Ministry of Agriculture and Food Security

University of Dar-Es-salaam

University of Nottingham

Soil-Water Management Research Group

NRSP PROJECT R8116 (b)
Benefits of RWH in Poverty Reduction in Tanzania

Reducing Poverty through Rainwater Harvesting: Evidence from the Semi-arid Areas of Maswa and Same Districts, Tanzania

SOIL WATER MANAGEMENT RESEARCH GROUP

October 2005

Tables of contents

List of Tables

List of Figures

List of Appendices

Abbreviations and Acronyms

A-average	Above average
ASDS	Agricultural Sector Development Strategy
B-average	Below average
GIS	Geographic Information System
GIS	Geographical Information System
GPS	Geographical Positioning Systems
Ha	Hectare
KSP	Knowledge Sharing Product
n	Number
NIMP	National Irrigation Master Plan
P	Probability
PPA	Participatory Poverty Assessment
PRSP	Poverty Reduction Strategy Paper
PSRP	Poverty Reduction Strategy Paper
RWH	Rainwater Harvesting
SWC	Soil Water Conservation
TShs	Tanzanian Shillings
URT	United Republic of Tanzania
US $	United States Dollar
WPLL	Western Pare Lowlands
%	Percent

Summary

The purpose of the project was to increase an understanding by relevant stakeholders, of the benefits of RWH in relation to poverty reduction. The project was designed with two outputs: 1) produce information on livelihood-related economics of RWH adoption, which is relevant to planners in the target districts, and 2) develop Knowledge Sharing Products to communicate results to target stakeholders. The first output was the centrepiece of the fieldwork which provided input to the second output. To deliver these outputs a study was conducted in two semi-arid watersheds in Maswa and Same Districts in Tanzania. Two comprehensive specific objectives proposed to guide the study, included: 1) to assess the livelihood and poverty dimensions in relation to gender, wealth, enterprise occupation, biophysical factors and typologies of rainwater management, and 2) to analyse the economics of RWH in the dryland agriculture as to reveal to development stakeholders (farmers, planners, and support agencies) if adoption and up-scaling of RWH can significantly contribute to poverty reduction. In pursuit of these specific objectives two hypotheses were developed, which are: 1) Rainwater harvesting reduces poverty, and 2) RWH reduces vulnerability (particularly of crop yield variability as a result of seasonality). Data that were analysed to test these hypotheses were collected from: 1) household questionnaire survey in Maswa and Same Districts, and 2) Yield monitoring exercise which involved actual measurement of yield from major RWH-based crops (paddy and maize). The findings show that:

- Prevalence of absolute poverty as depicted by per caput dollar expenditure was very high among households in the two project sites. In Maswa district, households in all four quartiles had a mean per caput expenditure of less than one US dollar. In Same district, only households in the upper forth quartile were found to have a mean per capita expenditure just equivalent to one US dollar
- RWH for crop production has demonstrated the potential for reducing poverty and vulnerability to the vagaries of weather in relation to intra-seasonal dry spells. The value of farm output and levels of returns to labour for RWH based crop enterprises is impressively above the national poverty and global poverty thresholds. This reveals a substantive contribution of RWH to the overall household income.
- Apparently, the yields of maize and cotton under *in-situ* RWH did not differ significantly from that realized under rainfed system in both above and below average seasons. In Same District, the yields and returns to land of maize under RWH with external catchment were significantly higher than those under rainfed and *in-situ* systems even during below average seasons. In Maswa District, paddy production under macro-catchment (with or without storage) and road drainage linked RWH systems performed better in terms of yield and returns to land and labour than micro-catchment systems. Similarly, vegetables under RWH with a reservoir provided higher returns to land though its returns to labour were reduced by its much higher labour input. Irrespective of seasonality, external catchment systems entailing micro-catchment, macro-catchment (with and without storage) and RWH linked with road drainage performed significantly better in terms of yields, returns to land and labour than rainfed and *in-situ* systems. Thus, external catchment RWH systems if further developed and efficiently managed would have much greater impact in reducing poverty and vulnerability. Socio-economic and ecological sustainability of these systems are vested in how robust and just the institutions of the State and that of the community are prepared for collective management with a watershed focus.
- The assessment of the economics of RWH for livestock enterprise shows that, the investment in RWH structures for providing water for animals particularly during dry periods did not result into higher financial returns per cattle head. This is because pastoralists who owned private RWH structures keep traditional cattle with low genetic potential in terms of milk yield or weight gain. In order for investment in RWH for livestock to have more benefits, improving productivity of traditional cattle breed is so imperative. However, field interaction with farmers who own private charco-dams had extra benefits beyond financial revenue targeted by the survey. Such benefits were mentioned to be utilization of reserved water for domestic purposes, watering of small home gardens and labour saving as temporal nomadic movement in search for water is now limited. Furthermore, permanent settling has improved children attendance to

schools especially boys who would otherwise move with livestock. However, to many farmers livestock is a form of a banking system for meeting fiscal obligations.

- Improvement of livelihood and subsequent poverty reduction requires similar emphasis to be accorded for non-farm activities in order to optimize the idle labour available during off-season. Broad-based approach to encourage enterprising in and beyond agriculture will assist in the flexible formation and movement of capital resources across a wider range of micro-investment opportunities.

1 INTRODUCTION

1.1 Background information

Nearly two thirds of Tanzania (939,701 km^2) can be described as semi-arid on the basis of having a probability of less than 25% of receiving 750 mm of rainfall per year (Bourn and Blench, 1999; Mascarenhas; 1995). The onset and duration of rainfall in semi-arid areas are inherently stochastic, and the probability of occurrence of acute dry spells during a growing period is high (Anschutz *et al*., 1997; Mahoo *et al*., 1999; Hatibu, 2000; Gowing *et al*., 1999; Kisanga, 2002). Such a situation makes farming in semi-arid areas a risky venture with the likelihood of production failure being so high (Hatibu *et al*., 1999; Rockstrom, 2000). Inadequate and extreme fluctuations in the amount of water available in the root-zone is a major constraint to productivity and profitability of agriculture making most poor women and men farmers remain at subsistence level and in perpetual poverty. Consequently, high risk of frequent failures of crop and livestock production limits financing of investments in the semi-arid areas. This condemns the majority of inhabitants of these areas to precarious survival without savings, credit, investments, infrastructure and trading links. To most development planners it seems irrational to invest for the poor in less favoured environment. As a result, semi-arid and other marginal areas harbour most of the poor in Africa, including Tanzania (Hatibu *et al*., 2004).

Studies have shown that, although shortage of rainfall is an important factor, the most critical problem in semi-arid areas is often the inter- and intra-seasonal variability (Barron *et al*., 2003). Thus, poor smallholder producers of crops and livestock in the semi-arid areas of Africa, face frequent food shortages and threats to their livelihood resulting from droughts or floods. The catastrophic consequences of inter-seasonal variation have recently (1999 – 2004) been experienced in Southern Africa, where many parts of the region have suffered from serious floods to serious drought and back to floods. A case study in Tanzania has shown that historically, floods have caused about 38% of all declared disasters, while droughts caused 33% (Hatibu and Mahoo, 2000). Sometimes the floods and droughts occurred in the same semi-arid area, and in the same season, and often only a small fraction of the rainwater reaches and remains in the soil long enough to be useful. Up to 80% of the rainfall falling on rain-fed farms in semi-arid areas can be “lost” as evaporation before it is used by the plants, or as runoff that causes erosion upstream and flooding downstream (Hatibu *et al*., 2004). Therefore, the detrimental consequences of both floods and droughts can be exacerbated by poor management of valuable rainwater. Virtually, public policies and interventions envisioned to reduce the extent of poverty in rural Africa should take the issue of water management for key sectors such as agriculture to be the development topic.

Since the mid 1990s, the Government of Tanzania has been implementing an intensive review and reform of its national policies and strategies in alignment to global agenda of poverty eradication. 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. In the semi-arid and sub-humid areas of Tanzania, where majority of the rural poor reside, agricultural production is sternly limited by shortage of soil-moisture as a result of droughts and erratic rainfall. Therefore, water resource management for different uses including agriculture is increasingly becoming a development issue that has attracted a significant policy attention in Tanzania and elsewhere in Africa (van Koppen, 2002).

In Tanzania, the Agricultural Sector Development Strategy (ASDS) published in 2001(URT, 2001) envisioned an agricultural sector that, by the year 2025 is modernized, commercial, highly productive and profitable, utilizes natural resources in an overall sustainable manner, and acts as an effective basis for inter-sector linkages. The ASDS identifies the need to enhance the efficiency of water utilization, especially rainwater, through the promotion of better management practices, by developing and implementing a comprehensive program for integrating soil and water conservation, rainwater harvesting and storage, irrigation, and drainage. Rainwater harvesting (RWH) is now accorded the highest priority by the authoritative political institutions and people in the governance machinery. Such situation sets out an enabling framework for public policy reforms and interventions for the development of RWH.

The National Water Policy recognizes the potential of RWH by stating that, "rainwater harvesting is a good source of water supply, especially in arid and semi-arid areas where it may prove to be the only reliable source of water in the dry season. The policy further states that, RWH will be promoted in rural areas (URT, 2002a). The Agricultural Sector Development Strategy (ASDS) also puts an emphasis on RWH and spells out that the Government is determined to enhance the efficiency of water utilization, especially rainwater, through promotion of better management. The major policy statement of the strategy is to develop a comprehensive programme that integrates soil and water conservation, RWH and storage, and irrigation and drainage (URT, 2001). Furthermore, RWH is given a considerable weight in the National Irrigation Master Plan (NIMP). The NIMP recognizes traditional RWH to be an effective practice for supplementary irrigation in marginal areas (NIMP, 2000).

Although RWH is given a high priority in sectoral policy documents, translation of such commitments into meaningful public investments requires an economic justification in terms of potential impact on poverty reduction. Much of the research done on rainwater management has been on the engineering and technology development both on station and on-farm rather than on the economics of it. Therefore, an empirical work that brings onboard the economic benefits of RWH to the poor is very pertinent for invigorating policy commitment and investments in improving rainwater harvesting and management in semi-arid rural areas.

1.2 Goal of the Project

Despite being recognized as a priority poverty reduction sector, growth of the agriculture sector is reported to have been low (4% for 2003) in the last decade (URT, 2003). Such a growth rate of the agriculture sector is not impressive compared to the population growth rate of 2.9% (URT, 2002b). Poor availability of moisture for plant growth has been identified as one root cause underlying poor production not only in dryland areas but also in areas known to have high amount of rainfall. 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 and harbour majority of the poor.

Although, rainwater management has recently been accorded appreciable recognition in public policy documents, we are yet to witness meaningful public investments in rainwater management projects targeting the resource-poor farmers in semi-arid areas. In view of the above, the project R8116(b) covered by this report was designed to contribute to better understanding of the economics and poverty reduction potential of RWH to smallholder farmers in semi-arid areas. Therefore, the Goal, Purpose and Outputs of the project are stated as follows:

Goal
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.*

Purpose
Understanding by relevant stakeholders, of the benefits of RWH in relation to poverty reduction, ***Improved*** and ***Enhanced***.

Outputs

i) Information on livelihood-related economics of RWH adoption, which is relevant to planners in the target districts, ***Produced***.
ii) Knowledge Sharing Products (KSPs) ***Developed*** and ***Used*** to communicate results.

In order to attain these outputs, the project implemented the activities listed in the project logframe in Appendix 1. With respect to the major purpose of the research project the development objectives were as follows:

1.3 Objectives and Hypotheses

The main objective was to provide empirical information that would improve the understanding by relevant development stakeholders of the benefits of RWH in relation to poverty reduction in semi-arid dryland areas

The specific objectives were the following

i) To assess the livelihood and poverty dimensions in relation to gender, wealth, enterprise occupation, biophysical factors and typologies of rainwater management in the study areas

ii) To analyze the economics of RWH in the dryland agriculture as to reveal to development stakeholders (farmers, planners, and support agencies) if adoption and up-scaling of RWH can significantly contribute to poverty reduction

Two pertinent hypotheses this study aimed to test in pursuit of its goal were:

i) RWH reduces poverty; and

ii) RWH reduces vulnerability to crop yield variability as a result of seasonality

2 METHODOLOGY

2.1 Study Areas, and Justification for their Selection

The research was conducted in two target sites, representing semi-arid areas of Tanzania. The locations were in Same District within the Western Pare Lowlands (WPLL) in North Eastern Tanzania, and Maswa District in Shinyanga Region, South of Lake Victoria (Fig. 1).

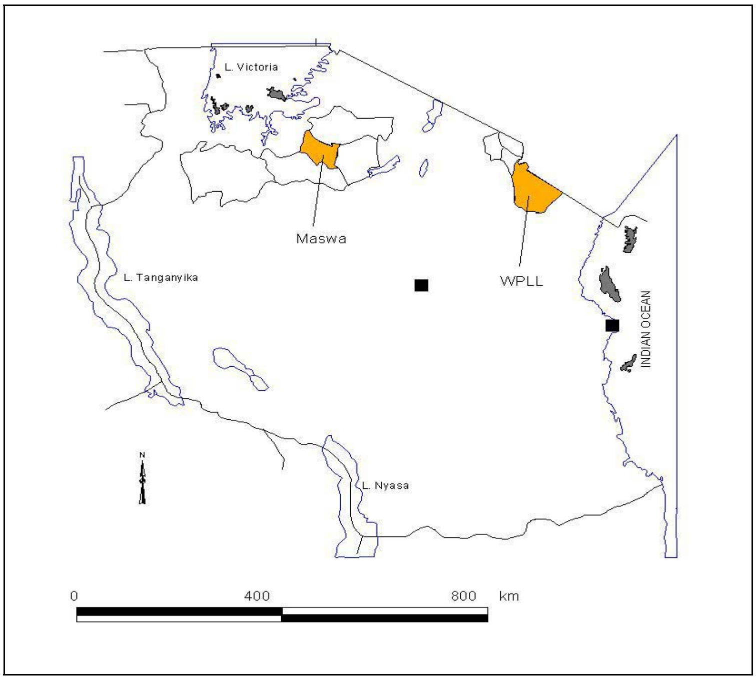


Figure 1: Map of Tanzania showing the study sites (Maswa and WPLL)

2.1.1 Same District

In Same District two major agro-ecological zones, namely the highlands and lowlands, characterize the study. The highlands which constitute the Pare Mountains are located to the South East of Mt. Kilimanjaro, between 600 and 2,424 m above mean sea level. The western side of the mountains constitutes the leeward side and thus receives low amount of rainfall. The extensive catchments of the steeply sloping mountains yield runoff that flows into the adjacent lowlands before joining the Pangani

River. It is important to mention that the study area is located in the Pangani River Basin. Small-scale farmers in the drier lowlands are innovatively utilizing the runoff generated from the mountain catchments for agriculture and other productive uses.

The Western Pare Lowlands (WPLL) have the following characteristics:

- They fall within the Maasai steppe agro-ecological zone, which is characterized by rolling plains with reddish sandy clay soils of relatively low fertility formed on basement complex rocks.
- Annual rainfall is in the range of 400 to 600 mm with bimodal pattern, with about 200 mm in *Vuli* (or the short rainy season) and 400 mm in *Masika* (or the long rainy season).
- Potential evapo-transpiration is over 2,000 mm per year.

The study was carried out in the following villages Tae (upstream), Mwembe (midstream) and Makanya (downstream). Farmers in the three villages are hydrologically linked by the runoff produced uphill (Tae and Mwembe) and flowing into the drier lowland plains where runoff farming is prominent. Topo-sequential alignment of study villages is presented in Figure 2.

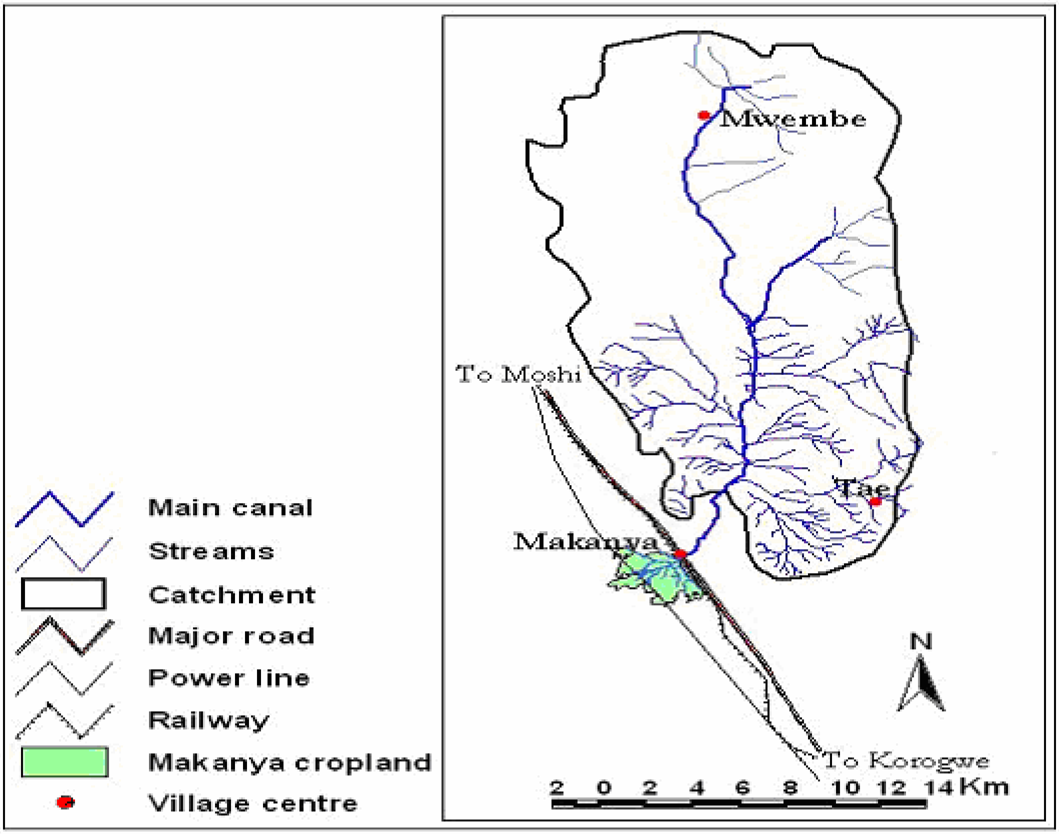


Figure 2: Map showing study villages in the WPLL

2.1.2 Maswa District

Maswa District falls within the extensive central semi-arid agro ecological zone, which is characterized by gently undulating plains with long slopes and wide valley bottoms. Annual rainfall ranges between 600 and 900 mm with a transitional regime. Availability of adequate soil-moisture for plant growth is a major constraint, mainly due to the occurrence of long dry-spells during the growing season. The land use pattern is linked to the recurrent topo-sequence of soils known as Sukumaland catena as first described by Milne (1936). Up to the 1980s, common crops grown were cotton and other drought resistant crops such as sorghum and millet. However, in recent years farmers' preferences have shifted in favour of maize and paddy rice as dual-purpose crops for both food and cash provision. Rice cropping system based on RWH techniques involving excavated bunded fields known as *majaluba*, is now a common component of the farming system.

There has been a major evolution associated with paddy and cotton enterprises in Maswa District in the recent past. Since the late 1980s the producer price and net returns from cotton have been unstable and declining in real terms. As a result, farmers have shifted resources, mainly the family labour to paddy enterprise. Such enterprise switching earmarks the rationality of small-scale farmers in the peasantry economy. Therefore, RWH-based paddy production is serving a dual purpose for being both a cash and food crop in the area. This means, efforts that aim at improving the performance of paddy will improve local food and income security as well. The study was conducted in three villages, namely Isulilo (upstream), Njiapanda (midstream) and Bukangilija (downstream) in a macro-catchment RWH system (Fig. 3).

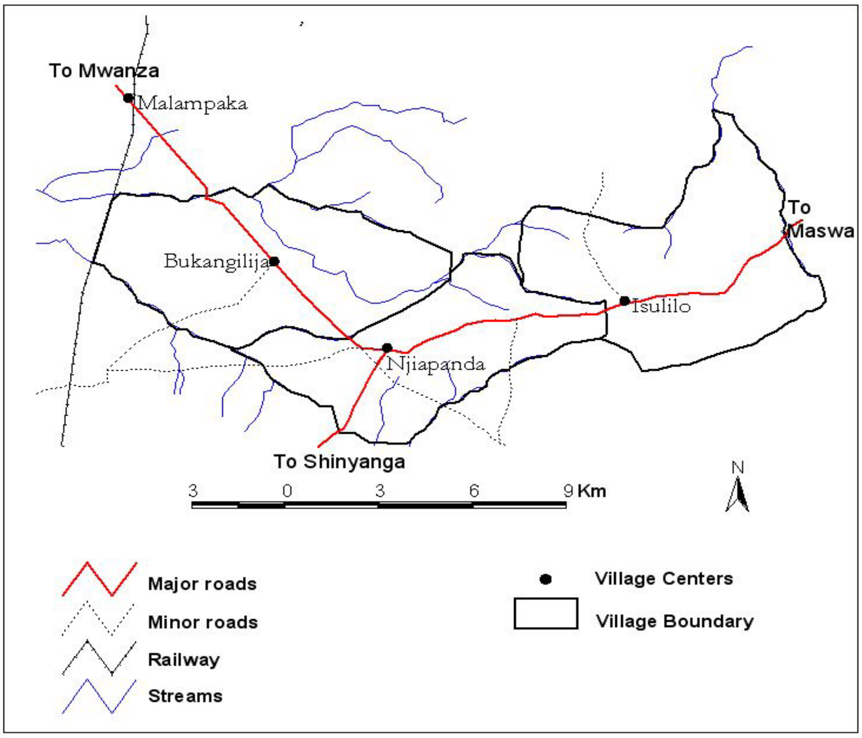


Figure 3: Map showing study villages in the Ndala river watershed (Maswa)

2.1.3 Justification for selection of the study areas

The WPLL and Maswa districts are typical semi-arid areas in Tanzania where farmer-based rainwater management practices are prominent. The two features of semi-aridity and prominence of smallholder rainwater management innovations justify selection of the study areas. Such features make results from a systematic study conducted in the two districts to be of wider application in the vast dryland areas of Tanzania, and possibly in other parts of tropical Africa.

2.1.4 Defining RWH options and their economic potential, and seasonality

The significance of RWH would be to smooth out the effect of seasonality which causes fluctuation of agricultural production. Smoothing out agriculture production variability reduces livelihood vulnerability associated with the odds of bad years mainly volatility crop yield. In this respect, the study underscores the concept of above average (A-average) and below average (B-average) years as a basis of RWH performance.

i) Definition of RWH systems

Definition of rainwater harvesting systems is broad and the nomenclature varies with factors such as location and cultural language, but in most cases the core of the concept remains similar. In case of this project, five typologies of rainwater harvesting and management were applicable and are briefly presented in the following sections.

a) In-situ rain capture systems

These are basically the common soil and water conservation (SWC) practices (Gowing *et al*., 1999). Capturing rainwater where it falls and storing it in the root zone is perhaps the most cost-effective means of increasing water availability for plants. For example, converting from ploughing to sub-soiling and ripping in parts of semi-arid Tanzania led to doubling of yields in A-average years (Johnsson, 1996). A-average years/seasons are those with good rainfall/runoff access - which is above long term mean, evenly spaced/well accessed in case of runoff throughout sensitive stages of plant growth and vice versa for below average (B-average) years/seasons. The study by Johnsson (1996) showed that it is possible to implement sub-soiling using animal powered ripper implements. Sub-soiling especially along the plant rows helps to increase the storage of water in the soil and thus reducing the rate of evaporative losses where vegetation cover is limited.

b) Micro-catchment RWH systems

These improve the in-situ approaches by adding provisions for supplying extra water from adjacent catchments. These systems normally exploit the natural concentration of rainwater and nutrients flowing into valley bottoms from the surrounding high grounds in the landscape.

c) Macro-catchment systems

Macro-catchment systems are technically similar to the previous micro-catchment systems. However, they are designed to provide more water for crop growth through the diversion of storm floods from gullies and ephemeral streams, into crop or pasture land. Large-scale systems involve diversion of storm floods from steep slopes by the construction of diversion and conveyance structures. In the study area, farmers are controlling large volumes of water using mainly earth structures. Macro-catchment RWH involving diversion of gully flows, road drainage, and sheet flows is crucial in supplementing localized water management practices such as in-situ and micro-catchment to mitigate soil moisture stress. One of the major advantages of this system is that, it utilizes the runoff generated relatively far from the cropped area even if no rain has fallen in the farm vicinity. However, the major challenge associated with this system is the need of a watershed/catchment-focused management approach of the runoff which is virtually utilized beyond micro-political territories such as village or wards, phenomenon which makes the runoff to be a common pool resource.

e) External catchment RWH (ex-situ)

This is a rainwater management system involving collection and concentration of runoff from the external catchments into the cropland. This system entails micro-catchment and macro-catchment typologies of rainwater management systems.

f) RWH with storage ponds

This is an improvement of both micro or macro systems by proving storage of water outside the crop field to allow for strategic supplementary irrigation. These have been adopted by only few farmers and are mainly used for the production of vegetables, livestock and domestic watering.

g) RWH linked to road drainage

This a system of rainwater management involving diversion and channelling of the runoff from road drainage structures such as culverts, bridges and roadside drains into the cropland.

ii) Economic potential of RWH

Many farmers in semi-arid areas of Tanzania through RWH, have changed from the cultivation of sorghum and millet, to paddy. There are now large areas treated with rainwater harvesting systems, in the semi-arid areas of central Tanzania, and the seasonally flooded black-cotton soils found in the central southern part, are all used for the production of paddy. The total combined area of these self-sustaining systems is thought to be of the order of several hundred thousand hectares, supporting about the same number of households. The systems account for over 70 % of the area cultivated with paddy and over 35% of the paddy produced in Tanzania (Meertens *et al*., 1999). In the semi-arid northern part of the country, farmers are successfully growing maize and other crops with high water requirements where it would not be possible without runoff harvesting (Lazaro, *et al*., 2000). RWH has enabled farmers to grow a marketable crop in dry areas, providing an opportunity for poverty reduction. They are an important means of livelihood for a large number of rural people.

iii) The concept of A-average and B-average in semi-arid context

Semi-arid areas experience seasons that we term "below average" or "above average" seasons. Below-average seasons have rainfall amount that is below the long-term mean and/or unevenly distributed within the season, while above-average seasons have rainfall above the long term mean and also more evenly distributed. If the seasonal rainfall is above average but unevenly distributed within a growing season to meet crop water requirement during critical growing stages, the season is still "B-average" because the yield is still affected as in case of "B-average" season (Hatibu *et al*., 2004). Rainwater harvesting has been used in many semi-arid areas to reduce water shortages particularly during B-average season. Virtually, the B-average seasons can be characterized by either seasonal drought or a series of dry spells. Recurrent famines in semi-arid areas are mostly associated with intermittent dry spells which hit during sensitive crop development stages such as grain filling (Mahoo *et al*., 1999). Better management of rainwater has the potential of smoothening dry spells. Ngana (1990) cited by *Mahoo et al*. 1999 observed the recurrence of prolonged dry period (B-average years) after every 2.5 years in a span of 5 years, that is twice in a every 5 years. However, in this study farmers were asked to rate the season whether it was bad (B-average) or good (A-average) not only in relation the amount or rainfall but also level of access to runoff. The results for seasonality analysis shows that farmers were not in 'the same boat' as a particular year was not similar to all respondent farmers (see Tables 10 & 25).

2.2 Data Collection process

Implementation of data collection was a multi-stage process. Specific activities undertaken included participatory poverty assessment (PPA), design of the questionnaire instrument, selection of respondents, implementation of the questionnaire survey and establishment of acreage correction factor. These activities are presented in the following sub-sections.

2.2.1 PPA exercise

PPA is an instrument for including the views of the stakeholders in the analysis and the formulation of the strategies to reduce poverty through public policy. PPA approach leads to increased understanding of the multi-dimensional nature of poverty and inclusion of the perspectives of poor people in poverty analysis. The approach underscores the reality that the poor people have the capacity and must be given a chance to analyze their situation and priorities. The PPA data/information that was collected through focus group discussions included the following:

a) Identification of broad socio-economic groups

Identification of broad socio-economic groups was implemented through a one-day workshop and focus group discussions in each of the target areas. Participants to these workshops were community development officers, divisional and ward leaders, village chairpersons and village opinion leaders. The workshop was conducted in plenary and group discussion sessions. The programmes were designed such that participants could build confidence and thus participate freely in giving out their opinions. The participants worked in groups of 5-6 members.

b) Developing criteria for assessing community wealth status

Fifteen meetings were held with representatives from different socio-economic groups at village level in each of the study areas. Focus group discussions were conducted in separate sessions involving participants from various categories of groups of the poor based on age (youth and elders), gender (male and female) and livelihood occupations (farmers, agro-pastoralists and pastoralists). These social groups were selected from villages along the toposequence. In the WPLL, Makanya village represents a run-off-receiving area (lowland) while Mwembe and Tae villages represent run-off-producing areas. In Maswa District, Isulilo, Njiapanda, and Bukangilija villages were selected. Individuals involved in the meetings were purposively selected based on their knowledge about the community. This was achieved with the collaboration of village leaders

c) Ranking the individuals into different wealth groups.
Participants were asked to propose criteria for assessing the wealth status in their respective socio-economic groups. The procedure involved introduction of the subject by the research team to which participants contributed ideas and agreed before writing down the criteria for determining wealth groups on a flip chart. These were then transferred onto flip charts and displayed for discussion. The criteria were then agreed upon by consensus. These included type of housing, livestock owned, land ownership, food security, business enterprises, clothes, remittance and farm implements. Non-material wealth ranking criteria such as power and social position were also in the consensus. Using the agreed criteria, attributes were defined for each of the wealth ranks. Workshop participants divided their respective social groups into three subjective wealth ranks: better off, middle and the poor.

2.2.2 Yield monitoring exercise

In both Maswa and WPLL, the yield monitoring exercise involved actual measurement of field sizes, collection of production costs and ascertaining typologies of rainwater harvesting for paddy, maize, and lablab production. The exercise was done for two seasons for the same farmers within the lifespan of the project in 2003 and 2004. Major RWH-based crop enterprises involved were paddy in Maswa district while in WPLL the enterprise mix involved sole maize, sole lablab and maize intercropped with lablab beans.

A sample of 30 farmers per village (three villages in Maswa and one in Same district) was randomly drawn from the village household roaster. In Maswa district, a sample of 90 farming households was proportionately drawn from upstream, midstream and downstream villages. In WPLL, 30 farming households in Makanya village were involved in the exercise. Selection of fields was randomly done in the beginning of every production season. The fields that a pilot farmer is determined to cultivate were listed and assigned numbers from which only one field was then chosen. The areas of the chosen fields were measured using GPS. RWH typology for each selected field was evaluated. In each village, yield measurements were taken by a research associate with assistance from a local field attendant and in the presence of respective pilot farmers. At the end of every week, the research associate visited all the pilot farmers to record the costs and labour input for that particular week.

During harvesting of paddy, a small block of 9 square meters in the selected field was harvested and yield measurements were recorded. In the case of maize and lablab beans, three plots of 30 square meters each were harvested and the yields were then sun-dried in order to attain moisture levels similar to those obtained by farmers. Local tests used by farmers when drying their grain were used. Such tests include easy of crushing or shelling for both paddy, maize and lablab beans and more of pale brownish colour for sun-dried paddy grains. Later on, using the laboratory moisture tester, it was verified that, all the samples had moisture content of 10 -12%, which is ideal under farmers' drying practices. Thereafter, the production costs and labour inputs for the selected fields and sun-dried weight from the small plots were extrapolated and reported as tons per hectare. In order to compute revenues, dry weights were multiplied by an average market unit price for a particular year (mean of prices immediate after harvest and that at the end of the season). The minimum and maximum producer prices were acquired by asking key informants in the village. The variable costs were taken together with yield measurements from the pilot farmers.

2.2.3 Questionnaire design

A structured questionnaire was designed to collect both qualitative and quantitative data from farming households in the study areas. The questionnaire instruments used for first and second round survey included open and pre-coded questions. The first version of the questionnaires was pre-tested in the field and appropriate adjustments were made before the final versions were produced. The key variables for which the questionnaires aimed to collect data on included socio-economic characteristics of households such as age, sex, health, education and occupation; farming information like acreage, crops grown, yield, information on livestock enterprise; and commodity prices, incomes and respective sources, consumption expenditure profiles and assets.

2.2.4 Selection of respondents

In Maswa district, the first round sample included a random set of 100 households in each of the three villages making an overall sample size of 300 respondents. This sample size is about 30% of all households in the three villages. Such sample size is adequate for a sample survey and is reliable to make statistical inferences about the population. In WPLL, the attained sample was 278 against the intended one of 300 households due to transport problems in the mountains whereby 22 households were not reached. However, according to the village registers, this is above 10% of the households in respective villages. During the second round survey, a sub-sample of 40 farmers for each village (40%) in the two study watersheds was used. However, three respondents in WPLL were not reached because of poor accessibility of these homesteads, which were located in the mountains. The structure of the second round survey sample is presented in Table 1.

Table 1: Structure of the households sample

Groups of poor/District	Downstream villages		Midstream villages		Upstream villages	
Maswa Disrict:	**Sample = 40**		**Sample = 40**		**Sample = 40**	
	n	%	n	%	n	%
Wealth category:						
Rich	1	3	3	7	-	-
Middle	16	40	26	65	10	25
Poor	23	57	11	28	30	75
Gender of head:						
Male	36	90	35	87	32	80
Female	4	10	5	13	8	20
RWH adoption status:						
Practice RWH	36	90	35	88	19	48
Do not practice	4	10	5	13	21	53
Same District:	**Sample = 41**		**Sample = 37**		**Sample = 39**	
Wealth category:						
Rich	7	17	4	11	-	-
Middle	20	49	13	35	35	90
Poor	14	34	20	54	4	10
Gender of head:						
Male	37	90	35	95	37	95
Female	4	10	2	5	2	5

2.2.5 Design and implementation of the survey

The second round survey aimed at addressing the conceptual and methodological pitfalls manifested in the first household survey, hence serving as an update of the first round survey. Therefore, the design of the second round involved the manageable sub-sample from the first round dataset in which every questionnaire was identified by an identity code showing the village and the household serial number. This approach made the second round survey so focused and reduced fatigue for both respondents and enumerators by spending less time in the questioning.

Specific targets of the second round survey were to obtain information, which would enable to elucidate the performance of crop enterprises under different options of rainwater management (yields, returns to land and labour) and economics of RWH for livestock sub-sector. Five enumerators were recruited and trained on the questionnaire before implementing in the field. During implementation of the questionnaire survey, which took twenty days for each site, two research associates were available fulltime in the field while two senior researchers were available only for the first week. For every workday the filled questionnaires were reviewed to check validity of entries, recording mistakes and clarification on non-responses. A few cases happened where enumerators were required to go back to the same household to rectify respective problems before the team moved to another study village.

2.2.6 Approaches to data analysis

i) Development of a correction factor for farmers' fields

Among the critical problems affecting the accuracy of yield estimation for smallholder farmers has been the challenge of getting the correct field sizes. This is because smallholder farmers do not practically measure their crop fields therefore their replies on acreage when asked by researchers or agricultural planners is a guess. For this study, in order to arrive at the best estimation of the acreage from farmers' recall, a special exercise was done to workout the correction factor (± actual value). This was undertaken by selecting one plot from a household and asking the farmer to give the size of the plot. Then, the plot was measured using GPS instrument and respective areas determined as polygons in GIS-ArcView. A regression model was estimated using STATA software to determine the coefficient that should be used as a factor to correct reported acreages in the vast survey sample. In WPLL and Maswa, the correction factors were -0.2 and –0.6 respectively. This means when a farmer says his/her plot is 1 acre the actual size is 0.8 and 0.4 acre for WPLL and Maswa respectively. The scatter plots of measured and cited acreages did not reveal a serious problem of outliers as indicated in Figures 27 (a & b) in Appendix 3.

ii) Adjustment of consumption to household composition and economies of scale

For comparative poverty studies based on expenditure or income measures centered on households as units of analysis need to adjust these households to their respective size and composition. The households were adjusted for both adult equivalents and scale economies to make them comparable. The published equivalence units were used to adjust the household size to which the consumption expenditure was expressed to reflect the per capita terms of welfare or poverty. The bottom line for adjusting the welfare to the composition and scale effect is that, it typically costs less to feed five children than five adults (composition effect) and doubling the size of the family does not imply doubling the amount of expenditure necessary to maintain living standards (scale effect). Adjustment of households to reflect composition and economies of scale involved a systematic procedure.

The dataset was explored to reveal all individuals in relation to their gender and age. Taking into account gender and age differences, each individual was adjusted to a respective adult equivalent scale. Then, the individuals adjusted to gender and age-weighted scales were summed to get the household size adjusted to composition to counteract what is termed as 'composition effect' in poverty analysis. This was done efficiently in SPSS software through a 'compute' command with flexibilities for use of 'if' scenario in the command syntax. Mathematical expressions are as follows:

$$H_i = \alpha_1 N_1 + \alpha_2 N_2 + \alpha_3 N_3 + ... + \alpha_n N_n$$

Where,

H_i = gender and age-weighted i^{th} household in the dataset/sample

$\alpha_{1...}\ \alpha_n$= relative weight given to individuals with respect to age and gender

$N_1 ... N_n$ = size of each type of components of household with equal sex and age range

The adult equivalent scales used are the ones mostly used in developing countries as found in Mkenda *et al.* (2004). These scales are shown in Table 2.

Table 2: Adult equivalent scales

Age	Adult Equivalent Scale		Household Size*	Economies of Scale
	Male	Female		
0 to 2	0.40		0 to 2	1.000
3 to 4	0.48		2 to 3	0.946
5 to 6	0.56		3 to 4	0.897
7 to 8	0.64		4 to 5	0.851
9 to 10	0.76		5 to 6	0.807
11 to 12	0.80	0.88	6 to 7	0.778
13 to 14	1.00	1.00	7 to 8	0.757
15 to 18	1.20	1.00	8 to 9	0.741
19 to 59	1.00	0.88	9 to 10	0.729
60+	0.88	0.72	10+	0.719

* Measured in number of age and gender-weighted, adult equivalent units.

Afterwards, the gender and age-weighted household size was adjusted to economies of scale. The mathematical expression for scale economies correction is as follows:

$$HE_i = (H_i)^{\psi}$$

Where,
HE_i = household size of i^{th} household in the dataset adjusted for both composition and scale effect
H_i = gender and age-weighted i^{th} household in the dataset/sample
ψ = scale economies within the household

Therefore, the expenditure per capita (indicator of welfare/poverty) adjusted to composition and scale effect is obtained through the following mathematical relation:

$$W_i = \frac{C_i}{(\alpha_1 N_1 + \alpha_2 N_2 + \alpha_3 N_3 + ... + \alpha_n N_n)^{\psi}}$$

Where,
W_i = adjusted welfare per capita of i^{th} household in the sample
C_i = aggregate consumption (value of own production, purchases of food and non-food, and transfers)

iii) Statistical tests of significance

Because most of the analyses undertaken were quantitative in nature testing for statistical significance amongst other statistics of enterprise performance parameters become a must. Comparative assessments evolved around contrasting the performance (yield, returns to land, and returns to labour) between A-average and B-average seasons, and different levels of rainwater management. Also, consumptive poverty figures were compared for statistical significance among different quartiles and adoption of rainwater management systems. However, the major challenge faced in pursuit of statistical tests was that, most of the categories to be compared did not allow for paired sample t-test, which would have been easy to undertake in standard software like SPSS. Instead another approach '**u**-test' suggested by Rayner (1967) that allow for unpaired sub-samples was widely used. Rayner (1967) suggested that, with two independent samples with varying sizes, one could test statistical significance between two means using a test statistic 'u' which is scaled on the tabulated value for eliciting the probability. Values of u give probabilities of exactly 0.05 and 0.01, i.e. $\mathbf{u}_{0.05}$ and $\mathbf{u}_{0\cdot01}$. If the value of u in the test is less than $\mathbf{u}_{0.05}$ the two means are not statistically significant, between $\mathbf{u}_{0.05}$ and $\mathbf{u}_{0.01}$ means are significant at 5% level. And when u statistic is greater than $\mathbf{u}_{0\cdot01}$ the two means are significant at the 1% level. For two-tail test, $\mathbf{u}_{0.05}$ and $\mathbf{u}_{0\cdot01}$ are equal to 1.96 and 2.58 tabular values. The basic equations are shown below:

Given that: $$\overline{X_1} - \overline{X_2} \approx N\left(0, \frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}\right)$$

$$u = \frac{(\overline{X_1} - \overline{X_2}) - 0}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}}$$

Where,
$\overline{X_1} and \overline{X_2}$ are two sample means for of n_1 and n_2; $\sigma_1^2 and \sigma_2^2$ are squares of respective standard deviations

2.3 Methods for data analysis

Descriptive and quantitative analyses were used on key variables such as household characteristics, absolute poverty and performance of RWH based agricultural enterprises. In these analyses numbers, means, ratios, frequencies, percentages and graphics were used to present analytical results. In principle the quantitative analyses are based on the data collected through the two round questionnaire survey and yield monitoring of RWH based major crop enterprises in the two study areas, that is Maswa and WPLL.

2.3.1 Characteristics of the respondent households

Insights into the characteristics of respondent households provide a better and elaborate understanding of the poverty dimensions and enrich interpretation of results from rigorous analyses. Assessment of characteristics of the respondent households was centered on analyzing the livelihood options with reference to subjective poverty, absolute poverty and gender of household heads. In analyzing the data for these variables, numbers, means, ratios, frequencies and percentages were used to present the analytical results.

2.3.2 Assessment of absolute poverty

The data for assessing absolute poverty were derived from the questionnaire survey and was based on expenditures data. Expenditures gave a better proxy for household income than simply income data from households. This is because respondents tend to understate/overstate income than expenditures. Expenditures for the households were listed in ascending order and were divided into four categories (quarterlies). The first and upper quartiles represent the poorest and the relatively richest households. This enabled the identification of respondents who live under or above the dollar poverty line in each quartile. This categorization was also used for further analysis representing different poverty groups in absolute terms. Because, the dollar poverty line is always too high for depicting the real poverty levels in the rural contexts in poor countries, a relative absolute poverty line constructed on 50% of the median expenditure was developed.

2.3.3 Economic performance of RWH-enterprises (crop and livestock)

The survey data was used to assess the performance of RWH for agricultural enterprises. For the case of livestock, sources of water for animals and revenues were assessed across wet and dry months in a year. Economic analyses for crop enterprises were based on respondents recall data and were supplemented by analyses based on actual yield monitoring for paddy and maize crop. Economic performance indicators used in both analyses included yield in tons per hectare, returns (gross margins) to land and family labor. Some theoretical considerations and the basic equations for computing the economic performance indicators are discussed in the following sections.

2.3.3.1 Yield (ton/hectare)

The physical productivity for a given crop enterprise refers to the total farm output per unit of land under a certain RWH system. The total farm output included the amount marketed, consumed at home and that was given out as social transfers. In production economics theory, the physical productivity reflects the level of technical efficiency where output is obtained from a given set of inputs. As opposed to allocative efficiency, technical efficiency refers only to the physical characteristics of the production process. In particular, measures of technical efficiency rely less heavily on the assumptions of perfectly competitive markets and the profit maximization objective. Though, productivity is not only a function of water (moisture) as it also depend on land quality and level of husbandry practices, it is a fact that in semi-arid areas water management remains to be a critical factor of production. Physical productivity is obtained by the following relationship:

$$P_{ijk} = \frac{1}{n}\sum_{i}^{n}\frac{O_{ijk}}{L_{ijk}}$$

Where,

P_{ijk}= average productivity by i^{th} farmer for j^{th} crop enterprise under j^{th} rainwater harvesting system (ton/ha),

O_{ijk} = output for i^{th} farmer from j^{th} crop enterprise under k^{th} rainwater harvesting system (ton)

L_{ijk} = acreage for i^{th} farmer for j^{th} crop enterprise k^{th} rainwater harvesting system (ha)

n= number of farmers involved in j^{th} crop enterprise under j^{th} RWH system ($i \ldots n$)

2.3.3.2 Returns to land (gross margins per hectare)

Economic evaluation of the performance of different techniques of rainwater harvesting varies between simple yield/productivity comparisons and more sophisticated risk analysis methods such as stochastic dominance analysis (Kunze, 2000). However, the highly sophisticated techniques are normally limited by data availability (Senkondo, *et al*., 2004). Gross margin analysis is static, and does not take into consideration the time value of money as compared to investment analysis. However, it is a useful tool, which can assist in improving the overall management as it addresses resource productivity in a given period of time. Further, in the study area, smallholder paddy growers use bunded basin structures, which are mainly constructed using family labour. Fox *et al*. (2000) reported the same fact, in rural Kenya, where family labour was the major capital input into the construction of small-scale water harvesting structures. These farmers also utilize rainwater from natural gullies and other public drainage structures such as roads and railways (investments that are already granted). The rural family labour has very low or zero opportunity cost (Fox *et al*., 2000). Labour being the major investment in smallholder RWH systems infrastructure makes gross margins an appropriate approach in analysing economics of rainwater harvesting. The basic equation for gross margins computation is presented as follows:

$$GM_{ijk} = \frac{1}{n}\sum_{i}^{n} P_{ijk}V_{ijk} - VC_{ijk}$$

Where,
GM_{ij} = Average gross margins earned by i^{th} farmer for j^{th} crop enterprise under j^{th} rainwater harvesting system (US \$),
P_{ij} = unit output price received by i^{th} farmer for j^{th} crop enterprise under j^{th} rainwater harvesting system (US \$),
V_{ij} = volume marketed/valued by i^{th} farmer for j^{th} crop enterprise under j^{th} rainwater harvesting system (tons),
VC_{ij} = total variable costs (that vary with level of output) incurred by i^{th} farmer for j^{th} crop enterprise under j^{th} rainwater harvesting system (US \$)
n= number of farmers involved in j^{th} crop enterprise under j^{th} rainwater harvesting system,

2.3.3.3 Returns to labour (gross margins per personday)

Valuation of rural family labour has been another area of economic debate. Many economic analyses of rural enterprises have focused on the use of official minimum wages and disregard the use of opportunity cost of unskilled labour. But, minimum wage usually over-estimate labour opportunity cost in rural areas (Senkondo *et al*., 2004). Some authors have suggested that family labour has an opportunity cost of zero while others like Kunze (2000) argue the opposite. Kunze (2000) argues that, even at high unemployment rates and even social activities, which often express social security involvement, require a rate above zero. Fox *et al.* (2000) suggested three scenarios of dealing with family labour in his paper on economic viability of water harvesting in rural Kenya and Burkina Faso. These are: full opportunity cost, alternative opportunity cost and zero opportunity cost. Full opportunity cost takes the value of labour to equal the daily labour wage. Alternative opportunity cost is the value of wage equivalent that someone has forgone for not being engaged in the alternative activities. Zero opportunity cost is when the family labour is considered zero which assumes that, due to unemployment, the alternative activity for labour is idle.

In this study, the family labour was retained as person-days and not valued in monetary terms. One person-day is considered to be equal to one adult (aged 18 years and above) working manually in the farm for 8 full hours. RWH structures are either long-term community or natural investments such as community reservoirs and natural gullies. Maintenance of these systems is done collectively some few weeks before the season sets in. In this study labour engaged in collective works was not included in the analysis as it was complex to work it out and attribute it to the output from individuals' fields. Therefore, zero opportunity cost was assumed to collective labour. However, labour in maintaining structures within one's cropland (e.g. field canals) was captured under the input in farm preparations. In order to get returns to labour, the gross margins were expressed in per person-days of family workforce employed in different farm operations.

3 RESULTS AND DISCUSSION

3.1 Household livelihood options

In the study sites the livelihood is enhanced from different sources. Major sources were crop production, livestock keeping and off-farm activities. Table 3 shows livelihood options and level of dependence on each option. In Maswa, the rich were equally dependent on livestock (50%) and crop enterprises (50%) as sources of livelihood. The livestock sub-sector as a major source of livelihood is replaced by crop as you move from middle (14% versus 72%) to poor (14% versus 75%) wealth groups. In Same district, crop enterprise is the most important source of livelihood for different wealth groups followed by livestock. Apparently, in both districts households in middle and poor categories tend to have a diversified livelihood options compared to the relatively rich households.

Table 3: Major livelihood options by subjective poverty in Maswa and WPLL

Livelihood options	**Subjective wealth categories (%)**					
	Maswa			**WPLL**		
	Rich (n=4)	**Middle (n=52)**	**Poor (n=64)**	**Rich (n=11)**	**Middle (n=67)**	**Poor (n=37)**
Crop production	50	72	75	46	46	54
Live stock keeping	50	14	14	27	22	30
Employment	-	6	2	9	3	-
Petty business	-	6	6	9	12	3
Artisan works	-	2	3	-	17	10
Traditional healing	-	-	-	9	-	3
Total	100	100	100	100	100	100

Results in Table 4 show that, in both Maswa and Same districts, crop production is the source of livelihood for all four poverty quartiles. For the case of Maswa, artisanal works appear to be the source of livelihood for majority of households in lower quartile (67%) as compared to other quartiles. The artisan works referred to here include masonry, carpentry, weaving and bicycle repairing.

Table 4: Livelihood options by absolute dollar poverty quartiles in Maswa and WPLL

Study site	**Absolute expenditure poverty levels**			
	Lower quartile (%)	**Second quartile (%)**	**Third quartile (%)**	**Upper quartile (%)**
Maswa:				
Crop production (n=87)	25	30	25	20
Livestock keeping (n=18)	28	11	33	28
Employment (n=4)	0	0	0	100
Petty business (n=7)	14	14	29	43
Artisan works (n=3)	67	33	0	0
WPLL:				
Crop production (n=56)	30	25	25	20
Livestock keeping (n=28)	10	32	29	29
Employment (n=3)	33	33	0	34
Petty business (n=10)	10	10	50	30
Artisan works (n=14)	50	29	7	14

Results on livelihood sources by gender in Table 5 reveal that, in both Maswa and Same districts, most of the female-headed households (90% and 63% respectively) were dependent on crop enterprises for their livelihoods compared to their counterpart male-headed households who were dependent on livestock (17% and 24% respectively). However, the extent of livelihood diversification was higher among males than females. Diversification was in salaried employment, petty business, and artisan works. Limited livelihood options for female-headed households and over-dependence on crop production, which is critically affected by the vagaries of weather, increase vulnerability of such households. This means, female-headed households are more at risk of vulnerability to poverty and shocks due to low level of diversification compared to male-headed households. Therefore, poverty reduction efforts targeting poor female households should aim at increasing their capacity to diversify their sources of livelihoods and improve the performance of crop enterprise by addressing critical constraints of soil moisture shortage and lack of linkage to profitable crop markets.

Table 5: Major livelihood options by gender of household head in Maswa and WPLL (%)

Livelihood options	Maswa		WPLL	
	Male (n=100)	Female (n=20)	Male (n=107)	Female (n=8)
Crop production	70	90	48	63
Live stock keeping	17	5	24	37
Employment	3	5	3	-
Petty business	7	-	9	-
Artisan works	3	-	12	-

3.2 Absolute dollar poverty and subjective poverty

Due to broadness and multi-factorial nature of poverty, its assessment is not an easy to do task. Along this line of argument, poverty assessment has been evolving around using physical, financial and social indicators. In this study two poverty lines used include the dollar poverty line and the relative absolute poverty line determined at 50% of the median expenditure per capita. The dollar poverty line asserts that a person living on less than 1 USD per day (about 365 USD per year) is said to be living in abject or extreme poverty. The official government poverty line of 73, 877 based on 1995 prices (World Bank, 1996) could have been also used in this analysis. However, it was felt that this poverty line requires revision to reflect actual/real Tshs exchange rate prevailing at the moment. Under this section the sample households are scaled on two definitions of poverty to note lines of departure and inform efforts on poverty reduction.

Results in Table 6 show that, in Maswa district, none of those rated non-poor by the society, that is, rich and middle, were actually non-poor under generic definition of poverty. Whereas, those rated poor by the society, 11% of them were actually non-poor under generic definition of poverty. In WPLL, results of society poverty rating were consistent to dollar poverty as relatively less of rich people (70%) were below the dollar poverty line than the middle (78%) and poor (87%) who were below the poverty line. In Maswa, the median expenditure poverty line grouped all 100% better-off households in the society as non-poor. In both Maswa and WPLL, the 50% median expenditure poverty line tends to indicate minimum prevalence of consumption poverty, as over 80% for the rich , middle and non-poor were found non-poor.

Table 6: Comparison of absolute expenditure poverty and subjective poverty (%)

Location/wealth	Above dollar poverty	Below dollar poverty	Above 50% median poverty	Below 50% median poverty
Maswa:				
Rich (n=4)	0	100	100	0
Middle (n=51)	4	96	92	8
Poor (n=64)	11	89	81	19
WPLL:				
Rich (n=10)	30	70	90	10
Middle (n=67)	22	78	91	9
Poor (n=38)	13	87	87	13

Levels of per capita dollar expenditure across different quartiles are presented in Table 7. The results show that, in Maswa all four quartiles had a mean per capita expenditure of less than a dollar a day (less than US $ 365 per year). The richer quartile realized expenditure per capita, which is 11 points less than the dollar poverty threshold. In WPLL, at least households in the upper quartile are out of poverty by having a mean per capita expenditure of US $ 553 per year. Difference in the level of poverty between Maswa and Same districts could be related to improved access to urban demand markets and other trading opportunities. Farmers in WPLL have good access to Dar es Salaam – Nairobi tarmac road while Maswa District is in the remote area. Apparently, the standard deviations for the upper better-off quartile is larger compared to the lower quarterlies. This suggests higher inequality amongst the relatively rich in the society than amongst the relatively poor.

Table 7: Poverty levels (US$/person/per year) for expenditure quartiles in Maswa and WPLL

Site/ quartiles	Descriptive statistics (US$/person/year)					
	N	**Mean**	**St error**	**St deviation**	**Skewness**	**Kurtosis**
Maswa:						
Lower quartile	30	58	2.9	16	-1.1	0.8
Second quartile	30	104	2.2	12	0.5	-0.5
Third quartile	30	163	4.0	22	0.5	-0.9
Upper quartile	29	354	31.7	171	2.0	4.4
WPLL:						
Lower quartile	29	111	7.1	38	-0.6	-0.3
Second quartile	29	190	2.6	14	-0.6	-0.4
Third quartile	29	277	6.8	37	-0.4	-1.1
Upper quartile	28	553	84.9	449	4.4	21.5

3.3 Impact of RWH on poverty reduction - double difference approach

In assessing the impact of RWH on household poverty reduction three scenarios were considered. These include before and after, performance on enterprise with and without, and farmers with and without RWH as presented below:

i) Before and after adoption of rainwater harvesting

Under this scenario the welfare/poverty level of the same household is monitored before adopting rainwater harvesting and after adoption. This approach is limited by lack of baseline data on the extent of poverty/welfare of the household before adoption of RWH on which the level of poverty/welfare can be scaled after adoption. Another limitation is the difficulty of explicitly dissociating the impact of RWH from other livelihood sources. Mainly, due to lack of baseline data on poverty/welfare this approach was not possible for the project

ii) Enterprise performance under with and without RWH

Under this scenario the same enterprises under rainfed and with different rainwater harvesting systems are compared in terms of performance. This approach has been used in this project and details are presented in the coming sections of this report.

iii) Households practicing RWH and counterparts who do not (with and without situation)

This approach requires the project to have a set of households that are similar or very close in terms of absolute poverty levels but only differ in practicing RWH. This is possible although requires redefinition of RWH. RWH for crop production is very inclusive. It includes runoff farming that involves external catchment and conventional soil & water management techniques such as deep tillage, ridging, pitting and other water management techniques within crop fields (*in-situ* RWH). RWH with external catchment (micro and macro-catchment) is what makes a difference in terms of 'with' and 'without' situation. Within field RWH (*in-situ*) does not distinguish households under 'with' and 'without' perspective, because almost every farmer has practiced it in his/her farming history. However, empirical evidence shows that, not necessarily that *in-situ* RWH practices are inferior to RWH with external catchment with or without reservoir. During A-average season the likelihood of runoff generation is high and RWH with external catchment may perform better than *in-situ* alone by concentrating distant runoff into the cropland even when it is not raining in the vicinity. However, during B-average season where the external catchment can hardly yield adequate runoff into the cropland, *in-situ* water harvesting systems may perform better by capturing the direct rain and optimize availability of soil moisture for plant growth.

Nevertheless, macro-catchment RWH involving diversion of gully flows, road drainage, and sheet flows is crucial in supplementing *in-situ* water management practices to mitigate soil moisture stress in semi-arid farming systems. As a result, the study used macro-catchment RWH to ascertain 'with' and 'without'

RWH situation (Tables 8 & 9). In both sites, absolute poverty levels were assessed for four quartiles under two scenarios of with macro-catchment and without macro-catchment RWH. The basic assumption that has enabled cross-comparison is that, households in the same quartile are more or less under the same level of poverty; therefore macro-catchment RWH is what makes a difference.

Results in Table 8 show that, in Maswa, farming households in the three lower quartiles with macro-catchment RWH had annual mean per capita dollar expenditure significantly ($P < 0.01$) exceeding their counterparts i.e. without macro-catchment RWH. This means, macro-catchment RWH has a great potential for reducing poverty among the relatively absolute poorer who occupy the lower quartiles. The pattern is reversed in the upper quartiles with those without being less poor compared to those with macro-catchment RWH. Such difference may be attributed to less dependence on crop production by the relatively rich households whose expendable incomes could be coming from other off-farm activities such as petty business and livestock. Apparently, the standard deviations reflect much high level of inequity for households in the upper than in lower quartiles. It can be said that improving macro-catchment RWH and integrating it with best practices of rainwater management in the fields can help the relatively absolute poorer to move out of poverty.

Table 8: Poverty level under with and without Macrocatchment RWH (Maswa)

Site/ quartiles	**Descriptive statistics (US$/person/year)**					
	N	**Mean**	**St error**	**St deviation**	**Skewness**	**Kurtosis**
With macro-catchment RWH:						
Lower quartile	24	60	2.8	14	-0.9	0.1
Second quartile	26	105	2.4	12	0.4	-0.5
Third quartile	22	166	4.3	20	0.6	-0.7
Upper quartile	17	323	40.5	167	3.2	11.6
Without macro-catchment RWH:						
Lower quartile	6	49	9.0	22	-1.0	-0.1
Second quartile	4	94	4.2	8	1.6	2.9
Third quartile	8	154	9.0	26	1.2	-0.3
Upper quartile	12	397	50.0	173	1.1	0.8

Test results for dollar per capita expenditure (US $ per hectare) were as follows:

Poverty comparison in the lower quartiles: $u = 2.9$ (sign. at $P < 0.01$)

Poverty comparison in the second quartiles: $u = 4.9$ (sign. at $P < 0.01$

Poverty comparison in the third quartiles: $u = 3.7$ (sign. at $P < 0.01$

Poverty comparison in the fourth quartiles: $u = 4.2$ (sign. at $P < 0.01$

Table 9 shows that, non-practitioners of macro-catchment RWH in the lower quartile had a mean per capita expenditure per year exceeded that of their counterpart practitioners, but the difference was not statistically significant ($P < 0.05$). Practitioners in the second and third quartiles had the mean per capita expenditure significantly ($P < 0.01$) exceeding that of non-practitioners of macro-catchment RWH. Expenditure per capita per year for non-practitioners of macro-catchment RWH in the upper better-off quartile was significantly ($P < 0.01$) higher than the same quartile of practitioners. In WPLL, most of the rich people have more access to runoff due to location advantage relative to the source and their power in the society (Msangi *et al.*, 2005). The level of standard deviations indicates higher inequity among households in the upper quartile than in the lower three quartiles.

Table 9: Poverty level under with and without Macrocatchment RWH (WPLL)

Site/ quartiles	**Descriptive statistics (US$/person/year)**					
	N	**Mean**	**St error**	**St deviation**	**Skewness**	**Kurtosis**
With macro-catchment RWH:						
Lower quartile	19	108	8.4	36.4	-0.4	-0.8
Second quartile	19	188	3.2	14.1	-0.6	-0.6
Third quartile	20	269	8.3	37.0	-0.04	-1.3
Upper quartile	23	579	102.8	493.2	4.0	17.7
Without macro-catchment RWH:						
Lower quartile	10	117	13.6	43.1	-1.3	1.6
Second quartile	10	194	4.5	14.3	-0.8	1.2
Third quartile	9	296	10.5	31.5	-1.6	3.7
Upper quartile	5	437	35.2	78.7	2.1	4.4

Test results for dollar per capita expenditure (US $ per hectare) were as follows:

Poverty comparison in the lower quartiles: ***u*** = 1.9 (not sig. P < 0.05)
Poverty comparison in the second quartiles: ***u*** = 3.6 (sign. at P < 0.01
Poverty comparison in the third quartiles: ***u*** = 6.8 (sign. at P < 0.01)
Poverty comparison in the fourth quartiles: ***u*** = 5.3 (sign. at P < 0.01)

3.4 Trends in the adoption of RWH

It is equally of interest to make trend assessment in relation to adoption of rainwater harvesting for paddy production in the economic context of structural reforms. In the cotton growing areas including Mwanza and Shinyanga (of which Maswa is a part), the downfall of cotton as for other traditional export crops, mainly due to unstable and declining producer prices, and high costs of insecticides has given a steady increase in the number of paddy producers. Resources such as labour and limited cash have been allocated to paddy production instead of cotton as used to be. Paddy production is the major crop under macro-catchment RWH in most of the semi-arid areas of central Tanzania. Therefore assessing the pattern of adoption of paddy production among different groups of the poor and spatially in the study localities is very pertinent.

Results in Table 10 show that, the period after 1990 onwards, a significant number of households in midstream (41% to 59%) and upstream (43% to 57%) switched to paddy production. These two villages occupying upper part of the catchment are predominantly cotton growers. In these villages there are evident attempts to cultivate paddy even in places where land quality and runoff harvesting do not allow the practice. Downstream village, which occupies the lowland part, is inherently an ideal place for paddy production given soil types and the landscape. An interesting finding for the case of the downstream village is that, the rate of adoption of paddy production declined substantially from 65% to 35%. Such drop could be related to the possibility of incentives to rent out paddy fields to farmers from other places as a result of improved competitive land rental price.

Wealth categorization as done by the society implies the level of social position may determine the level of resource access. Results in Table 10 show that, improved prices of paddy over that of traditional cotton crop did not attract any of the rich farmers. However, the number of middle and poor farmers who started paddy production increased from 40% to 60% while that of poor declined from 57% to 43%. The rate of adoption of paddy production during post reform period may be linked to inability of the poor to access paddy fields due to increased demand for land suitable for paddy. The trend for adopting paddy production in relation to gender shows that, while the number of male households slightly declined from 51% to 49% that of counterpart female-headed household remained constant (50%).

Table 10: Trend of adopting macro-catchment RWH for paddy production in Maswa (%)

Location/group	Before 1990	After 1990
Biophysical location:		
Downstream	65	35
Midstream	41	59
Upstream	43	57
Wealth category:		
Rich	100	-
Middle	40	60
Poor	57	43
Gender of household head:		
Male	51	49
Female	50	50

3.5 Performance of Rainwater Harvesting (Maswa)

The performance of RWH for crop production is assessed using three parameters namely yield (ton/ha), returns to land (gross margins/ha) and returns to labour (gross margins/person-day. In analyzing the economics of RWH for livestock enterprise, a different approach is used. Theoretical considerations and the basic equations for computing the economic performance are as presented in section 2.3.3. In the first place, it is important to explore seasonality phenomenon as it forms the grounds on which the performance analysis is based.

3.5.1 Seasonality perceptions

Seasonality is one of pervasive features of livelihood vulnerability in dryland farming systems. One of the major odds of seasonality is yield and farm income fluctuations as a result of critical shortage of moisture for plant growth. Here the concept of seasonality viewed in terms occurrences of years which are bad (below average) and good (above average) seasons. Table 11 presents respondents' assessment over 6 years of production that were referred to during recall survey across three study villages. Apparently, the year 2003 was rated B-average by most of respondents in the lowland village (81%). The proportion of respondents, which underlined the year 2003 as B-average season, decreases as you head through midland (42%) to the upland (38%). Actually, the year 2003 had a prolonged dry spell, which seriously affected crop production in most parts of the country, especially in the drylands (FEWSNET 2003, FIST, 2003). Respondents, that is, 100%, 93% and 92%, exaggeratedly mentioned the year 1998 to be A-average. It is very interesting to note that, the *elnino* of 1998, which caused devastating floods elsewhere in the country was regarded as an opportunity rather than being a threat in the semi-arid areas.

Table 11: Assessment of seasonality under the concept of A-average and B-average season, Maswa

Seasons	Lowland				Midland				Upland			
	A-average		B-average		A-average		B-average		A-average		B-average	
	n	%	n	%	n	%	n	%	n	%	n	%
2003	7	19	30	81	22	58	16	42	23	62	14	38
2002	31	84	6	16	37	95	2	5	30	85	5	15
2001	28	75	9	25	33	92	3	8	32	94	2	6
2000	31	86	5	14	33	97	1	3	26	84	5	16
1999	31	91	3	9	30	91	3	9	24	89	3	11
1998	32	100	0	0	27	93	2	7	23	92	2	8

Furthermore, comparison of seasonality situations for different localities in the study sub-catchment shows interesting results. The comparison was done by plotting cumulative percentages of respondents in the study villages who perceived a particular production year to be either A-average or B-average. Such plotting applies the technique of dominance analysis of cumulative density functions widely used in poverty analysis. The aim of this dominance analysis was to unveil divergence in seasonality with location on the toposequence. Figure 4(a) indicates that good seasonality manifested almost equally in the three study villages as respective curves are moving together. However, very slightly the midland cumulative curve of A-average dominated others from 2002 back to 1998. In the year 2003, the three A-average curves overlapped. Generally, it is very interesting to note that though the year 2003 was bad in terms of rainfall amount but still there are people who rated it good. This could be attributed to RWH possibility that reduces the adverse effect of seasonality. Figure 4(b) shows the cumulative curves for B-average seasons trend as experienced by respondent farmers along the toposequence. The lowland B-average cumulative curve dominates other curves, particularly from the year 2002 back to 1998. The upland curve occupies the mid position whereas the midland curve is dominated by others. The architecture of B-average cumulative curves shows that bad seasonality is predominantly felt in the lowland as compared to upland in years of no seasonal drought. This can be explained by location advantage as upstream villages could abstract whatever runoff available leaving very little or none to reach the downstream users in the lowland.

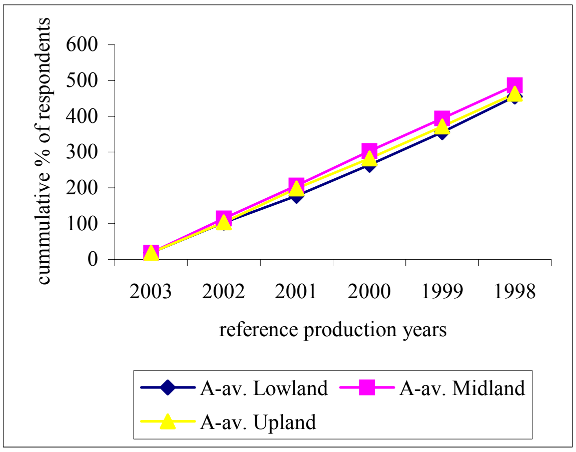


Figure 4(a) Dominance analysis of A-average seasons by location, Maswa

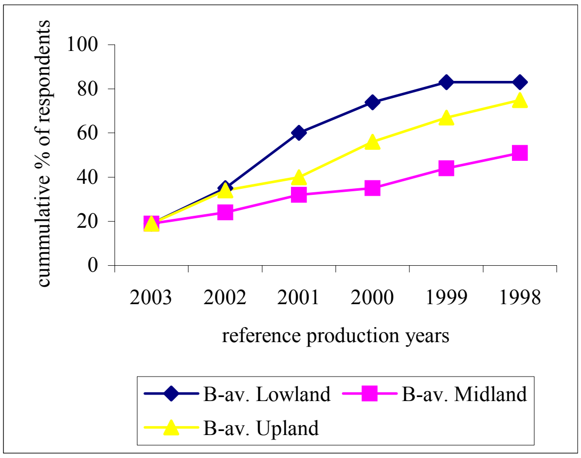


Figure 4(b): Dominance analysis of B-average seasons by location, Maswa

3.5.2 Paddy and vegetable enterprises based on the questionnaire survey

Performance of RWH based paddy enterprise is assessed for the two levels of rainwater management systems, that is micro-catchment and macro-catchment systems. Tables indicating explicitly the levels of performance of paddy enterprise under these two RWH systems are presented in Appendix 4.1 entailing Tables 12 & 13 respectively. Figure 5(a) shows that, for A-average seasons, the mean yield (ton/ha) for macro-catchment RWH significantly exceeds that of micro-catchment ($P < 0.01$). However, the mean yield differences for the two RWH systems do not differ significantly during B-average seasons ($P < 0.05$). This indicates the improvement in the effectiveness of micro-catchment RWH during B-average seasons, as it utilizes the surface runoff in the vicinity. Macro-catchment RWH system had significantly higher returns to land and labor in both A- and B-average seasons. This is attributed to the relatively high yield realized under macro-catchment system. Returns to labor per person per day even for B-average seasons is seven times higher than a dollar, which is the global poverty line. This implies that RWH reduces poverty and vulnerability to the odds of seasonality.

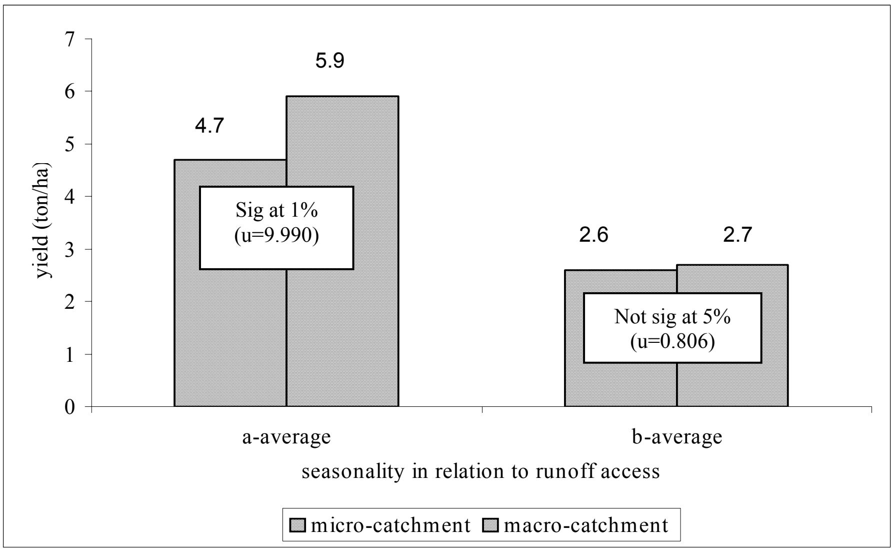
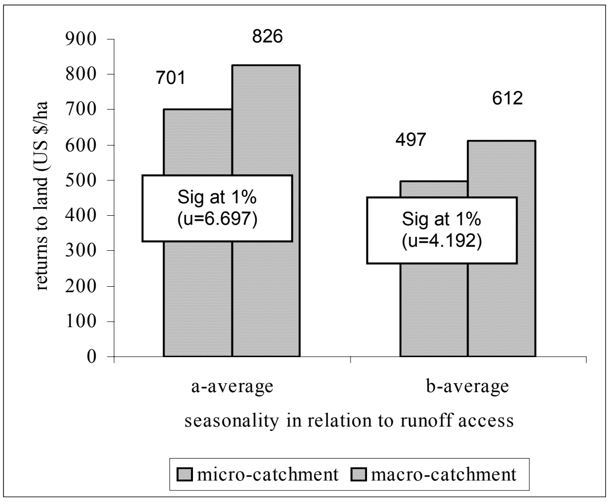


Figure 5(a): Yield from paddy under micro-catchment *Vs.* macro-catchment with seasonality



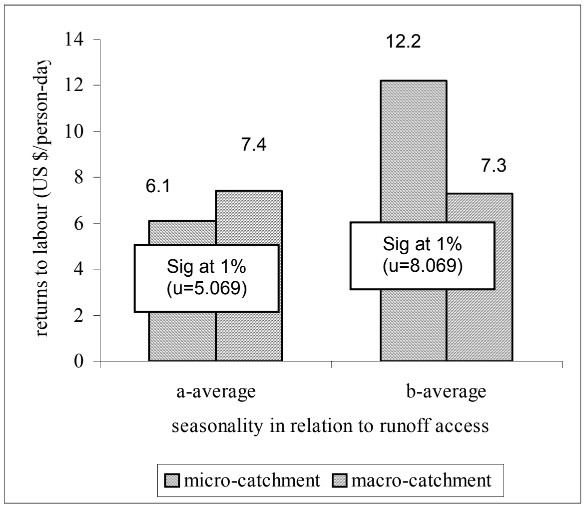


Figure 5(b): Returns to land from paddy under micro-catchment *Vs.* macro-catchment with seasonality

Figure 5(c): Returns to labour from paddy under micro-catchment *Vs.* macro-catchment with seasonality

Table 13 in Appendix 4.1 shows that performance of vegetables enterprise under RHW with reservoir was significantly higher ($P < 0.01$) in A-average than in B-average seasons. The vegetable crops include tomatoes, cabbages and onions. Assessment of vegetable enterprise was evaluated in terms of returns to land and labour. It was not possible to compute productivities because the local sale units varied remarkably in terms of size among different farmers for them to be confidently converted into standard units. It is interesting to compare the performance of paddy under macro-catchment and vegetables under RWH with reservoir. The essence of comparing these two enterprises is because they were identified to be highly profitable and can compete for water and other farm resources such as land, labour and capital. Figures 6 (a & b) compare returns to land and labour for paddy under macro-catchment and vegetables under RWH with reservoir. Figure 6(a) shows that, in both A- and B-average seasons, returns to land from vegetables were significantly higher ($P < 0.01$) than that realized from paddy under macro-catchment RWH system. Returns to labour from the enterprises during A-average seasons did not vary significantly. Also, during B-average seasons returns to labour from paddy significantly ($P < 0.01$) exceeded that of vegetables. This means vegetables growers engage more labour in production relative to paddy growers. Increased labour input in vegetables production could be attributed to labour demand for regular irrigation and management. Vegetable growers were taking water from a distant reservoir to the fields using pushcarts and carrying the water cans on their head, which are labour intensive (Mutabazi *et al*., 2004).

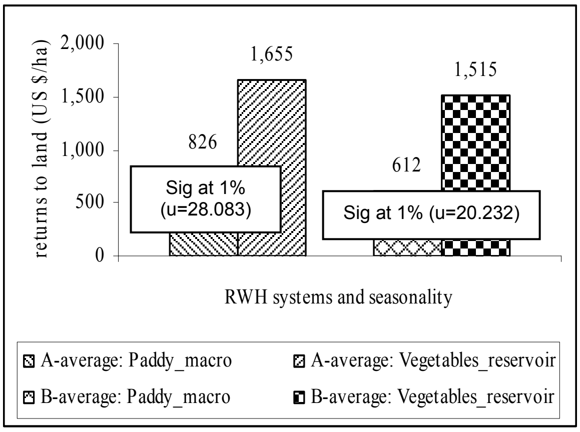


Figure 6 (a): Returns to land for Paddy_macro Vs. Vegetables_resevoir in A-average seasons

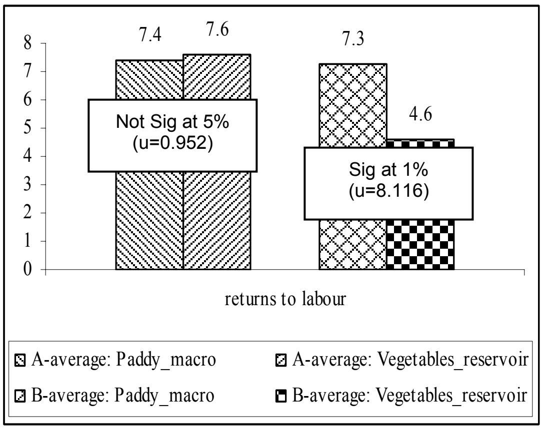


Figure 6 (b): Returns to land for Paddy_macro Vs. Vegetables_resevoir in A-average seasons

3.5.3 Maize enterprise based on the questionnaire survey

Performance of maize was assessed under rainfed conditions and *in-situ* RWH capture systems. These are the two systems practiced in Maswa for maize production. Virtually, rainfed system refers to flat cultivation with no conventional soil and water conservation practices. In-situ system refers to conventional soil and water management systems such as ridging, deep tillage through ripping. Tables indicating explicitly the levels of performance of maize enterprise under these two rainwater systems are presented in Appendix 4.2 entailing Tables 15 & 16 respectively. Figure 7 (a) shows no significant difference ($P < 0.05$) for the mean yields realized under rainfed versus *in-situ* in both A- and B-average seasons. However, interestingly rainfed system had yields slightly exceeding that of *in-situ.* Figures 7 (a & b) reveal that returns to land and labour were sensitive to seasonality. The slight difference seen in yield translated into significantly different returns to land and labour. The absolute ***u*** statistic is vividly higher for returns to land under rainfed condition (23.0) than that for *in-situ* system (2.9) during B-average seasons. However, returns to labour were inconsistent to the trend observed in yield and returns to land. Returns to land for *in-situ* system during A-average season significantly exceeded that of rainfed ($P < 0.01$). The results suggest that the credibility of in-situ rainwater harvesting over flat cultivation (rainfed) in Maswa and in the wider *Sukuma farming system* is questionable. However, it is very likely that some farmers who reported that they practice flat cultivation actually did *in-situ* unknowingly. This is because most farmers in the *Sukuma farming systems* plough their fields using ox-drawn implements which rip the soil to improve infiltration.

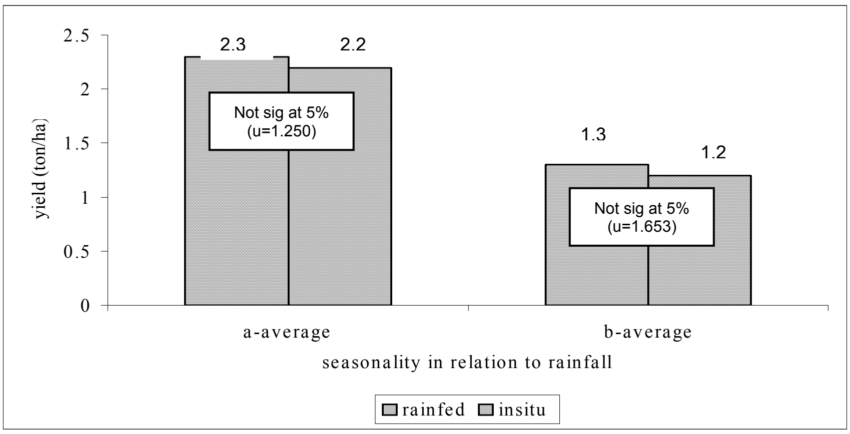


Figure 7 (a): Yield from maize under rainfed *Vs.* in-situ RWH with seasonality

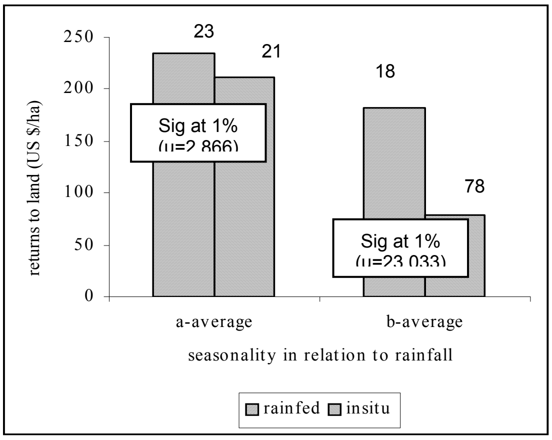


Figure 7 (b): Returns to land from maize under rainfed *Vs.* in-situ RWH with seasonality

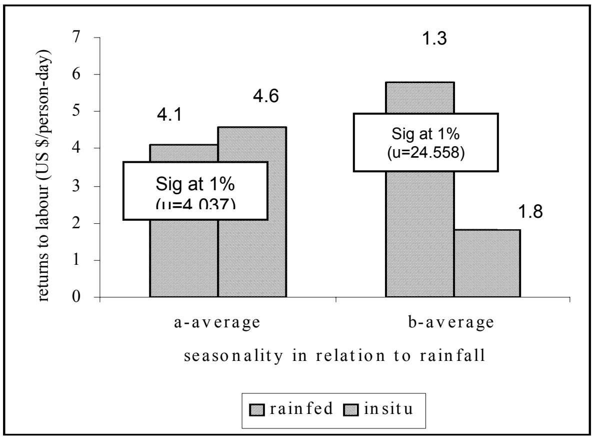


Figure 7 (c): Returns to labour from maize under rainfed *Vs.* in-situ RWH with seasonality

3.5.4 Sorghum enterprise and comparison with maize based on the questionnaire survey

The rationale of assessing the performance of sorghum is the vest interest to argue with respect to government advocacy and effort of promoting sorghum in semi-arid areas. Promotion of sorghum and millet over the locally preferred maize staple in the dryland farming systems has been a failure as adoption is still very low in most of these areas. This analysis is a modest attempt to reveal the underlying economics of rainfed sorghum and maize. Returns to land and labour are used as key performance indicators in this analysis. Table 18 in Appendix 4.3 show that, the yield of sorghum was 2.6 and 2.3 tons/ha for A-and B-average seasons, and the two figures are not significantly different statistically (P > 5%). Results in Table 17 indicate that returns to land and labour from rainfed maize were significantly higher than that from sorghum. Thus, besides the cultural preference of maize as a major staple crop, relative returns justify farmers' decisions to cultivate maize in the drylands.

Table 17: Comparative assessment of rainfed sorghum and maize enterprises

Items	N	Mean	Std
A-average seasons:			
Returns to land (Sorghum) (US $/ha)	15	61.1	7.6
Returns to land (Maize) (US $/ha)	81	234.2	306.1
Returns to labour (Sorghum) (US $/person-day	15	0.3	0.1
Returns to labour (Maize) (US $/person-day	81	4.1	3.0
B-average seasons:			
Returns to land (Sorghum) (US $/ha)	10	31.1	22.7
Returns to land (Maize) (US $/ha)	56	181.4	143.9
Returns to labour (Sorghum) (US $/person-day	10	0.4	0.3
Returns to labour (Maize) (US $/person-day	56	5.8	7.2

Statistical tests of significance A-average season	Statistical tests of significance A-average season
Returns to land u = 57.2 (sign. at P < 0.01)	Returns to land u = 100.9 (sign. at P < 0.01)
Returns to labour u = 43.8 (sign. at P < 0.01)	Returns to labour u = 40.9 (sign. at P < 0.01)

3.5.5 Cotton enterprise based on the questionnaire survey

As in the case of maize, cotton production involves rainfed and *in-situ* systems. Detailed Tables of statistics from central tendency analyses are presented in Appendix 4.3 – Tables 19 and 20. Results in Figure 8(a) show that, growing maize under *in-situ* system as compared to flat cultivation does not lead into increased productivity in Maswa irrespective of seasonality. Further, rainfed system performed significantly better than *in-situ* (P < 0.01) during B-average seasons. Returns to land did not differ significantly (P < 5%) between rainfed and *in-situ* systems for A-average seasons but did for B-average seasons (P < 0.01). This could be related to likelihood that, during A-average years the cotton supply is high, leading to low competition among private cotton buyers who tend to pay a constant price to all farmers. But during B-average seasons when the supply is reduced, despite producer prices hike, cotton buyers competition for produce may lead to price discrimination, that is paying differently for different farmers. Of course, this has been the case whereby farmers who harvest and bring the produce much earlier to the buying stalls are paid highly as buyers are eager to procure. Returns to labour realized during A-average seasons for rainfed system significantly exceeded that for *in-situ* ($P < 0.01$) implying allocation of more labour in the former compared to the latter system. Returns to land are about three times the national poverty line of 73,877 Tshs per capita per year (based on 1995 prices). Further, returns to labour ranges from three to nine times the global poverty line of a dollar per person-per day. This means RWH reduces poverty and vulnerability of semi-arid households.

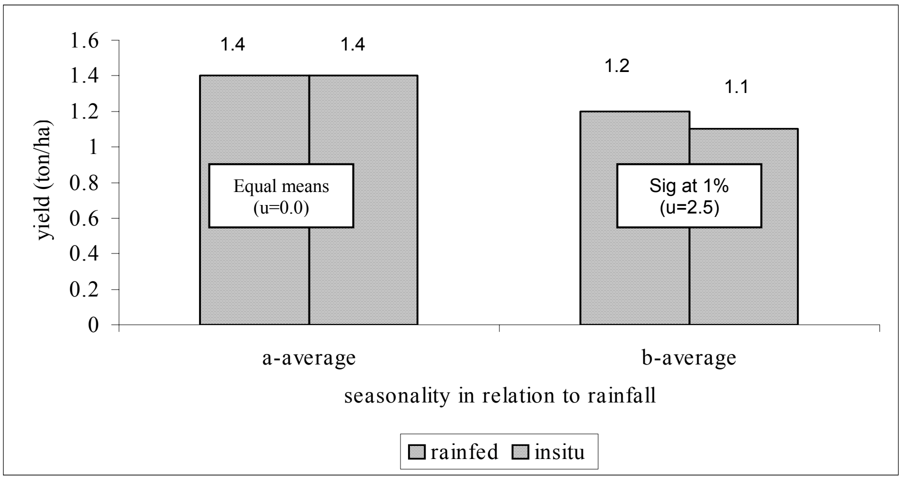
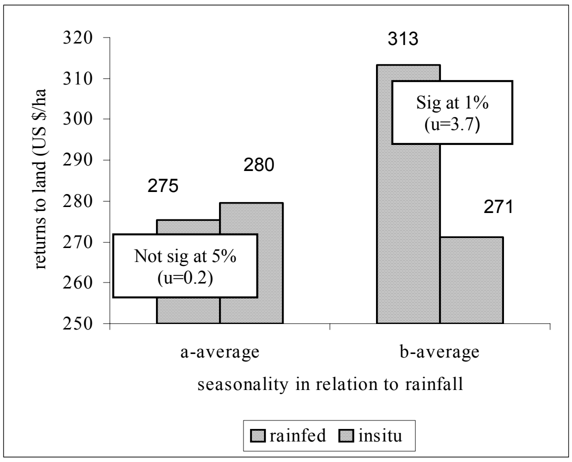


Figure 8 (a): Yield from cotton under rainfed *Vs.* in-situ RWH with seasonality



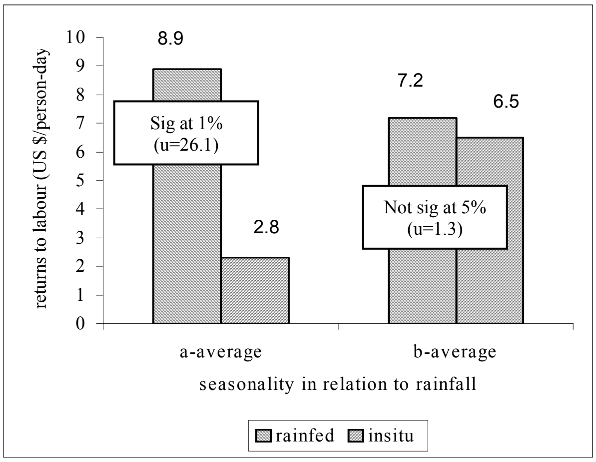


Figure 8 (b): Returns to land from cotton under rainfed *Vs.* in-situ RWH with seasonality

Figure 8 (c): Returns to labour from cotton under rainfed *Vs.* in-situ RWH with seasonality

3.5.6 Paddy enterprise based on yield monitoring, Maswa

Yield monitoring exercise was undertaken in order to have credible evidences of the actual benefits of RWH in poverty reduction. Results from the monitored yields were used to compare with information from large sample of farming households obtained through questionnaire survey. For cases where farmers are not keeping records, like in most farming systems of rural Tanzania, information from questionnaire surveys alone may not reflect the actual situation particularly due to problems related to memory lapse. In Maswa, four systems of RWH for paddy production were identified amongst pilot farmers. These include micro-catchment, macro-catchment, macro-catchment with storage pond, and macro-catchment linked to road drainage. It was a coincidence that the two years of 2003 and 2004 of yield monitoring exercise coincided with B- and A-average seasonality respectively.

Results in Figure 9(a) show that, the yield of paddy under different RWH systems during A-average season appreciably exceeds that of B-average season. In A-average seasons, the highest yield is 5.3 tons/ha under macro-catchment linked to road drainage while the minimum is 4.2 tons/ha realized under micro-catchment system. These two yield levels are significantly different ($P < 0.01$) with ***u*** statistic of 2.596 (see Appendix 4.4 – Table 24). In B-average seasons, the highest yield is 3.8 tons/ha observed in macro-catchment system while the lowest is 2.5 tons/ha recorded under macro-with storage pond. These two yield levels are also significantly different ($P < 0.01$) with ***u*** statistic of 9.087 (see Appendix 4.4 – Table 24). The low performance of micro-catchment RWH is associated with its dependence on a rainfall event in the nearby catchment. The advantage of macro-catchment over micro-catchment is that, it enables harvesting of runoff generated far from the cropland even if it has never rained around. Better yields of RWH linked to road drainage system is due to the fact that, the system has an extensive pavement which concentrates a large amount of runoff with minimum loss to a desired direction. The higher overall mean yields of paddy under different RWH systems during A-average seasons compared to B-average season would be explained by the fact that, during the former the rainfall amount is relatively enough to generate the runoff required for paddy production. During an A-average season, macro-catchment with pond storage realized yield that was higher compared to micro-catchment and macro-catchment but below that of macro-catchment RWH linked to road drainage. Apparently, micro/macro-catchment with storage pond realized the lowest yield of 2.5 tons/ha during B-average season. Because of low rainfall and/or low frequency of rainfall events during the B-average season, the small ponds are not filled with the runoff in and at required amount and frequency for supplying the runoff in the paddy fields is reduced. This is likely to be the major reason for the lower yields associated with paddy under macro RWH with storage pond.

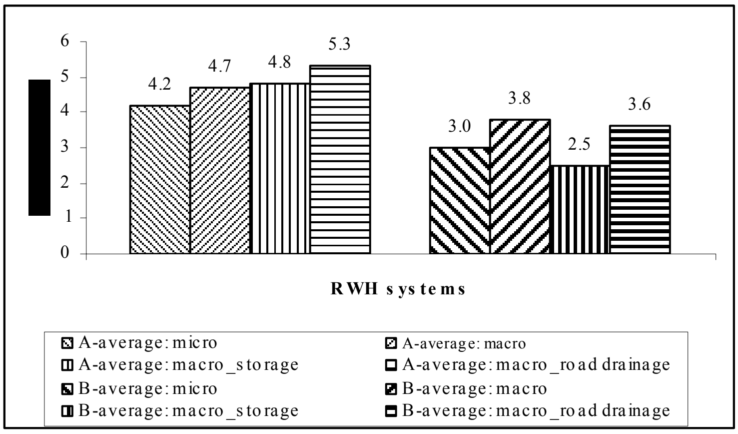


Figure 9 (a): Yield from paddy under RWH systems for monitored yields

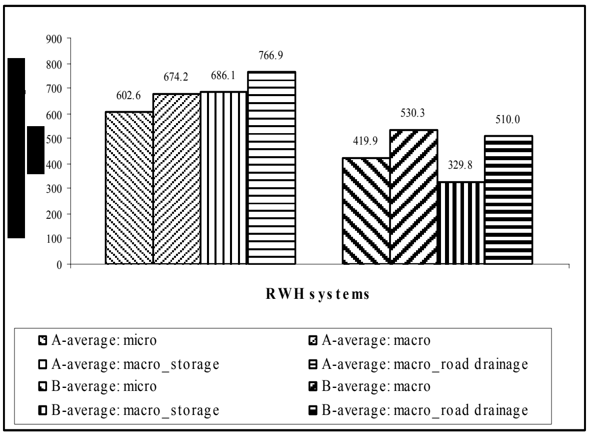


Figure 9 (b): Returns to land from paddy under RWH systems for monitored yields

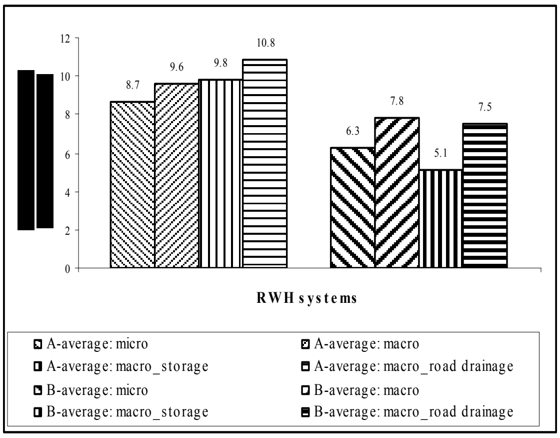


Figure 9 (c): Returns to labour from paddy under RWH systems for monitored yields

3.5.7 Performance of crop enterprises in WPLL (Same district)

The farming system of Same district involves two seasons 'masika' and 'vuli' that coincide with its bimodal rainfall pattern. Therefore, the results of analysis of performance of crop enterprises under different rainwater management systems in this site are presented for the two seasons. RWH based crop enterprises include maize and maize intercropped with lablab beans under rainfed, *in-situ*, and RWH involving external catchment (micro- and macro-catchment) systems. Sorghum was not included because the first round survey revealed that no one was producing sorghum in Same district despite the government efforts to promote it in the area. The major crop enterprises discussed in detail include sole maize, and maize – lablab intercrop for both long and short rainy seasons. However, the results for maize – beans intercrop are annexed to this report (Appendix 4.8).

3.5.7.1 Seasonality analysis

Table 26 indicates that no one in the lowland rated the year 2003 as being A-average as 100% of all respondents rated it B-average. Only 3% and 5% of respondents in the midland and upland villages respectively perceived the year 2003 to be A-average. Though the year 2003 was generally bad in terms of rainfall amount, still farmers upstream at least had an advantage of utilising the natural streams and the traditional night reservoirs '*ndiva*' to irrigate the fields. Apparently the year 1998 which had *elnino* phenomenon was rated by over 80% of respondents in lowland and midland villages as being A-average. Contrary, it is only 64% of respondent farmers in the upland who rated the year 1998 being A-average. During the survey, respondents said that most of their fields were excessively logged with water which affected the performance of the crop. Such reason is authentic because climatologically the upland is sub-humid while the midland and lowland are typically semi-arid.

Table 26: Assessment of seasonality under the concept of A-average and B-average season, WPLL

Seasons	Lowland				Midland				Upland			
	A-average		B-average		A-average		B-average		A-average		B-average	
	n	%	n	%	n	%	n	%	n	%	n	%
2003	0	0	41	100	1	3	36	97	2	5	37	95
2002	18	44	23	56	19	51	18	49	27	69	12	31
2001	18	44	23	56	17	46	20	54	28	72	11	28
2000	21	51	20	49	23	62	14	38	27	69	12	31
1999	25	61	16	39	25	68	12	32	28	72	11	28
1998	37	90	4	10	32	87	5	13	24	62	15	39

The seasonality was further evaluated in terms of dominance of badness or goodness of the reference production years of the survey. The dominance analysis indicates that the cumulative A-average seasonality curve for upland dominates curves for midland and lowland. This complies with the climate situation which ranges from sub-humid with relatively high rainfall and off-season irrigation, intermediate with moderate rainfall and limited off-season irrigation to semi-arid with extremely low rainfall and no off-season irrigation possibility. The cumulative curves of percentage of respondents with B-average are that the curve for lowland village dominates the curves for midland and upland villages (Figures 10 a & b).

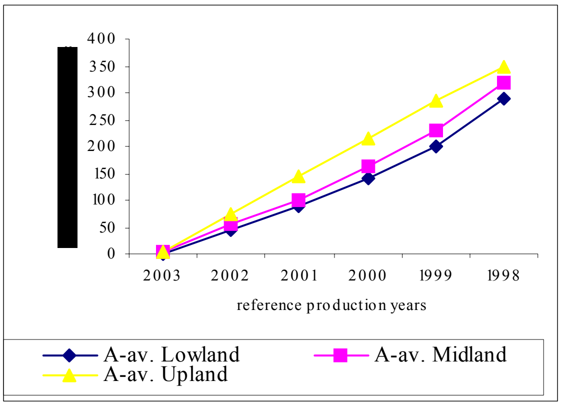


Figure 10(a) Dominance analysis of A-average seasons by location, WPLL

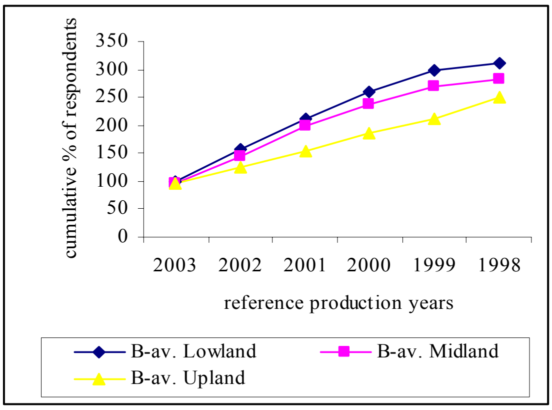


Figure 10(b) Dominance analysis of B-average seasons by location, WPLL

3.5.7.2 Sole maize enterprise (Masika)

The performance of maize under sole cropping was analysed in terms of yield, returns to land and labour under different RWH systems. As opposed to Maswa District, maize production in WPLL involves a range of rainwater management practices. Figure 11(a) reveals that, during A-average seasons rainfed system performed significantly better (1.7 ton/ha) than *in-situ* RWH (1.0 ton/ha) (P < 0.01). This means in WPLL when the season is A-average, it does not matter whether you practice *in-situ* or you do not. However, during B-average the yield realized under *in-situ* was a bit higher than that obtained under rainfed system, though the difference is not significant. Comparison of yields under rainfed and RWH with external catchment in Figure 11(b) did not differ significantly (P < 0.05). Furthermore, Figure 11 (c) shows that during A-average season, RWH with external catchment gave yields which were significantly higher than *in-situ* system (P < 0.01).

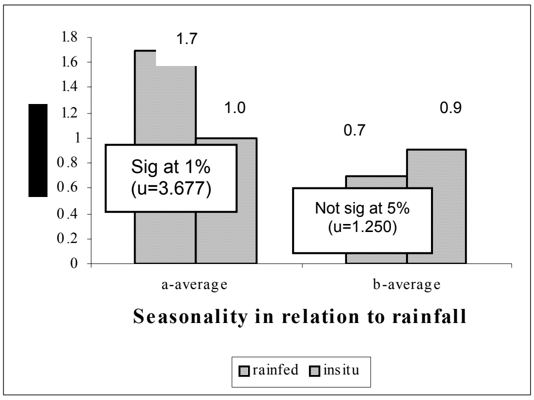


Figure 11 (a): Yield of maize (masika) rainfed *Vs.* *in-situ* with seasonality

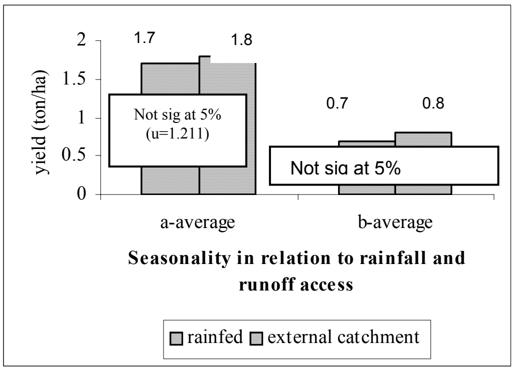
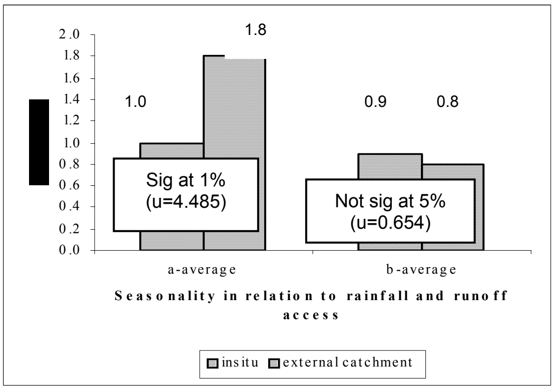


Figure 11 (b): Yield of maize (masika) rainfed *Vs.* external catchment with seasonality



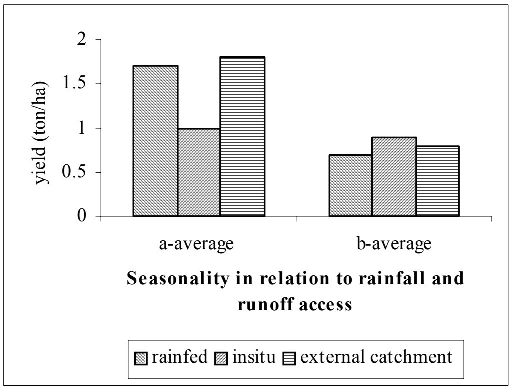
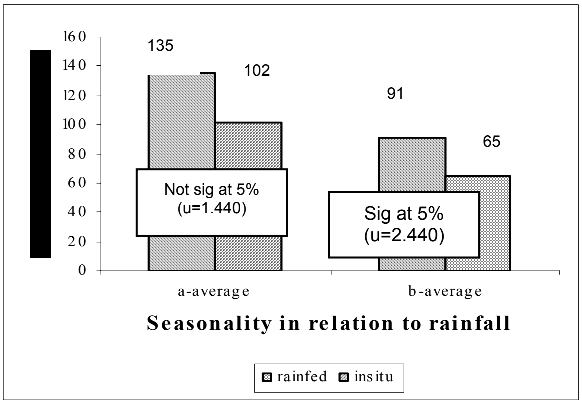


Figure 11 (c): Yield of maize (masika) insitu *Vs.* external catchment with seasonality

Figure 11 (d): Yield of maize (masika) rainfed, in-situ and external catchment with seasonality

Results in Figure 12(a) reveal that, there was no significant difference (P < 0.05) of the returns to land for maize crop grown under rainfed and *in-situ* systems. Complying with observed yield differences, returns to land under *in-situ* during A-average seasons were significantly (P < 0.05) lower compared to that of rainfed. Apparently, RWH with external catchment realized returns to land which were significantly (P < 0.01) better than rainfed and *in-situ* RWH systems in both A- and B-average seasons.



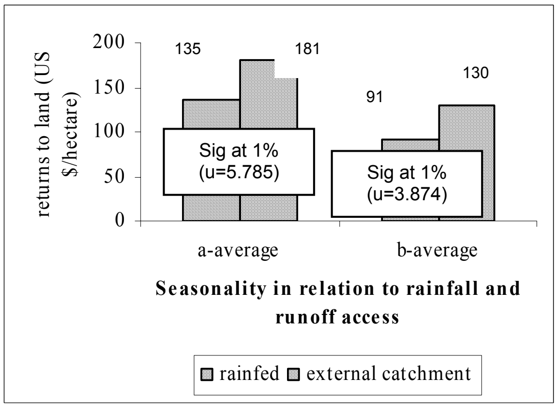
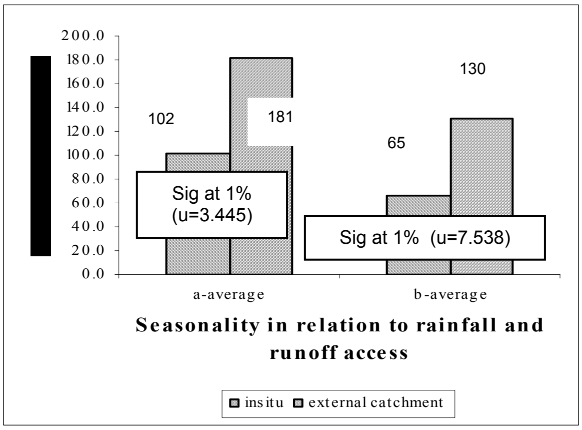


Figure 12 (a): Returns to land from maize (masika) rainfed Vs. in-situ with seasonality

Figure 12 (b): Returns to land from maize (masika) rainfed Vs. external catchment with seasonality



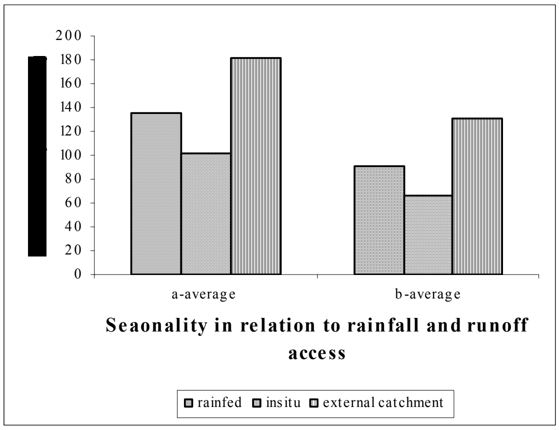


Figure 12 (c): Returns to land from maize (masika) insitu *Vs.* external catchment with seasonality

Figure 12 (d): Returns to land from maize (masika) rainfed, in-situ and external catchment with seasonality

Figures 13(a, b and c) show that under all types of RWH systems irrespective of seasonality, realized return to labour which exceed a dollar poverty line. In view of this, RWH reduces poverty by rewarding each person-day engaged, the sum which is more than a dollar. Returns to labour is subject to labour allocation decisions by individual farmers.

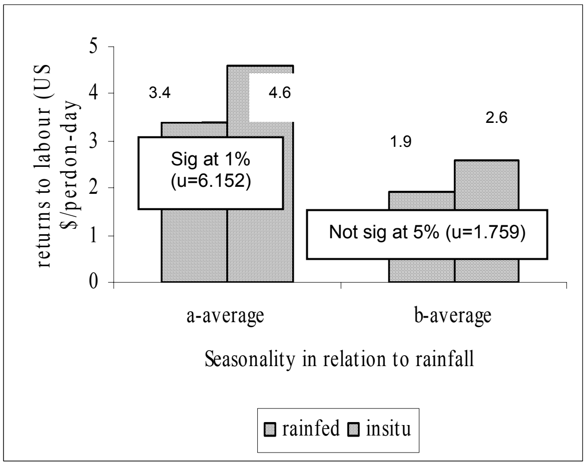


Figure 13 (a): Returns to labour from maize (masika) rainfed Vs. in-situ with seasonality

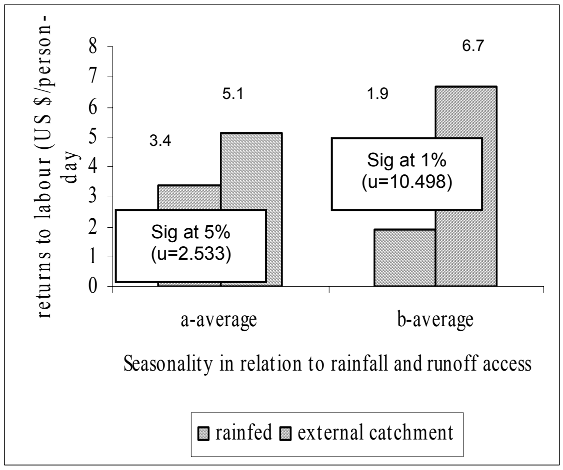


Figure 13 (b): Returns to labour from maize (masika) rainfed Vs. external catchment with seasonality

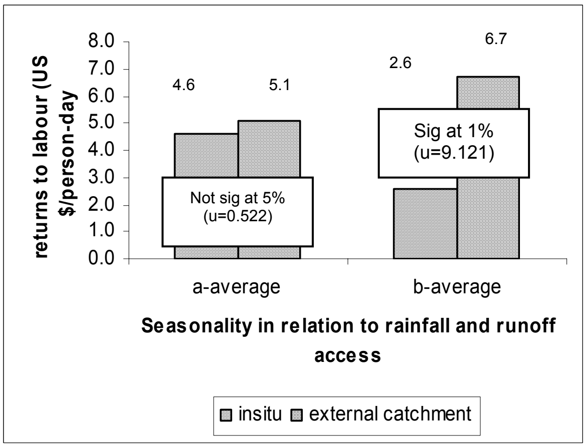


Figure 13 (c): Returns to labour from maize (masika) in-situ Vs. external catchment with seasonality

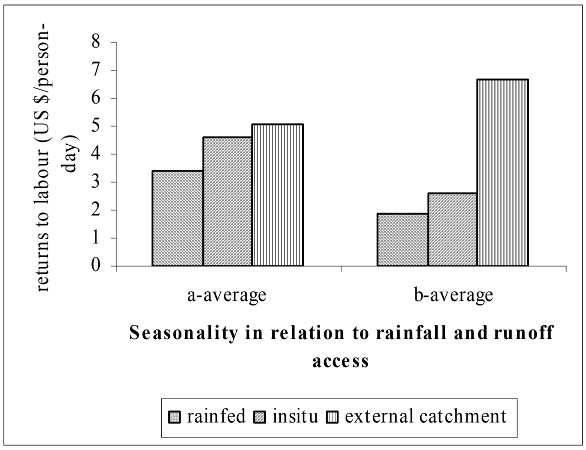


Figure 13 (d): Returns to labour from maize (masika) rainfed, in-situ and external catchment with seasonality

3.5.7.3 Maize - Lablab intercrop (Masika)

In Same district, intercropped maize and lablab is a common enterprise under rainwater harvesting systems during 'masika'. It is expected that, farmers would be able to accrue more benefits by mixing these crops by increasing nitrogen in the soil and optimising returns by reducing costs and diversifying saleable outputs. There was no maize – lablab intercrop under *in-situ* system. The yield of intercropped maize for maize under rainfed and RWH with external catchment was not significantly different ($P < 0.05$). The yields of these two systems during B-average seasons were significantly different ($P < 0.01$). The yields of intercropped lablab under rainfed and RWH with external catchment were not significantly different ($P < 0.05$). Returns to land realized from maize – lablab intercrop enterprise under rainfed system during A-average season significantly ($P < 0.05$) exceeded that of RWH with external catchment. During B-average season returns to land under RWH with external catchment significantly ($P < 0.01$) exceeded that of rainfed system. This indicates that RWH with external catchment was able to reduce income shock due to bad seasonality. Returns to labour under RWH with external catchment from maize – lablab intercrop were not significant different from that obtained under rainfed system.

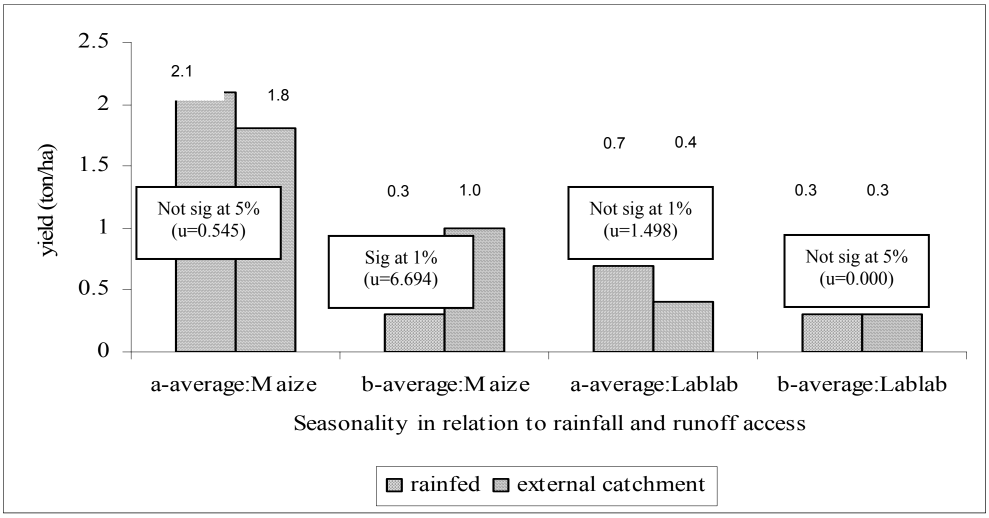


Figure 14 (a): Yield of maize+Lablab (masika) rainfed Vs. external catchment with seasonality

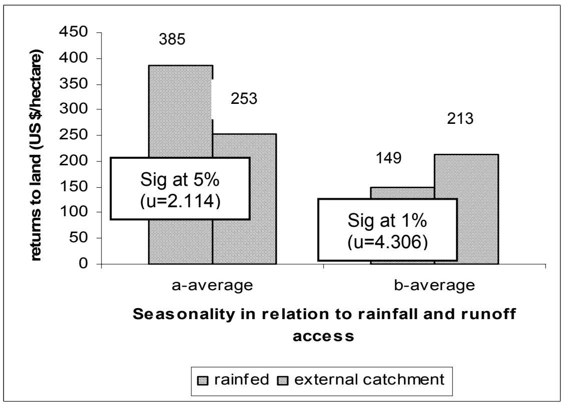


Figure 14 (b): Returns to land of maize+Lablab (masika) rainfed Vs. external catchment with seasonality

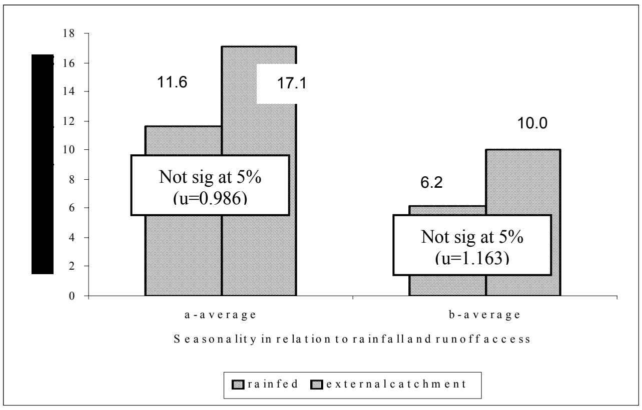


Figure 14 (c): Returns to labour of maize+Lablab (masika) rainfed Vs. external catchment with seasonality

3.5.7.4 Performance of maize enterprise during the short rainy seasons 'Vuli' in WPLL

During the short rainy season ' Vuli', maize is the predominant crop in the farming system. Lablab beans are not cultivated during 'Vuli' because it is photoperiodic crop which in order to flower requires a maximum light intensity available during end of June and July. So, farmers have to plant the crop at the beginning of 'Masika' in February so that the flowering period coincides with months of June and July. If the crop is planted during 'Vuli' in November the crop will not flower until the same months of June and July.

The yields of maize under rainfed and *in-situ* systems in both A- and B- average seasons were exactly similar (Figure 15 (a). In A- and B- average seasons, yield under RWH with external catchment was significantly ($P < 0.01$) higher than that obtained under rainfed and *in-situ* systems (Figure 15 (b & c). These results indicate that RWH with external catchment is more effective than other systems in 'vuli' regardless of whether the season is either A- or B-average. Characteristically, in the WPLL short rains (vuli) tend to yield much runoff compared to the long rains (masika).

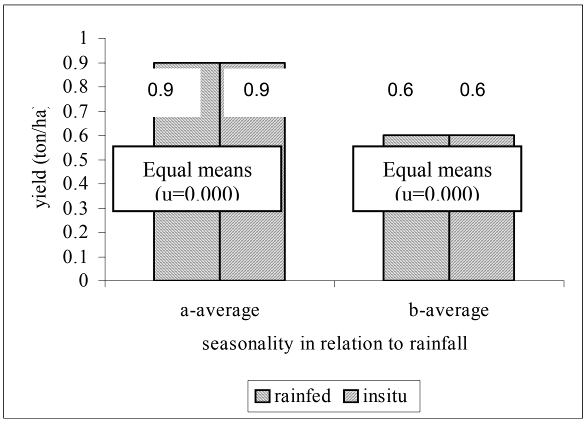


Figure 15 (a): Yield of maize (Vuli) rainfed Vs. in-situ with seasonality

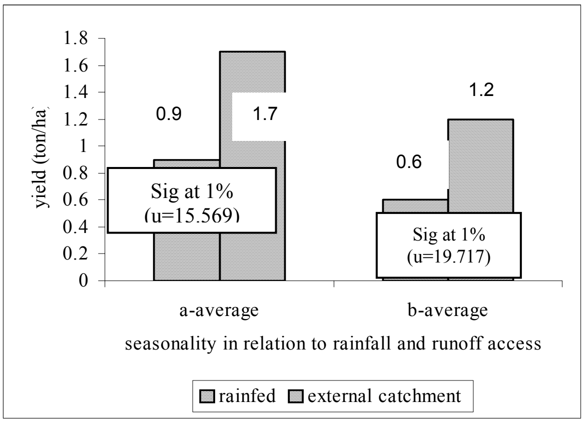


Figure 15 (b): Yield of maize (Vuli) rainfed Vs. external catchment with seasonality

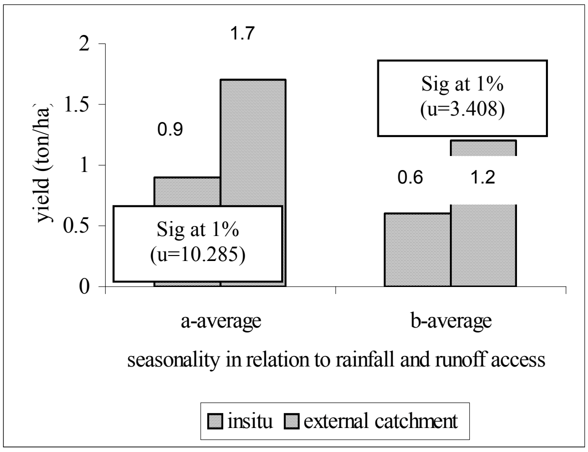


Figure 15 (c): Yield of maize (Vuli) in-situ Vs. external catchment with seasonality

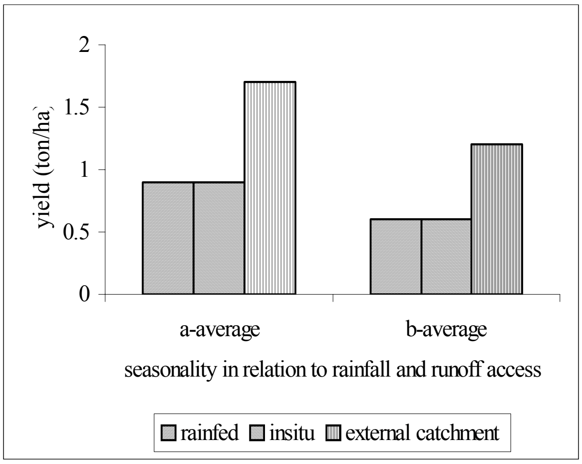


Figure 15 (d): Yield of maize (Vuli) rainfed, in-situ and external catchment with seasonality

Comparative assessment of returns to land from maize under rainfed and *in-situ* RWH systems in both A – and B- average seasons did not vary significantly ($P < 5\%$) as indicated in Figure 16(a). However, the yield of maize under RWH with external catchment in both A- and B- average seasons was significantly higher ($P < 0.01$) than that for rainfed and *in-situ* systems (Figures 16(b & c)). These findings prove the robustness of RWH with external catchment in smoothening out the effect of seasonality in the short rainy seasons.

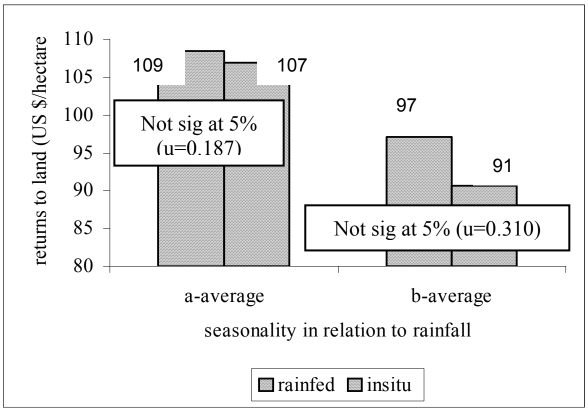


Figure 16 (a): Returns to land maize (Vuli) rainfed Vs. in-situ with seasonality

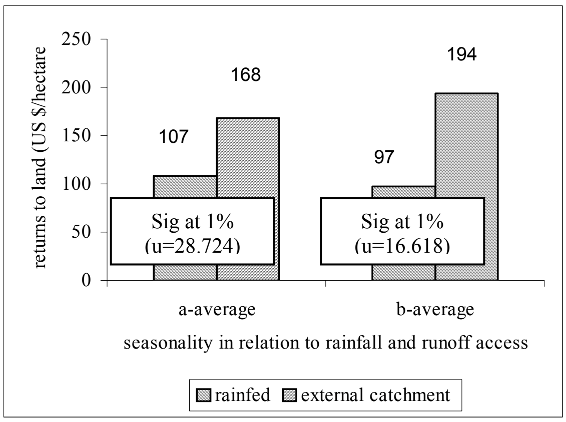


Figure 16 (b): Returns to land maize (Vuli) rainfed Vs. external catchment with seasonality

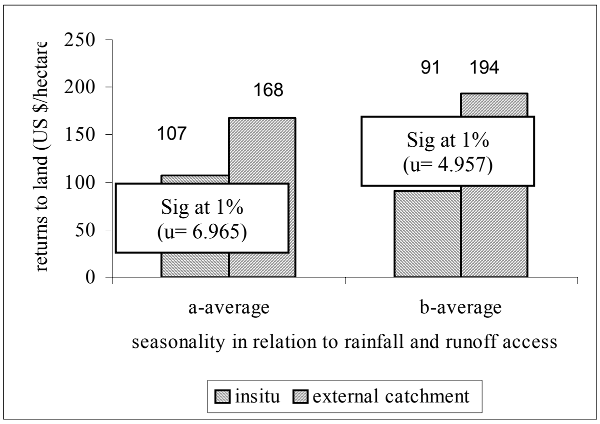


Figure 16 (c): Returns to land maize (Vuli) insitu Vs. external with seasonality

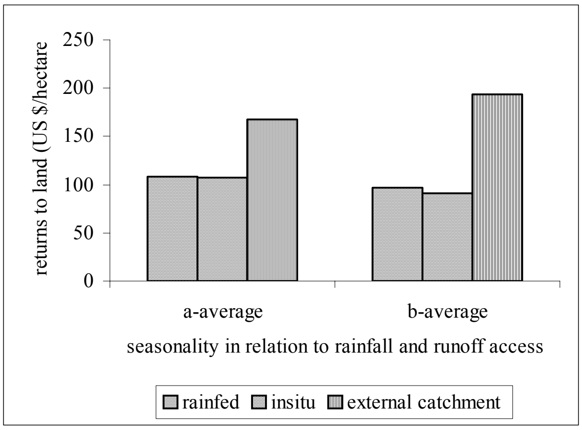


Figure 16 (d): Returns to land maize (Vuli) rainfed, in-situ and external catchment with seasonality

Figure 17(a) shows that in both A- and B- average seasons; returns to labour for *in-situ* RWH system were significantly higher than that of rainfed system. Figure 17(b) indicates that, RWH with external catchment realized significantly (P < 0.01) higher returns to labour than rainfed system. However, *in-situ* systems gave yields, which were significantly (P < 0.01) higher than that of RWH with external catchment (Figure 17(c)). As noted earlier, returns to labour depend on labour allocation decisions, which are complex to understand. Labour allocation at the household level is a function of available labour force and a portfolio of duties the household aims to execute in a particular season. Such elements vary according to household circumstances.

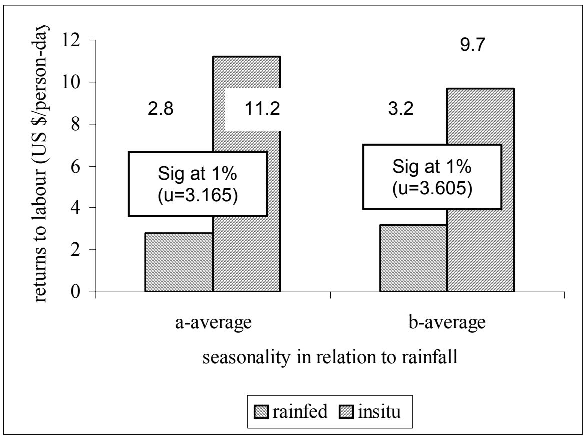


Figure 17 (a): Returns to labour maize (Vuli) rainfed Vs. in-situ with seasonality

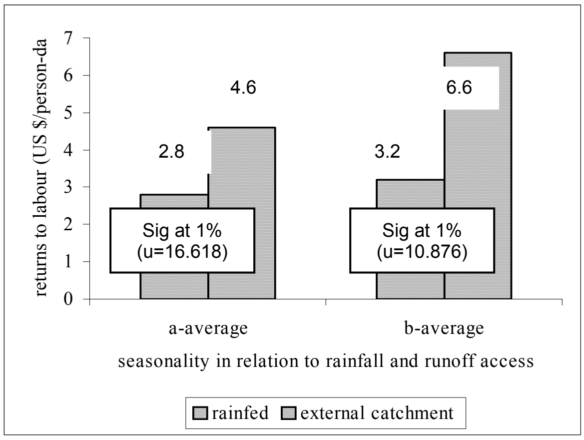


Figure 17 (b): Returns to labour maize (Vuli) rainfed Vs. external catchment with seasonality

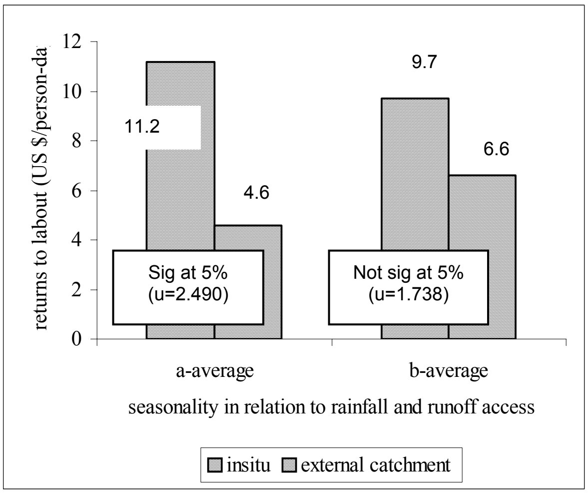


Figure 17 (c): Returns to labour maize (Vuli) in-situ Vs. external catchment with seasonality

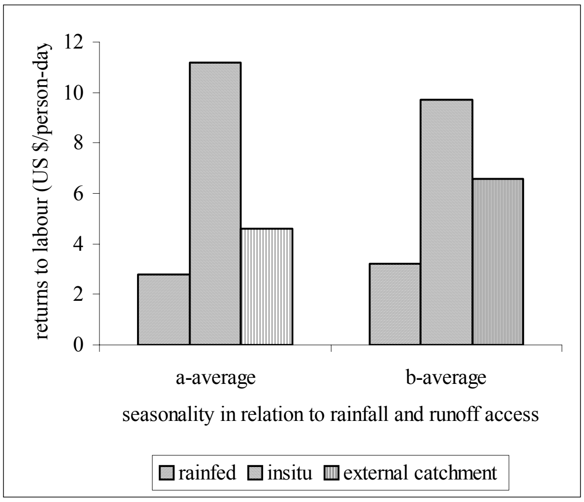


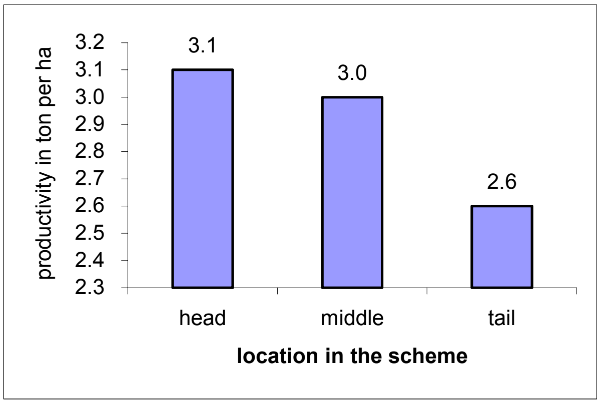
Figure 17 (d): Returns to labour maize (Vuli) rainfed, in-situ and external catchment with seasonality

3.5.7.5 Yield monitoring (WPLL)

For the case of the WPLL, a different approach was used in analysing data from the monitored yield exercise. The exercise was implemented in the downstream village within the farming scheme served by the main gully linked to the road drainage. As a result, all the pilot farms were under the same typology of rainwater management. The basic scenarios that can distinguish the performance of crop enterprises remain to be locational difference and frequency of access to runoff during a particular growing season. The 2004 short rainy season 'vuli' was the only season rated as A-average. During this season, the lowland received adequate runoff as a result of two to three consecutive rainfall storms in the highlands. The generated flood was able to pass the crop through to harvest without any other extra storm event of rainfall. Therefore, locational difference becomes a critical source of variation regarding the performance of crop enterprises rather than frequency of runoff access. Cropland served by the macro-gully in the downstream village was mapped into the head, middle and tail locations according to readiness of access and easiness of diverting the gully flow into crop fields. Farm plots in the head are closer to the water source than plots located at the tail of the scheme. The performance of crop enterprise for other seasons (all B-average) apart from 'vuli' 2004, were evaluated based on how frequent a particular field received the runoff. Production seasons and crops analyzed with regards to level of runoff access included sole maize in ‘masika’ 2003, maize – lablab intercrop in ‘masika’ 2004, maize – lablab intercrop in ‘masika’ 2003, sole lablab in ‘masika’ 2004, and sole lablab in masika 2003.

Performance of sole maize in ‘vuli’ 2004 – A-average season

Figure 18(a) shows that, the yield of maize enterprise during the short rainy season of 2004 (A-average) decreased gradually from head, middle to the tail of the main runoff gully. Table 40 in Appendix 4.9 show that, the maize yield at the head and mid locations on the RWH scheme was not significantly different ($P < 0.05$). Also, yield levels for mid and tail locations were not significantly different ($P < 0.05$). However, the yield realized by farmers at the head was significantly ($P < 0.01$) higher than that of farmers at the tail end of the scheme. Returns to land and labour realised at the head of the scheme were significantly ($P < 0.01$) higher than that realized at the tail (Table 40 – Appendix 4.9). Such inequality urges for robust institutional arrangements for equitable sharing of the runoff between advantaged farmers at the head and disadvantaged farmers at the tail.



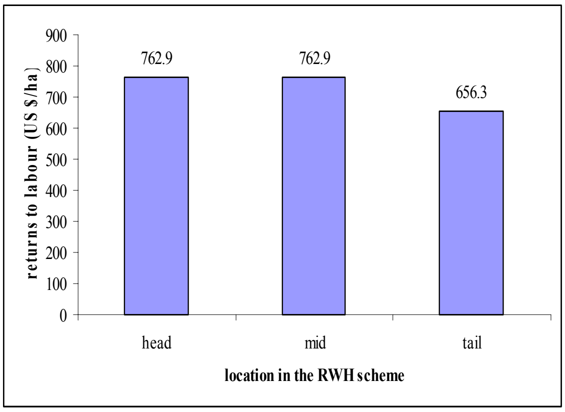


Figure 18(a): Yield of maize from A-average, 'vuli' 2004

Figure 18(b): Returns to land from maize in A-average, 'vuli' 2004

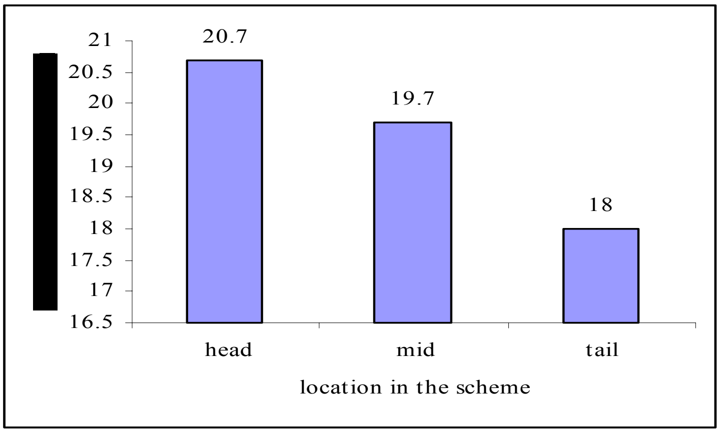
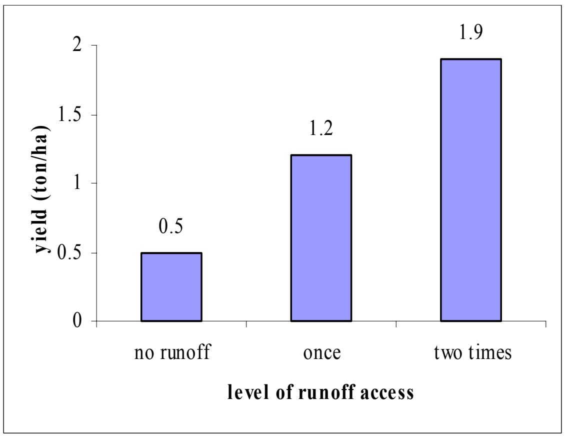


Figure 18(c): Returns to labour from maize in A-average, 'vuli' 2004

Performance of sole maize during 'masika, 2003 – B-average season

During 'masika' 2003 which was a B-average season, performance of maize fields that received no runoff was the worst (Figures 19(a, b & c)). As indicated in Table 41 – Appendix 4.9, there was only one observation per category of runoff access level, which was not adequate for rigorous statistical analysis (tests of significance). However, the absolute levels are presented in order to portray the relative performance. Apparently, Figures 19 (a, b & c) reveals that yield, returns to land and returns to labour improved gradually as the level of runoff access improved. Although, there were no sufficient observations to undertake statistics to test how significant the difference was, but it can be said that performance of maize crop improved with more runoff events.



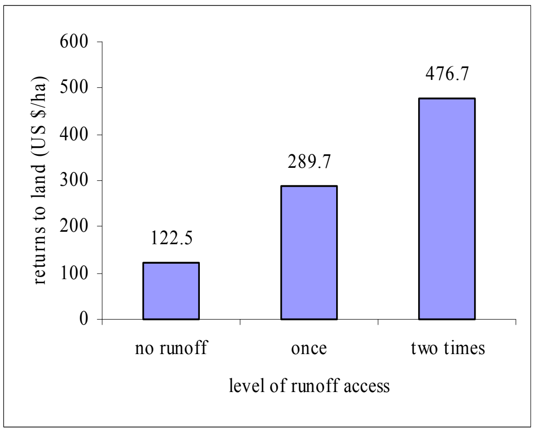


Figure 19 (a): Yield of maize in B-average, 'masika' 2003

Figure 19 (b): Returns to land from maize in B-average, 'masika' 2003

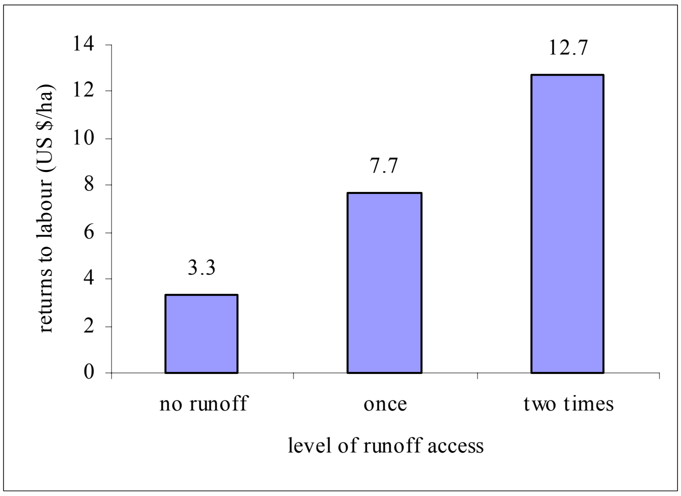


Figure 19 (c): Returns to labour from maize in B-average, 'masika' 2003

Performance of maize – lablab intercrop during 'masika, 2004 – B-average season

Figure 20(a) indicates that the yield of maize intercropped with lablab improved with improving level of runoff access. The yield of lablab improved from 0 ton/ha with no runoff access to 0.5 ton/ha with one runoff event. Financial performance in relation to returns to labour and land also improved with improving level of runoff access (Figures 20 c & d). Rigorous statistical analyses were not done due to limitation in the number of observations.

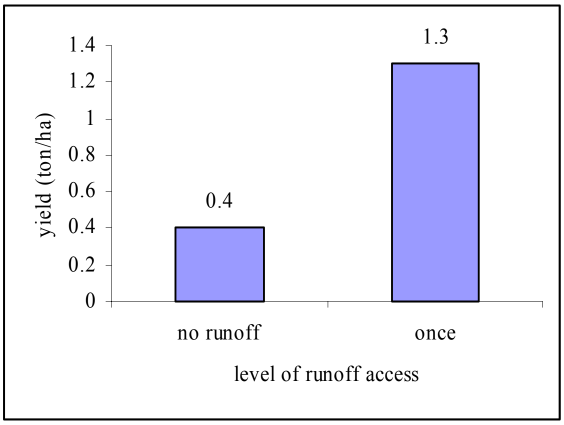


Figure 20 (a): Yield of maize intercropped with lablab in B-average, 'masika' 2004

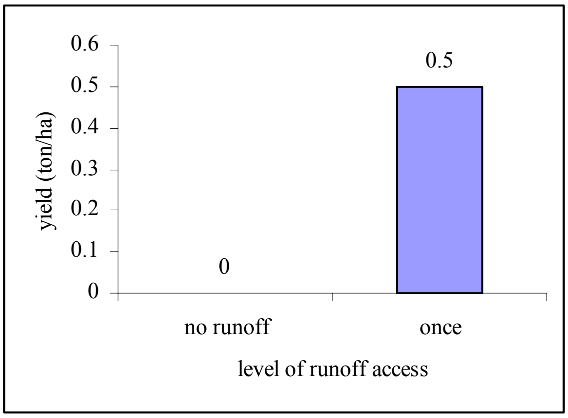


Figure 20 (b): Yield of lablab intercropped with maize in B-average, 'masika' 2004

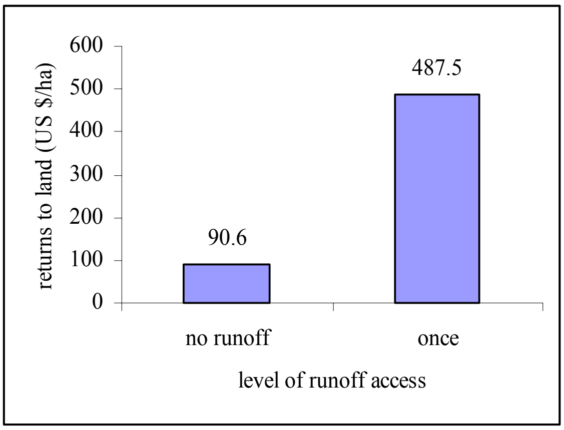


Figure 20 (c): Returns to land from maize – lablab intercrop in B-average, 'masika' 2004

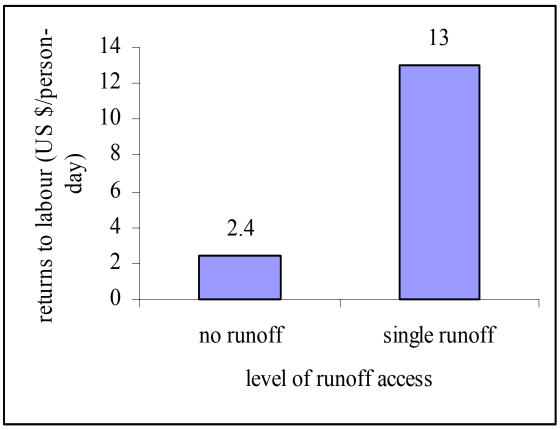


Figure 20 (d): Returns to labour from maize – lablab intercrop in B-average, 'masika' 2004

Performance of maize – lablab intercrop during 'masika, 2003 – B-average season

Figures 21(a & b) indicate that the yield of intercropped maize and lablab improved with level of runoff access. Maize yield was zero when the runoff events were zero or one. However, with two runoff events, the yield was 1.1 ton/ha. Likewise, for lablab two runoff events gave yield of up to 1.9 ton/ha compared to 0.3 and 0.03 ton/ha obtained with none and one runoff event respectively. Returns to land and labour also improved with improving access to runoff (Figures 21(c & d)). Despite the fact that the observations were not adequate for statistical tests of significance, but the rationale of runoff agriculture could still be realized.

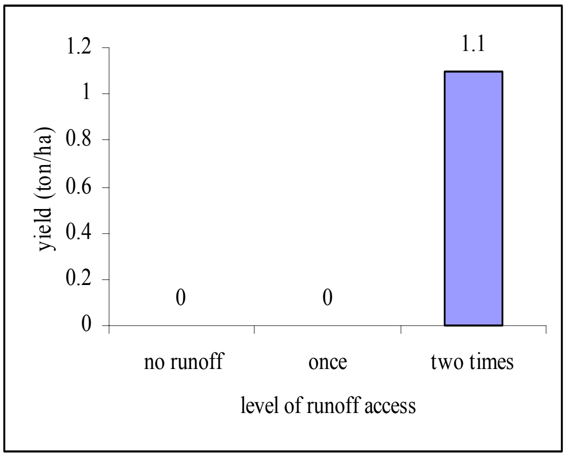


Figure 21 (a): Yield of maize intercropped with lablab in B-average, 'masika' 2003

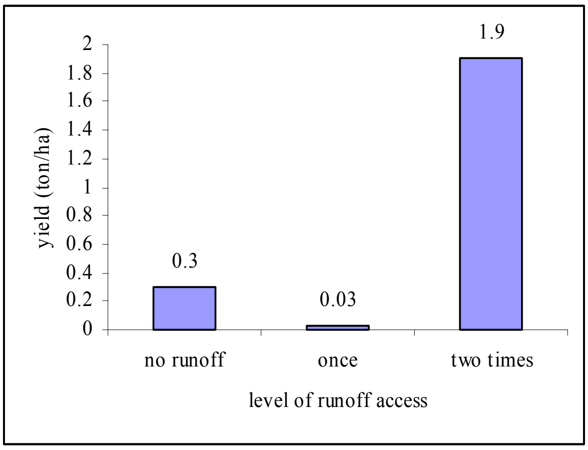


Figure 21 (b): Yield of lablab intercropped with maize in B-average, 'masika' 2003

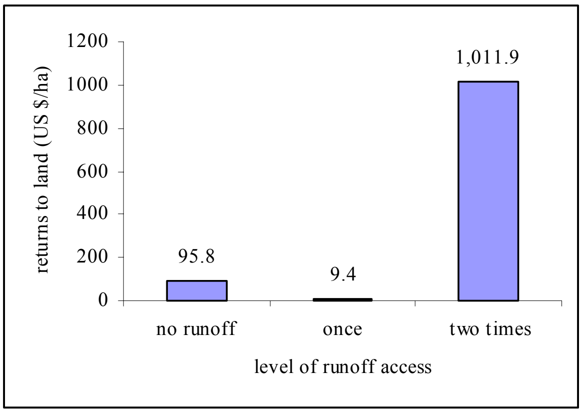


Figure 21 (c): Returns to land from maize – lablab intercrop in B-average, 'masika' 2003

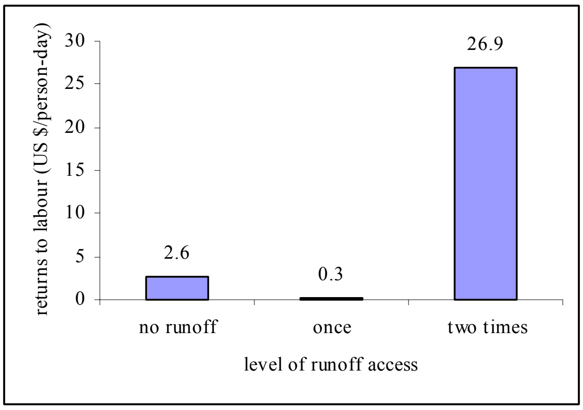


Figure 21 (d): Returns to labour from maize – lablab intercrop in B-average, 'masika' 2003

Performance of sole lablab during 'masika, 2004 – B-average season

Performance of sole lablab during 'masika' season of 2004 was assessed with respect to four scenarios of rainwater access. These were no runoff situation, one runoff event, two runoff events, and three runoff events. The fist two scenarios had sufficient observations that enabled rigorous statistical tests of significance to be undertaken. Peak yields and consecutive returns to land and labour were realized with a single and two runoff events (Figures 22(a, b, & c)). Surprisingly, the yield dropped to 0.2 ton/ha with three runoff events from a peak of 0.8 ton/ha. Though it is known that lablab crop is sensitive to water logging but the observations for two and three runoff scenarios were not sufficient to rely on. The no runoff and single runoff scenarios had a number of observations which could be subjected to statistical analysis. For these, it was observed that the yield, and financial returns to land and labour with a single runoff were significantly ($P < 0.01$) higher than that of no runoff, which is synonymous to rainfed system.

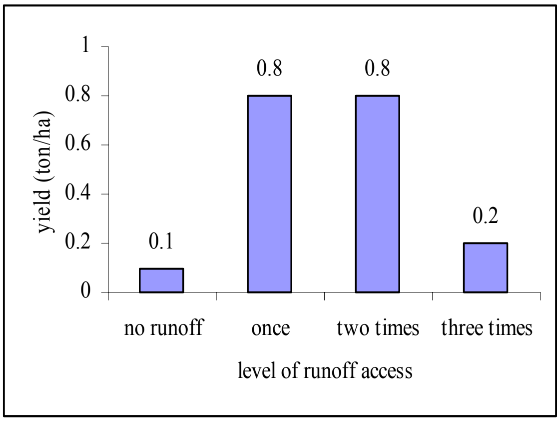


Figure 22(a): Yield of lablab in B-average, 'masika' 2004

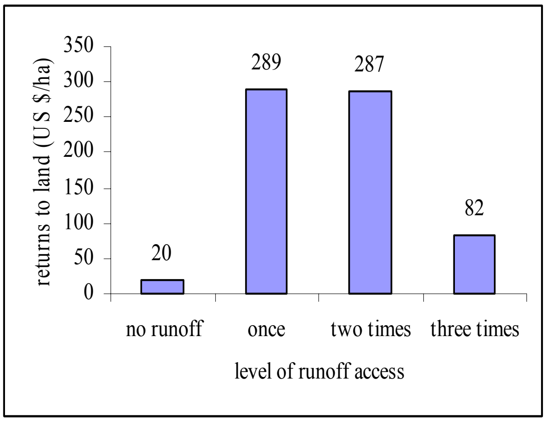


Figure 22(a): Returns to land from lablab in B-average, 'masika' 2004

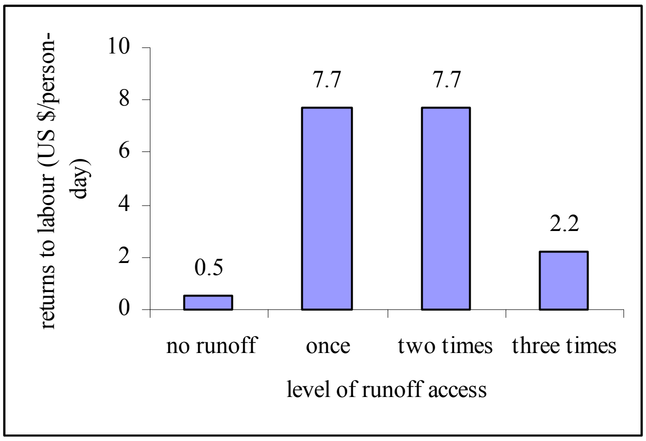


Figure 22(a): Returns to labour from lablab in B-average, 'masika' 2004

Performance of sole lablab during 'masika, 2003 – B-average season

The performance in terms of yield, returns to land, returns to labour of sole lablab improved with improving level of access to runoff (Figure 23(a, b, & c)). The yields with single and two runoff events were five times higher than that obtained under rainfed system (no runoff). The two-runoff scenarios had only one observation hence was not subjected to rigorous statistics to test significance levels. Results from **u** test revealed that, the yield, and financial returns to land and labour with a single runoff event were significantly ($P < 0.01$) higher than that of no runoff. Conclusively, this means increasing runoff access contributes to improved performance of the lablab crop under RWH.

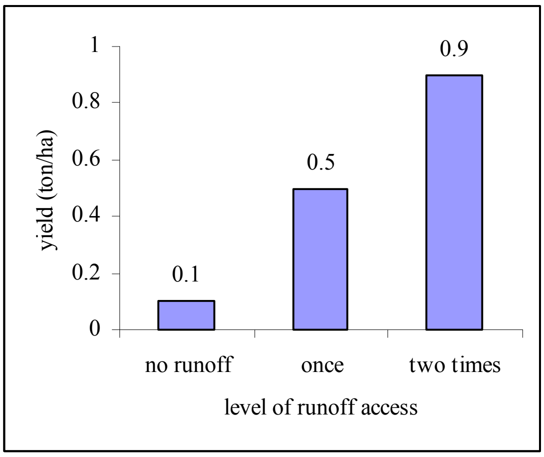


Figure 23(a): Yield of lablab in B-average, 'masika' 2003

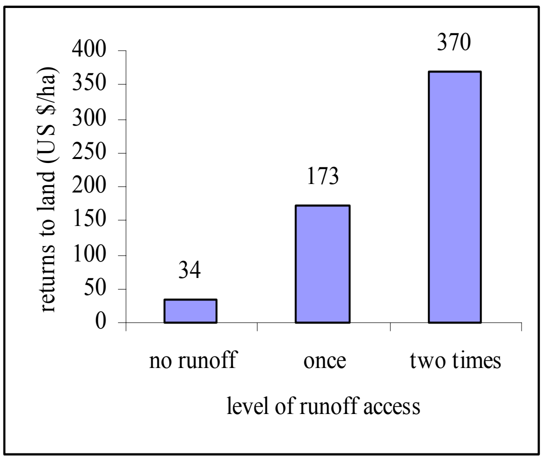


Figure 23(b): Returns to land from lablab in B-average, 'masika' 2003

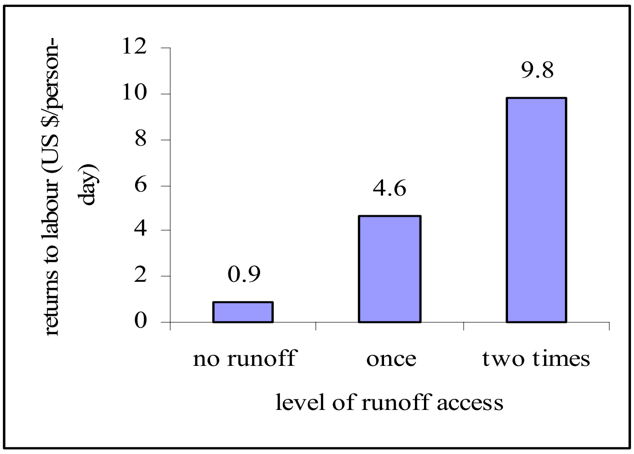


Figure 22(c): Returns to labour from lablab in B-average, 'masika' 2003

3.5.8 Economics of RWH in Livestock enterprise

3.5.8.1 Ownership of RWH structures for livestock

Rainwater harvesting (RWH) is being promoted widely as a technology to improve production of livestock and crops in semi-arid areas. Agro-pastoralists in semi-arid areas are already individually or communally adopting different RWH systems including construction of charco-dams, storage tanks, and extraction of water from beds of ephemeral sand rivers. Whereas a modest attempt has been made in terms of research on the economics of RWH for crop production, very little has been done for the case of livestock enterprise. Temporal mobility of livestock herds, during dry period in search of water from distant permanent water bodies makes it difficult to workout the actual benefits of RWH. The study has innovatively studied net benefit streams associated with RWH for livestock production with reference to cattle enterprise. Results in Table 45 indicate that, most of pastoralists (60%) who possessed own RWH storage structures were in the lower two quartiles and the remaining 40% were in the upper two quartiles. In Maswa as in Same district, proportions of agro-pastoralists dependence on communally owned water harvesting structures is somewhat invariant between the lower and upper quartiles. In Same district, majority of agro-pastoralists (58%) with private structures are found in the two upper quartiles (the relatively rich).

Table 45: Possession of private RWH structure by poverty level (%)

Quartiles	Possess private RWH structure	CPR dependent
Maswa:		
Lower two quartiles	60	54
Upper two quartiles	40	46
WPLL:		
Lower two quartiles	42	52
Upper two quartiles	58	48

3.5.8.2 Temporal pattern of sources of water for livestock

It is important to depict the temporal pattern of sources of water for livestock during a normal year in the semi-arid context. In Maswa district, the months from November to May are relatively wet, while the remaining months from June to October are dry. Sources of water for livestock vary with varying precipitation regime. Figure 14 shows that, during the wet months most of agro-pastoralists depend on ephemeral streams and other natural water ponds in the rangeland as sources of water for their animals. In Maswa, extraction of water from sand riverbeds for both livestock and domestic needs is very prominent and effective in supplying water even during critical dry months (see Figure 23). However, the problem related with such water harvesting system is lack of appropriate technology of extracting water without obstructing river flow in the next rainy season. The current practice involves digging within the river course and making heaps of sand that obstruct and diverts gully flows in the next rainy season. Distant permanent water bodies are important sources of water during critical dry periods.

However, distant search for water and pasture by moving large herds of animals across has been blamed for causing environmental degradation and being a source of bloody conflicts between pastoralists and farmers in the country. Harvesting of ground water by digging private shallow wells is among the reliable sources of water for livestock. Apparently, Figure 23 reveals that, rainwater harvesting using charco-dam structures is a stable source of water for animals across both wet and dry months of a normal year. This means somewhat proportion of agro-pastoralists with private charco-dams were able to use these structure as sources of water for animals all the year round.

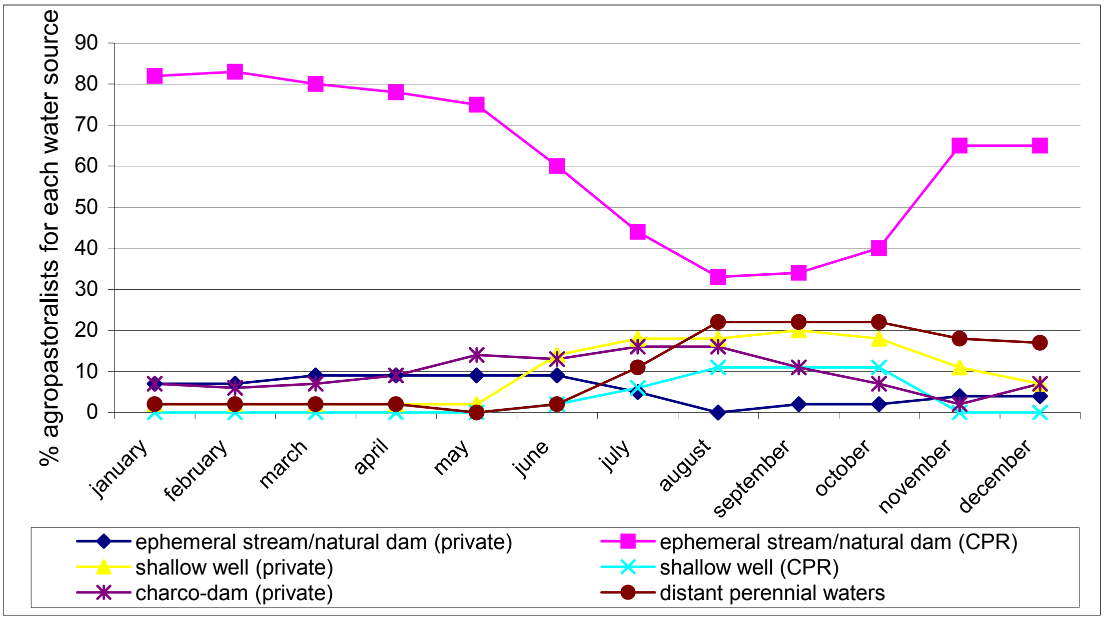


Figure 23: Temporal pattern of sources of water for livestock in Maswa

The results for Same district (Figure 24) when compared to that of Maswa (Figure 23), show resemblance but differ in some aspects as well. In Same district, a significant number of agro-pastoralists are dependent on distant perennial water bodies during critical dry months of August, September and October. As in the case of Maswa district, charco-dam are able to supply water constantly through both dry and wet months. Apparently, the use of private shallow wells as sources of water for livestock is not common in Same as compared to Maswa district.

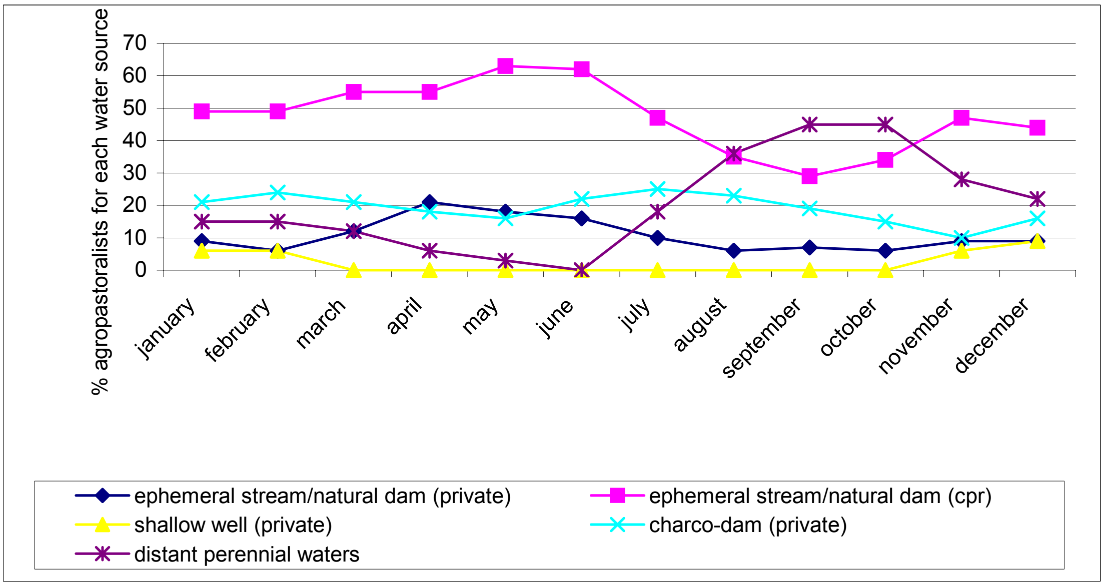
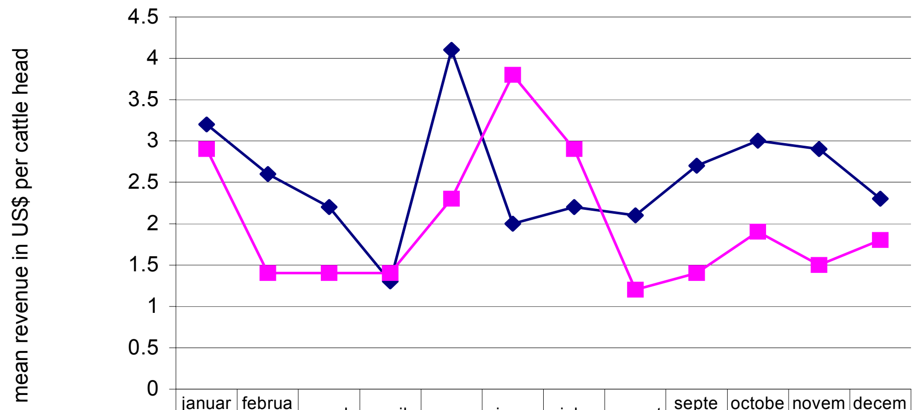


Figure 24: Temporal pattern of sources of water for livestock in WPLL

3.5.8.3 Revenue associated with RWH for livestock (cattle)

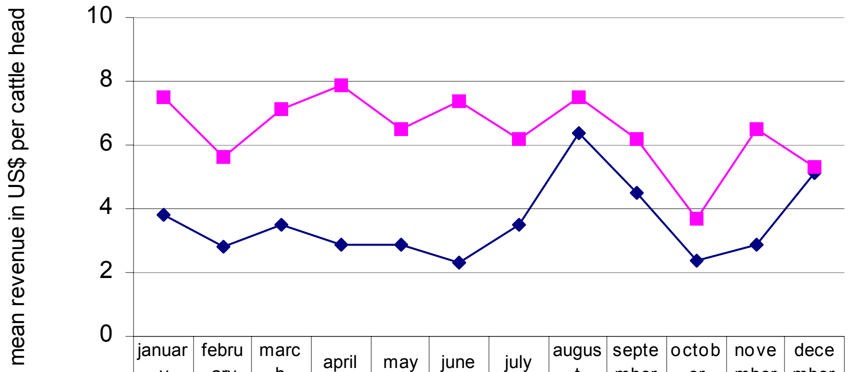
In order to arrive at elucidating the benefits of RWH, the monthly gross revenue from cattle for the whole year was compared for agro-pastoralists who have invested in private RWH structures and those who have not. The revenues were worked out by valuing the sales, home consumption and gifts of cattle and cattle products at current market prices. To enable cross-comparison of such revenues (scale economies), the revenues were expressed in terms of per cattle head for every household that owned cattle. The aim of this analysis was to reveal whether there are differential benefits that justify investment in RWH for livestock especially during critical dry months. Figure 25 shows that, in Maswa district gross revenues per cattle for households with private RWH structures exceeded that for households that depended on communal sources of water during critical dry months of August, September and October with 2.1 versus 1.2, 2.7 versus 1.4 and 3.0 versus 1.9 US $ per cattle head per month respectively. Such differences justify private investment in RWH microstructures (at affordable costs) for supplying water to livestock particularly during critical dry months.



	january	february	march	april	may	june	july	august	september	october	november	december
with private RWH structure	3.2	2.6	2.2	1.3	4.1	2	2.2	2.1	2.7	3	2.9	2.3
dependent on CPR water sources	2.9	1.4	1.4	1.4	2.3	3.8	2.9	1.2	1.4	1.9	1.5	1.8

Figure 25: Monthly mean revenue in US$ per cattle head with and without private RWH structure in Maswa

In Same district, Figure 26 indicates that, households that depended on communally owned water sources realized relatively high gross revenue than those with private structures. However, the level of gross revenue for the households with private RWH structure improved significantly during critical dry months. Such finding can be explained in a number of ways. Survey involved three villages along the watershed, that is, upstream, midstream and downstream. The downstream village is located in the driest lowland (rainfall as low as 200-400 mm per year) and in this place most of pastoralists have own RWH structures. Pastoralists in the lowland keep traditional cattle that give very low returns due to poor genetic potential. In the two villages up the catchment, livestock keepers are dependent on communal permanent springs starting from the Shengena forest catchment and most of the farmers keep dairy cattle that give higher returns. These may be some of the reasons as to why the mean gross returns for livestock keepers who had no private RWH structure surpassed their counterparts who have invested in RWH structures. This finding implies that, investments in RWH for livestock should go hand in hand with programmes for improving the genetic potential of animals to ensure higher returns from such investments. Given the fact that, capital should be allocated to the most rewarding alternative, investment in RWH for livestock enterprise should be guided by expected returns per unit of rainwater harvested. However, field interaction with farmers who own private charco-dams had extra benefits beyond financial revenue targeted by the survey. These include labour saving as temporal nomadic movement in search for water is now limited. This improves children attendance to school especially boys who would otherwise move with livestock. Also, as in other rural parts of Africa, livestock is a form of banking system.



	january	february	march	april	may	june	july	august	september	october	november	december
with private RWH structure	3.8	2.8	3.5	2.9	2.9	2.3	3.5	6.4	4.5	2.4	2.9	5.1
dependent on CPR water sources	7.5	5.6	7.1	7.9	6.5	7.4	6.2	7.5	6.2	3.7	6.5	5.3

Figure 26: Monthly mean revenue from cattle herd in US$ per cattle head with and without private RWH structure in Same

4 CONCLUSIONS

Based on the findings from this project, the following conclusions can be drawn.

i. Crop production and livestock farming are the major livelihood options in semi arid Tanzania. Diversification of sources of livelihoods is made between the two sub sectors, whereby the rich and male-headed households put equal importance on both sub sectors. On the other hand, the resource poor and female-headed households depend more on crop farming than livestock farming. More dependence on crop production which is critically affected by drought implies that resource poor farmers and female headed households are more at risks of vulnerability to weather and poverty shocks

ii. Poverty is a multi-factorial phenomenon and therefore cannot be ascertained using one approach. Some discrepancies were noted between subjective poverty and absolute poverty indicators. In some locations all individuals rated rich by subject assessment were found below the threshold using absolute dollar poverty criterion. This suggests that a combination of approaches need to be employed to assess poverty.

iii. Rainwater harvesting for crop production has a great potential of poverty reduction given impressive returns to land and labour even during B-average seasons.

iv. Despite the low physical productivities in terms of yield per unit land, intercropping of maize and lablab beans under different RWH systems in Same District accrued higher returns to land and labour. Such practice should be encouraged since it improved income and therefore reduced poverty. High returns realized here is because of the existing linkages to profitable markets of both maize grain and lablab beans in Arusha and Nairobi.

v. Generally, the performance of crop enterprises under different RWH systems in terms of physical productivity returns to land and labour is relatively good during A-average seasons. In addition, there are some cases of better performance during B-average seasons due to good rainwater management in the field. However, the trend of returns to land and labor of the RWH system is variable depending on seasonality, crop type, enterprises' cost structure, levels of output price and wages. Therefore, efforts of improving the performance of RWH should be inclusive of entrepreneurial strategies that can improve profitability particularly through increased market access and linkages.

vi. Due to the benefits of RWH for livestock, some pastoralists have started to invest in RWH structures to improve water availability for their animals. Experience from WPLL has shown that, pastoralists are able and willing to invest in RWH structures through participatory advocacy and technological support is still needed.

vii. RWH has demonstrated the potential of reducing vulnerability as it smoothen the effects of the poor distribution of rainfall and dry spells manifesting in B-average years. Specifically, RWH with external catchment, RWH linked to road drainage and RWH with reservoir improved yield, return to land and labour from RWH based crop enterprises.

viii. The role of RWH should be assessed in the livelihood context in conjunction with a multitude of other livelihood options. Therefore, improvement of livelihood and subsequent poverty reduction requires similar emphasis to be accorded for non-farm activities in order to optimize the idle labour available during off-season.

ix. Further, a broad approach to encourage enterprising in and beyond agriculture will assist in the flexible formation and movement of capital resources across a wider range of micro-investment opportunities.

References

Anschutz, J., A. Kome, M. Nederlof, R. de Neef and van de Ven, T. (1997). Water Harvesting and Soil moisture retention. Agrodok-series No. 13, CTA, Wageningen, The Netherlands. pp 92.

Barron, J., J. Rockström, F. Gichuki, N. Hatibu (2003) Dry Spell Analysis and Maize yields for Two Semi-arid Locations in East Africa. Agricultural and Forest Meteorology 117 (1-2): 23 - 37

Bourn, David and Roger Blench (editors) (1999), Can Livestock and Wildlife Co-exist? An interdisciplinary Approach, Overseas Development Institute, London.

Deaton, A. and Zaid, S. (2002). Guidelines for Construction Consumption Aggregates for Welfare Analysis. The Living Standards Measurement Study, LSMS Working Paper No. 135. The World Bank, Washington D.C. USA. 104 pp.

FEWSNET. (2003). Tanzania Food Security Report: December 22, 2003. Famine Early Warning Systems Network (FEWS NET). Dar es salaam. pp7.

FIST (2003). Food Security Information Team Report on Crop and Food Situation in Tanzania, 9th April 2003. Disaster Management Department in the Prime Minister's Office. Dar es salaam. pp6.

Fox, P., J. Rockstrom and Barron, J. (2000). Risk Analysis and Economic Vialbility of Water Harvesting for Supplemental Irrigation in Semi-arid Burkina Faso and Kenya. CNRT/INERA. Ouahigouya, Burkina Faso. 19pp.

Gowing, J. W.; H. F. Mahoo, O. B. Mzirai and N. Hatibu (1999). Review of Rainwater Harvesting Techniques and Evidence for their Use in Semi-Arid Tanzania. Tanzania Journal of Agricultural Sciences Vol. 2(2): 171 –180

Hatibu N. and H.F. Mahoo [eds] (2000). Rainwater Harvesting for Natural Resources Management: A planning guide for Tanzania. Technical handbook No. 22, ISBN 9966-896-52-x, Sida Regional Land Management Unit (RELMA), Nairobi. 136 pp

Hatibu, N. (2000). Introduction. In: Rainwater Harvesting For Natural Resource Management: A planning Guide for Tanzania. Hatibu, N. and Mahoo, F. (Eds). Technical Handbook No. 22. RELMA, Nairobi. pp 1-5.

Hatibu, N., H.F. Mahoo, E. Lazaro, and F.B. Rwehumbiza and A.M. Bakari (1999). Soil and Water Conservation in Semi-arid Areas of Tamzania: National Policies and Local Practices. Tanzania Journal of Agricultural Sciences 2(2) 151-170.

Hatibu, N.; K. Mutabazi; E. M. Senkondo and A.S.K. Msangi (2004). Economics of Rainwater Harvesting for Crop Enterprises in Semi-Arid Areas of East Africa. © 2004 "New directions for a diverse planet". Proceedings of the 4th International Crop Science Congress,26 Sep – 1 Oct 2004, Brisbane, Australia. Published on CDROM. Web site www.regional.org.au/au/cs

Mahoo, H.F., M.D.B. Young and O.B. Mzirai (1999). Rainfall Variability and its Implications for Transferability of Experimental Results in the Semi-Arid Areas of Tanzania. Tanzania Journal of Agricultural Science, Vol. 2 No. 2: 127-140.

Meertens, H.; L. Ndege and P. Lupeja (1999) The cultivation of rainfed lowland rice in Sukumaland, Tanzania. Agricultural Ecosystems and Environment 76:31-45.

Mutabazi, K., E. Senkondo, B. Koda, N. Hatibu, B. Mbilinyi, F. Rwehumbiza and Mahoo, H. (2004). Encouraging Investment in Land productivity in Semiarid Areas by Reducing Water Supply Risk and Linking Farmers to Profitable Markets. A Paper Presented at the 22nd Annual Conference of Soil Science Society of East Africa (SSSEA) held in Arusha, Tanzania from 29th Nov to 4th of December 2004 on 'Land Resources Management to Enhance Livelihood of Land users'.

Msangi, A.S.K, E.M Senkondo, E. Lazaro, K.M Mutabazi and N Hatibu (2005) Transaction Costs of Rainwater Harvesting System Management and their Effects on Access to Runoff Resource. Proceedings of East Africa River Basin Management, 7 - 9 March 2005, Morogoro, Tanzania.

Ngana, J.O. (1990). Modelling for periodic features in seasonal rainfall and its implications to water resources and agricultural planning. Institute of Resources Assessment, Research Report No. 60. University of Dar es salaam. 27pp.

Johnsson, L.O. (1996) Rainwater Harvesting to Avoid Drought. Proceedings of SEASAE International Conference, SWMRG, Morogoro. pp 82 – 91.

Kisanga, D. (2002). Soil and Water Conservation in Tanzania – A Review. In: Rethinking Natural Resource degradation in Sub-Saharan Africa: Policies to support sustainable soil fertility management, soil and water conservation among resource-poor farmers in semi-arid areas. Vol. 1- Country Overviews. Tom, S. and Roger, B. (Eds) University of Development Studies, Tamale Ghana. pp V1 - 62.

Kunze, D. (2000) Economic Assessment of Water Harvesting Techniques: A demonstration of Various Methods. Quarterly Journal of International Agriculture.39 (1): 69-91

Lazaro, E.A., E.M. Senkondo and Kajiru, G.J. (2000). In: Rainwater Harvesting For Natural Resource Management: A planning Guide for Tanzania. Hatibu, N. and Mahoo, F. (Eds). Technical Handbook No. 22. RELMA, Nairobi. pp 87-100.

Mahoo, H.F, M.D.B. Young and O.B. Mzirai (1999). Rainfall Variability and its Implications for the Transferability of Experimental Results in Semi-arid Areas of Tanzania. Tanzania Journal of Agricultural Sciences 2(2) 127-140.

Mascarenhas A. (1995) The Environment under Structural Adjustment in Tanzania with Specific Reference to the Semi-arid areas, In: Bagachwa, M.S.D and F Limbu (eds). Policy Reform and the Environment in Tanzania.

Mkenda, A.F., Luvanda E.G., Rutasitara, L and A. Naho (2004). Poverty In Tanzania: Comparisons Across Administrative Regions. An Interim report, University of Dar es salaam, Tanzania.

Mwisomba and Kiilu (2001). Demographic Factors, Household Composition, Employment and Household Welfare. REPOA Research Report No. 01.5 pp 48. Dar es salaam.

Rockstrom, J. (2000). Water Resources Management in Smallholder Farms in Eastern and Southern Africa: An Overview. Phys. Chem. Earth (B) 25(3), 275-283.

Senkondo, E.M.M, A.S.K. Msangi, P. Xavery, E.A. Lazaro and Hatibu, N. (2004). Profitability of Rainwater Harvesting for Agricultural Production in Selected Semi-Arid Areas of Tanzania. Journal of Applied Irrigation Science, 39(1): pp 65-81.

United Republic of Tanzania (URT) (2001). Agricultural Sector Development Strategy. National Printing Company (NPC-KIUTA). Dar es salaam. 79 pp.

United Republic of Tanzania (URT) (2002a). Water Policy. Ministry of Water and Livestock Development. Dar es salaam (Swahili version). 90 pp.

United Republic of Tanzania (URT) (2002b). National Census. www.tanzania.go.tz/economicsurveyf.html.

United Republic of Tanzania (URT) (2003). Economic Survey. www.tanzania.go.tz/economicsurveyf.html.

Van Koppen, B. (2002). Water Reform in Sub-Saharan Africa: What is the Difference? A paper presented at 3 rd WaterNet/Warfsa Symposium 'Water Demand Management for Sustainable Development', Dar es Salaam, 30-31 October 2002. pp 8.

Worl Bank, (1996). Tanzania, The Challenge of Reforms: Growth, Incomes and Welfare. Vol. II. Report No. 14982-TA. Wold Bank, Washington D.C.

List of Appendices

Appendix 1: Project Logframe

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**			
Purpose			
Understanding by relevant stakeholders, of the benefits of RWH in relation to poverty reduction, **Improved** and **Enhanced**	From 2004, District Agricultural Development Programs (DADP) in at least one target district, contains ex-ante analysis and economic benefits to justify programme activities in RWH	Approved DADP Documents SWMRG monitoring and evaluation reports	The Agricultural Sector Development Strategy (ASDS) and Rural Development Strategy (RDS) are implemented as planned
Outputs			
1. Information on livelihood-related economics of RWH adoption, which is relevant to planners in the target districts, **Produced**	By June 2004, a database of Economics of RWH available By Sept 2004, results from poverty analysis are compiled and shared with relevant stakeholders	Poverty analysis reports available in the target districts	Market orientation will be adopted in the development of DADPS
2. Knowledge Sharing Products (KSPs) **Developed** and **Used** to communicate results	By June 2003, demand (type and form) for KSPs established By June 2004, draft KSPs evaluated by a sample of the relevant stakeholders By December 2004, KSPs are distributed and accessible to relevant stakeholders at regional, national and local levels		

Narrative	Milestones	Assumptions
Output 1	**2003 February**, survey questionnaires tested and finalized	
1.1 Test and Finalize questionnaires (income, yields and forward linkages)	**2003 June**, information demanded by key stakeholders regarding economics of RWH, understood and KSP identified	
1.2 Select representative samples for categories of farmers (see R8115/6), Enterprises & RWH systems		
1.3 Conduct survey in both WPLL and Maswa.	**2003 June**, 1st round of PRA and questionnaire survey completed	
1.4 Under-take direct observations of sub-samples to obtain data for verification (over 4 seasons)	**2003 December**, 2nd round of survey completed	
1.5 Analyse data and develop database	**2004 June**, technical report of findings available	
1.6 Use the data to undertake analysis of impact on poverty	**2004 September**, Poverty analysis completed	
Output 2		
2.1 Confirm Knowledge Sharing Products (KSP) demanded by stakeholders (*refer to Pre-Nodal Meeting*)	**2004 December**, KSP distributed and FTR produced	
2.2 Design and test KSPs		
Produce and distribute KSPs		

Appendix 2: Household questionnaire

A: BACKGROUND INFORMATION
Respondent's Name______ ______________________
Name of enumerator_______ ____________________
Date of interview______________ _______________
Time started__________ Time finished_____________

Questionnaire ID ________________

Q1. Village name_______
Q2. Ward___________ __
Q3. Division_________ __
Q4. District__________ __

Q5. Were you born in this village? [ ]1= Yes 2= No

Q6. In case you were not born in this village fill in the following table

Where migrated from (village, district)	Year of migration	Reason for migration

Codes
Reasons for immigration
1 = Marriage, 2 = Accompanied parents, 3= Farming in RWH served area, 4= Employment transfer, 5= Searching for wage work, 6= Other(s) Specify

Q7. Are you married? [__]
1= Yes, still together 2 = Yes, separated 3 = No, Single 4 = Widowed
5 = Other(s) Specify
If Yes, how many wives in the marriage___

Q8. Fill in the following household Roaster

Name	R/ship	Sex	Age	Health	Education	Working on farm	Yrs in education	Other occupation
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								
9.								
10.								
11.								

Codes

Relationship with head
1= Head
2= Spouse
3= Child
4= Father
5= Mother
6= Other relative
7= Non relative

Sex
1= Male
2= Female

Health status
1= Able
2= Very young
3= Very old
4= Disabled/permanently sick

Education
1= None
2= Std 4
3= Std 8
4= Adult education
5= Primary school
6= Secondary school
7= Collage
8= University

Working on farm
1 = Doesn't participate in farming
2 = Rarely participate in farming
3 = Always/frequently participate in farming

Other main occupation
1= None
2= Herding/stockman
3= Salaried employment
4= Businessman/woman
5= Handcraft
6= Student
7 = Others (specify) ______

B: ECONOMICS OF WATER HARVESTING FOR CROP AND LIVESTOCK PRODUCTION

Q9a: Performance of RWH based crop enterprises, Maswa

SN	Crop enterprises	2003		2002		2001		2000		1999		1998	
		Acres	Yield	Acres	Yield	Acres	Yield	Acres	Yield	Acres	Yield	Acres	Yield
1	Sorghum (rainfed)												
2	Maize (rainfed)												
3	Maize (insitu)												
4	Cotton (rainfed)												
5	Cotton (*insitu*)												
6	Paddy (micro-catchment)												
7	Paddy (macro-catechment)												

Q9b: Performance of RWH based crop enterprises (Masika), WPLL

SN	Crop enterprises	2003		2002		2001		2000		1999		1998	
		Acres	Yield	Acres	Yield	Acres	Yield	Acres	Yield	Acres	Yield	Acres	Yield
1	Maize (rainfed)												
2	Maize (*insitu*)												
3	Maize (external catchment)												
4	Maize_Lablab (rainfed)												
5	Maize_Lablab (*insitu*)												
6	Maize_Lablab (external catchment)												
7	Lablab_Maize (rainfed)												
8	Lablab_Maize (*insitu*)												
9	Maize_Beans (rainfed)												
10	Maize_Beans (insitu)												
11	Maize_Beans (external catchment)												
12	Beans_Maize (rainfed)												
13	Beans_Maize (insitu)												
14	Beans_Maize (external catchment)												

Q9c: Performance of RWH based crop enterprises (vuli), WPLL

SN	Crop enterprises	2003		2002		2001		2000		1999		1998	
		Acres	Yield	Acres	Yield	Acres	Yield	Acres	Yield	Acres	Yield	Acres	Yield
1	Maize (rainfed)												
2	Maize (*insitu*)												
3	Maize (external catchment)												
4	Maize_Beans (rainfed)												
5	Maize_Beans (insitu)												
6	Maize_Beans (external catchment)												
7	Beans_Maize (rainfed)												
8	Beans_Maize (insitu)												
9	Beans_Maize (external catchment)												

Q9d: Average commodity prices and individual perception for that year with respect to rainfall amount

Crop	2003	2002	2001	2000	1999	1998
Prices:						
Sorghum (Unit price)						
Maize (Unit price)						
Cotton (Unit price)						
Paddy (Unit price)						
Lablab (Unit price)						
Beans (Unit price)						
Seasonality perception*:						

*Codes for Seasonality: **1= Above average 2= Below average**

10. CROP ENTERPRISES COSTS SHEET [QUESTIONNAIRE ID__________ENTERPRISE ID_____________________________________SEASON_________].

	Hhd members who work always on the farm				2005/2004		2003/04		2002/03		2001/02		2000/01		1999/00		1998/99	
	Adult(≥ 15 yrs)		Child(< 15yrs)		Cost	PD	Cost	PD	Cost	PD	Cost	PD	Cost	PD	Cost	PD	Cost	PD
	n	hrs/day	n	hrs/day														
Ploughing (cultivation and excavation of irrigation canals)																		
Ploughing: oxen																		
Seed																		
Fertilizer: FYM																		
Fertilizer: Inorganic																		
Chemicals																		
Storage bags																		
Planting																		
Fert./chem appl.																		
Weeding (all)																		
Harvesting																		
Transporting																		
Shelling																		
Strc. Main. Costs																		
Land rent																		
Marketing costs																		

Q11. Economics of rainwater management for Livestock enterprise

Water sources, access and seasonality (during a normal year in the dryland contet)

Months	Source	Pasture availability	No. of stock retained during water crisis (possible as a result of RWH)				Average income/benefits (TAS) from animals eclusively dependent on harvested water (sales and home consumption of animals and products e.g. milk, hides & skins, manure)			
			Cattle	Goats	Sheep	Donkey	Cattle	Goats	Sheep	Donkey[1]
January										
February										
March										
April										
May										
June										
July										
August										
September										
October										
November										
December										

Codes:

Source of water: 1= ephemeral stream/dam (private element), 2= ephemeral stream/dam (CPR), 3= well (private), 4= well (CPR), 5= charco-dam private, 6= distant perennial water bodies

Pasture availability in the vicinity: 1= Adequate (no distant search/herd split), 2= somewhat inadequate (distant search), 3= seriously inadequate (herd split), 4= very seriously inadequate (moving out the entire herd)

C: INCOME FROM OFF-FARM LIVELIHOOD OPTIONS

Q12. Please quantify the income sources for the PAST 6 years from off-farm activities and associated constraints

Source of income	Gross incomes (TAS/year)							
	2005	2004	2003	2002	2001	2000	1999	1998
Livestock production								
Business								
Remittances (monetize in-kind items)								
Wages/salary								
NR*-based (honey, charcoal etc)								
Artisan works (weaving, b. repair)								
Pension								

D: Land tenure and access to Rainwater/runoff

Q13. Size of land holdings, means of acquisition (tenure) and typology of access to rainwater

Farm ID	**Acreage**	Means of acquisition (tenure)*	Major water harvesting system*
1			
2			
3			
4			
5			
6			

Codes:

Land acquisiotion: 1= opened new land, 2= inherited, 3= purchased, 4= given by village government, 5= granted by relative/friend, 5= rented in, 6= rented out, 7= borrowed temporal use

Water harvesting system: 1: rainfed, 2= enters with difficult, 3= channeled, 4= direct entrance

[1] Benefits of donkeys include sales plus the value of labor saved from draft services during the period when they are eclusively dependent on harvested water

E: CONSUMPTION EPENDITURE, ASSETS INVENTORY, HOUSING QUALITY AND LIVESTOCK HERD VALUE

Q14a Household consumption expenditure on food items

Food purchases					**Home production**				**In-kind**
[Food] consumed during the past 12 months	How many months in the past 12 months did you purchase [food]?	In a typical month during which you purchased [food] how much did you purchase?	How much would you normally have to spend in total to buy this quantity?	How much in total have you spend on [food] last 12 months?	How many months in the past 12 months did you consume [food] that you produced yourself?	In a typical month during which ate own-produced [food] How much did your household consume?	How much your household would have spent to buy this quantity of [food] from the market?	How much in total is the value of own-produced [food] ate at the household for the past 12 months?	What is your total value of [food] consumed that you received in-kind over the past 12 months?
Food items	**Months**	**Amount (unit)**	**TAS**	**TAS**	**Months**	**Amount (unit)**	**TAS**	**TAS**	**TAS**
Maize									
Maize flour									
Rice/paddy									
Cassava									
Sorghum									
Millet									
Beans									
Lablab									
G'nuts									
Cowpeas									
Pigeon peas									
Banana									
Sweetpotatoes									
Irish potatoes									
Vegatables									
Fruits									
Meat									
Poultry									
Milk									
Fish (large+dagaa)									
Sugar									
Wheat									
Edible oil/fat									
Other(specify)									

Q14b. Household expenditure on non-food items

[Item] consumed in the past 12 months	**What is the money value of the amount purchased or received in-kind by you household in the past**	
	30 days (TAS)	**12 months (TAS)**
Consumer goods (household items, clothes, footwear)		
Medical expenses		
Development levies, taxes, cess, license, fees		
Social occasions (funerals, weddings, ngoma etc)		
Drinks, refreshments		
Gifts		
Transport & fare		
House repair		
Water bills or costs		
Electricity, kerosene, charcoal, firewood, candles, battery		
Education expenses (fees, contributions, school stationeries)		
Other(s) Specify		

Q14c. Housing quality (main dwelling) ***(Ask rent for WPLL was not asked in the first survey)***

Construction			**No. of rooms occupied by people**	**No. rooms for other purposes (kitchen, store, toilets, shop etc)**	**Total rooms**	**No. of people sleeping in the house**	***Monthly rent (eplicit/implicit)***
Roof	Wall	Floor					

Codes:
Construction:
Roofing: 1= Iron sheet, 2= Metal remnants, 3= Plastic material, 4= Grass/mud/cowdung
Wall: 1= Cement blocks, 2= Burnt earth bricks, 3= Raw earth bricks, 4= Mud/cow dung
Floor: 1= Cement, 2= Earth

Q14d. Livestock herd value

Item/Livestock	**Adults**		**Calves/yearlings**	
	No.	**Total value**	**No.**	**Total value**
Cattle:				
Goats:				
Sheep:				
Chicken:				
Donkeys:				

Q14e. Household inventory of durable items

[Item] owned by the household	Year bought, received *If more than one item ask about most recently acquired item*	How many does your household own now? *If more than one item ask about most recently acquired item*	*How did you got it?	How much was it worth when you acquired it?	If you wanted to sell this [item] today how much would you receive for it? *If more than one item ask about total value of all items*
House					
Radio					
Sprayer					
Sewing machine					
Bicycle					
Motorcycle					
Canoe/boat					
Boat engines					
Fishing nets					
Car/vehicle					
Tractor					
Spongy mattress					
Torch					
Hurricane lamp					
Charcoal stove					
Kerosene stove					
Hand hoe					
Ae					
O-implements					
O-cart					
Panga					
Debe/drum					
Television set					
Refrigerator					

Appendix 3: Acreage correction factor regression results and scatter plots

Regression results of acreage correction factor, Maswa & WPLL

Variable	Coeff.	Std Error	t	P > | t |
Maswa site:				
Acreage cited	0.355	0.016	22.27	0.000
Constant	0.042	0.033	1.28	0.21
WPLL site:				
Acreage cited	0.832	0.107	7.77	0.000
Constant	-0.341	0.154	0.22	0.827

Model information: Maswa	***Model information: WPLL***
Dep. Variable = measured acreage (acres)	Dep. Variable: measured acreage (acres)
# of observations = 54	# of observations = 18
Prob. > F = 0.000	Prob. > F = 0.000
R^2 = 91%, Ad. R^2 = 90%	R^2 = 79%, Ad. R^2 = 78%

b) Scatter plot with a line of best fit for acreage correction factor

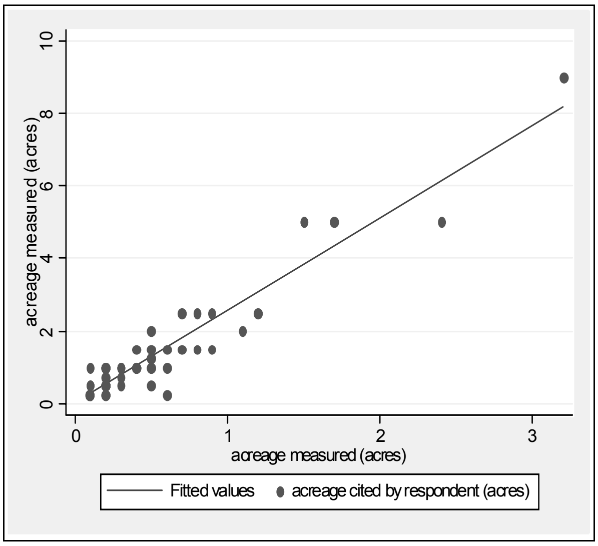


Figure 27: Scatter plot for Maswa Correction factor

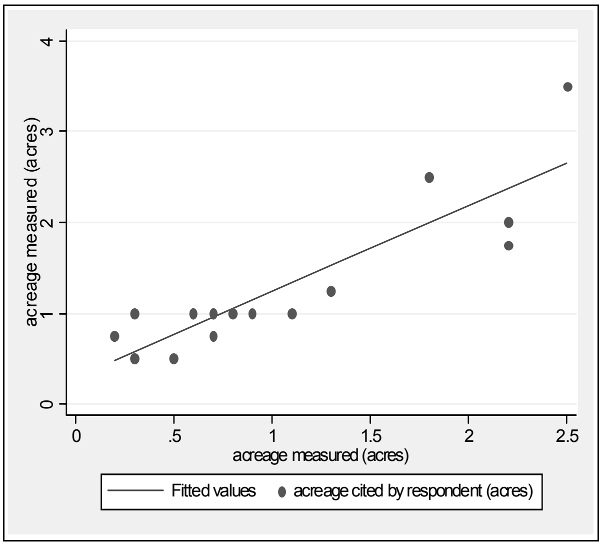


Figure 27: Scatter plot for WPLL Correction factor

Appendix 4.1: Performance Tables of Paddy and Vegetable enterprises under RWH systems

Table 11: Paddy under micro-catchment RWH, survey results - Maswa

Items	N	Mean	St error	Std	Skewness	Kurtosis
Above average seasons:						
Yield (ton/ha)	43	4.7	0.5	3.2	0.859	-0.092
Returns to land (US $/ha)	43	701.0	75.1	492.4	0.935	0.180
Returns to labour (US $/person-day	43	6.1	1.4	8.9	3.268	11.015
Below average seasons:						
Yield (ton/ha)	30	2.6	0.4	2.2	2.090	6.268
Returns to land (US $/ha)	30	496.8	60.3	330.2	0.759	0.199
Returns to labour (US $/person-day)	30	12.2	2.9	15.7	3.804	17.305

Test results for A-average Vs B-average seasons

Yield **u** = 41.157 (significant at 1%)
Returns to land **u** = 12.856 (significant at 1%)
Returns to labour **u** = 10.839 (significant at 1%)

Table 12: Paddy under macro-catchment RWH, survey results - Maswa

Items	N	Mean	St error	Std	Skewness	Kurtosis
Above average seasons:						
Yield (ton/ha)	35	5.9	0.6	3.3	1.419	1.498
Returns to land (US $/ha)	35	825.5	86.6	512.6	1.645	2.373
Returns to labour (US $/person-day	35	7.4	0.9	5.3	2.715	10.896
Below average seasons:						
Yield (ton/ha)	25	2.7	0.5	2.5	1.533	1.885
Returns to land (US $/ha)	25	611.5	125.3	626.3	1.838	3.309
Returns to labour (US $/person-day)	25	7.3	1.5	7.7	1.747	3.197

Test results for A-average Vs B-average seasons

Yield **u** = 23.283 (significant at 1%)
Returns to land **u** = 7.374 (significant at 1%)
Returns to labour **u** = 0.291 (not significant at 5%)

Table 13: Vegetables under RWH-reservoir, survey results - Maswa

Items	N	Mean	St error	Std	Skewness	Kurtosis
Above average seasons:						
Returns to land (US $/ha)	46	1,655.3	174.1	1,180.5	0.581	0.019
Returns to labour (US $/person-day	46	7.6	0.9	6.7	0.688	-0.232
Below average seasons:						
Returns to land (US $/ha)	35	1,515.0	218.7	1,293.9	1.171	0.828
Returns to labour (US $/person-day)	35	4.6	0.7	4.4	0.783	-0.129

Test results for A-average Vs B-average seasons

Returns to land **u** = 3.118 (significant at 1%)
Returns to labour **u** = 15.592 (significant at 1%)

Appendix 4.2: Performance Tables of Maize and Sorghum enterprise under RWH systems

Table 14: Performance of maize under rainfed system, survey results - Maswa

Items	N	Mean	St error	Std	Skewness	Kurtosis
Above average seasons:						
Yield (ton/ha)	81	2.3	0.3	2.7	6.529	51.221
Returns to land (US $/ha)	81	234.2	34.0	306.1	6.874	55.176
Returns to labour (US $/person-day	81	4.1	0.3	3.0	1.607	2.404
Below average seasons:						
Yield (ton/ha)	56	1.3	0.1	0.9	1.613	3.577
Returns to land (US $/ha)	56	181.4	19.2	143.9	2.096	7.159
Returns to labour (US $/person-day)	56	5.8	0.9	7.2	2.573	6.282

Test results for A-average Vs B-average seasons

Yield **u** = 27.023 (significant at 1%)

Returns to land **u** = 11.532 (significant at 1%)

Returns to labour **u** = 12.796 (significant at 1%)

Table 15: Performance of maize under in-situ RWH, survey results, Maswa

Items	N	Mean	St error	Std	Skewness	Kurtosis
Above average seasons:						
Yield (ton/ha)	22	2.2	0.3	1.6	2.060	5.969
Returns to land (US $/ha)	22	211.7	32.3	151.4	2.444	8.055
Returns to labour (US $/person-day	22	4.6	0.5	2.6	0.961	0.519
Below average seasons:						
Yield (ton/ha)	12	1.2	0.2	0.7	0.251	-0.607
Returns to land (US $/ha)	12	78.9	12.6	43.6	0.189	-0.550
Returns to labour (US $/person-day)	12	1.8	0.4	1.2	0.872	-0.523

Test results for A-average Vs B-average seasons

Yield **u** = 10.726 (significant at 1%)

Returns to land **u** = 17.065 (significant at 1%)

Returns to labour **u** = 18.086 (significant at 1%)

Table 17: Performance of sorghum under rainfed system, survey results - Maswa

Items	N	Mean	St error	Std	Skewness	Kurtosis
Above average seasons:						
Yield (ton/ha)	15	2.6	0.3	1.2	0.694	-0.022
Returns to land (US $/ha)	15	16.1	1.9	7.6	0.688	0.128
Returns to labour (US $/person-day	15	0.3	0.03	0.1	0.724	-0.110
Below average seasons:						
Yield (ton/ha)	10	2.3	0.4	1.4	0.961	-0.283
Returns to land (US $/ha)	10	31.1	7.2	22.7	1.099	-0.244
Returns to labour (US $/person-day)	10	0.4	0.1	0.3	2.166	4.613

Test results for A-average Vs B-average seasons:

Yield **u =** 1.861 (not significant at 5%)

Returns to land u = 6.449 (significant at 1%)

Returns to labour u = 3.254 (significant at 1%)

Appendix 4.3: Performance Tables of Cotton enterprise under RWH systems

Table 18: Performance of cotton under rainfed system, survey results - Maswa

Items	N	Mean	St error	Std	Skewness	Kurtosis
Above average seasons:						
Yield (ton/ha)	60	1.4	1.1	1.1	4.460	27.185
Returns to land (US $/ha)	60	275.4	31.1	240.7	4.886	30.879
Returns to labour (US $/person-day	60	8.9	1.7	12.9	3.000	9.223
Below average seasons:						
Yield (ton/ha)	34	1.2	0.1	0.6	1.366	3.021
Returns to land (US $/ha)	34	313.3	31.1	181.2	1.263	2.642
Returns to labour (US $/person-day)	34	7.2	1.3	7.7	2.607	7.487

Test results for A-average Vs B-average seasons

Yield **u** = 7.860 (significant at 1%)
Returns to land **u** = 5.682 (significant at 1%)
Returns to labour **u** = 5.444 (significant at 1%)

Table 19: Performance of cotton under in-situ RWH, survey results - Maswa

Items	N	Mean	St error	Std	Skewness	Kurtosis
Above average seasons:						
Yield (ton/ha)	3	1.4	0.2	0.3	0.892	-
Returns to land (US $/ha)	3	279.6	36.2	62.7	-0.667	-
Returns to labour (US $/person-day	3	2.3	0.3	0.4	-0.864	-
Below average seasons:						
Yield (ton/ha)	18	1.1	0.1	0.6	0.140	-0.950
Returns to land (US $/ha)	18	271.2	42.8	181.6	1.034	0.044
Returns to labour (US $/person-day)	18	6.5	2.0	8.8	3.621	14.165

Test results for A-average Vs B-average seasons

Yield **u** = 2.846 (significant at 5%)
Returns to land **u** = 0.362 (not significant at 5%)
Returns to labour **u** = 8.288 (significant at 1%)

Appendix 4.4: Performance Tables of paddy under RWH systems for monitored yield

Table 20: Performance of Paddy under micro-catchment for monitored yield, Maswa

Items	**N**	**Mean**	**St error**	**Std**	**Skewness**	**Kurtosis**
Above average season 2004:						
Yield (ton/ha)	30	4.2	0.3	1.7	0.364	0.485
Returns to land (US $/ha)	30	602.6	46.7	255.8	0.379	0.497
Returns to labour (US $/person-day	30	8.7	0.6	3.3	0.291	0.330
Below average season 2003:						
Yield (ton/ha)	28	3.0	0.3	1.5	2.117	5.892
Returns to land (US $/ha)	28	419.9	46.8	248.2	2.263	6.572
Returns to labour (US $/person-day	28	6.3	0.6	3.0	2.033	5.567

Test results for A-average Vs B-average season:

Yield **u** = 15.388 (Significant at 1%) Returns to land **u** = 14.854 (Significant at 1%)

Returns to labour **u** = 15.629 (Significant at 1%)

Table 21: Performance of paddy under macro-catchment for monitored yield, Maswa

Items	**N**	**Mean**	**St error**	**Std**	**Skewness**	**Kurtosis**
Above average season 2004:						
Yield (ton/ha)	42	4.7	0.3	1.8	1.462	3.430
Returns to land (US $/ha)	42	674.2	43.1	279.0	1.460	3.426
Returns to labour (US $/person-day	42	9.6	0.5	3.6	1.328	2.972
Below average season 2003:						
Yield (ton/ha)	51	3.8	0.2	1.5	0.656	0.361
Returns to land (US $/ha)	51	530.3	32.1	229.2	0.621	0.240
Returns to labour (US $/person-day	51	7.8	0.4	2.9	0.578	0.173

Test results for A-average Vs B-average season:

Yield **u** = 17.315 (Significant at 1%) Returns to land **u** = 17.942 (Significant at 1%)

Returns to labour **u** = 17.499 (Significant at 1%)

Table 22: Performance of paddy macro-catchment with storage pond for monitored yield, Maswa

Items	**N**	**Mean**	**St error**	**Std**	**Skewness**	**Kurtosis**
Above average season 2004:						
Yield (ton/ha)	4	4.8	0.5	1.1	-0.323	-3.033
Returns to land (US $/ha)	4	686.1	83.6	167.1	-0.294	-3.419
Returns to labour (US $/person-day	4	9.8	1.1	2.2	-0.307	-3.379
Below average season 2003:						
Yield (ton/ha)	5	2.5	0.3	0.7	-0.310	-2.362
Returns to land (US $/ha)	5	329.8	47.9	107.3	-0.209	-2.348
Returns to labour (US $/person-day	5	5.1	0.6	1.4	-0.218	-2.347

Test results for A-average Vs B-average season:

Yield **u** = 7.453 (Significant at 1%) Returns to land **u** = 7.587 (Significant at 1%)

Returns to labour **u** = 7.615 (Significant at 1%)

Table 23: Performance of paddy macro-catchment linked to road drainage for monitored yield, Maswa

Items	**N**	**Mean**	**St error**	**Std**	**Skewness**	**Kurtosis**
Above average season 2004:						
Yield (ton/ha)	5	5.3	0.9	2.1	-1.769	3.563
Returns to land (US $/ha)	5	766.9	145.5	325.3	-1.760	3.532
Returns to labour (US $/person-day	5	10.8	1.9	4.3	-1.794	3.621
Below average season 2003:						
Yield (ton/ha)	6	3.6	0.6	1.6	-0.067	-0.253
Returns to land (US $/ha)	6	510.0	101.4	248.3	-0.087	-0.279
Returns to labour (US $/person-day	6	7.5	1.3	3.3	-0.140	-0.261

Test results for A-average Vs B-average season:

Yield **u** = 3.417 (Significant at 1%) Returns to land **u** = 3.332 (Significant at 1%)

Returns to labour **u** = 3.233 (Significant at 1%)

Table 24: Tests of mean variation for paddy monitored yield, Maswa

RWH systems	Micro-catchment		Macro-catchment		Macro-storage		Macro-road drainage	
	A-av.	B-av.	A-av.	B-av.	A-av.	B-av.	A-av.	B-av.
Micro-catchment								
A-average		15.879	7.037	6.265	2.137	11.256	2.596	2.201
B-average			25.815	13.791	6.440	3.363	5.438	2.211
Macro-catchment								
A-average				17.315	0.359	15.026	1.421	4.073
B-average					3.616	9.087	3.563	0.745
Macro-storage								
A-average						7.453	0.996	3.133
B-average							6.325	3.652
Macro-road drainage								
A-average								3.417
B-average								

Appendix 4.5: Performance Tables of maize under RWH systems, WPLL

Table 26: Performance of maize under rainfed system during Masika, suvery results -WPLL

Items	N	Mean	St error	Std	Skewness	Kurtosis
Above average seasons:						
Yield (ton/ha)	12	1.7	0.3	0.9	0.458	-0.519
Returns to land (US $/ha)	12	135.4	22.6	78.4	0.697	-0.872
Returns to labour (US $/person-day	11	3.4	0.8	2.7	1.402	1.082
Below average seasons:						
Yield (ton/ha)	9	0.7	0.2	0.5	1.261	1.459
Returns to land (US $/ha)	9	91.3	25.1	75.2	0.758	-1.127
Returns to labour (US $/person-day)	8	1.9	0.8	2.3	2.043	4.716

Test results for A-average Vs B-average seasons

Yield **u** = 10.714 (significant at 1%)
Returns to land **u** = 4.158 (significant at 1%)
Returns to labour **u** = 3.968 (significant at 1%)

Table 27: Performance of maize under *in-situ* during Masika, survey results -WPLL

Items	N	Mean	St error	Std	Skewness	Kurtosis
Above average seasons:						
Yield (ton/ha)	4	1.0	0.4	0.7	0.705	-2.075
Returns to land (US $/ha)	4	101.5	45.3	90.5	0.101	-5.001
Returns to labour (US $/person-day	4	4.6	1.9	3.8	-0.020	-5.810
Below average seasons:						
Yield (ton/ha)	4	0.9	0.3	0.6	1.846	3.412
Returns to land (US $/ha)	4	65.4	13.1	26.2	0.294	-0.010
Returns to labour (US $/person-day)	4	2.6	0.6	1.1	-1.344	2.022

Test results for A-average Vs B-average seasons (paired sample T-test

Yield **t** = 0.059, df=3, P=0.957 (not significant at 5%)
Returns to land **t** = 0.684, df=3, P=0.543 (not significant at 5%)
Returns to labour **t** = 0.922, df=3, P=0.425 (not significant at 5%)

Table 28: Performance of maize external catchment (ex-situ) during Masika, survey results - WPLL

Items	N	Mean	St error	Std	Skewness	Kurtosis
Above average seasons:						
Yield (ton/ha)	26	1.8	0.2	0.9	0.519	-0.843
Returns to land (US $/ha)	26	180.9	22.5	114.5	0.940	-0.123
Returns to labour (US $/person-day	26	5.1	0.6	3.3	0.790	0.263
Below average seasons:						
Yield (ton/ha)	27	0.8	0.1	0.8	1.147	0.976
Returns to land (US $/ha)	27	130.2	28.9	150.3	1.322	1.048
Returns to labour (US $/person-day)	27	6.7	1.9	9.6	2.521	7.516

Test results for A-average Vs B-average seasons

Yield **u** = 21.947 (significant at 1%)
Returns to land **u** = 7.143 (significant at 1%)
Returns to labour **u** = 4.238 (significant at 1%)

Appendix 4.6: Performance Tables of maize-lablab intercrop under RWH systems, WPLL

Table 29: Peformance of maize+lablab beans under rainfed masika, survey results - WPLL

Items	**N**	**Mean**	**St error**	**Std**	**Skewness**	**Kurtosis**
Above average seasons:						
Yield (ton/ha): Maize	2	2.1	0.8	1.1	-	-
Yield (ton/ha): Lablab	2	0.7	0.2	0.4		
Returns to land (US $/ha)	2	385.1	87.5	123.8	-	-
Returns to labour (US $/person-day	2	11.6	7.7	10.9	-	-
Below average seasons:						
Yield (ton/ha): Maize	2	0.3	0.1	0.2	-	-
Yield (ton/ha): Lablab	2	0.3	0.1	0.1		
Returns to land (US $/ha)	2	149.3	19.5	27.5	-	-
Returns to labour (US $/person-day)	2	6.2	4.6	6.5	-	-

Test results for A-average Vs B-average seasons (paired sample T-test)

Yield: Maize **t** = 1.097, df=1, P=0.471 (not significant at 5%)
Yield: Lablab **t** = 2.600, df=1, P=0.234 (not significant at 5%)
Returns to land **t** = 2.204, df=1, P=0.271 (not significant at 5%)
Returns to labour **t** = 1.761, df=1, P=0.329 (not significant at 5%)

Table 30: Performance of maize+lablab under external catchment during masika, survey results WPLL

Items	**N**	**Mean**	**St error**	**Std**	**Skewness**	**Kurtosis**
Above average seasons:						
Yield (ton/ha): Maize	35	1.8	1.2	0.9	0.359	-0.531
Yield (ton/ha): Lablab	33	0.4	0.05	0.3	0.757	-0.181
Returns to land (US $/ha)	35	253.9	25.9	153.6	1.177	2.181
Returns to labour (US $/person-day	35	17.1	7.0	41.4	5.040	27.084
Below average seasons:						
Yield (ton/ha): Maize	36	1.0	0.2	1.1	1.567	2.193
Yield (ton/ha): Lablab	34	0.3	0.05	0.3	1.882	3.735
Returns to land (US $/ha)	37	213.8	36.2	219.9	2.164	6.247
Returns to labour (US $/person-day)	37	10.0	2.0	12.2	1.576	1.494

Test results for A-average Vs B-average seasons

Yield: Maize **u** = 20.032 (significant at 1%)
Yield: Lablab **u** = 78.934 (significant at 1%)
Returns to land **u** = 0.135 (not significant at 5%)
Returns to labour **u** = 0.814 (not significant at 5%)

Appendix 4.7: Performance of maize in short rains seasons Tables, WPLL

Table 31: Performance of maize under rainfed system during 'vuli', survey restults - WPLL

Items	N	Mean	St error	Std	Skewness	Kurtosis
Above average seasons:						
Yield (ton/ha)	17	0.9	0.2	0.8	1.722	2.260
Returns to land (US $/ha)	17	108.5	20.1	8.3	1.696	2.642
Returns to labour (US $/person-day	17	2.8	0.6	2.6	1.425	1.673
Below average seasons:						
Yield (ton/ha)	17	0.6	0.1	0.4	0.911	0.003
Returns to land (US $/ha)	17	97.1	19.1	78.6	1.458	2.786
Returns to labour (US $/person-day)	17	3.2	1.2	4.9	2.615	7.190

Test results for A-average Vs B-average seasons (paired sample T-test)

Yield **t** = 1.339, df=13, P=0.204 (not significant at 5%)
Returns to land **t** = 0.186, df=13, P=0.855 (not significant at 5%)
Returns to labour **t** = 0.909, df=13, P=0.380 (not significant at 5%)

Table 32: Performance of maize under in-situ during 'vuli', survey results - WPLL

Items	N	Mean	St error	Std	Skewness	Kurtosis
Above average seasons:						
Yield (ton/ha)	4	0.9	0.1	0.3	-0.514	-3.104
Returns to land (US $/ha)	4	106.9	17.1	34.1	0.312	-2.795
Returns to labour (US $/person-day	4	11.2	5.3	10.6	1.684	3.180
Below average seasons:						
Yield (ton/ha)	5	0.6	0.3	0.7	1.682	2.569
Returns to land (US $/ha)	5	90.6	45.8	102.3	1.706	2.739
Returns to labour (US $/person-day)	5	9.7	3.9	8.9	1.520	2.600

Test results for A-average Vs B-average seasons

Yield **u** = 1.889 (not significant at 5%)
Returns to land **u** = 0.735 (not significant at 5%)
Returns to labour **u** = 0.470 (not significant at 5%)

Table 33: Performance of maize under external catchment 'vuli', survey results - WPLL

Items	N	Mean	St error	Std	Skewness	Kurtosis
Above average seasons:						
Yield (ton/ha)	63	1.7	0.7	1.3	0.940	-0.135
Returns to land (US $/ha)	63	167.9	15.9	126.6	0.905	0.279
Returns to labour (US $/person-day	63	4.6	0.5	4.3	2.556	8.192
Below average seasons:						
Yield (ton/ha)	57	1.2	0.1	1.1	1.847	4.180
Returns to land (US $/ha)	57	193.5	26.5	199.7	1.831	3.473
Returns to labour (US $/person-day)	57	6.6	0.9	6.9	1.857	3.350

Test results for A-average Vs B-average seasons

Yield **u** = 17.697 (significant at 1%)
Returns to land **u** = 6.338 (significant at 1%)
Returns to labour **u** = 14.392 (significant at 1%)

Appendix 4.8 (i): Maize – Beans intercrop for long rains seasons Tables, WPLL

Table 34: Performance of mMaize+beans under rainfed system during 'masika', survey results - WPLL

Items	N	Mean	St error	Std	Skewness	Kurtosis
Above average seasons:						
Yield (ton/ha): Maize	6	0.9	0.2	0.5	0.220	-0.316
Yield (ton/ha): Beans	6	0.4	0.1	0.3	0.338	-1.345
Returns to land (US $/ha)	6	226.7	65.7	160.9	0.817	0.545
Returns to labour (US $/person-day	6	8.9	3.3	7.9	1.482	2.080
Below average seasons:						
Yield (ton/ha): Maize	6	0.8	0.3	0.7	0.315	-2.103
Yield (ton/ha): Beans	6	0.3	0.1	0.3	1.578	2.783
Returns to land (US $/ha)	6	252.7	92.6	226.7	0.108	-2.783
Returns to labour (US $/person-day)	6	6.8	2.4	5.7	1.450	2.273

Test results for A-average Vs B-average seasons (paired sample T-test)

Yield: Maize **t =** 1.128, df=5, P=0.310 (not significant at 5%)
Yield: Lablab **t =** 1.478, df=5, P=0.199 (not significant at 5%)
Returns to land **t =** 0.531, df=5, P=0.618 (not significant at 5%)
Returns to labour **t =** 1.287, df=5, P=0.225 (not significant at 5%)

Table 35: Performance of maize+beans external catchment during 'masika', survey results - WPLL

Items	N	Mean	St error	Std	Skewness	Kurtosis
Above average seasons:						
Yield (ton/ha): Maize	7	1.7	0.6	1.5	1.132	0.445
Yield (ton/ha): Beans	7	0.4	0.1	0.3	0.877	-1.383
Returns to land (US $/ha)	7	290.9	117.1	30.9	1.176	-0.773
Returns to labour (US $/person-day	7	6.2	1.7	4.6	0.246	-2.348
Below average seasons:						
Yield (ton/ha): Maize	6	1.2	0.7	1.6	2.264	5.220
Yield (ton/ha): Beans	6	0.3	0.1	0.3	-0.103	-2.882
Returns to land (US $/ha)	6	329.4	159.3	390.2	2.038	4.582
Returns to labour (US $/person-day)	6	7.1	2.2	5.5	1.000	2.046

Test results for A-average Vs B-average seasons

Yield: Maize **u =** 1.462 (not significant at 5%)
Yield: Beans **u =** 1.519 (not significant at 5%)
Returns to land **u =** 0.591 (not significant at 5%)
Returns to labour **u =** 0.798 (not significant at 5%)

Appendix 4.8 (ii): Maize – Beans intercrop for long rains seasons Figures, WPLL

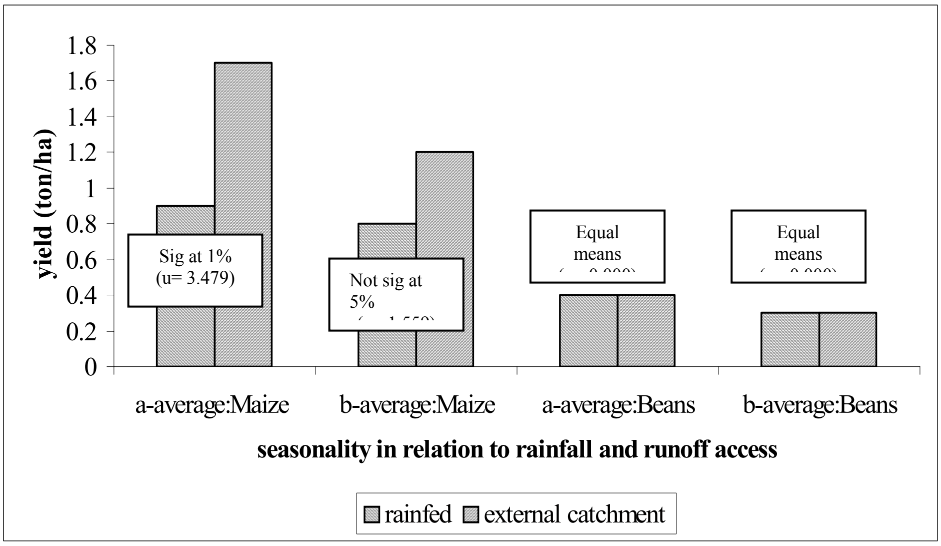


Figure 28 (a): Yield of maize+Beans (masika) rainfed Vs. external catchment with seasonality

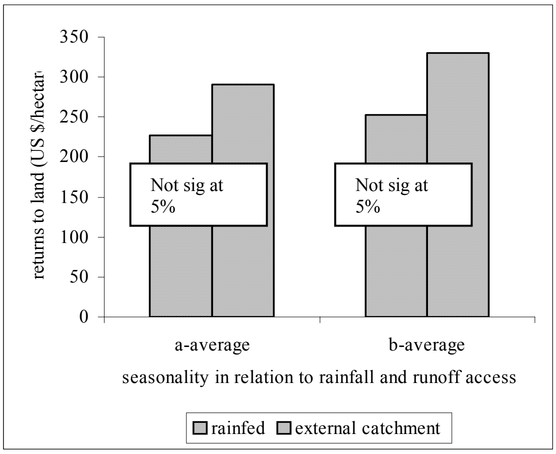


Figure 28 (b): Returns to land from maize+Beans (masika) rainfed Vs. external catchment with seasonality

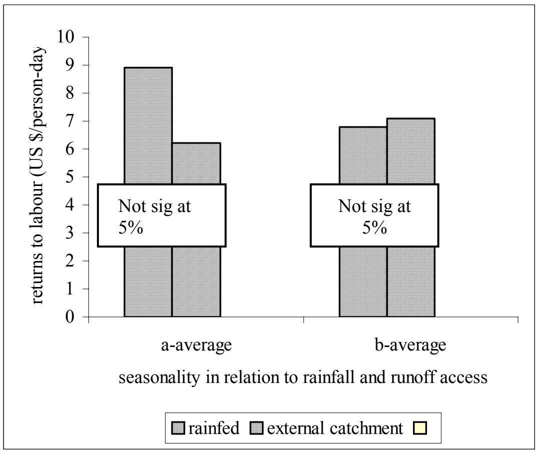


Figure 28 (c): Returns to labour from maize+Beans (masika) rainfed Vs. external catchment with seasonality

Appendix 4.8 (iii): Performance of Maize-Beans intercrop in short rains seasons Tables, WPLL

Table 36: Performance of maize+beans rainfed system 'vuli', survey results - WPLL

Items	N	Mean	St error	Std	Skewness	Kurtosis
Above average seasons:						
Yield (ton/ha): Maize	8	0.9	0.1	0.4	-0.378	0.371
Yield (ton/ha): Beans	8	0.4	0.1	0.3	0.379	-1.719
Returns to land (US $/ha)	8	228.0	37.7	106.5	0.276	-1.258
Returns to labour (US $/person-day	8	3.2	0.5	1.4	-0.028	-0.894
Below average seasons:						
Yield (ton/ha): Maize	10	0.7	0.1	0.5	0.128	-1.210
Yield (ton/ha): Beans	10	0.3	0.1	0.3	1.076	-0.776
Returns to land (US $/ha)	10	199.7	55.3	174.9	0.526	-1.830
Returns to labour (US $/person-day)	10	3.3	0.9	2.9	0.602	-1.643

Test results for A-average Vs B-average seasons

Yield: Maize **u** = 2.828 (significant at 1%)
Yield: Beans **u** = 2.082 (significant at 5%)
Returns to land **u** = 1.288 (not significant at 5%)
Returns to labour **u** = 0.295 (not significant at 5%)

Table 37: Performance of maize+beans external catchment during 'vuli', survey results - WPLL

Items	N	Mean	St error	Std	Skewness	Kurtosis
Above average seasons:						
Yield (ton/ha): Maize	5	1.4	0.4	0.9	-0.519	-2.719
Yield (ton/ha): Beans	5	0.6	0.2	0.5	1.866	3.522
Returns to land (US $/ha)	5	340.3	131.7	294.4	1.332	2.243
Returns to labour (US $/person-day	5	12.9	6.1	13.7	1.565	2.360
Below average seasons:						
Yield (ton/ha): Maize	5	1.4	0.5	1.0	1.078	1.123
Yield (ton/ha): Beans	5	0.5	0.2	0.4	1.523	2.921
Returns to land (US $/ha)	5	281.1	97.6	218.3	0.613	-0.316
Returns to labour (US $/person-day)	5	7.7	3.2	7.0	1.131	0.793

Test results for A-average Vs B-average seasons (paired sample T-test)

Yield: Maize **t** = 0.030, df=4, P=0.978 (not significant at 5%)
Yield: Beans **t** = 2.285, df=4, P=0.084 (significant at 10%)
Returns to land **t** = 0.502, df=4, P=0.642 (not significant at 5%)
Returns to labour **t** = 1.486, df=4, P=0.212 (not significant at 5%)

Appendix 4.8 (iv): Performance of Maize-Beans intercrop in short rains seasons Figures, WPLL

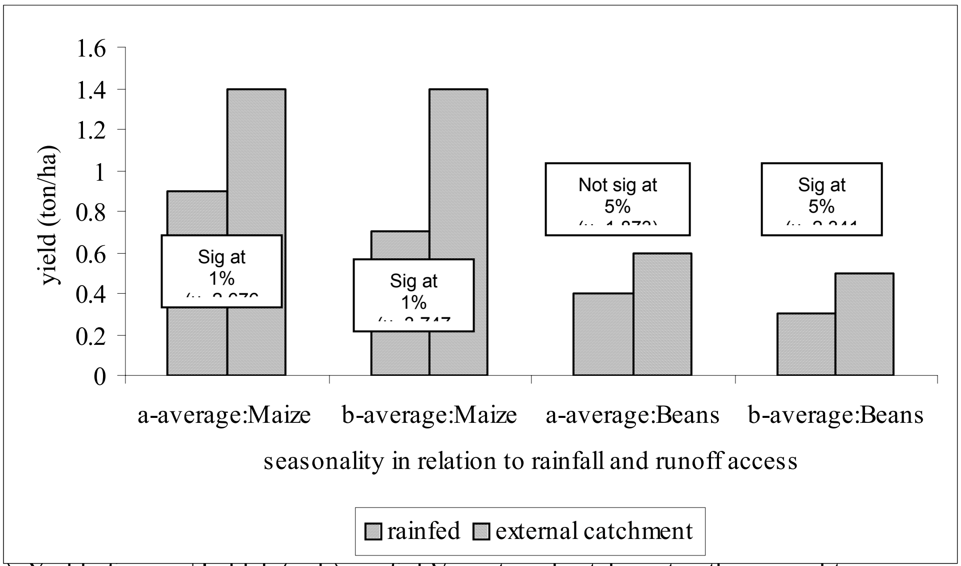


Figure 29 (a): Yield of maize+Lablab (vuli) rainfed Vs. external catchment with seasonality

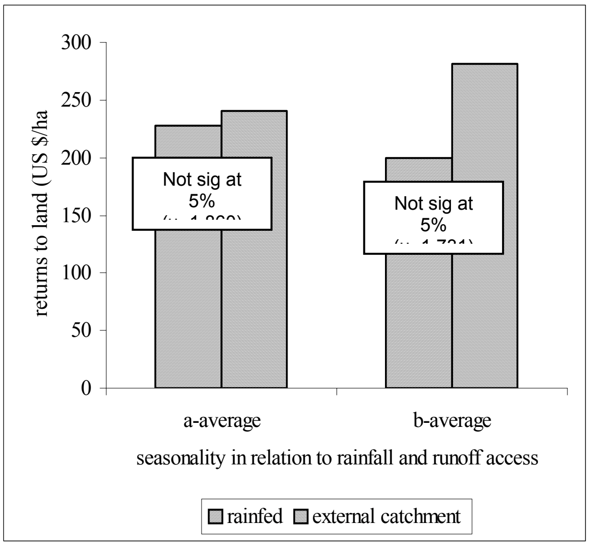


Figure 29 (b): Returns to land from maize+Lablab (vuli) rainfed Vs. external catchment with seasonality

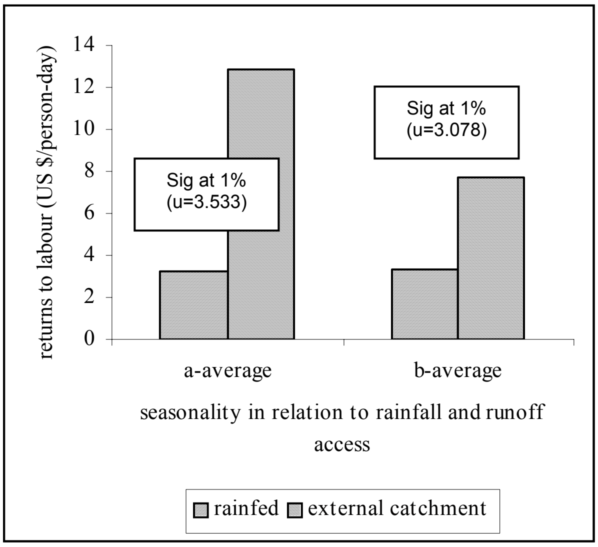


Figure 29 (c): Returns to labour from maize+Lablab (vuli) rainfed Vs. external catchment with seasonality

Appendix 4.9: Performance of Maize from yield monitoring, WPLL

Table 39: Performance of maize under macro-catchment during 'vuli' 2004 A-average, monitored yield - WPLL

Items	N	Mean	St error	Std	Skewness	Kurtosis
Farms located at the head:						
Yield (ton/ha)	5	3.1	0.2	0.5	-0.523	-3.006
Returns to land (US $/ha)	5	762.9	52.9	118.4	-0.419	-2.802
Returns to labour (US $/person-day	5	20.7	1.6	3.5	-0.476	-3.060
Farms located at the mid:						
Yield (ton/ha)	11	2.9	0.5	1.5	0.890	-0.896
Returns to land (US $/ha)	11	737.9	116.3	385.8	0.896	-0.884
Returns to labour (US $/person-day	11	19.7	3.1	10.3	0.896	-0.884
Farms located at the tail:						
Yield (ton/ha)	6	2.6	0.4	0.9	0.113	1.628
Returns to land (US $/ha)	6	656.3	88.5	216.7	0.150	1.646
Returns to labour (US $/person-day	6	18.0	2.6	6.4	0.883	2.207

Test results for head Vs mid:
Yield **u** = 1.183 (Not sig. at 5%)
Returns to land **u** = 0.591 (Not sig. at 5%)
Returns to labour **u** = 0.855 (Not sig. at 5%)

Test results for head Vs tail:
Yield **u** = 2.774 (Sig. at 1%)
Returns to land **u** = 2.468 (Sig. at 5%)
Returns to labour **u** = 2.116 (Sig. at 5%)

Test results for mid Vs tail:
Yield **u** = 1.480 (Not sig. at 5%)
Returns to land **u** = 1.621 (Not sig. at 5%)
Returns to labour **u** = 1.198 (Not sig. at 5%)

Table 40: Performance of maize under macro-catchment during 'masika' 2003 B-average, monitored yield - WPLL

Items	N	Mean	St error	Std	Skewness	Kurtosis
No runoff received:						
Yield (ton/ha)	1*	0.5				
Returns to land (US $/ha)	1	122.5				
Returns to labour (US $/person-day	1	3.3				
One runoff event:						
Yield (ton/ha)	6*	1.2	0.2	0.4	0.420	-1.781
Returns to land (US $/ha)	6	289.7	40.0	98.1	0.420	-1.781
Returns to labour (US $/person-day	6	7.7	1.1	2.6	0.420	-1.781
Two runoff events:						
Yield (ton/ha)	1*	1.9				
Returns to land (US $/ha)	1	476.7				
Returns to labour (US $/person-day	1	12.7				

**No statistical test was made as two situations lack other standard deviation statistics for u-test:*

Table 41: Performance of maize+lablab under macro-catchment during 'masika' 2004 below average, monitored yield - WPLL

Items	N	Mean	St error	Std	Skewness	Kurtosis
No runoff received:						
Yield (ton/ha): Maize	1*	0.4				
Yield (ton/ha): Lablab	1	0.0				
Returns to land (US $/ha)	1	90.6				
Returns to labour (US $/person-day	1	2.4				
One runoff event:						
Yield (ton/ha): Maize	4*	1.3	0.9	1.7	1.958	3.8.71
Yield (ton/ha): Lablab	4	0.5	0.3	0.6	0.000	-6.000
Returns to land (US $/ha)	4	487.5	175.5	351.1	-0.477	1.627
Returns to labour (US $/person-day	4	13.0	4.7	4.4	-0.477	1.627

**No statistical test was made as two situations lack other standard deviation statistics for u-test:*

Table 42: Performance of maize+lablab under macro-catchment during 'masika' 2003 B- average, monitored yield, WPLL

Items	N	Mean	St error	Std	Skewness	Kurtosis
No runoff received:						
Yield (ton/ha): Maize	1*	0.0				
Yield (ton/ha): Lablab	1	0.3				
Returns to land (US $/ha)	1	95.8				
Returns to labour (US $/person-day	1	2.6				
One runoff event:						
Yield (ton/ha): Maize	1*	0.0				
Yield (ton/ha): Lablab	1	0.03				
Returns to land (US $/ha)	1	9.4				
Returns to labour (US $/person-day	1	0.3				
Two runoff events:						
Yield (ton/ha): Maize	2*	1.1	1.1	1.6		
Yield (ton/ha): Lablab	2	1.9	1.1	1.6		
Returns to land (US $/ha)	2	1,011.9	719.3	1,017.2		
Returns to labour (US $/person-day	2	26.9	19.2	27.1		

**No statistical test was made as two situations lack other standard deviation statistics for u-test:*

Table 43: Performance of lablab under macro-catchment during 'masika' 2004 B- average, monitored yield - WPLL

Items	N	Mean	St error	Std	Skewness	Kurtosis
No runoff received:						
Yield (ton/ha)	4	0.1	0.02	0.04	0.000	0.711
Returns to land (US $/ha)	4	20.3	8.4	16.9	-0.200	-0.318
Returns to labour (US $/person-day	4	0.5	0.2	0.4	-0.200	-0.318
One runoff event:						
Yield (ton/ha)	15	0.8	0.1	0.5	0.269	-1.163
Returns to land (US $/ha)	15	288.8	46.4	179.7	0.284	-1.164
Returns to labour (US $/person-day	15	7.7	1.2	4.8	0.284	-1.164
Two runoff events:						
Yield (ton/ha)	1	0.8				
Returns to land (US $/ha)	1	287.0				
Returns to labour (US $/person-day	1	7.7				
Three runoff events:						
Yield (ton/ha)	1	0.2				
Returns to land (US $/ha)	1	82.0				
Returns to labour (US $/person-day	1	2.2				

Test results for one runoff event Vs no runoff:
Yield **u** = 20.114 (Significant at 1%) Returns to land **u** = 21.136 (Significant at 1%)
Returns to labour **u** = 21.476 (Significant at 1%)

Table 44: Lablab under macro-catchment during masika 2003 below average season

Items	N	Mean	St error	Std	Skewness	Kurtosis
No runoff received:						
Yield (ton/ha)	3	0.1	0.04	0.07	-1.688	
Returns to land (US $/ha)	3	34.2	15.1	26.1	-1.725	
Returns to labour (US $/person-day	3	0.9	0.4	0.7	-1.725	
One runoff event:						
Yield (ton/ha)	10	0.5	0.1	0.4	1.257	0.061
Returns to land (US $/ha)	10	172.6	55.6	175.9	1.271	0.115
Returns to labour (US $/person-day	10	4.6	1.5	4.7	1.271	0.115
Two runoff events:						
Yield (ton/ha)	1	0.9				
Returns to land (US $/ha)	1	369.5				
Returns to labour (US $/person-day	1	9.8				

Test results for one runoff event Vs no runoff: Yield **u** = 8.638 (Significant at 1%) Returns to land **u** = 7.052 (Significant at 1%) Returns to labour **u** = 7.051 (Significant at 1%)