CROP PROTECTION PROGRAMME

Increasing food security and improving livelihoods through the promotion of integrated pest and soil management in lowland maize systems.

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FINAL TECHNICAL REPORT

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Acronyms

ASARECA	Association for strengthening agricultural research in eastern and central Africa
BPGs	Best practice guidelines
CIMMYT	International maize and wheat improvement centre
CPP	Crop Protection Programme (of DFID)
DAEO	District Agricultural Extension Office
DFID	Department for International development (UK Government)
EARZ	Eastern Agricultural Research Zone (Tanzania)
ECAMAW	East and central Africa maize and wheat research network
EZCORE	Eastern Zone Client Orientated Research and Extension
FAO	Food and Agriculture Organisation of the United Nations
FFS	Farmer field school
GLS	Gray leaf spot
masl	metres above sea-level
MDC	Muheza District Council
MTI	Mbegu Technologies Incorporated (a Tanzanian seed company)
NGO	Non Government Organisation
NRI	Natural Resources Institute
OPV	Open pollinated varieties
OVIs	Objectively verifiable indicators
PREA	Participatory research and extension approach
PTD	Participatory technology development
SRI	Silsoe Research Institute
VEO	Village extension officer

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CONTENTS

Executive Summary

A very brief summary of the purpose of the project, the research activities, the outputs of the project, and the contribution of the project towards DFID's development goals. (Up to 500 words).

Project Purpose:

The project aimed to develop and promote strategies that reduce the impact of pests in particular *Striga* (whose effect was compounded by conditions of low soil fertility) and stemborer on poor people's maize crops, through: improved understanding of local coping strategies, identifying constraints to adoption, on-farm evaluation of selected technology options, improving access to inputs and linking stakeholders as partners during the project

Outputs:

[Summarise the significant results and the new knowledge obtained.]

Key outputs were:

i) An improved understanding of local pests of maize, existing coping strategies and constraints to adoption of improved technologies. The project brought key stakeholders using a participatory research and extension approach (PREA) ensuring that farmer and farmer institutions were fully involved from the outset of the project.

ii) Evaluation of farmer selected pest and soil fertility management options through farmer testing in Muheza District, Tanzania, selected as being representative of lowland maize production areas. This was based on participatory evaluation of appropriate maize varieties, alternative green manure crops and low cost methods of controlling stemborer over a two year, four season period. Although three of these seasons were adversely effected by drought, improvements were apparent with the improved rains in the last season of the project ensuring that farmers achieved positive gains.

iii) Improved access to inputs through establishment of two community based seed production units linked with a local seed production company. Ready access to inputs particularly maize seed in small packs was identified as important in promoting adoption. Two communities have established their own seed production units and a private sector company is supplying improved seed in small packs.

iv) Enhanced capabilities of local extension staff, farmers and researchers to provide useful information to farmers.

These Outputs were interlinked in a participatory research and extension approach designed to identify adoptable technologies and promote scaling-up.

Contribution of Outputs to Project Goal:

[Have the outputs of the project been achieved? In what way has the project contributed to meeting the research goal?]

Project Outputs have been achieved in so far as the Muheza District Council in conjunction with EZCORE has expanded activities to other parts of the District and a considerable number of households are using at least one of the technology options. In particular those farmers who have started to use new varieties of maize have achieved a considerable increase in production.

Despite adverse climatic conditions during much of the project, improved soil and pest weed management techniques have been adopted in target villages, indicating the success of PREA in allowing farmers and communities to identify and seek solutions for their own priority problems. At the same time close liaison between stakeholders (researchers, extension agents and close involvement of policy makers at village and District levels) has ensured that wide scaling-up should now be possible.

Follow-up indicated/planned:

To date benefits from increased productivity have only been assessed over a very short period necessitating a further year of activities which will concentrate on:

i) Building on existing farmer trials and their use in a farmer field school (FFS) approach and training of trainers in conjunction with EZCORE/DAEO

ii) Promoting seed sales in small packs through improving farmer access to input supplies through establishment of village level supplies linked to local seed production

Background

Information should include a description of the importance of the researchable constraint(s) that the project sought to address and a summary of any significant research previously carried out. Also, some reference to how the demand for the project was identified.

Importance of the researchable constraints

CIMMYT's maize programme in sub Saharan Africa recognises four basic agro-ecological zones in which maize is an important smallholder crop. Of these the **Lowland tropical Zone** (0-1,000 masl) located in Ethiopia, Kenya, Malawi, Mozambique, Tanzania, Somalia, South Africa and Zambia covers **18%** of the maize area in eastern and southern Africa (Hassan *et al*. 2002). Maize in this zone is often the predominant staple grain and is grown as a mono-crop or intercropped with grain legumes, sesame, cassava or in association with vegetables and rice. This has also been one of the three target agro-ecologies for maize variety improvement since the launch of the Tanzanian National Maize Research Programme in 1974. For instance most of the Eastern Agricultural Research Zone (EARZ) of Tanzania, which in 1998 had a population of 4.5 million people, falls into the lowlands. Maize is important for household food security and as a cash crop for producers in the zone, which accounts for 9% of the national maize production and 14.5% of the national area planted to the crop. Some 40% of maize in EARZ, 159 thousand tonnes in 1998/99 (Agricultural Information Services, 2000) was produced in Tanga region.

The Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) ranks maize as first priority among crops grown in the region with low soil fertility, drought, foliar diseases (including streak), stalk borers, weeds and *Striga* among the priority constraints to improved maize production. CIMMYT, working in collaboration with the Eastern and Central Africa Maize and Wheat (ECAMAW) research network of ASARECA, has developed cultivars (OPVs and hybrids) that are tolerant of moderate levels of *Striga* infestation, low soil N fertility and drought as well as being resistant to the major pests and diseases of the region, including streak virus, GLS and *Turcicum* leaf blight. Additionally, CIMMYT has developed a novel technology for controlling *Striga* in maize, which involves the application of low doses of herbicide as a coating to herbicide resistant maize varieties. These varieties are non-transgenic but derive their herbicide resistance from a naturally occurring mutation in maize that was identified and isolated on tissue culture.

Previous research

Despite the importance of the crop, maize yields on farmers' fields average less than 1.2 tonnes per hectare compared to the estimated potential yields of 4-5 tons per hectare (Kaswende *et al*. 1996). A PRA, conducted by CPP project R6291 in Muheza District in the lowlands of Tanga, established that the relatively poor yields of maize are due to a range of factors, which include declining of soil fertility, lack of high yielding varieties, stalk borer damage, diseases including Maize streak virus, *Striga asiatica* and availability of inputs (Mbwaga *et al.,* 1999).

Trials undertaken in the area by CPP project R7564 have indicated that *Striga* alone can reduce yield by over 50 %, depending upon cultivar and that this effect can be reversed by the addition of nitrogen fertiliser. The PRA revealed that, while farmers are aware of the *Striga* problem they lacked both knowledge about *Striga* biology and ability to affect some of the control measures that are compatible with their farming systems. However many small holders can not afford the cost of inorganic fertiliser (Kaliba *et al*., 2000) and in the Tanga area relatively few households own cattle and apply manure. Fallowing is rare due to population pressure. Temu and Aune (1998) working in southern Tanzania, and Kullaya *et al* (1998) working in Kilimanjaro have demonstrated that maize yield may be significantly increased by incorporation of the leguminous green manure *Crotalaria* (*Crotalaria juncea*), grown in rotation with maize. *Crotalaria* in rotation with maize was observed to have a mean nitrogen effect corresponding to about 80kgN/ha when cut and removed and when the whole plant was incorporated nitrogen effect corresponded to about 120kg N/ha. Farmers in Muheza District working with CPP project R7564 started to evaluate both Crotalaria and *Mucuna* during the long rains 2002 with a view to observing the effect on the follow on crop of maize in the subsequent short rains. An added advantage of *Crotalaria* is that it produces *Striga* germination stimulant (Riches, 2000) and has the potential to reduce *Striga* populations. The association between low maize yields, *Striga* and declining soil fertility in Muheza district was also established by recent diagnostic studies undertake by the EZCORE programme, working with district extension (Masuki *et al*., 2001a; Tenge *et al.,* 2001). Project R7564 also started to evaluate a number of open pollinated maize lines in *Striga* infested fields in Tanga (Ilonga AR!, 2001). The most tolerant and productive of these needed to be multiplied for farmer evaluation.

Maize streak virus, the main maize disease of the East African lowlands, is readily controlled by the use of host plant resistance. Released varieties, including TMV1 and Staha have been converted to carry resistance but farmers are not always aware of sources of clean seed and Kaliba *et al*. (1998) reported that MSV was a problem for 41% of farmers surveyed in the lowlands of Tanga Region. One of the reasons for this is the widespread practice of recycling improved seed for up to five years before new stocks are purchased.

Stemborers were reported by 54% of farmers in EARZ of Tanzania to be the major pest of maize (Kaliba *et al.,* 1998). Most farmers interviewed used no control method. Working in Kenya, Khan *et al*. (2000) have demonstrated that stalkborer numbers can be reduced and maize yields increased by planting a “trap-crop” border of Napier grass (*Pennisetum purpureum*) around maize plots. This practice needs to be tested with farmers in Tanga region to examine farmer acceptance of the practice and how it fits in with other production practices.

Compared to higher altitudes, the lowland maize system in Tanzania has proved to be an area where greater impact from extension of maize production technologies has been achieved in the past. The probability of adopting improved varieties for example has been 25% higher in the lowlands despite the risk of crop failure from drought. Kaliba *et al.,* (2000) attribute this to extension effort and a number of on-farm evaluation and demonstration programmes conducted in the ecology in recent years. The extension service was shown to be the most important source of knowledge for farmers and significantly influenced adoption of improved maize seed and fertiliser. However Kaliba *et al.* (2000) also concluded that factors such as price of input and output, input distribution and availability may also enhance or limit adoption in the area. In order to secure more widespread dissemination of these techniques in the farming community, a full understanding of the socio-economic environment is required, addressing problems such as cost-effectiveness, affordability, and access to equipment and labour issues. This is best achieved by encouraging local farmer innovation and building on existing farmer networks that in turn requires close partnership and collaboration between research (local and international), development organisations (both GO and NGO) and private sector input suppliers in the design and implementation of research and development projects.

The research process to be followed is designed to be inclusive involving all stakeholders as equal partners in order to encourage widespread scaling-up that will continue after project completion. (Güendel *et al*., 2001, Middleton *et al*., 2002)

Demand for the project

Demand was identified through a number of channels. Both district and national agencies accept soil fertility and pest problems targeted by this project as constraints to lowland maize-based systems in EARZ, Tanzania. These constraints, including low soil fertility, *Striga*, stalkborer, maize streak virus and poor access to improved seed and other inputs have been described as a result of a multi-agency household impact survey of the adoption of maize production technologies undertaken in the Zone in 1995 (Kaliba *et al.* 1998). Realising that few smallholders follow recommendations on the use of mineral fertilisers the Tanzania National Soil Survey, through the Soil Fertility Initiative in Eastern Zone is presently researching soil fertility management practices and developing participatory methods for an integrated approach to related problems in maize-based systems (Wikama *et al*., 2000). At a local level work to support increased productivity of maize-based systems has been initiated through the Irish aid funded Eastern Zone Client Oriented Research project (EZCORE) with which the project will form a working partnership. In most villages low soil fertility, *Striga* and limited access to crop protection inputs have been identified as key constraints to maize production (Masuki *et al*., 2001a; Tenge *et al.,* 2001). Work to address these problems is being incorporated into the on-going EZCORE[1] programme implemented in four districts including Muheza (Muheza district activity report 2001). *Striga* infestation of cereal crops is a national research priority in Tanzania and has been confirmed as a priority problem on maize in Eastern Zone Internal Programme Reviews and at a national Stakeholder workshop supported by CPP in 1999 (Riches, 2000). As a result work to identify *S. asiatica* tolerant or resistant maize lines is on-going at Mwele seed farm in Muheza with support from CPP project R7564. A programme development review of the need for maize pest management research in East and southern Africa (Blackie, Farrell and Giga, 2000) has confirmed the importance of associated issues of declining soil fertility, *Striga*, stalkborer and leaf diseases as key constraints in maize based-systems in these regions. Furthermore this review has pointed out that "too much research is conducted on single problems and too little effort is made to tie the results of research into the complex environment in which the farmer has to operate". The project is therefore designed to respond to the need to test technology combinations in a participatory manner as a powerful strategy for technology development. As well as responding to the demand for integration of testing and promotion of pest management strategies on-farm with technologies for soil fertility enhancement.

Project Purpose

The purpose of the project and how it addressed the identified development opportunity or identified constraint to development.

The project aimed to develop and promote strategies that reduce the impact of pests in particular *Striga* (whose effect was compounded by conditions of low soil fertility) and stemborer on poor people's maize crops, through: improved understanding of local coping strategies, identifying constraints to adoption, on-farm evaluation of selected technology options, improving access to inputs and linking stakeholders as partners during the project

[1] EZCORE is a programme within the Ministry of Agriculture and Food Security implemented by the district offices of the Department of Agricultural Extension in collaboration with the Eastern Zone agricultural research programme. EZCORE has been designed to improve the capability of the Eastern Zone Agricultural Research Institute at Ilonga to better respond to the needs of their clients at grassroots level and to empower the districts to obtain and implement relevant research results for the benefits of rural populations. It is currently working in Muheza District to identify farmers' constraints, train village extension workers and to put forward problems for research.

Research Activities

This section should include detailed descriptions of all the research activities (research studies, surveys etc.) conducted to achieve the outputs of the project. Information on any facilities, expertise and special resources used to implement the project should also be included. Indicate any modification to the proposed research activities, and whether planned inputs were achieved.

Improved understanding and confirmation of constraints

Stakeholder meetings and knowledge consolidation

Stakeholder meetings and a project initiation workshop were held in December 2003 to clarify the roles, networking arrangements, research responsibilities and integration of activities during the project. At the same time information available was consolidated through literature review of ongoing and previous work on pest and soil problems in EAZ that could contribute to increased adoption and scaling up activities planned during the project. This was presented as a series of papers during the project initiation workshop and as a result a detailed action plan for the next two and half years was put in place (Ellis-Jones *et al.,* 2002).

Community situation analysis and social mobilisation

Community situation analyses and social mobilisation activities were undertaken in four villages (Mapatano Mbambakofi, Mtakufa and Paramba, in Muheza District, Tanga Region) as the first phase of a participatory research and extension approach (PREA) (Figure 1) (Hagmann *et al*., 1998)

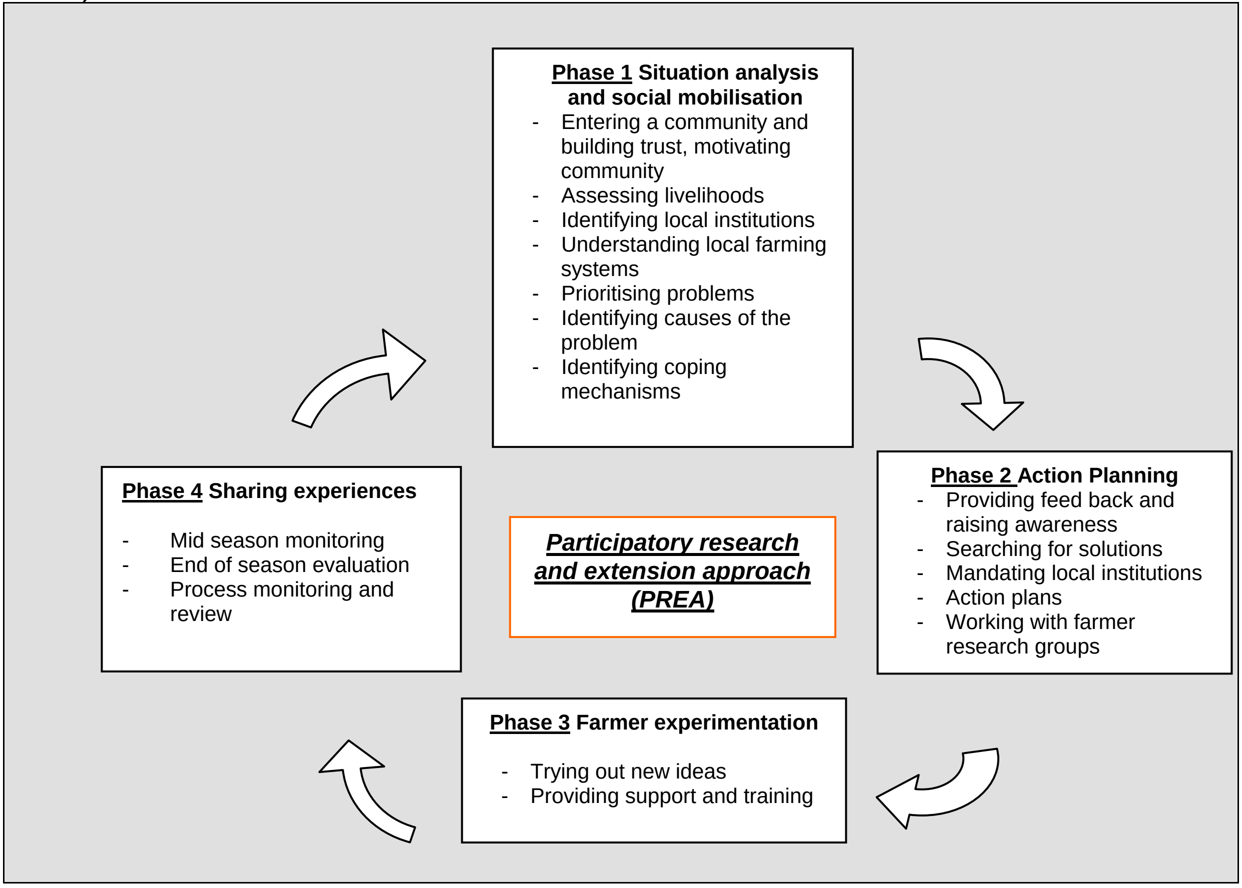

Figure 1: Participatory research and development approach used during the project

PREA Phase 1 activities assisted in 1) building trust and motivating the communities with which we were working, 2) assessing livelihoods including wealth or resource ranking, 3) identifying local institutions, 4) understanding local farming systems, 5) identifying and prioritising problems, 5) identifying coping mechanisms and constraints to adoption of possible improvements.

PREA Phase 2 activities were undertaken shortly thereafter and included providing feed back and raising awareness, searching for solutions, mandating local institutions, action planning and working with farmer research groups in each village.

A formal baseline survey was also undertaken in Muheza District (Hella and Akulumuka, 2004). This study confirmed that maize was the most important crop in the District despite the associated production and marketing problem. Declining productivity due increasing droughts and limited use of improved technologies greatly affect farmers' livelihoods. This study concluded that efforts to address the inherent problems facing maize production in the district should be centred on increasing productivity, though improving soil fertility and combating incidences of pests and diseases including *Striga*. The need for improved methods of technology dissemination to all villages and farmers within the village should be also given due emphasis.

Increasing farmer awareness and knowledge

From early 2003, existing extension material from both within and outside Tanzania was collated, modified and used to increase farmer awareness and knowledge about *Striga* and associated problems and possible control methods feeding into Phase 2 PREA activities. This was combined with exchange visits by farmers notably from Mapatano and Paramba to Mbambakofi and Mtakuja to view green manures and improved maize varieties leading to an early expansion of farmer research activities. At the same time problems of drought and the need for improved soil and water management were apparent. This led to increased emphasis on rain water harvesting during farmer awareness training.

During September 2004, modified extension material translated into Swahili was used in training of VEOs and lead farmers in problems of soil fertility, *Striga* management, appropriate maize varieties for the area and rain water harvesting. This was undertaken in close collaboration with EZCORE to facilitate expansion of project activities into another six villages (Songa Kibaoni, Songa Kilongo, Potwe, Masuguru, Ngomeni, and Mkanyageni). These new villages were selected by EZCORE for extension of project activities based on i) the VEO being present in the area, ii) farmers being well organised and iii) being in different agro-ecological zones within the district. Subsequently VEOs from the six new villages in addition to those from the existing four villages attended the Mlingano training seminar in September 2004. Farmers in each new village subsequently received appropriate feed back, 10 kg of *Crotalaria* seed and opportunity to purchase two kg packs of TMV1 seed.

Technology evaluation

Implementation of a series of farmer led trials

Following PREA-Phase 1 and 2 activities a research plan was implemented by farmers starting in two villages during the short *vuli* rains in 2002/3 and expanding to two more villages in the long *masika* rains in 2003 with the six new villages becoming involved in the *vuli* rains of 2004/5. (Table 1).

Table 1: On-farm trials implemented during the course of the project

	2003/2004			2004/2005	
	Nov 02 -Jan 03	March-July 03	Nov 03 -Jan 04	March-July 04	Nov 04 -Jan 05
Village	*Vuli*	*Masika*	*Vuli*	*Masika*	*Vuli*
Mtakuja and	GM	M	GM	M	GM
Mbambakofi	-	GM	M	GM	M
		SB		SB	SB
				RWH	RWH
Mapatano and	-	GM	M[2]	GM	M
Paramba	-	-	GM	M[3]	GM
				RWH	RWH
Songa Kibaoni, Songa Kilongo, Potwe, Masuguru, Ngomeni, and Mkanyageni					M/GM[1]

GM=Green Manure, M=Maize, SB=Stemborer, RWH=Rain Water Harvesting.
[1]Expansion with TMV-1 seed and *Crotalaria*

These farmer led trials comprised a range of pest and soil management options,

i) Integrating green manure cover crops (*Canavalia* spp, *Mucuna pruriens*, and *Crotalaria ochroleuca* or *Sunhemp*) with *Striga* tolerant maize varieties. Use of manure and inorganic fertiliser were excluded, as they were either unavailable or unaffordable.

ii) Considering alternatives methods of controlling stemborer notably neem powder, Napier grass field borders and endosulphan insecticide. The use of *Desmodium* in a push-pull system with the Napier grass was considered but germination of *Desmodium* seed was problematic.

At the same time improving soil water management through introduction of appropriate rain water harvesting method (ditches, *fanya-juu*, *fanya-chini*, tied ridges, deep tillage and mulching with weeds and grass. Napier grass used for stemborer control was planted sometimes below and sometimes above the ditches. Evaluations were based on observation rather than yield comparisons.

Some on-farm trials envisaged in the project proposal were not undertaken as the technologies were either not socially acceptable or were unaffordable. These included

- Using herbicide coated IR maize seed to control *Striga*.
- Combining in-crop weed control by banded application of herbicides with reduced tillage techniques.

<u>Research-managed testing of Ilonga and CIMMYT supplied maize varieties</u> was also undertaken using recently released varieties as well as those found to be performing well under local conditions. Two seed kits were supplied by Ilonga/CIMMYT for replicated trials at two locations (Melela-Morogoro, a site infested by both *S. asiatica* and *S. forbesii* and Mwele-Tanga, a site in Muheza infested by *S. asiatica*) during the 2003 and 2004 *masika* seasons. The first kit consisted of 12 *Striga* tolerance/resistance late/intermediate maize varieties. The second consisted of additional early materials with maize streak virus resistance, drought, *Striga* tolerance and herbicide resistance. They were compared with the locally adapted and registered TMV-1.

<u>*Climatic conditions*</u>
Difficult rainfall conditions were experienced during most of the project with both the short (*vuli*) and long (*masika*) rains in both 2003 and 2004 being well below average with very poor distribution resulting in maize crop failure (Figure 2). The 2004 <u>*masika*</u> rains started well but cut off completely one month early and a near total crop failure resulted. Some

yields were obtained after the *masika* in 2003 and again after the *vuli* in 2005, but none after *vuli* and *masika* 2004. This meant that there was little farmer experience of the green-manure maize crop cycle or stemborer control until February 2005 after the better rains of the 2004-5 <u>*vuli*</u> season. This also meant that on-farm testing of alternative stemborer control methods was only possible in the last season.

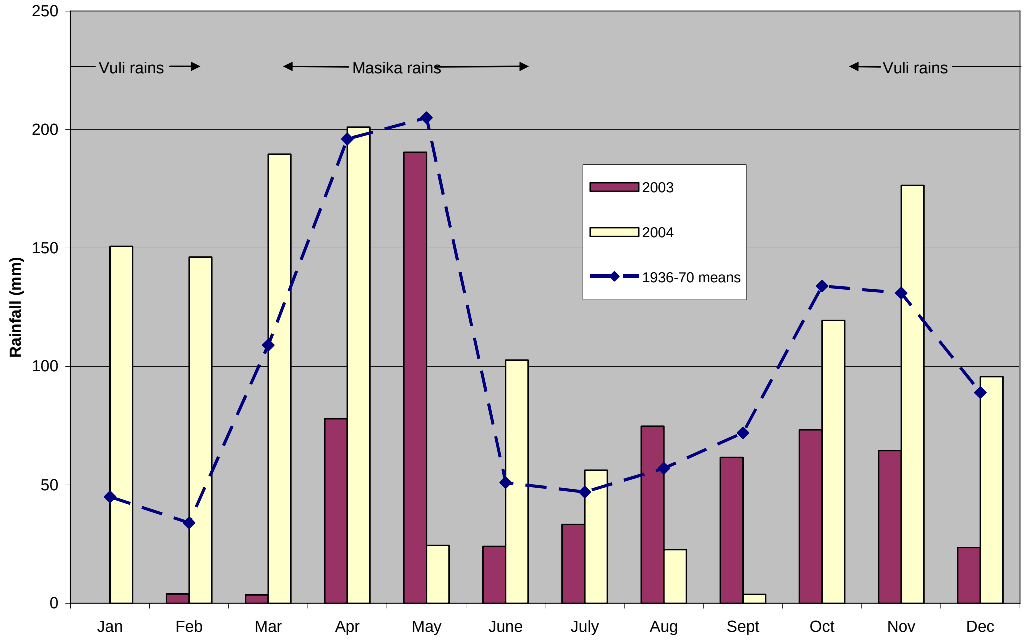

Figure 2: 2003 and 2004 rainfall compared with long term means at Mlingano (Mlingano Research Institute, 2005).

Monitoring and evaluating the trials

Monitoring and evaluating the trials (PREA-Phase 4,-Figure 1) was undertaken through a series of farmer led field days and end of season farmer workshops with stakeholders which were undertaken during the middle and at the end of each cropping season. Participatory technology evaluations (PTE) were undertaken in each village (Table 2) using the steps indicated.

Table 2: Evaluations undertaken (2004)

	Paramba	Mbambakofi	Mtakuja	Mapatano
Green manures				
<u>Matrix ranking</u> comparing green manures using farmers' criteria	√	√	√	√
<u>Establishing advantages and disadvantages</u> of green manure/ maize compared to continuous maize production		√	√	
<u>Participatory budgets</u> comparing best green manure and farmer practice over two seasons		√	√	
Maize varieties				
<u>Matrix ranking</u> comparing varieties using farmers' criteria		√	√	
Stemborer control				
<u>Matrix ranking</u> comparing control methods using farmers' criteria		√	√	

Farmer field schools established
In two of four villages (Mtakuja and Mbambakofi) farmers' trial plots were used as part of the ongoing agricultural extension activities of DAE in Muheza District for both exchange visits during 2003 by farmers outside of the village and in training of farmers within the village. Unfortunately this was not possible during 2004 due the serious drought conditions experienced.

Access to inputs improved

Identification of strengths and weaknesses of existing input supply chains
A survey of local suppliers of agricultural inputs was undertaken to identify the strengths and weaknesses of existing input supply chains through survey of local suppliers (Akulumuka and Hella, 2003). This survey was undertaken using a focused participatory approach to identify the principal components, key players, constraints and opportunities in selling maize inputs and purchasing maize harvest.

This showed that there were very few input agents. Those that do exist rely on their own past knowledge when ordering inputs from suppliers. Inputs are rarely promoted and most suppliers have little technical knowledge of the inputs they sell, referring customers to extension officers for information. The most common input sold by input vendors in Muheza was improved maize seed, largely Staha and Tuxpeno, mostly in 5, 10 and 50 kg packs with the largest quantities being sold for the *masika* long rains. The second input sold in large quantities. Actellic Super Dust (ASD) for protecting maize in storage. ASD is sold in 200 gram packets, sufficient for two 100 kg bags of maize. Very little chemical (mostly Thiodan 4% dust) is sold for stem borer control. Almost no fertiliser is sold.

Most maize is sold at harvest for cash to meet immediate household needs to buyers who then re-sell after collecting enough for transport to millers. Muheza maize is regarded as low quality due to both high moisture content (over 13%) and mixed colour, white being preferred. Information on the quality of maize required by millers is largely unknown to farmers.

Affordable sized packages of key inputs
Opportunities were identified to i) improve links between farmers and the market by providing better knowledge on the qualities and quantities of maize needed by millers, ii) providing input suppliers with technical knowledge so that they can advise farmers and iii) selling improved maize seed in half or one kg packs. Such actions should help in stimulating demand for improved technologies that increase yields. Greatest input demand from farmers was identified for improved seeds, though smaller packs are required than are presently available. Contact was made with a local seed supply firm (Mbegu Technologies Incorporated - MTI) to supply TMV-1 in two kg packs. Over four tonne of such seed was supplied to 10 villages for the *Vuli* rains in 2004-5 and commercial seed production was initiated by MTI on land made available by the sisal estates during *vuli* 2005..

Process of community based seed supply
At the same time a process of community based seed supply was initiated also during the short *vuli* rains of 2005-05 in two communities, Mapatano and Mtakuja. In Mapatano, 1.2 ha (3 acres) of TMV-1 was planted as a community-owned seed plot during *vuli* 2004-5, with 1.5 tonnes being harvested and being largely used for seed. There are also plots of *Canavalia* and *Crotalaria* planted for seed and used in a green manure maize rotation. The group has also shown interest in a future partnership with MTI for seed production. In Mtakuja the group had planted one ha (2.5 acres) of TMV1, and have harvested three tonnes of grain, which has been harvested and distributed amongst the group for both eating and use as seed. Some has also been sold as seed to others in the village.

Increased capability of local professionals

In-country stakeholder workshops
In-country stakeholder workshops involving farmers, NGOs, DAE and research professionals were a regular feature of information exchange and research reporting. These are documented in Project Working Reports 1-6.

Monitoring the process of farmer testing, uptake, modification and impact
The process of farmer testing, uptake, modification and impact assessment of technologies was undertaken during field visits that coincided with stakeholder workshops.

Unfortunately due to the drought situation that pertained during the first 20 months of the project it has not been possible to substantiate farmer uptake, modification or impact beyond those directly involved. A shortage of both green manure and maize seed has hampered scaling-up.

Distribution of research reports and other published outputs
Research reports and other published outputs were regularly distributed to stakeholders and other institutions.

Development and use of extension materials
Extension materials were developed for use in training by both extension staff and lead farmers. This has subsequently been used by .both village extension workers in their normal duties as well as by lead farmers in report backs after training to their groups.

Research outputs
The research results and products achieved by the project. Were all the anticipated outputs achieved and if not what were the reasons? Research results should be presented as tables, graphs or sketches rather than lengthy writing, and provided in as quantitative a form as far as is possible.

Improved understanding and confirmation of constraints
Phase 1 PREA indicated that almost all households depend on agriculture for their food security and derived the bulk of their livelihoods from agriculture. Interestingly, up to 60% were also involved in other livelihood activities such as trading in a range of commodities including grain, small business (excluding provision of agricultural inputs) and charcoal making and 50% worked as casual labourers either for other farmers or on adjoining sisal estates. Communities classified themselves into three resource or wealth categories, with 5-10% being described as relatively well-resourced having larger land areas (2-3 ha), more livestock and implements, 50% being described as average with 1-2 ha of land, some livestock and implements and up to 40% being described as poor having less than 0.5 ha of land, no livestock and few implements. The average and well resourced groups are more likely to be involved in trading and small businesses with the poorest most likely to be working as casual labourers. This is often seen as a survival mechanism for the most vulnerable households, when harvests fail due to drought, pest damage or market failure, which were seen to be increasing in frequency.

Key social and traditional issues raised during PREA Phase 1 were:
- Maize is the main staple and is often used as food during celebrations and as ritual during death. Nothing traditionally or culturally was associated with maize production. This was attributed mainly to having many different tribes within the community, as people were brought from all over Tanzania during colonial times to work on the sisal plantations.
- Collective farming (through *ujamaa)* among social groups is no longer practised.
- Villagers often do not trust each other, due to a lack of resources.
- The incidence of theft of maize has increased in recent years.

Key environmental concerns were:

- Decline in soil fertility.
- Drought, inadequate and uneven rainfall distribution during the season.
- *Striga* and stem borer infestation has increased.
- Termite attack on crops has increased.
- Serious deforestation, drying of rivers and disappearance of wild animals.

The most important crops for both men and women in priority order were maize, cassava, cowpeas, green gram and groundnuts with all crops being grown foremost for food security, thereafter for meeting household cash requirements. Most households sell some crops at harvest to meet their cash needs, even if they have to purchase grain later in the season at much higher prices. With two rainy seasons per year, short rains (*vuli*) from October-December and long rains (*masika*) two maize crops can be grown each year, although dates of planting vary considerably. Farmers often plant whenever reasonable rains fall even outside the main *vuli* and *masika* seasons in the hope of harvesting a crop, but rarely doing so. Although some crop rotation or intercropping is practiced, maize remains the predominant crop. Unfortunately maize yields have declined within living memory from over 3.5 tonnes $ha^{-1}$to less than 0.5 tonnes ha^{-1} today. The main reasons for this were identified by each of the communities as being due to low soil fertility, low plant populations, *Striga* and stemborer infestations and the fact that the main source of seed is recycled maize. Many farmers have never purchased seed. Causal diagrams were prepared in each community and although they differed slightly, each identified the same causes of declining maize yield (Figure 3).

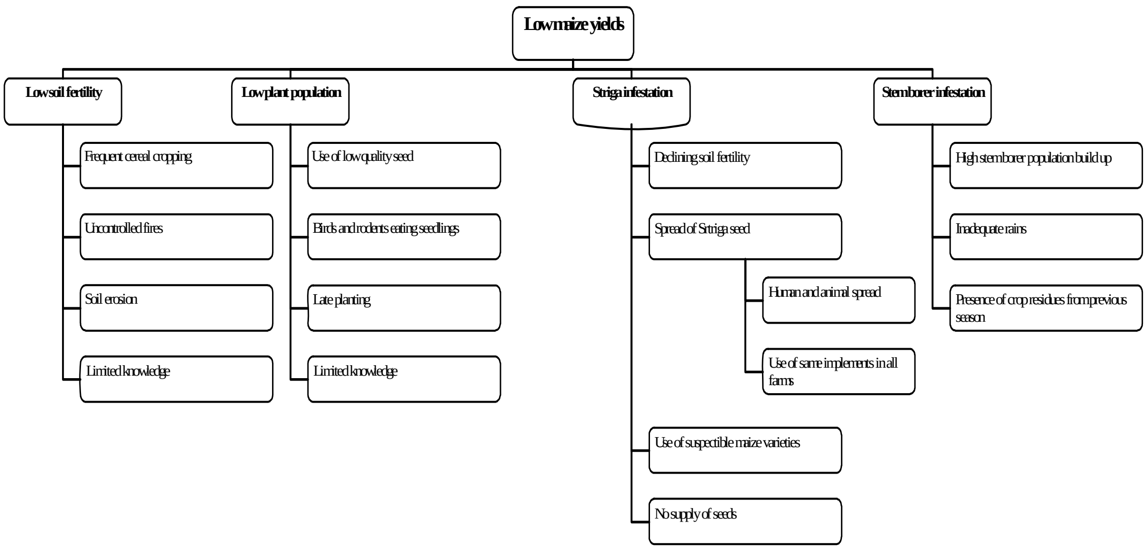

Figure 3: Causes of low yield of grain maize (Mapatano village)

Although many different coping strategies were identified for these problems, none of the four communities had been able to overcome them. Such strategies included using locally developed techniques as well as those introduced by research and extension. These comprised.

- Intercropping with maize, cassava, cowpeas and green gram*
- Planting early*
- Cultivating deeply to bury weeds*
- Hand pulling and burying *Striga*
- Weeding maize as soon as the *Striga* appears
- Using compost or manure*
- Incorporating crop residues
- Rotating maize with cassava and legumes

(*Indicates technique came from research or extension rather than local farmers)

Institutional analysis indicated a range of different research and development institutions working in each village at village, ward, district and regional level. However there were relatively few local institutions involved with crop production that could be mandated to take ownership of local farmer led trials. As a result

- In Mbambakofi an existing Mapambano Group, comprising and formed by EZCORE, which had important links with the village government took the trials forward.
- In Mtakuja, an existing research group (*Rasilimali ya Mnyonge ni Umoja*) took the lead and also established links with women's' groups working with Lugongo Sisal Estate and the Juhudi local livestock group, which was interested in Napier fodder..
- In Mapatano, the six administrative "quarters" of the village government were mandated and farmers elected from each to undertake trials.
- In Paramba, the village government elected farmers to take the trials forward.

In all cases the VEO played a key role, supported by the DAEO.

Technology evaluation

Participatory technology evaluations were undertaken for i) alternative green manures, ii) alternative maize varieties, iii) alternatives for stem borer control and iv) rain water harvesting. In addition on-station testing was undertaken of a number of maize varieties.

Maize varieties

In Mbambakofi and Mtakuja TMV-1 was ranked highest for all farmer identified criteria, except in time to maturity for the 2003 *masika* season. Overall TMV1 was ranked first, Syn White second, Synthetic 98 third and Staha fourth ahead of local varieties (Table 6). This exercise was repeated for the 2004 *vuli* season with TMV-1 and Synthetic 98 being ranked either first or second in all four villages for similar reasons.

<u>On-station maize variety trials</u>

Trials of mid-season maize varieties at Mwele and Melela were analysed using ANOVA of the completely randomized design in three blocks. The combined analysis was simply a split plot with years and sites as blocks and whole plots respectively. The results from showed that TMV-1 performed as well as other varieties across both sites and both seasons as well as in a combined analysis (Table 3).

Table 3: Maize yields from late and mid season varieties (Mwele and Melela) (kg ha^{-1})

Variety	Mwele 2003	Mwele 2004	Melela 2004	Combined analysis
WH_502	1091	1422	2542	1685
KBO2-OA15-4_IR	2987	1493	2062	2180
WH_904	2275	1635	960	1623
KBO2-OBO4-28	2347	1387	2133	1955
KBO2-OB12-10	2382	1387	1245	1671
TZ_96_STR_Syn-W	1973	1920	2098	1997
TZ_96_STR_Syn-Y	1618	1849	1849	1772
Acr_93_TZL_Comp_1-W	1803	1671	1955	1810
IWD_STR_CO	2702	1671	1991	2122
Z._Diplo._BC4C2	1678	2169	2205	2017
TMV-1	2531	1813	1920	2089
KSTP_94	1849	1991	2418	2086
s.e.d.	*545*	*439*	*495*	*312*
$F_{a,b}$	$F_{11,22}$ = 1.90	$F_{11,22}$ = 0.67	$F_{11,22}$ = 1.63	$F_{11,88}$ = 0.302
p =	*0.097*	*0.751*	*0.160*	*0.654*

Similarly results from early season varieties showed that TMV1 was as good as other varieties (Table 4). 98 Syn WEC performed very poorly in 2003 (and was excluded from the analysis), better in 2004 and although giving a higher mean yield there was no significant improvement over TMV-1.

Table 4: Maize yields from early season varieties (Mwele and Melela) (kg ha^{-1})

Variety		Mwele 2003	Melela 2004	Combined analysis
Acr_94_TZE_Comp_5-W		1728	2133	1933
Acr_94_TZE_Comp_5-Y		1013	2560	1787
98_Syn_WEC		-	2418	1899
TZE_Comp_4C2		1184	2418	1799
TMV_-1		1323	2240	1781
KSTP_94		1109	2382	1746
	s.e.d.	*359*	*521*	*347*
	F_n	$F_{4,8} = 1.22$	$F_{5,10} = 0.17$	$F_{5,24} = 0.36$
	$p =$	0.374	0.97	0.87

No data is presented on *Striga* infestation of maize lines as dry conditions resulted in negligible emergence on most plots. However in 2004 at Melela there was little emergence of *Striga* on TMV1 while the introduced entries Acr_94_TZE_Comp_5-W, TZE_Comp_4C2, 98_Syn_WEC and KSTP_94 all supported considerable emergence. At Mwele, on the other hand, TMV1 also supported *S. asiatica* emergence.

Green manures

Farmers became aware, during the research process, of the actual and potential benefits and likely costs of growing a green manure crop in a two-season rotation with maize (Table 5). They identified actual and potential advantages, disadvantages and risks associated with this new system. Some of these potential problems may not always be considered by researchers, but could be the main factors affecting future adoption.

Table 5: Farmer perceptions of advantages and disadvantages of using green manures

	Advantages	Disadvantages
<u>1st season</u> *Green manure vs maize*	▪ Soil fertility improvement ▪ Soil becomes softer ▪ Possible livestock feed from green manure crop ▪ People hope to be able to use the green manure as a food crop or sell as seed ▪ Weed suppression ▪ Crop is not eaten by monkeys and therefore guarding is not required ▪ Reduced soil erosion ▪ Land preparation for following maize is easier	▪ A crop is lost ▪ Limited knowledge of green manures - Other farmers think this is not a useful activity - Neighbours do not appreciate the work - Loss of respect by others for doing something strange ▪ Additional labour requirement for establishment of green manure
<u>2nd season</u> *Maize after green manure vs maize after maize*	▪ Greater harvest is or should be available with better quality grain ▪ Less weeds, fewer and easier weeding ▪ Less *Striga* is observed ▪ More produce for sale	▪ Decline in soil fertility as more nutrients are used ▪ More labour is required for handling the crop ▪ Increased transport and storage problems ▪ Prices of maize may go down and that of other crops may go up ▪ Unplanned spending due to expected higher yields ▪ Increase yields attracts theft ▪ More drinking resulting from additional incomes ▪ Having more dependants and more wives

Source: Participatory technology evaluations, Mapatano, Mbambakofi, Mtakuja and Paramba, 2003.

Table 6: Evaluation of maize varieties according to criteria identified by farmers-2003

	Time to maturity	Drought tolerance	Attack by storage pests	Seed weight	Palatability	Cob size	Ease of removing seed coat	Amount of porridge produced	Resistance to pests and diseases	Resistance to lodging	Yield	Resistance to *Striga*	Marketability	Score	Rank
Matakuja															
TMV1	2	3	3	3	3	2	3	3	3	2	2	3	2[4]	34	1
New Syn White	2	2	2	1	2	2	2	2	2	2	2	2	2	25	3
98 Syn	2	2	2	2	2[1]	3	3	3	2	2	3	2	2	31	2
Staha	1	2	2	2	2	3	1	2	2	1	2	1	3[2]	24	4
Katumani	3	1	1	2	2	1	1	2	1	3	1	1	1	20	5
Mbambakofi															
TMV1	2	3	3		3		3				3	3	3	23	1
New Syn White	3	2	1		2		3				3	3	2	19	2
98 Syn	3	2	1		2		2				3	3	2	18	3
Staha	1	1	2		1		1				1	1	1	10	4

3=Best, 1=worst,

Comments (Mtakuja)

[1]Best for green maize
[2]Flour is very white (which is preferred), even with the outer coat
[3]Storeability is important so that one does not have to rush and sell
[4]Preferred because it is heavy

Comments (Mbambakofi)

[1]If the cob is left covered by the husk, the problem is less.
[2]these are new varieties and they are not known in the market

Identifying farmers’ evaluation criteria and ranking legumes

In each village, after visiting and discussing the trial sites, farmers identified criteria they considered important in comparing the legumes. Interestingly in three of the four communities, farmers also wanted to evaluate cowpeas (being the most important legume crop grown in association with maize) together with the green manure legume crops. Farmers identified 15 criteria, although this varied across villages depending on the length of time each community had experienced the growing of the legume. These criteria reflected either, i) management criteria especially labour for establishing and looking after the legume, ii) agronomic considerations which may effect the subsequent maize crop and, iii) potential uses for the legume. When farmers’ criteria had been identified and agreed each legume in turn was ranked against each criteria and the scores totalled.

Not surprisingly views differed across communities with *Canavalia* and *Crotalaria* being ranked either first or second as green manure crops (Table 7). Cowpea although not included in the trial was scored alongside the green manures and scored highest or second highest in the three communities where it was considered along with green manures, primarily because it had alternative uses.

Table 7: Evaluation of legume crops according to criteria identified by farmers (n=39)

Farmer's criteria	**Paramba n=8**				**Mbambakofi n=11**				**Mtakuja n=13**				**Mapatano n=7**			
	Sunhemp	***Canavalia***	***Mucuna***	***Cowpea***	***Sunhemp***	***Canavalia***	***Mucuna***	***Cowpea***	***Sunhemp***	***Canavalia***	***Mucuna***	***Cowpea***	***Sunhemp***	***Canavalia***	***Mucuna***	***Cowpea***
Seed availability	3	3	3	3	1	1	3	3	1	3	2	2	3	3	3	-
Ease of planting	3	2	2	2					2	3	1	3	3	2	2	-
Ease of legume establishment	3	3	3	3	3	3	3	3					2	2	2	-
Ease of weeding	3	2	1	2	3	2	1	2	2	3	3	2	3	2	2	-
Resistance to pests	1	3	3	2	3	2	1	2	1	3	2	2	1	3	2	-
Drought tolerance	2	3	3	3	1	1	3	3	1	3	2	2	1	3	2	-
Erosion control					3	3	2	2								
Soil moisture conservation					3	3	2	2	1	3	1	3				
Short time to maturity									2	1	1	3				
Ease of incorporation	1	3	3	3	3	3	2	2	1	2	2	3				
Ease of land prep for next crop					3	3	2	2	3	2	1	3				
Striga reduction					3	3	2	2	3	3	2	2				
Alternative uses	1	1	1	3	1	1	2	3	2	2	1	3	1	2	1	-
Improvement to soil fertility									2	3	2	2				
Ease of management									2	2	1	3				
Score	**17/24**	**20/24**	**19/24**	**21/24**	**27/33**	**25/33**	**23/33**	**26/33**	**23/36**	**33/36**	**22/36**	**31/36**	**14/21**	**17/21**	**13/21**	**-**
Rank	**4**	**2**	**3**	**1**	**1**	**3**	**4**	**2**	**3**	**1**	**4**	**2**	**2**	**1**	**3**	**-**

1=performed below average, 2=average performance, 3=performed above average

Participatory evaluations undertaken during the 2004-5 *vuli* season indicated that overall *Canavalia* was ranked highest, *Mucuna* second and *Crotalaria* third (Table 8). However there was considerable variation between villages and even with some villages preferences varied, indicating individual and area variations

Table 8: Ranking of green manures after the 2004-5 *vuli* season.

	Mbambakofi	Mtakuja	Mapatano	Paramba	Total score	Rank
Canavalia	2	1	*1*	3	7	**1st**
Mucuna	*1*	3	3	1	8	**2nd**
Crotalaria	3	2	2	2	9	**3rd**
Cow pea		2/3	2/3	-		

Yield analysis from on-farm trials is based on a REML (residual maximum likelihood) analysis because of the unequal numbers of farmers in each village. , Results are shown as a significant effect of previous cropping (Wald statistic and probability). In 2005, in all villages maize grown after a green manure performed significantly better than maize following maize, but there was no significant difference between the legumes. However when the results were combined *Canavalia* significantly outperformed *Crotalaria* which significantly outperformed *Mucuna*. Maize following *Canavalia* gave the highest yields, being 50% greater than maize following maize. *Crotalaria* gave a 34% higher yield and *Mucuna* a 17% higher yield. In the *masika* 2003 season yields were substantially less with no difference between the green manures which gave 21% or 22% higher yields (Table 9). There was however considerable variation between villages with farmers perceptions mirroring yield results.

Table 9: Mean maize yields following green manure crops (kg ha^{-1}) (n=No. of farmers)

Maize after	Mbambakofi	Mtakuja	Mapatano	Paramba	Overall	% increase over maize
Vuli 2005	*n=7*	*n=10*	*n=8*	*n=5*	*n=30*	
Canavalia	3396	3933	3972	2317	3386	50%
Crotalaria	3176	3373	3756	1811	3021	34%
Mucuna	2892	3323	4282	2339	2624	17%
Maize	1982	2567	2852	1698	2250	
s.e.d.	*424*	*409*	*354*	*289*	*267*	
$Wald_n$	$Wald_3 = 13.5$	$Wald_3 = 8.2$	$Wald_3 = 18.9$	$Wald_3 = 7.5$	$Wald_3 = 20.9$	
p =	*0.004*	*0.042*	*<0.001*	*0.058*	*<0.001*	
Masika 2003	*n=13*	*n=3*			*n=16*	
Canavalia	1466	2733			2048	21%
Crotalaria	1377	3033			2048	21%
Mucuna	0	2800			2076	22%
Maize	1194	2088			1699	
s.e.d.	*149*	*428*			*259*	
$Wald_n$	$Wald_2 = 1.23$	$Wald_4 = 12.5$				
p =	*0.292*	*0.14*			0.002	
Maize varieties 2005					*n=30*	
98 Syn WEC					2776	
TMV-1					2864	
s.e.d.					*259*	
$Wald_n$					$Wald_1 = 0.07$	
p =					0.79	

n=degrees of freedom

There was no significant difference between the yields of the two maize varieties (TMV-1 and Syn 98 WEC) or significant interaction between maize variety and yields following the green manure crops (Table 9). Again this mirrors farmer's perceptions of the two varieties. Large variation in *Striga* emergence made any formal analysis of interactions with variety and green manure impossible. Occurrence is in patches on individual fields and does not occur on all participating farms. However where farmers have now planted green manures for 2 or three seasons they expressed the opinion that continuous use of these legumes has reduced the occurrence of the parasite, so that it no longer a significant issue. Further more they observed that cultivar Syn 98 is tolerant and performed well on infested fields.

Highest yields of biomass in the 2004-5 *vuli* season came from *Canavalia*, followed by *Mucuna* and lastly *Crotalaria* (Table 10)

Table 10: Mean green manure fresh weight yields (*vuli* season 2005)

Green manure	kg ha^{-1}
Canavalia (n = 21)	19,730
Crotalaria (n = 23)	13,280
Mucuna (n = 26)	16,350
s.e.d.	*2,771*
Wald$_n$	*5.35*
P=	*0.069*

Trial records from Mlingano Research Institute indicate that the green manures tested in Muheza generally produce about 20% dry matter if harvested when flowering. Further more these species contain approximately 3% nitrogen by dry weight. Using these conversion factors the dry weight and nitrogen yields have been estimated for the trial sites in Muheza (Table 11). *Canavalia* produced the highest yields and contributed most N. Median yields of *Canavalia* were also close to the mean. Performance of *Crotalaria* on the other hand was very variable. Gilbert (1998) proposed a "target biomass concept" for evaluating the performance of green manures and their potential for enhancing subsequent maize yields in Malawi where conditions are similar to those in Muheza. This assumes that to be effective a green manure crop needs to add >30 kg fertiliser equivalent ha^{-1}. Based on literature reports Gilbert assumed green manure is furthermore assumed to be only 50% as effective as fertiliser N. Therefore 60 kg N ha^{-1} will be needed from incorporation of green manure – at 3% N this will be provided by 2000 kg ha^{-1} dry biomass. In the Muheza trials this was only achieved on 47% of plots sown to *Crotalaria* compared to 83% and 92% of plots sown to *Mucuna* and *Canavalia* respectively.

Table 11:Estimated green manure dry matter and nitrogen yield *vuli* season 2004-5 (kg ha^{-1})

	Crotalaria		***Mucuna***		***Canavalia***	
Dry matter kg ha^{-1}						
Mean	2562	$\pm$ 444	3148	$\pm$ 437	4069	$\pm$ 409
Median	1600		2600		4100	
N kg ha^{-1}						
Mean	77	$\pm$ 13	94	$\pm$ 14	122	$\pm$ 12
Median	48		78		123	

Effect of green manure on soil properties

There were great variations in soil properties between plots, farms and villages. Most analysis indicated a medium acid to neutral reaction, favourable for plant growth with medium soil organic carbon content, medium to low total nitrogen content and low phosphorus content in most of the cases. Analysis after crop harvest showed higher soil fertility after the green manure compared with after maize. Although trends among the green manure crops were not consistent, in a significant number of cases effects of *Canavalia* was much greater than *Mucuna* and *Crotalaria*.

Stemborer control options

Stemborer damage was lowest where neem powder and endosulpan were used with no significant difference between these treatments (Table 12). It was highest when no treatment was used. Use of Napier grass proved better than no treatment.

Table 12: % stemborer damage in Mbambakofi and Mtakuja -2004-5 *vuli* season (n=6)

	Mean	**Low**	**High**
Napier	2.22%	0.60%	4.00%
Neem	0.95%	0%	1.30%
Endosulfan	0.82%	0.10%	1.10%
Untreated	4.62%	3.90%	4.60%

Yields were recorded at two trial sites (Table 13). Endosulphan was the most efficient treatment in terms of protecting cobs from damage and securing yield. The potential of locally available and low costs approaches of neem or Napier barriers was also demonstrated.

Table 13: Cob production and cob weight of maize following use of different stemborer control practices at two on-farm sites in Muheza in the 2004-5 *vuli* season

	Site 1		**Site 2**	
	% plants with cob	Cob kg m^2	% plants with cob	Cob kg m^2
Napier	73	7.4	59	4.0
Neem	83	9.9	66	2.7
Endosulfan	100	9.0	61	6.1
Untreated	76	4.4	56	2.3

In a participatory evaluation farmer ranked neem and Napier either one or two on the grounds that neem was readily available around the village, it was easy to use and that Napier grass was considered good for erosion control and provided cattle feed.

Participatory budgets and economic analysis

End of season evaluation comprising a participatory budget (partial budget analysis) was undertaken with farmers in Mbambakofi and Mtakuja following the 2003 *masika* season after completion of a two season cycle of green manure and maize. No such analysis was possible in 2004 due to drought and in 2005 this was not undertaken due to time constraints at project completion. This will however be undertaken during the follow-on phase of the project. Economic analysis has been undertaken for both 2003 and 2005, using information provided by farmers in 2003.

<u>Benefits</u>

The basis of determining benefits was yield, based on statistical analysis across all villages, where the two season cycle had been completed (Table 14).

Table 14: Benefits from green manure based on yield and values of maize (kg ha^{-1} and US \$ ha^{-1})

	2002-3					2004-5				
Maize following	***Vuli***	***Masika***	***Total***	***Increase***	***% increase***	***Masika***	***Vuli***	***Total***	***Increase***	***% increase***
Yields (kg per ha)										
Canavalia	0	2048	2048	49	2%	0	3386	3386	1136	50%
Crotalaria	0	2048	2048	49	2%	0	3021	3021	771	34%
Mucuna	0	2076	2076	77	4%	0	2624	2624	374	17%
Maize	300	1699	1999	0	0%	0	2250	2250	0	0%
Mean (gm)	*0*	*2057*	*2057*	*58*	*3%*	*0*	*3010*	*3010*	*760*	*34%*
Values (US \$ per ha)										
Canavalia	0	143	143	3	2%	0	237	237	79	50%
Crotalaria	0	143	143.	3	2%	0	211	211	53	34%
Mucuna	0	145	145	5	4%	0	183	183	26	17%
Maize	21	118	139	0	0%	0	157	157	0	0%
Mean (gm)	*0*	*144*	*144*	*4*	*3%*	*0*	*211*	*211*	*53*	*34%*

Assumptions: Maize is valued at US \$0.07 kg^{-1} (Tsh 70 kg^{-1}), US \$1=Tsh 1000), gm=green manure

Farmers had indicated that they had achieved yields of 300 kg ha^{-1} in *vuli* 2003 when the green manure crops were growing. Over the two seasons a small increase (2-4%) was achieved as a result of growing the green manures. No maize yields were obtained in *masika* 2004, meaning that larger benefits (17-50%) were achieved. This also showed that a yield of 1136 kg ha^{-1} would have been needed in *masika* 2003 for a maize-maize system to provide greater benefits than *Canavalia*-maize. This however takes no account of any direct benefits from the green manure crop, notably seed, which can be similar to maize grain yields or of benefits that may be achieved from a subsequent maize crop or improved soil water conservation.

Costs

Information provided by farmers during the participatory budgets (Ellis-Jones *et al.*, 2004) varied. In Mtakuja, farmers indicated that although incorporation of green manure would require additional labour at land preparation, a net saving of labour was experienced (40 days ha^{-1}), primarily as a result of decreased weeding both in the green manure and subsequent maize. However at Mbambakofi, farmers indicated that labour requirements had increased by a similar amount for additional land preparation, harvesting, transport, storage and sale of the increased maize. In both villages there was agreement that there was no increase in seed requirements costs over the two season cycle as seed requirements for green manure were similar to that for maize (Table 15). The net result indicates that the costs do not differ markedly between maize-maize and green manure-maize systems.

Table 15: Net increase or decrease in costs of a green manure-maize rotation compared to continuous maize over two seasons in 2003 (US \$ ha^{-1})

			Mtakuja		Mbambakofi	
Benefits	***Units***	***Value per unit (\$)***	***Quantity***	***Total***	***Quantity***	***Total***
Costs increase (+) or decrease (-)						
Maize seed	kg	0.4	-25	-10	-25	-10
Legume seed	kg	0.4	+25	+10	+25	-10
Labour	days	1	-40	-40	+40	+40
			Total	*-40*		*+40*

On the basis of these benefit and cost indications, it can be concluded that the green manure-maize system can outperform maize-maize. Clearly increased actual and potential benefits make the new technology attractive, in both terms of additional yield and overall productivity. However this needs to be seen against the concerns raised by farmers and the increased risks with which they may be faced (Table 5), if widespread adoption is to occur. Although it is difficult to reach firm conclusions before more households have had a chance to evaluate a number of cycles of the legume/maize rotation. However discussion with farmers suggests that:

Green manures are attractive and more likely to be adopted, when:

- Sustained increases in maize yield are achieved and a ready market is available.
- The green manures provide additional benefits over and above improving soil fertility and reducing *Striga* infestation, such as food or fodder for household use or sale.
- Land is not limiting and green manures can be used to improve fallows

The third criteria would mean that average and well resourced farmers are the most likely beneficiaries, although experience in other areas does indicate that a wide range of farmers are now planting *Crotalaria* in rotation with rice varieties.

Green manures are less attractive and less likely to be adopted, when:

- Farmers perceive the risks of using a green manure to be high, due to possible failure of the maize crop due to drought or low market prices.
- Land is limiting. In such cases grain legumes that improve soil fertility and suppress *Striga* may be more appropriate. This could include cowpea_, soybean or groundnut crops which induce suicidal germination of *Striga* followed by *Striga* tolerant maize variety (Ellis-Jones *et al.*, 2004; Schulz *et al.*, 2003). However these alternatives crops also presents risks of *Alectra* and marketing problems.

Access to inputs improved

Local access to inputs has been improved, through establishment of two community based seed production units growing TMV-1 seed as well as green manure seed. In addition a commercial seed company (MTI) has initiated seed production and is selling TMV-1 sees in one kg packages.

Increased capability of local professionals

Capability of local professionals and input suppliers (including lead farmers, scientists and extension workers, in partnership with collaborating institutions) to provide useful information to farmers has been strengthened and promoted. The use of a PREA approach to both research and extension activities has assisted in strengthening relationships with farmers

Contribution of Outputs to developmental impact

Include how the outputs will contribute towards DFID's developmental goals. The identified promotion pathways to target institutions and beneficiaries. What follow up action/research is necessary to promote the findings of the work to achieve their development benefit? This should include a list of publications, plans for further dissemination, as appropriate. For projects aimed at developing a device, material or process specify:: a) what further market studies need to be done; b) how the outputs will be made available to intended users; c) what further stages will be needed to develop, test and establish manufacture of a product; and d) how and by whom, will the further stages be carried out and paid for?

Contribution towards development impact

Development strategies that aim to improve food security, improve labour efficiency and reduce poverty (thereby improving rural livelihoods) in rural areas rely heavily on agriculturally led growth and productivity gains. This requires sustainable, appropriate and viable natural resource management strategies implemented at a farm and community level. An impact pathway for this requires improved knowledge by farmers, which is likely to be derived from many iterations of a learning cycle building on the Outputs of the project. This starts with project outputs, followed by a chain of intermediate outcomes related to vertical (scaling-up) and horizontal (scaling-out) aspects of scaling-up, which are intended to lead to wider and longer-term outcomes related to improvements of the livelihoods of poor people. This represents a set of projections about what needs to happen for project outputs to be transformed, over time, into impact (Figure 4). These projections have been recorded in a matrix, based on the project Log-Frame. Included within this are the ongoing participatory activities that the project has already established, namely, the community situational analysis and community mobilisation meetings in four villages. It includes pre project activities of building on the integrated pest management practices, already generated on research stations and local knowledge and farmer innovation identified in the situational analysis.

Project Outputs, Purpose and Goal are represented by shaded boxes. Unshaded boxes are intermediate outcomes that have been encouraged during the course of the project. These are related to good development practice and relate to scaling-up activities. For instance it was recognised that farmers test and modify new technologies under their own management conditions leading to adaptations of original approaches and development of new ones. Encouraging such testing and subsequent adaptation is likely to speed adoption rates. The FFS approach used was designed to encourage faster scaling-up. As such social and organisational processes are as important as the technologies themselves.

Livelihoods of poor people improved through sustainably enhanced production and productivity of RNR systems

The ultimate beneficiaries of project outputs are rural communities, individual households and their families as a result of scaling-up activities. At the time of project completion evidence was available of considerable adoption of improved maize varieties (notably TMV-1 and Syn 98) as well as to a lesser extent soil fertility and pest management practices. This occurred as a result of both use of PREA and the availability of appropriate technology options for increasing crop productivity: In the case of declining soil fertility, use of green manures has not only improved soil fertility but has meant that the curse of *Striga* has been reduced. More widespread adoption will result from stakeholders promoting the technologies in other areas as well as continuing changes in knowledge and attitudes of farmers. This in turn is likely to lead to a strengthening of the rural economy with consequent advantages for local seed production and agents selling agri-inputs. By approaching crop production constraints using PREA, the impact of different crop management practices has been evaluated by farmers themselves. The opportunity to use these management practices has increased productivity. The adoption of low cost, labour efficient weeding practices should release resources for other crops and non-farm activities. The combination of these outcomes in the long term should raise household incomes and improve basic food security. It is envisaged that the drudgery associated with hand labour, frequently carried out by women and children, should be alleviated.

Reduced impact of pests
Despite adverse climatic conditions during much of the project, improved soil and pest weed management techniques have been adopted in target villages, indicating the success of PREA in allowing farmers and communities to identify and seek solutions for their own priority problems. PREA has ensured that the improved management strategies have been evaluated by farmers themselves and the involvement of each community through existing groups and lead farmers selected by each group has contributed to improving farmer-to-farmer extension. At the same time close liaison between stakeholders (researchers, extension agents and close involvement of policy makers at village and District levels) has ensured that wide scaling-up should now be possible. The users of PREA have benefited from the knowledge generated both from their involvement with the participatory process as well as the development of alternative crop production practices. This has increased awareness of the constraints faced by farmers and the process is already being used in other villages by extension staff to promote wider farmer testing of technology options. Project partners who have also been target institutions include:

- Local research institutions (especially the Agricultural Research Institutions at Mlingano and Ilonga as well as Sokoine University of Agriculture).
- Private sector companies (notably, Mbegu Technologies Incorporated)
- Representative farmer and community organisations in Muheza District.
- Muheza District Council and its agricultural extension services, which have been given increased responsibility to promote local development initiatives.

Research outputs from this project are being promoted by project partners, communicating the knowledge gained to other stakeholders, including extension workers and farmers.

Enhancement of policy environment
Increased use of PREA is particularly important as many donors including DFID move from supporting free-standing projects in different sectors (including natural resources) to providing strategic level support for efforts to define and implement effective poverty reduction strategies through country assistance plans. For instance in Tanzania, DFID has increased financial assistance in the form of direct budget support (DFID, 2003). If progress is to be made towards accelerated poverty reduction key elements are likely to include:

- Longer pre-project planning phases are planned to allow scaling-up activities to be planned and initiated. .
- Research and development activities are closely linked with long term funding commitments, tied to intermediate targets.
- Capacity building, multi-disciplinary partnership development and institutionalisation are given high priority within integrated research and development approaches.
- Funds for monitoring, evaluation and impact assessment systems will need to be substantially increased.

Lessons, which are replicable to other projects
Partners and stakeholders involved with this project are now more aware that research they undertake needs to be relevant and contribute to local, District and National development priorities. We are aware that project partners are using the project findings and approaches in implementing new research and development activities in ways that are appropriate to local conditions. However some support will need to be provided to ensure that the process approach is monitored and adapted to fit local circumstances. This will be particularly important for monitoring and evaluation of the collaborating institutions success in achieving the longer-term benefits of the processes implemented, if optimum benefit is to be achieved.

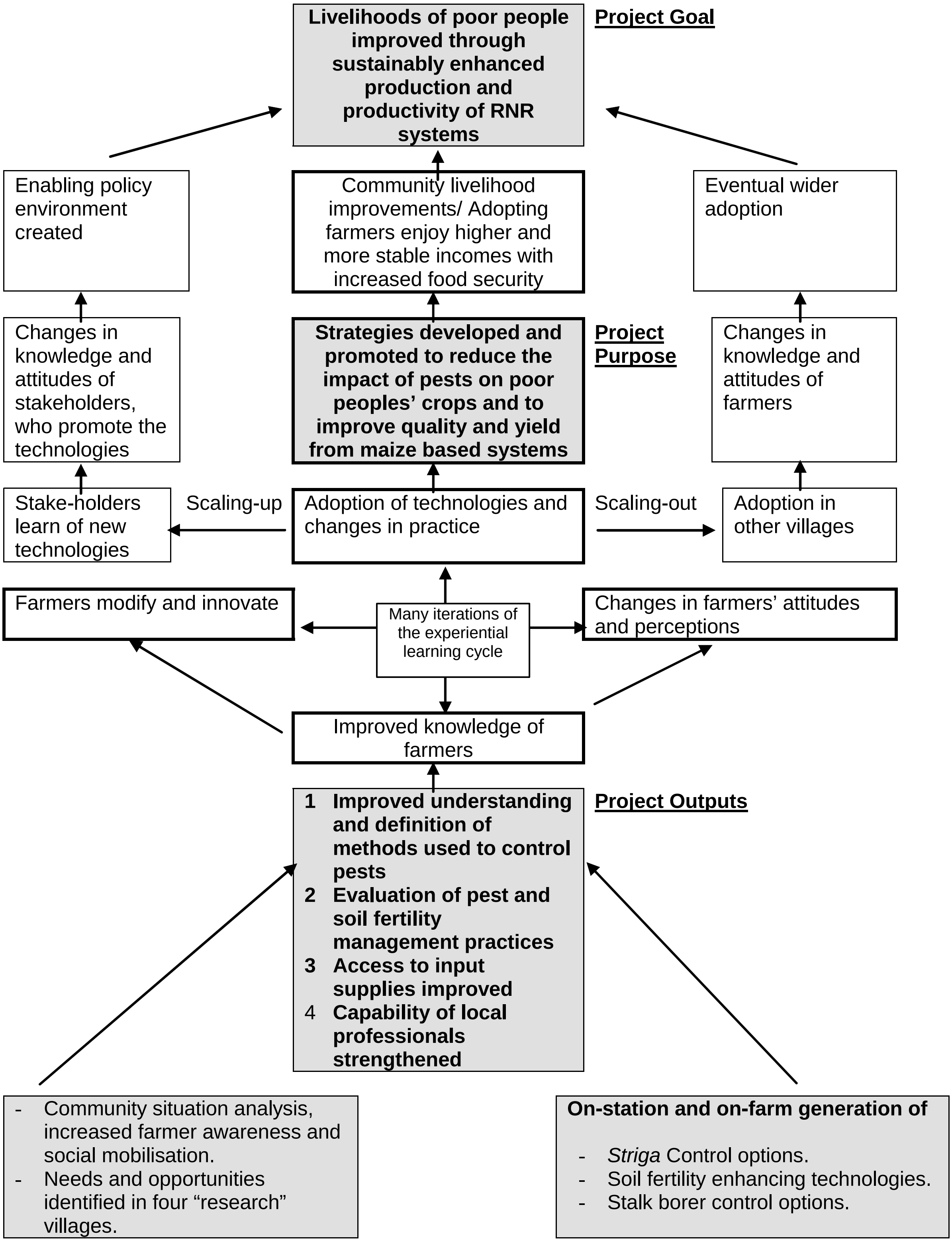

Figure 4: Impact pathway for R8215: Increasing food security and improving livelihoods through the promotion of integrated pest and soil management in lowlwnd maize systems

Publications:

Journal publications and refereed papers

[List only those published and in press i.e. accepted for publication. Please highlight in bold or with an asterisk outputs which have not been previously reported]

AKULUMUKA V. , ELLIS-JONES J**.,**, HELLA J., KANAMPIU F., KYAKAISHO P., LAMECK P., LEY G., MASSAWE C., MBWAGA A. M., MOSHI A., MROSSO F., NYAKI A., and RICHES C., 2004. *Improving food security through Striga and soil fertility management in lowland maize: a participatory development process.* Paper presented at the International Weed Society Conference, Durban, South Africa, 19-24 June 2004

Internal Reports:

[List of reports and dates. Please highlight in bold or with an asterisk outputs which have not been previously reported]

AKULUMUKA V., and HELLA J., 2003. Input-output chain for smallholder maize growers in Muheza District, Tanzania. Survey report. ARI-Ilonga and Sokoine University of Agriculture.

AKULUMUKA V., ELLIS-JONES J., HELLA J., KANAMPIU F., KYAKAISHO P., LAMECK P., LEY G, MASSAWE C., MBWAGA A.M., MOSHI A., MROSSO F., NYAKI A. and RICHES C. 2003. *Participatory technology evaluation of on-farm trials and review of progress –December 2003.* Project Working Report No 4

ELLIS-JONES J*.,* AKULUMUKA V., HELLA J., KANAMPIU F., KYAKAISHO P., LAMECK P., LEY G, MASSAWE C., MBWAGA A.M., MOSHI A., MROSSO F., NYAKI A. and RICHES C.*,* 2003. Proceedings of the inception workshop for the Muheza Maize project, Tanga District, Tanzania, held at Mlingano Agricultural research Institute, 9-13th December 2002. SRI and ARI. Project Working Report No 1. ID/03/09.

ELLIS-JONES J., AKULUMUKA V., HELLA J., KANAMPIU F., KYAKAISHO P., LAMECK P., LEY G, MASSAWE C., MBWAGA A.M., MOSHI A., MROSSO F., NYAKI A. and RICHES C.*,* 2003.. Social Mobilisation and action plan, Mapatano, Mbambakofi, Mtakuja and Paramba villages, Muheza District, Tanga. SRI and ARI. Project Working Report No 2 (English) ID/03/10.

AKULUMUKA V., ELLIS-JONES J., HELLA J., KANAMPIU F., KYAKAISHO P., LAMECK P., LEY G, MASSAWE C., MBWAGA A.M., MOSHI A., MROSSO F., NYAKI A. and RICHES C., 2004. Mid season participatory monitoring and evaluation of on-farm trials, Muheza maize project (7-12 July 2004). Mapatano, Mbambakofi, Mtakuja and Paramba, Muheza District, Tanga Region, Tanzania. Project Working paper No 5. SRI-ID/04/02.

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HELLA J., and AKULUMUKA V., 2004. *Muheza maize project: Baseline data on production practices in Muheza district*. Sokoine University of Agriculture.

MAROSSO F. P., 2003. On-farm maize storage practices against insect pests in selected areas of Tanzania (a review). Included in Project Working Report No 4.

MBWAGA A.M*.,* AKULUMUKA V., ELLIS-JONES J., HELLA J., KANAMPIU F., KYAKAISHO P., LAMECK P., LEY G, MASSAWE C., MOSHI A., MROSSO F., NYAKI A. and RICHES C. 2003. . Mid season evaluation of on-farm trials and review of progress. Muheza maize project, Tanga District, Tanzania, July 2003. Project Working Report No. 3. Ilonga Agricultural Research Institute.

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Other Dissemination of Results:

[Please highlight in bold or with an asterisk outputs which have not been previously reported]

MBWAGA A.M., *et al*., 2004 Mbinu za ugani za matumizi ya picha kwa ajili ya majadiliano na vikundi vya wakulima. Njia Bora za Udhibiti Husishhi wa Viduha, Mwongozo kwa Mtumiaji.

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Biometricians Signature

The projects named biometrician must sign off the Final Technical Report before it is submitted to CPP. This can either be done by the projects named biometrician signing in the space provided below, or by a letter or email from the named biometrician accompanying the Final Technical Report submitted to CPP. (Please note that NR International reserves the right to retain the final quarter's payment pending NR International's receipt and approval of the Final Technical Report, duly signed by the project's biometrician)

I confirm that the biometric issues have been adequately addressed in the Final Technical Report:

Signature:

Name (typed):

Position:

Date:

Annex 1: Project Logframe:

Narrative Summary	Indicators of Achievement	Means of Verification	Risks and Assumptions
Goal			
Livelihoods of poor people improved through sustainably enhanced production and productivity of RNR systems..			
Purpose			
Strategies developed and promoted to reduce the impact of pests on poor people's crops and to improve quality and yield from maize-based systems.	By Dec 2005 - at least 3 farmer support organisations are promoting improved technologies using processes developed by the project - 600 households are using at least one of the technology options. - Maize productivity has increased by at least 10% - At least 2 community-based seed production units are established and traders are stocking appropriate inputs	Project reports Studies over base-line information	Political and economic stability Widespread scaling up and adoption by farmers of technologies Demand for inputs is increased and input suppliers can access materials
Outputs			
1 Improved understanding and definition of methods used to control pests (diseases and weeds) and confirmation of the constraints to adoption of improved technologies in key lowland maize production areas of Tanzania. 2 Evaluation of pest management, and soil fertility management techniques, using both scientists' and farmers' evaluation criteria, achieved primarily by farmer testing of technology options in lowland areas. 3 Farmer access to input supplies improved through establishment of community based seed production units as well as local traders supplying inputs 4 Capability of local professionals and input suppliers (including lead farmers, scientists and extension workers, in partnership with collaborating institutions) to provide useful information to farmers strengthened and promoted.	By March 2003, opportunities for pest control technologies identified and selected by farmers for on-farm testing By Dec 2004, appropriate and cost-effective pest management strategies identified after evaluation in at least 4 village areas By March 2005, local access to inputs for pest management improved, through at least one community based seed production unit, and one commercial supplier By March 2005, appropriate information resource strategies identified to support dissemination of cropping practices by local professionals and input suppliers.	Project reports Project reports Jointly prepared refereed publications Extension and training material	Political and economic stability Suitable climatic conditions Farmer support organisations use the processes and technologies developed

Activities			
Improved understanding and confirmation of constraints 1.1 Stakeholder meetings to clarify roles, networking arrangements, research responsibilities and integration of activities. 1.2 Consolidation of knowledge (literature review) of work on pest (including *Striga,* maize streak and stalkborer), giving attention to both biophysical and socio-economic constraints in Eastern Zone to increased adoption and scaling up activities. 1.3 Community situation analysis to identify household livelihood options, existing pest, weed and soil management techniques and constraints to adoption of possible improvements and to agree upon a research plan with farmers and extension workers in each area. 1.4 Increase farmer awareness and knowledge on pest problems and possible control methods, using existing and if necessary new training material.	**By November 2002, detailed action plan in place** By December 2002, detailed literature completed. By February 2002,a detailed research plan agreed by with farmers at community workshops By February 2003, extension material developed and used by field staff with farmer groups.	Project reports Literature review Community workshop reports Project reports Extension material	Partner organisations continue to collaborate during the course of the project Farmers continue to work closely with the project

<u>Technology evaluation</u> 2.1 Implementation of a series of farmer led trials in partnership with EZCORE, SFI and CIMMYT evaluating a range of pest and soil management options, identified in Activity 1.3, and which are likely to include: i) Using <u>*Striga* resistant maize varieties</u> and <u>*Striga* trap crops</u> (cow peas, groundnuts and pigeon pea) ii) Using <u>herbicide coated IR maize seed</u> to control *Striga* iii) Using <u>streak resistant maize varieties</u> where maize streak is a priority problem. iv) Reducing losses to stalkborer by planting borders of maize plots to <u>Napier grass</u> to reduce populations of the pest in the crop v) <u>Integrating crop protection technologies with soil fertility improvement methods such as use</u> of *Crotalaria* spp, *Mucuna pruriens*, manure where available and inorganic fertiliser when affordable. vi) <u>Combining in-crop weed control by banded application of herbicides</u> with <u>reduced tillage</u> techniques 2.2 Monitoring and evaluating the trials through a series of farmer led field days and end of season farmer workshops with stakeholders 2.3 Farmer field schools established as part of the ongoing agricultural extension activities of DAE in Muheza District	By Sept 2003, 20 farmers (2 groups) are testing on-farm the range of technology options By Sept 2004, 40 farmers are involved. By Sept 2003, farmer technology assessment criteria are identified By Dec 2003, April 2004 interim farmer, extension worker and scientist evaluations undertaken for all technologies. By Dec 2004, full evaluation completed By March 2004, DAE and NGO field staff training farmers using FFS principles.		
<u>Access to inputs improved</u> 3.1 Identification of strengths and weaknesses of existing input supply chains through survey of local suppliers 3.2 Work with input suppliers to ensure affordable sized packages of key inputs are available to farmers 3.3 Initiating a process of community based seed supply	By June 2003, survey of input supply mechanism completed By March 2005, key inputs available in affordable sized packages By March 2005, at least one community has established a process for accessing improved open pollinated maize varieties		
Increased capability of local professionals 4.1 In-country stakeholder workshops involving farmers, NGOs, DAE and research professionals. 4.2 Monitoring the process of farmer testing, uptake, modification and impact assessment of technologies. 4.3 Distribution of research reports and other published outputs to stakeholders and other institutions. 4.4 Development and use of extension materials by farmers and extension staff in FFS activities.	By Dec 2003 and Dec 2004 Stakeholder workshops held By March 2005, Impact assessment report available By March 2004, at least 3 research publications distributed By March 2004, suitable extension material used in FFS.		