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FINAL TECHNICAL REPORT
MAIN REPORT

DFID Project Number

R 7888

Project title

Assessment of Rainwater Harvesting Demand and Efficacy

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Organisation

Sokoine University of Agriculture

NRSP Production System

Semi Arid

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ACRONYMS AND DEFINITIONS

ASDS	Agricultural Sector Development Strategy of Tanzania, approved in October, 2001.
Majaluba	Excavated bunded basins or cultivated reservoirs used to harvest and store rainwater for the production of rice in semi-arid areas of Tanzania.
PDC	Professional Development Course
PIDP	Participatory Irrigation Development Project – An irrigation project based on RWH systems. It is financed by the Tanzania Government using a loan from IFAD.
RELMA	Regional Land Management Unit of Sida, based in Nairobi Kenya, and working in Eritrea, Ethiopia, Kenya, Uganda, Tanzania and Zambia.
RWH	Rainwater Harvesting
Sida	Swedish International Development Agency
ToT	Training of Trainers
ASPS	Agricultural Sector Program Support
DRD	Division of Research and Development of the Ministry of Agriculture and Food Security - Tanzania
DRDI	DRD – Institute
MTR	Mid-term Review
SIAC	Statistics in Agricultural Climatology
PT	PATCHED-THIRST computer model for simulating RWH processes
IMTR	Institute of Meteorological Training and Research
WPLL	The lowlands located to the west of Pare Mountains within the Mwanga and Same districts
SUA	Sokoine University of Agriculture
URT	United Republic of Tanzania
CPR	Common Pool Resources
HH	Household
HHH	Head of household
GM	Gross Margin

1. Executive Summary

In the last five years, the Government of Tanzania has been implementing an intensive review and reform of its national policies and strategies. One result of this process is the approval of the Poverty Reduction Strategy Paper (PRSP), in October 2000. The PRSP focuses on *reduction of income poverty, and on improving human capabilities, survival and social well being, as well as containing extreme vulnerability among the poor*. Agriculture has been identified as a priority poverty reduction sector. Further, within the PRSP, development of irrigated farming is emphasized as one of five instruments for pursuing rural sector development and export growth.

Project R7888 was designed to contribute to the PRSP by raising awareness and technical knowledge of the role that rainwater harvesting can play in improving water availability for agriculture. It was a follow-up to project R6758 that demonstrated viability of RWH as a strategy for the up-grading of rainfed farming. However, in implementing R6758 it was also found that the main constraint to wider adoption of RWH systems was inadequate knowledge on appropriate approaches. Project R7888 was therefore designed to generate and disseminate knowledge that can be used to improve the understanding of the role of RWH by stakeholders at all levels, from farmers to policy markers.

The project purpose was stated as *productivity of water in rainfed agriculture, IMPROVED through accelerated uptake and intensive use of rainwater harvesting.* The outputs of this project have been delivered in several ways. Knowledge of the role of rainwater harvesting among all stakeholders has been increased in the target areas and beyond. Several products were produced that will continue to enhance this knowledge beyond the life of the project. Examples include:

(i) A baseline data that can be used in planning and promoting RWH activities in the target districts.

(ii) A compilation of training needs for those providing extension and support on RWH. This can be used by several organizations to develop training activities and materials.

(iii) Training and promotional materials, including eight booklets, more than 20 leaflets and three videos, which will continue to be used in improving knowledge and awareness on RWH systems.

(iv) The Parched-Thirst Model on rainwater harvesting has been further developed, mainly through another project R7949. Version 2.1 is now available and wider distribution to potential users, is in progress.

(v) Capacity building has been achieved through collaboration with researchers from DRD, extension staff of districts and NGOs, and farmers. Furthermore, training of trainers has been implemented for stakeholders in district authorities and NGOs, spread over 42 districts.

The baseline data shows that there is already a high level of adoption of *in-situ* RWH systems. The adoption of macro-catchment RWH systems, which are more complex by nature, was found to vary between 18% - 62% of the households. It was found that only about one quarter or fewer HHs practice macro-catchment systems with storage. In general, there is a substantial number of households practicing RWH systems. More importantly most schemes have been initiated, financed and developed by the farmers themselves, with minimal external assistance.

The findings from this study show that there has been a direct and correlated link between road drainage works and development of RWH systems in the study area. In most cases, a road infrastructure is also a RWH system, waiting to be exploited. Farmers in the study area have already shown that this is possible.

Furthermore, results from the economic analysis show that RWH enables farmers to grow high value crops such as maize, rice and vegetables in the semi-arid areas, where it is normally not possible to grow these crops. For example, growing onions enables farmers to realize a gross margin of more than 2 million TShs per hectare and return to labor of more than 11,000 TShs per person day. This is more than 10 times the prevailing wage for farm labor in the study areas.

Most of the OVIs at output level were attained and the project was able to influence policy and planning at national and district level. The government will now give priority to RWH within the Agricultural Sector Development Strategy (ASDS) approved in October 2001.

2. Background

2.1. Goal of the Project

The Poverty Reduction Strategy Paper (PRSP) approved by the Tanzania Government in October 2000 has identified agriculture as a priority poverty reduction sector (URT, 2000). The main reason for prioritizing agriculture in the strategy includes the facts that:

(i) Well over 80% of the poor live in rural areas and depend on agriculture for their livelihood;

(ii) More than 40% of the population is *food poor*, regularly facing inadequate food supply; and

(iii) Agriculture remains the single largest contributor to GDP and Foreign Exchange Earnings (FEE) in the country (World Bank and International Food Research Institute, 2000).

Despite being recognized as a priority poverty reduction sector, growth of the agriculture sector is reported to have been low (3% per year) in the last decade. Several factors have been identified as the root cause. One among these factors is the low availability of soil-moisture for crop and pasture growth. This is a consequence of poor management and ineffective utilization of rainwater, especially in the semi-arid areas that cover more than 50% of the country.

There are districts in the country where the long-term average rainfall is more than 1000 mm per season, yet crop production is very low. The main reason is failure to manage the distribution of the rainwater, so as to ensure adequate availability of soil-moisture throughout the growing period. When it rains in the semi-arid areas, runoff occurs very rapidly and if not captured the water flows as a flood wave to sinks, from where it is often not economical to recover it for beneficial use. Research has shown that only a small fraction of rainwater reaches and remains in the root zone, long enough to be useful to the crops. It is estimated that in many farming systems, more than 70% of the rain falling directly on a crop-field is *lost* as non-productive evaporation or flows into sinks before it can be used by plants. In extreme cases, only 4-9 % of rainwater is used for crop transpiration (Rockstrom *et al.,* 1998). Therefore, in rainfed agriculture, wastage of rainwater is a more common cause of low yields or complete crop failure than absolute shortage of cumulative seasonal rainfall.

In order to contribute knowledge for solving this problem, the project covered by this report was designed to contribute to the NRSP purpose stated as ***Benefits for Poor People in Target Countries Generated by Application of New Knowledge to Natural Resources Management in Semi-Arid Production Systems.*** The project was designed to address the NRSP output stated as **t*o develop and promote at catchment level, strategies, for improving the livelihoods of poor people through the integrated management of natural resources, including crops and livestock, and common pool resources*.**

Therefore, the objective of the project had the following components:

Goal Improved strategies for the integrated management of natural resources within catchments **developed** and **adopted** to reduce poverty.

Purpose: Productivity of water in rainfed agriculture, improved through accelerated uptake and intensive use of rainwater harvesting.

Outputs:

(i) Knowledge of the role and value of rainwater harvesting systems in semi-arid areas by all stakeholders, INCREASED.

(ii) Decision support system to assist planners, extension staff and others to plan, design and implement rainwater harvesting systems further DEVELOPED and VALIDATED.

To attain these outputs, the project implemented the activities listed in Chapter 9.

2.2. Addressed Constraints and Opportunities

For many years the issue of shortage of soil-moisture has been addressed in two contradictory approaches. First, there has been a misconception that droughts are caused by just shortage of rainfall. The pursued policies, strategies and programs therefore put a lot of emphasis, efforts and funds on drought-resistant crops. For example, the Tanzania Agricultural and Livestock Policy (TALP) approved in 1997, contained six policy statements on drought-resistant crops and none on soil moisture improvement and management (Hatibu *et al.,* 1999).

Second, there has been a notion that soil erosion is the major problem in the semi-arid areas. Many programs were therefore designed to control erosion by focusing on disposing runoff water that was considered as the enemy. There has been inadequate realization that in semi-arid areas, plants suffer more from water, rather than soil fertility constraints. A good example of how this thinking has dominated soil water conservation (SWC) strategies can be found in the premier SWC program in Tanzania, the *Hifadhi Ardhi Dodoma* (HADO) program. After more than 20 years (1973 – 1996) of implementation in Central Tanzania, it was realized that HADO had only a limited impact as a result of neglecting rainwater management (MTNRE/Sida, 1995). The program was criticized for focusing more on disposal of runoff water instead of managing rainwater and improving its productivity.

Farmers in semi-arid areas are aware that both crop and livestock production can be improved substantially through concentration of the scarce rainwater as well as provision of supplementary water during critical times. Critchley (1999) in a survey of farmers' innovations in semi-arid areas of Tanzania, Kenya and Uganda, found that innovations in RWH constituted 30% of the total innovations made by farmers. In general, innovations related to rainwater management were about 50% of the total.

2.3. Previous Research Work

Since 1991, the Faculty of Agriculture of Sokoine University of Agriculture has been implementing a research program on Soil-Water Management. The main purpose of the program is ***to develop, test and promote appropriate and socio-economically viable management interventions for optimizing the capture and utilization of rainfall in semi-arid areas of Tanzania***. Research and promotion of RWH technologies is one of the major projects being undertaken under the program. This program has been implemented through several projects, in various parts of Tanzania and in collaboration with various local and international partners. The projects included the following:

(a) Soil-Water Management in semi-arid areas, conducted in Dodoma, Central Tanzania (1991-1995) and funded by IDRC-Canada. The project was designed to "Investigate the means for improving the infiltration of water into the soil profile, reducing runoff and improving the efficiency of utilization of soil moisture by crops". The findings showed that crop production can be increased by a strategic combination of deep tillage, application of farmyard manure and tie-ridging (Mahoo *et al.,* 1999).

(b) The work in Dodoma was followed by a project designed to investigate effects of no primary tillage (NPT) on tied ridging. The project was conducted in 1996 – 1999 and was funded by NORAD. The objective of the project was to assess the performance and suitability of improving the NPT practice by introducing semi-permanent tied ridging thus making the practice a "No –Primary Tillage Tied Ridging [NPTTR]. The findings showed that the use of residual tie-ridges is a viable strategy for improving and stabilizing sorghum grain yields in semi-arid Central Tanzania (Rwehumbiza *et al.,* 2000).

(c) Evaluation and Promotion of Rainwater harvesting in Semi-Arid Areas. (Phase I and II). This project was implemented from 1992 to 1999 with DFID funding under NRSP (R 5170, R 5752 and R 6758) and implemented in collaboration with the University of Newcastle upon Tyne. The project, has been able to:

- Demonstrate viable cropping systems based upon rainwater harvesting techniques (TAJAS, 1999); and
- Develop a model of RWH processes as an aide to planning and design of RWH systems (Young *et al.,* 2001, Gowing *et al.,* 1999).

(d) Combining Systematic and Participatory Approaches for Developing and Promoting Strategies for Sustainable Land and Water Management. This was a three-year project (1996 – 1999) funded by the European Commission DGXII. The project was executed in collaboration with University of Newcastle upon Tyne (UK), Makerere University (Uganda), Katholieke Universiteit Leuven (Belgium) and Natural Resources Institute (UK). Results derived from this project included the following (Payton, 2000):

- A methodology for collecting geo-referenced indigenous knowledge about soils and land resources by interactive processes employing cognitive maps, farmer drawn maps and transect walks, linked to in-depth interviews, sorting tasks and focus group discussions.
- A methodology for transferring indigenous knowledge and scientific soil survey results to a GIS and relational database. It was found out that the GIS provided an effective forum for interdisciplinary comparison and analysis of scientific and indigenous soil surveys allowing natural and social scientists to collaborate in transparent and rigorous interrogation of dissimilar data sets. Both knowledge systems have strengths, and integration achieves better results.

(e) Another program that was taking place parallel to the Soil-Water Management Research Program (SWMRP), is the Land Management Program (LAMP) supported by Sida and implemented by several districts in Tanzania. Although this was a development program, it implemented some trials that showed very interesting results in relation to effective utilization of rainwater. The results showed that by using sub-soiling and ripping together with manure, maize yields can be increased by more than four-fold (Falkenmark *et al.,* 2001).

The few examples of previous work given above, together with farmers' experiences showed that there is a significant potential for improving agricultural production through better management of rainwater. One question remained, why was there still only a limited support for rainwater harvesting in policy, strategies and programs in the country?

2.4. Justification and Demand for the Project

A series of consultation workshops were conducted under the previous project (R 6758) to assess farmers' needs with regard to RWH uptake, and Extension Workers' requirements in meeting those needs. Also, several adoption studies were conducted to assess factors influencing or limiting the adoption of RWH. Results showed that inadequate knowledge at all levels was the most limiting factor (Senkondo *et al.,* 1999).

Further, a stakeholders' workshop held at the end of 1999 identified inadequate approaches, knowledge and awareness at all levels, as critical constraints to faster up-take of rainwater harvesting in Tanzania.

This project was therefore designed to generate and disseminate knowledge that can be used to improve the understanding of the role of rainwater harvesting by stakeholders at all levels, from farmers to policy markers. This was to be achieved by:

- Producing a baseline data of the extent, performance and profitability of RWH systems in the target areas of Maswa, Mwanga and Same Districts.
- Developing training materials and providing training and awareness raising to stakeholders at national and district levels.

3. Project Purpose

Purpose of the project was stated as *productivity of water in rainfed agriculture improved through accelerated uptake and intensive use of rainwater harvesting*. The project intended to increase awareness and knowledge of stakeholders on the role and benefits of rainwater harvesting. This was to be achieved through the promotion of findings from past research to stakeholders at different levels, from farmers to policy makers. It was expected that as a result of this project there will be an increased support for rainwater harvesting, in policy, strategies and programs. As a result, various stakeholders would take positive steps in the promotion and adoption of RWH systems, especially for agricultural production. These steps would involve the inclusion of RWH in the strategies, programs and funding by the government, district councils and NGOs.

4. Outputs

4.1. Extent and performance of RWH

Results from the baseline survey are presented and discussed in Annex A. The results show the following elements of the current extent of rainwater harvesting, in the study area:

a) A substantial number of households (HHs) are already using RWH systems especially for crop production. For example, the macro-catchment RWH system that includes the excavated bunded basins (*majaluba*) for rice production, is practiced by an estimated 28,000 HHs in Maswa District (Table 1a).

b) Rainwater harvesting is practiced for crop production and for domestic water supply by more than 60% of the households. Rainwater harvesting for livestock water needs is practiced by less than 40% of the households (Figure 1a).

c) *In-situ* RWH systems are predominant in the study areas. A good proportion of households in Maswa and Same Districts also practice at least one type of the macro-catchment systems (Figure 1b). Only about one quarter or fewer HHs practice macro-catchment systems with storage. It is interesting to note that the number of HHs using RWH for domestic and livestock water supply, is about three times those harvesting and storing water. This is a contradiction in the findings, which is not easy to explain. However, it is possible that some users do not own the charco dams or reservoirs, but access those owned by others.

d) From the survey data presented in Figure 1(b), it is estimated that current farm sizes treated with RWH range from 0.6 to 1 ha per HH. This is small and there is scope for expansion of area under RWH per HH.

e) It is difficult to estimate the number of livestock benefiting from RWH. This is because the true number of livestock owned are rarely revealed. However, rough estimates show that more than 24,000, 6,000 and 4,000 livestock units are benefiting from RWH in Maswa, Mwanga and Same districts, respectively.

f) Table 1(b) shows that most of those using macro-catchment RWH systems have adopted the technology since the 1990s. There has been a doubling in the adoption of most of the RWH techniques in the ten-year period between 1990 and 2000. Maswa district has seen the most rapid expansion in RWH especially in relation to excavated bunded basins (*majaluba*) for the production of paddy rice.

g) Performance of existing systems in relation to maize and rice production is summarized in Table 1(c). Maize yield in RWH systems is between 1.3 and 3.2 t/ha compared to the potential of 5 t/ha. The rice yields are currently 3.2 t/ha compared to a potential of 6 t/ha.

Table 1(a): Estimated number of HH practicing different categories of RWH

	Maswa	Same	Mwanga
In-situ	45,000	4,730	5,200
Macro Catchment	28,000	2,800	1,400
Macro Catchment with Storage	12,000	1,200	300
Roof top	1,800	750	2,400

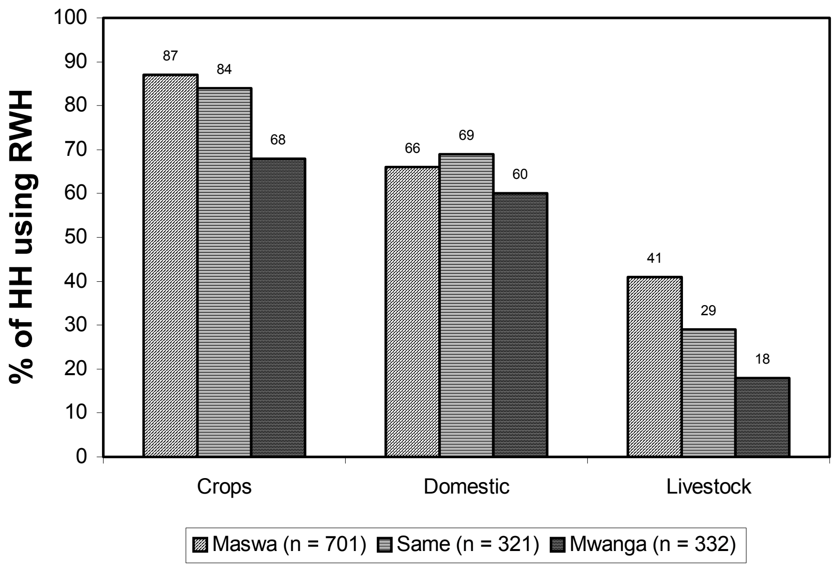

Figure 1(a). Purposes of RWH commonly practiced in the study areas

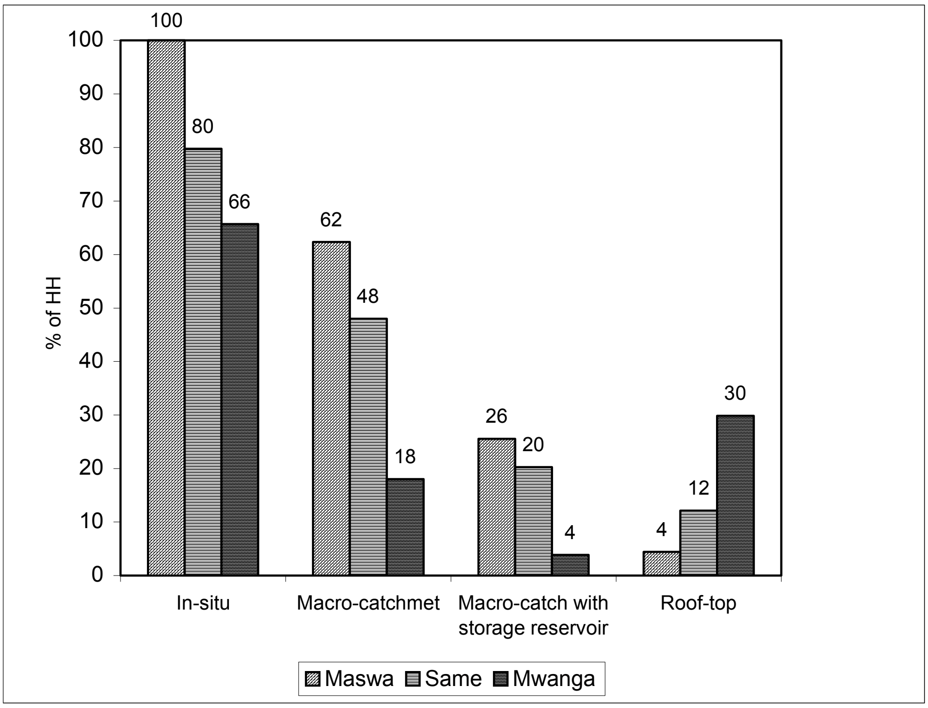

Figure 1(b). Extent of use of some form of RWH in the three study areas

Table 1(b): Indication by farmers of the time when macro-catchment RWH was first adopted and the extent of adoption

Period	% of Adoptions		
	Maswa	Same	Mwanga
2000/01	38	50	50
1990s	28	25	32
1980s	17	13	10
1970s	10	6	3
1960s	6	6	5

Table 1(c): Performance of existing RWH systems in relation to maize and rice production

RWH techniques	Yields kg/ha		
	Mwanga[1]	Same[1]	Maswa[2]
Large planting pits	1,512	2,484	N/A
Ridges and terraces	1,998	2,862	N/A
Diversion ditches	1,593	1,620	N/A
Diverting from rangelands	1,350	3,240	N/A
Diverting from ephemeral streams	1,350	2,970	N/A
Excavated bunded basins	N/A	N.A	3,228

[1] Maize yields [2] Paddy yields

The results summarized in this section indicate that the first steps towards effective management of rainwater have already been taken in the study areas. That is, the majority of farmers are already practicing *in-situ* systems on parts of their fields. They are therefore preventing runoff and promoting infiltration of the rain falling directly on their crop fields. This provides two major opportunities for improving the performance of the existing systems. First, the *in-situ* systems can be intensified through improvement of plant nutrient supply and use of improved inputs. For example, integration of manure into the system can effectively increase yields. Second, the fields in which *in-situ* RWH systems are already installed, are well prepared for effective exploitation of advanced RWH systems such as macro-catchment with or without storage. This is because the fields are already prepared for effective utilization of water. It can therefore be said that there is an ample opportunity for improving the productivity of RWH systems in the study areas.

4.2. Role of Road and Railway Infrastructure in RWH

Results of the study in this aspect are presented and discussed in Annex B. There is a clear indication that road and railway drainage works have facilitated the introduction of rainwater harvesting for crop production in WPLL to the following extent:

a) In the surveyed 144-km of highway, a high proportion (66-98%) of the 466 drainage works, have systems for run-off concentration (Table 2a). The concentration of run-off is achieved either by side drains or road protection bunds or a combination of both. This is an indication that drainage works facilitate the concentration of water and hence increase the potential for rainwater harvesting.

Table 2(a): Extent of run-off concentration by side-drains and bunds into culverts

Highway Section	Culverts Total	With Concentration System No.	With Concentration System %
Mpakani - Makanya	125	83	66
Makanya - Same	82	71	87
Same - Mwanga	161	158	98
Mwanga - Himo Bridge	98	67	68
Total	**466**	**379**	**81**

b) Table 2(b) shows that in most parts along the surveyed highway, more than 50% of the drainage works are being used to harvest water for crop production. The road section with low proportion (18%) of culverts being used for RWH was also found to have few (20%) side bunds for concentration of water. In general, the data show that the road infrastructure plays an important role in the introduction of rainwater harvesting systems.

c) The detailed study carried-out on three RWH 'schemes' shows that run-off concentrated by drainage works is used for relatively large "schemes". In two of the case study "schemes" more than 600 ha are "irrigated" using run-off from drainage works. In the Kifaru "scheme" the utilization is very intensive with a Cropped Basin Area Ratio (CBAR) of only 3:1 (Table 2(c)). The benefits obtained from these systems are discussed in section 4.3.

Table 2(b): Extent to which water concentrated into culverts is used for rainwater harvesting

Highway Section	Culvert with Concentration System Total	Culverts With RWH No	Culverts With RWH %
Mpakani - Makanya	83	55	66
Makanya - Same	71	13	18
Same - Mwanga	158	87	55
Mwanga - Himo Bridge	67	35	52
Total	379	200	53

Table 2(c): Land area benefiting from rainwater harvesting in the case study "schemes"

Case Study Scheme	Catchment Area (ha)	Cultivatable Area (ha) Current	Cultivatable Area (ha) Potential	Cultivatable Area (ha) Total	CBAR Current	CBAR Total
Kifaru	1,643	628	912	1,540	3:1	1:1
Kisangiro	4,979	148	979	1,127	34:1	4:1
Makanya	12,644	688	180	868	18:1	15:1

d) The findings from this study show that there has been a direct and correlated link between road drainage works and development of RWH systems in the study area. Evidence was also found, of establishment of settlements in areas where RWH has been made possible by the drainage works. In most cases, a road infrastructure is also a RWH system, waiting to be exploited. Farmers along the surveyed highway in WPLL have already shown that this is possible.

e) In summary it has been shown that:

- Road drainage structures have a substantial role in the introduction and use of RWH for agricultural production in the WPLL.

- The presence of culverts and bridges along the highway has facilitated the introduction of RWH in the WPLL.

- The runoff generated within the target area is not fully utilized due to various reasons. There is, therefore some scope for improvement and/or intensification.

- There is a need for nation-wide mapping of the potential for linking infrastructure to RWH, to ensure correct policy and strategic framework.

4.3. Economic Analysis of Costs and Benefits of RWH

A simple economic study and analysis was conducted in order to demonstrate the economic viability of RWH systems in Tanzania. Detailed description of the study and its results are given in Annex C. In summary, the findings indicated the following:

a) Rainwater harvesting improves Gross Margin (GM) as well as return to labor as shown in Table 3(a). The increase in GM and return to labor shows that there is an improvement in the means of livelihood, as a result of RWH. A maize farmer without RWH makes a loss of over TShs 50,000 per ha per season, and incurs a negative return to labor of 26 TShs per day. On the other hand, on average the GM is increased by nearly 175,000 TShs/ha as a result of RWH. The return to labor achieved with RWH is nearly four times the prevailing farm wages.

b) Under the maize system, the position of the farm is an important determinant of performance. Farms located at the head and middle of the system realized higher GMs than those at the tail end. This is an indication that either available water resources are not adequate, or there is inequity in the distribution of the harvested water. Water in these systems is a common pool resource (CPR) and is distributed from one farm to the next using crudely designed system of canals.

c) The difference between farmers at the head and those at tail end of the water system, was not significant in the rice system. The reason may be that the storage of water in *majaluba* helps to even out distribution of water, since even large flows can be captured. This is not the case with maize systems, where large flows must be allowed to drain to avoid water logging.

d) The relatively high GM and returns to labor obtained by onion farmers, show the tremendous benefit of RWH. Where markets are available, RWH enables farmers to switch to high value crops, with very significant improvement of incomes and thus livelihood.

e) Table 3(b) shows that maize production with RWH (using diversion canals) had positive Net Present Value (NPV), Benefit to Cost ratio (B : C) of greater than one and an Internal Rate of Return (IRR) of 57%. Similarly, paddy production with RWH had a positive NPV, B: C ratio greater than one and an IRR of 31%. The implications of these findings are:

(i) Rainwater harvesting for both maize and rice showed positive NPV, meaning they are profitable enterprises.

(ii) The cost to benefit ratio of greater than one means that the discounted benefits are greater than the discounted costs, implying that over the period (10 years) the enterprises give profit.

(iii) The IRR values are greater than the returns given by alternative use of funds, such as interest rate by the central bank, commercial banks (In Tanzania, this is about 10%). The RWH enterprises give IRR values far greater than 10% and also greater than average lending rate of 20%.

f) A more important message from these results is that none of the income enhancing enterprises is possible without RWH.

Table 3(a): Gross Margin Analysis of RWH

Enterprises	Position with respect to RWH system	With RWH		Without RWH	
		Gross Margin TShs / ha	Return to labor TShs/Man-day	Gross margin TShs/ha	Return to labor TShs/man-day
Maize	Head	126,496	3,997	NA	NA
	Middle	154,581	4,113	NA	NA
	Tail	51,854	2,556	NA	NA
	Overall	121,069	3,713	-53,197	-26
Paddy	N/A	136,814	868	NA	NA
Onion	N/A	2,204,017	11,057	NA	NA

Table 3(b): Cost-Benefit Analysis of RWH

Enterprise	NPV (10%)	NPV (20%)	B:C ratio	IRR (%)
Maize	379,669	202,460	1.6	57
Paddy	20,623	7,549	1.0	31
Onion	2,583,259	1,155,384	1.5	38

4.4. Training Needs for Those Disseminating RWH Technology

Inadequacy of knowledge and awareness on RWH has been identified as the most limiting factor to the wider uptake of the technology. The work reported in Annex D was therefore designed to assist in determining exactly what kind of knowledge was required. One of the most interesting findings, was the similarity of needs between the two target areas, as described in Chapters 3 and 4 of Annex D. The first major output has been the identification of training themes as described in Chapter 5 of Annex D. These are:

- Rainwater as a Resource.
- Rainwater Harvesting Methods and Techniques.
- Design and Construction of RWH Systems.
- Socio-Economic Aspects of RWH Systems.
- Ensuring Sustainability in RWH Projects.

The same Chapter 5 of Annex D provides a list and description of training materials (booklets, leaflets, videos and posters) required by trainers in order to facilitate training of end-users of RWH, such as farmers.

4.5. Development of Appropriate Training Materials

The process of developing the training materials is described fully in Chapter 6 of Annex D. The process was participatory and the most important outcomes have been the views of target users, on what aspects they would like to see contained in the training materials. The following have been accomplished:

(a) A comprehensive series of power point slides (over 400) for the five modules of the Training of Trainers (ToT) course (Annex E-1).

(b) Draft versions of eight booklets (Annex E-2), 21 leaflets (Annex E-3) and three 15-minute videos. The videos have already been distributed to the target users. However, the booklets and leaflets were made available only as handouts. At the moment they are undergoing technical review, before final printing. This is necessary for the purpose of ensuring quality.

4.6. Training and Awareness Raising

A total of three ToT courses, one professional development course, and two seminars have been implemented, reaching 224 trainers (Table 4). Unfortunately only 14% of the participants have been women although the invitation letter (Box 1, Annex F) specifically requested for a gender balance.

Table 4: Summary of implementation of training activities on RWH (2001)

No.	Description	Dates (*all in 2001*)	Location	Participants M	F	Total
1	1st PDC	23rd April – 18 May	Mpwapwa	15	1	16
2	1st ToT Course	30th April – 14 May	Mwanga	7	4	11
3	2nd ToT Course	30th July –10 Aug	Morogoro	37	7	44
4	3rd ToT Course	20th Aug – 30 Aug	Tabora	44	13	57
5	1st Seminar Lecture	9th Aug.	Morogoro	57	5	62
6	2nd Seminar Lecture	12th Sept.	Arusha	33	1	34
			Total	193	31	224

A total of 42 districts in the country were represented in the courses and seminars. This means that the training has reached more than 30% of the districts (120) in mainland Tanzania. The largest proportion (38%) of the participants was from the extension service. They identified their most important expectations as:

- Acquire knowledge in RWH (36%),
- Acquire training skills for RWH (28%), and
- Understand various RWH techniques (22%).

The evaluation of courses, by the participants, showed a high level of satisfaction. However, the main concern was that the two-week duration was not adequate. Also, participants strongly felt that practical exercises should have been included.

4.7. Review of the Performance of the Current Parched -Thirst Model

This work involved the running of one workshop with representatives of target users of the model as described in Annex F. Further, the model was introduced to an international group of users at the Statistical in Agricultural Climatology (SIAC) course held in Nairobi. The participants identified the following areas for improvement:

- Improvement of the file structure for input of weather data.
- Provision of capability to model different planting dates.
- Improvement of the output files to facilitate retrieval and processing by other software.

These ideas formed a basis for the short project R7949 that was designed to work on the identified weaknesses. The project has already been completed and the model is now ready for testing with users. The distribution was started in the first week of December with a demonstration at a regional workshop on RWH organised by RELMA. The workshop held in Lusaka brought together participants from Zambia, Tanzania, Kenya, Uganda, Ethiopia and Eritrea.

5. Research Activities

5.1. Survey and Field Work

Implementation of four of the activities (i.e. 1.1, 1.2, 1.3 and 1.4) described in section 9, required an elaborate data collection through social and physical surveys. The methods used are briefly described in this section.

5.1.1. Baseline data of current extent and performance of RWH

This involved the entire team but was lead by a core group composed of Dr. Evelyne Lazaro, Geoffrey Kajiru, two research associates (RA) at each target area and one RA at Morogoro. District Extension Staff were used as enumerators for the questionnaire survey. A three-stage survey was conducted using both participatory approaches and questionnaire interviews (see Chapter 2 of Annex A, for details). The work involved the following:

(i) Survey of key informants at village level – covering all the 37 villages in WPLL and all the 78 villages in Maswa District.

(ii) Survey of key informants at sub-village level – covering all the 147 sub-villages in WPLL.

(iii) Household survey using a structured questionnaire and covering random samples composed of 659 households (HHs) in WPLL and 701 HHs in Maswa.

The data were analyzed using SPSS computer program. The results were also used to quantify the opportunities for improving performance of existing RWH systems.

5.1.2. Role of road and rail infrastructure

This involved a detailed survey of the drainage works of the portion of Tanga –Arusha highway, falling within the WPLL (see Annex B for details). The team members involved in implementing this activity are Dr. Henry Mahoo and Dr. Siza Tumbo assisted by one RA and one technician in Remote Sensing/GIS. The work involved:

(i) Survey (using GPS) of drainage works for the entire length (144 km), including collection of attribute information characterizing each, and how the water is used downstream.

(ii) Detailed survey of a sample of drainage works to assess the extent of rainwater concentration and catchment areas.

(iii) Detailed assessment of three case study 'schemes' where water harvested from drainage works is used for supplementary irrigation in the production of maize. This included a questionnaire survey covering a random sample composed of 30 HHs on each "scheme".

(iv) Data processing involving conversion of GPS data using MSTAR, digitization of topo maps, and building the information into GIS.

5.1.3. Economic analysis of costs and benefits

This work is described in detail in Annex C. Dr Ephraim Senkondo and Mr. Peter Xavery led the work. One RA was also involved as well as field enumerators. The most important aspects of the study included the following:

(i) A case study approach was adopted. Makanya Village in WPLL was purposely selected to represent maize–based, and livestock-based systems. Bukangilija Village in Maswa represented rice-based system. A horticulture system was studied in Hedaru Village in the WPLL.

(ii) Thirty respondents were selected from each of the following categories of farmers:
- Maize Production with RWH,
- Maize Production without RWH,
- Rice Production with RWH,
- Onion Production with RWH, and
- RWH for livestock water supply.

(iii) Gross Margin and Investment (Benefit - Cost) analysis were the methods used to assess the economics of RWH systems. Whereas, the gross margin analysis was done using the with and without situations, the investment analysis was done using incremental costs and benefits, discounted at 10% and 20%.

5.2. Consultations on Training Needs and Production of Training Materials

In implementing activities 1.6 and 1.7 intensive consultations with the stakeholders, were carried out. This is described in full in Annex D, but in summary it involved the following stages:

(a) **Stage 1**: Participatory consultations with key stakeholders at district level in both WPLL and Maswa, on training needs.

(b) **Stage 2**: Further elaboration of training needs and target groups – during two three–day consultation meetings with stakeholders (from farmers to district officers), one for each target area.

(c) **Stage 3:** Participatory planning of training materials through a workshop attended by over 40 participants.

(d) **Stage 4:** Preparation and production of draft versions of training booklets, leaflets and videos.

(e) **Stage 5:** Preparation of Power Point presentation slides for all the training sessions and modules.

(f) **Stage 6**: Evaluation of draft manuscripts of the training materials by stakeholders. In this case, participants of the ToT courses critically commented on each of the draft, as well as the videos. Further, participants at other courses organized by the Ministry of Agriculture also evaluated the materials. These comments and ideas have been included in the final drafts of the manuscripts (Annex E-2 and E-3).

(g) **Stage** 7: Technical review of the manuscripts is now under way, before final printing.

5.3. Training and Awareness Raising

The training activities are described in detail in Annex F. In summary the training included:

- A Professional Development Course (PDC) for senior irrigation engineers in the Ministry of Agriculture. The course was requested and paid for by the Ministry under a project funded through a loan from IFAD, the *Participatory Irrigation Development Project* (PIDP).
- A ToT course requested by the Mwanga District Council.
- Two ToT courses for several districts and NGOs, which were advertised at national level. Interested districts and NGOs sponsored participants to either of the two courses.
- Seminar lectures given at two other courses, organized by other organizations.
- Study tour by farmers and extension staff from Ethiopia who visited Maswa District to learn about RWH for rice production. The visit was sponsored by Sida's RELMA.

Activity 1.9 (increasing awareness by policy makers) was implemented through a seminar for Members of Parliament on 21st- 23rd June, 2001 as part of a Science and Technology Exhibition and Seminar for Members of Parliament, organized by the Ministry of Science and

Technology. Furthermore, districts have written to request the SWMRG to give 3-hour seminars on RWH to the District Councilors and heads of departments. One such seminar has been implemented in Mwanga District. The next will be in Same District in mid-December and the 3rd will be implemented in February/March 2002.

5.4. Improvement of Parched-Thirst Model

For activity 2.1 and 2.2 (Review of PTv.2) the work done is described in Annex F. In summary the following was done:

(a) One workshop was organized on 26 – 28th February 2001. It brought together three of the model developers with 8 potential users. The purpose was to identify the major strengths and weaknesses of the model.

(b) A seminar was given for one week (17-24 June 2001) at the Statistics in Agricultural Climatology (SIAC) course held in Nairobi. Sixteen participants attended the seminar from 12 different African countries.

(c) Very valuable feedback obtained from the participants has been used in implementing the related project R 7949.

6. Contribution of Outputs

6.1. Summary of Outputs

As described in the previous sections of this report, the outputs of this project have been delivered in several ways. Knowledge of the role of rainwater harvesting among all stakeholders has been increased in the target areas and beyond. Several products were produced that will continue to enhance this knowledge beyond the life of the project. Examples include:

(i) A baseline data that can be used in planning and promoting RWH activities in the target districts.

(ii) A compilation of training needs for those providing extension and support on RWH. This can be used by several organizations to develop training activities and materials.

(iii) Training and promotional materials, including booklets, leaflets and videos that will continue to be used in improving knowledge and awareness on RWH systems.

(iv) The Parched-'Thirsty Model on rainwater harvesting has been further developed, mainly through another project R7949. Version 2.1 is now available and arrangements for wider distribution to potential users, have been completed.

6.2. Attainment of OVIs at Output Level

6.2.1. Inclusion of RWH in plans of districts and NGOs

The stated OVI was RWH is included in the Agricultural Development Plans of more than 30% of the target districts and NGOs, by May 2002. There is evidence that this has started to happen and the target is attainable. The following has already happened:

(i) The development plan approved in 2001 by Mwanga District Council, contains a substantial budget for RWH. The Agricultural Development Plan has 23% of the project budget (TShs 841,780,610) allocated to RWH and smallholder irrigation (Mwanga District Council, 2001).

(ii) Same Agriculture Improvement PROgramme (SAIPRO) Trust Fund (an NGO in Same District) has an approved program with 41% of project costs (TShs 66,745,240) in RWH and water management.

(iii) Mwanga Integrated Farming Improvement PROgramme (MIFIPRO) Trust Fund (an NGO in Mwanga District) has also finalized development of RWH program with a budget estimate of TShs 11 million.

(iv) The plan for developing the agricultural sector in Same District has also been drafted and it puts substantial emphasis on RWH and small-scale irrigation.

(v) Ministers and Members of Parliament are now discussing rainwater harvesting. In the last Parliament session, politicians, including the Prime Minister have emphasized the importance of rainwater harvesting strategy. One Member of Parliament attended the ToT course in Tabora, for a whole week.

6.2.2. RWH incorporated in SUA curricula by November 2001

This has been attained in full as follows:

(i) A B.Sc. Course was approved by SUA Senate during its 108th meeting held on 12th July 2001. The details are:
Title: AE 317 – Rainwater harvesting.
Credits: 1 credit; 15 lecture and 30 practical hours.

(ii) Faculty of Agriculture Board approved an M.Sc. Course on 26th July, 2001 and recommended it to SUA Senate. The details are:
Title: AE 605 - Rainwater harvesting and supplemental irrigation.
Credits: 1- credit; 20 lecture and 20 practical hours.

6.2.3. Training programs for farmers

The OVI was stated as one training programme for farmers fully paid for by the District Council and conducted by trainers trained by the project, implemented in all three target districts and at least one other district, by November 2001. This has not been implemented to the full yet. The progress is as follows:

a) By September 2001, the Mwanga District Council has implemented training courses on RWH for a total of 149 farmers.

b) The other districts and NGOs have not yet implemented courses, basically because the ToTs were implemented in August, 2001.

6.2.4. Increased investment in RWH

The OVI was stated as knowledge of benefits leads to increased investment in RWH through a development project in at least one target district, by November 2001. There has been good progress as follows:

(i) Soil-Water Management Research Group has signed a memorandum with Sida's RELMA for a small development project to assist livestock keepers in Makanya Village in the WPLL to improve their charco dams.

(ii) As indicated in Section 6.2.1, SAIPRO has obtained funds for a development project aimed at up-grading RWH in Same District.

6.3. Attainment of OVIs at Purpose Level

The purpose of the project was stated as "productivity of water in rainfed agriculture improved through accelerated uptake and intensive use of RWH". This was achieved by promoting RWH activities among stakeholders at different levels. There has been some good progress towards the development of strategies for RWH at national level.

As described in section 4.2.2 Annex F, Ministers and Members of Parliament are now discussing rainwater harvesting. In the last Parliament session, politicians, including the Prime Minister have emphasized the importance of RWH strategy.
Responding to the Members of Parliament who had raised many questions on RWH, the Prime Minister of Tanzania said:
Honourable Speaker, starting with the 2001/2002 financial year, the government will strengthen and promote the use of rainwater harvesting technology, in both urban and rural areas (URT Parliament Hansard Records for July 2nd , 2001). The minister responsible for water development elaborated on the strategy by saying:
Honourable Speaker, in order to ensure that RWH technology is widely used in rural areas, my ministry will work with District Councils to ensure that RWH is included in development plans of the councils. (URT Parliament Hansard Records for July 25th, 2001).

Further, the Tanzania Agricultural Development Strategy which was approved in October 2001, include specific strategy on RWH, which states that:
The Government in close collaboration and consultation with the private sector, will enhance the efficiency of water utilisation, especially rainwater, through the promotion of better management practices. This will be achieved by developing and implementing a comprehensive programme for integrating soil and water conservation, rainwater harvesting and storage, irrigation and drainage (URT, 2001).

At the local level, districts and NGOs have already started actions as already discussed in Section 6.2.1.

6.4. Contribution Towards NRSP Goal

The attainments at purpose and outputs levels described above indicate that initial steps towards contributing to the NRSP goal are in place. It is hoped that the strategies and plans being adopted and initiated at national and district levels, and by NGOs will lead to the following benefits to the target groups:

- Sustainable increase in the production of rice, maize, vegetables and livestock,
- Less variable production due to improved management of water, and
- Improved access by poor people to rainwater resources.

6.5. What Else Needs to be Done

As a result of this work, four areas for possible further work are being recommended. These are:

a) Development and Promotion of effective approaches to RWH, integrating water and plant nutrient issues at farm level.

b) Social-economic studies including:
   - Economic analysis.
   - Marketing issues.
   - Equitable distribution and management of water as a CPR.
   - Legal framework in relation to tenure and commercialization.

c) Promotion of DSS and supporting its wider use.

d) Effective approaches for scaling up to sub-basin levels.

These recommendations are formulated as a project proposal in the log frame shown in Appendix 1. In the following subsections, each of the recommended areas is elaborated and justified.

6.5.1. Effective ways of implementing appropriate, efficient and profitable RWH systems Developed and Adopted

Both national and local strategies and programs are aiming at increasing agricultural productivity. For example, the Agricultural Sector Development Strategy (ASDS) has set a target of an annual rate of growth of 5% by 2005. A budget of up to 30 million US$ is to be allocated to the improvement of management and utilization of land and water resources, in the first 5-years of ASDS implementation. The proposed research will therefore feed into the activities to be implemented under ASDS.

At district level, plans are being formulated to implement the ASDS. For example the Same District is developing a plan that has set a target of increasing maize yields from the current 1 ton per hectare to 4.5 tons per hectare, in five years (Same District Council, 2001). At the same time, results presented in Annex C, show that farmers who have adopted RWH at Makanya Village are already achieving an average, 2.5 tons per hectare of maize. This shows how RWH can contribute to meeting the district's targets. However, the productivity of RWH systems for maize requires further improvement. It is expected that further improvements to the effectiveness of using the harvested rainwater can contribute towards increasing the overall productivity.

The agricultural program of Maswa District Development Plan has its purpose stated as "facilitate the local community to increase crop and animal production per unit area and make them maximize economic returns in order to achieve food security and increased income". One of the outputs for achieving this is stated as "Rainwater harvesting area expanded and knowledge in the district has increased" (Maswa District Council, 2001).

These targets at national level justify further research to ensure that improved approaches to RWH are available to the planners, extension staff and farmers.

6.5.2. Socio-economics of RWH well Understood

The findings from the economic study described in section 4.3 and Annex C have shown that high value crops such as onions bring higher benefits from RWH. However, the effects of markets and marketing systems on the potential for successful enterprises in different areas are not well understood. The purpose of this study will therefore be to investigate in more details marketing potential and linkages and therefore assess economic potential for alternative enterprises for areas identified to have a RWH potential. A simple decision aide (DA) will be developed to assist Districts and NGOs in assessing alternative enterprises based on RWH systems.

6.5.3. Further Development and Promotion of PT and Supporting its wider use

The PTV2.1 is ready for use. The immediate need is a wider distribution and a help office to assist in a wider and intensive use of the model. This will exploit the following uptake pathways:

- Teaching of RWH courses now included in the curriculum of Sokoine University of Agriculture.
- Use by Soil-Water researchers at SUA and other institutions in Tanzania.
- Sida's RELMA Program and its supported network of RWH institutions and individuals in East and Central Africa.
- Soil-Water Management Research Network of ASARECA (SWMnet).
- Statistical in Agricultural Climatology (SIAC) course at the Institute of Meteorology Training and Research (IMTR), Nairobi.

Parallel with these, it is necessary to get feedback on the performance of the model and areas that require further development. However, some aspects for modification have already been identified as:

- Improvement of the modelling of macro-catchment and stream flow diversion systems,
- Improving the simulation of multi-crops in the same area, and
- Inclusion of simple economic assessment of alternatives.

6.5.4. Effective approaches for scaling-up RWH to sub-basin level, Developed and Adopted

Rainwater harvesting systems have been shown by this and other research work to be an effective technology for upgrading rainfed agriculture. However, the question of hydrological and environmental impact at watershed and catchment scales has not been well addressed. Research is therefore required on the inter-linkages at watershed scale between uses and users of rainwater. The focus for further work will be in assessing the technical, hydrological, environmental and socio-economic potential and impacts of up-scaling RWH systems to watershed scale.

6.5.5. Approach

From the experience gained it is being proposed that the recommended further work should be done in carefully selected model sub-catchments. Two are proposed, one for maize based system and another for the rice based system. The following criteria are being proposed for the selection of the 'model' sub-catchments:

(i) Location within a district where RWH development is among the priority strategies being pursued by District Authorities, NGOs and Private Individuals.

(ii) Where stakeholders have identified increasing scarcity and competition for water.

(iii) Where RWH systems are being used for several purposes, for example arable crops, horticulture and livestock enterprises.

(iv) Where there is RWH development project(s) going on. This is because stakeholders' participation in research is enhanced where they are assisted to implement the research results.

(v) The sub-catchment must be representative in-terms of characteristics of resources and rainwater management systems.

(vi) There is an identified potential for expansion or intensification of RWH systems.

(vii) Where there is good access to a potential market that is not being fully exploited due to water constraints.

7. Publications and other Communication Materials

7.1. Books and book chapters

Hatibu N., E.A. Lazaro, H.F. Mahoo and F.B.R. Rwehumbiza (In Press) Book Chapter: *Soil and Water Conservation in Semi-arid Tanzania: Government policy and farmers' practices*: in Barret *et al.,* (eds.) Natural Resources Management in African Agriculture. CABI Publishing, Wallingford

Rwehumbiza, F.B.R., H.F. Mahoo, N. Hatibu, E.A. Lazaro, and E.M. Senkondo (In Press) Book Chapter: Charco Ponds. RELMA Technical Handbook, RELMA, Nairobi

7.2. Journal articles

None

7.3. Institutional Report Series

None

7.4. Symposium, conference, workshop papers and posters

Mzirai, O.B., J.W. Gowing, N. Hatibu[1], F. B. Rwehumbiza and M.D.B Young *(2001) Investigating the Feasibility of Rainwater Harvesting (RWH) under Semi-arid Conditions: benefits of computer simulation in adding value to field experiments*. Poster Presentation at the 10th International Conference on Rainwater Catchment Systems, Mannheim Germany, 10 – 14 September 2001

Senkondo, E.M, A.S.K. Msangi, P. Xavery, E.A.Lazaro and N. Hatibu (2001) *Economic Analysis of Rainwater Harvesting Systems in Selected Semi-arid areas of Tanzania*. Poster Presentation at the 10th International Conference on Rainwater Catchment Systems, Mannheim Germany, 10 – 14 September 2001

7.5. Extension-oriented leaflets, brochures and posters

Booklets

- *Mbinu za uvunaji maji ya mvua*
- *Usanifu na maumbo*
- *Ujenzi wa malambo*
- *Ujenzi wa matenki*
- *Sera za nchi juu ya uvunaji maji ya mvua*
- *Sheria katika masuala ya uvunaji maji ya mvua*
- *Masuala ya jamii na uchumi*
- *Ushirikishwaji katika uvunaji maji ya mvua*

Leaflets

- *Maji ya mvua ni rasilimali*
- *Mbinu za uvunaji maji ya mvua – Ndani ya shamba*
- *Mbinu za uvunaji maji ya mvua – Kukinga na kuchepusha maji ya mtiririko*
- *Mbinu za uvunaji maji ya mvua – Maji ya nyumbani na mifugo*
- *Kutumia miundo mbinu na sehemu silizojengwa kuvuna maji ya mvua*
- *Kuchagua mbinu zinazofaa kuvuna maji ya mvua*
- *Usanifu na ujenzi*
- *Hatua-matuta ya ngoro*
- *Makinga maji na materasi*
- *Majaluba*
- *Kuta za mawe*
- *Mifereji ya kukusanya maji sehemu zenye vilima*
- *Mabanio ya kuchepusha*
- *Bwawa sehemu zenye miamba*
- *Mabwawa ya ardhini*
- *Lambo*
- *Sera*
- *Sheria*
- *Masuala ya jamii – kuzuia migongano*
- *Vikundi*
- *Masuala ya uchumu na fedha*

7.6. Media presentations

Three videos on RWH titled:

- *Mvua ni Rasilmali*
- *Mbinu za kuvuna maji ya mvua*
- *Masula ya kijamii na kiuchumi katika uvunaji maji ya mvua*

7.7. Reports and data records

7.7.1. Project web site, http:

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9. Project Logframe

Narrative Summary	Objectively Verifiable Indicators (OVI)	Means of Verification (MOV)	Important Assumptions
GOAL			
Livelihood Security in Rural Areas ENHANCED through Intensification of Agricultural Production			
Purpose			
Productivity of water in rainfed agriculture considerably improved through accelerated adoption of RWH			
Outputs			
1. Knowledge of the role of rainwater harvesting systems in semi-arid areas by all stakeholders, **INCREASED**	• RWH is included in agricultural development plans of more than 30% of target districts and NGOs' by May 2002 • RWH incorporated in SUA curricula by November 2001 • One training programme for farmers fully paid for by the District Council and conducted by trainers trained by the project, implemented in all three target districts and at least one other district by November 2001 • Knowledge of benefits leads to increased investment in RWH through a development project in at least one target district by November 2001	• Annual agricultural development plans produced in May each year • Published SUA curricula • Minutes of District Council meetings • Project memorandum between donor and implementing agency	Trainers have sufficient transport to reach farmers in target areas
2. Decision support systems to assist planners, extension staff and others to plan, design and implement rainwater-harvesting systems further **DEVELOPED** and **VALIDATED.**	• The paper based DSS is used by all target districts to plan RWH projects by 2004 • The E-DSS is used by researchers and trainers in MAFS and SUA to plan and implement RWH activities, by year 2001	• Orders to SUA for copies of the DSS and payment of a token fee • Numbers of orders for updated version of the DSS	

Activities:		
1.1 Produce baseline data of the current extent of rainwater harvesting (macro-catchments) within each farming system (West Pare Lowlands and Maswa District), including uptake over time. 1.2 Quantify opportunities for improving performance of existing systems, and for future expansion of rainwater harvesting in the same areas. 1.3 Describe, and quantify, role of road and rail infrastructures in facilitating introduction of rainwater harvesting systems. 1.4 Undertake (relatively simplistic) economic analysis of costs and benefits of rainwater harvesting systems (actual and potential) in each district, and assess the evidence for poverty alleviation. 1.5 Specify criteria for selection of 'model' sub-catchments (for phase 2). 1.6 Confirm the training needs of District Council extension staff, NGOs, and other agencies responsible for assisting farmers to implement rainwater harvesting systems in both areas. 1.7 Develop appropriate training materials (in Kiswahili) and disseminate within target districts. 1.8 Deliver 'training of trainers' courses in each target district. 1.9 Design and implement courses to increase the awareness by policy makers and others of the role of rainwater harvesting systems for agricultural production in semi-arid areas of Tanzania. 2.1 Review performance of current version of the Decision Support System (DSS) (computer model and paper version), for assessing where and when macro-catchment based rainwater harvesting systems are appropriate (a 'reality check'). 2.2 Identify modifications needed to improve the performance of the DSS.		

10. Keywords

Semi-arid. Rainwater harvesting, Tanzania, run-off, rice production in semi-arid areas.

11. Annexes

Eleven annexes available in separate volumes support this report. These are:

Annex **A**: Extent and Performance of RWH

Annex **B**: Role of Road and Rail Infrastructure in RWH

Annex **C**: Economic Analysis of RWH Systems

Annex **D**: Development of Training Programs and Materials

Annex **E-1**: Training Slides for the ToT Course

Annex **E-3**: Draft Extension Booklets on RWH

Annex **E-3**: Draft Extension Leaflets on RWH

Annex **F**: Training of Trainers and Awareness Raising

Annex **G**: Final Project Inventory

Appendix 1: Proposed Follow-Up Project

Narrative summary	Objectively verifiable indicators	Means of verification	Important assumptions
Goal			
SA Output 1 Strategies that can improve the livelihoods of the poor living in semi-arid areas through improved integrated management of natural resources under varying tenure systems developed and promoted	By 2002, livelihood strategies of poor individuals, households and communities and the nature of their dependence on the NR base, including the relative importance of access to common pool resources, in target areas in at least 2 target countries, understood By 2005, strategies for improving the livelihoods of poor people, by increasing the productivity of water in rainfed agriculture, through the use of appropriate rainwater harvesting and/or soil plant nutrient management practices, developed and promoted in target areas in at least two target countries By 2005, strategies that improve access to common pool resources by the poor under the most appropriate tenure and management regime identified, tested and promoted in at least one target area in each of 2 target countries	Reviews by programme manager Reports of research team and collaborating /target institutions	
Purpose			
Improved strategies for the integrated management of catchment NR that benefit the poor developed and promoted	By 2003, District Agricultural Development Programs (DADP) for implementing ASDS in at least two districts, contains a comprehensive component for integrated soil and water management.	DADP documents approved by District Councils	The ASDS is implemented as planned
Outputs			
1. Effective ways of implementing appropriate, efficient and profitable rainwater harvesting systems developed and adopted	• Productivity of maize (t/ha) in the model catchments increased from 2.5 to 4.0, by year 2004 • Productivity of rice (t/ha) in the model catchments increased from 2.5 to 4.0, by year 2004	• Baseline survey reports • Basic Agricultural statistics of MAFS	Stakeholders especially the poor are empowered and enabled to adopt and use strategies and/or approaches.
2. Socio-economics of RWH well Understood	Return to labor (TShs/pday) in real terms increased from 3,500 To 7,000, by year 2004	• HH Master Sample Surveys of the Bureau of Statistics	
3. Parched-Thirst Model widely Used and further Developed	• The model is used by at least three districts to plan RWH projects, by 2003 • The model is used for training in at least two universities within the ASARECA and SADC region, by 2002 • The model is used by researchers within SWMnet, by 2002	• Orders to SUA for copies of the model and payment of a token fee • Numbers of orders for updated version of the DSS	
4. Effective approaches for scaling up RWH to sub-basin levels, Developed and Adopted		DADP documents	
Activities			

For output 1:

1.1 Identify representative sub-catchments in which (macro-catchment) rainwater harvesting is practiced, one in each farming system (a) maize/beans (Western Pare Lowlands) and (b) rice (Maswa District).

1.2 Map each sub-catchment, including topography, land tenure, catchment (runoff) and cropped (runon) areas, water distribution networks, and soil physical and chemical properties.

1.3 Monitor water resources, runoff allocation, uniformity of application, and productivity of water (direct rain + runon) at farm level.

1.4 Identify and implement robust but flexible methods of floodwater control.

1.5 Investigate and implement opportunities for profitable intensification of crop production systems, within both sub-catchments.

1.6 Repeat processes outlined above in iterative and continuing ways to develop 'model' projects and thus determine productive potential of rainwater harvesting options.

For output 2:

2.1 Estimate the costs and benefits of each RWH system, and quantify risks.

2.2 Identify opportunities for improvements in security of water supply, and uniformity and equity of water distribution.

2.3 Describe and understand the role of social and human capital, including gender issues, in RWH practices.

2.4 Develop tools and a simple Decision Assist (linked to PT model) for assessing profitability of alternative RWH based enterprises or interventions.

For output 3:

3.1 Identify modifications needed to improve the performance of the PT model.

3.2 Develop the PT model further, and validate it within designated sub-catchments.

3.3 Use the PT model as a teaching aid in courses to train planners and others in rainwater harvesting (see above).

3.4 Use the PT model as a tool to a assist in the process of assessing future role of rainwater harvesting in semi-arid agriculture in Tanzania (‘scaling up’, see below)

For output 4:

4.1 Investigate the practicality of using air photographs and/or other remotely sensed images for determining the current extent and intensity of rainwater harvesting systems in each district, and the opportunities for further development.

4.2 Investigate rainfall partitioning within the model catchments and determine amount of rainwater available for harvesting.

4.3 Undertake a reconnaissance mapping of the potential for linking drainage works major highways and railways, to RWH in semi-arid areas.

4.4 Assess, understand and develop means to minimize the environmental impacts of rainwater harvesting systems, including the effects on down stream users of water.

4.5 Link the outputs to a GIS. This will include, for example, data on rainfall, soils (together with indigenous knowledge), slopes run-off, crop suitability, economic, social and environmental issues for assessing the potential for implementing successful and profitable rainwater harvesting systems elsewhere (scaling-up).

4.6 Link with researchers and others from elsewhere in the region (e.g. through ASARECA - Soil and Water Management Research Network (SWMnet)) to extend technologies even further.