Rainfall modelling can predict future yields

RIU

Validated RNRRS Output.

PARCHED THIRST (PT) is a decision-support tool that addresses the challenges of low and unreliable crop and livestock production in semi-arid areas. Unlike most other models, PT includes the effect of the weather, water management and soil variability on cereal crop yields. Planners can therefore use it to estimate food deficits or surplus, and so anticipate their import or export strategies. The model is currently used by the Early Warning Department of the Ministry of Agriculture and by agricultural extension offices and training institutes in several areas of Tanzania. It is also used for research and teaching in Uganda, Ethiopia, South Africa, Nigeria, India, Pakistan, Greece, the UK and the USA. It is available for download from websites in Tanzania, UK and Belgium.

Project Ref: **NRSP13:**
Topic: **4. Better Water Harvesting, Catchment Management & Environments**
Lead Organisation: **Sokoine University of Agriculture, Tanzania**
Source: **Natural Resources Systems Programme**

Document Contents:

Description

NRSP13

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

Geographical regions included:

Africa, India, Tanzania, UK,

Target Audiences for this content:

Crop farmers, Livestock farmers, Fishers, Forest-dependent poor,

A. Description of the research output(s)

1. Working title of output or cluster of outputs.

Rainwater harvesting and management

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

Natural Resources Systems Programme and the Government of Tanzania

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.

R8088

Collaborating institutions and partners included:

- Ministry of Agriculture, Food Security and Cooperative (MAFSC) (Ms. Mary Shetto, Mr. Tibanyenda, Mr. Ntikha)
- Tanzania Meteorological Agency (TMA) (Mr. Mike Mboya, Mr. Tharcis Hyera)
- Local Government Authorities (Same and Mwanga District Councils)

*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.*

The RNRRS output or clusters of outputs are Rainwater harvesting and Scaling up through uptake promotion. The outputs were:

PARCHED THIRST (PT) **model** v2.1 was further developed (v2.2, v2.3 and v2.4), validated and promoted to improve integrated management of rainwater. PARCHED-THIRST, which stands for Predicting Arable Resource Capture in Hostile Environments during the Harvesting of Incident Rainfall in Semi-arid Tropics, is a process-based model, which combines the simulation of hydrology with growth and yield of a crop. The PT model is a decision support tool that addresses challenges of low and unreliable crop and livestock production in semi arid areas. This is caused by low availability of soil moisture as a result of erratic distribution of rainfall and high losses through run-off and evaporation.

The model is applicable in assessing the influence of crop management on crop yields as affected by planting dates, weeding and plant population. An extension of capability of PT model is its usefulness in investigating the influence of weather variability, effect of land water management,

and soil variability on cereal crops yield, which most of other crop models are lacking. The model can therefore be used to estimate crop yield to establish food deficit/surplus and hence plan for import/export strategies.

The project facilitated the availability and use of the PT model to potential users. Effective communication and knowledge management strategies for assisting the scaling-up of PT Model and related research outputs in **rainwater harvesting** (RWH) that would benefit the poor in **semi-arid** areas were developed and promoted. This was achieved through use of interactive methods and reader-friendly written communication methods and media to create awareness, providing advice and help to target users. The communication products included **virtual laboratory experiments** (for agricultural colleges and universities), and Knowledge Sharing Products (booklets, posters, manual). **Case studies** using PT model to address specific problems for districts, MAFS and **Tanzania Meteorological Agency** (TMA) were developed and documented as part of the validation process. These activities were conducted between 2002 and 2006.

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*	*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 output focused on the following main commodities: Maize, rice, lablab, vegetables (onions, tomatoes, water melons, cabbage) and livestock. These outputs could also be applied to other commodities such as tree planting, domestic water use, aquaculture, brick making and construction.

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							

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*		*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.

Value could be added to the project outputs by clustering with outputs from the following RNRRS projects: R6621, R7987, R8115 and R8116. For example, outputs from RNRRS project R6621, dealt with the development of a hillsides system soil and water model used to study different soil conservation measures and climatic regimes, could supplement those from the PT model to come up with more elaborate decisions on soil water conservation. Also, outputs from project R7987 could be used to increase awareness/appreciation to extension staff of the potential of computer applications/models in agricultural and livestock planning. The R7987 project developed a computer-based decision support system known as 'Tsetse Plan' to help planners design and implement community-based interventions against tsetse fly infestation in Eastern African countries.

Project R8116 identified institutional, regulatory and tenure systems requiring improvement of the management of common pool resources (CPR) and project R8115 produced communication products on improved strategies for integrated soil and plant nutrient management in RWH. Both projects addressed issues in NRM the same as R8088. Therefore clustering with these outputs will have multiplier effects on poverty reduction through improved capacity of the policy makers, extension specialists to deliver services and smallholder farmers to better manage their resources.

Furthermore, the project outputs could also be clustered with non-RNRRS projects P185 and P113, funded by Water Research Fund for Southern Africa (WARFSA). Project P185 focused on the development and validation of a macro-catchment RWH module to be included into the PT model. This could increase the scope of application of the model. Project P113 developed a GIS-based decision support system for identifying potential sites for rainwater harvesting. This could assist in identifying potential locations/areas for rainwater harvesting and hence enable the identification of areas where the PARCHED-THIRST model could be applied successfully.

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)**.*

Preliminary validation of PARCH, which is the first component of PARCHED THIRST model, was done by various

research institutes. The validation of PARCH involved experiments conducted by J.L. Monteith in 1988/89 at ICRISAT center to study the interactions of water and nutrients on the growth of sorghum, under irrigated and drought conditions; simulation of cultivar DK 55 at the Katherine research station in the Northern Territory (Australia) using PARCH (Hammer & Muchow, 1992); validation of the soil-water balance sub-model of PARCH conducted in Botswana by Land and Water Management Project (L&WMP), with one variety of sorghum (MV) and one maize variety (KGN); and experiments conducted at the Tropical Crop Research Institute Unit at the University of Nottingham to validate PARCH simulation of sorghum (cv. 65D); Kenyi (1991).

Comparisons of actual growth data against PARCH predictions have been analysed. Simulated grain and dry matter have been plotted against the actual recorded values to produce 1:1 comparison graphs and linear regression analysis conducted on the pooled data gives an r^2 of 0.97 with 70 DF, resulting in a probability of $P<0.001$ which is a very positive result.

Further validation of various components of the PARCHED THIRST model was performed by researchers from SWMRG-SUA since year 2000 in collaboration with various stakeholders. Data sets on soils and crop yields from Kigonigoni site in Mwanga district (Kilimanjaro-Tanzania) and from Magadu site in Morogoro district were collected and a comparison with simulated values of maize (TMV1) yields under both rainfed and RWH systems was done. Results showed good agreement between simulated and measured yields under both RWH and rainfed conditions. To improve the performance of the model in the design of RWH system, a new sub-routine that allows macro-catchment RWH was developed, validated and incorporated into the model (Mzirai,O.B, 2006).

To promote the use and adoption of PT, SWMRG established the 'PT Help Office', with the intention to collect feedback from and to provide support to the model users. Training and feedback workshops have been organised for target stakeholders including district agricultural extension officers, agricultural tutors from various agricultural training institutes, researchers and lecturers from the Sokoine University of Agriculture (SUA) (in the field of agriculture, soil science and irrigation engineering), staff from the MAFSC and from the TMA. Through these training sessions, district agricultural officers were able to identify areas where the model can be applied to solve problems at their work stations, and thence developed a number of relevant case studies. For example, agricultural extension officers from Kilosa district used the model to study and compare the effects of different soil and water conservation techniques on maize crop yields in Vidunda village; this enabled them to advice farmers on best options regarding planting dates. Agricultural tutors and lecturers from SUA were also involved in the development of a teaching manual of virtual experiments in agriculture using the PT model. The manual is meant to assist in teaching some topics in agriculture to undergraduate and postgraduate students at SUA and to diploma students in Agricultural Training Institutes. Feedback from different stakeholders has made it possible to upgrade the model from version 2.1 to version 3.0 (through versions 2.2, 2.3 and 2.4).

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)****.*

PARCHED-THIRST outputs have been validated in various locations in semi arid tropics. Validation of the PARCH component was done since in the late 1980's and continued in the beginning of 1990's in Australia and Botswana (refer Q10). Since year 2000, the RWH component of the model as well as the new macro-catchment

RWH module, incorporated into the model recently, have been validated and the results are now applied at different sites, in semi-arid areas of Tanzania. District agricultural extension officers in Morogoro, Kilosa and Same districts validated the model by applying it to their environments by developing case studies in 2005. The same year (2005), instructors at SUA and other colleges and researchers at Uyole and Ilonga agricultural research and training institutes validated the model by developing virtual experiments. At national level, Ministry of Agriculture, Food Security and Cooperatives and Tanzania Meteorological Agency, using PT model, developed case studies relating to food security.

Current Situation

C. Current situation

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

Currently, agricultural extension officers in Morogoro, Kilosa, Mwanga and Same districts are using the model to simulate various agricultural practices, from which they are able to deduce useful information they need to advise farmers on different crop management aspects; such as optimal planting window, appropriate soil and water conservation techniques and rainwater harvesting systems design. SWMRG provided computers to the four districts agricultural offices to enable them use the model.

PT is also being used by tutors at Ilonga and Uyole agricultural training Institutes, and SUA lecturers, whereby conventional experiments in agriculture are complemented by virtual experiments using the model.

At national level, the Early Warning Department of the Ministry of Agriculture, Food Security and Cooperatives anticipates using PT and seasonal climate forecasts to predict crop yield.

At continent level, PT model is used for research and teaching in the following African institutions: Department of Soil Science, Makerere University, Uganda; Department of Geography and Environmental Studies, Addis Ababa University, Ethiopia; University of Kwazulu-Natal and University of the Witwatersrand, School of Civil and Environmental Engineering; Department of Soil, Crop and Climate Sciences, University of Free State, South Africa; Department of Agricultural Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria.

Use of PT model outside Africa, again, for research and teaching is at the following institutions: Cornell University, USA; Centre for Ecology and Hydrology, UK; Water Management, Pakistan; Columbia University, USA; Agricultural University of Athens, Greece; HR Wallingford, UK; Agricultural Engineering College and Research Institute, India; Katholieke Universiteit Leuven, Belgium and University of Newcastle upon Tyne, UK.

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 of the project are being used in Morogoro, Kilosa and Same districts in Tanzania. The outputs are also used by Sokoine University of Agriculture and Ilonga agricultural training Institute located in Morogoro, Uyole and

Igurusi agricultural training institutes located in Mbeya region in Tanzania. Furthermore, PT Help Office continues to receive and to respond to requests about the model from within and outside Tanzania.

Use in Africa:
Department of Soil Science, Makerere University, Uganda; Department of Geography and Environmental Studies, Addis Ababa University, Ethiopia; University of Kwazulu-Natal and University of the Witwatersrand, School of Civil and Environmental Engineering, South Africa; Department of Agricultural Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria.

Use outside Africa:
Cornell University, USA; Centre for Ecology and Hydrology, UK; Water Management, Pakistan; Columbia University, USA; Agricultural University of Athens, Greece; HR Wallingford, UK; Agricultural Engineering College and Research Institute, India; Katholieke Universiteit Leuven, Belgium and University of Newcastle upon Tyne, UK.

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

The scale of use in this context was measured by the number of software copies distributed or downloaded by clients. By 2002, more than 200 copies were distributed to various clients. They include 9 district agricultural and extension officers from targets areas; ;8 Irrigation engineers; 8; personnels working with NGOs in the targets areas; 9 government departments working on agriculture and water resources; 14 agricultural research institutions; 14 rainwater harvesting projects and organizations; 13 lecturers from SUA and University of Dar-es-Salaam; 28 scientists/researchers working on different SWMnet/ASARECA network and countries; 5 scientists and researchers in international organization and networks,; 10 participants who attended Statistics in Agricultural Climatology (SIAC) courses; 22 participants who attended PT launching workshop; 4 postgraduate students at SUA.

Websites in Tanzania, UK and Belgium house the model. The sites in Tanzania and UK do not have means to keep track of the number of downloads while that in Belgium does. From the Belgium website the number of downloads, between November and December 2005, were 7 and between May and July 2006 were 14. This finding implies that the scale of use is quite high given the 21 downloads recorded in only five-month period in Belgium alone.

Through a feedback workshop organized by the SWMRG in August 2006, it was revealed that there is a significant and continuous increase of the number of model users and aspirant users. Participants drawn from different parts of the country included water and irrigation specialists, agronomists, extension specialists and instructors.

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).***

The following programmes, platforms, policy and institutional structures have assisted in the promotion and

adoption of the outputs:

- *The Sokoine University of Agriculture through Soil-Water Management Research Group, promoted the use of PT model through workshops, writeshops and conferences. The Directorate of Computer Centre at SUA established PT-Help Office, which is housing the model and supports users' queries.*
- *Three agricultural colleges, MATI Ilonga, Igurusi and Uyole, provide PT training to students in their colleges. These are future extension agents at village and ward levels.*
- *Staffs, who received training on PT-model, from Kilosa, Same and Morogoro District Councils are training other staffs in their Councils.*
- *Tanzania Meteorological Agency newsletter has been publishing articles on PT model.*
- *Southern and Eastern Africa Rainwater Harvesting Network (SEARNET) is promoting the model through its annual conferences and publications.*
- *Soil and Water Management Research Network (SWMnet) of the Association for Strengthening Research in East and Central Africa (ASARECA) has been promoting PT in its workshops and publications.*
- The Water Policy of 2002 and Agricultural and Livestock Policy of 1997 *are promoting the use of rainwater harvesting for agriculture, livestock and domestic use. This has made the model popular and attracted more interest by more professionals in the ministries. As a result, staffs from the ministries have shown interest in learning the model.*
- *Water Research Fund for Southern Africa (WARFSA) provided funds for more research and promotion of the PT model.*
- *Annual conferences by WATERNET/WARFSA /GWP-SA have been used as a platform to present research and outreach activities from the model.*
- *SIAC and AICAD trainings had a module on PT model. SIAC trainings were conducted for five years (2000 – 2004).*
- *Launching of the model was done at national and regional levels. The national launching was officiated by the Minister of Science, Technology and Higher Education in Tanzania and was attended by several directors of different departments in the line Ministries, while at the regional level it was done during the SEARNET workshop in Zambia and attended by National Coordinators of Rainwater Harvesting Associations from 10 countries in Eastern and Southern Africa. These events provided opportunity for wider promotion of the model.*
- *National Agricultural shows conducted in 2006 and Annual Engineers' Exhibition Day (2005 -2006), were used to create awareness.*

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).***

Currently, limited promotion of the model is going on in Tanzania, led by the SWMRG. Of recent, A workshop was organized in August 2006 to train and receive feedback from stakeholders. The participants included

agricultural officers from Hai and Rombo districts in Kilimanjaro Region; tutors from agricultural training Institutes-Igurusi and Kilimanjaro Agricultural Training College; hydrologists from Pangani and Rufiji Basin Water Offices; zonal irrigation officers from Morogoro and Kilimanjaro region and staff from the Mixed Farming Improvement project (MIFIPRO) operating in Kilimanjaro region. Brochures for short courses have been produced and are planned to be distributed to all line ministries and district councils. The model is freely available over the Internet through the three websites in Tanzania (Sokoine University of Agriculture), UK (NRSP website, University of Newcastle upon Tyne) and Belgium (Katholieke Universiteit Leuven). This has allowed a global promotion of the model and some of the downloads which have been recorded were from countries like India, Pakistan, Malawi, Iran, South Africa, Cuba, USA, Australia, Ethiopia and Uganda.

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)****.*

The current barriers preventing the adoption of outputs include little understanding of the importance of crop models among stakeholders. For example, the majority of agricultural extension officers in the country were not exposed to the ideas of crop models during their college education. In addition, most of them have little knowledge in computers, and/or they have limited or completely no access to computers at their work places. In addition, politicians and policy makers have little awareness and knowledge on the role of models in assisting policy formulation and decision-making.

For colleges, the main factor limiting adoption is limited teaching facilities such as computers as well as resource persons knowledgeable with models. The majority of those appointed, by their institutions, to attend PT training have been male scientists (extension specialists and researchers), while there is a substantial number of qualified female scientists. In addition, PT Help-Office is currently constrained in-terms of facilities, connectivity and specialized manpower even though is handling all queries from users.

There is also a problem in the acquisition of the meteorological data leading to its limited availability. This is caused by lack of conducive policies on data acquisition and sharing. On the other hand, there is no policy of creating databases on soil and crop parameters, this is despite the fact that researchers have been generating data, which is scattered and sometimes lost.

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).***

- *In order to remove these barriers, it is needed to invest more efforts in training more stakeholders on the use of models, especially district agricultural extension officers. However, this will succeed if they are also provided with facilities to be able to use the model.*
- *Emphasis should also be put on strengthening the idea of modelling in colleges and university, from where expected stakeholders are trained.*
- *Devote extra efforts on data acquisition and compilation.*
- *Create awareness to model users on the availability of data through other source such as networks, and FAO.*

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).

- *Our experience has shown that a minimum of three weeks of interactive training, involving case studies relevant to areas of work of extension specialists, is needed. For example, training of extension staff in three districts has led to more training of other extension staff in those districts by their colleagues who attended a three week interactive training. Thus, the length and the methods of training extension specialists are crucial in building their competence and confidence.*
- *Development of training materials with college and University instructors enhanced wider uptake of PT model. In this project, virtual experiments were developed together with college and University instructors at SUA, Ilonga and Uyole Agricultural Training Colleges. These experiments targeted specific subjects taught by instructors to make sure that after development they will be used. Graduates from these institutions are the future researchers and extension specialists.*
- *Use of a communication strategy allowed all stakeholders identified during project design to fully participate and contribute towards attainment of the outputs.*
- *Use of case studies and virtual experiments, to solve real-life problems found in actual field situations, allowed stakeholders to appreciate the usefulness of the model.*
- *Presence of PT Help Office played a pivotal role in sustaining the use of PT model. This was achieved through prompt responses to users' queries. For example, clarifications and guidance to users when they get stuck and further improvement of the model based on users' feedback.*
- *Other lessons include provision of facilities, monitoring/tracking of use of the model, and involvement of national level stakeholders. Provision of computers including tracking, allowed wider use of the model by those who received training. Policy makers were made aware by involving staff from national level institutions, such as Ministry of Agriculture, Food Security and Cooperatives and Tanzania Meteorological Agency.*

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.

An impact study for this CLUSTER titled "Benefits of RWH in Poverty Reduction in Tanzania" was conducted in Maswa and Same districts under the auspices of project R8116.There is a strong link betweenR8116 and R8088 because Project R8116 identified institutional, regulatory and tenure systems requiring improvement of the management of common pool resources (CPR), which were linked with R8088. The impact study involved yield monitoring of paddy and maize crops to establish evidence of benefits of RWH in poverty reduction. The study showed that:

- *RWH for crop production under different RWH systems in both Maswa and Same districts showed*

impressive returns to land and labour. The overall returns to land from paddy per hectare progressively increased from micro-catchment (US $ 701.1), macro-catchment (US $ 746.4) and macro-catchment with road drainage (US $ 879.7) before declining to US $ 779.7 in the case of micro/macro-catchment with storage pond. The returns to labour were 8.7, 9.3, 11.0 and 9.7 US $ per person-day for micro, macro, macro linked to road drainage and micro/macro with storage pond respectively during above-average season. Returns to labour during below-average season were 6.2, 7.8, 7.4 and 4.9 US $ per person-day for micro, macro, macro linked to road drainage and micro/macro with storage pond respectively. (Note: under rice based farming system pure rainfed production is not common, therefore no data for comparison).

Impressive performance of paddy under RWH linked to drainage suggests a need for integrating rural road drainage systems with RWH for agricultural production in semiarid areas. Such development plan optimizes the benefits from public investment in road drainage infrastructure.

- *Intercropping of maize and lablab beans resulted to lower returns to land (US $1,011.9 per ha) compared to sole maize crop (US $ 1,594.7 per ha) under RWH. This was significantly higher compared to sole maize crop without RWH (US $ 414.2 per hectare). Similarly, returns to labour was US $ 43 and US $ 27 per person day in sole maize and maize intercropped with lablab respectively.*

However, for investments in RWH to have an impact on poverty reduction, increased linkages to profitable markets is critical.

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*

The following positive impacts on livelihood have been recorded:

- *In terms of human assets, the knowledge base of most communities has been enhanced through trainings, workshops, study tours, farmer field schools and transfer of the needed knowledge to different stakeholders including farmers and support agencies namely extension, private sector and non-state agencies).*
- *Membership and active participation of the socially marginalized women, youths and pastoral groups in resource users' groups and other social networks were improved. These achievements amplified the voices of the poor in influencing decisions regarding access to CPRs whose governance is widely the mandate of the institutions of the society.*
- *Rainwater user institutions from different positions in the watershed (upstream, midstream and downstream) were brought together in the dialogue on efficient and equitable use of the common runoff. This*

remains to be an important avenue to ensure equity in runoff access and conflict resolution among users with spatial differences

- *The productivity, amount of land and number of households that receive adequate amount of run-off have increased due to better management of rainwater.*
- *Improved access to run-off and storage of rainwater has enabled supplemental supply of water for both crop and livestock in critical times of water scarcity. This has reduced the risks of crop failure and mortality of reared animals, especially vulnerable stocks such as young and sick animals, which cannot be trekked longer distances to perennial waters.*
- *Realization of the potential of livelihood-enhancing potential of rainwater management has attracted investments in RWH by farmers privately and/or through partnership with the government and donor agencies. Such investments include construction of water storage structures (charco-dams and ponds, water tanks).*
- *All together, improved access to water through RWH has contributed to wealth creation in the target areas through increased and stabilized agricultural production and incomes. From increased incomes, the households have constructed better houses, capital formation, payment for child education, and creation of other assets such as agricultural* implements (e.g. plough and rippers).

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.

Some of the environmental benefits related to this output include runoff management, soil and water conservation and optimum water abstraction. The model is capable of determining the required catchment areas and cropping areas based on the rainfall pattern and amount of runoff generated for a given location. This allows the runoff water to be captured and applied to the cropping area and therefore reducing possibility of unnecessary flooding and soil erosion. The model can also be used to simulate the effect of soil and water conservation measures by constructing virtual terraces on the software. The long-term effect of lack of soil conservation measures is erosion of the agriculture land, which leads to lower productivity. This effect is normally not easy for farmers to understand or perceive. However, the model is capable of illustrating the effects through simulation. Furthermore, optimum water abstraction can be achieved with PT model. This is important because unnecessary water abstraction can lead to negative environmental impact downstream or conflicts with downstream users. The model can be used to estimate the amount of water required over time and therefore abstraction amounts and schedules.

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

None. Mainly positive impacts are expected because the outputs aimed at addressing proper water harvesting for livestock and crop production and, soil and water conservation.

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)***

Yes, the outputs could play an important role in increasing people's capacity to cope with the effects of climate change. For example, by using the model with climate forecasts, it is possible to tell which could be the appropriate planting dates for a particular location, and what combination of agricultural inputs/ resources and management practices will result into optimum yields. Therefore, people could be able to use the available resources rationally and also to prepare for prevention or at least to reduce the impact of disasters that could result from climate change.