Legume rotations improve fertility and help control witchweed

RIU

Validated RNRRS Output.

Farmers in eastern and southern Africa could double their yields simply by growing legumes for a year in between cereal crops. Two problems that cause low yields are poor soil fertility and the rampant witchweed, Striga. Rising populations in rural areas mean that land is cropped more intensively. So farmers plant cereals—maize, upland rice, sorghum and finger millet—year after year, instead of leaving the land crop-free to recover and to help control witchweed. Villagers in Kyela, Morogoro and Mbeya in Tanzania now rotate cereals and legumes. They dig in the legumes as green manure. In rice–legume rotations, witchweed dropped by half. These rotations could have a major impact in the region, as many poor farmers cannot afford fertilizers or herbicides.

Project Ref: **CPP66:**
Topic: **1. Improving Farmers Livelihoods: Better Crops, Systems & Pest Management**
Lead Organisation: **ARI, Tanzania**
Source: **Crop Protection Programme**

Document Contents:

Description

CPP66

Research into Use
NR International
Park House
Bradbourne Lane
Aylesford
Kent
ME20 6SN
UK

Geographical regions included:

Tanzania,

Target Audiences for this content:

Crop farmers,

A. Description of the research output(s)

1. Working title of output or cluster of outputs.
In addition, you are free to suggest a shorter more imaginative working title/acronym of 20 words or less.

Green manure to control *Striga*

Suggested title: Enhanced cereal productivity on *Striga* infested land using legumes.

2. Name of relevant RNRRS Programme(s) commissioning supporting research and also indicate other funding sources, if applicable.

DFID Crop Protection Program

3. Provide relevant R numbers (and/or programme development/dissemination reference numbers covering supporting research) along with the institutional partners (with individual contact persons (if appropriate)) involved in the project activities. As with the question above, this is primarily to allow for the legacy of the RNRRS to be acknowledged during the RIUP activities.

R6654 [1996-2000]; R8194 [2002-2005] R8436 [2005-2006]

Partners

Tanzania Department of Research and Development
Ilonga Agricultural Research Institute, Kilosa
Dr. A. M. Mbwaga (Plant Pathologist/*Striga* specialist) Project Leader
(ambwaga@yahoo.co.uk - **now moved to ARI-Uyole, Mbeya**)
Mr C. Massawe (plant protectionist)
Mlingano Agricultural Research Institute, Tanga
Dr. G. Ley (Soil scientist)
(gjley2@yahoo.com)
Uyole Agricultural Research Institute, Mbeya
Dr J. Kayeke (Weed scientist/Agronomist)
Sokoine University of Agriculture, Morogoro
Dr. J. P. Hella (Agricultural economist)
jp_hella@yahoo.com
District Councils
Morogoro Rural District Council
E. Masangya (Crops, subject matter specialist)
Mrs E. Kishinda (District Education Officer)
Kyela District Council
Mr M. Mwampaja (Crops, subject matter specialist)
Mrs V. Mbena (District Education Officer)

INADES Formation Tanzania
Mr P Lameck (Farmer Group Specialist)

Natural Resources Institute, UK
Dr. C.R. Riches (Weed Scientist/Agronomist)
(charlie@riches27.freeserve.co.uk)

4. Describe the RNRRS output or cluster of outputs being proposed and when was it produced? ***(max. 400 words)****. This requires a clear and concise description of the output(s) and the problem the output(s) aimed to address. Please incorporate and highlight (in bold) key words that would/could be used to select your output when held in a database*

Studies by projects R6654 (in 2000) and R8194 in farming communities in Kyela District and Matombo ward of Morogoro Rural District (in 2002) identified that low yields of **upland rice** and **maize** are associated with declining **soil fertility** and widespread infestation by the parasitic **witchweed *Striga*** *asiatica* (known as ***viduha*** in Kiswahili). Subsequently on-farm trials and participatory monitoring and evaluation of a demonstration programme generated the following outputs:

- **Technology validation** of the use of rotations of *Striga* infested cereals with legumes. Two options were evaluated on a field-scale by farmers: rotating rice or maize with the locally available green manure ***Crotalaria*** *ochreluca* OR rotating these cereals with wilt (*Fusarium udum*) resistant cultivars of **pigeon pea**;
- Supporting **extension training materials** for transferring knowledge of the rotations to farmers (one training of trainers manual; one pictorial guide for farmer group training; one leaflet; one poster and four farmer training videos);
- Multiplication and dissemination of seed of *Crotalaria* and pigeon pea through farmer groups and farmer to farmer exchange;
- Validation of a pilot **process** for **up-scaling promotion** of cereal-legume rotations. Led by district council extension officers this farmer group approach involves a combination of methods including village seminars, on-farm demonstrations, farmer-exchange visits and partnerships with village primary schools for teaching students the value of soil fertility management to overcome *Striga* and declining yields;
- Key policy implications and lessons from pilot promotion were provided to district councils in upland rice growing areas of southern and eastern Tanzania. Central government policy makers and senior research and extension managers from the Ministry of Agriculture, Food and Co-operatives were also participated in project workshops.

5. What is the type of output(s) being described here?
Please tick one or more of the following options.

Product	***Technology***	***Service***	***Process or Methodology***	***Policy***	***Other Please specify***
	X		X		

6. What is the main commodity (ies) upon which the output(s) focussed? Could this output be applied to other commodities, if so, please comment.

The outputs focused on rain-fed upland rice and maize. The problem of soil fertility and *Striga* is a regional problem in East and southern Africa affecting cereals (maize, upland rice, sorghum and finger millet) crops of resource poor small scale farmers who cannot afford to purchase inorganic fertilizer. Application of legume/rice rotations can benefit these cropping systems, although choice of the green manure or pulse species will vary with environment.

7. What production system(s) does/could the output(s) focus upon?
Please tick one or more of the following options. Leave blank if not applicable

Semi-Arid	***High potential***	***Hillsides***	***Forest-Agriculture***	***Peri-urban***	***Land water***	***Tropical moist forest***	***Cross-cutting***
	X	X					

8. What farming system(s) does the output(s) focus upon?
Please tick one or more of the following options (see Annex B for definitions).
Leave blank if not applicable

Smallholder rainfed humid	***Irrigated***	***Wetland rice based***	***Smallholder rainfed highland***	***Smallholder rainfed dry/cold***	***Dualistic***	***Coastal artisanal fishing***
X			X			

*9. How could value be added to the output or additional constraints faced by poor people addressed by clustering this output with research outputs from other sources (RNRRS and non RNRRS)? (**max. 300 words**).*

Please specify what other outputs your output(s) could be clustered. At this point you should make reference to the circulated list of RNRRS outputs for which proformas are currently being prepared.

Farmers in areas of Tanzania where the use of cereal-green manure rotations could be scaled up generally rely on recycling of farm saved seed of local land-races or cultivars that were introduced some years ago. Experience elsewhere has demonstrated the benefit of combining improved cultivars with soil fertility management by using legumes. This has been validated in Muheza district of Tanzania (maize-based systems) by CPP as described in the dossier for R8452/R8215. Studies in Southern Highlands of Tanzania (dossier for projects R8220/R8406/R8422) also validated mechanisms for improving farmer's access to high yielding maize cultivars, while other relevant outputs are available from R8219/R7405 in Kenya.

Screening studies undertaken by NRI working in partnership with WARDA (The Africa Rice Centre) [funded by the DfID Integrated Pest Management Strategy Area between 1992 and 1995] identified rice lines showing resistance to *S. aspera and S. hermonthica*. These were used in a subsequent breeding programme by WARDA to introduce *Striga* resistance into improved lines. From seven lines provided to farmers group in Kyela for evaluation three were selected during projects R8194 and R8436. The farmers undertook further multiplication

and have reported a preference for lines WAB 928-22-2-1-1-B, WAB 935-5-1-1-1-B and WAB 935-5-1-2-1-B on the basis of early maturity, *Striga* resistance, yield performance and cooking qualities. Indications are that there is already an increasing demand for seed but further validation is needed with a large number of farmers prior to registration.

Stemborers are a major constraint to maize production in lowland *Striga* infested areas where *Striga* is also a constraint. Planting of napier fodder on field margins or application of locally available neem-based botanical insecticides to control stemborer is described in dossier for R8452/R8215.

The soil borne wilt disease of pigeon pea (*Fusarium udum*) is a widespread in Tanzania. Increased use of the crop by smallholders in cereal-legume rotations, to improve household nutrition and soil fertility, should be based upon the use of wilt resistant cultivars. These are available in the country as a result of collaboration between Ilonga Agricultural Research Institute and ICRISAT.

Validation

B. Validation of the research output(s)

*10. **How** were the output(s) validated and **who** validated them?*

*Please provide brief description of method(s) used and consider application, replication, adaptation and/or adoption in the context of any partner organisation and user groups involved. In addressing the "who" component detail which group(s) did the validation e.g. end users, intermediary organisation, government department, aid organisation, private company etc... This section should also be used to detail, if applicable, to which social group, gender, income category the validation was applied and any increases in productivity observed during validation **(max. 500 words)**.*

Validation used farmer groups, which undertook evaluation of cereal-legume rotations using on-farm demonstration plots that also provided for farmer learning. Demonstrations were established on fields of 12 farmers in each of 4 villages of Kyela District and 2 villages in Matombo Ward, Morogoro Rural district. In general three plots were established at each farm, of *Crotalaria*, disease resistant pigeon pea (Cv. Mali) and rice (in Kyela) and rice or maize (in Matombo). All plots were planted to rice (local cultivars selected by farmers) or maize (Cv. TMV1) in the following season. Farmer evaluation of the rotations was designed and co-ordinated by Ilonga Agricultural Research Institute and NRI. Implementation was undertaken by district council agricultural teams, including crop specialists and village extension officers. At mid-season evaluation farmers discussed their observations including the advantages and disadvantages of growing legumes compared to continuous cereal cropping. Rice yields were assessed and statistical analysis undertaken – farm sites were used as replicates. Farmer groups in Kyela achieved average rice yield increases in 2003 and 2004 of 1114 (108%) and 827 kg ha^{-1} (72%) respectively when planting after a one year break of *Crotalaria* and an additional 119 kg ha^{-1} (18%) when planting rice in 2004 after pigeon pea. On average there was more than a 50% reduction in *S. asiatica* in rice in rotation with the green manure. Farmers ranked the performance of *Crotalaria* for restoring rice yields higher than pigeon pea, even though the latter provides food in the year when it is grown. Although additional labour is

needed for incorporating *Crotalaria*, advantages of this option were soil fertility enhancement, increased rice yields, and the reduction in the labour needed for weed control in rice. Upland rice is usually weeded two or three times but following *Crotalaria* only one light weeding is needed.

R8194 assisted district council extension teams with pilot promotion of rice/maize-legume rotations to an additional 8 villages. Learning tools such as leaflets, posters and training manuals were prepared. Extension officers formed farmer groups who established demonstration plots - the process of farmer evaluation of green manure, which was initiated by the research team, became farmer driven. Rice crops monitored in 2005 showed mean yield gains of 791 (74%) and 487 kg ha^{-1} (46%) when planted after *Crotalaria* or pigeon pea compared to continuous rice. In 2005 maize yields were increased by 180 and 153% following *Crotalaria* and pigeon pea respectively from 296 kg ha^{-1} under continuous cultivation. Partnerships between district council agricultural and education staff resulted in training of primary school teachers on knowledge of *Striga* and soil fertility management. This information was incorporated into school activities including demonstration plots and performances of drama, songs and dances, portraying the use of legumes.

By the 2005 season 189 farmers had been involved in the validation process. Farmer group members were not purposively selected on the basis of wealth or other social criteria. Situation analysis meetings, led by the NGO INADES, established that crop yield decline and *Striga* were general problems in participating villages. Validation took place in both Islamic and Christian dominated villages with the “moderate poor”, including, female headed households, youth and elderly.

11. ***Where and when*** *have the output(s) been validated?*

Please indicate the places(s) and country(ies), any particular social group targeted and also indicate in which production system and farming system, using the options provided in questions 7 and 8 respectively, above ***(max 300 words)****.*

Validation activities described in section 10 were undertaken between 2002 and 2005, with resource poor farmers (“moderate poor”) in Kyela District (Mbeya region), Southern Highlands of Tanzania and in Matombo Ward of Morogoro region in the Eastern Zone of Tanzania**.** The farmers in the sub-humid, mono-modal rainfall area of Kyela mainly cultivate rice. Upland fields lie above the Lake Nyasa flood-plain at an altitude of 500-600 m.a.s. Rice yields have fallen from approx. 10 to 2 bags of rough rice per acre in living memory causing farmers to increase production of less favoured cassava. The rice produced in Kyela is aromatic and attracts a premium price from buyers who market it in major urban centres and also export it to the Gulf states. The crop has therefore been an important source of income to the district, in addition to providing for household food needs.

Matombo is characterised by a hillside production system in the Uluguru Mountains at altitudes ranging from 1500-1900 m.a.s. This is bimodal rainfall area. Farmers practice a bush-fallow rotation, growing maize near to settlements and rice on the higher less accessible slopes. Both upland rice and maize yields have been in decline and *Striga* has increased in abundance in living memory as fallow periods have fallen to little more than two years with an increase in population pressure. Field sizes range from 0.5 – 2 acres per household.

In both districts few farmers can afford to use fertiliser on cereal crops as they lack liquidity in the planting season. For example Morogoro Rural District was allocated in 2005 500 t of urea under the Tanzanian government fertiliser subsidy scheme but only 50 t were purchased.

A total of 18 village primary schools were involved in promotion activities, 12 in Kyela and 6 in Matombo.

Current Situation

C. Current situation

12. ***How and by whom*** *are the outputs currently being used? Please give a brief description* ***(max. 250 words****).*

Both Kyela and Morogoro District councils have implemented plans for promotion of cereal/legume rotations that were outlined at an end of project workshop in June 2005. In Kyela farmer group members participating in this programme has been given approx. 1kg of *Crotalaria* seed to establish a demonstration plot to create awareness of the technology among village members.

Morogoro Rural District council is also using the outputs described in this dossier to expand promotion to new wards since the termination of CPP projects. They have used the existing farmer groups to produce *Crotalaria* seed to be distributed to more farmers within and outside their ward. They have established collaboration with other institutions working in the Uluguru Mountains including CARE International, Uluguru Mountain Agricultural Development and Extension Project (funded by the Global Environment Fund), and DAI PESA, who are also involved in farmer group organization/strengthening, empowerment and environmental conservation.

The above institutions continue to use the posters, leaflets, training manuals and videos produced by the CPP project.

13. ***Where*** *are the outputs currently being used? As with Question 11 please indicate place(s) and countries where the outputs are being used* ***(max. 250 words).***

Outputs are currently being used in 29 villages in Kyela, and in Matombo, Tawa, Kibungo Juu, Lundi and Mtombozi wards in Morogoro Rural District, Tanzania. Use of *Crotalaria* has also been adopted by Kimango Organic Farm in Morogoro Rural district. The NGO Ileja Rural Development Organisation is demonstrating *Crotalaria* to farmers on hillsides in Ileja District, Mbeya Region.

Displays of *Crotalaria* seed, demonstrations and information on use of the rotations have been mounted at annual agricultural shows in Southern highlands (Mbeya) and Eastern Zone (Morogoro).

14. What is the scale of current use? Indicating how quickly use was established and whether usage is still spreading ***(max 250 words).***

The use of the legume-cereal rotation expanded during 2006 both on farms of previous project participants and through initial adoption by new growers in both existing and expansion villages. In Itope and Kilasilo, the first villages in Kyela where green manures were demonstrated from 2002, individual areas planted to *Crotalaria* in 2005, averaged 660 and 2862 m^2 respectively. Farmers adopting the green manure for the first time in Kilasilo

have planted up to 0.5 ha^{-1}. The largest grower planted 1 ha^{-1} of a total farm size of 2ha. In Sinyanga, where plots were planted for the first time in 2003 individual farmers planted up to 0.6 ha^{-1} in 2005 with new adopters sowing areas of 350 to 550 m^2. The project has been unable to undertake an extensive survey to assess the extent of adoption beyond the participating groups. However in a spot survey in early 2005 in Itope, Konjulas, and Kilasilo villages, 11 farmers reported either giving or selling *Crotalaria* seed to a total of 37 others who had learnt of the benefits of the legume-rice rotation from the demonstration plots. The Kyela District Council has distributed more than one metric tonne of *Crotalaria* seed, sufficient for planting on approx. 50 ha, while Kyela farmers have sold an additional 2.5 t of seed in the 2006 season, indicating rapid spread of the technology.

15. In your experience what programmes, platforms, policy, institutional structures exist that have assisted with the promotion and/or adoption of the output(s) proposed here and in terms of capacity strengthening what do you see as the key facts of success? ***(max 350 words).***

District council extension services have been the key to facilitation of the promotion to date. Success has been achieved following the development of partnerships involving extension, education officers, NGOs and researchers from Ilonga and NRI to ensure a co-ordinated set of activities for mobilization of farmers to form groups, management of the demonstration plots and regular monitoring of progress at both village and ward level. Selection of active and respected lead farmers by participating communities has been an essential element to ensure farmer ownership of the process. Some groups formed to validate and promote the technology (e.g. in Kilasilo and Itope villages, Kyela) have registered as legal entities and have opened bank accounts to operate a Savings and Loan facility for members. Farmers prefer to learn from the experiences of other farmers rather than by simply accepting new knowledge directly from extension providers. Exchange visits for elected lead farmers and village extension staff from the “new” villages to well established groups have been very effective in spreading the technology.

Interaction between extension service and education departments at district level has facilitated primary schools to engage in promotion of the project outputs through choir, plays, demo plots, and poems. The partnership with NGO like CARE International with a similar objective of addressing a problem of soil fertility for resource poor farmers has helped to promote the technologies to a wider audience of the farmers. National and zonal agricultural shows (Nane Nane) have been useful fora for farmers to exchange information and materials and hence facilitate the promotion process.

The mass media through radio and television programmes, plays and other activities performed by schools and farmers have played an effective role in raising awareness of project outputs to the wider farming community.

District councils, have the opportunity to prioritise technology promotion through their District Agricultural Development Plans. The CPP projects therefore engaged District councillors, local policy makers and district budget holders in discussions at various stages to ensure they were all well informed of the emerging technologies and farmer demand.

Current Promotion

D. Current promotion/uptake pathways

*16. **Where** is promotion currently taking place? Please indicate for each country specified detail what promotion is taking place, by whom and indicate the scale of current promotion **(max 200 words)***

Kyela District Council set a side £3500 (8 million Tz shillings) in 2006 to train lead farmers, (400 groups in 21 villages) on how to minimize the effect of *Striga* in rice by improving soil fertility in infested and exhausted fields by using the cereal-legume rotations. As described in section 13 Morogoro Rural District council has initiated promotion activities in 5 wards. CARE International is aiming to work in 32 villages in Uluguru south area and plans to include demonstrations of *Crotalaria* for soil fertility improvement is to use crotalaria to farmers. The NGO purchased 40 kg of seed from Peramiho in Songea to begin seed multiplication in their target areas.

*17. What are the current barriers preventing or slowing the adoption of the output(s)? Cover here institutional issues, those relating to policy, marketing, infrastructure, social exclusion etc. **(max 200 words)**.*

Although rapid dissemination of the outputs described in this dossier has taken place on a limited scale further promotion has been prevented by unavailability of seed of the green manure, and pigeon pea, limited marketing opportunities for pigeon pea grain in areas such as Kyela and Matombo where it has not previously been an important commodity on local markets, and the limited numbers of extension officers serving target communities, both subject specialists at district and front line staff at village level. District councils also have limited budgets for training and promotion of staff and farmers.

While the use of *Crotalaria* has clear benefits for improving soil fertility and subsequent cereal yields when used in rotations farmers loose the opportunity to harvest a food crop. This is a disadvantage for poor households cultivating limited areas of land. Few farmers in Matombo, for example, produce sufficient rice for sale in addition to household consumption.

*18. What changes are needed to remove/reduce these barriers to adoption? This section could be used to identify perceived capacity related issues **(max 200 words).***

To achieve wide-spread adoption of outputs will need further multiplication of seed of both *Crotalaria* and pigeon pea. District and NGO extension staff need to link current producers in areas where CPP projects worked with farmers with similar problems in areas that are targeted for promotion. The experience to date shows that multiplication of seed can be achieved on a local scale by training farmer groups. Farmers are not aware of the value of pigeon pea for processing as dhal. Information needs to be supplied to farmers on how to access markets including those in Dar es Salaam and efforts made to link them with buyers. New markets have recently been established on major routes through the Uluguru mountains with technical support from the NGO INADES. These could be used as information points on pigeon pea marketing. The limited number of extension staff could be augmented by training of lead farmers in target areas who in turn can train others and be foci for seed multiplication and distribution.

A few farmers in Matombo have experimented with relay cropping of *Crotalaria* after completion of weeding their maize. This allows them to produce nitrogen rich biomass for soil fertility improvement AND harvest a grain crop in the same season. This promising practice needs to be validated prior to promotion.

19. What lessons have you learnt about the best ways to get the outputs used by the largest number of poor people? ***(max 300 words).***

Green manures are nothing new, indeed there was a campaign some years ago calling on Tanzanian farmers to plant *Crotalaria*. What is different now that is leading to farmers to try green manures for themselves? A study by project R8436 indicated that a number of factors appear to be contributing to adoption. Understanding how farmers see soil fertility challenges, involving them in the selection of "best bets" and identifying the knowledge that they need to adopt new methods successfully has been central to laying the foundations for up-scaling. Previously farmers were recommended to use *Crotalaria*, often without having previously seen it and with out the knowledge of how it should be incorporated into the cropping system. Now, as a result of village seminars, exchange visits, field days at demonstration plots, work with primary schools and radio programmes organised by researchers and extension there is increasing awareness of the use of green manures in the farming community. District council policy makers, councillors and field staff have also been involved from an early stage and encouraged to attend field days and workshops. As a result Kyela district council voted funds to extend training of lead farmers to all villages in the district in 2006 after the project ended. There is a history of limited adoption of "package defined" soil fertility technologies. Solutions clearly need to be context specific and it is therefore important to identify local circumstances that will favour adoption.

Impacts On Poverty

E. Impacts on poverty to date

20. Where have impact studies on poverty in relation to this output or cluster of outputs taken place? This should include any formal poverty impact studies (and it is appreciated that these will not be commonplace) and any less formal studies including any poverty mapping-type or monitoring work which allow for some analysis on impact on poverty to be made. Details of any cost-benefit analyses may also be detailed at this point. Please list studies here.

No specific studies on the impact of these outputs on poverty have been undertaken. However some indication on the impact of adoption of green manure or rotation of cereals with pigeon pea is available from participatory cost analysis of inputs and outputs completed by project R8194 and reported in:

A.M. Mbwaga (2005). *On farm verification and promotion of green manure for enhancing upland rice productivity on Striga infested fields in Tanzania*. Final Technical Report for project R8194. Kilosa, Tanzania: Ilonga Agricultural Research Institute.

21. Based on the evidence in the studies listed above, for each country detail how the poor have benefited from the application and/or adoption of the output(s) ***(max. 500 words):***

- *What positive impacts on livelihoods have been recorded and over what time period have these impacts been observed? These impacts should be recorded against the capital assets (human, social, natural, physical*

and, financial) of the livelihoods framework;

- *For whom i.e. which type of person (gender, poverty group (see glossary for definitions) has there been a positive impact;*
- *Indicate the number of people who have realised a positive impact on their livelihood;*
- *Using whatever appropriate indicator was used detail what was the average percentage increase recorded*

No studies have been conducted on the impact of application of the outputs described in this dossier on livelihoods and poverty. Such work was not included in the agreed work programmes of the projects that generated these. Farmer participatory analysis of input costs and outputs suggests that as the use of green manure or pigeon pea reverses the yield decline seen over many years in maize and rice farmers benefit from improved harvests, particularly at sites with low mean yields for continuous cereal production which typically are heavily infested by *Striga.* For example crop budgets prepared in a participatory budgeting exercise in Kyela revealed that when labour is costed at local rates, farmers actually incur a loss from continuous upland rice production. Rice production becomes profitable once soil fertility has been raised through a one year break crop of green manure with higher income from sales of *Crotalaria* seed and increased yields of rice in year two. Further more labour use for weeding rice following the green manure, that itself does not need weeding at all, is only 50% of that for continuous rice. Increased profitability may be translated into either increased household food supply or increased income from crop sales. The reduction in weeding labour is particularly welcomed by women who are able to allocate more of their time to other household activities.

Environmental Impact

H. Environmental impact

24. What are the direct and indirect environmental benefits related to the output(s) and their outcome(s)? ***(max 300 words)***

This could include direct benefits from the application of the technology or policy action with local governments or multinational agencies to create environmentally sound policies or programmes. Any supporting and appropriate evidence can be provided in the form of an annex.

Recent estimates from the International Fertiliser Development Center have drawn attention to the scale of plant nutrient loss through erosion and nutrient mining in sub-Saharan Africa. While average fertilizer use in Tanzania was less than 2 kg ha^{-1} in 2002, loss of nitrogen, potassium and phosphorus was estimated at 61 kg ha^{-1}, one of the highest annual rates in Africa. As few poor farmers are in a position to purchase fertiliser, the use of a low-cost organic approach is an essential alternative. Trials in Kyela have demonstrated that *Crotalaria* dry biomass production levels of more than 4 t ha^{-1} can be achieved. Regular incorporation of these levels of organic material will also improve soil water holding capacity. As cereal yields have fallen in the Uluguru mountains so farmers have exploited higher wooded slopes which have thin soils. This is leading to serious erosion in the area that is an important water catchment for urban areas including Dar es Salaam. More than 50% of the original forest cover of the Ulugurus has been lost, largely to expansion of agriculture and little accessible wooded land now

remains outside forest reserves that could be utilised for crop production The mountains are also recognised as an important site for biodiversity conservation by the UN Global Environment programme and include a number of endemic species of birds. Environment protection is therefore of up most importance. As the legume green manure rotations can reverse the yield declines experienced in the area over recent years they will help relieve pressure from farmers expanding cultivation to higher wooded slopes.

25. Are there any adverse environmental impacts related to the output(s) and their outcome(s)? ***(max 100 words)***

The outputs have no any adverse impacts on the environment as they deal with an organic approach that will improve the soil structure.

26. Do the outputs increase the capacity of poor people to cope with the effects of climate change, reduce the risks of natural disasters and increase their resilience? ***(max 200 words)***

People in Morogoro region, including Matombo in the Uluguru mountains live with significant climatic variability with drought approximately once in 4 years since 1970. Models suggest an increase in mean annual temperature of 2-4 ^{0}C here by 2100 with decreased and more variable rainfall and a consequent increase in the variability of agricultural productivity. Average maize yield in Tanzania is predicted to fall by up to 33% by 2075 if actual atmospheric CO_2 concentrations and temperatures are in line with current models. Farmers in Morogoro region make adaptive agricultural decisions, including how much land to plant to maize, in response to seasonal variability or switch to environmentally more damaging enterprises including charcoal burning or migrate temporarily in search of employment, putting pressure on services in urban areas. Farmers need to optimise land productivity more than ever. Rotation with leguminous crops is a low cost approach that does not expose farmers to losses of cash investment as is the case when droughts follow use of fertiliser. Greater attention needs to focus on protecting land from erosion in periods of heavy rainfall on the one hand AND maximising soil moisture conservation for periods of drought but labour intensive approaches (contour bunds, terraces, etc) are only likely to find favour if accompanied by practices such as green manuring that provide a rapid return to investment.
