little potential for expansion (FAO 2003). At the same time, food insecurity, poverty and ill-health are widespread (Waterlow et al. 1998). The farming systems are characterized by low productivity, vulnerability to frequent drought (and sometimes devastating floods), and poorly developed input and output markets. Many parts of the Limpopo basin are routinely food-deficient and rely on food aid. In recurrent situations, there have been confirmed reports of starvation related deaths in the basin areas in both Zimbabwe and Mozambique.

Farm labor is increasingly scarce because of out-migration and HIV/AIDS (HIV incidences in the 15-49 age group, which is rated at 34% in Zimbabwe, 20% in South Africa and 13% in Mozambique, FEWSNET 2003). Consequently, farming in many areas is left to women and the elderly who are often labor constrained since women are also particularly responsible for provision of care for orphans and the sick.

This project recognized that subsistence agriculture alone would neither meet future food needs nor address the growing poverty problem. Developmental interventions must therefore integrate varietal improvement, improved water and soil management, markets and other institutional arrangements, in order to promote adoption of new technologies.

<u>Building on past work</u>: Past work by a number of institutions provided the launching pad for this project. The SADC/ICRISAT Sorghum and Millet Improvement Program (recommended by SADC heads of state in 1983), the SADC/ICRISAT groundnut and pigeonpea projects, the Southern Africa Drought and Low Fertility (SADLF) maize project implemented by CIMMYT and the CGIAR's Deserts Margins Program operated in the region for a number of years, in collaboration with national research programs leading to proof that technologies could raise the water-use efficiency of cereal-based systems. Over 60 improved varieties of sorghum, pearl millet, groundnut, pigeonpea and cow pea, many of them bred specifically for drought tolerance, were released. Maize germplasm with tolerance to drought and low soil fertility had been developed. Innovative seed production and distribution mechanisms were developed and tested in southern Africa, and could be used in the Limpopo basin (Monyo and Mgonja 2003, Mgonja et al. 2003).

Soil, water and crop management technologies for drought-prone environments have been researched (Twomlow et al. 2003). Mineral and organic nitrogen management strategies to optimize water use efficiency have been developed. Crop stimulation models and farmer-participatory research methods have been used to optimize the whole-farm resource allocation in at least one climatic zone of the Limpopo basin (Kamanga et al. 2003, ICRISAT/SDARMP 2003). However, adoption of these technologies has been poor in the past, but innovative approaches such as Farmer Field Schools and Participatory Extension proved to be successful in enhancing adoption of integrated soil, water and crop management practices (Masendeke 2001). There is also evidence that farmers are more likely to invest in soil and water management if appropriate varieties (and markets) are available that improve the returns to these investments.

It was therefore with the above understanding that this project worked on the following hypothesis: Diversified crop, soil and water management options can be combined to reduce risks and improve productivity, profitability and sustainability of smallholder agriculture in the Limpopo, including the returns to scarce water supplies. The benefits can be promoted more widely by using model-based decision support tools. Strengthened public and private partnerships to deliver seed, information and other input, and linking farmers to product markets, will create incentives for farmers to adopt these technologies, and thus improve incomes and food security.

PROJECT OBJECTIVES

Goal

The overall project goal is to improve food security, incomes and livelihoods of smallholder farmers in the Limpopo basin. We expect to improve food security and livelihoods of at least 10,000 smallholder farm families by 20% by end of five years.

To achieve this goal, the project will verify and disseminate practical, cost-effective technologies improved varieties of staple food crops; crop, water and soil fertility management methods. This will build on past research on crop-water productivity in drought-prone areas. New institutional arrangements that overcome the limitations of previous organizational structures, and stimulate technology adoption, will be tested, adapted as necessary and promoted. The project will stimulate farmer investments in increasing productivity by improving their participation in commercial markets. The combined strategies will (1) improve food security by mitigating the effects of recurrent drought; and (2) offer new market opportunities for building wealth in the basin and beyond.

This project goal is in the line with NEPAD Agriculture and the Millennium Development Goals – eradicating extreme poverty and hunger and ensuring environmental sustainability – as well as those of national strategies for agricultural development and poverty reduction. The project will contribute directly to the developmental objectives of the Challenge Program Water for Food: to increase the productivity of water for food and livelihoods in a manner that is environmentally sustainable and socially acceptable.

SPECIFIC OBJECTIVES

1. Delineate agro-ecological recommendation domains in the smallholder dryland areas of the Limpopo Basin, based on biophysical and socio-economic factors (e.g. socio-economic stratification of smallholder communities and households). Collate baseline information on the domains, to be used as entry points to improve crop-water productivity at the field level, livelihood strategies, market opportunities, and for targeting of technology, monitoring of project benchmarks, and for scaling up within and beyond basin borders.

2. Validate and adapt integrated cereal and legume crop variety and soil management practices that are suitable for resource-poor smallholders in a risk-prone environment. These technologies will aim to diversify cropping and livelihood options, maximize crop water productivity, and increase incomes from rainfed farming systems in the basin.

3. Use innovative research and extension methodologies, linked to public-private partnerships, to facilitate promotion and uptake of management options and strengthen linkages to input and product markets. Draw lessons from this experience for application to other areas and countries in southern Africa.

4. Strengthen capacity of farmer and partner institutions to develop and implement innovative research and extension approaches; improve stakeholder participation in agricultural development; and strengthen public-private partnerships that will create income opportunities and improve crop water productivity.

The project was focused on smallholder farming communities in three target countries as follows:

Mozambique**:** Gaza province (Chokwe, Mabalane and Macia in, Inhambane province

South Africa: Limpopo province (Sekhukhune, Capricorn, and Mopani districts

Zimbabwe**:** Matebeleland South province (Gwanda and Matobo districts) and southern Masvingo Province (Chiredzi district).

The detailed implementation, progress and achievements on the objectives are presented chronologically objective by objective as follows:

Objective 1: Delineate agro-ecological recommendation domains in the smallholder dry-land areas of the Limpopo Basin, based on biophysical and socio-economic factors (e.g. socio-economic stratification of smallholder communities and households). Collate baseline information on the domains, to be used as entry points to improve crop-water productivity at the field level, livelihood strategies, market opportunities, and for targeting of technology, monitoring of project benchmarks, and for scaling up within and beyond basin borders

The main output for this objective was to have agro-ecological zonations, crop water productivity, socio-economic and institutional characterization of target population established and constraints to farm productivity in the cereal-based smallholder rain-fed sector identified.

Two main activities were envisaged at the project development for this objective. The activities include; agro ecological zonation and stratification and base line surveys.

Agro-ecological zonation and site stratification

The environment of the Limpopo catchment is highly diverse. It ranges from sea level to well over 2000 meters above sea level. There are generally 5 dry months, but the growing season length, temperature, and reliability in the basin vary greatly.

Methods

Agro-ecological characterization was done as the first step, and using the baseline data, Geographical Information System (GIS) was used to integrate the information to identify entry points for project intervention. The 25 sites listed in Table 1 were suggested as possible research sites because they have research infrastructure and some history of agricultural research. Efforts to characterize and classify these sites within the wide range of agro-environments in the Limpopo valley were undertaken. This was decided to be a more realistic alternative to producing a simple agro-environmental classification of the basin.

Table 1: Sites used in the analysis, with Ward's method clusters

Site	Latitude	Longitude	Agency[a]	Country	Cluster
Chokwe	-24.53	32.98	CP17	MOZ	1
Mabalane	-23.80	33.60	CP1+17	MOZ	1
Macia	-25.03	33.10	*	MOZ	1
Massingir	-23.80	32.20	CP1+17	MOZ	1
Xai Xai	-25.10	33.50	CP1+17	MOZ	1
Xilembene	-24.60	33.20	CP1+17	MOZ	1
Giyani	-23.33	30.73	LDA	RSA	2
Makulele	-22.86	30.92	LDA	RSA	2
Matibi	-22.08	30.65	*	ZIM	2
Mbahela	-22.81	30.45	LDA	RSA	2
Mopane	-22.60	29.85	*	RSA	2
Mtetengwe	-22.00	30.00	CP17	ZIM	2
Musina	-22.34	30.04	LDA	RSA	2
Filabusi	-20.80	29.30	CP17	ZIM	3
Insiza	-21.42	29.42	*	ZIM	3
Mwenezi	-21.42	30.73	*	ZIM	3
Bochum	-23.30	29.12	LDA	RSA	4
Burgersfort	-24.62	30.33	MDA	RSA	4
Mafefe	-24.17	30.08	CP wet	RSA	4
Mashushu	-24.32	29.65	LDA	RSA	4
Nebo	-23.03	29.85	*	RSA	4
Sikororo	-24.20	30.42	CP17	RSA	4
Strydkraal	-24.47	29.74	LDA	RSA	4
Tzaneen	-23.77	30.16	LDA	RSA	4
Spitzkop	-23.77	29.85	LDA	RSA	5

LDA, Limpopo Department of Agriculture; MDA, Mpamalanga Department of Agriculture; CP 'n', Water and Food Challenge Program section 'n'; CP wet, Water and Food Challenge Program wetlands; * Planning Meeting July 2003, Bulawayo.

The sites were clustered by climate using Ward's method (Ward 1963) as described in Jain and Dubes (1988) using the FloraMap package (Jones and Gladkov 2001). This method uses a squared distance method and typically produces well-defined clusters when applied to the 36 climate variants used in FloraMap. The data showed five clear clusters, with only one small cluster consisting of the Spitzkop site (see Figure 1 for the cluster dendrogram). Moving the separation line further down the dendrogram quickly produces seven clusters and then immediately subdivides to many small roughly equal-sized clusters. This shows that further grouping of the sites may be beneficial for more in-depth analysis but that the complexity involved is not warranted at this time.

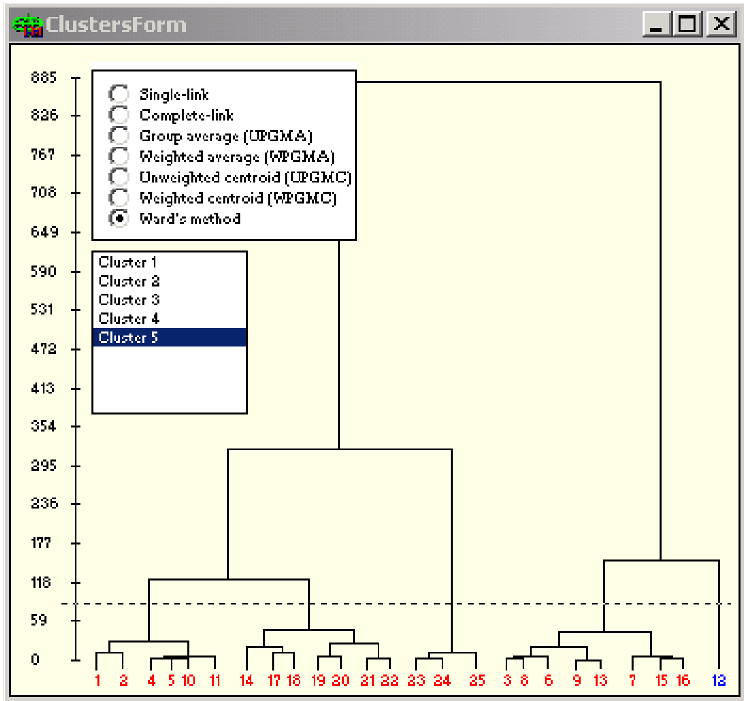


Figure 1: Dendrogram for the climate clustering of 25 proposed sites

Each of the sites was processed through Homologue (Jones et al. 2005) to give the map of its area of climatic influence. At this stage, no soil constraints were applied in the algorithm. The variance chosen for the analysis was one consistent with a moderately adapted species or variety and the probability cut-off below which the probability was not mapped was chosen as 0.3. Climates with a lower probability were deemed unlikely to be included in the adaptation area of a moderately adaptive variety ideally suited for the climate of each site.

Results and discussion

The agro-ecological work resulted in geo-referencing of 40 Progress Milling depots, showing the coordinates of the depots in the Limpopo Province in terms of latitudes and longitudes. This information was then shared with the project team members at IWMI-Pretoria with a view to use the coordinates for generation of several interlinked variables which when overlaid could provide insights to potential investment areas to be undertaken by both government and the private sector to accelerate smallholder development in the Limpopo Province. Key components in the overlay are agro-ecologies, market access and population densities. The main output realized from this activity was the stratification of the proposed 25 sites and identification of benchmark sites as intervention and control sites for the project in the first year. The information collected was used to identify sites for on farm testing of crop, soil fertility and water management technologies.

Baseline survey on crop water productivity in the basin, socio-economic and institutional characterization of target populations; constraints to farm productivity in the cereal-based rainfed sector

A baseline survey on households in the basin was part of objective one. The activities to achieve this output consisted of PRAs and a baseline survey on farming systems and markets. The objective of the socio-economic, farming system and livelihoods survey was to: set priorities for points of intervention in terms of water, crops, soil fertility and health aspects; establish baseline levels of farmers' knowledge, levels of adoption and constraints to uptake of improved crop, water and soil fertility technologies; establish baseline levels of farmers participation in input and output markets, access to credit, extension, market information and social networks; establish baseline on effects of HIV/AIDS on smallholder livelihoods including crop management practices. The farming systems were characterized in both biophysical and socio-economic terms with specific focus on crop management issues relative to the control of other biotic and abiotic constraints (Project Document, Challenge Program, 2005). Specifically, the baseline survey was aimed at providing information on the following:

i. contribution of crop and livestock to household incomes relative to other income sources
ii. access to resources, particularly farm power, implements, seed and fertility inputs
iii. adoption of crop and livestock technologies
iv. marketing
v. labor allocation
vi. gender roles in the crop cycle and
vii. effect of HIV/AIDS pandemic on households

Method and approach

Two approaches were used in the baseline study of the households in the Limpopo river basin. The first approach was focus group discussions (FGD) in the selected communities. These focus group discussions with community leaders and the general public were aimed at collecting qualitative information on farmer typologies, crop and livestock markets, institutions working within the communities, HIV/AIDS related problems and community coping mechanisms and access to crop and livestock technologies by communities. The FGDs were also used to sensitize communities on the quantitative survey and to seek their permission for implementing the survey.

The second approach was the formal quantitative survey in selected communities. The formal survey was conducted to capture quantitative data on crop management systems, asset ownership, adoption of crop technologies, adoption of livestock technologies, input and output markets, household incomes and expenditure and other socio-economic factors.

The survey was targeted at smallholder households resident in the Limpopo river basin in Zimbabwe and South Africa. A three-stage sampling frame was used for selecting districts, villages and households to be interviewed. Households not classified as smallholder farmers were not targeted in the survey and examples of such households included teachers, households at mini urban centers in the communal areas as well as other civil servants.

The districts in which the survey was conducted were purposively selected, three districts in South Africa and five districts in Zimbabwe. The districts that were selected in South Africa were Capricorn, Sekhukhune and Mopani. In Zimbabwe the selected districts were Chiredzi, Mwenezi, Gwanda, Insiza and Matobo. Initially only three districts were supposed to be selected for the survey in Zimbabwe but because of the requirement to maintain a distance of 100 kilometers between project and non-project villages the sample spilled into the neighboring districts.

The second stage in the sampling frame was the selection of the villages. In both South Africa and Zimbabwe a list of all the villages in each of the selected districts was obtained from the agricultural extension offices responsible for the district. Villages falling outside the basin were identified and deleted from the list for selecting the villages. Each of the villages on the list was allocated a unique number and the numbers were entered into SPSS and a random sample of 16 villages was selected, eight villages for the control area and eight villages for the project area. Villages in the control area had to be at least one hundred kilometers away from the project villages. The control villages will be used for the "with" and "without" project comparisons. Project villages are those villages where the project will be implemented and the control villages are those where no project activities will be conducted.

The third and final stage of the sampling strategy was the actual selection of the households. A pre-survey visit was arranged within the selected areas with the tribal authorities of each area. The objectives of the pre-survey visit were:

(a) to meet the tribal authorities such as headman, chief and civil organizations of the selected area;
(b) to demonstrate the objective of the survey and the content of the intended questionnaires;
(c) to introduce the survey team to the tribal authorities and to seek permission to be able to work in each of the communities (Capricorn, Mopani and Sekhukhune).

Traditional leaders normally keep records of the households in their respective villages. A request of the village household list was made to each of the traditional village leaders for the selected villages. The lists were verified to ensure they were as exhaustive as possible. Each household on the list was allocated a unique number and like in the case of villages SPSS was used to pick a random sample. The households to be interviewed were randomly selected per village using probability sampling according to size. An additional five households were selected to act as substitutes in case some of the selected households would not be available on the day of the interviews. Tables 2 and 3 shows the districts, villages and sample sizes selected for the survey in Zimbabwe and South Africa. The targeted sample was one thousand households per country.

Table 2: Districts and villages selected for the survey in Zimbabwe

District	**Project area villages**	**Sample size**	**Non-project area**	**Sample size**
Chiredzi	Mpandle	21	Malufumuni	21
	Chiteya	12	Sengwe	19
	Thlaveni	15	Gezani	25
	Chamabvuwane	12	Chibwedziwa	31
	Chikwawa	20		
	Muchingwizi	18		
	Fariseni	21		
	Chikulungo	22		
Mwenezi			Bhadhagi	24
			Machena	15
			Ramela	20
			Chiraranye	23
Insiza	Mbaulo	24	**Gwanda Villages** Thibeli	15
	Mabuze	18	Silonga	24
	Dandabagwa	21	Nkalange	24
	Thuthuka	24	Zvamagwamba	22
	Masiyephambili	17	Sizeze	11
	Shakwe	18	Mayezane	21
	Thandanani	23	Sitheze	26
	Asibambaneni	16	Sibhula	27
Matobo	Makwati	29	Sihwaba	30
	Magololo	**	Manuka	19
	Sontala	16	Lubangwe	18
	Silongwe	28	Zwananani	16
	Ndiweni	20	Beula	24
	Mangala	22	Ntabansimbi	23
	Mhlasi	19	Humbana	34
	Malindi	23	Khapeni	31

Table 3: Villages selected by district for South Africa

District	Project area	Selected households	Control site	Selected households
Capricorn	Juno	20	Matlapa	20
	Ga-Manamela	20	Makotopong	20
	Ga-Semenya	21	Ntshishane	20
	Ga – Seshaba (Moletjie)	21	Madiga	21
	Mabasotho (Longsdale)	19	Manyapye	20
	Prospect	20	Dikgale (Magobane)	20
	Saaiplaas	21	Gakololo	20
	Ceres	20	Manthedimg	20
Sekhukhune	Thoto	35	Moshate	75
	Platklip	11	Maesela	14
	Eenzaam	26	Mohlaletsi	24
	Sepakuh	13	Mooiplaas	10
	Motsephiri	32	Tswaing	18
	Luckau	23	Strydkraal A	6
	Gakopa	15	Strydkraal B	11
	Magukubjan	15	Wonderboom	11
Mopani	Ngove	14	Bonn	30
	Nkomo	11	Mohlatlareng	29
	Mashavele (Bongwani)	36	Mhangweni	17
	Hlaneki	13	Mulati	15
	Dzingidzingi	16	Burgersdorp	21
	Mavalani	13	Julesburg	30
	Xivulani	29	Mhlara	11
	Thomo	38	New Sedan	20

Results and discussion

The purpose of the survey was to provide quantitative data that could be used to characterize the farming systems of the Limpopo river basin before the implementation of project activities.

Household size

The mean size of households in the South African districts was six members and this was the same with that for three districts in Zimbabwe namely Insiza, Gwanda and Matobo. Chiredzi and Mwenezi had a slightly higher mean household size of seven members per household (Table 4).

Table 4: Average size of households in the Limpopo basin for Zimbabwe and South Africa

Country	District	Mean household size
South Africa	Capricorn	6
	Mopani	6
	Sekhukhune	6
Zimbabwe	Chiredzi	7
	Mwenezi	7
	Insiza	6
	Gwanda	6

	Matobo	6

An analysis of household size by gender of household head revealed that male headed households had a slightly higher number of household members compared to female headed households though the difference was not significant. If household size is taken as a proxy for availability of labor resources to households, then this finding may imply that male headed households have slightly more labor resources at their disposal compared to female headed households. Therefore, male headed households would be most likely to be able to adopt labor intensive technologies when only labor resources are considered.

Household headship

In South Africa more than half of the households interviewed were headed by females. In contrast the majority of households interviewed in Zimbabwe were headed by males as female headed households only constituted a third of the total number of sampled households (Table 5).

Table 5: Gender of household heads by country and district

Country	District	Proportion of male headed households (%)	Proportion of female headed households (%)
South Africa	Capricorn (n=323)	44.3	55.7
	Mopani (n=340)	48.8	51.2
	Sekhukhune (n=342)	45.9	54.1
Zimbabwe	Chiredzi (n=234)	54.3	45.7
	Mwenezi (n=86)	65.4	34.6
	Insiza (n=160)	66.5	33.5
	Gwanda (n=171)	68.4	31.6
	Matobo (n=351)	61.1	38.9

A very small proportion (2% or less) of households in some of the districts were child headed (Table 6). Child headed households are those with household heads aged less than sixteen years old. The expectation was that the proportion of child headed households in the sampled areas would be high due to the high levels of HIV/AIDS prevalence in the sampled areas especially for Zimbabwe. In Mwenezi no child headed households were observed. Most children orphaned by HIV/AIDS were being taken care of by extended family system and the proportion of orphans within households would be telling more of the extent of the HIV/AIDS problem.

Table 6: Proportion of households headed by children in the sampled districts of Zimbabwe and South Africa, 2005

Country	District	Proportion of households headed by children (%)
South Africa	Capricorn (n=323)	2.2
	Mopani (n=340)	0.9
	Sekhukhune (n=342)	0.9
Zimbabwe	Chiredzi (n=234)	1.8
	Mwenezi (n=86)	0.0
	Insiza (n=160)	0.6
	Gwanda (n=171)	0.6
	Matobo (n=351)	0.3

Educational status of household head

The educational status of the household head is important in as far as it affects assessment and adoption of new technologies by smallholder farmers. Sekhukhune in South Africa had the highest proportion (51.8%) of household heads that did not go to school. In Zimbabwe, Chiredzi (27.3%) and Mwenezi (28.4%) had higher proportions of household heads that did not go to school when compared with the other districts and this was higher than expected. The literacy level for Zimbabwe is around 90%. The majority of household heads in both countries were able to attain primary level education (Table 7).

Table 7: Educational status of household heads by country and district, 2005

Country	**District**	**Proportion of household heads with identified educational levels (%)**			
		Did not go to school	Primary	Secondary	Tertiary
South Africa	Capricorn (n=323)	28.8	34.4	34.4	2.5
	Mopani (n=340)	35.3	29.4	32.6	2.7
	Sekhukhune (n=342)	51.8	24.0	22.5	1.8
Zimbabwe	Chiredzi (n=237)	27.3	52.9	19.8	0.0
	Mwenezi (n=82)	28.4	48.1	23.5	0.0
	Insiza (n=161)	10.3	51.9	37.8	0.0
	Gwanda (n=171)	11.1	58.5	29.2	1.2
	Matobo (n=351)	10.2	57.9	31.3	0.6

The majority of female household heads did not go to school compared to their male counterparts. Historically the girl child has been disadvantaged as priority on resources allocated for educational purposes has been placed on males. Lower proportions of female heads were able to attain secondary level education compared to their male counterparts for both Zimbabwe and South Africa. Education is one of the variables normally used to explain adoption behavior in adoption studies. The differences in education levels between male and female headed households could suggest that male headed households are more likely to adopt a technology compared to female headed households when only educational levels are considered.

Household health status

The health status of the household head is important as the head is the key decision maker in the household. Most training sessions and workshops on agriculture are attended by household heads. A chronically ill head may therefore fail to access information on new crop and livestock technologies and to provide additional labor resources required in crop and livestock production. An analysis of the proportion of households with chronically ill heads showed that Sekhukhune in South Africa had the highest proportion of households (37.1%) headed by chronically ill household heads compared to the other two districts, Mopani (19.3%) and Capricorn (34.8%). In Zimbabwe, Matobo (24.1%) followed by Gwanda (24.0%) had the highest proportion of households headed by chronically ill heads (Table 8).

Table 8: Health status of household head by country and district, 2005

Country	District	Proportion of households with a household head in good health (%)	Proportion of households with a household head with short illnesses (%)	Proportion of households with a household head chronically ill (%)
South Africa	Capricorn (n=323)	58.4	6.8	34.8
	Mopani (n=340)	74.4	6.3	19.3
	Sekhukhune (n=342)	55.0	7.9	37.1
Zimbabwe	Chiredzi (n=237)	69.2	13.1	17.8
	Mwenezi (n=82)	78.2	7.7	14.1
	Insiza (n=161)	76.3	6.9	16.9
	Gwanda (n=171)	70.2	5.8	24.0
	Matobo (n=351)	68.4	7.5	24.1

The variable on chronic illness was meant to be a proxy for identifying HIV/AIDS infected and affected households. The age of the chronically ill member can be used to identify the affected members or households. In Zimbabwe, Chiredzi (27%) and Mwenezi (25%) had higher proportions of chronically ill household heads aged between 17 and 30 years compared to all the other districts. The household heads that were chronically ill in South Africa were relatively older, more than 46 years old, than those in Zimbabwe. Zimbabwe had a larger proportion (15.7%) of chronically ill heads aged 30 and below compared to South Africa (7.7%), Table 9.

Table 9: Age distribution of chronically ill household heads by country and district, 2005

Country	District	Proportion of chronically ill household heads by age category (%)				
		16 and under	17-30 years	31-45 years	46-60 years	61 and above
South Africa	Capricorn (n=111)	4.5	2.7	7.2	28.8	56.8
	Mopani (n=65)	0.0	0.0	13.8	33.8	52.3
	Sekhukhune (n=124)	0.8	1.6	4.8	29.8	62.9
Overall for South Africa (n=300)		2.0	1.7	7.7	30.3	58.3
Zimbabwe	Chiredzi (n=37)	0.0	27.0	24.3	29.7	18.9
	Mwenezi (n=12)	0.0	25.0	25.0	33.3	16.7
	Insiza (n=26)	0.0	0.0	15.4	26.9	57.7
	Gwanda (n=40)	2.5	0.0	10.0	27.5	60.0
	Matobo (n=83)	0.0	0.0	13.3	22.9	63.9
Overall for Zimbabwe (n=198)		0.5	6.6	15.7	26.3	51.0

The HIV/AIDS pandemic has meant losses to households in terms of labor and income contributions. Less than 15% of the households lost members to various diseases in the 2004/05 season. Mopani (8.0%) in South Africa and Chiredzi (8.2%) in Zimbabwe had the least losses over the year compared to the other districts (Table 10). Some households lost two or more members though the proportion of such households was very small (2% or less) for both Zimbabwe and South Africa. Some of the deceased members contributed income and labor to the household and such losses would obviously affect household livelihoods more so for households that lost more than two members.

Table 10: Proportion of households that lost members due to death by country and district, 2005

Country	District	Proportion of households that lost household members (%)		
		None	Only one	More than two
South Africa	Capricorn (n=323)	85.4	12.5	2.2
	Mopani (n=340)	92.0	7.4	0.6
	Sekhukhune (n=342)	84.4	14.5	1.2
Zimbabwe	Chiredzi (n=237)	91.8	7.3	0.8
	Mwenezi (n=82)	89.2	10.8	0.0
	Insiza (n=161)	84.3	13.2	2.5
	Gwanda (n=171)	84.7	14.7	0.6
	Matobo (n=351)	87.4	11.5	1.1

Economic losses to households due to the deaths included labor and income contributed by the deceased. When the deaths are analyzed in terms of household economic losses the results show that at least 30% of the deceased members contributed labour towards agricultural operations in both Zimbabwe and South Africa. For Zimbabwe none of the deceased members contributed income to the household except for one case in Chiredzi for one household. Zimbabwean households mainly lost the labor resource through the deaths of household members. In South Africa at least 40% of the deceased members contributed income to the household (Table 11). These losses meant household's livelihood options could be limited to those not demanding in terms of labor and income.

Table 11: Proportion of households receiving contribution of income and labor from deceased members

Country	District	Proportion of households that used to receive labor and income contributions from deceased member (%)	
		Labor	Income
South Africa	Capricorn (n=47)	44.9	60.9
	Mopani (n=27)	28.6	40.0
	Sekhukhune (n=53)	42.9	58.5
Zimbabwe	Chiredzi (n=19)	36.8	100.0*
	Mwenezi (n=9)	33.3	0.0
	Insiza (n=25)	41.4	0.0
	Gwanda (n=26)	37.0	0.0
	Matobo (n=44)	40.0	0.0

* only one household had a deceased member who used to contribute income

Of the households that lost members in Sekhukhune and Capricorn, a significant proportion lost the head of the household. The most commonly lost member was either a son or daughter and this was consistent in both South Africa and Zimbabwe. With the HIV/AIDS pandemic most HIV/AIDS infected individuals normally spent the last months of their lives in the custody of their parents in the rural areas. The other high losses on other relatives could be explained by the fact that those lost to HIV/AIDS leave behind spouses and children that could be HIV positive as well and are left in the care of parents.

Household asset ownership

Household asset ownership is normally used as a proxy for the wealth status of the household and it is also used to judge the capacity of the household to till the land and produce enough food for the household. Ownership of a plough, hoe and draft is the key in evaluating the capacity of the household to utilize early rains to plough and plant early and therefore increase the chances of a harvest in the event of dry spells or droughts. Several studies conducted in Zimbabwe have indicated that the ownership of draft power is critical if households are to achieve food security. The survey looked at the ownership of various assets from those required for draft to assets required for improving access to information (electronic media). The results on asset ownership are separately reported in the survey report submitted to CPWF.

Conclusions

The female headed households had limited access to both assets and income and as such they may not be able to produce enough grain to ensure household food security. Activities to be implemented by the WFCP therefore needed to take the female headed households as a special category in which resource constraints threatened the livelihood base of the female headed households. There were male headed households as well that appeared to be vulnerable especially those facing the burden of chronically ill members. Area cropped by households with chronically ill members was found to be smaller compared to area cropped by households without a burden of the chronically ill members.

Access to draft resources was found to present the biggest challenge for households in the basin to achieve food security. Ownership of draft resources was positively related to the total area cropped meaning that a cheaper and affordable tractor hire service in South Africa would boost the total area planted as most households appeared to be depended more on tractor hire service and most households did not own cattle or donkeys which could be used as a substitute for tractors. In Zimbabwe ownership of draft cattle or donkeys was the key determinant of the total area cropped. Limited tillage or zero tillage technologies therefore might be important for the households that do not own any livestock. The WFCP would have to explore ways of improving smallholder farmers' access to information on planting basins and other limited tillage technologies.

A significant proportion of Zimbabwean households were spending more than what the households were earning due to the economic problems Zimbabwe had been experiencing since 2002. It appeared that most of the households spending more than they earn would have to rely on credits thereby increasing their debt load. The disposal of assets will then be the other option for those households' livelihoods thereby further crippling the households' chances of enhancing livelihoods. The WFCP would therefore have to explore other livelihood enhancing options for households to raise incomes and limit the disposal of keys assets (cattle, plough, hoes etc).

Droughts and mid-season dry spells was the biggest threat to household food security in the basin. Smallholder farmers interviewed confirmed this. Water harvesting technologies have been found to be effective in retaining moisture and boosting crop yields. However, households in the basin were found to have limited access to information on these technologies. Although a significant proportion of households especially in Zimbabwe have had information on water harvesting technologies, their adoption remained very low in both countries. Participatory testing of water harvesting technologies would therefore be important in trying to raise crop yields through this project.

Soil fertility management is important in boosting crop yields. This is evident in the findings that although the 2004/05 season was a poor season, households that applied mineral fertilizer generally had higher yields compared to those households that did not use any. Improving access to fertilizers and also providing information on efficient use of fertilizers therefore remained a possible task for the project to take advantage of the observed better yields from farmers who used fertilizer.

Challenges faced during the baseline survey

The baseline survey was not conducted in Mozambique. Efforts to plan for survey were undertaken to link up with IIAM social economic scientists and budgets were submitted. The plan was drawn to start the survey in January 2007. However, the lead scientist for this activity left and this affected the progress of the planned survey until it became too late to conduct the base line as the project was nearing the final season of implementation.

Objective 2: Validate and adapt integrated cereal and legume crop variety and soil management practices that are suitable for resource-poor smallholders in a risk-prone environment. These technologies will aim to diversify cropping and livelihood options, maximize crop water productivity, and increase incomes from rainfed farming systems in the basin

The main output for this objective was to have improved drought-tolerant crop varieties integrated with improved soil, water and crop management technologies appropriate to smallholder agriculture, verified and promoted

Preliminary work on this objective involved reconnaissance surveys which, were aimed at documenting technology options for improving crop water productivity and soil fertility sustainability for smallholder farmers in the Limpopo Basin. Technology options identified in collaboration with extension and farming communities included crop species grown by farmers such as drought tolerant early maturing varieties of sorghum, maize, groundnuts, cowpea and pigeon peas, and soil and water management technologies including: pot holing, intercropping, crop rotation, mulching and application of manure/compost trenches. Micro-dosing fertilizer technology and the three factors above (varieties, soil fertility and water management) were therefore included in the adaptive trials through out the project period starting from 2005/06 in order to validate them through farmer participatory trials. The aim was to scale up the adoption of these technologies to demonstrate their benefit in increasing crop water productivity, food security and income for small scale farmers in the basin.

In order to validate the different technologies identified in the reconnaissance surveys as stated above, a wide range of adaptive trials were involving both single factor and in some cases various factor combinations designed and evaluated. The single factor trials mainly included crop species variety trials (Maize, Sorghum, Millet and Groundnut). However, the choice of target site for evaluation in the basin was dependent on agro-ecology and prevalent information about farmer preferences. The multi-factor technology combinations focused on a series of adaptive and exploratory trials aimed at validating and assessing the interaction effects of the factors on improving crop water productivity. Notable multi-factor trial combinations included testing of water use efficiency, water management technologies, soil fertility management options and legume integration into the cereal based cropping systems and seed systems. Specific treatment factor levels included: water harvesting (mulching, tied ridges and basins), fertilizer (inorganic and lime), and cereal-legume intercropping (maize-cowpea, maize-pigeonpea, and sorghum-cowpea) and cereal-legume rotation systems.

An account of the methods and approaches used, and a syntheses of results obtained, and discussion including implications for improved crop water productivity in the target sites of the basin is given by season and by country to improve presentation, owing to the dynamic nature of the treatment combinations across seasons and even across sites within a season. As implementation progressed, treatments for specific trials kept being modified based on prevailing circumstances and as implementing partners became familiar with project interventions.

The major drawback of the changes in protocols for trial implementation has been the inability to carry out statistical analyses across years to determine the performance of any one technology, and also across countries for extrapolation.

Methods and approaches for adaptive trials

The "Mother – Baby approach" which provides for extensive participation of farmers while providing data for systematic analysis of treatment effects was adopted for implementation of the trials. In this approach, one site that had enough land to contain a whole set of trials or technologies to be tested was selected within the community. Several other sites were then selected to host sub-sets of the trials; in so doing each site exposed the farmers to a given technology and was managed by the farmer themselves with backstopping by the extension staff. The "Mother" site that has all the treatments of the trials provides an opportunity for the farmers who are hosting sub-sets ("Babies") of the trails to evaluate the performance of all the technologies in one place. Because of the usually large size of the Mother trials, they are located on fields of farmers who have a better understanding of crop management, but are closely monitored by researchers and extension staff who take some of the most critical data that the farmer may not easily be able to record. Data are collected on all the trials and analyzed to evaluate the performance of the individual treatments under both research or extension managed trails and the farmer-managed trials.

Protocols for individual trials were jointly developed by researchers and extension personnel with farmer input for each target country in the basin. After each season, a meeting of all partners was held to review outcomes of the previous season's activities and assess progress and challenges encountered in implementation to enable planning for the next season based on outcomes. Necessary modifications to the protocols were introduced as a way of making sure there was smooth implementation in the following seasons trials.

Trials implemented in 2005-06 season

The reconnaissance surveys conducted at the beginning of the activities identified technology options (drought tolerant early maturing varieties for sorghum, maize, groundnuts, cowpea and pigeon peas and soil and water management technologies including pot holing, intercropping, crop rotation, mulching and manure/compost trenches and micro-dosing fertilizer) as candidate technologies to be tested in the Limpopo basin. Three factors (varieties, soil fertility and water management) were tested in adaptive trials in 2005/6 season using Mother and Baby approach and also on station trials where soil water was to be monitored during the cropping period. Achievements by country are indicated below:

Mozambique

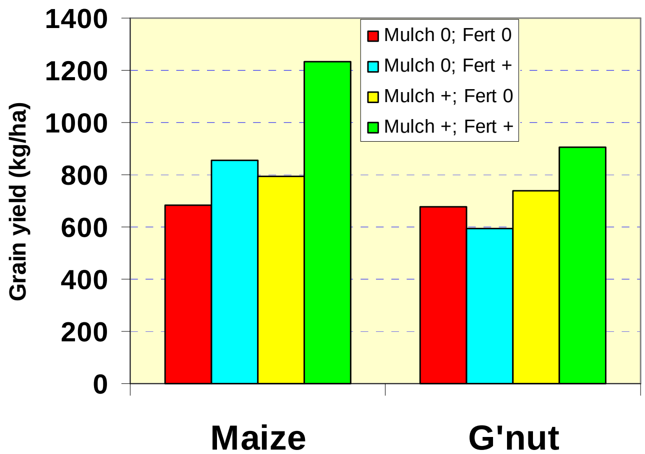
A total of nine mother trials and 19 baby trials were implemented in the 2005/06 season. Trials that were successfully done were Maize water harvesting, and fertilizer trial and the groundnut water harvesting, and fertilizer trial.

Maize water harvesting by fertilizer and groundnut water harvesting by fertilizer trials

Both trials used mulch and no mulch and fertilizer and no fertilizer scenarios as a 2 x 2 factorial design.

Results and discussion

Results for the maize water harvesting by fertilizer; and groundnut, water harvesting by fertilizer trials showed highest grain yield especially when mulch and fertilizer were combined (Figure 1). The data on grain yield for the two crops showed that there were positive effects of mulching and fertilizer N micro-dosing on the two crops implying that mulching and N fertilizer micro-dosing can improve crop yield in the dry environments such as Macia and Chokwe where the trials were conducted. Mulch gave a positive effect on maize yield both with and without a small dose of N fertilizer, but almost doubled yield when both mulch and a micro-dose of N were applied (although this interaction was not statistically significant). In the case of groundnuts, yield was slightly reduced by mulch alone, possibly due to the effect of decomposition of mulch that probably held up some of the nitrogen, but was increased when both mulch and N were applied. The effects of mulch were considerably greater on maize than on groundnuts.



Prob F
Maize
Mulch: 2%
Fert: 7%
M x F: NS

Groundnut
Mulch: 1%
Fert: NS
M x F: 5%

Figure 2: Maize and groundnut mean yield (kg/ha) in Mozambique

Zimbabwe

Seed for trials for the different crop species could be a constraint if not properly incorporated in the project plan. Fortunately, USEBA in Mozambique had a successful seed production season in 2005/06 (3 tons of three major crops included in the trials - groundnuts, sorghum and pearl millet). The seed from USEBA was therefore made available for the project in Mozambique and Zimbabwe. Seed availability for the project activities helped Zimbabwe partners to implement a total of 96 mother trials and over 600 baby trials which were implemented in 2005/06 season.

Field days were organized in April 2006 for the trials in Zimbabwe and Mozambique. The field day in Zimbabwe attracted more than 1000 people. During this field day, the concepts of the CPWF and PN1 specifically were articulated and were well received by stakeholders attending the field day

Results and discussion

Despite the large number of trials implemented in Zimbabwe in 2005/2007 season, the yield data was not provided in the annual report. It was learnt in the process that the Zimbabwe team could not do statistical analysis of the data. It was therefore resolved that in future, the data could be sent as raw data to the responsible theme leaders to help in the analysis**.**

Institutional innovations to improve access to good quality seed

Seed is the basic input required to enhance adoption of new crop varieties. The project therefore put up seed production initiatives to increase seed amounts of the target crop varieties. Therefore, efforts to promote adoption rates of farmer and market acceptable varieties were linked to institutional building for seed production and distribution. Varieties of the various crops important in the basin for use for the crop water productivity studies were as follows: Sorghum (Macia, SV1, SV2, SV3, SV4, Sima and Chokwe), Pearl Millet (Okashana 1, PMV2, PMV3, Kuphanjala-1, Kuphanjala-2 and Changara), Maize (ZM 421, ZM 403, and ZM 521) and groundnuts (Jesa, Nyanda, Ilanda, Mwenje, JL 24, Sellie, Nematil). Concerted efforts for seed production were concentrated in a few preferred varieties from the list – particularly Macia for sorghum, PMV3 for pearl millet, Nyanda and ICG 12991 for groundnuts, ZM 421 and ZM 521 for maize.

During the 2005-06 off season, seed production activities were implemented by ICRISAT and NARS in Zimbabwe in preparation for the 2006-07 on-farm trials: Sorghum variety Sima 0.32 ha, Macia 2.2 ha, Pearl Millet variety PMV 3, 0.32 ha and groundnut variety Mwenje 0.8 ha were planted and multiplied at Chiredzi Research Station in Zimbabwe.

Nucleus and breeder seed of elite and released lines respectively was multiplied and availed to NARS collaborators as source for foundation seed. In 2006 enough seed of 7 groundnut varieties was multiplied at the ICRISAT Chitedze Station in Malawi for on-farm work of the CPWFPN1. Varieties and quantities included Nyanda, 650 kgs; ICGV-SM 01513 200 kgs; ICGV-SM 99541, 97kgs; ICG 12991, 900kgs; JL 24, 500kgs; ICGV-SM 90704, 200kgs; and ICGV-SM 99568, 200kgs. A total of 440kgs were sent to Mozambique for trials.

A new groundnut variety suitable for the Limpopo Basin ICGV 94297 was released in 2006 in Zimbabwe under the name Illanda; and because of its early maturity it would particularly address the drought constraints that had limited groundnut productivity in the Limpopo in the past.

Trials implemented in 2006-2007 season

Learning from the experiences drawn from implementation of project activities across the three countries in Limpopo Basin during the 2005-2006 season, work towards identifying suitable technologies for increased productivity continued in target sites during the 2006-2007 season. Although the technologies tested virtually remained the same, some treatments were streamlined to improve on the approaches to experimentation and reflect lessons learned from the challenges faced during the previous year of implementation. The activities commenced with a review of the previous season's activities focusing on an analysis of major outcomes and drawing a plan of operation for the subsequent season based on challenges and constraints encountered.

Mozambique

In the case of Mozambique only multi-factor trials aimed at evaluating the interaction effects of factors on crop water productivity were conducted during the 2006-2007 season. A total of 7 trials were implemented, and the list included: Groundnut variety by mulch by fertilizer, Maize land preparation by mulch by fertilizer, Sorghum variety by mulch by fertilizer, Groundnut variety by mulch by fertilizer, Groundnut exploratory trials, and Rotation and intercrop trials. The trials mainly focused on groundnuts in the Macia and Chokwe Districts, and sorghum on the drier, but heavier alluvial soils in Mabalane District, supported by some on-station trials at the Chokwe Experiment Station.

Although the majority of trials planned for the 2006/07 were established in Chokwe District (75%) and in Macia District (67%), logistical problems coupled with limited seeding opportunities due to erratic rains resulted in none of the sorghum trials being planted for Mabalane. Additionally, data could only be obtained for the Groundnut variety by mulch by fertilizer (mother and baby) trials and the Groundnut exploratory trial.

Groundnut variety by mulch by fertilizer trial

The objective of was to evaluate the importance of variety, mulch (moisture capture and savings) and fertilizer application, and their interactions in determining the productivity of groundnut at three seeding dates. The trial was laid out in a split plot design with mulch as the main plot and variety and fertilizer as sub-plot factors. At least 2 replications were maintained with three sites in Macia and two sites in Chokwe at three seeding dates. Treatment factors included: mulch at 2 levels (no mulch, and 3 t/ha mulch applied as soon as possible, preferably before first planting rains. For land prepared normally, mulch was removed for seeding and then reapplied whereas a hole was poked into the soil at each planting station to place the seed for the no till (zero tillage) mulch treatments, and making a separate hole alongside each seeding hole for the fertilizer. While two groundnut varieties including Nematil (small seeded) and ICGV-SM99541 were used, fertilizer levels included no fertilizer and 20 kg N/ha applied at seeding or 0.4g urea per planting station if plant spacing was 50 cm x 20 cm. Seeding was done early September, mid-October and early December for first, second and seeding, respectively.

Results and discussion

The results given in this section involve comparison of treatments with and without mulch (3 t/ha of thatching grass), two varieties of groundnut (Nematil and Mamane) and with and without 20 kg/ha of nitrogen fertilizer as a starter fertilizer on the extremely sandy soils of Chokwe and Macia districts. Four sites of the single-replication mother trial were harvested including, two early seeded and two seeded at the normal time of late November. Overall, and on the two early seeded trials, there was a significant difference between yields of the two groundnut varieties. Nematil yielded 2.2 t/ha of grain at both seeding dates, compared to 0.39 t/ha and 1.94 t/ha for Mamane on the early seeding dates, and the late seeding dates, respectively. At the early seeding date, Mamane possibly suffered from poor seed set, as the relationship between grain weight and fresh pod weight was very low (13%) compared to the same variety at the later seeding date (29%). Nematil had a 33% higher grain to pod weight ratio reflecting a higher shelling percentage compared to an average of 21% for Mamane. The results also revealed some considerable degree of stability in the shelling percentage of Nematil for different seeding dates while that of Mamane varied with seeding time probably due to the inherent differences in seed size between the two varieties which allowed for rapid grain filling for the small seeded Nematil compared to Mamane under a reduced growing period.

Unfortunately, only four baby trials in addition to the mother trial survived the season, thus, allowing only one complete analyzable replication. Furthermore, shortage of seed of Nematil variety meant that the variety could not be included in the baby trials. Therefore, the only comparison that could be made with this baby trial was the effect of mulch on groundnut productivity. A striking outcome of the groundnut variety by mulch by fertilizer trial was that mulch increased groundnut yield by 27% (1.37 t/ha with mulch compared to 1.05 t/ha obtained without mulch), but this difference was not statistically significant owing to the lack of sufficient replication.

As would be expected, a significant relationship was observed between plant stand and groundnut yield. Over all treatments and seeding dates, the linear regression of yield on plant population was highly significant (r^2 = 0.25**). Although this was the case, other factors responsible for accumulation of yield in groundnut may have influenced the relationship.

Groundnut Exploratory Trial

The objective of the Groundnut exploratory trial was to quantify the main effects of planting basins, complete inorganic fertilizer application and gypsum, and their interactions, on groundnut yields. The results of such a trial would guide decisions on the incorporation of these factors into mother trials in the subsequent seasons.

The trial was laid out as a 2 x 2 x 2 factorial in randomized blocks with three replications per site at Chichango and Manzir. Three factors (land preparation, fertilizer and gypsum) each at 2 levels were evaluated. Two levels for each factor were farmers' normal practice and planting basins for land preparation, unfertilized plots and application of 200 kg/ha 12-24-12 (Total = 24N-48P_2O_5-24K_2O) for fertilizer, unlimed and application of 500 kg/ha lime at planting (in a band about 25 cm wide over the rows with farmers seeding practice, and around each basin in the basin treatment) for gypsum. The variety used was Nematil.

Results and discussion

The results from the Groundnut exploratory trial revealed that a combination of water harvesting, fertilizer and lime application had a positive effect in enhancing biomass productivity of the groundnut crop. As can be observed in Table 12, both the grain yields and the ratio of grain weight to pod weight were generally very low with a range of 3−41 kg/ha and 1−11%, respectively. The biomass yields were acceptable, but grain development was compromised resulting in very low grain yields. Interestingly the treatment that had the highest grain yield and grain as a percentage of pod weight (Treatment 8) had the lowest plant population and biomass yield. In groundnut it is commonly observed that increased biomass production occurs at the expense of grain yield accumulation since groundnut has a tendency for luxurious growth under high levels of nitrogen nutrition which suppresses nodulation. Therefore the higher grain yield was simply a result of some water saving through lower plant populations and earlier growth. Although the check plot (no mulch, no lime and no fertilizer) was unfortunately lost in two replications, and hence discarded from the analysis, some interesting differences were evident despite the very low yields. The use of planting basins with fertilizer or lime meant that there was enhanced nutrition and water availability for photosynthate production, translocation and accumulation in the plant resulting in a significant positive effect in increasing groundnut productivity under water limited conditions in the basin.

Table 12: Effect of water harvesting, fertilizer and lime on plant population and yield in the Groundnut exploratory trial at Macia, Mozambique in the 2006-07 season

Water harvesting (planting basins)	**Fertilizer**	**Lime**	**Plants/m^2**	**Biomass (kg/ha)**		**Grain yield (kg/ha)**		**Grain % of pod weight**	
-	-	+	11.9	4667	ab	16.5	ab	3.1	b
-	+	-	13.0	5111	ab	7.9	b	1.4	b
-	+	+	25.8	10175	A	25.3	ab	2.2	b
+	-	-	22.5	8750	ab	18.2	ab	1.8	b
+	-	+	12.5	4917	ab	19.4	ab	3.5	b
+	+	-	12.5	4944	ab	21.6	ab	3.8	b
+	+	+	8.0	3139	A	34.6	a	9.7	a

Total biomass production in the exploratory trial was very closely related to plant population as can be seen in Figure 2 below. The relationship between plant population and total biomass suggested that increasing plant population resulted in high biomass production, but reduced grain yield. This might entail that maximum grain yield could be produced with lower biomass yields. Total biomass appeared to be inversely related to grain production due to luxury growth.

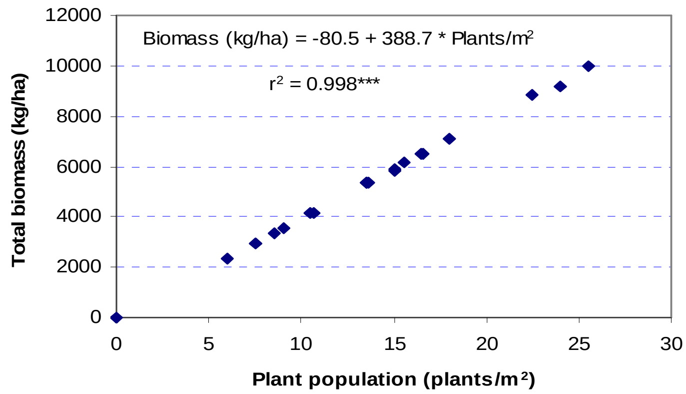


Figure 3: *Relationship between total biomass and plant population in the Groundnut exploratory trial in Macia district, Mozambique during 2006-2007 season*

Zimbabwe

In 2006/07 season the project partners in Zimbabwe made very ambitious plans to conduct a total of 965 trials across technologies covering crop species varieties, water management options and fertilizer. However, only 330 (34%) trials were established with only 74 (22%) of the established trials harvested. The trials implemented in Zimbabwe were distributed as follows: 110 on Maize, 108 on Sorghum, 46 on Groundnut, 14 on Pearl millet, and 4 trials on Water harvesting. Most of the trials that were not harvested were as a result of complete crop failure rather that being lost, but in many cases farmers harvested the trials on their own without researcher involvement. This at least was a positive result signifying commitment of partner farmers to address the data requirements from the trials. The trials were mainly conducted in three Zimbabwean districts of Chiredzi, Gwanda and Matobo within the Limpopo Basin.

Crop variety by water management by fertilizer trials

The objective of the crop variety by water management by fertilizer trials was to quantify and demonstrate the effects of variety, water management and nitrogen fertilizer on grain production as a measure of crop water use efficiency. The trials involved four crop species, including maize, sorghum, pearl millet and groundnut. For each crop species, the trial was laid out as a 2 x 2 x 2 factorial arranged in randomized blocks in each of the four villages in Chiredzi-Ward 13 and 11, Gwanda-Ward 15 and 18 and Matobo-Ward 1 and 5. The treatment factors comprised two varieties for each crop (farmer's variety designated as V1 and an improved variety as V2), two levels of fertilizer (no top dressing as N1 and top dressing with 1 bag/ha ammonium nitrate to supply 17.5 kg N/ha) used for all crops except groundnut, and two water harvesting techniques (farmer's normal land preparation designated as W1 and planting basins or tied ridges/furrows for cereals and Zai trenches for groundnut as W2). For groundnut, the fertilizer treatment comprised no gypsum designated as (G1) and gypsum applied at 300 kg/ha in two splits (50% each at first pegs and 4 weeks later as G2). The fertilizer treatment was not included on the basalt soils in Chiredzi. The crop varieties used included a farmer's local for the site as V1 and either ZM 421 or ZM 521 (replaced by PAN 513 in some cases) as V2. Similarly, improved varieties compared to the farmers local comprise SV4 and Macia, Okashana, PMV 2 and PMV 3, and Nyanda and Ilanda for sorghum, pearl millet and groundnut, respectively. Two villages in each Ward compared farmer's normal land preparation (flat planting) to tied ridges/furrows while the other two villages in each Ward compared farmer's practice to planting basins. Farmers hosting trials were advised to prepare planting basins well before the first rains based on ICRISAT guidelines.

As the mother trial was a single replicate of a trial and that there were three different configurations of the partial replications that comprised the baby trials, in many cases there were hardly two complete replications of a trial. In several instances, the baby harvested would only include mostly one conformation of the partial replication and therefore full replications were not available. Efforts were however, made to analyze as many comparisons as possible.

Results and discussion
In order to ease comprehension, the results of the trials are presented by crop considering that the water management and fertilizer treatments were evaluated for each crop.

Maize Trials
Good quality data that could be analyzed statistically for maize came from trials conducted in Shavani and Thlaveni Villages in Ward 13 of Chiredzi. In these sites, there were no significant differences in maize yield performance of the farmers' variety compared to either ZM 421 in Shavani and ZM 521 in Thlaveni. This might be expected as the farmers' variety used at Thlayeni was a hybrid known as PAN 513. Hybrids have been found as being more productive and stable under a wide range of environments than open- pollinated varieties. It is worth noting that different varieties of maize were used at different sites in Shavani based on availability. Again, there were no significant differences between the treatments, with and without N top dressing and also between the farmers' normal land preparation and planting basins (Table 13).

The results on maize grain yield revealed a generally low average of 273 kg/ha across varieties in Shavani and 568 kg/ha in Thlaveni. The slightly raised average yield in Thlayeni might be attributed to inherent agro-ecological differences in soil fertility between the sites. Most of the baby trials received some manure application to all treatments. However, no manure was applied on one farm in Thlaveni Village and average maize grain yield across varieties was less than 100 kg/ha. One striking result of the maize trials pertained to the observation that farmers' used a hybrid PAN 513 as a local check. This might entail that farmers in Thlayeni have learnt over the years that hybrids tend to be more adapted and give superior yield performance compared to local varieties and improved open pollinated varieties under water and nutrient limited conditions. This was reflected by the generally higher average maize grain yields obtained in Thlayeni where PAN 513 was compared with ZM 521.

Sorghum trials
Sorghum grain yields from trial sites in the Limpopo basin districts in Zimbabwe were generally very low. Notably, few comparisons gave significant differences between treatments. Trials from four villages in Chiredzi District covering Kudzanayi, Thlaveni, Shavani and Chamabvani gave adequate data that could be analyzed. In several cases N top-dressing and/or land preparation as water harvesting option had not been done. Yields were generally very low with variety as the only factor that resulted in statistically significant differences between treatments. Macia gave the highest grain yield of 861 kg/ha at Kudzanayi Village compared to the farmer's variety locally known as Chigangara, which only yielded 715 kg/ha.

Two different analyses were possible for sorghum data obtained for the mother trial at Shavani Village. Although two replications of variety by water harvesting did not include top-dressing with N because the factor was not applied, the mother trial data was combined with data from 5 baby trials and analyzed as 7 replications, but with different farmers' varieties. The results from the analyses showed highly significant grain yield benefits with Macia variety. When compared only with SV4 in the mother trial, the difference between Macia (1.12 t/ha) and SV4 (0.33 t/ha) was highly significant ($P \leq 0.01$). When the baby trials were included, the results revealed a significantly higher ($P \leq 0.05$) average grain yield for Macia (1.42 t/ha) compared to the mean (0.76 t/ha) of the different farmer varieties.

An analysis of all the three factors including: variety, top-dressing with 17.5 kg/ha N and water harvesting options was only meaningful for data obtained from two mother trials conducted in Thlaveni village. The results revealed a significant ($P \leq 0.05$) interaction between variety and tied ridges as a water harvesting option (Table 13) despite the generally low grain yield levels. SV4 gave higher yield than Macia under tied ridges while Macia yielded better under flat planting implying that might their differencesto moisture deficits. However, no significant differences were detected between the main treatment effects. The three sorghum baby trials conducted at Sitezi Village in Gwanda District gave an average yield of 0.21 t/ha, but did not show any significant differences between variety, water harvesting and fertilizer treatments nor their interactions.

Table 13: The effect of variety and tied ridges on sorghum yield performance (t/ha) at Thlaveni Village, Chiredzi District in Zimbabwe during the 2006/07 season

Sorghum variety	Water harvesting option	
	Farmer's flat planting	Tied ridges
Macia	0.39	0.29
SV4	0.30	0.44
Mean	**0.34**	**0.37**
Fpr variety	NS	
Fpr water harvesting	NS	
Fpr variety x water harvesting	0.03	

When the crop performance data from trials conducted at Chamagutise Village on water-use efficiency was analyzed, the results revealed statistically significant differences between treatments for sorghum, but not for maize (Table 14). Planting basins gave significantly (Fpr=0.05) higher grain yields than tied ridges with respect to sorghum. Maize total above-ground biomass was highest (0.54 t/ha) for mulched planting basis, seconded by mulch only at 0.47 t/ha. However, the results for both total above-ground biomass and grain yield were not significant for maize. This might be attributed to increased biomass accumulation due to enhanced assimilate production supported by improved water availability to the crop as a result of water storage properties of mulch during the vegetative phase, which became limiting towards the grain filling stage, especially for maize. For sorghum, only two water harvesting treatments comprising tied ridges and planting basins were applied. Planting basins gave significantly (Fpr=0.05) higher sorghum grain yields (0.44 t/ha) than tied ridges (0.29 t/ha). Despite the generally low yields obtained, the results support the general thinking that sorghum is inherently drought tolerant compared to maize, and presents a great deal of potential for improving crop water productivity in the Limpopo Basin districts of Zimbabwe, if farmers were willing to invest in water harvesting technologies whenever a decision was made to produce sorghum.

Table 14: Effect of water harvesting on maize total above-ground biomass and sorghum grain yield at Chamagutise Village in Zinbabwe during the 2006-2007 season

Treatment	**Maize stover (t/ha)**	**Sorghum grain (t/ha)**
Farmer's practice (flat planting)	0.32	
Tied ridges	0.20	0.29
Basins	0.17	0.44
Mulch	0.47	
Basins + mulch	0.54	
Fpr	0.10	0.05

Pearl millet trials

Very few pearl millet trials were harvested in Zimbabwean sites during the 2006-2007 season, making it difficult for any statistical analysis to be conducted on of the data.

Groundnut trials

Of the groundnut trials conducted in Zimbabwe during the 2006-2007 season, only baby trials conducted at Sitezi Village in Gwanda-Ward 8 had sufficient data warranting statistical analysis. However, the results of the analysis revealed no significant differences due to treatments, but huge site effects were detected largely due to planting date. Mean groundnut yield of the baby trials ranged from 0.12 t/ha to 2.65 t/ha. Lack of adequate trial management and poor data collection resulted in the established trials being put to waste as no meaningful analysis could be conducted on the data that was generated. This stresses the importance of proper trial management and getting the basic agronomic practices right, or else if trials are not managed correctly then the results become meaningless or at the very least difficult to interpret.

In summary, the trials in Zimbabwe in the 2006/07 season were very variable, compounded by the lack of sufficient replication due to the fewer number of sites established and harvested. There were several cases of improved varieties giving significantly better yields than the commonly used farmer varieties, but results were not consistent. The problems with the trial management were taken to the Planning Meeting later in the year and formed the basis for a complete re-thinking of the experimental programs for the remaining project lifespan in Zimbabwe.

South Africa

The project partners in South Africa could not implement any trials in the 2006-2007 season due to several constraints. Notable setbacks included a series of problems of inter-institutional misunderstandings as it was not clear to the partners where the project resources would be disbursed from. The tussle for management of project financial logistics was mainly between the Agricultural Research Council and the Limpopo Department of Agriculture as principal partner institutions in South Africa. This led to seed shortages for the implementation of trials in the target sites as the host farmers were not supplied with the necessary inputs. For the few sites where seed was made available for the trials, erratic early season rainfall made it very difficult for the trials to be implemented as planned, resulting in very few trials being established in the target Limpopo Basin districts in South Africa in the 2006/2007 season. Regrettably, even for the few trials which were established, none was adequately monitored to provide tangible results worthy statistical analysis.

It is however, worth mentioning that besides the evaluation and planning meetings, other events took place in South Africa before and during the 2006-2007 season. The first meeting was held on the 1st of June 2007 in Polokwane in order to explore strategies that would bring together the South African project partners and improve cooperation in implementation of on-farm research trials in the subsequent seasons.

Trials implemented in 2007-2008 season

Mozambique

The implementation of PN1 project activities continued in all the target districts in the Limpopo Basin covering the three countries of Mozambique, South Africa and Zimbabwe. Except for modifications necessitated by emerging challenges associated with project implementation, the majority of the trials were carried out according to original methods and protocols designed at the start of the project in 2005. In the Limpopo Basin districts of Mozambique, the start of the 2007-2008 season was relatively abnormal with infrequent, but heavy rains, resulting in limited seeding opportunities for trials on the sandy soils. However, most of the planned trials were established, although seeding was very late on some of the trials as a result of the sporadic rains and problems of transport and manpower.

Groundnut variety by mulch by fertilizer trials
The groundnut mother and baby **t**rials were conducted to compare the response of two groundnut varieties to water harvesting techniques and fertilizer use. The treatments applied in the previous season were maintained and involved two levels of mulch (1=mulching and 2=no mulching), two levels of fertilizer application (1= fertilizer and 2= no fertilizer applied), and two groundnut varieties (1= Nematil and 2= ICGV-SM 99541). The mulch was applied at 3 t/ha, and fertilizer was applied at 20 kg N /ha to the 2 groundnut varieties. A total of 22 trials were established in Macia, Chokwe and Mabalane.

Results and discussion
Groundnut plant stands were generally poor, especially for Nematil. The level of variability was very high in the trials due to poor rains. Trial results did not reveal any significant differences between treatment effects on yield and yield components (Table 15). Yields were generally very low propably due to sporadic rains which resulted in late planting in many of the sites. Although the grain yield level for the two varieties was similar, fertilizer gave 8% yield increase over an unfertilized groundnut crop. However, the grain yield differences were not significant. The lack of significant differences might be attributed to the limited moisture as fertilizers and mulch could not work effectively in a failed rainfall season since soils were consistently dry limiting fertilizer dissolution and consequent crop uptake and water retention, respectively.

In Mabalane, both varieties showed serious, but variable necrosis of the leaf margins. This tended to be worse on ICGV-SM 99541 than for Nematil. Tissue samples were taken for analysis as part of an effort to identify the problem. Farmers in Mabalane usually gave two applications of mulch to the relevant treatments because the initial mulch was eaten by termites. This was not a sustainable practice as it was considered as being labor intensive. Another observation was that mulch was always applied after seeding contrary to the idea of applying it before seeding or at seeding so that the residual moisture could be optimized.

More importantly, it was noted from the data that yield levels were too low compared to variety potentials, and this reflected that the season was unfavorable for optimal growth of groundnut in 2007-08. Similar yield trends were made in the previous season when yields were again consistently low.

Table 15: Effects of variety, mulch and fertilizer on groundnut grain and biomass yield (t/ha) during 2007-2008 season in Mozambique

Treatments			**Yield (t/ha)**		
Variety	**Mulch**	**Fertilizer**	**Grain**	**Biomass**	**No. of Plants**
Nematil			0.13	2.99	64219
ICGV-SM 99541			0.13	3.08	86576
	1		0.13	3.03	76338
	2		0.13	3.05	74456
		1	0.14	3.22	78936
		2	0.13	2.99	71859

Sorghum and Cowpea Trials
Sorghum trials were originally planned for Mabalane, but farmers expressed dissatisfaction to grow the crop due to severe bird damage at grain filling stage from past experience. As farmers were not interested in the crop, no sorghum trials were planned for establishment in the 2007-2008 and other subsequent seasons. Instead, some cowpea trials were planned for implementation in Mabalane in the 2007-2008 season, but these were not established due to lack of seed.

Maize Exploratory Trial
As in the previous season, the trial evaluated the effects of two factors each at three levels including: land preparation at three levels; 1) zero tillage, 2) tillage with 3 tons of mulch and 3) use of micro basins, and fertilizer, which was applied at three levels; 1) no fertilizer, 2) 200 kg/ha of 12-24-12 plus 50 kg/ha urea (Total = $47N\text{-}48P_2O_5\text{-}24K_2O$) and 3) compost manure to provide the same rate of nutrients as that of the fertilizer in treatment 2) on maize productivity. The trials were conducted in three districts of Macia, Chokwe, and Mabalane in the Limpopo Basin in Mozambique, but data reported in this section came from trials conducted in Chokwe.

Results and discussion
Data analysis showed that there were no significant differences among water harvesting techniques used as well as fertilizer treatments in terms of their effects on grain yield, total above ground biomass and harvest counts (Table 16). Although fertilizer application did not significantly influenced parameters measured, the zero fertilizer treatment had the lowest grain yield (0.97 kg/ha), above ground biomass (7.90 kg/ha) and number of plants per ha (48314) implying that fertilizer is still one of the most important limiting factors to better maize response in the study areas. The lack of significant effects might be attributed to the limited moisture availability due to the sporadic and early cessation of the rains (end of season drought). The data also shows non- significant interactions between water harvesting technique and fertilizer.

Table 16: Grain yield and above ground biomass (t/ha), and final plant counts of maize under moisture conserving strategies and fertilizer in Mozambique during the 2007-2008 season

Water harvesting	Grain yield	Biomass	Plant counts/ha
1	1.03	8.83	57366
2	1.66	9.88	63978
3	1.11	7.04	31157
Fertilizer			
1	0.96	7.90	48314
2	1.36	8.67	53214
3	1.46	9.82	50974

Groundnut Mother Baby Trials

The groundnut Mother-Baby Trials were conducted to compare the response of two groundnut varieties to water harvesting techniques and fertilizer use. The treatments included were 1. Mulching and no mulching; 2. Fertilizer and no fertilizer application; and 3.Two groundnut varieties. The mulch was at 3 t/ha, and the fertilizer was at 20 kg N /ha; and the two groundnut varieties were Nematil and Mamane. In total, 22 trials were established in Macia, Chokwe and Mabalane.

Results and discussion

Results from this trial showed no significant differences among treatments on their effects on yield and yield components (Table 17). Although this was the case, Nematil gave lower yield, less biomass and lower number of plants per ha. The effect of fertilizer and mulch however, did not lead to any meaningful differences and this could be attributed to the limited moisture as fertilizers and mulch could not work effectively in a failed rainfall season as it was consistently dry limiting fertilizer dissolution and consequent crop uptake and water retention respectively.

More importantly, it can be noted from the data that the yield levels were too low compared to variety potentials and all this reflect the fact that growth factors were not favourable for optimal growth of groundnut. Same observations were made in the previous season when yields were again consistently low.

The non-significance of the treatment differences might have been due to poor management of the trials by the host farmers owing to inadequate supervision by the implementing institutions. Lack of adequate replication was a major setback for trials in Mozambique. Communication barriers also contributed to data collection and reporting flaws as progress reports could sometimes be submitted to the project leader in Portuguese without proper translation into English resulting in inconsistencies in data processing and management.

Table 17: Grain and biomass yield performance (t/ha) of groundnut varieties under mulch or no mulch and fertilizer or no fertilizer conditions in Mozambique during 2007-2008 season

Treatments			**Yield (t/ha) and plant stand**		
Variety	**Mulch**	**Fertilizer**	**Grain**	**Biomass**	**Plants/ha**
1			0.19	2.87	75149
2			0.20	3.10	84175
	1		0.19	2.94	81268
	2		0.13	3.03	78056
		1	0.20	3.08	85146
		2	0.18	2.88	74178

South Africa

Although there were a number of difficult logistical problems experienced during the season especially around the issue of the provision of funds to the RSA-Agricultural Research Council (ARC) and then to Limpopo Department of Agriculture (LDA) the project partners in South Africa managed to implement more than half of the planned trials with a sizeable number of them having been properly implemented and rated as good trials during the 2007-2008 season. The total number of trials planned including replications was eighty (80) and more than fifty (50) trials were established across the three districts. These logistical problems resulted in some of the trials being planted late in the season and such trials did not generally do well. There was again a mid-season drought which affected the Limpopo Province from February 2008 to the end of the season. Trials which were planted earlier in the season however, did very well despite the drought and the results are presented below.

Soil characterization

The results on soil characterization revealed that Sekhukhune has slightly more fertile soils than Mopani and Capricorn. Sekhukhune soils registered higher (25.4 mg/kg of soil P content) than Capricorn (6.4mg/kg) and Mopani (3.7 mg/kg). While there was enough evidence to suggest that the Mopani and Capricorn soils are slightly basic, the soils from Sekhukhune showed to be of a moderately acidic status (Table 18).

Table 18: Variation in chemical properties of soils sampled from the three districts of Sekhukhune, Mopani and Capricorn in the Limpopo Basin during the 2007-2008 season

District	**P**	**K**	**Ca**	**Mg**	**Na**	**pH**	**Total acid**
	mg/kg	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**		**cmol (+)/kg**
Sekhukhune	25.4	93.1	365.3	74.7	16.6	5.7	0.2
Mopani	3.7	245.0	1817.0	760.8	115.2	7.0	0.0
Capricorn	4.6	130.2	641.7	148.0	15.2	6.2	0.0

Quality of the season

The Limpopo Province is generally a dry land environment particularly due to the short rainfall season, relatively high minimum average daily temperatures and a typically low altitude. The 2007-2008 season was generally good in terms of a stable rainfall onset which resulted in satisfactory performance of early planted trials. However, late planted trials met with a mid-season drought which affected their performance. Most of the field crops suffered moisture stress in the Province, but severity varied by Districts; with Capricorn and Mopani being more affected than Sekhukhune and as reflected in the grain yield data.

Maize variety trials

The objective of the Maize variety trials was to compare and demonstrate the yield performance of improved maize varieties with the varieties commonly used by farmers in the three districts of Mopani, Sekhukhune and Capricorn in the Limpopo Basin in South Africa. The trials were laid out in randomized blocks with one replication per site, and four replications per district. Treatments included: one most common farmer variety in the district and three improved open pollinated varieties (ZM 423, ZM 521 and Obatambo).

Results and discussion

The grain yield results of the Maize variety trials evaluated in Capricorn and Mopani showed no significant differences among different maize varieties included in the trials in 2007-2008 season (Table 19). However, the local variety yielded (10%) higher than the highest yielder (ZM 423) among the improved varieties. The improved varieties yielded consistently lower than the local across all sites in Capricorn and Mopani except at Juno where ZM 423 gave 1.7 tons/ha.

While Obatambo and ZM 521 gave grain yields that were lower than the mean for the two districts, ZM 423 out yielded the mean for the two districts.

Table 19: Grain yield (t/ha) of four improved maize varieties compared to a local variety in Capricorn and Mopani Districts

	Capricorn		**Mopani**		
	Gordon	**Juno**	**Masabalele**	**Nkomo**	**Mean**
ZM423	0.55	1.66	0.51	0.95	0.92
ZM521	0.73	0.30	0.18	0.57	0.45
Obatambo	0.92	0.23	0.11	0.48	0.44
Local	0.52	1.36	1.18	1.01	1.02
Mean	0.68	0.89	0.50	0.75	0.70
Significance					NS
CV%					50.0

Results from Sekhukhune are given in Table 20. Here the maize varieties gave generally higher grain yield in Sekhukhune than in either Capricorn or Mopani Districts as observed earlier (Table 19). Although the yield differences were not significantly different between the varieties, all improved varieties yielded higher than the local with SAM 1109 giving grain yields that were 25% higher than the mean for the district. This implies that the improved maize variety (SAM 1109) has considerable potential for contributing to water productivity in the Limpopo Province. The results in Table 20 suggest that crop water productivity in the Limpopo Province, particularly in Sekhukhune District could be improved through use of improved maize varieties by farmers.

Table 20: Grain yield performance (t/ha) of four improved maize varieties compared to a local variety in Sekhukhune District in the Limpopo Basin during 2007-2008 season

	Sekhukhune		
Variety	**Ga-Marishane**	**Platklip**	**Mean**
ZM423	2.84	1.35	2.09
ZM521	2.91	1.94	2.42
SAM1109	3.95	2.17	3.06
Local	2.67	1.77	2.22
Mean	3.09	1.81	2.45
Significance			NS
CV%			10.6

Sorghum variety trials

The objective of the Sorghum variety trials was to compare the yield performance and demonstrate improved sorghum varieties with the varieties commonly used by farmers in Sekhukhune district in the Limpopo Basin in South Africa. The trials were laid out in randomized blocks with one replication per site, and four replications per district. Treatments included: one most common farmer variety in the district and four improved varieties (Macia, M4, M105, and M153).

Results and discussion

A total of five sorghum varieties were evaluated in Sekhukhune District during the 2007-2008 season. The results in Table 21 revealed that although the differences in grain yield between the five varieties were not significant, some varieties (M48, M105, M153) gave yield in excess of 1 ton/ha than others (Local, Macia). The variety, M105 outperformed all the other varieties and registered a 21% higher grain yield compared to the trial mean. However, harvest plant stand remarkably revealed significant (Fpr=0.05) differences between varieties, despite the variety with the highest grain yield (M105) not necessarily being the one with the highest number of plants at harvest. Since sorghum is often heavily seeded by farmers in anticipation that the plants would be thinned to the recommended population after establishment, the results suggest that the fewer plants that survived up to harvest for M105 compared to the rest of the varieties meant that there was no competition for resources for growth. In general, all improved test varieties out yielded the local except Macia which gave yield lower than the Local and lower than the trial mea. Again these results show the potential of increasing sorghum productivity with use of improved varieties.

Table 21: Grain yield of four improved sorghum varieties compared to a local variety in Sekhukhune District

	Sekhukhune	
Variety	**Grain yield t/ha**	**Harvest stand**
Local	0.73	924
Macia	0.69	473
M48	1.06	680
M105	1.13	324
M153	1.06	817
Mean	0.93	644
Significance	NS	*
$LSD_{0.05}$	0.69	361
CV%	26.8	20.2

Groundnut variety trials
The Groundnut variety trials aimed at comparing and demonstrating the yield performance of improved groundnut varieties with the varieties commonly used by farmers in Mopani district in the Limpopo Basin in South Africa. The trials were laid out in randomized blocks with one replication per site, and four replications per district. Treatments included: one most common farmer variety in the district and four improved groundnut varieties. However, three trials were implemented in Mopani District during the 2007-2008 season, but none were properly managed to generate usable yield data. Crop establishment was extremely poor, resulting in poor yields and absence of meaningful data collection.

Maize cowpea intercrops by planting method by fertilizer trial
The Maize intercrop by planting method by fertilizer trials were set up to evaluate the total productivity of a maize/cowpea intercrop with that of a sole maize crop under four management options involving fertilizer and planting configuration. The trials were implemented in Mopani and Capricorn Districts based on a split-split block design with one replication per site, and four replications per district. Treatment combinations included: two levels of planting method (M1= broadcast and M2=row seeded), two levels of cropping pattern (C1= monocrop of maize and C2=maize/cowpea intercrop) and two levels of fertilizer (F1= common farmer fertilization amounts and strategy designated as the most common fertilizer amount and fertilization strategy used by farmers in the District, and maintained across sites in each district and varying the amount applied according to district and F2= 200 kg/ha basal fertilizer broadcast and incorporated). An improved open pollinated variety of maize (ZM 521) and a common farmer's cowpea variety were used in the trials.

Results and discussion
The results from trials to evaluate the total productivity of a maize/cowpea intercrop as compared to that of a sole maize crop under four management options with different fertilizer levels and planting configuration are given in Table 22. The interaction of the three factors under evaluation was not significant, neither were the effects of each one of the individual factors in influencing water and crop productivity in Mopani and Sekhukhune Districts during the 2007-2008 season. However, row seeded maize with 200 kg/ha of broadcasted or incorporated basal fertilizer (M2C1F2) gave the highest (1.18 t/ha) mean maize yields. The row seeded maize/cowpea intercrop basal dressed with 25 kg/ha of fertilizer without any top dressing (M2C2F1) gave the lowest (0.55 t/ha) mean maize yield. Mean maize grain yield was generally higher under sole cropping as compared to intercropping. Fertilizer increased mean maize yield by 16%. Broadcasting maize under either sole cropping or intercropping with different levels of fertilizer application did not seem to have any advantageous effect on maize yield. However, the grain yields were generally lower and hardly in excess of one t/ha for many of the main factor effects including some interactions. This might imply that the

trials were drastically affected by the mid season drought which interfered with cob formation and grain filling in most parts of the Limpopo Basin.

Table 22: Effect of seeding method, planting configuration and fertilizer on grain yield (t/ha) of improved maize in Mopani and Sekhukhune Districts in the Limpopo Basin during 2007-2008 season

			Mopani	Sekhukhune				Overall
M*	**C+**	**F#**	**Nkomo**	**Thotho**	**Platklip**	**Marishane**	**Mean**	**Mean**
1	1	1	0.09	0.97	1.35	0.32	0.88	0.68
1	1	2	0.17	1.74	0.41	1.05	1.07	0.85
1	2	1	0.20	2.09	0.37	0.35	0.94	0.75
1	2	2	0.13	1.74	0.24	0.22	0.73	0.58
2	1	1	0.16	1.25	1.74	0.51	1.17	0.91
2	1	2	0.32	1.73	1.74	0.94	1.47	1.18
2	2	1	0.24	0.69	0.84	0.43	0.65	0.55
2	2	2	0.19	1.84	0.48	0.63	0.98	0.79
		Mean	0.19	1.51	0.90	0.56	0.99	0.79
1			0.15	1.64	0.59	0.49	0.90	0.72
2			0.23	1.37	1.20	0.63	1.07	0.86
	1		0.19	1.42	1.31	0.71	1.15	0.91
	2		0.19	1.59	0.48	0.41	0.83	0.67
		1	0.17	1.25	1.07	0.40	0.91	0.73
		2	0.20	1.76	0.72	0.71	1.06	0.85
Method							NS	NS
Pattern							NS	NS
Fert.							NS	NS
M x P							NS	NS
M x F							NS	NS
P x F							NS	NS
CV%								47.6

*Seeding method where M1 stands for broadcasting; M2 stands for row seeding
+Planting configuration where C1 stands for sole maize; C2 stands for maize intercropped with cowpea
#Fertilizer level where F1 stands for 25 kg/ha of fertilizer without top dressing; F2 stands for 200 kg/ha of broadcasted or incorporated basal fertilizer

Sorghum cowpea intercrop by planting method by fertilizer trial

The sorghum intercrop by planting method by fertilizer trials were set up to evaluate the total productivity of a sorghum/cowpea intercrop with that of a sole sorghum crop under four management options involving fertilizer and planting configuration. The trials were implemented in Sekhukhune District based on a split-split block design with one replication per site, and four replications per district. Treatment factor combinations were same as those tested in the Maize intercrop by planting method by fertilizer trials. An improved sorghum variety (Macia) and a common farmer's cowpea variety were used in the trials.

Results and discussion

Only one trial to evaluate the total productivity of a sorghum/cowpea intercrop as compared to that of a sole sorghum crop under four management options with different fertilizer levels and planting configuration was harvested in Sekhukhune. Due to the failure to achieve adequate degrees of freedom for meaningful statistical analysis, it was not possible to draw any statistically sound inferences from the results, except for the trend in the mean response to the various treatment factors.

From the results in Table 23, the highest sorghum grain yield (1.31 t/ha) was obtained for broadcasted sole sorghum with 200 kg/ha of fertilizer (M2C1F2), seconded by a broadcasted sorghum/cowpea intercrop (1.14 t/ha) where 200 kg/ha of fertilizer was applied (M1C2F2). However, growing a sorghum intercrop with cowpea in rows with 25 kg of basal fertilizer without top dressing (M1C2F1) gave the lowest grain yield (0.27 t/ha). While this could be attributed to competing demands by sorghum and cowpea for moisture and nutrients in the soil in the absence of fertilizer, the result might also indicate that there is some degree of sensitivity of sorghum to competition when intercropped with cowpea. Intercropping sorghum with cowpea reduced sorghum yield from 0.83 t/ha to 0.71 t/ha, and the effect of fertilizer resulted in doubling the sorghum yield. Other treatment factor combinations (M1C1F1, M1C1F2 and M2C2F1) gave fairly good sorghum grain yield in Sekhukhune District.

Table 23: The effect of planting pattern, seeding method and fertilizer application on grain yield of sorghum for Ga-Maloma site in Sekhukhune District

			Sekhukhune (Ga-Maloma)	
M*	**C+**	**F#**	**Grain yield (t/ha)**	**Harvest stand**
1	1	1	0.72	55
1	1	2	0.83	59
1	2	1	0.27	899
1	2	2	0.73	696
2	1	1	0.46	73
2	1	2	1.31	524
2	2	1	0.68	750
2	2	2	1.14	105
		Mean	0.77	395
1			0.64	427
2			0.90	363
	1		0.83	178
	2		0.71	612
		1	0.53	444
		2	1.00	346

* Seeding method where M1 stands for broadcasting; M2 stands for row seeding;
+ Planting configuration where C1 stands for sole sorghum; C2 stands for sorghum intercropped with cowpea
# Fertilizer level where F1 stands for 25 kg/ha of fertilizer without top dressing; F2 stands for 200 kg/ha of broadcasted or incorporated basal fertilizer

A detailed examination of the number of plants at harvest revealed that there was a tendency to have a high population of plants under broadcasting method than under row seeding. The mean number of plants at harvest was highest (899) with a broadcasted sole sorghum crop but with 25 kg/ha of basal fertilizer without top dressing (M1C1F1) and lowest (55) where sole sorghum was seeded in rows with 25 kg/ha of basal fertilizer. The results also suggest that the low grain yield obtained where the harvest plant stand was highest (M1C2F1) might imply presence of stiff competition for growth resources which might have ensued among the plants in the populous treatment resulting in poor seed set and low grain yield.

Maize water harvesting by plant population by fertilizer trials

The Maize water harvesting by plant population by fertilizer trials aimed at evaluating the effects and interaction of water harvesting (tied ridges), plant population and fertilizer level on maize yield and water productivity. The trials were laid out in Split-split plot design with one replication per site and four replications per district across three districts of Mopani, Sekhukhune and Capricorn in the Limpopo Basin in South Africa. Treatment combinations included: water harvesting techniques at two levels (W1= farmers' normal land preparation and W2= tied ridges), plant population at two levels (P1= 22 222 plants/ha based on 90 cm row spacing by 50 cm intra-row spacing with two seeds/hill thinned to one plant per hill when plants are 15-20 cm tall, and P2= 44 444 plants/ha 44,444 plants based on 90 cm row spacing by 25 cm intra-row spacing with two seeds/hill thinned to one plant per hill when plants are 15-20 cm tall, and fertilizer applied at two levels (F1=common farmers' rate and application method, and F2=200 kg/ha basal fertilizer followed by top dressing with LAN at 100 kg/ha.

Results and discussion

Analysis of the grain yield data revealed significant (Fpr $\leq$ 0.01) effects of fertilizer, considering data from both Capricorn and Mopani Districts (Table 24). The application of fertilizer at 200 kg/ha gave significantly higher grain yield than the lower rate of 25 kg/ha of basal dressing fertilizer without top dressing. The application of 200 kg/ha of basal dressing fertilizer increased maize grain yield by 35% over the lower rate of 25 kg/ha in the absence of top dressing. Although none of the interactions of water harvesting, plant population and fertilizer was significant, the effect of some interactions gave higher mean grain yield than others. The highest grain yield in Capricorn (2.80 t/ha) was realized from farmers normal land preparation at 44 444 plant/ha with 200 kg/ha of basal dressing fertilizer, but without top dressing (W1P2F2) while tied ridges used in combination with high plant population and 200 kg/ha of basal dressing fertilizer (W2P2F2) registered highest grain yield in Mopani. The results also revealed a generally low yield potential (>1.02 t/ha) for maize productivity in Mopani than in Capricorn where most treatment combinations gave maize grain yield in excess of 2.00 t/ha. Grain yield was lowest (1.10 t/ha) when maize was grown under the farmers normal practice of land preparation with 25 kg/ha of fertilizer applied without top dressing, maintaining a plant population of 44 444 plants/ha (W1P2F1). This might imply that use of higher plant population with high fertilizer rate irrespective of water harvesting strategy is likely to increase crop water productivity in moisture limited environments, typical of the Limpopo Basin. The results however, suggest that this might be true in seasons where moisture is adequate, otherwise water harvesting has consistently been associated with higher yields in similar trials.

Table 24: Effect of water harvesting on grain yield performance (t/ha) of maize under different plant population and fertilizer regimes across Capricorn and Mopani Districts

			Capricorn				Mopani			Overall
W	**P**	**F**	**Ga-Seema**	**Juno**	**Ga-Ramoswane**	**Mean**	**Nkomo**	**Hlaneki**	**Mean**	**Mean**
1	1	1	2.32	1.78	1.37	1.82	0.10	0.48	0.29	1.31
1	1	2	1.74	2.08	2.38	2.07	0.04	1.74	0.89	1.68
1	2	1	1.14	1.93	1.51	1.53	0.10	0.24	0.17	1.08
1	2	2	2.75	2.82	2.70	2.76	0.12	0.37	0.24	1.92
2	1	1	3.51	1.06	2.65	2.40	0.16	0.84	0.50	1.77
2	1	2	1.84	2.86	3.00	2.57	0.04	1.35	0.69	1.94
2	2	1	1.86	1.36	2.99	2.07	0.17	0.41	0.29	1.48
2	2	2	3.31	1.88	2.79	2.66	0.15	1.74	0.94	2.09
		Mean	2.31	1.97	2.43	2.24	0.11	0.90	0.50	1.66
1			1.99	2.15	1.99	2.05	0.09	0.71	0.40	1.50
2			2.63	1.79	2.86	2.43	0.13	1.09	0.61	1.82
	1		2.36	1.94	2.35	2.22	0.08	1.10	0.59	1.68
	2		2.27	2.00	2.50	2.25	0.13	0.69	0.41	1.64
		1	2.21	1.53	2.13	1.96	0.13	0.50	0.31	1.41
		2	2.41	2.41	2.72	2.51	0.09	1.30	0.69	1.91
Water harvesting strategy						NS			NS	NS
Population						NS			NS	NS
Fertilizer						*			NS	**
M*P						NS			NS	NS
M*F						NS			NS	NS
P*F						NS			NS	NS
$LSD_{0.05}$										0.42
CV%										41

W1 stands for farmer's normal land preparation usually flat planting;
W2 stands for Tied ridges
P1stands for 22 222 plants/ha (90 cm between rows, 50 cm between planting stations with two seeds/hill thinned to one plant per hill when plants were 15-20 cm tall;
P2 stands for 44 444 plants/ha 44,444 plants/ha (90 cm between rows, 25 cm between planting stations with two seeds/hill thinned to one plant per hill when plants were 15-20 cm tall
F1 - 25 kg/ha of fertilizer without top dressing;
F2 - 200 kg/ha of broadcasted or incorporated basal fertilizer

Maize water harvesting by weed control by fertilizer trial

The Maize water harvesting by weed control by fertilizer trials were a modification introduced to the water harvesting by plant population by fertilizer trials based on the challenges of maintaining adequate plant population under designated planting configurations. The trials aimed at comparing the effect of water harvesting options for capturing and conserving moisture, weed management and fertilizer regimes, and their interactions on maize crop water productivity in three districts of Mopani, Sekhukhune and Capricorn in the Limpopo Basin in South Africa during the 2007-2008 season. A randomized complete block design with one replication per site and four replications per district was used. Treatment factors evaluated involved farmers' normal land preparation method of flat planting, planting basins, tied ridges, mulching at 3 t/ha applied as early as possible and seeded without soil tillage using a pointed stick or jab planter. The trials were basal dressed with 200 kg/ha basal fertilizer dressing followed by top dressing with

2 bags/ha nitrogen fertilizer (LAN) at the 5−6 leaf stage. An improved open pollinated maize variety (ZM 521) was used in all trial sites.

Results and discussion

According to yield results presented in Table 25, it was surprising to note the absence of any significant effects and interactions of the factors on maize yield performance across the two districts of Capricorn and Mopani. Although the trial generally gave satisfactory mean maize yields of about 1.01 t/ha, site specific challenges were evident as some sites registered disappointingly lower mean grain yields than the others. One site in Capricorn (Lonsdale) and another site in Mopani (Hlaneki) consistently recorded lower yields across all treatment factors. This could be due to site-specific soil conditions at these sites with lower moisture retention capacity and greater effect of mid-season drought.

While tied ridges, weeding twice and applying 200 kg/ha basal dressing and 100 kg/ha of Urea (W2C2F2) gave the highest mean grain yield (1.36 tons/ha), the yield was lowest (0.82 tons/ha) for the treatment that involved the lower rate (25 kg/ha) of fertilizer (W2C2F1). However, similarly impressive maize yield was obtained with tied ridges, weeding once and application of 25 kg basal dressing (W2C1F1), Farmers' normal land preparation, weeding once and the higher fertilizer rate (W1C1F2) and Farmers normal land preparation, weeding once and 25 kg basal dressing (W1C1F1). Water harvesting using tied ridges enhanced maize yields by 8% over untied ridges (Farmers normal land preparation) while weeding twice positively gave a 6% contribution to maize yield performance under dry land conditions. Higher fertilizer rate (F2) resulted into a 11% yield increase over Lower fertilizer rate (F1) portraying that farmers could still increase crop yield through enhancement of water productivity by applying a holistic approach to crop management and timely weed control.

Table 25: Effect of water harvesting on maize grain yield under different weed control and fertilizer regimes across Capricorn and Mopani Districts

			Capricorn				Mopani	**Overall**
W$^-$	**C$^+$**	**F$^\#$**	**Lonsdale**	**Gordon**	**Juno**	**Mean**	**Hlaneki**	**Mean**
1	1	1	0.22	1.92	1.56	1.23	0.42	1.03
1	1	2	0.13	1.36	2.07	1.19	0.85	1.10
1	2	1	0.14	1.59	1.14	0.95	0.57	0.86
1	2	2	0.10	1.27	1.59	0.99	0.58	0.89
2	1	1	0.16	1.86	1.72	1.25	0.71	1.11
2	1	2	0.16	1.22	1.90	1.09	0.38	0.91
2	2	1	0.09	1.50	1.11	0.90	0.58	0.82
2	2	2	0.26	1.57	2.60	1.48	1.00	1.36
		Mean	0.16	1.54	1.71	1.14	0.64	1.01
1			0.15	1.53	1.59	1.09	0.61	0.97
2			0.17	1.54	1.83	1.18	0.67	1.05
	1		0.17	1.59	1.81	1.19	0.59	1.04
	2		0.15	1.48	1.61	1.08	0.68	0.98
		1	0.15	1.72	1.38	1.08	0.57	0.96
		2	0.16	1.36	2.04	1.19	0.70	1.07
Method						NS		NS
Weed Control						NS		NS
Fertilizer						NS		NS
M*P						NS		NS
M*F						NS		NS
P*F						NS		NS
CV%								50

W1 stand for normal farmer land preparation, W2 means tied ridges
C1 stands for weeding only once, C2 means weeding twice
F1 stands for lower rate of fertilizer (25 kg/ha), F2 stands for higher rate of fertilizer (200kh/ha basal and 100 kg/ha top dressing)

Two trials were not implemented namely: the Maize Variety x Water Harvesting x Fertilizer and the Water Harvesting strategies at the University of Limpopo Farm due to logistical reasons. The land allocated for the trials was not ready on time for planting and it was only made available too late to for planting.

Summary conclusions for RSA

There was tangible improvement in the coordination and overall management of trials by partners in South Africa during the 2007-2008 season despite continued many logistical and technical challenges. Out of a total of 83 planned trials, 66% were seeded, but many of these were seeded late due to an erratic onset of rains in the three districts. Late planting of the trials consequently resulted in very poor germination and emergence in many fields. While about 50% of the established trials were harvested, only about 36% of the trials harvested produced analyzable data because of the unfamiliarity of Extension staff with data collection at harvesting and unacceptable changes to the protocols provided.

In many of the cases, the yield results were not significant for the interaction of factors and in some cases the individual factor main effects did not come out significant. Trends from mean yields seemed to suggest that effects of water harvesting strategies, fertilizer application, cropping pattern, seeding method and weed control strategies were variable and site-specific. The lack of significance might have been a result of inadequate replications, poor trial management by farmers or a combination of several other factors that increased the magnitude of error and reducing the sensitivity of the analysis. However, information from the analysis of data collected from the wide range of trials implemented provided useful highlights for strengthening the technological platform for facilitating farmer adoption of innovations for improving water productivity in the Limpopo Basin.

Zimbabwe

Monitoring of the trials was not possible in the Limpopo Basin in Zimbabwe during the 2007-2008 season because of political problems related to the National elections in some of the rural areas where the project was being implemented. Trials were, however, established in all the three districts to varying degrees of success of implementation. Logistical problems and lack of transport continued to be important limitations to the successful and timely installation of the some of the trials. These problems were exacerbated by other problems, including the relatively late delivery of inputs to the sites (most inputs were only delivered in mid-December, due largely to the difficulty of accessing fertilizer) and to some degree by the splitting of the Ministry of Agriculture Research and Extension Branch (AREX) into Agricultural Extension (AGRITEX) and Agricultural Research for Development (ARD) as separate entities

Quality of the season

The 2007-2008 rainy season had a very late onset, delaying up to the end of November. Rains started on December 4, and poured continuously without any break until the end of January 2008. This was immediately followed by a dry spell up to the end of the season. During the wet period it was too difficult to carry out critical farm operations such as planting, land preparation and weeding. Some trials were not planted especially in Chiredzi and Matobo where trial plots were not established before the rains and attempts to establish the trials after the onset of the rains was futile. In almost all sites, crops wilted and no yield data was obtained. The season in 2007-08 therefore was a failed season due to drought, most trials dried before flowering or maturity, and only biomass data was available for a few trials.

Although total rainfall received for the season was normal, the distribution was problematic. Figure 3 illustrates the average monthly rainfall amount and the distribution in Gwanda and Matobo in 2007-2008 season.

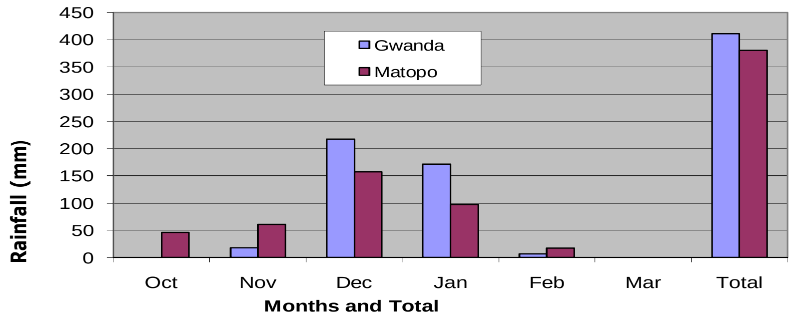


Figure 4: Rainfall distribution for Matobo and Gwanda districts during 2007-2008 season

Water use efficiency trials

In order to identify potential water harvesting methods that could lead to better crop performance in the dry environments of Chiredzi, Gwanda and Matobo Districts in the Limpopo Basin in Zimbabwe, different crop species (maize, sorghum, pearl millets and groundnuts) were evaluated under different water harvesting options. Water use efficiency trials aimed at quantifying the crop and water productivity of different crop species under different management practices in order to generate data for the validation of the crop/soil simulation models. A total of ten trials were conducted in Zimbabwe with a spread of four trials in Chiredzi, four in Gwanda and two trials in Matobo districts. All the trials were laid out in randomized blocks with three replications per site and incorporated a 2 x 3 factorial treatment structure with two management treatments and three crop species.

Treatment factors comprised the crop species planted according to the farmers' normal practice of flat planting compared to tied ridges and planting basins and Zai pits. Mulch was also applied as a treatment at 3 t/ha before seeding to each crop. Sorghum and groundnut were planted on tied ridged furrows. Plant population and planting configuration depended on crop species and water harvesting treatment. The crop varieties used included: ZM 421 for maize, Macia for sorghum, PMV 3 for millet and Ilanda for groundnut, respectively. Except for groundnut, top dressing with nitrogen was done at the 5-6 leaf stage. Gypsum was applied to groundnut at the rate of 300 kg/ha as a split dressing at flowering and pegging. Manual weed control was emphasized in all treatments.

Results and discussion

Results on above ground biomass revealed significant differences ($P \leq 0.001$) for the different water harvesting techniques and crop species (Figure 5). Maize planted in basins and Zaipits, and maize basins and mulch gave almost the same amount of biomass yield. The lowest maize biomass yield was realized from the maize mulch treatment. Tied ridges generally had a positive effect on amount of biomass produced by Sorghum, Pearl millet and Groundnut. However, biomass yield from basins, mulch and basins for Sorghum, Groundnut and Pearl millet, respectively were lower compared to tied ridges. These results may indicate that tied ridges retained moisture better that other treatments, implying that crop water productivity could be enhanced if farmers adopted the practice of tied ridging.

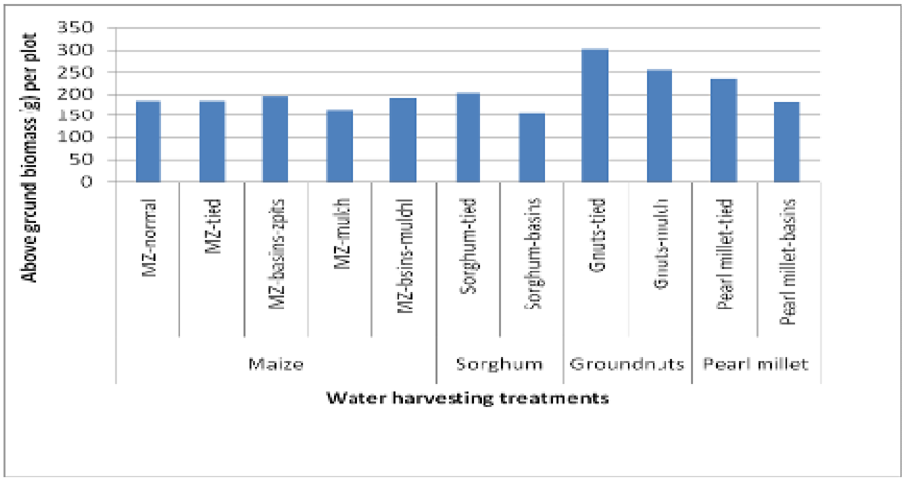


Figure 5: Above ground biomass for crop species and water harvesting methods in Gwanda 2007–2008 season

Crop species by variety trials

The Crop species by variety trials aimed to evaluate the scale of genotypic variation in water use efficiency between three varieties of maize, sorghum and groundnuts representing the commonly used varieties at the time of project implementation in the Limpopo Basin, the best released variety available and a potential variety selected for its water use efficiency and yield under conditions similar to those of the target areas. A total of 12 trials, two sites each in two villages in Chiredzi, Gwanda and Matobo districts were conducted. The trials were laid out as a split plot in randomized blocks with three replications maintaining crop species as main plots and the varieties as sub-plot treatments.

Three varieties comprising one commonly grown hybrid (SC 513), ZM 421 and ZM 309 were used for maize in all districts. A commonly used variety (SV 2), Macia and SV 4 were used for sorghum while Ilanda, Mwenje and Natal common were used for groundnuts across the three districts.

Results and discussion

Results showed highly significant (P ≤0.001) differences in initial plant and final plant stand among the crop species (Table 26). These results were expected as the crop species involved differ in plant spacing resulting from different seed rates. However, varieties within each crop species did not differ on initial and final plant stands as the same seed rate were used within each of the crop species. Above ground biomass significantly (P ≤ 0.01) differed among crop species, again depicting the differences in growth habit and rate of biomass accumulation. However, no significant differences were observed within varieties of the same crop species. This was rather surprising as varieties of the same species can still differ due to genotypic differences which may determine the biomass accumulation rate. No grain yield data was obtained from the trials due to severe end of season drought in Zimbabwe. Therefore, it not possible to identify the best performing variety based on biomass due to the failure of the crops to produce grain yield.

Table 26: Initial and final stand counts and above ground biomass (g/plot) averaged across Gwanda and Matobo districts in Zimbabwe during 2007-2008 season

Crop Species	Variety	Initial stand	Final stand	Biomass (g/plot)
Maize	SC 543	62	56	219
	ZM 421	63	57	213
	ZM 309	60	53	242
	Mean	62	55	225
Sorghum	SV2	86	74	339
	Macia	84	71	323
	SV4	78	70	278
	Mean	83	72	313
Groundnut	Natal Common	118	95	307
	Ilanda	113	102	291
	Famers Local	118	105`	360
	Mean	117	101	319
L.S.D $_{0.05}$				
Variety		**8.11**	**8.77**	**64.9**
CV %		13.7	17.1	33.5

Crop species by nitrogen fertilizer trials

The objective of the Crop species by nitrogen fertilizer trials was to quantify the effect of nitrogen fertilizer on water use efficiency in maize and sorghum. Six trials were conducted in Chiredzi, Gwanda and Matobo districts of the Limpopo Basin in Zimbabwe. Two villages were selected for trials per district and one trial was established in each village using a split plot design with three replications. Crop species comprised the main plots while nitrogen levels were sub-plots. Two improved varieties comprising ZM 421 and Macia for maize and sorghum respectively were used in Chiredzi. In addition, pearl millet was included for trials in Gwanda and Matobo using the improved variety PMV 3. Nitrogen was applied at four levels, which included: top dressing with 0 kg/ha N, micro-dosing with 17.5 kg/ha N (equivalent to 1 bag of 50 kg/ha), 35 kg/ha N equivalent to 2 bags/ha, and 52.5 kg/ha N equivalent to 3 bags/ha. Ammonium Nitrate was used as the source of nitrogen in all the trial sites.

Results and discussion

The results showed no significant differences in all parameters as determined by crop species and nitrogen levels. Above ground biomass actually showed a declining trend as N levels were increased from 0 to 52.5 kg N per ha (Table 27). This trend might mean that in very dry conditions, use of N fertilizer may not be cost-effective because moisture becomes the greatest limiting factor rather than soil fertility. The up take of fertilizer by the plants must have been severely limited due to lack of soil moisture resulting from the severe drought. In this case, no meaningful conclusions could be drawn as the results were confounded by the drought condition.

Table 27: Effect of varying nitrogen fertilizer levels on biomass (g/plot) production of different crop species averaged across Gwanda and Matobo districts in Zimbabwe during 2007-2008 season.

Crop species	Quantity of nitrogen applied (g/plot)				Mean
	0	**17.5**	**35**	**52.5**	
Maize (ZM 421)	218	220	132	110	**170**
Sorghum (Macia)	157	190	158	122	**157**
Pearl millet (PMV 3)	150	200	165	200	**179**
Mean	**175**	**203**	**152**	**144**	

Main challenges in the season in Zimbabwe

The general elections which were held in March 2008 also posed a security risk to most people for field work as it was followed by controversy and uncertainty of the results which brought all field activities to a standstill for a long period of time. Movement within the rural areas where the trials were planted was restricted and it was difficult for outsiders to travel to the rural areas to monitor project activities.

Due to the difficult economic situation the country was going through earlier and in 2008, project activities were adversely affected by low staff morale and high staff turnover from government leading to inadequate staff to implement trials.

Trials implemented in 2008-09 season

Three crop productivity increasing factors (varieties, soil fertility and water management) continued to be tested in the three countries in the 2008-09 season. Achievements made are presented by trial type by country as detailed bellow.

Mozambique

In Mozambique, a planning meeting for the season was held in Chokwe on June 19-22, in 2008. During this meeting, it was agreed that, Groundnut mother trial, Groundnut variety and nutrient trial, Maize variety trial, Maize exploratory trial, Intercrop and Rotation trial, Sorghum planting method trial, Cowpea mother trial and Crop species by variety by water harvesting trial be conducted.

Despite the timely land preparation and plot lay outs in the season as agreed in the planning meeting, erratic rainfall onset led to many trials not being implemented. A total of 32 out of the planned 61 trials were planted in Chokwe, Macia and Mabalane Districts. Four of the planted trials were lost due to drought before harvest.

Groundnut variety by mulch by fertilizer trials

The objective of this trial was to evaluate the relative importance of mulch (moisture capture and savings) and fertilizer in determining yield and water productivity in two varieties of groundnuts, and the interactions between these three factors.

The trial was planted in Macia and Mabalane Districts. Three factors (variety, mulching, and fertilizer) were laid out in a randomized complete block design as a 2 x 2 x 2 factorial with six replications using farmers as replications. Groundnut varieties used were; Nematil (V1) ICGV – SM 99541 (V2), mulching was at two levels (1= without mulch, 2= 3 ton/ha mulch) and fertilizers were at two levels (1= without fertilizer, 2= 200 kg/ha 12-24-12 of compound fertilizer).

Results and discussion

Results from the trial showed no significant differences in harvest counts and total biomass among all factors except for marginal differences ($P \leq 0.05$) in total biomass between sites (Table 28). There was more biomass produced at Mangol as compared to Chitlangol. Grain yield results however showed highly significant differences ($P \leq 0.001$) between sites and slight significant differences ($P \geq 0.05$) between varieties. Nematil out-yielded ICGV SM 99541 by 29% reflecting differences in the yield potential between the two varieties. These results suggest that more gains in groundnut yield could be realized by proper choice of variety and accurate targeting to sites.

Table 28: Harvest counts and grain yield (t/ha), and total biomass (t/ha) of groundnut as affected by treatments

	Treatments			Yield and yield components		
Site	**Variety**	**Mulch**	**Fertilizer**	**Harvest count**	**Grain yield (t/ha)**	**Biomass (t/ha)**
1				132	0.62	2.82
2				119	0.30	3.23
	1			128	0.54	3.11
	2			125	0.42	2.90
		1		126	0.50	2.90
		2		127	0.45	3.10
			1	142	0.50	3.16
			2	111	0.46	2.84

Varieties: 1- Nematil, 2- ICGV SM 99541 Sites: 1- Chitlango , 2-.Mangol

Groundnut exploratory nutrient trial

The objective of the groundnut exploratory trial was to evaluate the effect, importance and possible interactions between phosphorus (P), potassium (K) and calcium (Ca) in determining groundnut yield and water productivity in Macia at six farmers' fields in Macia.

A Randomized blocks design in a 2 x 2 x 2 factorial for Phosphorus (1 =0kg/ha P, 2 =100 kg/ha Tripple supper phosphate), Potassium (1= 0 kg/ha K, 2 =50kg/ha KCl) and Calcium (1 = 0 kg/ha Ca, 2 = 300 kg/ha $CaSO_{4\ (gypsum)}$)

Results and discussion

Results from the groundnut exploratory trial showed no significant differences ($P \leq 0.05$) in harvest counts, grain yield and total biomass among all factors (Table 29). These results indicate that P, K and Ca might not be limiting nutrient element in the soils of Macia District. This is however strange in that sandy soils like those in Macia could have been lacking these elements and should have therefore shown yield response when these elements were applied. Probably, factors other than the three elements applied influenced this outcome. The generally low yields might suggest that there indeed were other factors determining the groundnut yield. Being a dry season, moisture availability could be the reason for lack of response.

Table 29: Performance of groundnut varieties under different fertilizer regimes

Treatments			Yield and yield components		
Phosphorus	Potassium	Gypsum	Harvest counts	Grain yield (t/ha)	Biomass (t/ha)
1			105	0.44	3.06
2			92	0.42	1.77
	1		98	0.45	2.72
	2		100	0.41	2.11
		1	102	0.44	2.68
		2	95	0.42	2.16

Pigeonpea maize intercropping trial

The objective of the pigeonpea–maize intercropping trial was to evaluate the productivity of two pigeon pea varieties each with and without fertilizer application, and in both pure and intercropped stands with maize. The secondary objective was to demonstrate to farmers in Mabalane, the benefits of growing pigeonpea.

The trial was conducted in Mabalane and Chokwe Research Station as a Randomized Complete Block design with 2 x 2 x 2 factorial and 6 replications. Pigeonpea varieties used were; (1) ICEAP 00040 and (2) ICEAP 00020; these long duration pigeonpea varieties are being used for production in Mozambique though not yet released. The three factors were: Two Varieties (1. 00040 and 2. 00020), Two cropping systems (1. Pure stand and 2. intercrop with maize) and then two fertilizer levels (1. No fertilizer and 2. 200 kg/ha 12-24-12)

Results and discussion

Only maize yield data was given and analyzed. Maize yield showed no significant differences between maize in pure stand and maize in intercrop with pigeonpea; an indication that there was no competition exerted by the pigeonpea on maize. If pigeonpea data had been provided, it would have been possible to analyze the performance of pigeonpea in the intercrop plant arrangement. Pigeonpea yield data was not yet ready at the time the report was submitted. This was so because pigeonpea had not given pods during the data collection trip as it matures late in the season.

Maize legumes intercropping trial

The objective of the trial was to assess different legume intercrops and rotations with maize and evaluate the total productivity of these systems. It was conducted at on-station at Estacao Agraria Chokwe and it included a number of legumes; Groundnut, Cowpea and Pigeonpea. The design was a single factor design laid out in a Completely Randomized design. The trial had 10 treatments as follows: 10 Maize only in rows, 2) Maize/Groundnut intercrop with farmers' planting arrangement, 3) Maize/Groundnut intercrop in rows, 4) Maize/Cowpea intercrop with farmers' planting arrangement, 5) Maize/Cowpea intercrop in rows, 6) Maize/Pigeonpea intercrop with farmers' planting arrangement, 7) Maize/Pigeonpea intercrop in rows, 8) Groundnuts in rows, 9) Cowpea in rows, 10) Pigeonpea in rows.

Results and discussion

Results of the maize legume intercropping showed highly significant ($P < 0.001$) differences between treatments. Comparison here should be made between the same crop species but grown with another crop. Significant differences in yield were expected among crop species due to the differences in their yield potential (Table 30). Note however should be taken of the difficult to explain the lower maize yield in the maize cowpea intercrop as the cowpea was not expected to exert any shading to the maize. By implication, the lower maize yield could mistakenly be attributed to competition yet that's not the case. Pigeonpea yield data was not given probably because the pigeonpea did not give yield due to the end of season drought that affected the area. The low groundnut yield in the pure groundnut stand was a result of poor plant establishment and no seed was available for replanting or supplying. There was no significant difference between maize in pure stand and maize in intercrop with pigeonpea indicating that there no competition for resources between the two crops.

Table 30: Grain yield of maize and different legume crop species under intercropping and sole cropping systems

Treatments	**Grain yield (t/ha)**
Maize sole crop	2.90
Maize-groundnut intercrop with farmers planting pattern	1.12
Maize-groundnut intercrop in rows	2.12
Maize-cowpea intercrop with farmers planting pattern	0.98
Maize-cowpea intercrop in rows	1.06
Maize-pigeonpea intercrop with farmers planting pattern	2.68
Maize-pigeonpea intercrop in rows	3.27
Groundnut in sole crop	0.27
Cowpea in sole crop	1.08

Maize variety by mulch trial

The objective of the maize variety by mulch trail was to evaluate the performance of maize varieties with and without mulch scenarios and the interaction between variety and moisture retention. The trial was conducted at Chokwe in Macia. It was laid out in a Randomized block design as a 6 x 2 factorial with 6 maize varieties and 3 ton/ha mulch and without mulch treatments. The maize varieties were; Chuvukane, Djadza, Changalane, Tsangano, Chinaca and Matuba.

Results and discussion

Results showed highly significant ($P < 0.005$) differences in harvest count between varieties. Mulch did not lead to differences in harvest count. The difference in plant counts between varieties could be due to differences in seed quality implying that one some varieties with poor might have had lower germination right from the beginning. Maize grain yield also differed significantly ($P \leq 0.01$) between varieties indicating that there were differences in yield potential among varieties (Table 31). The highest yielding variety was Chuvukane seconded by Changalane. Total biomass also significantly differed ($P \leq 0.006$) between varieties. The mulch or no mulch treatments did not show differences in their effect on total biomass and grain yield indicating that that mulching did not help in moisture retention. Probably, the mulch was eaten away by termites or was not applied on time due to lack of mulching materials as experienced in some on-farm sites. It should however, be noted that the yields were generally good at Choke Research Station in this season.

Table 31: Performance of six maize varieties under mulch and no mulch

Variety	Mulch	Yield and yield components		
		Harvest count	Grain yield (t/ha)	Total biomass (t/ha)
Changalane		93	3.93	17.67
Djadza		103	3.82	19.54
EV 8430-SR		80	3.78	15.04
Lhuvukane		87	4.36	16.48
Matuba.		64	2.77	12.36
Suwan 1		54	2.30	10.26
Suwan 2		64	2.59	12.16
	1	77	3.14	14.63
	2	84	3.89	16.14

Note: 1=No mulch, 2=with mulch

Zimbabwe

The 2008−2009 rainy season's project activities in Zimbabwe started with a planning meeting held in Bulawayo. During this meeting, the team agreed to implement four types of trials namely: 1) Water Use Efficiency, Species x Variety, Crop species x Nitrogen, and Species x Water harvesting x Weed control. The trials were planned for two villages in each of the target districts - Gwanda, Chiredzi and Matobo. The Species x water harvesting and Weed management trials were only targeted for Gwanda and Matobo Districts.

Inputs were delivered in October during the mid project survey trips and more inputs were delivered around December 2008. This time, inputs were delivered to Extension offices in time. Farmers collected the inputs from extension offices. However, some farmers collected the inputs late due to poor communication from the Extension workers and this impacted on the implementation in those late planted trials mostly led to crop failures. The achievements in the season are highlighted by type of trial as follows:

Water Use Efficiency Trial

The objective of this trial was to quantify crop and water productivity of different crop species under different management practices and collect data for the validation of crop/soil simulation models. Four trials were implemented in the season. The treatments were laid out in a Randomized blocks design with three replications. Embedded in the trial was a 2 x 3 factorial with two management treatments and three crop species. The treatment were: 1) Maize normal farmer land preparation (check), 2) Maize tied ridges prepared before planting, 3) Maize basins (Zai pits), 4) Maize mulch applied at 3 t/ha as soon as possible (i.e. as long before seeding as possible), 5) Maize basins plus mulch 3 t/ha, 6) Sorghum tied ridges prepared before planting. Sorghum planted in furrows, 7) Sorghum basins, 8) Groundnuts tied ridges prepared before planting, 9) Groundnut planted in furrows, and 10) Groundnuts mulch applied at 3 t/ha as soon as possible, seed into the mulch using a pointed stick. Perl millet was included in Gwanda and Matobo Districts apart from the sorghum and this made it 12 treatments.

Results and discussion

The 2008 −2009 season was generally better than the 2007−2008. Rainfall started earlier than expected and as such, where inputs were colleted on time, planting started in November and continued to December 2008. This led to more successful trials across the sites except those that were planted late.

Results from water use efficiency (WUE) trial showed no significant ($P \leq 0.05$) differences in both plant counts at harvest and grain yield between crop species (Table 32). This reflected the high variability in the parameters measured due to poor germination of some of the crop species such as groundnuts as was observed during trial establishment in Matobo. Under normal circumstances, harvest counts for the different crop species differ only due to different seed rates resulting from different planting spacings between rows and between plants. The high variability in this context was confounded by the poor data sets obtained hence comparisons between crop species does not reflect treatment effects but rather reflect different seed rates used. The data from Chiredzi and Gwanda for this trial were not adequate for statistical analysis and were therefore left out due to too many gaps in the data sets whose cause was not explained.

It should however, be noted that although there were no significant differences in yield between treatments, the data showed that mulching gave the highest yield of maize, while tied ridges and planting in furrows gave the highest grain yield for sorghum, groundnut and millet. These results are consistent with the observations made in the previous season when initial and final stand counts were highest for sorghum in tied ridges and had higher initial and final stand counts. Groundnut tied ridges had higher initial and final stand counts while pearl millet had higher initial and final stand counts on tied ridges as well. These results showed the potential moisture retention capacity by the various water harvesting methods on different crop species.

Table 32: Harvest count and grain yield of different crop species and water harvesting techniques

Crop species	Water harvesting technique	Harvest count/harvested rows	Grain yield (t/ha)
Maize	Normal farmer practice	27	2.78
Maize	Tied ridges planting in furrow	34	1.93
Maize	Basins	27	0.93
Maize	Mulch	32	4.38
Maize	Basins + Mulch	20	2.37
Sorghum	Tied ridges planting in furrow	37	2.71
Sorghum	Basins	29	0.12
Groundnut	Tied ridges planting in furrow	32	0.98
Groundnut	Mulch	50	1.81
Pearl millet	Tied planted in furrows	39	0.33
Pearl millet	Basins	28	0.11
Mean		**32**	**1.85**
SE		**12.18**	**1.378**

Species by variety trial

The objective of this trial was to evaluate genotypic variation between three varieties of maize, sorghum and groundnuts representing the commonly used varieties, the best released variety available and a potential variety selected for its water use efficiency and/or yield under conditions similar to those of the target areas. The trial was conducted in Chiredzi, Gwanda and Matobo. The trial was designed as a Randomized Block design laid as a split plot with three replications.

Results and discussion

This trial had three crop species (maize, sorghum and groundnut). Three varieties of each crop species were included in the trial. The results showed highly significant ($P \leq 0.001$) differences for both District and crop species on plant counts, total biomass and grain yield (Table 33). Varieties within crop species however did not show significant differences in the above parameters. Maize variety 421, Lundende and farmers variety for sorghum and groundnut had the highest grain yields in Chiredzi respectively. In Matobo, maize variety SC 513, Lundende and Nyanda (groundnut) gave the highest grain yield. This observation shows that there is need for area specific variety recommendations for the districts involved since different varieties performed differently in different districts, except for Lundende sorghum variety which performed similarly in both districts. There was no adequate data for the same trial in Gwanda due to poor germination and severe damage of grain by Quelea birds before the crop matured.

Table 33: Harvest count, total biomass and grain yield of crop species in Chiredzi and Matobo Districts

District	**Crop species**	**Variety**	**Harvest count**	**Total biomass (t/ha)**	**Grain yield (t/ha)**
Chiredzi	Maize	SC 513	46	3.94	2.62
		ZM 421	54	3.50	3.08
		Zm 309	47	3.48	2.06
	Sorghum	Lundende	93	4.77	1.99
		Macia	62	3.83	1.58
		SV 4	69	5.04	1.35
	Groundnut	Farmer variety	51	1.70	0.67
		Nyanda	24	1.70	0.45
		New Variety	29	1.13	0.45
	Mean		53	3.23	1.58
Matobo	Maize	SC 513	44	2.27	2.23
		ZM 421	25	2.03	1.84
		Zm 309	43	1.10	2.28
	Sorghum	Lundende	26	0.54	1.86
		Macia	15	0.33	0.88
		SV 4	15	0.32	1.47
	Groundnut	Farmer variety	20	0.07	0.57
		Nyanda	33	0.29	0.82
		New Variety	21	1.11	0.44
	Mean		27	0.65	1.38
	L.S.D $_{0.05}$				
	District		11.62	1.14	ns
	Crop species		12.32	1.21	0.29
	Variety		ns	Ns	0.29
	CV %		56.3	100.1	41.1

Species x Nitrogen Trial

The objectives of these trials were to determine the performance of different crop species under different levels of N fertilizer. The trial was laid out as a split plot in a Randomized block design with three replications. Species were the main plots and nitrogen levels were sub-plots. The sub plots included: 1) 0 kg/ha N as top dressing, 2) 17.5 kg/ha N as top dressing (Micro-dose) = 1 bag/ha, 3) 35 kg/ha N as top dressing = 2 bags/ha, and 4) 52.5 kg/ha N as top dressing = 3 bags/ha.

Results and discussion

Both plant counts and grain yield respectively did not significantly differ between crop species in Matobo and Chiredzi Districts (Tables 34a and 34b). In both sites, the effect of nitrogen application did not result in any increase in grain yield. This is not conclusive enough that N is not limiting but rather that other factors such as rainfall might have confounded the results. The season was a bit dry during mid-season which means that the initial N might not have been leached quickly enough to demand further N leading similar response by crop species. Results from Gwanda were not included due to in adequate data sets collected.

Table 34 a: Harvest count per plot of different crop species under different N levels

District	**Crop species**	**Nitrogen levels (kg N /ha)**				
		0	**17.5**	**35**	**52.5**	**Mean**
Chiredzi	Maize (ZM 421)	60	62	63	60	**61**
	Sorghum (Macia)	84	86	78	79	**82**
	Pearl millet (PMV3)					
	Mean	**72**	**74**	**70**	**70**	
Matobo	Maize (ZM 421)	40	44	41	46	**43**
	Sorghum (Macia)	13	16	16	11	**14**
	Pearl millet (PMV3)	32	28	32	21	**28**
	Mean	**28**	**29**	**29**	**26**	

Table 34 b: Grain yield (t/ha) of different crop species under different N levels

District	**Crop species**	**Nitrogen levels (kg N /ha)**				
		0	**17.5**	**35**	**52.5**	**Mean**
Chiredzi	Maize (ZM 421)	2.69	7.44	2.33	2.256	**3.68**
	Sorghum (Macia)	0.84	0.11	0.03	0.247	**0.18**
	Pearl millet (PMV3)	NA	NA	NA	NA	
	Mean	**1.77**	**7.38**	**1.02**	**1.005**	
Matobo	Maize (ZM 421)	3.41	2.05	2.53	1.93	**2.48**
	Sorghum (Macia)	2.15	1.65	1.89	1.61	**1.83**
	Pearl millet (PMV3)	0.88	1.25	1.26	1.29	**1.17**
	Mean	**2.15**	**1.65**	**1.89**	**1.61**	

Species x water harvesting x weed control trial

The objective was to evaluate and compare the effects of species, water harvesting with tied ridges and weed control on water-use efficiency, as measured by crop yield. The crop species were: 1) Maize Variety ZM421, 2) Sorghum Variety Macia, and 3) Groundnut variety Ilanda. The sub plot treatments were: 1) Flat planting (no ridges), one weeding (only) when weeds are 10 cm tall, 2) Flat planting (no ridges), weed whenever weeds are 10 cm tall (multiple weedings), 3) Tied ridges, one weeding (only) when weeds are 10 cm tall, 4) Tied ridges, weed whenever weeds are 10 cm tall (multiple weedings). These treatments were laid out in Randomized Blocks design with three replications.

During the planning meeting in Polokwane in 2008, consensus was reached that the main variables limiting crop productivity in the basin were crop varieties, soil moisture and weeding regimes. Therefore, a trial combining these factors was designed. For crop species, it included maize, sorghum and groundnut while two levels of water harvesting, and for weed control were used.

Results and discussion

Results are given in Tables 35a and 35b. Highly significant differences ($P \leq 0.001$) were noted between crop species on harvest counts and grain yield. The harvest counts reflected the seed different rates for different crop species. The grain yield also reflected different species potential in the districts. Regarding the water harvesting and weed control treatments, although there were no significantly differences were observed on grain yield, higher grain yields were obtained on tied ridges and normal weeding regimes for maize and sorghum but not for groundnut. In Matobo, the pattern was not clear indicating that other confounding factors might have played a role such as poor management.

Table 35 a: Harvest counts and grain yield of different crop species in Gwanda

Crop species	**Water harv and weed control**	**Harvest count**	**Grain yield (t/ha)**
Maize	Flat one weeding	152	1.49
Maize	Flat normal weeding	149	1.79
Maize	Tied ridges one weeding	148	2.35
Maize	Tied ridges normal weeding	149	1.58
Sorghum	Flat one weeding	144	1.06
Sorghum	Flat normal weeding	147	1.21
Sorghum	Tied ridges one weeding	138	1.16
Sorghum	Tied ridges normal weeding	150	0.95
Groundnut	Flat one weeding	161	0.64
Groundnut	Flat normal weeding	153	0.73
Groundnut	Tied ridges one weeding	156	0.70
Groundnut	Tied ridges normal weeding	159	0.69
	Mean		
	Crop species		
	Maize	149	1.80
	Sorghum	145	1.10
	Groundnut	157	0.69
	Water harv. and weeding		
	A	152	0.06
	B	150	1.24
	C	147	1.40
	D	152	1.07
	CV %	4.7	21.5

A - Flat one weeding
B - Flat normal weeding
C - Tied ridges one weeding
D - Tied ridges normal weeding

Table 35 b: Harvest counts and grain yield of different crop species in Matobo

Crop species	**Water harvesting and weed control**	**Harvest count**	**Grain yield (t/ha)**
Maize	Flat one weeding	50	4.54
Maize	Flat normal weeding	33	3.61
Maize 1	Tied ridges one weeding	32	3.83
Maize 2	Tied ridges normal weeding	34	5.66
Sorghum	Flat one weeding	29	2.15
Sorghum	Flat normal weeding	31	2.75
Sorghum	Tied ridges one weeding	35	2.12
Sorghum	Tied ridges normal weeding	28	1.25
Groundnut	Flat one weeding	40	2.37
Groundnut	Flat normal weeding	43	2.60
Groundnut	Tied ridges one weeding	45	2.72
Groundnut	Tied ridges normal weeding	46	1.67
	Mean		
	Crop species		
	Maize	37	4.41
	Sorghum	31	2.07
	Groundnut	44	2.34
	Water hav. and weeding		
	A	40	3.02
	B	36	2.99
	C	37	2.89
	D	36	2.86
	CV %	29.8	44.8

South Africa

A planning meeting held in Polokwane in August 2008 agreed on a number of trials to be implemented for the 2008/2009 rainy season. The trials agreed included: Maize variety, Groundnut variety, Sorghum variety, Water harvesting x Variety x fertilizer, Water harvesting x weed control x fertilizer (on-farm) and Water harvesting x crop species trials at University of Limpopo farm; In Capricorn: at Thompi Seleka and for Sekhukhune at an emerging farmers' farm.

Water harvesting x weed control x fertilizer trials

The objective was to evaluate the effects of tied ridges, recommended weeding practices and fertilizer on maize yields, and the interactions between these three factors. These trials were conducted in Mopani, Sekhukhune and Capricorn Districts. A Split-split plot design, one or two replications per site, eight replications per district were used. Water harvesting treatments included W1 – Farmers normal land preparation and W2 – Tied ridges, Wed control included: C1 – One weeding (Farmer's practice), and C2 – Weed each time weeds are approximately 10 cm tall. At least two weedings carried out and the fertilizer treatments included: F1 – 25 kg/ha basal fertilizer, no top dressing, and F2 – 200 kg/ha basal fertilizer and 100 kg/ha urea as top-dressing.

Results and discussion

The season started in early in October but was very erratic. This caused germination problem especially of one maize variety ZM 521 on all trials that used this variety. In Giyani, it was found that it the variety failed to germinate in all sites and all trial plots of this variety were replanted with ZM 421 where ever possible.

Grain yield results presented in Table 36 showed no significant differences ($P \leq 0.05$) between treatments and their interactions. It was surprising to note the absence of any significant effects and interactions of the factors on maize yield across the two districts of Capricorn and Sekhukhune. However, highly significant effects ($P \leq 0.001$) were detected in grain yield between districts. Capricorn registered mean yields that were four times higher (2.9 tons/ha) compared to Sekhukhune (0.5 tons/ha). This might reflect the differences in environmental factors that affected crop growth and productivity such as: rainfall pattern, soil types and temperature ranges. The trial mean across the two districts was generally high at 1.5 tons/ha with significant yield effects noted between the districts. The poor quality of the rainfall season in Sekhukhune that was characterized by extremely erratic onset, which in some sites resulted in poor crop emergence requiring replanting of the trials in some cases coupled with time lag between initial planting and replanting, might have inflicted a yield penalty on the replanted maize crop. The yield levels ranged from 0.2- 4.5 tons/ha across the two districts. Capricorn is generally warmer with predominantly loam sands while Sekhukhune is generally cooler with predominantly red loams.

Comparisons between the different water harvesting strategies and different weed control methods in combination with different rates of fertilizer did not have any significant influence on maize productivity. Weeding twice and applying 200 kg/ha basal dressing and 100 kg/ha of Urea with tied ridges (W2C1F2) gave the highest maize grain yields while lowest average yields came from farmer's land preparation used in combination with weeding twice and applying a higher rate of fertilizer (W1C2F2). The lack of significant differences between treatment combinations might have resulted from untimely application of treatments such as construction of tied ridges and weeding. Evidence from monitoring visits revealed that many farmers delayed weeding and construction of water harvesting structures in the trial plots which might have masked the effects of the treatments.

Table 36: Effect of water harvesting on grain yield (t/ha) performance of maize under different weed control and fertilizer regimes across Capricorn and Sekhukhune Districts

			District		
W⁻	**C⁺**	**F#**	**Sekhukhune**	**Capricorn**	**Mean**
1	1	1	0.6	2.8	1.7
1	1	2	0.6	2.9	1.7
1	2	1	0.5	2.9	1.7
1	2	2	0.5	2.6	1.5
2	1	1	0.5	3.0	1.7
2	1	2	0.5	3.4	1.9
2	2	1	0.5	3.1	1.8
2	2	2	0.6	2.8	1.7
		Mean	0.5	2.9	1.7
1					1.4
2					1.5
	1				1.5
	2				1.5
		1			1.5
		2			1.5
District					***
Method					NS
Weed Control					NS
Fertilizer					NS
W*C					NS
W*F					NS
C*F					NS
W*C*F					NS
CV%					25

Crop variety Trials

The main objective of these trials was to identify adaptable improved varieties to be used by farmers in the basin. The idea was to compare and demonstrate improved open pollinated maize, sorghum, and groundnut varieties with the varieties commonly used by farmers.

Maize Variety Trial

This trial was targeted for Mopani, Sekhukhune, and Capricorn Districts. The design was a Randomized Blocks design with one or two replication per site. There were a total of eight replications in Capricorn District and 6 replications each in Mopani and Sekhukhune Districts. The varieties tested were: Local for the District, ZM521, Obatambo, and SAM1109.

Results and discussion

Three maize varieties were evaluated against a local variety in each of the three districts of Limpopo. Grain yield results obtained for the only usable data set from Sekhukhune (Table 37), showed significant differences ($P \leq 0.05$) in grain yield for the different varieties. Out of the four varieties (ZM 521, SAM, Obatambo and local), ZM 521, an improved open pollinated variety, registered the highest (0.8 tons/ha) grain yield while the lowest yield (0.5 tons/ha) was from SAM 1109. Since any slight yield difference matters for farmers especially in dry land environments like Limpopo Basin, ZM 521 holds the promise to contribute to increased maize productivity in the target district having out-yielded the local variety by 12%. Despite the maize variety trials having been implemented in Capricorn and Giyani districts, there was no data collected from Capricorn and Giyani due to drought.

Table 37: Grain yield of four improved maize varieties compared to a local variety in Sekhukhune District in the Limpopo Basin during 2008-2009 season

Variety	Yield (tons/ha)
ZM521	0.8
SAM 1109	0.5
Obatambo	0.6
Local	0.9
Mean	0.70
Significance	*
CV%	27.0

Sorghum variety trials

This trial was conducted the same way as the maize variety trial. It had five varieties including a Local check (The most common farmer variety in the district), Macia, M126, M148, and M153.

Results and discussion

Sorghum is generally considered as a naturally drought tolerant crop. In order to exploit its adaptive potential to low rainfall environments for the benefit of small scale farmers in the Limpopo Basin, a number of varieties were evaluated during the season.

Results from the trial (Table 38) showed that there were no significant differences in grain yield between the varieties. Although the yields were generally low at about half a ton/ha for all varieties, M26 and M153 gave slightly better yields than M148, Macia and local. M26 gave the highest grain yields than the rest of the varieties with a 69% yield advantage over the local. The yield advantage of three of the improved sorghum varieties was above 25% of the local implying tremendous potential of improved sorghum varieties in enhancing water productivity in the Limpopo Basin of South Africa.

Table 38: Grain yield of four improved sorghum varieties compared to a local variety in Sekhukhune District

Variety	Yield (tons/ha)
M26	0.6
M153	0.5
M148	0.4
Macia	0.3
Local	0.3
Mean	0.43
Significance	NS
$LSD_{0.05}$	0.24

Groundnut Variety Trial

The objective was to compare (and demonstrate) improved groundnut varieties with the varieties commonly used by farmers. The trials were conducted in Mopani and Sekhukhune.
The design was Randomized blocks design with one replication per site, six replications in Mopani District and four replications (sites) in Sekhukhune District. Varieties evaluated included: Nwa-Chuchululu, Akwa, Supernut, Kangwana Red, and Thusang. There were no yield results given for this trial.

Maize water harvesting x variety x fertilizer trial

The objective was to evaluate effects of water harvesting (tied ridges), variety and fertilizer levels on maize yield. The trial was conducted in Mopani, Sekhukhune and Capricorn Districts. The design was a Randomized Blocks with a split plot structure, with sub-treatments in a 2 x 2 factorial, with replication per site. There were eight replications per District, sown as two replications in each of four sites (fields).

Main plot treatments were: Water harvesting techniques -W1 – Farmers normal land preparation and W2 – tied ridges. The sub plot factors were: Fertilizer - F1 – 25 kg/ha basal fertilizer, no top dressing and F2 – 200 kg/ha basal fertilizer and 100 kg/ha LAN as top-dressing. The sub-sub plot factors were: Variety - V1 – the farmers' variety. This should be the most common variety sown by farmers in the District, and should be the same on all replications in the District and V2 - ZM521 in Mopani and Sekhukhune; ZM423 in Capricorn.

Results and discussion

Results on grain yield for the water harvesting x variety x fertilizer in Sekhukhune district revealed that water harvesting, variety, fertilizer and their interactions did not significantly (Table 39) affect yield. However, slight yield differences were noted between treatments reflecting that the lack of significance might have resulted from poor management of the trials by farmers. Substantial evidence of both delayed weeding and delayed construction of water harvesting structures might have confounded the outcome.

As given in Table 39, the highest (0.65 tons/ha) grain yield was obtained with the farmer's local maize variety grown on untied ridges using a higher rate of fertilizer (W1V1F2). This was seconded (0.62 tons/ha) by the improved variety (ZM 521) grown on tied ridges and using a higher rate of fertilizer (W2V2F2). Maize grain yield was lowest (0.41 tons/ha) with farmers local variety grown on untied ridges and with a lower rate of fertilizer (W1V1F1) implying that farmers could realize tangible benefits from improved maize varieties if they used them in combination with water harvesting strategies and high fertilizer rates. The use of improved maize variety and tied ridges with additional application of fertilizer increased maize grain yield by 48% over the combination of local maize with untied ridging in the absence of additional fertilizer application.

Table 39: Effect of water harvesting on grain yield of local maize and improved maize under different fertilizer regimes in Sekhukhune district

W⁻	V⁺	F#	Yield (tons/ha)
1	1	1	0.42
1	1	2	0.65
1	2	1	0.54
1	2	2	0.52
2	1	1	0.56
2	1	2	0.52
2	2	1	0.51
2	2	2	0.62
		Mean	0.54
1			0.53
2			0.55
	1		0.54
	2		0.55
		1	0.51
		2	0.57
Water harvesting strategy			NS
Maize Variety			NS
Fertilizer			NS
W*V			NS
W*F			NS
V*F			NS
W*V*F			NS
$LSD_{0.05}$			301.4
CV%			27

- Water harvesting: 1 = untied ridges; 2 = Tied ridges
+ Maize variety: 1 = Local maize; 2 = Improved (ZM 521)
# Fertilizer: 1 = Lower rate of fertilizer (25 kg/ha); 2 = Higher rate of fertilizer (200kh/ha basal and 100 kg/ha top dressing)

Water harvesting trial

The objective of this trial was to compare the efficiency of farmers' land management practice and four different water harvesting strategies on soil moisture dynamics and the yield of maize, sorghum and groundnuts. The trial was located at the University of Limpopo farm, in Capricorn; Thompi Seleka, Sekhukhune; an emerging farmer in Mopani District. It was designed as a Randomized block design with four replications per site. The treatments were: Maize under normal farmer land preparation (check), Maize with tied ridges prepared before planting, Maize basins (Zai pits) prepared as early as possible during the dry season, Maize mulch applied at 3 t/ha as soon as possible (i.e. as long before seeding as possible), Seed into the mulch using a pointed stick, Maize subsoiled before planting, If subsoiling cannot be done, then make this treatment basins + mulch, Sorghum in ormal farmer land preparation (check2), Sorghum tied ridges prepared before planting, Groundnuts in normal farmer land preparation (check 3), and Groundnuts with tied ridges prepared before planting.

The partners in South Africa only implemented one out of the three planned water harvesting trials namely: the water harvesting x crop species trial at the University of Limpopo Farm. However, no data was recorded on soil moisture measurements due to faulty soil moisture probes.

Objective 3: Use innovative research and extension methodologies, linked to public-private partnerships, to facilitate promotion and uptake of management options and strengthen linkages to input and product markets. Draw lessons from this experience for application to other areas and countries in southern Africa

The main output for objective 3 was to have alternative farmer-market linkage models that provides incentives to adopt improved crop, soil and water management options evaluated, and promoted in two countries

The hypothesis of this objective was that farmers would adopt improved technologies when they are assured of product markets. This is an important innovation and lessons from case studies would help stimulate adoption of future crop water productivity technologies, and thus improve livelihoods. The expected outputs were that;

- At least two out of four models /case studies that link production with marketing through public-private partnerships would be developed, promoted and adopted
- Synthesis reports of case studies would be published, on new institutional arrangements that facilitate development and uptake of improved crop and water technologies; and effects of these systems on adoption would be documented.

Methods

Implementation of these activities started in June 2006, a year after initial plan.
Preliminary activities included the following:

1) Evaluating commodity collection points linked to input supply (and output collection)

Spatial distribution of Maize large and small scale producers and the selling and buying points of grain in the Limpopo Province were necessary as this would shape the path towards a better understanding of marketing arrangements for grain and consequently leading to their improvement.

The main output on this activity was geo-referencing of 40 Progress Milling depots—showing the coordinates of the depots in the Limpopo Province in terms of latitudes and longitudes. This information was then shared with the project team members at IWMI-Pretoria with a view to use the coordinates to generate several interlinked variables which when overlaid could provide insights to potential investment areas to be undertaken by both government and the private sector to accelerate smallholder development in the Limpopo Province. Key components in the overlay are agro-ecologies, market access and population densities. The premise is that agricultural potential largely influences the absolute advantage (productivity) of a location in production of particular agricultural commodities, while access to markets and infrastructure and population pressure help to determine the comparative advantage (profitability) of particular livelihoods, given the absolute advantages. For example an area with suitable climate and soils may have absolute advantage in producing high value perishable vegetables but little comparative advantage if this is remote from markets and roads. Improvements in markets and road access are therefore expected to favour high value perishable commodities.

2) Evaluating the impacts of convenient access to small packs of seed and fertilizer

Activities towards strengthening public and private sector partnerships in South Africa and Zimbabwe regarding the distribution of different small packs of fertilizer to stockists started by; Conducting partnerships meetings held with LPDA, SASOL Nitro, Progress Milling and ICRISAT to discuss and reach consensus on fertilizer small packs distribution modalities in the Limpopo Province. Understanding perceptions on the distribution of small packs of fertilizer was sought from LPDA, SASOL Nitro and Progress Milling. Consultations meetings were held with Zimbabwe Fertilizer Development Company (ZFC) and agreements were reached to supply 5 tons of fertilizer in small packs of 5, 10 and 20kg for distribution to targeted retailers in Gwanda and Matobo in Zimbabwe for 2006/7 season in order to test whether there was demand for small packs of fertilizer and differential demand for different fertilizer packs. These were targeted to farmers/areas where CPN1 carried out demonstrations on participatory soil fertility and water management trials in 2005/2006. Other consultations were held with TA Holdings and Agricultural Seed Company and a Business Plan was developed to produce 5000 tons of Ammonium Nitrate in Tablet Form. Evaluation of small packs of fertilizer uptake was conducted using conceptual framework and questionnaires of formal interviews where 90 farmers were interviewed to determine the uptake of various fertilizer size packs

Results and discussion

A survey to asses the acceptability of the small fertilizer packs was conducted in South Africa. Findings from the survey demonstrated preferential access by farmers for small packs. However the intensity of preference was a function of amount of rainfall, cash availability and history of use of fertilizer.

After the successful study on smaller fertilizer packs, a second study was undertaken by IWMI entitled "Understanding the role of input and output service providers to smallholder farmers: the case of a medium-scale miller in the Limpopo Province of South Africa". This survey sought to explore the strategies used by Progress Milling (PM) in the maize production and marketing sector. The study came up with the following results:

Farmers with experience in fertilizer use consistently applied fertilizer although sometimes occasionally used it because of lack of cash for purchasing the fertilizer. They also claimed that the other reason was that the soils were already fertile enough and hence preferred farm manure. This implies that unless means of bringing cash income through easily accessible markets, farmers may not have the desire to use fertilizer. The survey also found that first time fertilizer users had sourced fertilizer from local depots and only bought small packs (5kg, 10kg and 20kg bags). This implies that selling fertilizer at close by depots in small packs encouraged farmers to use fertilizer. However, the study further found that buyers and non-buyers were not different in terms of age, farming experience, number of livestock kept, quantity of manure applied an indication that easy access though smaller packs and from local depots played a major role in encouraging fertilizer purchase and use. It was found in the same study that Fifty kg bags still dominated the size of fertilizer packs procured by farmers− perhaps because of less availability of the smaller packs at the time of the survey. For the non buyers, the reasons given included too high cost, too risky to apply fertilizer in their areas hence preferred manure to in-organics, and unavailability of fertilizer at the right time.

The case of Progress Milling gives insights into an interesting business model. Its major feature is the distribution of depots throughout the Limpopo province that provide access to a range of services to small-scale farmers, mainly milling service and market access for their maize and sorghum. Contrary to formal markets, small farmers face almost no barrier to entry when dealing with the depots of PM: quality requirement are very low and there is no volume requirement and also given the location of PM in remote areas, many farmers can have very low transport cost. Therefore, the milling service provided by PM constitutes a pivotal dimension of its establishment in rural areas as most rural households are producing maize for their own consumption and only a small share regularly sale maize.

Through its network of depots and its depot management, PM has achieved proximity with local communities. This also renders this company an interesting partner for public and international institutions aiming at poverty reduction and rural development who can use it as a channel to reach poor population on the ground.

Given its size and its very good embeddedness in the Limpopo Province as well as its commercial establishment in the Gauteng and in the Mpumalanga provinces through selling maize meal to retail shops, PM can easily absorb increases in local production. PM is thus developing an interesting territorially based strategy at Limpopo level of investment in local procurement and of consolidation of local demand with rural maize consumption being stable in contrast to declining urban consumption.

Objective 4: Strengthen capacity of farmer and partner institutions to develop and implement innovative research and extension approaches; improve stakeholder participation in agricultural development; and strengthen public-private partnerships that will create income opportunities and improve crop water productivity

The main output for objective 4 was to have training and information needs of technical collaborators and farming communities identified and addressed

Methods and results

Needs assessment on capacity was done through consultation with stakeholders (National research and extension services, NARES) and farmers. From the consultative process, the needs in terms of areas concerning research capacity for scientists, technicians, extension personnel and farmers were identified**.** Some of the trainings proposed at the beginning of the project were not of urgency as those that stakeholders proposed were necessary to assist in the implementation of the project. From the identified capacity areas, a range of trainings were planned. These included; Field officers training on crop water productivity including soil/water conservation, seed production and harvesting technologies, Post graduate training on soil fertility, breeding for drought tolerance and economics of water productivity, and finally short term training on trial protocols and general implementation of trials.

Field officers training on crop water productivity including soil/water conservation, seed production and harvesting technologies

Training workshops conducted included: Training on crop varieties, seed production and water management techniques which trained 72 collaborators from extension and farming communities in Zimbabwe (25–30th September, 2006 Bulawayo Zimbabwe) and South Africa 4–6 October, 2006. Collaborators from Mozambique participated at the Bulawayo training.

Post graduate training on soil fertility, breeding for drought tolerance and economics of water productivity

A total of six post graduate students were identified – two per country in 2006. The students study areas proposed were mainly around output 2 and 3 and most often the topics cut across the two outputs. Two MSc students from Mozambique and one MSc student from Zimbabwe studied at the University of Pretoria. The PhD student from RSA was admitted at The Orange Free State University and the other MSc student from RSA was admitted at the University of Limpopo.

Short term trainings organized for NARES in 2007

Two short term trainings were organized one in each country for Mozambique (June 20−21, 2007) and Zimbabwe (Sept. 19−20, 2007). These trainings covered areas of trial protocols, and the layout and management of trials. The expected outcome was a greater achievement of plans and better quality data.

Trainings in 2008-09 for NARES

During the 2008-09 season, six extension workers from Mabalane and Macia districts were trained on planting and management of on-farm trials and data collection.

Training of farmers

In the same season, 18 farmers in Mozambique were trained to take care of trials (weeding, application of chemicals to control pests). One field day was conducted in Macia during the time of harvest, to allow farmers assess the trials together with extension workers. They were asked to judge which treatments were the best for the groundnut variety x mulch x fertilization trials.

Impact assessment of drought-tolerant crops, new high-value crops, and soil, water and crop productivity enhancing technologies; policy recommendations developed

The aim was to document farmers' perceptions of technologies and socio-economic and technical constraints to adoption of soil water management technologies. This was with the realization that farmer and researcher perceptions of a technology may be quite different. Better understanding of smallholder farmers' perceptions, their views on adoption constraints could therefore help identify means to increase adoption.

Methods

Getting information on technologies tested was done in four phases. The first phase was through observations by farmers hosting trials. Farmers compared new technologies against the existing traditional farming practices and varieties. Secondly, field days were used as a platform for evaluating the various technologies, which were incorporated in the project. In this method, participatory variety selection was used for farmers to select the best variety with good traits. Rapid assessment through household interviews was also used as another form of technology evaluation. Lastly, end of project workshops served as plat forms for farmers to give feedback on the project activities.

Results

Through the four processes highlighted above, farmers managed to identify the following as the aims of CPWF trials:

a) To introduce new crop varieties and ensure that farmers have access to good seed which was early maturing and drought tolerant
b) To assess the performance of different crop varieties especially comparing the varieties introduced by the program to the local varieties
c) To conserve moisture and soil so as to improve crop yields in drought-prone areas
d) To compare different moisture conservation techniques
e) To compare the effect of applying nitrogen fertiliser to not applying any
f) To grow crops at the recommended plant spacing
g) To impart more knowledge to farmers and encourage hard work

Technology assessment by farmers in Zimbabwe came up with the following:

1) Water-use efficiency trials

Farmers pointed out that tied ridges demanded a lot of labour and tended to collapse when there was too much rain, which ultimately required reconstruction (Gwanda and Matobo farmers in Zimbabwe). However, in Chiredzi, farmers mechanized the construction of tied ridges using an ox-drawn plough and hence preferred tied ridges or tied furrows as a water conservation technology. Farmers felt that mulching combined with zero tillage tended to conserve more moisture and reduced the need for weeding.

However, they said they do not have access to mulching materials as it is used as livestock feed. In Gwanda and Matobo farmers cited basins as the most recommended technology because more water was collected and there was more than one plant in each basin. They also observed that plants in basins grew better as they got more growth resources. The indicated that the quantity of fertiliser applied per basin was sufficient for the plants and yield ultimately tended to be higher in basins compared to the other two soil water conservation techniques. On soil-water management technologies coupled with early maturing varieties, farmers said they got better yields compared to the time the project had not yet brought the technologies. Some farmers managed to harvest maize even though the area was suitable for small grains such as sorghum and millet.

Tied Ridges/ furrows– farmers felt that tied ridges/furrows exposed the crop to stress and again that there was too much labor required due to reconstruction

Planting Basins – gave higher yields compared to the other techniques, because basins were efficient in conserving water and soil. Farmers without draft power can still plant early and get a good harvest.

Mulching – no weeding was needed after mulching which made the job easier, however farmers failed to achieve the 30% mulch cover required. Therefore, the sustainability of basins and mulch remained questionable and this left tied ridges as a better option especially for farmers who can use draft animals to make the ridges.

Farmer experiences – South Africa

Overall, farmers in South Africa appreciated the project's efforts to test new technologies, such as tied ridges and new varieties of maize, which were suited to their particular circumstances. They particularly appreciated the concept of planting in rows rather than broadcasting their seed.

2) Crop Species by variety trial

The focus of this trial was to compare and contrast medium and early maturing varieties within crop species since days to maturity, growth rates, plant height and sizes were different. When asked the best early maturing varieties, farmers cited Macia, PMV3, SC 421 and ICG 12991 for sorghum, pearl millet, maize and groundnut respectively. However, they indicated that improved short duration varieties were very susceptible to field as well as storage pests especially for sorghum variety, Macia which, farmers found to be very susceptible to birds because of its sweetness and the open grains on panicles. Farmers' variety preference was therefore based on palatability, period of maturity, pest resistance and yield in that order.

3) Species by Nitrogen trial

Farmers already knew about fertilizer but the rate of use was generally low. It is traditionally believed that in semi-arid areas with less rains and high temperatures both basal and top dressing fertilizer are not good for crop growth. However, observations from on-farm trials have proved otherwise because tillering on some millet plants went up to about eight plants and the heads were of the same size on all tillers. Maize plants had 2–3 cobs per plant leading to increased yields.

4) Weed control trials

Farmers learnt that weeds compete with crops for nutrients, air, water and sunlight. This was observed in non-weeded plots where plants were thin, tall with small cobs, ears and low yields as weeds smothered them.

Formal and informal linkages with other projects

Linking up with other projects was a deliberate effort in this project to achieve results in a cost effective way. This was achieved through: Planning and implementation workshop with project partners and stakeholders to identify target communities and specific interventions in each project area – 2 provinces each in Mozambique, South Africa and Zimbabwe. Private partner linkages were made with Progress Milling in South Africa and NGOs in Zimbabwe and fertilizer companies. Information sharing was done through project reports and participation in international fora and other Challenge program projects through workshops.

Internal and external monitoring and evaluation system

Members of Project Management Team (PMT), were identified and their terms of reference for internal monitoring, e.g. assessing workplans and progress toward achieving milestones were formulated. Annul Project Management Team Meetings (PMT meetings) were being held and were reported in all annual reports for this project. These meeting allowed for progress monitoring and fine tuning project activities across seasons.

OUTCOMES AND IMPACTS

Summary Description of the Project's Main Impact Pathways

Actor or actors who have changed at least partly due to project activities	**What is their change in practice? i.e., what are they now doing differently?**	**What are the changes in knowledge, attitude and skills that helped bring this change about?**	**What were the project strategies that contributed to the change? What research outputs were involved (if any)?**	**Please quantify the change(s) as far as possible**
Farmers	New varieties and use of Water conservation structure	Training on the importance of use of improved seed and soil moisture conservation	Use of Mother-baby trials to expose farmers to technologies and Field Days	
Extension	Carrying out of On-farm trails, Design of trails and analysis of data; report-writing	Ability to layout trials and work closely with farmers; exposure to new method of participatory technology dissemination	Training and Field visits with partners and Field Days	
Research Managers	Learnt how to work with other partners	Project coordination and implementation	Interaction at Planning and Management meetings	
Private Sector	They realized the need to work with researchers to enhance the efficiency of fertilizer delivery systems	They realized the opportunities in changing marketing strategies used in the past and saw new opportunities in both input and output markets if farmers adopted the technologies being tested	Close interaction and involvement of their personnel in planning and implementation of the project	

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?

The changes in the knowledge of the extension Staff in all the three countries will enhance their ability for technology delivery to farmers. Framers knowledge of the new varieties and water conservation methods will provide yield gains that will translate into increased food and household incomes

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.

In all the countries the unfavourable weather and other logistical problems made it difficult to achieve the full potential of the planned activities especially in determining water productivity and simulation modeling. In each country there are plans to seek more funding to continue with the project activities so that the adoption process can be enhanced further. However, initial limited adoption studies and interviews with farmers indicate that the remaining tasks are not very difficult in order to achieve full potential of what the project had intended.

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 lack of skills within the Extension in carrying out the field-work was not expected because it was assumed that it was already part of their training for the job.
- -Previous work had shown that water harvesting in drier areas was not widely adopted, but from the work of this project it is evident that the adoption process can be enhanced if proper technology delivery is done through On-farm trials in a participatory way.

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

- The project took advantage by training the Extension staff in field trial implementation and data collection and allowed for the variation of protocols depending on the situation prevailing in the project target areas.
- The inability for the different partners to work together in some of the countries was unexpected, but eventually through this project the issues were resolved and the partners worked together until the project completion

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

- Ensure that the staff on the ground at the project target sites are well trained and have the necessary skills for implementing the project
- Provide "Team building" opportunities at the beginning of the project to ensure "buy-in" by all partners and clarity of roles
- Scrutinize the technologies to be tested so that only those with the greatest chance of impact are tested

MAIN CONCLUSIONS

Baseline survey

The female headed households had limited access to both assets and income. Therefore activities to be implemented by the WFCP therefore needed to take the female headed households as a special category in which resource constraints threatened the livelihood base of the female headed households.

Area cropped by households with chronically ill members was found to be smaller compared to area cropped by households without a burden of the chronically ill members.

Access to draft resources was found to present the biggest challenge for households in the basin to achieve food security. In Zimbabwe ownership of draft cattle or donkeys was the key determinant of the total area cropped. Limited tillage or zero tillage technologies therefore might be important for the households that do not own any livestock. The WFCP would have to explore ways of improving smallholder farmers' access to information on planting basins and other limited tillage technologies.

A significant proportion of Zimbabwean households were spending more than what the households were earning due to the economic problems faced in Zimbabwe. The disposal of assets was then the other option for those households' livelihoods thereby further crippling the households' chances of enhancing livelihoods.

Droughts and mid-season dry spells was the biggest threat to household food security in the basin.

On soil fertility management it was that although the 2004/05 season was a poor season, households that applied mineral fertilizer generally had higher yields compared to those households that did not use any. Improving access to fertilizers and also providing information on efficient use of fertilizers therefore remained a possible task for the project to take advantage of the observed better yields from farmers who used fertilizer

Water use efficiency trials

Water management using mulch in Mozambique gave a positive effect on maize yield both with and without a small dose of N fertilizer, and almost doubled grain yield when both mulch and N were applied. Although this interaction was not statistically significant, moderate grain yield increase obtained at smallholder farm level in marginal environments would go a long way in sustaining livelihoods in such conditions. In the case of groundnuts, grain yield was slightly reduced by mulch alone, possibly due to the effect of decomposition of mulch that probably held up some of the nitrogen. However, groundnut yield increased when mulch was complemented by the application of N fertilizer. A closer examination of the results from crop species by mulch by fertilizer trials for Mozambique revealed consistency in two out of the three seasons of experimentation, including 2005/2006, 2006/2007 and 2007/2008 seasons. We can conclude therefore that this outcome suggests the importance of mulch and fertilizer as components for improving water productivity in the Limpopo Basin of Mozambique. The effects of mulch were considerably greater on maize than on groundnut, implying higher water use efficiency for maize compared to groundnuts.

It is worth noting that there was variation in the water harvesting treatments tried either in different years within the same country or across countries. Water harvesting strategies comprising zero tillage, tillage with 3 tons of mulch and micro basins applied either alone or in combination with fertilizer did not give significant differences in maize yield in Mozambique in 2007-2008 season. However, fertilizer application resulted in marginal yield increases compared to no fertilizer pointing to the need for fertilizer application if maize yields were to be increased in the Limpopo Basin. The minimal yield increase might be due to the season being too dry for the fertilizer to be properly utilized by the maize crop.

In the case of Zimbabwe, maize-basins and zai pits, and basins and mulch gave similar effects on maize productivity. The biomass yield obtained from basins and zai pits in 2007/2008 season was nearly the same as that due to basins where mulch was applied. Additionally, tied ridges generally resulted in increased biomass yield across crop species evaluated in the trials in the Limpopo Basin of Zimbabwe. This implies that crop water productivity could be enhanced in the Limpopo Basin if farmers integrated tied ridges, mulch and basins into the existing water management strategies.

Water use efficiency trials also revealed that tied ridges generally had a positive effect on amount of biomass produced by both cereal and legume crops under dry conditions of the Limpopo Basin. Sorghum, pearl millet and groundnut registered higher biomass yield under tied ridges than when grown on the flat. However, biomass yield from basins only, and mulch and basins for sorghum, groundnut and pearl millet, respectively were lower compared to tied ridges. Although the crops failed completely to produce any grain yield due to drought during the 2007-2008 season in Zimbabwe, the differences in biomass production might reflect the inherent differences in the yield potential of the different crop species evaluated in the basin. Realizing that livestock plays a vital role in stabilizing livelihoods of farming communities in dryland environments, integration of crops such as sorghum, pearl millet and groundnut with water harvesting strategies would not only enhance crop water productivity through increased grain yields, but also contribute to improved livestock productivity through enhanced feed availability.

It should however, be noted that although there were no significant differences in yield between treatments in Zimbabwe in the 2008-2009 season, the data showed that mulching gave the highest yield of maize, while tied ridges and planting in furrows gave the highest grain yield for sorghum, groundnut and millet, respectively. These results were consistent with the observations made in the previous season when initial and final stand counts were highest for sorghum under tied ridges. Tied ridges were associated with higher initial and final stand counts for groundnut and pearl millet. These results showed the potential of the various water harvesting methods for enhancing moisture retention capacity for ensuring plant survival and productivity of the different crop species.

Groundnut exploratory trials

The groundnut exploratory trials were mainly conducted in Mozambique. Highest grain yield results were obtained from treatments involving water harvesting strategies, fertilizer and lime in which combined application was done in the 2006/2007 season. However, the combination of phosphorus, potassium and calcium application to groundnut did not result in any grain yield benefits in the 2008/2009 season for the same trials, implying that the nutrients might not be a limiting factor to crop productivity in the soils of Macia district of the Limpopo Basin in Mozambique. The generally low yields realized from the groundnut exploratory trials suggest that reduced moisture availability due to drought resulted in limited plant access and uptake of the applied nutrients. Ultimately, it could be advanced that moisture availability is indeed the major constraint to crop water productivity for groundnut in the Limpopo Basin.

Water harvesting by variety by fertilizer trials

Treatments in the water harvesting by variety by fertilizer trials comprised water harvesting strategies, crop varieties, and fertilizer application. All the treatment factors resulted in inconsistent differences in yield attained for the crops included in the evaluation across the seasons. This could probably be due to poor trial management which resulted in some treatments such as water harvesting structures not established in some trials or if done, they were done late in the seasons. The lack of response to fertilizer could be attributed to the lack of adequate moisture which might have limited the dissolution of the fertilizer and failure of uptake of the applied fertilizer by the crops. This conclusion is largely emanating from trials conducted during the 2006-2007 season in Zimbabwe since no results were reported for South Africa due to logistical difficulties, which hampered trial implementation during the season.

Crop variety evaluation trials

Although there were no significant differences between improved varieties of maize and sorghum, and the farmer's local, improved varieties generally out-yielded the farmers local except where farmers referred to a hybrid as a local variety owing to a long time association with a particular variety. The misrepresentation of a hybrid for a local variety might have arisen from familiarity with a particular variety having grown it for several seasons in the respective district in which case the variety was not a true local. It was evident from the trials that some farmers were already conscious of the risk of crop failure due to harsh conditions experienced in the Limpopo Basin, and therefore valued hybrid maize as a promising technology for improving crop water productivity in the Basin.

Cereal – cowpea intercrop by fertilizer trials

The cereal-cowpea intercrop by planting method by fertilizer trials showed no significant differences in yield. However, row seeding and fertilizer gave marginal increases in maize yield compared to broadcasting method, an observation that needed not be ignored under harsh environments. The sorghum cowpea intercrop gave similar results to maize which was produced under row seeding, while the highest rate of fertilizer resulted in increased productivity for the sorghum crop in South Africa. Arguably, both maize and sorghum production could be increased in the Limpopo Basin if farmers integrated row seeding and fertilizer application in the predominant farming systems of the Basin. The maize legume intercrop trials conducted during 2008-2009 season in Mozambique, revealed lower maize grain yield when maize was intercropped with cowpea. It is generally unexpected and strange for cowpea to exert any substantial competitive effect on maize since cowpea is a short crop that could not exert any shading effects on the maize. Therefore the lower maize yield for maize cowpea intercrop can be easily explained.

Maize water harvesting by plant population by fertilizer trials

In the maize water harvesting by plant population by fertilizer trials in South Africa, grain yield generally increased at the highest plant population coupled with a high rate of fertilizer applied on both flat and tied ridges. By implication, better management of plant population and fertilizer were more important in determining maize yield under moisture limited conditions typical of the Limpopo Basin. This however, might be true in seasons of adequate moisture availability; otherwise water harvesting techniques have consistently proved as being important in similar trials. Zimbabwe was hit by extreme drought during the 2007-2008 season, which resulted in failure of crops to produce any grain yield. This strange occurrence eliminated any possibilities of identifying best performing varieties of any of the three crop species evaluated due to failure to produce grain yield.

Maize water harvesting by weed control by fertilizer trials

The maize water harvesting by weed control by fertilizer trials gave highest grain yield on tied ridges integrated with more than one weeding and the highest rate of fertilizer. The results suggest that maximizing benefits of water harvesting strategies in dry environments requires holistic approaches that effectively integrate proper weeding with application of high fertilizer rates to meet the nutrient demand of the crop.

Crop species by nitrogen fertilizer trials

Trials conducted in the Limpopo districts of Zimbabwe revealed a lack of significant treatment effects on the parameters evaluated in the crop species by nitrogen fertilizer trials, particularly with reference to the 2007-2008 season. In the light of severe drought conditions in the target districts of Chiredzi, Gwanda and Matobo which confounded the treatment effects on crop water productivity, no meaningful conclusions could be drawn from the results.

Groundnut variety by mulch by fertilizer trials

Variable grain yield response was observed between varieties grown in different sites in the groundnut variety by mulch by fertilizer trials conducted in Mozambique in the 2008-2009 season. Although it could be advanced that the differences in response was due to inherent genetic differences in yield potential of the varieties, the results might also imply that proper choice of varieties suited to a particular production environments would determine the amount of grain yield obtained. Arguably, appropriate targeting of varieties to production environments would enhance crop water productivity under water limited conditions.

Both mulch and fertilizer application did not significantly affect yield and yield components for groundnut. Even though this was the case, the 29% yield advantage of Nematil over ICGV SM 99541 reflected the differences in their yield potential, suggesting that more gains in groundnut yield could be realized through proper choice of variety and accurate targeting to the most productive sites.

Maize variety by mulch trials

In the maize variety by mulch experiments, maize grain yield significantly differed between varieties indicating that there were differences in yield potential among maize varieties evaluated especially in Mozambique. Although mulch did not lead to any yield advantage as was evidenced in the 2008-2009 trials, lack of adequate mulch and untimely application of the treatment might have compromised the extent of moisture retained for crop use.

Overall conclusions

The four seasons of experimentation under the CPWF project in the Limpopo Basin of Zimbabwe, Mozambique and South Africa resulted in the identification of several strategies for improving crop water productivity from the small-scale farmer's perspective. However, there was generally a lack of significant differences between treatments in the majority of trials evaluated. While it was regarded as being necessary to modify treatments in specific trials to reflect implementation challenges encountered in the previous seasons during the project's life span, the modifications created a great deal of analytical problems than opportunities, making it difficult for data analysis to be conducted in some cases. Crop failure which resulted in no yield data in some seasons restricted data analysis across seasons. Lack of uniformity in the design of treatments across countries also posed a big challenge for across site analysis of the data. Consequently, the challenges made it difficult for conclusions to be drawn over the entire Limpopo Basin across the entire life span of the project due to lack of continuity in the technologies evaluated, as treatments kept being modified in response to contributions from project partners during yearly review and planning meetings.

Future research on technologies for improving crop water productivity in the Limpopo Basin needed to consider uniform design aspects of the trials in older to isolate the best bet options for improving crop water productivity in the Basin.

Challenges

Loss of trials due to frequent droughts posed a big challenge. In Mozambique for example, trials planted in Mabalane were lost before reaching harvest stage in 2008-09 due to drought.

Inability to collect some data was in some cases due to lack of expertise and faulty equipment. Capacitance probes as an example posed a problem in terms of usage and hence soil moisture data was not taken.

Extensions workers were involved in other activities in addition to activities on this is project and this resulted in weak or less participation in the monitoring and data recording of the trials. Poor communication between extension workers and the research team was still a constraint.

Staff movement was another challenge as some staff left during planting time a good example being in Mabalane in Mozambique where the only extension staff left at the time of planting the trials when he got another job out side government.

Despite the large number of trials implemented in Zimbabwe in 2005-2007 season, yield data was not provided in the annual report. It was learnt in the process that the Zimbabwe team could not do statistical analysis of the data. It was therefore resolved that in future, the data could be sent as raw data to the responsible theme leaders to help in the analysis**.**
Poor data collection was another big challenge. Some staff did not bother record moisture content of the grain harvested and only provided the fresh weight data which could not make sense when analyzed.

It took a long time into the third season to have proper implementation of trials in South, a situation which led to data being available only for the last two seasons of the project.

The partnership approach to the project implementation was good for the purpose of integrated approach to food security achievement. However, the multi-stakeholder integration seemed to be difficult to work with as the attainment of certain outputs relied on actions by other partners whom one institution would have no direct control. As such the weaker institutions determined the pace of activities or the failure of activities.

The political mess in Zimbabwe worsened during the project phase and the economic turmoil led to failures by the implementing staff to monitor the trials and in many case data was lost as farmers did the yield measurement without supervision.

Bird damage on sorghum disappointed farmers and they became hesitant to grow the crop.

MAIN RECOMMENDATIONS

Farmers

Farmers recommended that the project should continue as some farmers only worked in the project for one season and therefore felt there was still more to be learnt from the technologies tested.

It was recommended that resident extension staff from the country ministries of agriculture must continue back-stopping farmers even after the end of the project.

As promising technologies were identified, it was recommended that the proven technologies be up-scaled so that more farmers can adopt them.

Farmers recommended that the size of the trial plots in future be increased as the 25m by 20m plots used were too small for sustainable production. They indicated that there was need to multiply crop varieties of the promising crop species so that seed should not be a constraint.

Farmers also recommended that there should be more training of farmers in terms of use of specialized equipment and record keeping. They wanted to have more look and learn tours (exchange visits) within the country and across countries to ensure that there is exchange of ideas and sharing of knowledge.

Extension staff

Since all activities depended on extension staff as front line people in the implementation, who besides other duties as their daily work, still had to drive the project activities, they recommended that future projects build in an incentive package for the increased work load for extension staff. The incentives could include transport and fuel, stationery and protective clothing.

They also recommended there should be intensive training so that they become familiar with data collection in future. The current project did not put enough effort in training of extension staff and this consequently led to a lot of loss of data over seasons. Some of the data required full time staff on the project other than extension alone because the processes were time demanding e.g. days to flowering assumed that the extension worker will be there in almost daily.

General

On partnership approach to project implementation, it is recommended that in future, proper stakeholder analysis should be done to make sure that only serious stakeholders are brought on board. The weaker partners in this project determined the failure of some activities as some activities depended on the actions of other institutions.

The size of the project activities were far too ambitious than required considering the type of data needed. Such complicated data collection procedures were proposed yet the extension staff had limited expertise to be able only to collect simple other than complicated data unless it was to be collected by students. An example here is the soil data, canopy temperature and soil moisture data all of which extension staff had problems to take in this project. It is therefore recommended that simple and straight forward data should be targeted in future so that even extension staff can be able to collect it from the trials with little supervision or backstopping.

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Forthcoming Publications:

Msc Thesis – Mr. Manuel Sitoe, Mozambique – University of Pretoria, South Africa

Msc Thesis – Mr. Thomas Maculuve – Mozambique – University of Pretoria, South Africa

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PROJECT PARTICIPANTS AND INSTITUTIONS

The project was multi-disciplinary in nature. As such, it involved a number of institutions and specialists. The details of the participating scientists and institutions are as given in Table 40 below:

Table 40: Project participants and their institutions

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Extension Officers	Matobo District	***AREX Zimbabwe***	
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