Project R 7069. Increasing pearl millet production through improved use of grain legumes and animal manures[1].

Final Technical Report

known in Namibia as the 'PSP project'

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ACRONYMS

ACT	African Conservation Tillage Network
AET	Agricultural Extension Technician
ART	Agricultural Research Technician
ADC	Agricultural Development Centre
AEZ	Agro-Ecological Zoning Programme
CARO	Chief Agricultural Research Officer (DART)
CT	Conservation Tillage
DAP	Draft Animal Power
DART	Directorate of Agricultural Research and Training
DEES	Directorate of Extension and Engineering Services
DFID	Department for International Development
DSSAT	Decision Support System for Agrotechnology Transfer
EU	European Union
FAO	Food and Agriculture Organisation
FSREU	Farmers Systems Research and Extension Unit
GIS	Geographic Information System
GRN	Government of the Republic of Namibia
GTZ	Deutche Gesellschaft fur Technische Zusammenarbeit
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFAD	International Fund for Agricultural Development
IITA	International Institute of Tropical Agriculture
IPM	Integrated Pest Management
KFSRE	Kavango Farming Systems Research and Extension
ProjectMADI	Mashare Agricultural Development Institute
MAWRD	Ministry of Agriculture, Water and Rural Development
MET	Ministry of Environment and Tourism
NCD	North Central Division
NFFP	Namibian Finland Forestry Programme
NGO	Non Government Organisation
NNEP	Northern Namibia Environmental Project
NNFU	Namibian National Farmers Union
NNRDP	Northern Namibia Rural Development Project
NOLIDEP	Northern Regions Livestock Development Programme
NOREESP	Northern Regions Epidemiology, Extension and Research Support Programme
PI	Principal Investigator
PSP	Plant Science Project
RA	Research Associate
RCBD	Randomised Complete Block Design
RDSP	Rural Development Support Program
REMP	Research and Extension Management Programme
RNRKS	Renewable Natural Resources Knowledge Strategy
RS	Research Station
SADC	Southern African Development Community
SARDEP	Sustainable Range Development Project
SARO	Senior Agricultural Research Officer
SOILNET	Soil Management Network of Namibia
SFM	Soil Fertility Management

SRO	Senior Agricultural Research Officer
TCP	Technical Co-operation Project
TM	Thematic Mapper
UNESCO	United Nations Education, Science and Culture Organisation
UNAM	University of Namibia
VSO	Voluntary Service Overseas
WOC	Workshop Organising Committee

Project R 7069. Increasing pearl millet production through improved use of grain legumes and animal manures[1,2].

Final Technical Report

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Collaborating with:

- The Department of Agriculture, Research and Training (DART) and the Department of Engineering and Extension Services (DEES) of the Ministry of Agriculture, Water and Rural Development (MAWRD), Namibia;

- Northern Namibia Environmental Project (NNEP);

- Kavango Farming Systems Research and Extension Project (KFSRE);

- North Central District Farming Systems Research and Extension Unit (NCDFSREU).

EXECUTIVE SUMMARY

This research employed a wide range of approaches to address the potential for improving soil fertility management and productivity in pearl millet systems in northern Namibia. Emphasis was placed on improving the management of grain legumes and their contributions to soil fertility and system productivity and so directly addressed the major goal of DFID: poverty elimination.
Research activities comprised a programme of on station and on farm field research supported by a literature review, a number of different survey and mapping exercises and nutrient budget modelling.

New grain legume germplasm was accessed from a number of sources outside Namibia and introduced into the existing Namibian legume screening programme. The project adopted a predominantly on-farm form of new varietal screening that promised to identify varieties more robustly suited to on farm conditions and farmers' needs than is possible with on station screening. The research indicated that cowpea had particular potential for making greater contributions to soil fertility but that the most likely route to legume assisted productivity improvements is through the adoption of a number of different legume management options that *cumulatively* have an impact on soil fertility.
The modelling activities suggested that the adoption of a single management practice involving a legume is unlikely to make a substantial contribution to soil fertility. The modelling also revealed the importance of (legume) residue management and nitrogen fixation rates in determining whether the legume was a net nitrogen contributor or miner of the system.

Promising new legume technologies identified included:

- cowpea/millet intercropping with increased cowpea densities,
- increasing the productivity of millet/cowpea intercrops with modest phosphorus and manure additions
- the use of cowpea and other short duration grain legumes as green manures for pearl millet

There is great potential for farmers to work in adapting legume species and varieties to fit the complex biophysical and management niches that exist in their farming systems. From the project experiences it is clear that more needs to be done in facilitating the access of farmers to new legume germplasm and some recommendations are made for changes in the approach to grain legume screening in Namibia.

The project collaborated on work on systematising indigenous systems for land classification and combined them with more formal systems based soil characteristics. This has yielded a very useful GIS map-based framework for understanding the complexity of the biophysical environment in the study areas. This promises to be a very useful tool in research planning and targeting research activities and advice to individual fields, farms and households.

1 BACKGROUND

The problem of declining soil productivity and the need for improved soil fertility management in pearl millet systems were identified by DART, DEES and NGOs operating in Northern Namibia prior to the start of this project. Though rural livelihoods may have diversified away from agriculture in northern Namibia (Keyler 1995) somewhat more than many other Sub-Saharan African (SSA) countries rural communities remain dependant on farming for household food production. Soil fertility management had been little addressed in the area prior to the start of this project. Demand for the research was clearly expressed by a number of different stakeholders (including farmer groups, farmers' union representatives, researchers and NGOs at annual research planning meetings). This demand was also clearly demonstrated throughout the project through farmers' (increasing) interest and involvement in the research, the wide ranging collaboration that developed and the interest from all sectors and levels in the research results and the SoilNet (the Soil Management Network of Namibia) initiative facilitated by the project.

This research was important because:

- it came at a time when there was little soil fertility research ongoing in northern Namibia to satisfy the demand from farmers and local professionals.

- it departed from what little had been done in that much of it was participatory, working on farm in target communities through farmer groups with the farmers identifying the problems and research issues on which they most wanted to work

- it recognised the complexity of the physical landscape, the farming systems and the livelihoods of the rural poor and attempted to incorporate an understanding of this into project activities and recommendations for improved soil fertility management.

Much interest has been expressed in the research *process* followed by the project and elements of this have been adopted by some key organizations in northern Namibia (e.g. the NCD Farming Systems Research and Extension Unit and the continuing DART research programme).

2 PROJECT PURPOSE

Improved soil fertility management techniques, particularly those using legumes and animal manures, in pearl millet systems identified, developed and tested in northern Namibia.

3 RESEARCH ACTIVITIES

Project activities are described in the order they appear in the project log-frame (Appendix 1).

3.1 Accessing new germplasm

Facilities: DART and IITA
Expertise: PI, RA and SARO (Mr Fleissner)
Special resources: New germplasm from IITA and ICRISAT(India)

At the start of the project existing literature and reports documenting the cereal and legume programmes of Namibia were reviewed. The most important of these were a special study by Balogun & Tripp (1997), various KFSRE/U working reports on their on-farm millet and legume tests, NOLIDEPs working reports on imported pasture and forage legume species and DARTs own legume screening programmes. Discussions were held with all the key project personnel to identify their view of farmers' seed requirements. Within the first six months of the project a Farming systems survey (see below) was conducted that included a significant section on farmers germplasm resources and needs. The result of these activities are highlighted:

- a general lack of all Bambara groundnut seed since much had been lost in recent successive drought years
- a lack of improved cowpea seed especially short season varieties
- limited species diversity of grain legumes (i.e. only cowpea, Bambara groundnut and some groundnut)

As a result a trip was organised for the SARO responsible for legumes, Mr Fleissner, to visit IITA. The visit included one-to-one advice on breeding and selection procedures for Bambara groundnut and detailed information on species and varieties available. The SARO returned with an extensive collection of new Bambara Groundnut varieties and new cultivars of cowpea especially adapted for intercropping and low fertility soils. Additionally, species new to Namibia were imported from ICRISAT in India. See Table 4 in section 4 below for the list of germplasm imported by the project. In addition to collaborating with DART researchers and the FSREUs, the project also collaborated with NOLIDEP and an Indian funded project based at Musesi in Kavango. Both of these projects were working with the introduction of new seed species.

The imported new seeds were incorporated into DARTs new legume screening programme monitored by the SARO and were planted at Mahanene RS during both seasons. Results from this work can be found in Appendix 3. Seed multiplication was also carried out during both dry seasons. The multiplication in the first season only included seeds identified by the SARO at that point (i.e. not including the new imports from IITA and ICRISAT). The second season involved multiplying a wide cross section of the new seed for farmers to test in their own fields in the 1999/2000 season. Results from these farmers' trials are found in Appendices 8 & 0. At the end of the project all the imported and multiplied seed was left under the jurisdiction of the CARO and the SARO to incorporate into future research station and farmers trials.

3.2 Literature review

Facilities: UEA library and on-line services
Expertise: PI
Special resources:

A review was conducted of grey and published Namibian and international literature relevant to soil fertility management in semi-arid Africa. Printed copies of the document were disseminated at the 1998 National Namibian Research Reporting and Planning Conference and more copies are available from ODG. It is attached in Appendix 2 of this report. The findings of this review informed the development of the project research activities that are summarised in section 4

3.3 Surveys

Three baseline data collection surveys were conducted during the project: i) Farming systems survey; ii) Pearl millet cultivation survey and iii) Nitrogen fixation and soils survey.

3.3.1 Farming systems survey

Facilities: DART, DEES, KFSRE, NCD FSREU
Expertise: RA, SARO, AROs, AETs and PSP researchers (with on-the-job training)
Special resources: advisor Christine Okali

This survey was conducted in June/July 1998 prior to the participatory planning exercise that took place before the first season of project trials (1998/1999). The design focused on farmers' perceptions of soil fertility and crop yields and also on the different management practices used to maintain crop production. The respondents were the small and middle scale farmers in the communal lands of northern Namibia.

The survey was conducted in the four villages selected to host project activities. Located across the east/west rainfall gradient in the northern part of the country these villages encompass a number of different ethnic groups and farming systems. They were selected after considerable consultation with relevant staff from DART, DEES and the two farming systems units in Kavango and North Central Districts. Small teams were engaged to conduct the survey with officers from DART and DEES as well as native speakers for translation purposes working alongside project staff. There was also some input from KFSR/E and NCD FSREU staff.

During the reporting trip in May/June 2001 discussion arose about the selection procedure for project villages. This is a general discussion that has been running in northern Namibia since before the beginning of this project and it is one that this project was necessarily drawn into. Prior to 1998 the NCD FSREU adopted a policy of concentrating on-farm research activities in eight focus communities. There has been a lot of controversy around this decision. During the first year this project worked in two of the focus communities and then in the second year dropped them due to confounded data. These issues are discussed in the paper contained in Appendix 8.

3.3.2 Pearl millet cultivation survey

Facilities: DART, DEES, NCD FSREU and Ogongo Agricultural College
Expertise: RA, AETs, PSP researchers and Dr Philip Chikasa
Special resources: Ogongo Agricultural College and 24 final year students

At the time of project initiation there was little documented research relating farmers pearl millet cultivation practice linked to yields. Field observation identified millet crop populations and yields were highly variable across farmers' fields and between villages. A previous survey had been conducted by the RDSP that supplied some data on seeding and thinning rates used but it did not proceed to relate this to yields. The survey was designed to address this gap. It was conducted in two stages during February to April of 1999 with analysis and reporting during the dry season of that year.

As this survey required labour intensive field sampling that could not be done by government employed AETs or ARTs and an arrangement was reached with the Ogongo Agricultural College (NCD) to give third year students active experience in field research. A group of 24 final year agricultural students participated in the study supervised by a senior lecturer from Ogongo AC. Several theoretical and practical training sessions were held with the students at Ogongo before the survey. This work is described fully in appendix 5.

3.3.3 Soils and legume N_2-fixation fixation in farmers fields

Facilities: DART, DEES,
Expertise: PI, RA, and PSP researchers (with on-the-job training)
Special resources: Wye College stable isotope laboratory, soils analysis laboratory in RSA.

In May 1998 a phase of topsoil and grain legume/reference crop sampling was completed in selected farmers' fields in the two main project villages (Katope in Kavango Region and Oshaala in North Central Region) and also from Mahanene and Mashare Research Stations. Samples were analyzed for soil characteristics and nitrogen fixation using the ^{15}N natural abundance method. A second more substantial phase of sampling for N_2-fixation measurements in project research fields was conducted during the 1999 season. Soil samples were sent to the Institute for Soil, Climate and Water (ISCW) labs in RSA for characterization. Plant samples were sent to Wye College, London University for ^{15}N and total N determinations. The results of these surveys were combined with other available reports on soil characteristics in Namibia and reported at the 1999 Namibian Research Reporting Conference. Full reports are attached in Appendix 6. The findings from this activity were used in the modelling (see below) and in planning the on farm and on station research activities.

3.4 Modelling

Facilities: UEA pc
Expertise: PI

3.4.1. Model design and objectives

A spreadsheet nutrient budgeting model was developed to quantify potential contributions from grain legumes to the nitrogen balance in the pearl millet systems. Inputs and outputs and the main nutrient transformations were quantified. Secondary data on nitrogen flows and transformations in semi-arid cereal systems were integrated with data from the analysis of legume N_2-fixation and growth in farmers' fields in the focus villages in 1998. Key parameters in the model determining whether legumes are likely to contribute significantly to the field N budget are *Nitrogen harvest index (NHI) of the legume*, *Legume biomass production* and *N_2-fixation rate.* The results from the modelling informed the planning and interpretation of the on farm and on station research activities.

3.5 On station research

Facilities: DART, Mahanene and Mannheim Research Stations
Expertise: RA, CART, CARO, SARO, ARTs and dedicated project technician
Special resources: casual staff, improved seed, superphosphate, field equipment

In consultation with DART a decision was made to conduct up to 4 project field trials (described individually below) at two of the government research stations , Mahanene RS in Omusati Region and Mannheim RS in Oshikoto Region and a multiplication programme of the new legume seed (Mahanene RS). In 1998/9, due to resource constraints on station the project trials were planted late and this affected results (1998/9). In the second year a DART prioritisation exercise ensured that all rain-fed trials, including project trials, were planted with the early rains.

The PSP activities required land representative of farmers' fields but most of the research station had a long history of fertiliser application resulting in high residual fertility, particularly phosphorus. In an effort to avoid this residual effect relatively inferior land was chosen for project experiments at Mahanene thought by Station staff to have no history of fertiliser application (though subsequently this proved not to be the case).

A dedicated project technician, a graduate from Ogongo Agricultural College was employed by the project, to manage the trials on a day to day basis.

Table 1 gives details of the experimental programme and objectives over the two seasons. Fuller details are available from project reports attached in Appendices 7 & 9.

The rationale behind the experiments was that, although grain legumes are present in the current farming systems, they are not there in quantities sufficient to make much contribution to soil fertility. Experimentation with density, planting configurations and management practises such as green manuring were carried out to ascertain the potential for increasing the legume component of the production system without unacceptable penalty to the millet or unrealistic resource input requirements from farmers.

The project also looked at the simple seed priming technology developed by DfID under KRIBCO in India with grain legumes and pearl millet in northern Namibia.

Table 1. Details of PSP on station experimental programme 1998-2000

Experiment	Seasons	Location	Objective: to...
1. Pearl millet & cowpea intercropping	both	Mahanene	Investigate influence of legume spacing, legume/millet variety and relative planting date on productivity and competition in millet/legume intercrops.
2. Pearl millet & pigeonpea intercropping	1998/9 only	Mahanene	Investigate viability and productivity of millet/pigeonpea intercropping.
3. Pearl millet green manuring	both	Mahanene	Investigate potential of cowpea, mungbean and lablab as green manures in pearl millet production systems.
4. Seed priming in pearl millet & legumes	1998/9 and 2(cowpea the only legume)	Mahanene[1] and Mannheim	Investigate effect of seed priming (seed-soaking) on germination, development and productivity of millet.

[1]Mahanene in season 1 (1998/9) only.

3.5.1 Pearl millet and cowpea intercropping trials

The objectives were to investigate the influence of legume spacing (two densities), legume/millet variety (two legume & two millet varieties) and relative planting date (two planting dates) on productivity and competition in millet/legume intercrops. This was the largest of the trials with 14 treatments and 4 replications in a RCBD design. This trial was established at Mahanene Research Station in 1997/8 and 1998/9.

3.5.2 Legume green manures

The objectives were to investigate the potential of cowpea, mung-bean and lablab as green manures in pearl millet production systems. The trial was established at Mahanene with 5 treatments and 4 replications in both seasons. In the first season only it had a split-plot design, with a sub-treatment receiving phosphorus fertiliser. In all other respects the design and objectives remained for the same for both years.

3.5.3 Seed priming trials: legumes

The objectives were to investigate the effects of seed priming on germination, development and productivity of the legumes. This trial was established at both Mahanene and Mannheim in 1997/8 and 1998/9. In both years a RCBD design was used with two treatments and four replications. In the first season one cowpea and one Bambara groundnut variety were used whereas in the second year there was a lack of Bambara seed and an additional cowpea treatment was included.

3.5.4 Seed priming trials: millet

The objectives in both seasons were to investigate the effects of seed priming on germination, development and productivity of pearl millet. In the first season the seed priming treatment was combined with population treatments in a split plot randomised blocked design. In the second year seed priming was combined with variety and planting date treatments in a RCBD design. Both trials were planted at Mahanene and Mannheim RS in 1998 and 1999 although results from the Mahanene trial in 1998/9 had to be discarded due to the site of an old kraal that raised variation to an unacceptable level.

3.5.5 Pigeon-pea and millet intercropping trials

The objective of this trial was to investigate the viability and productivity of millet/pigeon-pea intercropping. It was planted at Mahanene RS in 1998 and the intention was to prune the pigeon-pea after the harvest and to interplant with millet in the second year. Unfortunately the trial had to be abandoned even before the first harvest, due to very poor pigeon-pea establishment.

3.5.6 Legume Seed Multiplication

The main objective of the multiplication plots was to produce enough new seed for on station and on farm experimentation. Large plots were planted during each dry season and managed with irrigation. This provided the project and screening programme with most of the required seed though occasional disease and labour problems limited the success of multiplication for some varieties. In the second season Bambara groundnuts were particularly late in maturing and ready for distribution to farmers rather late in January.

3.6 Farm trials

Facilities: DART, DEES, NCD FSREU, Mahanene Research Station.
Expertise: PI, RA, CART, SARO and dedicated project technician
Special resources: improved seed, P fertilizer, vehicles, camping equipment and field equipment.

On-farm trials were conducted in four villages in 1998/9 and in only two of these villages in 1999/2000. Implementation of the on-farm trials was preceded by workshops with the farmers of the four villages to discuss soil fertility principles and select different themes for investigation. The workshops were conducted by the PI and RA with translation by the project technicians. Once farmers had selected the themes these were developed by the PI and RA and then brought back to the farmers and AETs. Farmers contributed to the design and wholly managed their own trials with support from PSP researchers while the researchers collected samples and data.

There was a dedicated researcher allocated to each village although these researchers were over-stretched in the first year. For this reason it was decided to trim the 1999/2000 programme in two of the villages and then later, to cut them altogether. In the second field season the researchers resided in the villages. The RA visited the villages regularly to monitor progress and manage the researchers up until January 2000. At this point military activity on the border prevented visits to Kavango but the programme in NCD continued almost normally.

The research themes of the on-farm experimental programme are summarised below in Table 2. As for the on-station experimental programme, the main rationale for the on farm programme is that legumes are not present in local farming systems in sufficient quantities to make much contribution to soil fertility. Testing new legumes generally aims to increase the quantity and diversity of legumes grown on farm. The phosphorus and manure trials aim to improve productivity of both millet and legumes at the same time, while the legume density trials focus on increasing the legume component of the system. Both quantitative and qualitative data sets were generated from these trials in both seasons.

Table 2. Summary of on-farm experimental programme 1998-2000

Research theme	Season	Site	Objective: to...
1. New legume testing	1998/99 1999/00	Oshaala & Katope	assess performance of new legumes on farm.
2. Fertiliser & manure	1998/99	Oshaala, Katope, Eefa & Ekolola	Investigate phosphorus & manure effects on millet & legume crop performance on farm
	1999/00	Oshaala & Katope	
3. Legume density	1998/99	Oshaala, Katope, Eefa & Ekolola	Investigate viability of increasing legume biomass by increasing legume crop density on farm
	1999/00	Oshaala & Katope	

New legume testing

In the 1998/9 season the quantity of available seed was limited. This included several promising cowpea varieties (Nakare, Shindimba, Bira), and one or two varieties each of Bambara groundnut, pigeonpea, mungbean, groundnut and lablab. In Katope, it was agreed to entrust seed to five farmers who planted all the seed together in ‘legume gardens’. These farmers were able to compare the seeds and in the following year these seeds were distributed among themselves for other farmers to try. In Oshaala, farmers wished to have their own seed to try rather than entrusting it to chosen individuals and the new seeds were distributed among all those wishing to participate.

In the 1999/2000 season, due to the multiplication activities, the quantity and variety of available seed was much greater. It was organised into sets of 4 species/varieties and distributed to 74 different farmers. They agreed to compare the new varieties with a local "control" variety on their farms. Only 23 of these farmers laid out their plots in a way that made it possible to collect quantitative data (Table 3), however, all farmers participated in the evaluation meetings. Seed was distributed in Oshaala and Katope villages but security problems in Katope made data collection difficult.

Table 3. On-farm research with new legumes, Oshaala, 1999/2000.

Set:	Characteristics	Species/variety	No. of farmers from which quantitative data could be collected
A	new cowpea varieties 1	Shindimba, Bira, Ngoli Epase	8
B	new long season legumes	small pigeon-pea, large pigeon-pea, black lablab, white lablab	1
C	new short season legumes	Mungbean, Guar, Nakare, Grounduts	5
E	new cowpea varieties 2	IT96D 666, IT93K205-29, IT96D-733, IT89D-867-11	3
F	new cowpea varieties 3	IT93K734, IT93K-573-1, IT96D 740, IT93K-608-13-1	1
G	Bambara groundnut	AS17, KFBN 9501, AHM 753, SB16-5A	5

3.7 Farm trial evaluations

Facilities: DART, DEES, NCD FSREU,
Expertise: PI, RA, CART, SARO and dedicated project technician
Special resources: advisor Christine Okali

The farm trials' evaluation was a review process based on the Knowledge, Attitudes and Practice methodology. It was developed in 1999 over a two-week period of intensive interviews in Katope and Oshaala by the RA and project researchers working closely with the special advisor. In the second year the evaluation was updated to reflect changes that had occurred in the trials and new approaches that had emerged in the course of research (e.g. to relate outcomes to land unit choices).

The objectives of the exercise were to establish farmer perceived outcomes of their research as well as establishing as precisely as possible what the farmers actually did with inputs they were given by the project and why. The information requested in the questionnaire related specifically to the on-farm trials in which informants were engaged. The questions covered: their initial understanding about what they were doing in their own trial; what they actually did (who was responsible, where the trial was located, what comparisons were being made and precisely how this was done);and, what they learnt from the experience (the outcome of the trial itself, crop performance, comparison with expectations and comparison with their own crop performance etc). It also covered their interest in participating in on-farm work in the following year.

End of season 98/99

This first evaluation was carried out in all four of the villages where farm trials were implemented, Oshaala, Eefa, Ekolola and Katope. The sampling frame was the list of all farmers who had received inputs for trials and stratified random sampling ensured a representative sample (of trial inputs received, gender and wealth ranks). Four researchers were engaged to carry out the work and analysis was conducted under supervision of the advisor. The results from the analysis fed back into the planning process for the second season of farm trials that were adapted accordingly.

3.7.2 End of season 99/00

The second evaluation was carried out in the two villages that implemented trials, Oshaala and Katope. Four researchers carried out the exercise in Oshaala but only two in Katope because of the access restrictions imposed by the border troubles. The RA monitored the process in Oshaala but was unable to do so in Katope. A consequence of this was an inferior output from Katope and some data had to be excluded from the analysis.

3.8 Case studies

Facilities: Eight farming households (4 in each village)
Expertise: RA and 2 project researchers
Special resources: GPS

The aim of the case studies was to investigate how farmers, of different social groups, manage nutrients to ascertain whether the legume and manure components of local farming systems can be boosted and utilised to raise pearl millet productivity. The study households were selected after the first season's data analysis was completed. The selection was made on the basis of wealth, gender and willingness to participate in the study. The activities involved closely monitoring the farming decisions and practices to see how these played out in the field. Exercises included a detailed calendar and map of planting times, species and variety placement and labour allocations as well as population counts. During the season these case studies informed other project activities, in particular the mapping and characterisation of indigenous land units (ILUs) but also, importantly, the analysis of farmers' trial results.

3.9 Mapping and characterising ILUs

Facilities: DART, DEES, NCD FSREU, MET-NNEP,
Expertise: RA, 2 project researchers, ARO
Special resources: Ecologist/GIS specialist - Dr Alex Verlinden, Mr Bertrand Dayot-Kahuure, GPS equipment and GIS computer technology

This activity occurred during the final field season of the project. A collaboration with MET-NNEP arose when it was recognised that there was potential for integrating findings of this project with those of NNEP (based within MET). This project had identified, through the farm trials and individual case studies that farmers fields were 'patchy' and that these patches had different characteristics and were managed in distinctly different ways by farmers. The NNEP working with Forestry (MET) and the NCD FSREU (DEES in MAWRD) had begun work on identifying different Indigenous Land Units and their distinguishing ecological characteristics. A collaboration developed between the two projects investigating the land resource endowments of different farmer groups and the patterns of distribution of ILUs throughout the village. The investigation examined the suitability and capability of the different ILUs and was rooted in farmers' knowledge of appropriate management.

The process began by selecting a group of elders to work with. In the case of Oshaala they were all older men who had historic knowledge of the area pre-dating the relatively dense settlements now found. The whole area was mapped and the characteristics and uses of different land units were discussed in depth. A number of other sources of information were accessed (including GPS readings of individual household fields) and brought together to generate GIS maps. These maps were then discussed, evaluated and refined with the group of elders. The verified system of ILU distribution has provided a framework for case studies (above) and soil and crop sampling samplings. These data have been analysed and integrated to inform other project results.

3.10 Feedback and dissemination

Facilities: DART, DEES,
Expertise: RA (PSP), ARO (DART), DAP Co-ordinator (DART), TA for NOLIDEP (DART), Acting DD Training (DART) and Specialist (GTZ)
Special resources: workshop funding (GTZ) and in-kind contributions from MAWRD, PSP, NOLIDEP and REMP

Feedback to DART, DEES and farmers was an integral part of the project process. Results from the various activities were widely discussed in preparation for the new season or new activity. Workshops held were held in the villages prior to each season. Monthly reports were made to DART via the Agronomy Meeting (which became bi-monthly late in 1999) and DEES via the FSREU meetings. Documents and posters were prepared and presented to each of the Annual Research Reporting & Planning Conferences. The project participated fully and at all times in departmental planning exercises when invited to do so.

Final reporting and dissemination occurredduring May/June 2001. Presentations and workshops were held for different groups of stakeholders including farmers, researchers, extension workers and academics. Draft copies of the final technical report were circulated widely for comments and feedback and this has been incorporated into this document. Agreement was reached about the supply of posters for DART and DEES to distribute. Finally, discussions were held with project partners about producing papers for Namibian and international publication.

3.11 Networking

Facilities: DART, DEES,
Expertise: RA (PSP), ARO (DART), DAP Co-ordinator (DART), TA for NOLIDEP (DART), Acting DD Training (DART) and Specialist (GTZ)
Special resources: workshop funding (GTZ) and in-kind contributions from MAWRD, PSP, NOLIDEP and REMP

During the early months of 1998 this project responded to a suggestion from DART for the initiation of a network to enhance information exchange on soil fertility issues in Namibia. An initial letter was distributed to people at the Annual Research Reporting Conference[1] to ascertain the extent of demand for such a network. In October of the same year the MAWRD hosted a workshop in Rundu titled Conservation Tillage with Animal Traction for soil-water Management and Environmental Sustainability. One of the outputs from this workshop was the establishment of a regional network for Conservation Tillage for which GTZ funding had been secured. Since the objectives of the two networks were similar it was agreed to form one network to incorporate issues relevant to both.

The RA co-ordinated a small team of Ministry and other independent project staff to organise a three day workshop that was held in Otjiwarongo in May 2000 with the objective of establishing a mandate for the intended Network. The proposed network was named SoilNet, the Soil Management Network of Namibia and a committee and President were appointed to fulfil the mandate. A second workshop held in May 2001 and funded by this project was a forum for final reporting back of project results. Considerable feedback generated from this engagement has been incorporated into this document. The full Proceedings of both these workshops are available on request.

4. OUTPUTS: RESULTS AND PRODUCTS

4.1 Output 1: Useful legume germplasm available to Namibian researchers and farmers increased

4.1.1 Identifying and accessing new legume germplasm.

Table 4 contains a summary of the new germplasm identified and brought into Namibia. Grain-legumes were targeted, particularly species and varieties with a short duration and adapted to dry or infertile conditions. All material was stored at Mahanene RS and available for Namibian researchers to use while some of it was multiplied for farmers to test in their own fields. Results from on station screening work involving germplasm accessed through this project have already been presented and published by the SARO in Namibia (see Fleissner 2000, Appendix 3) and this work is expected to continue. One persistent concern is that DART carries out all its primary screening activities on station with its relatively good soils and optimum management. The PSP project has recommended the development of on farm screening through farmer networks to and this may happen in the future. A screening structure where farmers grow and select seed directly themselves allows a

[1] held at Neudamm Agricultural College, Windhoek in September 1998.

consideration of crop management qualities to be incorporated into the selection process.

Table 4 Legume germplasm brought in to Namibia by project.

Species	Varieties	Provenance	Fate
*Vigna unguiculata (*Cowpea)	Several hundred (varieties bred for low fertility soils, intercropping, aphid resistance, grain cum fodder production)	IITA	Incorporated into DARTs legume screening programme from 1998. Selected varieties multiplied through 1999 for on farm work in 1999/2000
Vigna subterrannea (Bambara)	Twelve varieties	IITA	Incorporated into DARTs legume screening programme from 1998. No particularly strong varieties emerging from on station work.
Dolichos biflorus. (Horse gram or Kulthi)	red and white varieties	India	Incorporated into DARTs legume screening programme from 1998. Poor germination and growth.
Phaseolus aconitifolius (Moth bean)	Three varieties	India	Incorporated into DARTs legume screening programme from 1998. Poor germination and growth.
Cyamopsis tetragonaloba (guar or clusterbean)	Three varieties	India	Incorporated into DARTs legume screening programme from 1998. Most promising of small seeded legumes but farmers not enthusiastic about seed size.

4.1.2 New germplasm screened and tested on farm in NCR and Kavango

These trials were the most popular of the three themes in both seasons and researchers were inundated with farmers requesting to participate.

In the 1998/9 season group evaluation sessions were held with those responsible for the legume gardens and most were enthusiastic about the performance of the new seed. Interest was most keen in the new cowpea varieties, particularly Bira and Shindimba (not the varieties most heavily promoted at the time) and in the mungbean. Many villagers had seen or heard of the new varieties and this partly explained the large numbers of farmers wanting to try them in 1999/00.

In 1999/00 the on farm legume screening worked well though the project was only able to collect quantitative data from a proportion of the farms and farmers were reluctant to make comparisons between new and local seed. The results are presented in more detail in Appendix 10 and are summarised here:

- **Bira** was ranked top by farmers despite quantitative results showing that it yielded significantly lower (in biomass) than the local control. Surprisingly, it was not the highest yielder in terms of grain either but it scored very well for germination, establishment and growth, indicating showing that farmer’s preferences are based on a complex set of criteria.

- **Ngoli** was the highest yielder both in biomass and grain but was not significantly different from the local control. Farmers ranked this 2nd highest and some linked their local seed as being about equal to it.

- **Epase** was ranked 3rd despite being the lowest yielder

- Overall, **Shindimba** was ranked last although it produced biomass about equal to that of the local control.

- Grain production was not the lowest and farmers in Katope actually preferred it to **Ngoli** and **Epase**.

The long season legumes introduced in 1999/2000 had not flowered at the time of evaluation thus farmers were unable to judge their value in the system. Mungbean performed well on station and on farm though some farmers did not like the small size of the seed. Of the short duration legumes accessed by the project, guar was the only one to establish well on station but did not perform particularly well on farm.

Bira was a clear front runner by preference despite its mediocre production score. This suggests that the bias of the on-station selection programme towards quantitative yield data generation may be excluding varieties that are more suitable to farmers' conditions and preferences.

Unfortunately a single season of farmers' trials is insufficient for making specific varietal recommendations as the quantitative data, in particular, is very patchy. However, it is clear that there are a number of new cowpea varieties in particular of great interest to farmers. If they continue to perform well Bira, should be made more widely available.

4.1.3 guidelines for use and dissemination of new germplasm

A relatively small proportion of the cowpea germplasm in Namibia has been tested on farm. The emphasis is on station selection of a small number of varieties for on farm testing. The on farm screening approach followed by this project and recommended to DART allows the integration of qualitative data from farmer evaluations with more conventional quantitative production data. This ensured that considerations of the biophysical environment of the farm, and farmer management & preferences were important in the screening process. Though the project followed this approach for only one season the approach revealed that the cowpea variety most favoured by farmers: Bira, was not the one being most heavily promoted by DART (Ngoli). Thus a major recommendation from this research is that there should be a move towards on farm screening for most of the new material. A large amount of this work needs to be done before a selection of robust new varieties can be made for wider dissemination.

Cowpea remains the most variable and adaptable legume in the region and interest from farmers in small-seeded legumes as a food source appears to be modest. Bambara is an indigenous crop and widely grown but the range of available varieties is more limited and thus the management options are more restricted than for cowpea. There is growing interest in Bambara, however, and new varieties of this crop and its potential could be further developed. Groundnut is popular in the more fertile soils but the environment is rather marginal for this crop.

The legume species/variety is an important part of any improved SFM technique involving legumes and thus output 1 is of direct relevance to output 2 (discussed below). Moreover increased researcher and farmer access to improved legume germplasm is likely to be as important as anything else in facilitating the development of new SFM techniques in northern Namibia.

4.2 Output 2: Improved pearl millet/legume/manure combinations and management techniques identified and tested on farm

As indicated above all project activities were to some extent directed towards the achievement of output 2. Individual activities have all been reported on and these reports are included as appendices and summarised or referred to where appropriate below. For the purposes of this report an integrated summary of the activities is produced and the extent to which this output has been achieved is discussed. Output 2 can be divided into the identification of improved techniques (activities 2.1-2.4) and the field testing of these techniques (activities 2.5 & 2.6).

4.2.1 Literature review (Appendix 2)

The review was wide-ranging and directly informed the subsequent research design in a number of ways. In summary:

- Pearl millet is and will remain the most important staple food crop in most of NCR and Kavango Region.

- Nitrogen and P are limiting in cultivated soils across Kavango and in most of the soils in NCR (particularly central areas).

- Pearl millet/cowpea intercropping systems, in particular, deserve particular attention with research emphasis on density of both crops, cowpea varietal choice and relative planting date.

- Modest N (20-30 kg N/ha) and P (10-15 kg P /ha) fertilizer application are likely to dramatically improve yields in adequate and good rainfall years. However, the likelihood of rain failure in at least 50 % of the years means N fertilizer application to millet cannot be recommended. The greater potential for a residual effect with P fertilizer if rains fail, combined with the absence of any other source of P in the system means modest chemical P applications should be considered.

- Incorporation of cowpea or other good quality residues before planting millet will improve millet yields in adequate or good rainfall years as 20-25% of the residue N will become available to the millet.

- Legume residue management is likely to be very important in determining their net contribution to soil fertility. More legume residues are required and research is needed to find the best legume varieties (cowpea particularly) for intercropping and rotating with pearl millet and the optimum plant densities and spacings.

- Manure applied in amounts realistic when considering production (perhaps 2 tonnes/ha) will have little soil fertility benefit but may have a longer term benefit on soil physical properties and ameliorate long term negative effects of mineral fertilizer application (acidification, depletion of minor nutrients). These effects are important and mean that if any chemical fertilizers are applied to these soils they need to be combined with some organic inputs, manure particularly.

- Improved manure management options (in situ kraaling, covering, straw additions) need to be explored with farmers. Also new ways of increasing the legume component of the system (new species combinations and mixes) require attention.

The review findings were the basis for the initial attempts at formulating broad themes for possible field research. The field surveys covering general farming systems and millet cultivation (activity 2.2, appendices 4 and 5) generated a number of important findings that were used to inform the project about local perception and practice with regard to SFM. Information from the surveys was also used to give the possible research themes local systems and management context. The key review findings are summarised below:

4.2.2 Farming systems survey (Appendix 4)

- Poor soil fertility is considered to be one of the three most important concerns for farmers, the others being low rainfall and crop pests. Over a third of farmers interviewed believe that land productivity is declining and linked this with the lack of manure. While perceived problems of pests and rain seem to be more widespread than poor soil fertility, the majority of those raising the issue rank fertility as their most urgent concern.

- Local soil fertility management practices vary across NCD and Kavango. Farmers interviewed in the villages of the North Central Districts have well developed manuring strategies whereas those farmers situated in Kavango tend to open ‘new’ fields.

- Fallowing, crop rotations and the use of synthetic fertilisers or organic crop residues for maintaining soil fertility, are rare across the region.

- Millet and cowpea residues already have multiple and competitive other uses.

- Millet, sorghum and cowpeas are the most important and widespread crops inNCD and Kavango. Combinations of species and varieties are located to deliberately exploit particular niches within the field. Most farmers combine two different varieties/landraces of each of the top three species but between 4-6 may be found on a single farm. The most common combination of millet is a farmer local with the ‘new’ short season Okashana 1.

- There are multiple sources for millet seed whereas seed for other crop species are usually retained from the previous season.

4.2.3 Pearl millet cultivation survey (Appendix 5)

- The most common seeding rates across all sites are between 66,000 and 150,000 seeds per hectare at 6-10 seeds per hill and 11,000-15,000 hills per hectare. The hill density range found across the sites was below 5,000 hills/ha and above 31,000 hills/ha.

- The most common thinning rate among all farmers is 3 plants/hill but up to 6 plants/hill were found at particular sites.

- Analysis across all sites shows that post establishment crop hill survival is generally good but at population densities below 6,000 hills/ha it is poor. This poor establishment at low densities may well be related to particular land units and soil types.

- Mean and potential millet yields differ quite significantly between different villages and farming systems. The range of mean yields, stratified by village, was 370 kg/ha to 1450 kg/ha.

- Across all sites, millet population densities in the range 10,000-25,000 hills/ha have little affect on final yield but above 25,000 hills/ha yields drop off rapidly. Below 10,000 hills/ha yields decline but little can be ascertained about the relationship below 6,000 hills/ha.

Information on soil characteristics and legume N_2-fixation was also required to inform the research planning process and results on these were presented in a paper at the 1999 Namibian Research reporting and planning conference (appendix 6). Key findings are summarised below

4.2.4 Soil characterization (Appendix 6)

Table 5. . Summary of results from analysis of soil samples collected in April 1998.

Village/station	pH (H_2O)	Ecw (μs/cm)	OM (%)	Olsen P (ppm)	Texture[1]	Sand (%)	Silt (%)	Clay (%)
Shikoro	7.03	52	0.40	3.4	s	94	3	4
Mbore	7.13	30	0.45	0.8	s	94	3	3
Mayana	7.54	31	0.33	2.1	s	92	2	6
Katope	5.94	44	0.85	1.7	ls	82	1	6
Mashare Station	7.56	49	0.59	14.0	s	85	4	12
Oshaala	7.04	106	0.42	2.7	s/ls	88	6	6
Onesi	8.41	349	1.04	43.0	ls	84	4	12
Mahanene Station 1	6.52	36	0.26	50.0	ls	87	7	6
Mahanene Station 2	7.12	35	1.60	1.6	ls	88	7	6
Mean for farmers' fields in Kavango	7.17	35	0.42	1.9	-	93	3	4
Mean for farmers' fields in NCD	7.23	140	0.51	2.7**	-	87	6	7
Overall mean for farmers' fields	7.19	71	0.45	4.1	-	91	4	5

[1] s = sand, ls = loamy sand
* available P value excluded in calculating this average as it was extraordinarily high (43 ppm)

- Soils in northern Namibia are infertile with deficiencies in P, N and organic matter almost across the board (though there are areas of higher potential soils associated with water action in NCR: the cuvelai and the oshanas but these soils often have salinity or drainage problems).

- With the current millet production system (no external inputs in most areas), the most important factor in determining yield success is timeliness of planting. This enables the crop to utilize the early nutrient flush and early rainfall both of which will be lost to the crop if planting is late. This will continue to be as important in systems with improved soil fertility management.

- Some of the worst soils in Kavango Region may not be worth cultivating as there are a number of different nutrient deficiencies as well as problems with low water retention, possible salinity etc. From what farmers say this is probably also the case in NCR.

- Other nutrients (calcium, potassium magnesium) are probably deficient in some areas but adequate in much of the cultivated area in the short term at least. They do not seem to represent major constraints to increased production at the moment.

- The samples are insufficient to make any broad statements about salinity but clearly salt affected soils are locally important in some areas of NCR particularly.

This preliminary analysis was considerable strengthened with the development of the land-unit classification system during 2000 (see section 4.7 below.

4.2.5 Legume nitrogen fixation (Appendix 6)

Table 6. Summary of nitrogen fixation data by species

Species measured in 1998	**Nitrogen fixation (%)**[1]	**Standard deviation (n)**	**Species measured in 1999**		**Nitrogen fixation (%)**[2]	**Standard deviation (n)**
cowpea	33a	26 (28)	Cowpea	local	*56*	*30 (12)*
Bambara	60b	32 (8)		Nakara	*52*	*28 (29)*
groundnut	32a	18 (9)		Shindimba	*61*	*24 (43)*
Aeschynomene	68	1		average	57	26 (84)
Cajanus cajan	60	1	Bambara		48	26 (2)
Crotalaria	40	1	groundnut		64	23 (10)
Lablab	14	1	Lablab		50	25 (4)
Leucaena	21	1	Mungbean		29	30 (5)
Sesbania	35	1	Pigeonpea		45	31 (5)
Stylosanthes	50	1				

[1] t tests performed on estimates for first three species. Different letters denote significant differences at p=0.05
[2] No significant differences between species or varieties in 1999

- The initial study gave us confidence that the ^{15}N natural methodology is suitable for use in the field in northern Namibia.

- For cowpea, estimates were very variable in both years but much lower in the first season (33%) compared with the second (57%). Although cowpea is currently the most widely known, adaptable and interesting legume in the production systems, it is clear that it is sometimes not fixing very much nitrogen.

- Groundnut is fixing, on average, similar proportions of nitrogen to cowpea. This is a more demanding crop, less widely grown and thus with less potential to make large contributions to the soil fertility but there is also likely to be room for management improvements that will improve productivity.

- In the first season (1999) Bambara nut was, on average, fixing at almost double the rate of the other legumes studied (60%). It is a popular crop, already grown by many farmers and clearly important in their production system. Although this crop is not as 'flexible' as cowpea its obvious high degree of adaptation to local conditions suggests it has good potential for contributing N to the system

- A number of exotic legumes were doing well at Mashare and Mahanene Research Stations in soils with elevated P levels relative to surrounding farmers' fields. The extrapolation of legume productivity data from Station to Field is therefore not easy.

4.2.6 Modelling (Appendix 11)

As far as possible the model was parameterised using local data on nitrogen fixation, productivity etc. Three very important parameters in determining the model outcome were **legume nitrogen fixation rate, legume residue management** and **legume production.**

The modelling work informed the field research planning process in a number of ways. Key findings were:

- The amount of N produced in several hundred kg residues per hectare (typical of fields measured in 1999) is negligible.

- Increasing cowpea density was believed to be the best way of increasing biomass as a) cowpea intercrop densities in farmers fields are low and b) the literature suggests densities could be doubled (to 20,000 hils/ha) with no great risk of competition with millet. Competition for water and nutrients is likely to prohibit higher legume densities in most years.

- The model output indicated that the net N provided and utilized from such a cowpea crop (20,000 hills/ha) was likely to be in the region of 4 kg N, sufficient for approximately a 100 kg increase in millet yield.

- Such an increase is unlikely to be measurable in farmers' fields and a millet yield improvement of at least 300 kg/ha, is likely to be required to interest farmers in a change of practice.

- The model indicates that unrealistically high legume densities of 35,000 - 60,000 hills/ha (depending on how the millet residues are managed) would be required to provide sufficient legume residue N for this 300 kg millet yield increase.

- The much smaller benefits suggested by the model outputs are a benefit but are unlikely to encourage farmers to learn and adopt a new practice.

These results whilst significant in their own right shaped the development of the on farm and on station research and the final project recommendations.

4.2.7 On station research (Appendices 7 & 9)

Experiment 1: Pearl millet/cowpea intercropping

Results, particularly in the 1999/00 season showed that cowpeas can be very productive (> 1 tonne grain/ha, Table 7) when intercropped with millet at higher densities than farmers are using (8,000 or 16,000 hills/ha in this research). The lower densities used in this research, 8,000 hills/ha are still higher than most farmers use in an intercrop and even at these densities the cowpea can compete strongly with the millet if the season is favourable for cowpea growth (as in 1999/2000). Long duration indeterminate cowpeas e.g.

Kalumya compete more strongly than short duration determinate cowpeas e.g. Nakare though in 1999/2000 even Nakare reduced local millet yields by 50% when intercropped at 8,000 hills/ha. If the farmer can obtain a good price for cowpea this might not deter him/her from growing it at these densities. If, however, the market for cowpea is poor and/or the farmer is not prepared to accept a decline in millet yields then the best option may to continue planting at low densities. Pest attack is always a risk associated with cowpea production and this deters farmers from increasing their reliance on it as a cash or food crop by, for example, mono-cropping cowpeas in large areas.

Table 7. Summary of treatment effects on pearl millet yields relative to sole crop yields 2000 (*Shaded areas are cowpeas intercropped with Okashana 1; unshaded ares are cowpeas intercropped with local millet).*

Treatment		**Okashana millet (kg/ha)**		**local millet (kg/ha)**		**Kalumya cowpea (kg/ha)**		**Nakare cowpea (kg/ha)**	
	Cowpea variety	**Grain**	**% sole crop**	**Grain**	**% sole crop**	**Grain**	**Residue**	**Grain**	**Residue**
Millet sole crop		222	***100***	887	***100***				
With cowpea at *WIDE*[1] spacing	**Kalumya:**	114	***51***	140	16	1060	281	151	137
	Nakare:	168	***76***	466	53	907	411	96	77
With cowpea at *CLOSE*[1] spacing	**Kalumya:**	42	***19***	106	12	1209	428	288	191
	Nakare:	96	***43***	320	36	884	400	191	136

[1]Wide spacing = 7,800 hills/ha, Close spacing = 15,600 hills/ha

Thus, to intercrop millet with cowpea at densities sufficient to produce enough residue N for noticeable increases in millet yields the following year (> 300 kg grain/ha) exposes the millet crop to more risk than many farmers can reasonably be expected to accept. Maximum cowpea residue production without risk of high competition is probably 6-800 kg/ha containing 12-16 kg nitrogen, only 8-12 kg/ha of which are fixed and 3-5 kg/ha of this fixed N might be available to the following millet giving a maximum yield increase of 1-200 kg/ha. This yield increase is unlikely to be noticed by most farmers against the back-ground of substantial year to year variation in millet yields.

In neither year was there a significant difference in millet yields with different legume planting date or density. This suggests cowpea compensates rather well for differences in density and that a 10 day delay in cowpea planting did not affect either crop significantly.

Experiment 2: Pearl millet/pigeonpea intercrops

Pigeonpea did not establish well (approximately 20%) on the soils available for the on station work thus this experiment failed in 1998/1999 and was not repeated in 1999/2000. Once established, pigeonpea can grow well, even on *omufitu* soils as has been shown at Mahanene.

Experiment 3: Legume green manures

Cowpea incorporated as a green manure increased yields by approximately 50% or 120 kg/ha (Table 8). About 40 kg N is required for 1 tonne millet and associated residues suggesting a legume N use efficiency of approximately 40% (i.e. 5 kg of the 12 kg N supplied by the legume green manure).

Table 8. Millet production in experiment 3, 2000

Treatment	Density	Millet production (kg/ha)		
	hills/ha	residue	grain	total
millet control	63a	481ab	214ab	813ab
Lablab grown to maturity	65ab	330a	150a	550a
Lablab as a green manure	70bc	570abc	290bc	990bc
Mungbean as a green manure	70bc	760c	320c	1220c
Cowpea as a green manure	70c	700bc	340c	1160bc
p	0.022	0.052	0.005	0.019

(Means in the same column followed by the same letter are not significantly different at $p < 0.05$)

Lablab did not get off to a very quick start in this experiment. Again this is probably because the soil at the site was quite poor. Lablab grown to maturity as an intercrop competed with and depressed the yields in millet.

Green manuring appears to be a useful technology for the poor soil areas (e.g. *omufitu* soils) in north central Namibia (of which this site was typical). On better soils both crops would probably grow better and the potential yield increases in millet would be greater. It is a useful option as it allows farmers to decide relatively late (March) whether the rainfall pattern is such that an N input to the millet (effectively an N top dressing) is likely to substantially boost yields. If rains prove to be poor and the prospects of good millet yields low the farmer can opt to leave some or all of the legumes in the ground to produce grain as a food or cash crop. Bira cowpea performed best in this work but it is unlikely to fit the needs of most farmers hence the need to test many varieties of cowpea on farm.

It is important to choose a legume variety and plant at densities (16,000 hills/ha in this work) that are capable of producing substantial amounts of biomass and nitrogen. Farmers have to accept the need for a management decision and an extra activity (turning in the green manure) mid-season but their options are expanded and turning in residues can be combined with a late weeding. It is encouraging to see the positive effect of mung-bean and cowpea, two species more likely to give a harvestable yield (grain for mungbean, leaves and green pods for cowpea) before they are incorporated.

Experiment 4: Seed priming

There was no evidence of a benefit from seed priming to either pearl millet or cowpea.

4.2.8 On Farm research (appendices 8 & 10)

Legume density trials

Table 9. Mean quantitative results from Katope legume spacing trials.

Treatment	Cowpea density (hills/ha)[1,2]		Cowpea biomass residue production (kg/ha)		Pod production (kg/ha)
	1998/99	1999/2000	1998/99	1999/2000*	1999/2000*
wide spacing	12800 (10) **a**	9140 (14) **a**	230 (7)	2850 (13) **a**	400 (11)
close spacing	18400 (7) **b**	15210 (14) **b**	160 (7)	4740 (13)**b**	680 (11)

[1] the number of cases for each data point is given in brackets
[2] means followed by different letters are significantly different (p <0.05)
* fresh weights only available

Table 10. Mean quantitative results from Oshaala legume spacing trials.

Treatment	Cowpea density (hills/ha)[1,2]		Cowpea residue production (kg/ha)		Cowpea grain production (kg/ha)	
	1998/99	1999/2000	1998/99	1999/2000*	1998/99	1999/2000
wide spacing	**-**	9170 (6) **a**	-	4020 (5)	-	580(5)
close spacing	**-**	43500 (6) **b**	-	5670 (5)	-	540(5)

[1] the number of cases for each data point is given in brackets
2 means followed by different letters are significantly different (p <0.05)
* fresh weights only available

Trials in both seasons show significantly higher densities in the closely spaced treatments. Where the number of replications are sufficiently high, the trials also show significantly higher residue production in the closely spaced plots. This does not necessarily translate to significantly higher pod and grain production but equally, pod and grain production does not appear to suffer from denser cowpea stands. Samples paired by variety showed significantly higher biomass production by Kalumya ($p<0.001$, $n=18$) but once again there was no significant difference in pod production ($p=0.8$, $n=15$).

Only fresh weights are available for the second season and therefore not comparable to the 1998/1999 season. Biomass residue production in the 1999/2000 is considerably greater, probably at least double that of the previous season (1998/9). However, this still represents a net contribution of only about 5kgs of nitrogen per hectare[2]

Generally these on-farm trial results show that higher density stands of cowpeas can produce significantly higher biomass residues without a penalty to pod and grain production. Choice of variety is critical as indeterminate and determinate varieties have different harvest indices (HIs) and a different response to drought. The indeterminate types produced significantly higher biomass in both seasons and have lower nitrogen HIs than the determinate varieties. The 1999/2000 was a better rainfall season than the 1998/99 season and this resulted in higher legume production, though even in this

[2] If nitrogen concentration is about 2%, then in 250kg of dry matter there is approximately 5kg of N. Since 30-60% of this nitrogen is fixed from the atmosphere, the net contribution of nitrogen to the soil is between 5-10kgs at the most.

better year the net contribution of nitrogen from (ungrazed and unburnt) legumes was still likely to be low, around 5-10kg/ha.

Additional residues produced by higher density stands could be used for soil amelioration (or dry season animal feed) but most farmers are unfamiliar with the management practices involved. Most farmers do not actively alter planting density and would not normally consider this as a management option.

Fertiliser and manure trials

Despite low application rates at Katope, the use of phosphorus fertiliser was beneficial at both sites for cereal and legume crops (Tables 11-14). The combination of P fertiliser and manure also greatly increased yield, sometimes several-fold. Although application rates of manure (and therefore crop nutrients) were relatively low, this practice generally improved hill emergence and establishment. Response to phosphorus was also strong. Since trials were harvested before grain filling was complete for all millet heads, it is likely that left until full maturity, the measured responses to phosphorus and manure applications would have been even greater.

Table 11. Means of quantitative results from Katope legume P/manure trials

Treatment	Cowpea density (hills/ha)[1,2]		Cowpea pod production (kg/ha) [1,2]	Cowpea residue production (kg/ha) [1,2]	
	1998/99	1999/00	1999/00	1998/99	1999/00
control	17000 (5)	6000 (7)	340 (7)**a**	1250 (3)	2460 (7)**a**
P	35000 (4)	8500 (7)	520 (7)	1130 (3)	5300 (7)**b**
manure	11000 (1)	4500 (7)	1050 (4)**b**	-	5750 (4)**b**
P + manure	32000 (1)	5000 (7)	1160 (4)**b**	-	6640 (4)**b**

[1] the number of cases for each data point is given in brackets
[2] means followed by different letters are significantly different (p <0.05)

Table 12. Means for quantitative results from Katope millet P/manure trials

Treatment	Pearl millet density (hills/ha)[1]		Whole plant fresh weight (kg/ha) [1,2]		Millet head production (kg/ha)	
	1998/99	1999/00	1998/99	1999/00	1998/99	1999/00
control	-	13000 (5)		2640 (5)**a**	-	750 (5)
P	-	12000 (5)		6400 (5)**b**	-	1570 (5)
manure	-	14000 (3)		4300 (3)	-	1070 (3)
P + manure	-	19000 (3)		5380 (3)**b**	-	1550 (3)

[1] the number of cases for each data point is given in brackets
[2] means followed by different letters are significantly different (p <0.05)

Table 13. Means for quantitative results from Oshaala legume P/manure trials 1998/9

Treatment	Cowpea density (hills/ha)[1,2]	Cowpea residue production (kg/ha)	Cowpea pod production (kg/ha)
control	16200 (10) **a**	790 (10)	950 (9)
P	22000 (6) **b**	690 (8)	570 (2)
manure	19000 (2)	950 (2)	2000 (1)
P + manure	14000 (2)	740 (2)	1150 (1)

[1] the number of cases for each data point is given in brackets
[2] means followed by different letters are significantly different (p <0.05)

Table 14. Means for quantitative results from Oshaala millet P/manure trials

Treatment	Pearl millet density (hills/ha) [1,2]		Number of millet heads (heads/ha) [1,2]		Millet grain production (kg/ha) [1,2]	
	1998/99	1999/00	1998/99	1999/00	1998/99	1999/00
control	11000 (5)	15000 (7)**a**	-	46000 (6)**a**	780 (5)	240 (4)**a**
P	12400 (5)	20000 (7)**a**	-	73500 (6) **a**	1050 (5)	500 (4)
manure	15500 (2)	22000 (7)**ab**	-	57500 (6) **ab**	1480 (2)	300 (4)
P + manure	12000 (2)	28000 (6)**b**	-	77000 (5)**b**	1200 (2)	510 (3)**b**

[1] the number of cases for each data point is given in brackets
[2] means followed by different letters are significantly different (p <0.07)

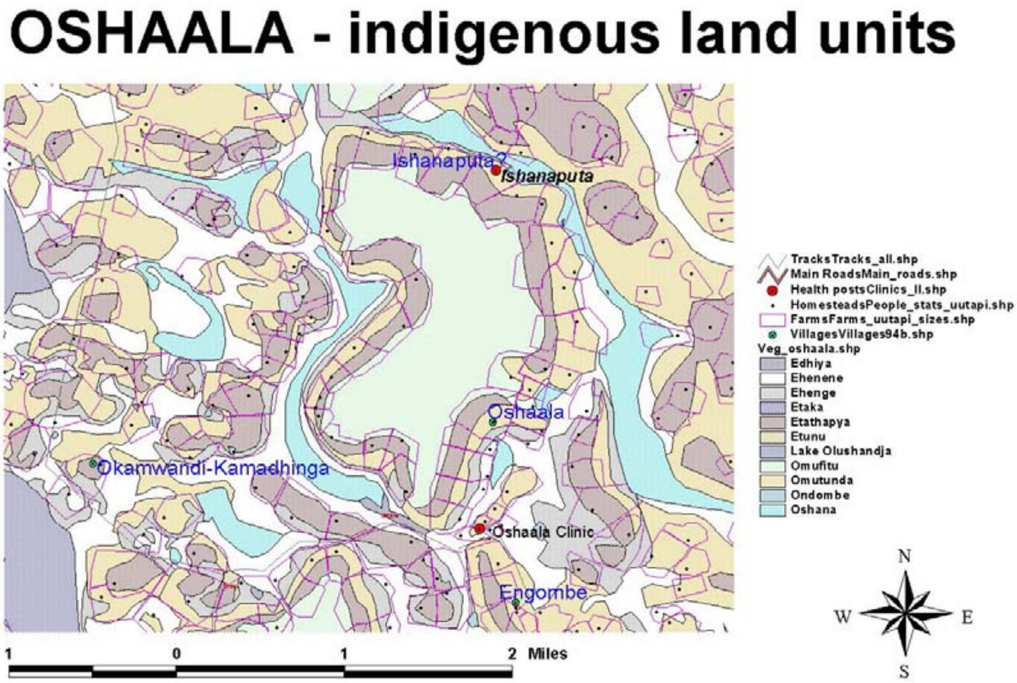
Although the quantitative data indicate the effect of manure applications on productivity are generally positive a number of farmers, mentioned negative effects of manure use. Dark patches of manure can absorb heat and warm surrounding soil to temperatures that harm crop emergence and establishment. Manure can also "burn" seed or young plants if applied fresh or too near to planting holes and there is a period of dry weather. Different land units and soil types have different characteristics with respect to water table depth, the presence of hardpans and other factors that affect the movement of water. These factors in turn influence the impact of manure management and soil temperatures that influence crop growth and development. These factors vary across farmers fields in complex ways. The key to unravelling and understanding the complexity lies in the soil types, landscape units and farmers management of them.

4.2.9 Mapping and characterising ILUs

Much of the data generated from the case study households was used to inform other project activities particularly those of the mapping and characterising of indigenous land units (ILUs). The laboratory characterisations of soil samples taken from the case study household fields was combined with farmers knowledge to characterise the different units contained within their fields and this synthesis is included in Appendix 12. Results show that clear differences exist between the potential millet productivity of different ILUs and that the etathapya (local term) soils support significantly higher yields. Etathapya are land units that have been cultivated for extended time periods (typically 30 years or more) with consistent fertility management including manure amendment during the cultivation period.

These results are important because they indicate that farmer cropping and management strategies are systematically and logically tailored to land-unit differences. An awareness of these differences needs to be incorporated into research activities and, ultimately, be reflected in advice given to farmers by extension and other local professionals. Prior to this work there was no comprehensive understanding of the ILU system. One significant effect of this on research activities is the high variation and difficulty in identifying treatment effects caused by locating trials across a range of ILUs. In some cases cereal or legume crops perform poorly on particular ILUs. Only certain ILUs are suitable for supporting both types of crops so that trials that contain millet and cowpeas intercropped must be sited carefully if the results are to supply any meaningful information for farmers.

Figure 1. Indigenous land-unit classification in Oshaala village



The project work on local land unit classification systems section provided some revealing insights into relationships between indigenous soil classification systems, soil physio-chemical properties, the performance of legume crops on different types of soil and farmers' rationale when making cropping and management decisions.

Results from soil and crop samples, and farmers ITK have been combined to characterise the ILUs. This is summarised in the following table.

Table 14. Indigenous land unit (ILU) classification in Oshaala village, northern Namibia.

ILU	**Topsoil type**	**Hardpan depth (m)**	**Drainage**	**Strength**	**+ve effect if manure applied**	**Legume productivity**	**Millet productivity**
etathapya	Organic loamy sand	1-2	Well drained	moderate	>10 years	Low - moderate	High
ehenene	Thin top soil of fine sands over clayey hard pan	<0.3	Poorly drained	Strong-very strong	For drainage	Low - high	Low - high
okahengethitu	Loamy sand Medium grained sand	> 2	Well drained	Moderately weak	2-3 years	Moderate – high	Low-moderate
ehenge	Loamy sand	1-2	Moderately well drained	moderate	5-6 years	Moderate – high	Moderate
omutunda	Sandy loam	< 1	Imperfectly – moderately drained	Moderately strong	2-5 years	Low – moderate	Moderate
oluma	Sandy clay loam	-	Poor- very poorly drained	Very strong	For drainage	-	High
omuthitu	Coarse sand	-	Very well drained	Weak	< 2 years	Moderate – high	Very low- low
etunu	Termite enriched sandy loam	< 1	Well drained	strong	Never	-	High

4.2.10 Networking: SoilNet

The project was instrumental in co-ordinating a workshop held in Otjiwarongo in May 2000, the objective of which was to establish SoilNet, the Soil Management Network of Namibia. The workshop agreed among other details the initial Mission Statement for the network, the guiding principles and operational framework as well as appointing a steering committee for the new SoilNet.

The Mission statement, objectives and guiding principles of SoilNet were agreed as follows:

Mission Statement

To establish and maintain a network for strengthening collaboration and communication among the stakeholders. The purpose is to improve information exchange, free of charge to users, to facilitate the adoption of sound soil management practices in Namibia.

In addition to providing an effective forum for presentation and discussion of soil management research agreements were reached at the first workshop on objectives and management of SoilNet. The agreed objectives are:

- To promote exchange of information on sustainable soil management among stakeholders
- To establish a database of all information on soil management
- To create and maintain a database of individuals and organisations involved in soil management

Full details discussed and agreed at the workshop can be found in “Proceedings of the workshop on soil fertility management and conservation tillage for sustainable land use in Namibia” Otjiwarongo 16-18 May 2000.

The second workshop held in May 2001 reviewed SoilNet’s progress during the first year and ratified the new constitution. Details can be found in “Proceedings of the workshop on the establishment of the Soil Management Network of Namibia” Tsumeb 29-30 May 2001.

5. CONTRIBUTION OF OUTPUTS

The outputs of this research address the broad DFID RNRKS goal:

- **The elimination of poverty and the improvement of poor people's livelihoods**

in addition to the more specific Plant Science Research Programme goals:

- **Production of target crops on impoverished soils in semi-arid conditions increased by physiologically appropriate practises**

- **Expanded knowledge of plant physiology and agronomy incorporated into improved agronomy practises and promoted**

5.1 Poverty focus

Despite the relative diverse nature of people's livelihoods in northern Namibia pearl millet cropping is the dominant activity in rural areas. The unreliable rainfall across the whole of the region militates against investment in chemical fertilizer, particularly for subsistence crops such as pearl millet. The project focus on low input fertility management strategies for pearl millet systems was directly relevant to the rural population, particularly the poor who rely more on growing millet for food. There are also potential environmental benefits from non chemical, low input strategies.

5.2 Grain legume contributions

The modelling established that it is more difficult than commonly believed to generate detectable yield increases in a single year using grain legumes in semi-arid areas. This is a finding of widespread relevance for semi-arid regions and leads to the conclusions that:

- if farmers are to elect to include more grain legumes in their fields it will be for reasons other than soil fertility (taste, food security etc.) and

- for legumes to impact substantially on soil fertility there must be several types present occupying different niches and making a cumulative contribution.

The shortage of grain legumes available to farmers limits the scope for finding and exploiting niches within the farming systems. Through supporting the DART legume screening programme and strengthening its links with regional breeding centres (particularly IITA) the project has considerably increased the quantity of new varietal material available to Namibian researchers and, through them, to farmers. Dividends are already evident (e.g. see Fleissner 1999 appendix 3). The project approach of involving farmers in a systematic but flexible evaluation of new germplasm has identified varieties both new and attractive to farmers. If DART adopts the recommended on-farm germplasm screening approach, piloted by the project, its outputs are likely to have a more significant impact on farming systems and farmer's livelihoods than is currently the case. The NCD FSREU has indicated it would like to follow the intensive on farm research model this project has pioneered in the region but that the necessary human resources are limiting. Trained S/ARTs and S/AROs, dedicated specifically to on-farm work would have to be allocated to the unit from DART. Currently however, the capacity and structure within MAWRD simply doesn’t facilitate this happening.

Cowpea is the most popular and physiologically suitable grain legume crop for intercropping with pearl millet. Experimentation on station has shown that biomass and N inputs can be increased by increasing planting density but in favourable years competition with the millet is likely to be unacceptably high at the higher cowpea densities. This research has also shown that legumes and pearl millet both perform better on farm if P fertilizer and/or animal manure is applied. The research has also demonstrated the potential of legume green manuring to make contributions to the systems with modest additional input requirements.

The optimisation of legume contributions to soil fertility and productivity necessitates species/varietal choices and management finely tuned to the farmer and field level biophysical variability. The farmers were full partners in the on farm research and provided the results and evaluations that indicate its success. The NCD FSREU, DART and DEES have taken up some of the project themes (e.g. screening new legume varieties, legume green manures) and this should lead to a stream of results and practical advances in soil fertility management in the future.

5.3 Manure use

Apart from the on farm work on combining P and manure applications to cowpea and millet, the management of animal manures was not emphasised in this research. This is largely because it was clear from the initial village workshops that there is relatively little manure available to farmers and, the quantities are decreasing. Recommendations were made on improved management (relocating kraals over fields from time to time, adding cereal straw to manure to reduce N losses, covering kraals etc.) and a small number of farmers indicated willingness to try this. Most farmers in the villages had relatively little access to manure so these issues were rather academic. As it is there is a quite sophisticated system of manure application and placement in NCD and it is unlikely the project could have improved on this. Feedback from Researchers and Extensionists indicate that they consider manure quantity and quality to be important issues deserving more attention.

5.4 Indigenous land Units

Institutional knowledge about different niches within the farming systems of Namibia is weak and indigenous technical knowledge is unevenly distributed among farmers. The ILU characterisation and mapping was clearly very revealing to farmers and local professionals (extension workers etc.) alike. It is likely to provide a very important framework in the future for research and extension planning and the targeting of management advice. Potentially it strengthens the ability of the Extension Service to work with communities in adapting new technologies to local environments and farming systems. The improved knowledge it affords of the farming environment allows researchers to adapt their activities to the variable environment in the field. e.g. blocking trials appropriately, and selecting sites to suit the objective.

This work generated a great deal of feedback across all stakeholder groups. There was considerable discussion around names and how names are used within different language groups and locations. There was also particular interest about who has the knowledge and how it is spread among the community. It was suggested that the mapping could be used as a tool by teachers to ensure traditional knowledge is passed on to children and retained in the local communities. Researchers commented that results specific to a single village are insufficient for developing wider extension messages and that the work should be extended. UNAM academics asked various questions around how this research would be continued and co-ordinated. There was some concern that it was associated with a finite project rather than within mainstream national research. It was acknowledged that some ILU work continues in other Ministries but with quite a different focus and application.

5.5 Dissemination pathways

The project has been particularly well embedded within DART in the Namibian MAWRD. The project RA and project activities were considered by all to be formally located within the DART structure, though clearly funding and other support has come from DFID and ODG. The project is very well known in northern Namibia and has participated fully in planning, training and reporting activities since its initiation. Workshops and meetings for farmers have been held in the villages throughout the research process. The project has also reported fully (presentations, papers (7) and posters (2)) on its research plans and results at the 1999 and 2000 Annual Namibian Research Reporting and Planning conferences. It also submitted a highlighted paper for the 2000 DFID PSRP annual report (Appendix 11). Documents (e.g. McDonagh 1998) summarising key results and research recommendations were provided to the target institutions, DART and DEES including the North Central Districts and Kavango Farming Systems Research and Extension Units. Recommendations for on station and on farm research have been incorporated into their 2000/2001 research programme.

A special initiative conducted in line with the need for dissemination of project results and other appropriate knowledge on soil fertility management was the SoilNet. The initial demand for an information network came from within DART's plant division. The suggested need was for knowledge and research results to be gathered together (either physically or in the form of a database identifying source and site) and to be made widely accessible. In its final year the project was instrumental in co-ordinating a workshop of stakeholders that put together the foundations of the network. The steering committee comprises stakeholders from different departments and ministries that include research, extension, training, forestry and academic. The elected president was an academic in agriculture at UNAM. A programme of activities including annual meetings and the design and operation of a SoilNet web-site were agreed. The workshop participants emphasised the need for SoilNet to be a network targeted at action in the field and not purely knowledge that remains within research. The second workshop held in May 2001 reviewed the progress of the network. The first year presented operational difficulties especially regarding funding and a new strategy was agreed. A new president (a SARO from DART) and committee was elected to take things forward. The initiative is still young and it remains to be seen whether it is sustainable in the longer term or has an impact on activities. However, potentially it directly contributes to the PSP goal of:

"Expanded knowledge of plant physiology and agronomy incorporated into improved agronomy practises and promoted"

The RA made a final trip to Namibia in May/June to disseminate the project results and recommendations. Presentations were made at the SoilNet Workshop, the UNAM Research Conference, the DART Agronomy Meeting and there was a special dedicated workshop held that was open to anyone interested. Among the participants of these events were academics, researchers, foresters, agricultural extensionists technicians and farmers. Meetings were also attended with project partners and collaborators including DART, DEES, the NCD FSREU, REMP, the NNEP and the Namibia Finland Forestry Programme (NFFP). Draft reports were circulated widely for comments and feedback. Publication was also discussed and several papers are underway for submission to both Namibian and international journals. Finally, it was agreed to supply DART and DEES with posters for them to distribute to local officers and technicians.

5.6 Follow up research

5.6.1 Legumes and soil fertility

Individual legume based technologies are likely to make relatively modest contributions to soil fertility in northern Namibia. Substantial contributions are most likely to come from the adoption of multiple legume technologies. Research in this area needs to be more participatory than it is at present with more imaginative experimentation with legume/millet mixed cropping systems, particularly the intercropping, green manuring and P-supplemented cultivation worked on in this research. If this is to happen access for farmers, extension and other local professionals to improved legume germplasm must be facilitated. The protocols followed by this project for conducting on farm research have been widely reported within Namibia and provide a useful model for future work.

5.6.2 New germplasm

DART is continuing with its grain legume screening programme and the accessions obtained through collaboration with the project are likely to prove a valuable resource for several years to come. The project has suggested DART moves more of its screening activities away from high fertility (P particularly) plots at Mahanene Research Station and into farmers fields, perhaps using farmer networks to systematically screen and multiply new varieties. It has yet to be seen whether DART is willing or able to do this. Capacity to bulk up, store and market seed at Mahanene has been built up in recent years via a farmers seed co-operative that is linked to the CGIAR Sorghum and pearl millet improvement programme (SMIP). Potentially the Co-op could diversify to include the larger seeded grain legumes. However, constraints to such a development include storage capacity and grading technology for larger seeds as well as issues revolving around personalities and the ethics of seed supply.

5.6.3 Technology and knowledge

Recommendations made to Research and Extension include the continuity of characterising ILUs and documenting ITK specifically related to their management. Such knowledge then facilitates researchers and farmers to better target experimentation. This is a long process requiring the

development of a strong partnership between DART/DEES and farmers to make sure that ITK is not lost and widely accessible to researchers, extensionists. Currently aspects of research on the ILUs continue within the Forestry Department of the Ministry of Environment and Tourism. There is also a good link between Forestry and the NCD FSREU but little is known about the commitment of Research to follow up on this work.
Recommendations include deliberate experimentation on intercropping and green manuring applied to different ILUs. The RA intends to develop research on farmers management of ILUs as an important part of a PhD study already underway.

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7. APPENDICES

Appendix 1. Project Logframe

Appendix 2. A Review of Soil Fertility in Northern Namibia: An Aid for Assessing Research Needs

Appendix 3. Outputs of the legume screening programme

Appendix 4. Farming systems survey of the pearl millet based production systems of northern Namibia

Appendix 5. A Survey of Pearl Millet Cultivation in the North Central Districts of Namibia

Appendix 6. Soils and Nitrogen fixation in northern Namibia

Appendix 7. On station soil fertility research 1998/1999

Appendix 8. On farm soil fertility research 1998/1999

Appendix 9. Modelling and on station work

Appendix 10. Results and recommendations: On farm trials

Appendix 11. Soil fertility, legumes and livelihoods in northern Namibia

Appendix 12. The Characteristics and Productivity of Different Indigenous Landscape Units of Northern Namibia