FOOD AND AGRICULTURE ORGANISATION OF THE UNITED NATIONS

FNPP

COMPREHENSIVE ASSESSMENT OF WATER RESOURCES OF MKOJI SUB-CATCHMENT, ITS CURRENT USES AND PRODUCTIVITY

DRAFT

SOIL WATER MANAGEMENT RESEARCH GROUP

OCTOBER 2003

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ABBREVIATIONS

CWR = Crop Water Requirement
CWP = Crop Water Productivity
Eta = Actual Crop Water Used
RF = Rainfall
ERF = Effective Rainfall
TRL = Total Rainfall Loss
RE = Efficiency of Rainfall
MD = Moisture Deficit
CY = Crop Yield
TGI =Total Gross Irrigation
TNI = Total Net Irrigation
AIR = Actual Irrigation Requirement
PW_{RF} = Crop Water Productivity (Rainfall)
PW_{ERF} = Crop Water Productivity (Effective Rainfall)
PW_{DP} = Crop Water Productivity (Actual Evapotranspiration)
PW_{W} = Crop Water Productivity (Rainfall+ Irrigation)
Perc = Percolation loss
Lprep = Land preparation
RiceRq = Rice water requirement
IrReq = Irrigation water requirement for paddy ri

1 INTRODUCTION

1.1 Background to the project

Enhancement of the productivity of water in various mosaics of crop production is a key intervention in reducing poverty levels among the agricultural based rural livelihoods. The Food and Agriculture Organisation (FAO) of the United Nations has been at the forefront of exploring such opportunities and supporting the agricultural based livelihoods.

FA0 is implementing the FNPP Water and Food Security: Integrated Water Resource Management for Vulnerable Groups component in Tanzania. The main thrust is to promote and apply the concept of Integrated Water Resources with special attention to vulnerable Groups (IWRM-VG), to assure that strategies directed towards the disadvantaged will at the same time contribute to protect the environment through and efficient use of the natural resources.

As a step towards implementing FNPP, FAO has initiated a comprehensive study that will be carried out in the Mkoji sub catchment within Mbarali and Mbeya Rural Districts in order to get a better understanding into the opportunities to enhance crop water productivity so as to achieve food security. As part of this program, FAO requested the Soil Water Management Research Group (SWMRG) of Sokoine University of Agriculture (SUA) to expand its activities of assessing water use and formulating water resource management strategies in the Usangu plains of the Great Ruaha River, to include a comprehensive water use and productivity assessment and IWRM – VG strategy for the Mkoji sub catchment. The study will be carried out over a period of six months (July – December 2003).

1.2 Objective of the study

The main objective of the study is to secure water and food security for the vulnerable water users. This study will contribute to this objective by delivering the following five outputs.

The current water uses, described across different sectors, such as cropping (rainfed and irrigated), domestic, livestock, and environment ; and among differnt users, in particular the vulnerable smallholder farmers, female-headed households and the youth.
The current productivity of water in cropping enterprises (rainfed and irrigated), estimated.
Appropriate strategies for enhancing the productivity of water in crop enteprises, identified.
Institutional development of water management organisations in MSC, supported.
Two comprehensive reports of the above four outputs and relevant databases, produced.

This report is addressing the first output i.e. “comprehensive assessment of water resources of the MSC, its uses and productivity”.

1.3 Outline of the report

The report is organized into four chapters. Chapter two gives details of the methodologies that were used in data collection and analysis. The conceptual approach and methodological development of FNPP’s Water theme were considered in the formulation of project activities methodologies. The results and discussions are presented in chapter three, while conclusions and recommendations are presented in chapter four. The report is supported by various maps and appendices, which form part of the database.

2 METHODOLOGY

2.1 Description of Mkoji Sub-Catchment (MSC)

2.1.1 Location, size and population

The Mkoji Sub-catchment, is drained by the Mkoji River and is located in the southwest of Tanzania, between latitudes 7048' and 9025' South, and longitudes 33040' and 34009' East (Figure 1). It is a sub-catchment of the Rufiji River Basin and covers an area of about 3400 km². Most of the sub-catchment lies within Mbarali and Mbeya Rural districts, while smaller portions of the sub-catchment lie within Makete and Chunya districts in Iringa and Mbeya Regions respectively (Figure 2).

According to the 2002 population census, Mkoji Sub-catchment has a population of about 146,000 people with an average annual growth rate of 2.4%. The highest population density is found along the Tanzania-Zambia Highway and in the Southern highlands. Scattered villages are located in the plains.

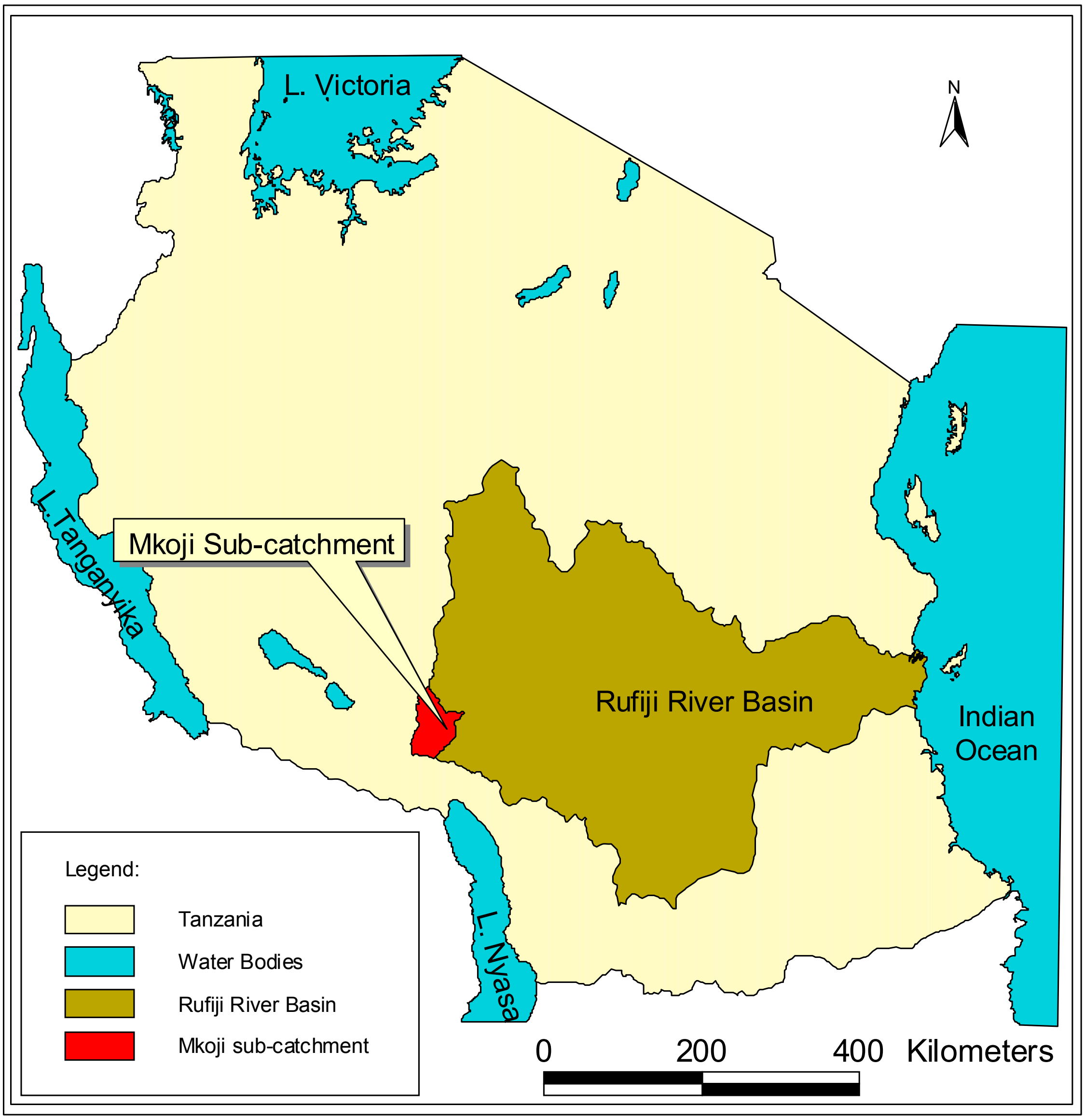


Figure 1: Location of Mkoji Sub-catchment within the Rufiji Basin in Tanzania

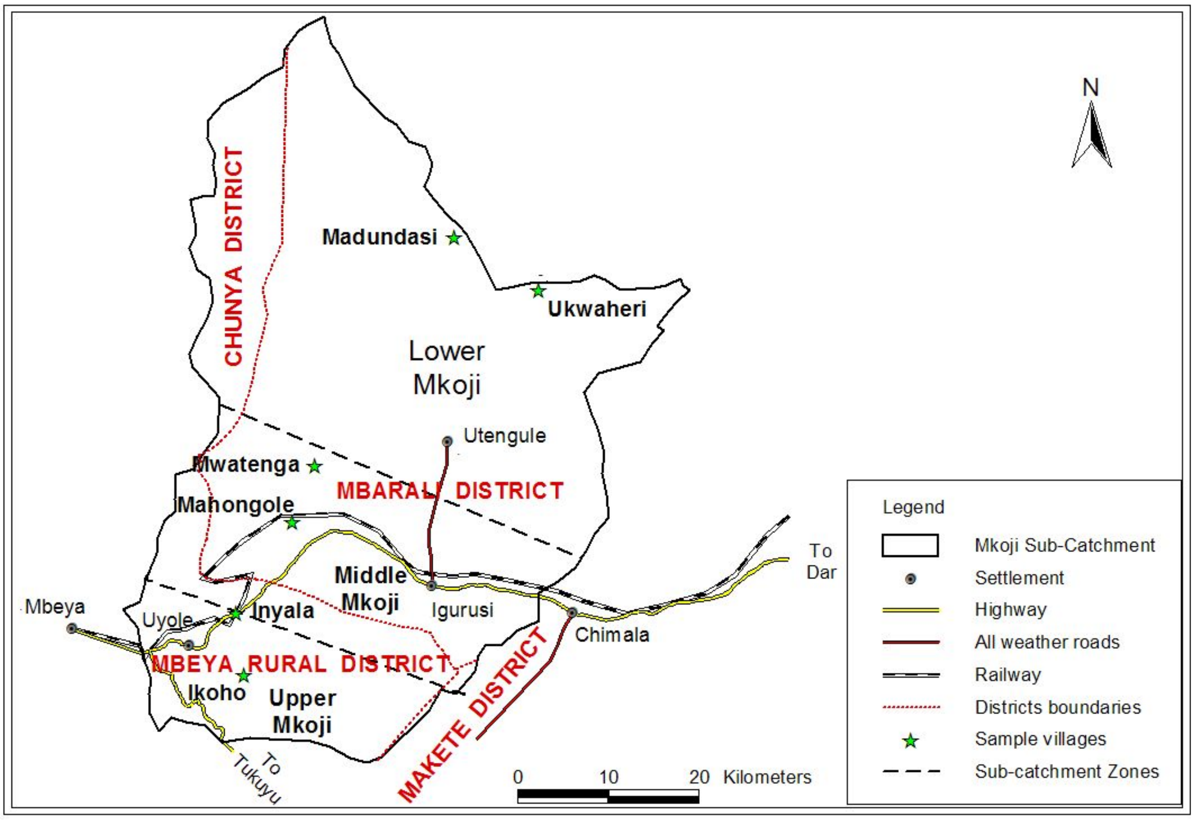


Figure 2: Administrative boundaries and Mkoji Sub-catchment zones'

2.1.2 Topography

The Mkoji Sub-catchment is characterised by two distinct landscapes; a central plain (the Usangu Plains), which is a natural sedimentation basin and part of the East African Rift Valley, surrounded by highlands. The fairy flat Usangu Plains have an average elevation of 1100 m above sea level. The highlands are composed of the Chunya escarpment to the West and Kipengere Range and Poroto Mountains to the South, and rise from about 1100 m to over 2400 m above sea level.

2.1.3 Climate

(i) Temperature

The annual mean temperature varies from about 180C at the higher altitudes to about 220C at Igurusi and Kapunga (representing the middle and lower zones of Mkoji Sub-catchment respectively). Most of the lower zone of the sub-catchment, comprising the Usangu Plains, is semi-arid, whereas the upper zone (in the highlands) of the sub-catchment is semi-humid to humid.

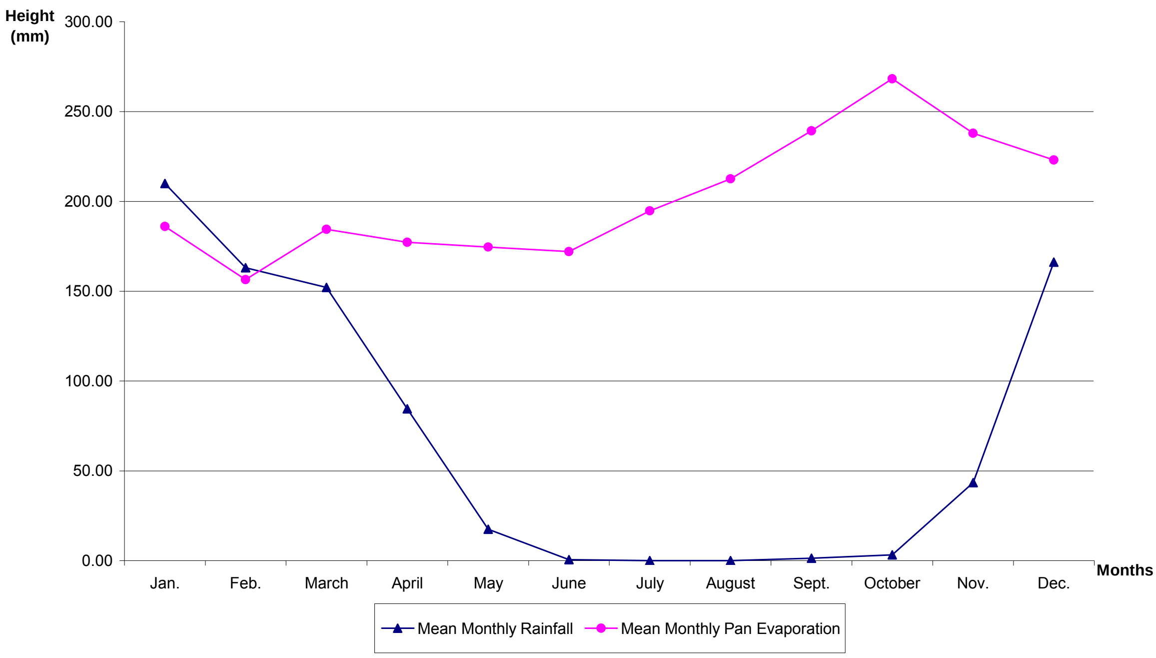
(ii) Rainfall

The rainfall regime in the Mkoji Sub-catchment is unimodal with a single rainy season starting from the third decad of November and ending in the first decad of April in the plains and third decad of April in the highlands. Hardly any rain falls during the rest of the year. In the high rainfall areas the dry season is shorter as the rainy season tends to continue until May. The heaviest rainfall generally occurs in December-January and March-April. The driest months are June to October.

The highlands receive the highest annual rainfall. For example the mean annual rainfall at Mbeya meteorological station (which represent the highland) is about 1070 mm. The annual rainfall decreases towards the plains to about 840 mm at Igurusi (in the middle of MSC) and 520 mm at Kapunga (representing the lower MSC area). The mean annual areal rainfall over the MSC is about 898 mm (3052 Mm3 for the catchment). The rainfall amounts as well as the onset of the rainy season can vary considerably from year to year (annual coefficient of variation is over 20% at Igurusi), which often have a detrimental effect for crop production and other activities that depend on availability of water, especially in the drier areas.

(iii) Evaporation

Potential evaporation varies considerably within the Mkoji Sub-catchment. There is a tendency for decreasing evaporation with increasing altitude. The pan evaporation is 2430 mm/year at Igurusi (middle zone) and decreases to 1890 mm/year in Mbeya (representing the upper zone). The yearly variation is smaller and steady (coefficient of variation is 7% at Igurusi). The lowest evaporation is experienced in February (during the wet season) and increases during the dry season (from August to December), reaching a maximum in October/November. The moisture deficits calculated using average evaporation and rainfall data (using Igurusi meteorological station) are presented in Figure 3. Significant moisture deficits are evident in the months of March to December. The annual total moisture deficit is of the order of 1585 mm.



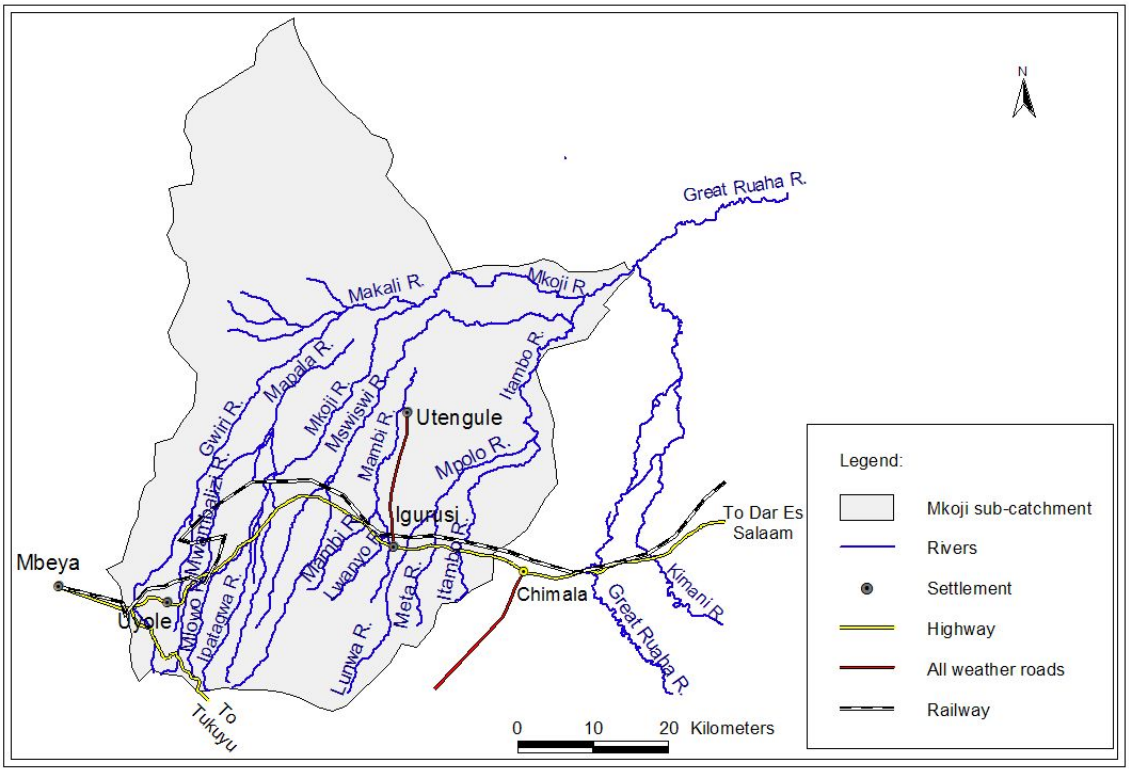
	Jan.	Feb.	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Mean monthly evaporation (mm)	**186**	**156**	**184**	**177**	**175**	**172**	**195**	**213**	**239**	**268**	**238**	**223**	**2427**
Mean monthly rainfall (mm)	**210**	**163**	**152**	**85**	**17**	**1**	**0**	**0**	**1**	**3**	**43**	**166**	**842**
Moisture deficit (mm)	**24**	**7**	**-32**	**-93**	**-157**	**-171**	**-195**	**-213**	**-238**	**-265**	**-195**	**-57**	**-1585**

Figure 3: Mean monthly rainfall and pan evaporation for Igurusi met station

2.1.4 Water Resources

The Mkoji River, which has given name to the sub-catchment, is the main river draining through the whole sub-catchment. It originates from the northern slopes of the Poroto Mountains from where it flows to the Usangu Plains, collecting en route Makali and Itambo rivers before joining the Great Ruaha River. Other important rivers that drain the Mkoji Sub-catchment are Meta, Lunwa, Lwanyo, Mambi, Mswiswi, Ipatagwa, Mlowo, Mwambalizi and Gwiri (Figure 4). All the rivers draining the Mkoji Sub-catchment, including the Mkoji River itself, are perennial during the dry season upstream of the Tanzania-Zambia Highway. Downstream of this highway, all these rivers dry up and are perceived as seasonal mainly due to dry season irrigated agriculture, which uses all the water that would have kept them flowing during the dry season.

There are two springs located at Inyala and Idunda villages that provide water used for dry season irrigated agriculture. Flows from these springs were 8 l/s and 12 l/s for Inyala and Idunda respectively, when measured on 9/9/2003. Ground water use is confined to domestic use only. There are a total of three pump-tested boreholes and nineteen wells in Luhanga, Muhwela, Mwatenga, Ukwaheri, Azimio and other villages.



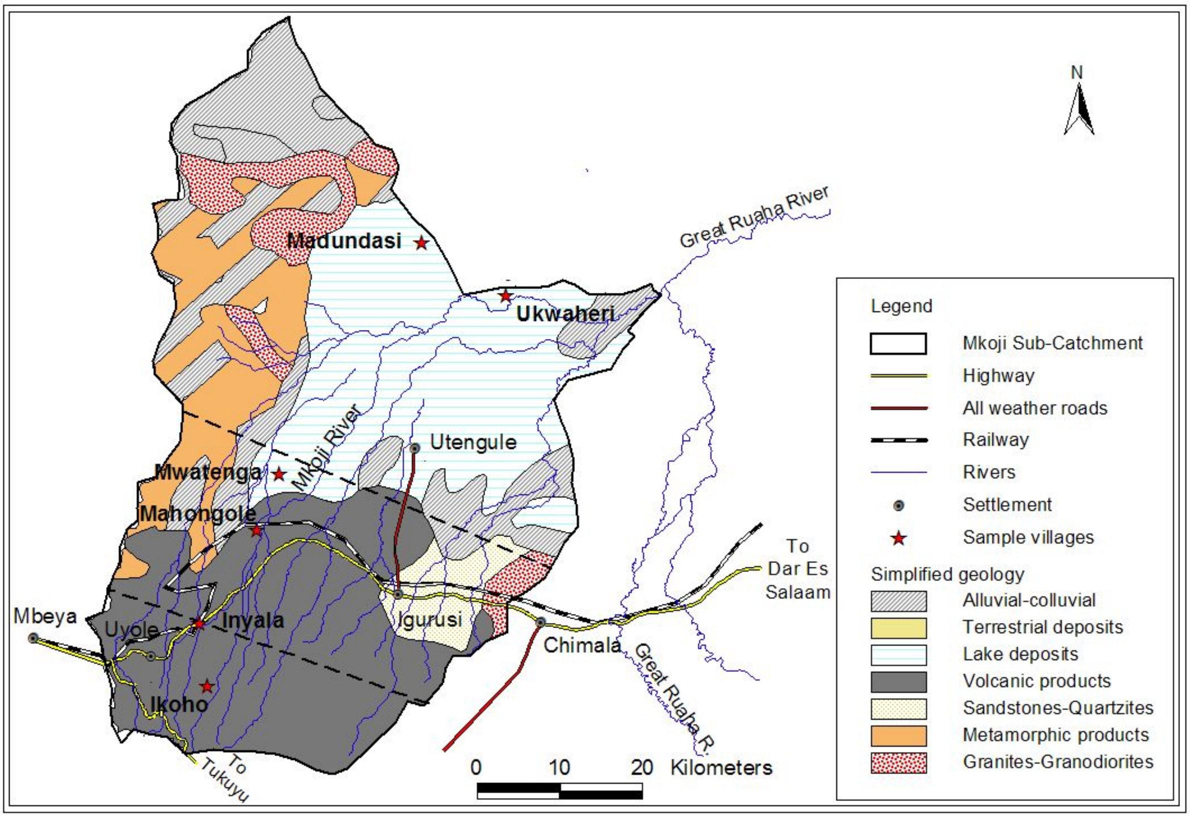
Map Sources: 1. Modified SMUWC data; 2. RIPARWIN data (mainly GPS measurements); 3. East Africa (Tanzania) Topo sheets 1:50 000. Sheets 244/2, 244/4, 245/1, 245/2, 245/3, 245/4.

Figure 4: Mkoji Sub-catchment – Water Resources

2.1.5 Geology and Soils

A basement complex of Precambrian rocks dominated by gneiss and granite under lays the major part of the sub-catchment. Mudstones, siltstones, quartz sandstones and quartzitic sandstones are found outcropping around Igurusi. In the south western part of the sub-catchment, in the Poroto Mountains, the parent material is volcanic ash deposit originating from the Rungwe-Mbozi volcanic complex (Figure 5). The relief surrounding the plains and the rivers cutting across have generated quaternary alluvial, colluvial and terrestrial deposits that can be found in the western part of the Mkoji Sub-catchment.

In the higher rainfall areas most of the soils are deep weathered and highly leached red and yellow soils with high iron and aluminium concentrations (Ferrasols). In the highly dissected parts, the soils are however shallow and rocky. Most of the soils still have a relatively high organic content and a good soil structure. Thus many of these soils are still relatively resistant to soil erosion. In the Usangu Plains a variety of textural classes can be found according to the variation in sedimentation conditions prevailing when the deposition took place. Alluvial clay and clay loam soils occupy the greatest part of the existing paddy producing area. These soils are generally of high fertility, though poorly drained (Vertisols).



Map Sources: 1. Modified SMUWC data; 2. RIPARWIN data (mainly GPS measurements); 3. East Africa (Tanzania) Topo sheets 1:50 000. Sheets 244/2, 244/4, 245/1, 245/2, 245/3, 245/4.

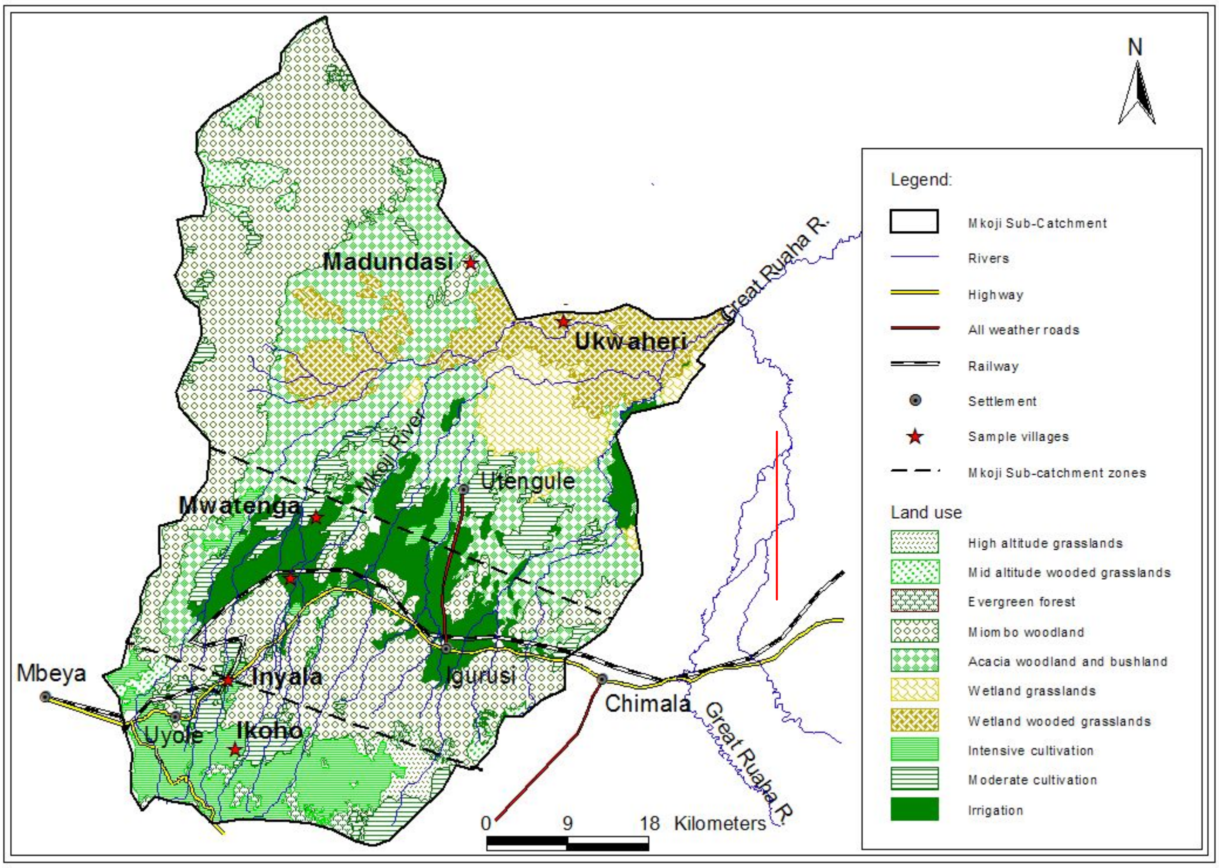
Figure 5: Mkoji Sub-catchment – Geology and Soils

2.1.6 Land use

The distribution of the land use patterns in the Mkoji Sub-catchment is shown in Figure 6. The middle Mkoji and the Chunya escarpment in the west are covered with Miombo woodlands. Acacia woodlands and bushlands cover the plains in the lower Mkoji with grasslands and wooded grasslands in the wetlands. The highlands in the South are covered with high altitude grasslands, mid altitude wooded grasslands and evergreen forests that have been partly replaced by woodlots of Eucalyptus. Cultivation is mostly found in the southern highlands and along the Tanzania-Zambia Highway. Table 1 describes the crops grown under three different agricultural production domains in different parts of MSC.

Table 1: Crops grown in the Mkoji Sub-catchment

Zone/agricultural domain	Irrigated	Intermediate	Rainfed
Upper Mkoji	Maize, beans, tomatoes, Irish potatoes, onion	vegetables	Maize, millet, bean, round potato, tomato, spring wheat
Middle Mkoji	Maize, beans, tomatoes, Irish potatoes, onion	rice	Maize, sorghum, bean, ground nut, tomato, onion, sugarcane
Lower Mkoji		rice	Maize, sorghum, bean, green bean, ground nut



Map Sources: 1. Modified SMUWC data; 2. RIPARWIN data (mainly GPS measurements); 3. East Africa (Tanzania) Topo sheets 1:50 000. Sheets 244/2, 244/4, 245/1, 245/2, 245/3, 245/4.

Figure 6: Mkoji Sub-catchment – Land use pattern

2.2 Assessment of available water resources

2.2.1 Analysis of Climatic Data

In this study analysis of climatic data was limited to the analysis of observed rainfall and evaporation data in the Mkoji Sub-catchment. Rainfall and evaporation are two important hydrological processes that influence the climate of a catchment and the available water resources. Rainfall in particular is the most variable element and has the fundamental effect on the catchment response. The study of the rainfall and evaporation was therefore aimed to facilitate the assessment of water resources in the Mkoji Sub-catchment. The analyses presented in this section are based on data collected from 11 rainfall and 3 climatic stations (Table 2, Figure 7).

(i) Rainfall

(a) Selection of stations

The available historical rainfall data for stations located within and just outside of the boundary of MSC have gaps of missing data. Data used in the analysis was therefore accepted basing on the following criteria.

- Rainfall months were accepted if at least 25 days out of 30 are available.
- Rainfall years were accepted if at least 11 months out of 12 are available

The distribution of the stations selected for the analysis is as shown in Figure 7. It is worth noting that most of the stations are located in the upper catchment. The mean annual rainfall of the Mkoji sub catchment was calculated using Simple Arithmetic Mean method. The same approach was used to compute mean monthly rainfall over the long term for each station.

(b) Trend Analysis

The annual areal rainfall was analysed for linear trend to check for any significant increase or decrease in rainfall for the period 1940 to 1999.

A linear trend was fitted to the mean areal rainfall and then the slope of the fitted line was tested for statistical significance to conclude whether there was linear trend or not in the observed data.

Table 2: Rainfall stations in and around the MSC, which were used in the analysis

S/no	Station Code	Station name	Easting	Northing	Open date	No. of Years available	% Missing
1	09833000	Mbeya Boma	549475	9016173	01/01/1923	67	35.10
2	09833001	Mbeya Met	551340	9012854	01/01/1937	62	5.65
3	09833002	Chunya Agriculture	545892	9057084	01/01/1934	65	6.88
4	09833015	Kawetere Forestry	554980	9021694	01/01/1951	44	6.28
5	09833020	Mbeya Boma	551343	9015065	01/01/1961	38	12.53
6	09833025	Allsa Farm	571468	9018020	01/01/1970	29	3.74
7	09933004	Rungwe Tea Estate	564051	8986632	01/01/1934	65	17.94
8	09933013	Rungwe Secondary School	565919	8986629	01/01/1949	24	49.51
9	09933028	Igembe Primary School	549453	8998483	01/01/1961	39	52.43
10	09833031	MATI Igurusi	593485	9029364	01/01/1984	19	22.03
11	-	NAFCO Kapunga	619271	9053893	01/01/1991	12	30.01

(ii) *Potential Evapotranspiration*

Limited amounts of climatic data are available for the estimation of potential evapotranspiration in the Mkoji Sub-catchment. Data available are on minimum and maximum daily temperature, wind speed, sunshine hours and relative humidity for only one climatic station located within Mkoji sub-catchment, namely Igurusi (for the middle zone). Therefore two more stations that lie just outside of Mkoji Sub-catchment were included. The stations are Kapunga (to represent the lower zone) and Mbeya (for the upper zone-the highlands). The length of record for Kapunga and Igurusi is short and there are gaps of missing data. The length of record for Mbeya is longer, but again there are gaps of missing data. It was therefore decided to use data from these three climatic stations, by selecting only those years with complete data sets, in order to be able to estimate potential evaporation in the Mkoji Sub-catchment. The potential evapotranspiration was computed using CROPWAT for Windows version 4.3 that uses the Penman - Monteith approach.

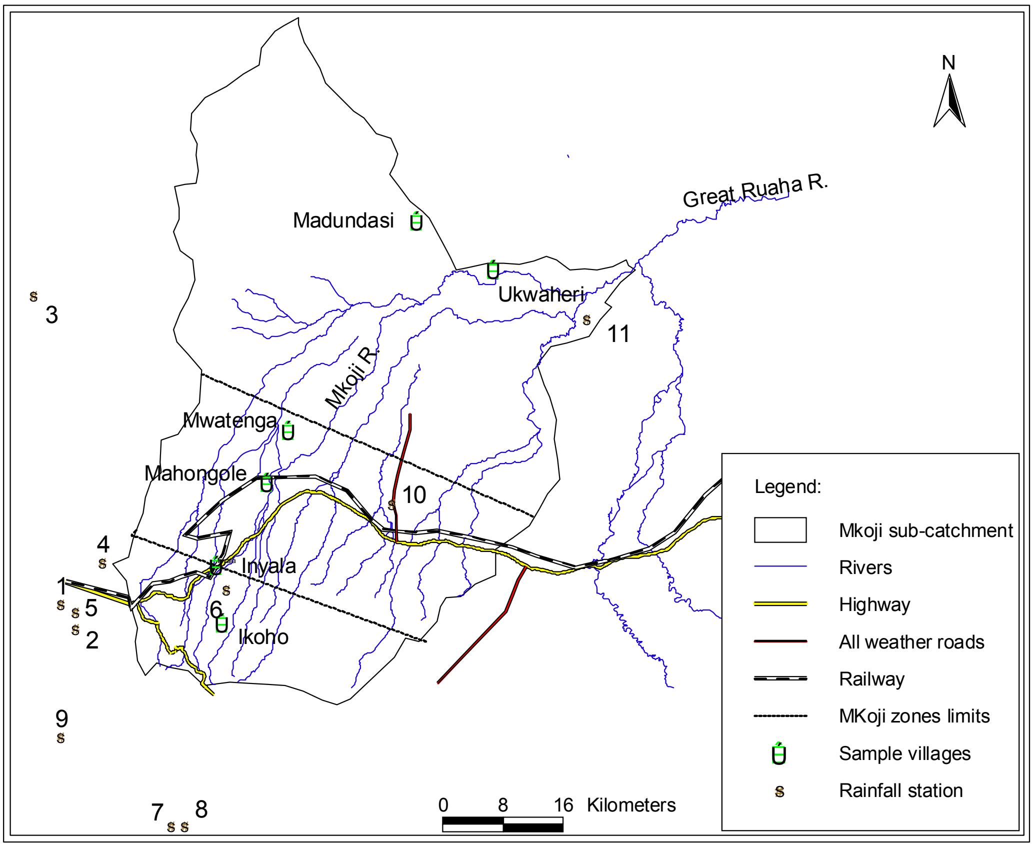


Figure 7: Distribution of rainfall stations used in rainfall analysis

2.2.2 Analysis of Runoff

Runoff analysis was carried out in order to get a better understanding of the river flow characteristics in Mkoji Sub-catchment. The analyses are based on stream flow data recorded at Lunwa River at Igurusi (1KA16a), Mswiswi River at Wilima (1KA50a) and Umrobo River at Great North Road (1KA51a).

(i) Reconstruction of streamflow data

The river flows recorded at the three gauging stations contain gaps of missing data. The gaps in the data were filled by using the Usangu Basin Model (SMUWC, 2001), which uses the techniques of Rainfall/Runoff modelling and cross correlation.

Inflows at Umrobo were estimated using a cross correlation model for the period 1958–2000 using the flow data of Mswiswi River. The estimated discharges were then used to fill in the missing values of the observed data.

The missing values at Mswiswi were filled by using the flows at Umrobo as inputs. For the case of Lunwa River, the inflows were estimated by using the data from Mswiswi River.

(*ii) Trend Analysis*

In a similar manner as was the case of rainfall, trend analysis was carried out on runoff from the three gauging stations to check for any significant increase or decrease in runoff over the period of record. A Linear Regression Model was used to generate the required parameters.

2.2.3 Ground water

The study of ground water in the Mkoji Sub-catchment was done through collection of ground water data and review of available literature and information regarding ground water potential from various sources. The sources include previous research reports and government institutions. Furthermore the information was supplemented by conducting field surveys in MSC, discharge measurements on water sources and consultations with key stakeholders such as the Regional Hydrology Office, Mbeya.

2.3 Typology of Livelihoods and Farming Systems

2.3.1 Selection of villages

The MSC is large (about 3400 Km2) and can only be studied through random sampling of the villages and then the households within the villages. The sub-catchment was therefore purposefully divided into three zones – upper (27 villages), middle (19 villages), and lower (7 villages). Two villages were purposively selected from each zone, to capture the variability in livelihood and production systems among the water users in the catchment. The most important criteria used were:

- Sub-zonal representation within the major zone
- Inclusion of a wide range of production systems (including irrigated and rainfed crop production); and
- Availability of good amount of secondary data

The selected villages are described in Table 3.

Table 3: Selected study villages

Name of village	1st Criteria	2nd Criteria	3rd Criteria
Ikhoho	Upper	Rainfed (maize, potatoes and wheat)	RIPARWIN Database and SHARDI reports
Inyala	Upper	Dry-season irrigation (maize, beans, potatoes, vegetables)	RIPARWIN Database and SHARDI reports
Mahongole	Middle	Dry season irrigation (maize, beans, vegetables) and wet season irrigation (paddy)	SMUWC and RIPARWIN Databases
Mwatenga	Middle	Wet season irrigation (paddy)	RIPARWIN Database
Ukwaheri	Lower	Rainfed (maize, sorghum/millet) and Livestock	SMUWC and RIPARWIN Databases
Madundasi	Lower	Rainfed (maize, sorghum/millet) and Livestock	SMUWC and RIPARWIN Databases

2.3.2 Vulnerability Group Assessment and Gender Analysis

Vulnerability relates to the presence of factors that place people's livelihood at risk of becoming food-insecure or malnourished, including those factors that affect their ability to cope. Vulnerable groups living in the agro-ecological zones within the targeted agricultural production systems were identified and their conditions assessed. Key questions to be answered included, among others: i) who are the insecure and vulnerable? ii) Where are they located within the agricultural production system? iii) Why and how are they vulnerable to food insecurity? iv) what strategies do they adopt to cope with the vulnerability? and v) how effective are these strategies?

There is a wide range of both internal and external factors that contributes to the vulnerability of food security. The internal factors are numerous, and relate to the socio-economic position of an individual or a group, physical constraints, culture or geo-political situation. The external factors may include changes in their social, physical, economic or natural environment. The study analysed a multiplicity of these factors in as much as they interact with the Crop Water Productivity (CWP) conditionality parameters. An integral component of this methodological approach consists in the inclusion of gender relationships, with special attention to the disadvantaged groups especially women and children.

2.3.3 Household sampling

The sample households were drawn from the registers of the study villages listed in Table 3, on the basis of vulnerability/poverty groups. For each village the sample included about ten percent of the total households as well as about ten percent of each vulnerability/poverty groups. The selection was random within each category. The total sample households were thus 246.

2.4 Data collection

(i) Participatory Rural Appraisal

This included meetings, transect walks, open-ended interviews of key informants, and focus group discussions. Group meetings were held in each of sample villages for wealth ranking. A list of between 20 – 30% of the village households randomly selected from the village register was used for this activity. Members for the group meeting were deliberate on the criteria for wealth ranking in each village. Focus group discussions based on gender and wealth was used for livelihood analysis. The groups drew activity charts, time charts, labour profiles, livelihood scenarios, mobility maps, historical profiles and food calendars using locally available aids as decided by the participants. Furthermore, semi-structured interviews and focus group discussions were used.

(ii) Questionnaire survey

In order to quantify data that were collected during the PRA exercise, a questionnaire was administered at household level. The intended respondents were heads of households but the possibility for engaging other knowledgeable family members was explored during the exercise, particularly for the questions that required recalling up.

2.5 Data analysis

(i) Qualitative analysis

The data collected were first summarized and a database template containing the collected information was made in Statistical Package for Social Science (SPSS) computer software. Descriptive statistics such as frequencies, means and cross-tabulations were used to decode the attached messages in the data collected. Content analysis was employed on qualitative data collected during the PRA session.

(ii) Quantitative analysis

According to Kanbur, (2001), there is a growing recognition that sensible combination of qualitative and quantitative methods can help solve problems that are associated with each type of method taken separately. Booth et al., (1998) urged that qualitative methods in particular, are often more appropriate for capturing the social and institutional context of people's lives than the quantitative methods. In this study the quantitative component of analysis assessed the assets and incomes among sample households where a multivariate regression analysis was employed to determine factors influencing vulnerability. Predictor variables fitted in the model were: Distance from major markets sheds, household asset value, farm area under cultivation and household size.

2.6 Assessment of cropping patterns

Cropping calendars, patterns and sequences in the study area were assessed using PRA exercises. The PRA meetings constituted between fifteen and twenty people. Each meeting included male and female participants. The exercise was conducted in six villages, purposefully sampled, two from each of the upper, middle and lower Mkoji sub catchment respectively. The checklist (appendix 5) quided the PRA exercise.

3 RESULTS AND DISCUSSIONS

3.1 Assessment of available water resources

3.1.1 Rainfall

(a) Mean monthly rainfall

The long-term annual rainfall for MSC is shown in Figure 8 and range from 300mm to 1300 mm. The annual average is about 900 mm. The monthly rainfall on the other hand has a unimodal pattern with the rainy season starting from November to April. The average monthly rainfalls for the stations used in the analysis are shown in Appendix 1, (Figures A1-1 – A1-9). Typically, those stations in the highlands have higher rainfall and the rainy season is more pronounced. In the lowlands, less rainfall is received and the dry season sets much earlier in May or June.

(b) Rainfall variability

It is important to note that total rainfall figures may be misleading especially in dry regions, which is typical of the lowlands in MSC. The variability of the seasonal rainfall is therefore an important parameter. The rainfall variability is represented by the coefficient of variation (CV) for both Igurusi and Kapunga stations (Appendix 3 Table A3-1 to A3-2). For Igurusi, the mean annual rainfall has a CV of 23% while Kapunga has CV of 18%. If the rainy season is considered, the monthly CVs for both stations range from 34% to over 100%. These are large variations and to a great extent may contribute to crop failures especially in rainfed agriculture.

(c) Trend analysis

The results of linear trend analysis for annual mean areal rainfall are presented in Table 4. The trend analysis revealed that there is no significant statistical trend on the mean areal rainfall in Mkoji sub catchment at 95% ($p<0.05$) level of confidence. This implies that the rainfall within the Mkoji sub catchment has not changed with time.

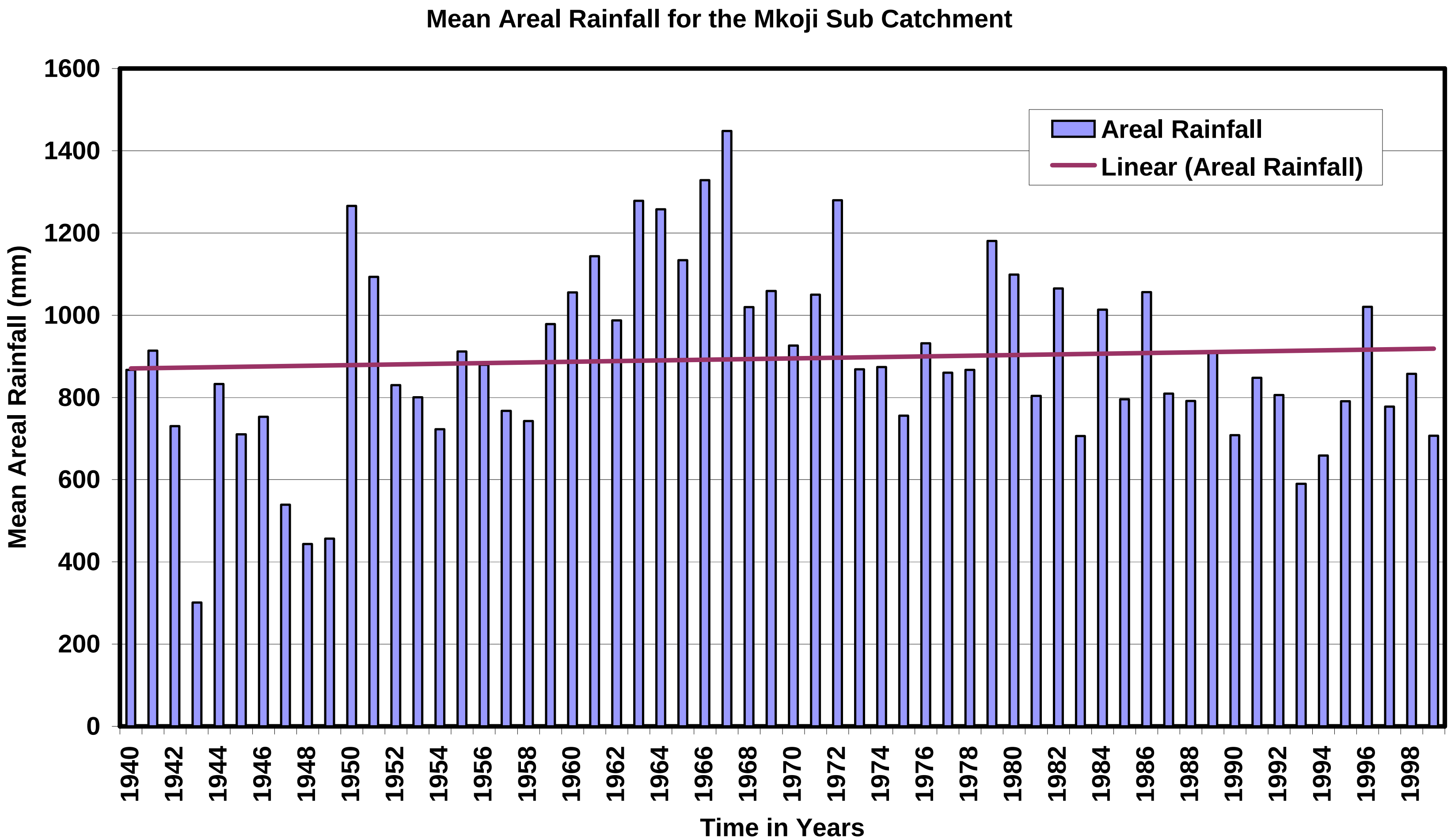


Figure 8: Mean annual areal rainfall for Mkoji Sub-catchment

Table 4: Results of trend analysis to areal mean annual rainfall

Parameter	Coefficient
α	0.817
β	-714.3
t statistic	0.489

3.1.2 Potential evapotranspiration

Tables 5,6 and 7 present climatic and potential evaporation from Mbeya, Igurusi and Kapunga meteorological stations respectively. The results show that the potential evapotranspiration is 4.48 mm/day at Kapunga (representing the lower zone), 3.94 mm/day at Igurusi (Middle zone) and 4.65 mm/day at Mbeya (representing the upper zone). The lowest potential evapotranspiration is experienced in February (during the wet season) and increases during the dry season (from August to December), reaching a maximum in the months of October/November.

These results show that potential evaporation in the MSC increases with increasing altitude. Although this may look unusual, this is supported by the fact that wind speeds are very high at high altitudes. For example at Mbeya meteorological station wind speeds of up to about 300km/day are recorded. On the other hand, the other meteorological stations have lower wind speeds (Tables 6 and 7).

3.1.3 Runoff

(a) Monthly distribution of annual flows

The mean monthly discharges of a few selected rivers in MSC are summarized in Table 8. The rivers are Lunwa, Mswiswi and Umrobo and their annual flows are 516, 412 and 245 m3/s respectively. The mean monthly discharges of all these rivers are highest during the wet season and contribute less during the dry season. For Mswiswi River, the lowest flow is in October (0,93m3/s). The other two rivers have discharges greater than one cumec during the dry season. The long term mean monthly discharges of these rivers are shown in Appendix 2 (Tables A2-1 – A2-3).

Table 5: Mean monthly climatic data for Mbeya meteorological station (mean values obtained fro five years data- 1995,1997-1999,2001)

Month	Max Temp (^{0}C)	Min Temp (^{0}C)	RH (%)	Sunshine hours (hrs)	Wind speed (km/day)	ETo (mm/day)
January	**24.5**	**14.6**	**66.9**	**4.8**	**163.0**	**3.91**
February	**23.8**	**14.5**	**66.1**	**5.3**	**134.7**	**3.87**
March	**23.6**	**14.2**	**66.4**	**6.3**	**148.9**	**4.00**
April	**23.2**	**12.4**	**61.6**	**7.0**	**163.3**	**3.95**
May	**22.8**	**7.6**	**60.8**	**9.5**	**176.6**	**3.96**
June	**21.4**	**6.3**	**54.7**	**10.1**	**194.8**	**3.88**
July	**21.7**	**6.5**	**50.3**	**10.2**	**228.9**	**4.28**
August	**23.1**	**8.4**	**51.0**	**9.5**	**252.3**	**4.81**
September	**25.5**	**10.6**	**44.1**	**9.1**	**292.4**	**5.87**
October	**26.7**	**12.2**	**38.7**	**9.5**	**299.5**	**6.54**
November	**26.3**	**14.4**	**45.3**	**7.5**	**283.8**	**5.89**
December	**25.2**	**14.6**	**52.2**	**6.3**	**198.9**	**4.79**
Mean	17.7		54.8	7.9	211.4	4.65

Table 6: Mean monthly climatic data for Igurusi meteorological station (mean values obtained from five years data-1989-1993)

Month	Max Temp (^0C)	Min Temp (^0C)	RH (%)	Sunshine hours (hrs)	Wind speed (km/day)	ETo (mm/day)
January	27.4	17.6	79.1	4.8	67.2	3.57
February	27.3	17.8	81.5	5.1	52.3	3.59
March	27.8	17.4	80.8	5.7	56.6	3.67
April	27.9	16.6	79.9	6.8	61.9	3.61
May	28.2	14.7	71.2	7.9	64.3	3.45
June	27.5	12.0	66.4	9.3	69.6	3.38
July	26.9	10.3	59.6	9.2	82.1	3.52
August	27.7	11.7	59.0	8.7	77.1	3.86
September	29.6	13.2	58.9	8.5	104.6	4.61
October	31.1	15.3	55.6	8.4	108.5	5.05
November	31.7	17.4	56.7	7.1	103.7	4.85
December	30.0	18.2	67.4	5.8	73.9	4.09
Mean	21.9		68	7.3	76.8	3.94

Table 7: Mean monthly climatic data for Kapunga meteorological station (mean values obtained from five years data-1992-1995, 1997)

Month	Max Temp (^0C)	Min Temp (^0C)	RH (%)	Sunshine hours (hrs)	Wind speed (km/day)	ETo (mm/day)
January	28.7	18.04	74.5	6.1	75.1	4.03
February	28.12	17.98	81.0	4.6	47.5	3.50
March	28.98	17.72	76.5	9.2	59.9	4.61
April	28.74	16.48	74.2	8.2	75.4	4.05
May	28.18	13.6	71.1	9.3	83.3	3.79
June	26.48	10.46	67.7	12.6	96.5	3.60
July	26.3	8.84	65.0	12.8	114.5	3.81
August	27.04	10.48	58.2	16.7	143.3	4.52
September	30.44	15.22	55.9	12.2	163.5	5.47
October	30.7	17.08	51.2	12.1	196.5	6.11
November	27.96	19.2	55.6	11.3	198.4	5.60
December	29.88	18.8	60.2	8.9	107.6	4.68
Mean	21.85		65.9	8.6	113.5	4.48

Table 8: Mean monthly and annual flows (m^3/s) for selected rivers in Mkoji Sub-catchment

River	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Lunwa	51.05	72.32	130.59	132.44	50.37	20.22	13.80	7.17	3.91	3.41	8.33	22.89	516.49
Mswiswi	31.96	56.07	103.28	119.68	62.26	15.68	6.88	3.40	1.72	0.93	1.55	9.17	412.56
Umrobo	20.29	26.47	43.65	50.44	30.06	13.18	11.29	10.81	10.07	9.04	7.51	12.34	245.16
MEAN	34.43	51.62	92.51	100.86	47.56	16.36	10.65	7.13	5.23	4.46	5.79	14.80	391.40
Monthly volume (Mm^3)	3.0	4.5	8.0	8.7	4.1	1.4	0.9	0.6	0.5	0.4	0.5	1.3	33.8

(b) Discharge hydrographs

The hydrographs for Lunwa, Mswiswi and Umrobo rivers are shown in Figures 9,10 and 11 respectively for the period 1995 – 1999. The hydrographs correspond with the seasons. Peak flows are observed during the rainy season and the recession starts with the onset of the dry season. Umrobo River has much higher discharges compared to the other two during the dry season. This is partly explained by the fact that there are several springs (e.g. Inyala and Abadaa), which contribute significantly to this river during the dry period.

(c) Trend analysis

The linear trend analysis of the three rivers is presented in Table 9. The results show that there were significant trends for the annual flows for Umrobo and Lunwa rivers but no significant trend was detected for Mswiswi River. However, from this analysis, the flows of Mswiswi have been decreasing over the period of record.

Table 9: Results of linear trend analysis for Lunwa, Mswiswi and Umrobo rivers

Station name	No. of years	Mean annual flow (m^3/s)	Slope of the trend line (m^3/year)	t- statistic	t-critical	Significant level	Remarks
Umrobo 1KA51a	**46**	**245.16**	**1.56**	**2.15**	**2.01**	**0.05**	**Significant increasin g trend**
Mswiswi 1KA50a	**46**	**412.56**	**-1.59**	**-0.97**	**2.01**	**0.05**	**Insignificant trend**
Lunwa 1KA16a	**46**	**516.49**	**5.74**	**2.1**	**2.01**	**0.05**	**Significant increasin g trend**

3.1.4 Base-flow into wetlands

All the rivers draining the Mkoji Sub-catchment, during the dry season are perennial upstream of the Tanzania-Zambia Highway. This means that during this period, because of dry season irrigation, no flow passes downstream of the highway. However, Mkoji River receives drainage water from the Kapunga Rice Scheme at its confluence with the Itambo River (Figure 4).

The drainage water flows throughout the year because during the dry season, Kapunga Rice scheme is allowed to abstract about 1.5 m3 /s in order to satisfy domestic and livestock water needs of people living in nearby villages.

Monitoring of temporary flow measuring gauges installed upstream of irrigated areas showed more or less constant water levels and discharges in most of the rivers in the Mkoji sub-catchment since late July 2003. This implies that the flows of water in the rivers have reached or are nearing base flows. Table 10 summarises the results of discharge measurements using current meter. For Lunwa River, the flow was measured where the gauging station (1KA51a) is located. The measured flow (0.283 m3/s or 7.89 m3 /month compares very well with the long term mean monthly flow for August (7.2 m3/months) (Table 10). The implication is that the 2003 flows, for at least Lunwa River, are representative of long-term mean flows.

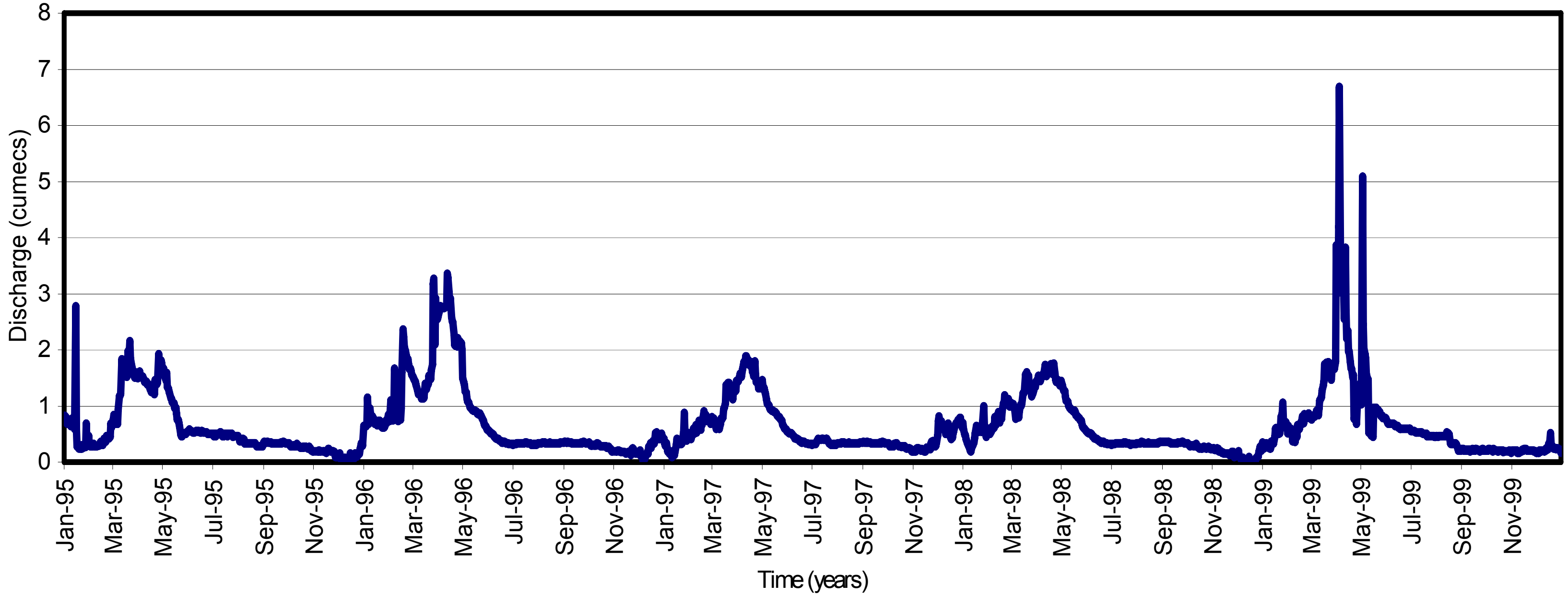


Figure 9: Mean annual areal rainfall for Mkoji Sub-catchment

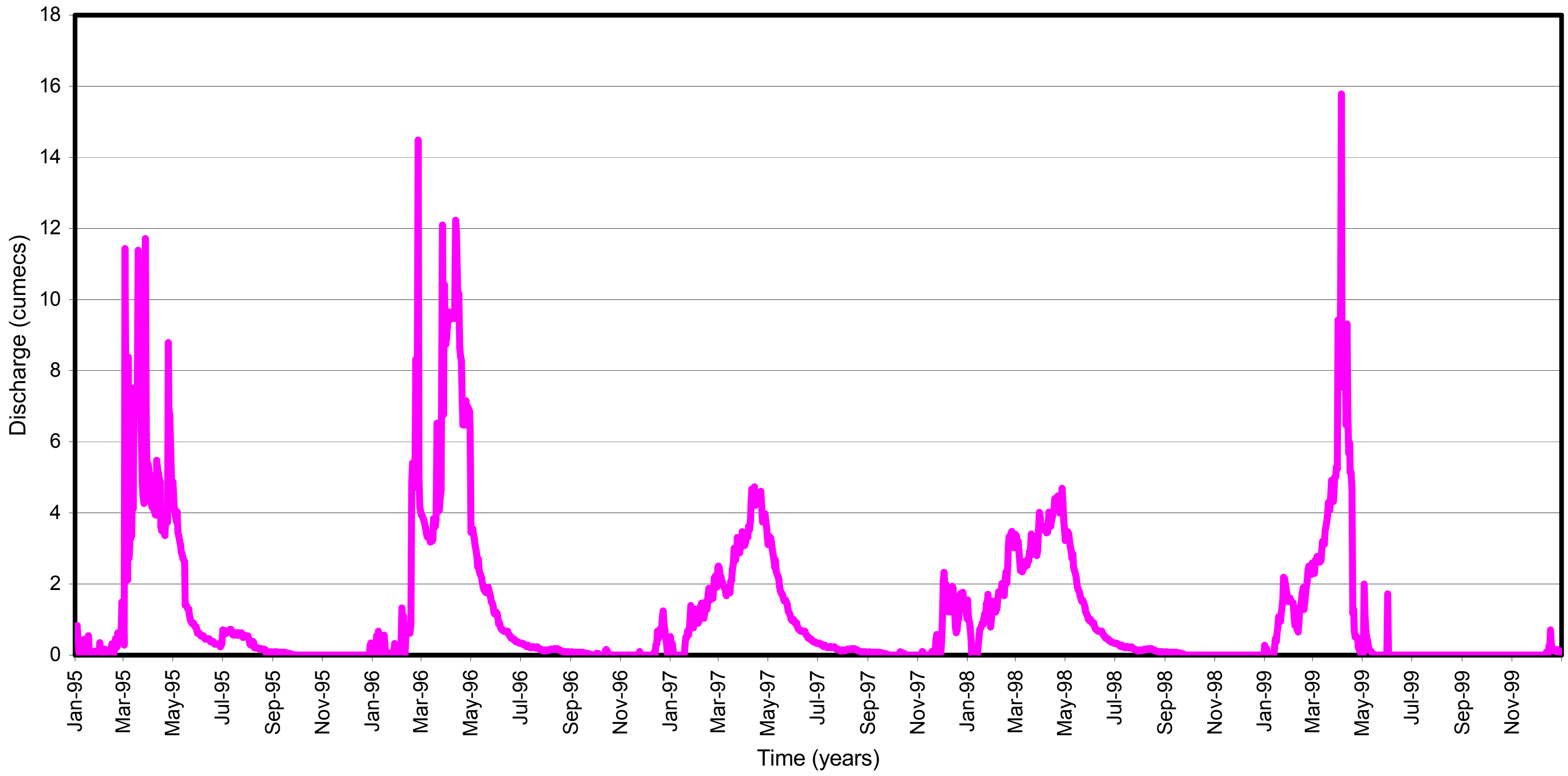


Figure 10: Daily streamflow hydrograph for Lunwa river 1KA51a (1995-1999)

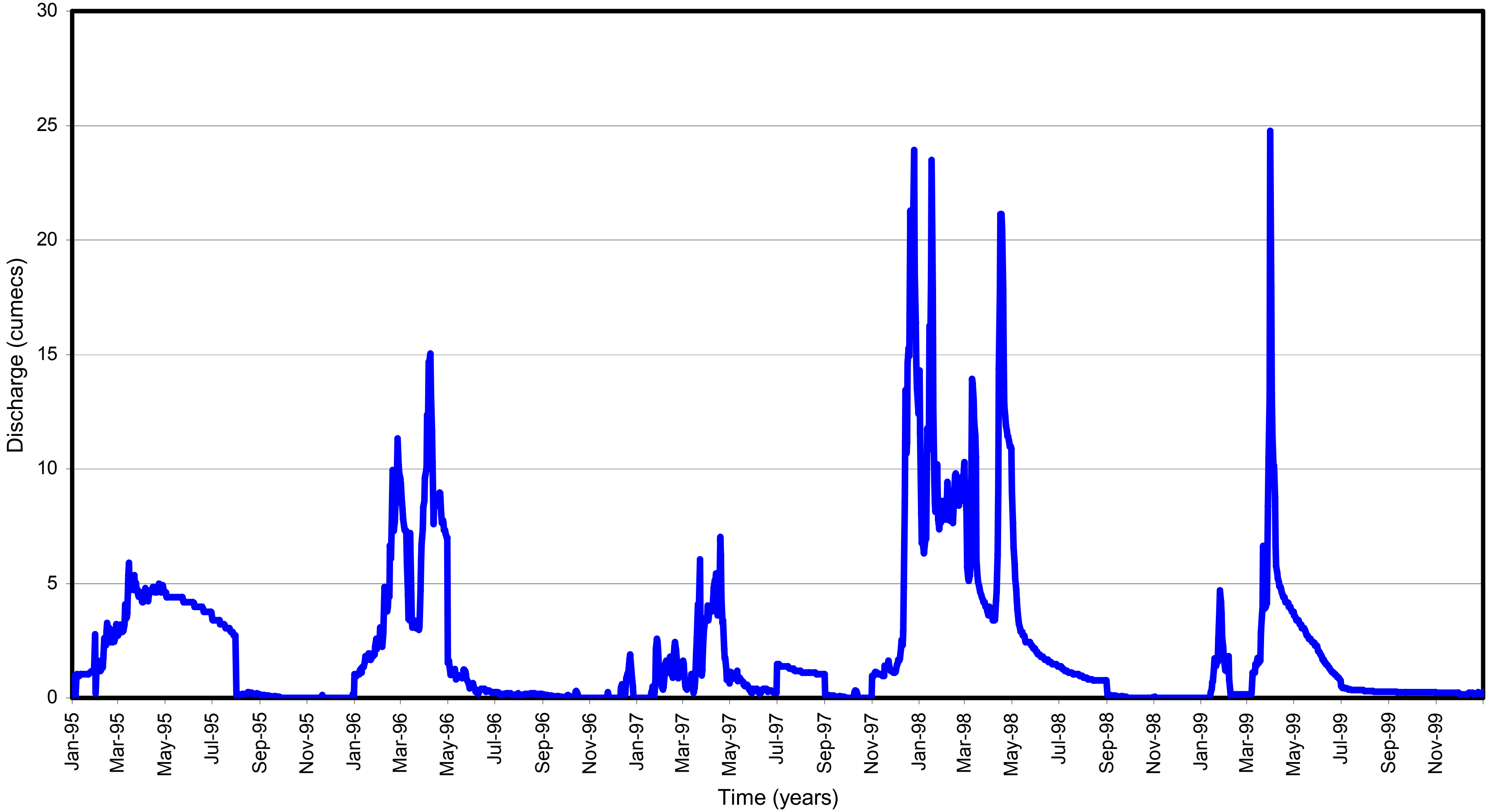


Figure 11: Daily streamflow hydrograph for Mswiswi 1KA50a (1995-1999)

Table 10: Results of low flow discharge measurements of rivers in MSC

Date	20/08/03	10/09/03	10/09/03	10/09/03	11/09/03	11/09/03	14/09/03	10/09/03
River	Itambo	Meta	Lunwa	Lwanyo	Mambi	Mswiswi	Ipatagwa	Mkoji
Flow (m^3/s)	0.003	0.007	0.263	0.085	0.165	0.28	0.155	0.027
Flow (l/s)	3	7	263	85	165	280	155	27

Date	09/09/03	09/09/03	09/09/03	09/09/03	09/09/03	09/09/03	09/09/03
River	Uta	Inyala Spring	Abadaa Spring	Mlowo	Mwambalizi	Sawa	Gwiri
Flow (m^3/s)	0.022	0.008	0.012	0.045	0.048	0.004	0.04
Flow (l/s)	22	8	12	45	48	4	40

3.1.5 Groundwater resources

The assessment of available groundwater resources requires an in-depth understanding of the physiography, geomorphology, geology and hydrogeology of the area under investigation. However such assessment is always limited by data availability. Little data exists in the Mkoji sub-catchment to enable adequate assessment of the groundwater resource. Despite that, there are some wells and boreholes within the Mkoji SC that could be used to give a general assessment of the groundwater resources of the catchment. To gain an insight of the groundwater in the catchment, existing information and data from existing boreholes were examined. Pumping test data for the three boreholes (BH 205/81, BH 208/81 and BH 209/81) done by CCKK in the early 1980s and shallow wells developed for domestic water supply were used to give a picture of the groundwater resources in the MSC.

(a) Groundwater occurrence

Groundwater occurrence in the Usangu area can be described in two modes, which are mostly controlled by geological set up. These are groundwater occurrence in the Usangu flats and groundwater occurrence in basement rocks (Tesha, 2000).
Groundwater in Usangu flats is found in semi-confined aquifers. Most of the groundwater occurs in intergranular materials of lake deposits or of recently river deposits. Most of the shallow wells in the area are found to be of unconfined aquifers while few of them are semi confined characterized by drop in water level during the dry season and recovering rapidly during the rainy season. The central part of the flats is crossed by sluggish flowing rivers, which carry bed load clastic materials, dominated by fine to utrafine sediments deposits of siltstones, sands and clays. Two wells drilled in Ukwaheri village have shown only alternating layers of clay and silty sands to a depth of 60 meters (Tesha, 2000). The condition may have been different in the past pluvial periods and buried channel aquifers may occur at greater depths. Each of the two wells can yield a maximum of two cubic meters per hour. Moreover, there is evidence that this central part is recharged by the rivers crossing it (Tesha, 2000).
Groundwater in the basement rocks is mostly found in weathered and fractured rocks. Generally, wells drilled in this formation have low yield unless good fractured rocks or considerable depth of weathered rock is found. Nevertheless, such formation occupies a limited portion of the Mkoji SC.

(b) Groundwater quality

The chemical analysis of water from wells drilled in the area showed that most of the parameters are within Tanzania standards with few exceptions (Tesha, 2000). This means that the water is acceptable for domestic and irrigation purposes. Based on electrical conductivity (EC) values, water from almost all shallow well is of low electrical conductivity. Electrical conductivity of water from boreholes varies from few hundreds to more than 2000 μs depending on the location of site and depth of the well (Tesha, 2000). Water from boreholes with high conductivity was found to be saline. However, salinity problems seem to be localized. An example of this localization is that of wells drilled at Luhanga village. Well No. 536/2/97 drilled at Luhanga had EC of 2600µs which is twice that of well No 536/6/97, 536/4/97 and 536/1/97 each with EC of 1300µs.

(c) Groundwater potential and development

The extraction of groundwater has been to a very small scale mainly based on hand pump schemes that provide water for domestic purposes. Even boreholes drilled in the area have been equipped with hand pumps for domestic purposes only. It is due to this fact that even the capacities of wells have not been established since they were drilled for domestic purposes using hand pumps (Tesha, 2000). The possibilities are that the capacities given were the pump capacity and not the actual well yield. Generally the pump tests carried out in wells drilled in this area were made to suit the purpose for which they were drilled. Groundwater development coverage in the Usangu flats has not fully exploited the full groundwater potential. The non-uniformity of the geology of the area does not allow one to use the data obtained from one area of the basin to access another area (Tesha, 2000). This can be seen even from the variation of well data obtained from one village such as Luhanga and Matebete.

(d) Groundwater recharge

The groundwater recharge mechanisms have not been studied in the MSC. However it is believed that the flats are recharged by rainfall mainly from the upper catchment and also streams flowing across the flats. Groundwater monitoring in the area is also non-existent. There is no established monitoring network even for the existing wells. This leaves the groundwater knowledge limited to the little information from the available boreholes and wells construction data.

(e) Existing information on wells and boreholes from previous studies in the MSC

Groundwater studies in the area were carried out in 1981 and 1984 during the Water Master Plan for some districts in Iringa, Mbeya and Ruvuma regions. The studies were initiated and financed by DANIDA Rural Water Project to assess groundwater potential. During the 1981 study, only five boreholes (BH Nos. 205 -209/81) were drilled in the Usangu flats. All these boreholes were drilled in two adjacent villages of Luhanga and Ukwaheri and four of them are in Luhanga village. The existing information and data on wells and boreholes are summarized in Tables 11 and 12. The summary is composed of information and data extracted from the survey of boreholes conducted by CCKK in the early 1980s. More boreholes and shallow wells information were extracted from the Groundwater Assessment Survey Report conducted in January 1999 by the Hydrogeologist Office.

The examination of the information on boreholes and wells (Tables 11 and 12) reveals that:

- The most common aquifer from which the yields are obtained is the weathered granite, which form part of the Usangu flats.
- Most boreholes and wells are concentrated in the northern part of the MSC and the static water levels are generally fairy uniform for the boreholes and wells in Luhanga Village but with variable yield. This reveals the difference in aquifer formation and variability in the area.
- The yields are small and this might have been attributed to unconsolidated lake deposits and the alluvial and colluvial deposits. The water yielding properties of these unconsolidated sediments are controlled by their grain size and degree of sorting. Well-sorted gravels and coarse sands are the best aquifers, where fine grained mud and sifts are relatively poor having high porosities, and very low permeabilities. Such formations may form aquifuges rather than aquifers. It is likely that the very low transmissivity values and specific storage from the pump testing data as presented in Table 11 and 12 are

associated with this. Despite that, such yields are suitable for relatively small-scale domestic water supplies.

- It was revealed that some boreholes have been abandoned because of insufficient yield

Table 11: Test pumping results for boreholes in Mkoji SC

Village Name	Well ID	Pump Test Date	Well depth (m)	Static Water Level (m)	Disch-arge Rate (m^3/h)	Draw-down (m)	Transmi ssivity T 3.1.5.1	Specific capacity Q/s_w ($m^3/h/m$)
Luhanga	BH NO. 205/81	-	36.60	26.15	1.90	-	2.4	0.37
Luhanga	BH NO. 208/81	09/10/81	30.80	21.56	1.0	0.63	7	0.25
Ukwaheri	BH NO. 209/81	10/10/81	30.50	13.05	1.15	9.00	0.6	0.08

Source: CCKK, 1982 and SMWUC, 2001

Table 12: Summarized Borehole and Shallow well data in Mkoji SC

Well No.	Village Name	Coordinates Easting	Coordinates Northing	Well Depth (m)	Water level (m)	Yield (m^3/h)	Aquifer
536/1	Luhanga	599734	9047213	60.00	18.70	7.20	Coarse sand, clay
536/2	Luhanga	597823	9048439	44.00	18.60	0.90	Sandy clay, sandstone
536/3	Luhanga	595906	9045990	36.00	26.00	1.90	Sandy clay, silt
536/4	Luhanga	595947	9049055	46.00	18.50	0.80	Sandstone, clay
536/6	Luhanga	596604	9047720	30.00	25.00	1.00	Sandy clay, silt
536/7	Luhanga	596814	9043941	40.00	25.00	6.00	Sandy clay, sandstone
MB 205/81*	Luhanga	597372	9044185	36.60	18.30	1.90	Fine sand, silt
MB 208/81*	Luhanga	598114	9047684	30.80	20.10	1.00	Fine sand, silt
MB 327/97	Muhwela	577208	9033822	42.00	2.65	3.30	Sandy clay, sandstone
MB 328/97	Muhwela	579988	9036522	42.00	10.20	1.00	Sandy clay, sand
MB 329/97	Muhwela	575584	9034008	42.00	6.40	0.60	Sandy clay, clay
MB 330/97	Muhwela	577557	9033250	42.00	1.20	1.80	Sand, coarse grained sand
MB 331/97	Muhwela	578033	9034001	42.00	8.74	1.20	Sandy clay, clay
MB 332/97	Muhwela	577499	9033729	42.00	9.50	1.00	Sandy clay, sand
BH 209/81*	Ukwaheri	602594	9060250	30.50	11.60	1.20	Fine sand, silt
1./98	Azimio	586765	9035603	47.50	10.00	1.80	Fine sand, silt
2./98	Azimio	586041	9034537	57.00	11.34	1.03	Medium sand, volcanic tuff
3./98	Azimio	586901	9038125	56.00	7.01	2.88	Coarse sand, silt
MB 333/97	Matebete	612683	9032796	68.00	3.80	4.50	Sand clay, gravel
MB 367/97	Matebete	611930	9032392	64.00	7.60	6.55	Course sand, clay
MB 368/97	Matebete	612889	9031696	68.00	8.60	2.00	Course sand, clay
MB 369/97	Matebete	612977	9034140	68.00	40.56	1.60	Sand, gravel, clay

Source: * CCKK, 1982; SMWUC, 2001

(f) Groundwater discharge from springs in the Mkoji Sub catchment

There are several springs within MSC, which are used for irrigation and domestic purposes. However the two springs located in Inyala and Idunda villages are used to irrigate substantial areas, which are about 6 and 14ha respectively. Flows from these springs, when measured on 9/9/2003 amounted to 8 l/s and 12 l/s for Inyala and Idunda respectively.

3.2 Typology of Livelihoods and Farming Systems

3.2.1 Socio-economic Characteristics of the Households in the Study Area

The socio-economic characteristics of the sample households are given in Table 13.

Table 13: The socio-economic profile of sample households in the study area

Characteristics	Value
Sample size (n)	246
Male-headed households (%)	84
Female-headed households (%)	16
Percent attended formal education (%)	49.9
Average age for head of households (years)	39
Average household size (members)	6
Average number of children less than 15 years	3
Average adult members working fulltime on farm	2
Average number of children working full time on farm	1
Average number of children working part time on farm	1
Average adult labour equivalent	4
Average dependency ratio	0.40
Average net household income per annum (US$)	495

Source: Survey data, 2003

The average households size for the entire sample households in MSC was found to be 6 people. This is slightly above the national average of 4.9 (TNBS, 2002[1]). The higher average household size in the study area can largely be associated with polygamy, which was reported to be popular among agropastoralists in the lower plains. The mean age for the head of households was found to be 39 years and the average number of children with age of less than 15 years was 3. This means that on average, half of the household members are children, a reflection of high birth rates and population growth. Female-headed households constituted about 16% of the total households, somewhat lower than the national figure of 20%. About half (49.9%) of all members of the sample households were reported as having formal education.

Agriculture (crop farming and livestock keeping) is the major economic activity in MSC. About 80% of all the members in the sample households were reported to be engaged in on-farm activities either as part time or full time workers. The average adult labour equivalent for the farming households was put at 4.[2] The involvement of children in farming activities is fairly low. The findings show that, children rarely work full time on-farm: only four percent were reported as working full time on-farm and only eight percent were working on part time basis. The possible explanation for this could be that most children spend much time in schooling and/or doing other domestic chores as the elderly go out to farm. The dependency ratio[3] was found to be 0.40, which is slightly lower than the national ratio (0.42). With regards to household incomes, a wide

[1] **Tanzania National Bureau of Statistics (TNBS), Household budget survey, 2002**

[2] **Different types of labour make different contributions to production, depending on the nature of the task performed, age and sex of the person performing it. In this study the family size variable was used to calculate a common denominator for all age and sex groups (the Adult Labour Equivalent) using the coefficients given in ILCA, 1990.**

[3] **Dependants are considered as the number of people younger than 15 and older than 65. The dependency ratio is the number of dependants over the remaining members of the household.**

range of disparities was noted among households. The average net household mean income was put at US $ 495 per annum, which is more than twice the national average of about US $ 209.

3.2.2 Wealth Ranking

For the PRA wealth ranking exercise that was conducted in all the six sample villages, 10% of the total households were chosen in each village (from the village registers) in order to provide a logistically feasible sampling frame. The wealth ranking exercise eventually resulted in identification of five wealth groups that acted as the sampling frame for a stratified random sample. With a list of households in each wealth group, 10% of the households were then randomly chosen from each of the wealth category resulting in a sample size of 246 households (10 from the "very rich" category, 30 from the "rich" category, 96 from the "medium" category, 80 from the "poor" category and 30 from the "very poor" category). The purpose of the wealth ranking, apart from the perceptions about poverty and wealth gained from the exercise, was to ensure that the sample drawn represent the full range of livelihood circumstances to be found in MSC, rather than being accidentally clustered around the mode of the range. The characteristics of wealth groups in the sample villages are shown in Table 14.

Land holding was considered as one of the most important determinants of wealth and various types of land ownership were noted. These included: inherited, Government given,[4] borrowed, hired or purchased. Those who are not able to cultivate their own land can hire it for money or in ex-change of agricultural produce especially the crop that was grown on that particular farm for that particular period. In terms of land ownership the determining factors for wealth include the total area cultivated and that which is inherited (owned). In addition, the quantity of crops harvested is another important determinant. In the upper MSC, the priority crops are maize, potatoes and vegetables. Rice is the priority crop in the middle MSC and maize, millet and sorghum in the lower MSC. Hence the measure for wealth is not only dependent on the number of hectares cultivated but also on the crop yield which is often expressed in number of bags.

Possession of paddy was considered as the most important factor determining the well being of a family, particularly in the middle MSC. A person who harvests adequate rice has almost everything such as money, food, can build a good house, and has social status in the community. The poor category of farmers harvests little rice because they cultivate little land using mostly family labour. Again, because of low life standards, the poor is more likely to become sick and hence reduced time for working on-farm. The poor have therefore, problems in securing their food.

Livestock (mainly cattle and shoats) was also considered as another important indicator of wealth, particularly in the lower MSC, where the majority of the people are Sukuma agropastoralists. Other than cattle and shoats, the villagers, particularly in the upper and middle MSC considered owning pigs as an important resource that can help promote a person to a wealthier rank.

The "very rich" and "rich" households cultivate between 4 and 20 hectares of land or more. They harvest 45 – 200 bags of paddy or more and they own 15 -200 heads of cattle or more. They have modern houses and can afford to pay for their children's education. Some own assets like milling machines and involve themselves in other income generating activities (may own shops, lodgings, bars, trading, etc).

Households in the "Medium" category cultivate between 1.2 - 4 hectares and harvest 10 – 45 bags of paddy and they own between 2 and 15 heads of cattle. Their houses are normally made of burnt bricks or mud walls, iron roof or thatch. They have the means to own a bicycle and a radio.

The "poor" and "very poor" households cultivate not more than 1.2 hectares and harvest atmost 10 bags of paddy and they own less than 2 heads of cattle or none. They normally have grass-

[4] **The government given land, refers to a land given to *bonafide* residents and can be passed over to children (son) as long as the initial recipient does not migrate out of the village.**

thatched houses with mud walls. They cannot afford paying their children's school fees. The very poor, sometimes manage only one meal a day or none.

Table 14: Local criteria and indicators derived from the wealth ranking exercise in the sample villages

Indicator	Wealth categories				
	Very rich	Rich	Medium	Poor	Very poor
Land owned	Up to 8 - 20 ha or more	4 - 8 ha	1.2 – 4 ha	0.4 – 1.2 ha	Less than 0.4 ha or do not own land at all
Land rent	Rent out land	Rent out land	May rent in/out land	Many rent in land	Do not rent in/out land
Paddy harvest (bags)[5]	70 – 200 bags or more	45 – 70 bags	10 – 45 bags	3 – 10 bags	1 – 3 bags
Maize harvest (bags)[6]	40 – 100 bags	10 – 50 bags	5 – 10 bags	1 – 3 bags	1 – 2 bags
Livestock	Cattle: 20 – 200 or more, shoats: 50 – 180, pigs: 10 – 20	Cattle: 15 – 20, shoats: 20 – 50, pigs: 5 – 10	Cattle: 2 – 15, shoats:3 – 20, pigs: 2 – 5	Less than 2 cattle or no cattle, shoats:1 – 2, pigs: 1 – 2, a few chickens	A few chickens only
House	Cement blocks/ burnt brick walls Cement floor Iron roof	Burnt brick walls Iron roof	Burnt or mud walls, iron roof or thatch	Mud walls, Thatch roof	Have houses with mud walls or no houses at all Thatch roof
Labour	Hire labour	Hire labour seasonally	May hire labour seasonally	May sell labour	Selling labour
Education	Primary level or above	Primary level	Primary level	Many have not been to school	Many have not been to school
Health services (Govt Hospitals, Dispensary, Clinics, traditional healers)	Can always pay for health services	Can pay for health service	Can afford to pay for services from Dispensaries and traditional healers	Can afford to pay for services from traditional healers /use traditional medicines	Can not afford paying for health service (use traditional medicines)
Other assets owned	Vehicles, Milling machine, Sewing machine, Refrigerator, Bicycles, TV, Radio, (ox-carts, oxen ploughs), private water point	Bicycle(s), Radio, Implements (ox-carts, oxen ploughs)	Bicycle(s), Radio	Few have radios	None
Other activities	Run different businesses (shops, lodgings, bars, milling machine)	May run few businesses (trading, beer brewing)	Handcraft and petty trading	Handcraft	None
Food security	Food secure all year round	Food secure all year round	Most are food secure all year	Seasonally food insecure	Food insecure most of the year

Source: PRA, 2003

[5] For paddy, 1 bag is 80kgs
[6] For Maize, 1 bag is 100 kgs

Clothing was also used as one of the wealth indicators but no difference was reported among the ranks. Essentially, those who are rich are expected to wear new clothes and not second hand clothes (mitumba) and those under rank number 5 (very poor) to have the poorest clothes because the income they earn does not allow them to buy expensive clothes. In general clothing was to a large extent, considered as a personal taste, interest and occasional. Some people who are considered poor dress better than the rich do. From the PRA, the general conclusion was that clothing was not an important indicator for wealth. Table 15 presents the summary of households falling under each wealth group as obtained from the wealth ranking exercises in the sample villages.

Only 13% of the total households in the sample villages were grouped as "very rich" and "rich". The "Medium" category constituted 35%, the poor 32% and the remainder about 20%.

Table 15: Summary of wealth ranks in the sample villages

Village/ Wealth Rank	Very rich	Rich	Medium	Poor	Very poor	Unranked	Total
1. Ikhoho (hhs)	8	24	104	90	44	0	270
2. Inyala (hhs)	2	5	287	138	51	1	484
3. Mahongole (hhs)	8	40	187	336	167	10	748
4. Mwatenga (hhs)	4	17	124	59	9	1	214
5. Madundasi (hhs)	36	67	192	197	204	8	704
6.Ukwaheri (hhs)	48	102	95	73	62	3	383
Total (hhs)	106	255	989	893	537	23	2803
%	4	9	35	32	19	1	100

Source: PRA, 2003

3.2.3 Farming Systems

Different authors have defined the term "farming systems" differently. FAO and World Bank, 2001, for example, define it as a population of individual farm systems that have broadly similar resource bases, enterprises patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate." A frequently quoted definition of a farming system is that it is "a unique and reasonably stable arrangement of farming enterprises that the household manages according to well-defined practices in response to physical, biological and socio-economic environments and in accordance with the household's goals, preferences and resources. These factors combine to influence output and production methods. More commonality is found within the system than between systems. The farming system is part of larger systems – e.g., the local community – and can be divided into subsystems – e.g., cropping systems." (Shaner *et al.*, 1982, p 16).

However, although it may be more logical to consider only farming enterprises in a definition of farming systems, farming systems analysis usually casts its net wider. The authors quoted above recognize that non-agricultural commodities (e.g., handicrafts) and income earned off the farm also interact with the household's goals, preferences and resources (op cit., p 3). Hence an alternative definition: "A specific farming system arises from the decisions taken by a small farmer or farming family with respect to allocating different quantities and qualities of land, labour, capital, and management to crop, livestock, and off-farm enterprises in a manner which, given the knowledge the household possesses, will maximize the attainment of the family goal(s)" (Norman, 1980, p 2).

A further definition also includes consumption: "The total of production and consumption decisions of the farm-household including the choice of crop, livestock and off-farm enterprises and food consumed" (Byerlee and Collinson, 1980, p 70).

The analysis of farming systems in this study borrows from all the above definitions and the existing farming systems are considered to condition both the actual and potential crop water productivity of the agro-zones. They are either a driving force towards food security or a crucial limitation on it and the resultant vulnerable groups.

In general, the family incomes in MSC are almost entirely dependent on natural resources. Other non-natural based activities (e.g., local merchandizing and trading) are indirectly dependent on natural resources in one way or another. Cultivation is the primary activity in the sub-catchment, both in terms of numbers employed and total income generated. This, together with the adaptation to resource opportunities has in turn resulted in different farming systems, reflecting the spatial variation in resource availability and land uses. The major divisions in MSC and their associated major farming systems are categorized as:

- The Upper MSC: has been divided into two major areas: the most upper (represented by Ikhoho village and dominated with rainfed agriculture and the lower upper (e.g., Inyala village) which is dominated by supplementary and dry season irrigation. Both areas benefits from access to the main road and railway. Human population in the Upper Mkoji is put at 59,234 people and the total number of households at 14,870 (2002 Census).

- The Middle MSC: has been divided into two major areas: the upper middle (represented by Mahongole village and dominated by both wet and dry season irrigation and benefits from access to the main road and railway) and the lower middle (represented by Mwatenga village and dominated by rainfed maize and irrigated paddy), both making use of favourable land and water resources available in the area. Middle Mkoji has a population of 48,366 people and 12,695 households.

- The Lower MSC: is an *agro-pastoral area* with both pastoralism and rainfed cultivation being important farming systems, responding to local variations in opportunity — lighter soils permitting cultivation, and grassy *mbugas* favouring livestock in the northern western wetland and the eastern wetland, and seasonal grasses on the northern fans. Human population in the lower Mkoji is 25,868 people and the total number of households is 4,352 (2002 Census).

(i) The Upper Mkoji

In the most upper Mkoji, cultivation is primarily rainfed. Irrigation, while locally important, is trivial in the area and is largely confined to narrow valley bottoms. Cultivation strongly reflects climatic variables. As altitude and rainfall increase, the range of crops and the length of the cropping season also increase. However, at the highest altitudes crop choice again becomes more restricted. The cool conditions favour long maturing crops, which is facilitated by the favourable moisture conditions. Most areas of the highlands have standing crops most of the year, with staggered cropping calendars for the major crops. Crop choice is influenced by conditions of soil and topography and, to a lesser extent, accessibility to markets.

At high altitudes especially along watersheds and on the high altitude grasslands, potatoes and pyrethrum are grown *(the potato farming system*). Potatoes are primarily planted from May to August, and harvested from December to February. Rainfall is high and the area benefits from moisture (both rain and cloud) drifting over from the Lake Nyasa catchment to the south. Soils are often shallow, poor, and gravely, and the climate cool and sometimes with frosts from June to August. Despite this, the area has become one of the major potato producing areas of Tanzania, with most of the crop transported to Dar es Salaam.

At lower altitudes, maize is the dominant crop. The break with the potato farming system is quite marked and abrupt. This perhaps reflects the limit of influence of the Lake Nyasa weather systems. Three maize-dominated highland systems have been recognized. On the western part, maize is mixed with potato production, along with wheat and pulses (beans and peas). This is a *maize-potato farming system*. Tree fruits (e.g., peaches, papaya, bananas and citrus) and vegetables are also important crops. The farming system takes advantage of fertile and well-structured volcanic soils and favourable climate. Incorporation of stubble and crop rotation are the primary means of maintaining soil fertility and the use of agro-chemicals is limited. Where land availability allows, fallowing may also be used. Not only does this area receive high annual rainfall, but also has low evapotranspiration and occasional dry season rains.

Labour comes mainly from the family. Only a small number of families have cattle, which are used primarily for milk production. Animal traction is uncommon. Families generally have a small stock of animals, 23 (sheep, goats and pigs), and a few chickens. Grazing land is in short supply, especially during the dry season from July to November.

At still lower altitude, especially in areas close to Uyole, beans supplant potatoes as the second crop, followed by wheat, potatoes and vegetables *(this is a maize-beans farming system*). The cropping season is somewhat shorter than the maize-potato system, reflecting lower rainfall, little dry season rains, and higher temperatures. However, the areas are favoured by moderate slopes, and are intensively cultivated. Almost all the forests and shrubs have been entirely cleared to pave way for crop production and fertilizer use is relatively high.

(ii) The Middle MSC

In the middle Mkoji, wet season paddy cultivation is an important activity. Amongst farmers, paddy plot sizes are typically between 0.5 and 2 hectares. Majority of farmers depend on family labour, which is normally provided by both men and women for maintaining their crop fields. Sometimes family labour becomes a constraint especially when the rainy season is delayed and the labour demands of the rainfed maize and paddy overlap. Farmers respond to these constraints by managing the available labour in several ways (e.g., stopping their children from going to school). Although hired labour could be a viable option it turns out to be expensive especially at peak times of labour demand. If the rains are delayed, many farmers may not be able to cultivate all their land and will hire out land to others.

While paddy is an important cash crop for most farmers in this area, priority is given to maize, which is a staple food. Most of the former crop is sold to traders with only small amounts reserved for family use.

In general, despite the importance of marketed rice as an income supplement, cultivation of both maize and rice is still essentially a low input-low output activity. Management is driven by the need to minimize risk rather than maximize opportunities (yields), and the emphasis is on provision for the family. As such, few inputs are used apart from hired labour in the paddy. There is almost no use of fertilizers, herbicides or pesticides. Varieties grown are generally local, and seed is typically carried over from one year's crop to the next year.

While taste is often cited for the choice of local varieties, other factors are also important. Improved seeds are expensive; they may not allow seed to be carried over from year to year, thus necessitating seed repurchase every year; and they are typically more demanding of both water and nutrients, require increased inputs (and associated cost) and are less adapted to the vagaries of climate.

(iii) The Lower MSC

In the lower MSC, pastoralism and rainfed cultivation are the major farming systems. The area has the largest number of livestock in MSC owned mostly by immigrant pastoralists (e.g., the Sukuma people from northern Tanzania). The Sukuma are agropastoralists and cultivate much larger areas. Charnley (1994, p. 330) reports that on average they cultivate about 2.2 hectares of maize, 1.4 hectares of millet, and 1.76 hectares of rice. The use of draught animal power has enabled majority of Sukumas to cultivate larger areas and on heavy clay soils.

In the lower MSC, other cropping systems within the pastoral zone are primarily opportunistic. On the northern part, small, isolated and fenced fields may be found on mounded sandy patches. Rainfall is equivalent to or greater than that on the southern part, but soils are generally not favourable. However, within the pastoral zone there are also islands of extensive cropping. In the north-east of Ukwaheri village, extensive areas have recently been cropped by the Sukuma. The soils are heavy (vertisols) and the areas cleared are local *mbuga*s, extending into the *Acacia seyal* woodland. The vegetation and soils indicate strongly that these areas have until recently been seasonally inundated. The conversion to cultivation suggests that, while these areas may still be relatively wet, inundation is no longer a constraint.

3.2.4 Livelihood Analysis

This section presents the livelihood analysis in the MSC. In particular, four questions are addressed:

- What are the available livelihood platforms in MSC?
- What are the factors influencing access to the above livelihood platforms?
- What are the livelihoods strategies commonly adopted by people?
- How effective are those strategies on livelihood security and environmental sustainability?

Variables chosen for the livelihood analysis are as summarized in Table 16.

Table 16: Variables used in livelihood analysis

Variable	Upper MSC	Middle MSC	Lower MSC
a) Average number of household members	5	5	8
Men	2	2	2
Women	2	2	2
Children	2	2	3
b) Average land owned (ha)	0.9	2.5	4.9
c) Average Tropical Livestock Units (TLU)	190.7	453.8	3749.9
d) Sources of income			
Paddy (US$)	NA	461.3	228.8
Non-paddy crops (US$)	157.6	35.9	110.0
Livestock (US$)	453.2	768.9	19324.8
Remittance (US$)	29.2	32.5	23.8
Fishing (US$)	NA	NA	NA
Brick making (US$)	221.3	140.6	165.6
Other NR-based (US$)	164.7	16.5	654.5
Non-farm (US$)	9.6	16.5	23.8
Labouring (US$)	NA	461.3	228.8

Source: Survey data, 2003

NA = Not Applicable

(i) Livelihood platforms

There exist major differences in the types of livelihood platforms among the three major areas in MSC. The prominent feature in the upper middle Mkoji, for example, is that livelihoods for the majority of people in the area is derived primarily from agriculture (both rainfed and irrigated). The economy of the areas is relatively more monetised, land is relatively scarcer than in the lower MSC and there are vibrant markets in land renting (Table 17), prevalence of labour hiring, income generating clubs and associations and little collective action or traditional forms of co-operation.

The prominent features in the lower Mkoji include: mixed crop production and pastoralism, seasonal access to markets, land availability, co-operative forms of labour arrangement, few income generating clubs or associations and higher levels of collective action in managing natural resources.

Table 17: Land renting and purchasing prices in the upper Mkoji Sub catchment

Item	Average Cost (US$ per ha)
Renting an irrigable land	28.5
Purchasing an irrigable land	742.8
Renting rainfed land	24.0
Purchasing rainfed land	247.0

Source: Survey data, 2003

(ii) Livelihood strategies

As for the livelihood platforms, livelihood strategies in MSC are diverse and can generally be categorized into the following three groups:

- Those relating to farming practices,
- Those relating to business and market relations and
- Those relating to social and cultural relations.

As often expected, richer people in MSC combine a diverse of income generating activities, draw on a variety of social relationships, collective labour arrangements, lending and borrowing mechanisms to spread risks. On the contrary, however the poor people have little scope for risk management and the poor are normally confined to growing drought resistant crops and selling their labour.

In general, the poor people in MSC have the most ineffective coping strategies, which erode their asset base. The most prominent of these are distress sales of household goods and sale of labour. Rich people on the other hand are more likely to be able to sell stored assets (grain, livestock) to cope with disasters without substantially eroding their asset base.

In the middle Mkoji, for example, coping strategies revolve around sale of assets, sale of labour and support from clubs and credit arrangements. In the lower Mkoji, sale of stored crops and livestock is important but the value of collective arrangements and drawing on social networks is also strongly stressed.

In the lower-upper and upper-middle Mkoji, diversification into small businesses, and strategies involving storage and sale of produce at high prices were prominent while in the lower MSC collective action, good social relationships and traditional ceremonies as well as expanding cultivated plots are the common livelihood coping strategies.

High seasonal stress (defined as high demands on household resources) was experienced by all households at the peak of the rainy season, due to labour shortages, food shortages, disease prevalence and cash demands. Poor households feel such seasonal stress most acutely and have to meet basic needs by selling their labour and taking children out of school, so reinforcing a vicious cycle of low productivity on their own fields.

In all the sample villages, many households experience some degree of labour shortage throughout the year. In the lower- upper and upper-middle Mkoji, households which combine dry season and rainy season crop growing experience few "slack periods" in the year whereas in lower Mkoji, dry season demands are increased by labour needs for herding and for collecting water.

Little strict gender differentiation between livelihood activities of men and women was found although gender specializations in certain tasks were commonly noted. Women have variable degrees of command over household resources and livelihood decision-making, some having a considerable degree of freedom and independent command of resources, while others are severely constrained by marriage and cultural norms.

3.2.5 Assessment of vulnerable groups

A variety of techniques and indicators were used to distinguish between households of different levels of wealth and the processes of impoverishment and accumulation. The study defines the vulnerable groups in MSC as those:

- Who are poor (including the poor women)
- Who get an income of less than US $ 1 per day per person
- Who lack assets and the capability to use them
- Who have limited access to livelihood platforms or capital (natural, physical, human, financial and social)
- Who are located distant from the major centres and main roads
- Who are highly dependent on, and disadvantaged by, market relations
- Who rely on small and ineffective social networks
- Who are unable to respond effectively to change
- Who are food insecure or malnourished
- Households falling under the bottom income quintile for different family types

Key issues, which arose from the assessment of the vulnerable group include the need to recognize different values and preferences for investment and expenditure between ethnic groups, people's own preference for identifying capabilities rather than assets as significant in determining wealth and poverty, the importance of tracking changes to household status over life-courses, and the difficulty of reconciling household wealth with intra-household allocation of resources. The vulnerability indicators and results obtained in this study are presented and discussed in the following sections.

(i) Life-course and dependency

Given the association between large families and poverty, it is worth exploring the structure of family life in MSC. Large families are generally expected to be far more common among the poorest households of the bottom quintile and average family size to be smaller for households in the upper income quintiles. Small households, those with very young children and those dominated by older people are also more likely to be poor and vulnerable.

Table 18 presents a probability analysis, which was done so as to highlight the impact of family size and composition on vulnerability to poverty in MSC. Households made up of three or more adults and three to four children are more than twice as likely to be in the bottom quintile as households with a single adult and one to two children. The female–headed households are also more likely to be vulnerable than the male head-households (compare probability of 27% versus that of 21%).

Table 18: Probability analysis of low-income households in the MSC

Family type	Percent in the lowest quintile
Female headed household	27
Male headed households	21
Single adult 1-2 children	12
Single adult more than 2 children	32
2 adults 3 – 4 children	30
2 adults with 6 –10 children	35
Household with 11+ people	38

Source: Survey data, 2003

In a close analysis of the percentages shown in Table 20, one would suggest that, vulnerability in MSC, as in most other rural communities increases with the number of dependants. This is evidenced by the higher probability value for the households with 6 to 10 or more children.

(ii) Natural resources/livelihood assets and poverty

The analysis in this study has shown that the poor (low-income/vulnerable groups) in MSC are also characterised by low resource endowment (Table 19). The average land holdings for the poorest in the area is put at 1.9 ha, which is about three times lower than the average size of land owned by the "very rich" category (about 6 ha).

Table 19: Resource ownership and income by wealth rank

Variable	Very poor	Poor	Medium	Rich	Very rich
Average land owned (ha)	1.9	3	2.1	4.5	5.7
Average value of household assets (US$)	70.5	91.3	155.7	450.3	481.2
Average household annual income (US$)	370	450	468	607	1002

Source: Survey data, 2003

With regards to other livelihood assets, the findings in this study suggest that the poorest are also prone to vulnerability because they either lack or own assets of low values. When put differently, the lack of valuable assets among the poor makes them remain in the vicious cycle of poverty while the rich, who own valuable assets have good chances of climbing the ladder because they may mortgage their assets so as to get loans from credit institutions. As shown in the regression results in Table 22, the value of household assets is one of the important determinants of wealth (as measured by the value of annual household incomes).

Table 20: Regression results between household incomes (US$) versus selected determinants of income

Predictor	Coefficients	Std. Error	T	P
(Constant)	-0.05	0.130	-0.409	0.683
Farm size (ha)	0.147	0.021	2.003	0.047
Household asset value (US$)	0.134	0.000	1.873	0.063
Household size	0.187	0.014	2.459	0.015
Relative distance from markets	0.158	0.061	2.040	0.043

ANOVA

	Sum of Squares	Df	Mean Square	F	P
Regression	11.164	4	2.791	7.604	0.000
Residual	63.503	173	0.367		
Total	74.667	177			
		R^2 = 46.4%			

Source: Survey data, 2003

The average household income for the “very poor” was low (US$370): three times lower than that of the “very rich” category (Table 20), which implies limited consumption and/or expenditure for goods and services, including health. This has negative implication, particularly on their health status as it may lead to reduced labour force, deaths and increasing number of orphans, widows and families without able-bodied, working-age adults. This situation will increase their vulnerability.

Due to lack of adequate livelihood capital, the poor people are also inclined to adopting production practices, which do not ensure sustainability of their resource bases. The lack of labour flexibility and other important inputs like irrigation water disproportionately affect their livelihoods and make them more vulnerable to poverty and hunger. The ability to diversify their production systems is also limited due insufficient livelihood capital. They are also adversely affected by commercialisation of natural resources (such as water, firewood and thatching grass) because they lack adequate financial capital. When access to these resources is commercialised the poor may have to travel long distances to collect “free” supplies or purchase only smaller amounts than what they actually need.

(iii) Poverty and the limits of social capital

Limited social networks and a high degree of social isolation also characterize the poor/vulnerable households in MSC. They may have difficulty in accessing help from relatives, are unable to pay entry fees of contributions to clubs and associations and infrequently attend village government meetings.

In the lower Mkoji, associational activities (in the form of collective labour arrangements, traditional ceremonies and informal groups such as drinking circles) cross cut rich and poor households and resulted in higher levels of social capital. In the middle Mkoji, co-operation and social interaction was primarily around income generating clubs and livelihood associations, membership of which was dominated by-middle income households.

4 CURRENT WATER USES IN MSC

4.1 2002/2003 wet season

(i) Crop water use under rainfed and intermediate agriculture

Table 21 shows water use of different crops in the wet season for MSC. The area under rainfed agriculture is distributed into 2680 ha for upper, 2867 ha for middle and 4407 ha for lower MSC. Total crop water use for rainfed crop is 37.07 Mm^3. This amount is apportioned into 11.49 Mm^3 for upper, 9.53Mm^3 for middle and 15.84Mm^3 for the lower MSC. The increase in crop water use in the lower part of the sub-catchment corresponds to the increase in area under rainfed agriculture.

Table 21: Crop water use under rainfed agriculture in the upper, middle and lower MSC

Crop name	Upper			Middle			Lower		
	Area (ha)	CWR (m)	Volume of water (Mm^3)	Area (ha)	CWR (m)	Volume of water (Mm^3)	Area (ha)	CWR (m)	Volume of water (Mm^3)
Maize	**575**	**0.49**	**2.81**	**665**	**0.35**	**2.33**	**1056**	**0.34**	**3.59**
Wheat	**362**	**0.34**	**1.23**						
Millet	**728**	**0.44**	**3.21**						
Sorghum				**1274**	**0.33**	**4.26**	**1995**	**0.38**	**7.57**
Beans	**468**	**0.46**	**2.13**	**231**	**0.28**	**0.65**	**484**	**0.31**	**1.50**
Onions				**47**	**0.23**	**0.11**			
Tomatoes	**311**	**0.39**	**1.20**	**207**	**0.33**	**0.68**			
Potatoes	**236**	**0.39**	**0.91**						
Ground nuts				**444**	**0.34**	**1.50**	**871**	**0.37**	**3.18**
TOTAL	2680	2.50	11.49	2867	1.86	9.53	4407	1.4	15.84

Table 22 shows the crop water use for paddy in the middle and lower parts of MSC. Paddy is cultivated under supplementary irrigation in these locations. Crop water use for the middle part of the sub-catchment is 13.25Mm^3 while for the lower part is 23.95Mm^3. The total water use is 37.20Mm^3.

Table 22: Paddy rice water use under intermediate agriculture for middle and lower MSC

Location	Total area (ha)	CWR (m)	Mm^3
Middle	**2194**	**0.30**	**6.63**
Lower	**3072**	**0.39**	**11.97**
TOTAL	**5265**	**0.69**	**18.60**

Figures 13 and 14 show areas under different agricultural domains and corresponding amount of water used under each production domain in the MSC. The area under rainfed production is lager in lower MSC followed by middle and upper of MSC respectively. The volume of water consumed by crops is also comparably higher in the lower part of the sub-catchment. The area under dry season irrigation is higher in the upper MSC than the middle MSC. The rainfall runoff generated from the catchment, which is used for growing paddy rice during the wet season, contributes to increased area under intermediate cropping system.

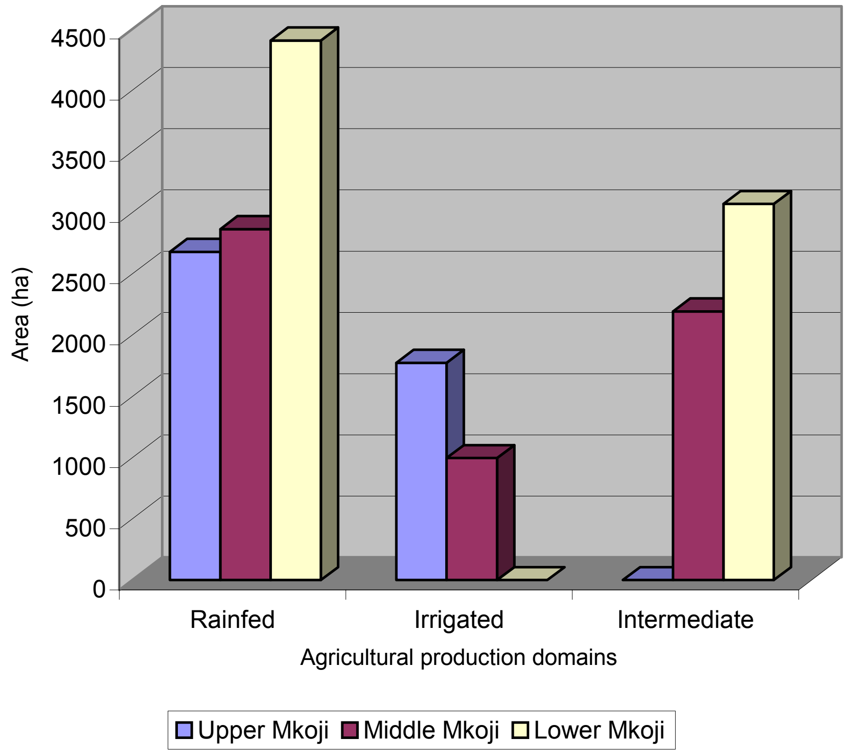


Figure 12: Area under different agricultural domains in MSC

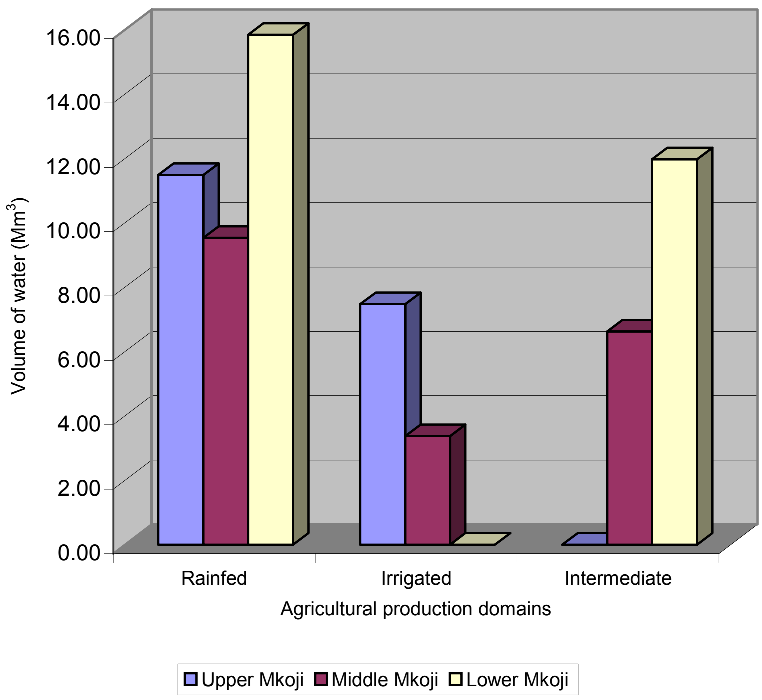


Figure 13: Crop water use under different agricultural domains in MSC

(ii) Domestic water use

This part presents an analysis of domestic water uses in MSC using the average amount of water consumed which was obtained during the sample survey. In addition, the 2002 Census results were used to estimate the total water requirements at the ward and sub-Catchment levels. During the wet season, domestic water uses were found to range from 0.1 to 0.41 million m^3 (Table 23). The total domestic water uses for the whole of MSC was estimated at 0.9 million m^3.

Table 23: 2002/2003 Wet season domestic water uses

District	Mkoji zone	Household consumption (m^3/hh/day)	Ward	Household number (Census)	Domestic water uses ($10^5 m^3$)	Sub-Total ($10^5 m^3$)	Total (10^6 m^3)
Mbeya rural	Upper	0.151	Inyala	2780	0.76	4.09	0.9
			Tembela	3836	1.05		
			Ilembo	5173	1.42		
			Ulenje	3081	0.84		
Mbarali	Middle	0.143	Ruiwa	2587	0.67	3.30	
			Mahongole	3681	0.95		
			Igurusi	6427	1.67		
	Lower	0.153	Utengule	4352	1.21	1.21	

Source: Survey data, 2003 and 2002 census results

(ii) *Livestock water uses*

The average number of livestock owned per household was converted into Tropical Livestock Units by applying the Tropical Livestock Units (TLUs) conventionally used for Sub-Saharan Africa. According to ILCA (1990), Jahnke (1982) and Williamson and Payne (1978) the units are given as follows: an adult cow is equivalent to 0.7 TLU; a donkey to 0.5TLU;a pig to 0.3 TLU; goats and sheep to 0.1TLU; and poultry 0.01TLU. The average numbers of livestock and their corresponding TLU for the sample villages are summarised in Table 24.

Table 24: Wet season average numbers of livestock and their corresponding TLU for the sample villages.

Area	Average	Cattle	Sheep and goats	Chickens	Pigs	Average TLU per household
Upper MSC	Livestock number	154	337	1710	107	2.4
	Livestock per household	2	4	22	1	
	TLU	107.8	33.7	17.1	32.1	
	TLU per household	1.4	0.4	0.2	0.4	
Middle MSC	Livestock number	428	426	2491	289	4.9
	Livestock per household	5	5	29	3	
	TLU	300	43	25	87	
	TLU per household	3	0.5	0.3	1.1	
Lower MSC	Livestock number	4987	2010	4514	43	47.5
	Livestock per household	63.1	25.4	57.1	0.5	
	TLU	3491	201	45	13	
	TLU per household	44.2	2.5	0.6	0.2	

Source: Survey data, 2003 and 2002 census results

Average TLUs increase as one moves from the highlands to the plains. The average TLUs for the upper, middle, and lower MSC were estimated at 2.4, 4.9 and 47.5 respectively (Table 26). It is worth noting that livestock ownership in the study area is in essence not uniformly distributed. Most of the households own none or few TLUs and few households own numerous units. The largest average TLU was reported in the lower MSC where only 4% of the total households own more than 250 cattle and the majority (about 70%) own none or less than 5 cattle.

The calculation of water use by livestock was mainly based on estimates given by King (1983) and SMUWC (2000). King (1983) states that an African indigenous adult cattle with 350 kg live weight in semi arid area consumes about 25 litres of water per day but discussions with herders and owners revealed that water consumption by cattle (250 kg) is about 40 litres/day in the dry season when forage has low moisture content and 20 litres/day during the rainy season. These latter estimates are in line with the estimates given by SMUWC (2000).

The study extrapolated the 2002 census results for the number of households in MSC to get the estimated total number of TLUs in the sub-catchments using the average number of TLUs obtained during the sample survey. The total number of TLUs in the sub-catchment was estimated at about 300 000 with 35, 000; 66, 000; and more than 200, 000 in the upper, middle and lower MSC respectively. Using these estimates, the volumes of water consumed by livestock were therefore estimated at 0.2 million m^3 for the upper MSC; 0.4 millions m^3 for the middle MSC and 1.1 million m^3 for the lower MSC. The total amount of water for the whole MSC was put at 1.7 million m^3 (Table 25).

Table 25: 2002/2003 Wet season livestock water uses in MSC

District	Area	TLU per household	Ward	Number of Households	Number of livestock	Livestock water uses (m^3)	Total for each area ($10^6 m^3$)	Total for MSC ($10^6 m^3$)
Mbeya rural	Upper	2.4	Inyala	2780	6672	35795	0.19	1.7
			Tembela	3836	9206	49392		
			Ilembo	5173	12415	66608		
			Ulenje	3081	7394	39671		
Mbarali	Middle	4.9	Ruiwa	2587	13452	72172	0.35	
			Mahongole	3681	19141	102693		
			Igurusi	6427	33420	179300		
	Lower	47.5	Utengule	4352	206720	1109053	1.1	

Source: Survey data, 2003 and 2002 census results

(iii) *Brick making*

According to the respondents, no brick making activities are carried out in the wet season. This is because the practice requires a dry weather to dry the bricks before being burnt.

(iv) *Fishery*

Although all of the interviewed households reported as not been engaged in fishing activities, discussions with key informants during the PRA exercises indicated that there are small-scale fishing activities going on. This is particularly done in irrigation canals or in-streams mainly in the middle and lower MSC. Few fishing ponds were also observed which are mostly constructed next to irrigation canals and filled once a year by diverting water from the irrigation canals. The study could not capture the actual catches from this activity because none of the respondents reported as being involved in fishing activities. This implies that the activity, while important in other parts of the Usangu area, is seen to be insignificant in MSC.

4.2 2003 Dry season

(i) Crop water use (irrigation)

Table 26 shows crop water use during the dry season for middle and lower part of the MSC. There is no dry season crop in the lower part of the MSC because all the irrigation water from the rivers in the MSC is completely depleted within the middle part. The total area under dry season irrigation is
2772ha. The area is distributed into 1775ha for the upper and 997ha for the middle parts of MSC. The total water use for dry season irrigation in the MSC is 10.86Mm3.

Table 26: Crop water use under irrigation in upper and middle MSC

Crop	Upper			Middle		
	Total area (ha)	CWR (m)	Mm^3	Total area (ha)	CWR (m)	Mm^3
Maize	**902**	**0.47**	**4.24**	**402**	**0.36**	**1.45**
Onions	**214**	**0.51**	**1.08**	**47**	**0.39**	**0.18**
Beans	**413**	**0.33**	**1.35**	**313**	**0.27**	**0.84**
Tomatoes	**245**	**0.33**	**0.81**	**235**	**0.39**	**0.92**
Total	1775	1.63	7.48	997	1.40	3.38

(ii) Domestic water use

The analysis of domestic water uses during the dry season was done using the same approach as for the wet season. As shown in Table 27, the average water uses were estimated at 0.36; 0.4; and 0.11 million m3 for the upper, middle and lower MSC respectively. The total volume of domestic water use for the whole of MSC was estimated at 0.87 million m3.

Table 27: 2002 Dry season domestic water uses in MSC

<table>
<tr><th>District</th><th>Mkoji area</th><th>Household consumption
(m^3/hh/day)</th><th>Ward</th><th>Number of Households
(Census)</th><th>Domestic water uses
(10^5m^3)</th><th>Sub-Total for each area (10^5m^3)</th><th>Total for MSC
(10^5m^3)</th></tr>
<tr><td rowspan="4">Mbeya rural</td><td rowspan="4">Upper</td><td rowspan="4">0.131</td><td>Inyala</td><td>2780</td><td>0.66</td><td rowspan="4">3.55</td><td rowspan="8">8.7</td></tr>
<tr><td>Tembela</td><td>3836</td><td>0.91</td></tr>
<tr><td>Ilembo</td><td>5173</td><td>1.23</td></tr>
<tr><td>Ulenje</td><td>3081</td><td>0.74</td></tr>
<tr><td rowspan="4">Mbarali</td><td rowspan="3">Middle</td><td rowspan="3">0.175</td><td>Ruiwa</td><td>2587</td><td>0.82</td><td rowspan="3">4.02</td></tr>
<tr><td>Mahongole</td><td>3681</td><td>1.17</td></tr>
<tr><td>Igurusi</td><td>6427</td><td>2.04</td></tr>
<tr><td>Lower</td><td>0.143</td><td>Utengule</td><td>4352</td><td>1.13</td><td>1.13</td></tr>
</table>

Source: Survey data, 2003 and 2002 census results

(iii) Livestock water use

During the dry season there is shortage of pasture and water resources in the MSC to support big herds of livestock. Consequently, livestock keepers with huge number of cattle are forced to migrate to the Usangu wetlands. The *Ihefu* wetland was the main dry season grazing area but since it was gazetted in 1998, it is now part of the Usangu Game Reserve where livestock is now prohibited to enter and graze. Discussions with cattle keepers revealed that only livestock keepers with less than 40 herds of cattle could stay with their herds within the MSC. Those with large cattle herds are forced to migrate and they do so with their shoats (sheep and goats). Thus, the number of livestock found in MSC is normally very low during the dry season particularly in the lower MSC where the average TLUs per households were found to decline from 7.5 in the wet season to 7.4 during the dry season (Table 28). This is a decline of about 75%.

Table 28: Wet season average numbers of livestock and their corresponding TLU for the sample villages.

Area	Average	Cattle	Sheep and goats	Chicken	Pigs	Average TLU per household
Upper MSC	Livestock number	94	207	1710	107	1.7
	Livestock per household	1	3	22	1	
	TLU	65.8	20.7	17.1	32.1	
	TLU per household	0.8	0.3	0.2	0.4	
Middle MSC	Livestock number	207	305	2491	289	3.4
	Livestock per household	2.4	3.5	29	3	
	TLU	145	31	25	87	
	TLU per household	1.7	0.4	0.3	1.0	
Lower MSC	Livestock number	697	382	4514	43	7.5
	Livestock per household	8.8	4.8	57.1	0.5	
	TLU	488	38	45	13	
	TLU per household	6.2	0.5	0.6	0.2	

Source: Survey data, 2003 and 2002 census results

The quantities of water consumed by livestock during the dry season were estimated at 0.2 million m^3 for the upper MSC; 0.4 million m^3 for the middle MSC; and 0.3 million m^3 for the lower MSC. The total amount of water used for livestock in the whole of MSC was estimated at 1.0 million m^3 (Table 29).

Table 29: 2003 Dry season water needs for livestock in MSC

District	Mkoji area	TLU per household	Ward	Number of Households	Number of livestock	Livestock water uses (m^3)	Total for each area ($10^6 m^3$)	Total for MSC ($10^6 m^3$)
Mbeya rural	Upper	1.7	Inyala	2780	4726	49028	0.26	1.0
			Tembela	3836	6521	67651		
			Ilembo	5173	8794	91230		
			Ulenje	3081	5238	54336		
Mbarali	Middle	3.4	Ruiwa	2587	8537	88564	0.43	
			Mahongole	3681	12147	126016		
			Igurusi	6427	21209	220023		
	Lower	7.5	Utengule	4352	32205	334093	0.33	

Source: Survey data, 2003 and 2002 census results

(iv) Brick making

Brick making is normally a dry season activity. The study has revealed that about 35% of the total households in the upper MSC, and 25% both in the middle and lower MSC are involved in brick making. The average number of bricks made per household were 971; 508; and 422 for the upper; middle; and lower MSC respectively. According to the questionnaire results, the amount of water used to produce 400 bricks was put at about 1 m^3. Using this figure, water used for brick making in MSC was therefore, estimated at 0.16 million m^3 with most of it being used in the upper and middle MSC (Table 30).

Table 30: Water uses for brick making in MSC

Location	Average number of bricks produced per household	Number of households	Total number of bricks produced	Quantity of water needed (m^3)
Upper MSC	**971**	**31917**	**30987771**	**77469**
Middle MSC	**508**	**61054**	**30990168**	**77475**
Lower MSC	**422**	**4352**	**1836324**	**4591**
MSC	**633**	**97323**	**63814263**	**159536**

Source: Survey data, 2003 and 2002 census results

4.3 Cropping Calendars, Sequences and Patterns

4.3.1 Upper Mkoji sub catchment

(i) Cropping Calendar

In this zone farming activities are carried out throughout the year. Main crops grown are maize, sorghum, beans, irish potatoes, tomatoes and other vegetables such as cabbages and peas. The cropping calendar, shown in Table 31, indicates that the main growing season extends from November, during which all major crops are planted, to July when the longest crop, maize, is harvested. Sorghum, which is grown in the lower parts of the upper MSC, is harvested in June. Short duration crops (i.e. beans and irish potatoes) planted in November are normally harvested in February and March. There after, a sequential cropping of similar short duration crops begins to make use of end of season rains and residual moisture. While residual moisture is very useful in the upper part of the MSC, supplementary irrigation is used in the lower part.

Table 31: Cropping calendar for the upper MSC

CROPS\ MONTHS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Cropping system	Production domain
Maize	Harvest/Weeding						Harvest/Planting				Ploughing and Planting		Mono/Mixed	Rainfed
Sorghum		Weeding				Harvest					Ploughing and Planting		Mono crop	Rainfed
Beans			Harvest/ Planting				Harvest/Planting				Land preparation and ploughing		Mono/Mixed	Rainfed/ Intermediate / Irrigation
Irish potatoes			Plantin g			Harvest					Ploughing and Planting		Mono crop	Rainfed/ Irrigation
Groundnuts		Weeding			Harvest						Ploughing and Planting		Mono/Mixed	Rainfed
Tomatoes		Harvest/planting			Harvest/planting				Harvest /planting		Ploughing and Planting		Mono crop	Rainfed /Irrigation
Wheat		Ploughing and planting					Harvest/ Planting						Mono crop	Rainfed

Source: Survey data, 2003

(ii) Cropping sequences

There are four major cropping sequences in the zone. These are:

a) Maize/ beans (intercropped) followed by maize or beans

Beans are intercropped with maize during the main rainfed-farming season. Beans are harvested in February and March while maize is harvested in July. Soon after harvesting maize, another crop of maize or beans is planted under irrigation. The maize is normally harvested green and fetches more market prices in January.

b) Beans followed by beans or irish potatoes

The first bean crop is planted in November and December and harvested in February. The second crop is planted in March under both rainfed and irrigated conditions and is harvested in June. The third crop of either beans or irish potato is planted in July/August under irrigated conditions.

c) Vegetables

Vegetables, such as tomatoes, cabbages, spinach, and lettuce contribute substantially to household income. Tomatoes and cabbages are normally planted in November and December (beginning of rainy season) and harvested in February and March after which tomatoes or leafy vegetables are planted. In May (end of rains) most farmers plant leafy vegetables, which take short growing duration of even three weeks (for spinach). As a result farmers could get four or even more cropping cycles.

D) WHEAT/SORGHUM (MONOCROPPED)

Normally these crops are planted in November/December and harvested in June and July.

(iii) Cropping patterns

The cropping patterns found in the study area include monocrop, intercrop and mixed cropping. Wheat, sorghum, tomatoes, irish potatoes and vegetables are normally grown as monocrop. Maize is usually intercropped with either beans or groundnuts. Irrigated crops are seldom mixed/intercropped and are grown as monocrop.

4.4 Middle Mkoji sub catchment

(i) Cropping calendar

The cropping calendar for the middle MSC is shown in Table 32. The main growing season begins in November and ends in May. In irrigated fields, maize harvested in May is immediately followed by another crop of maize, which is harvested in October and November. Other crops grown include paddy and sorghum, which are planted in late November/December and harvested in June. Rainfed agriculture with runoff harvesting in paddy basins is also practiced in this zone. Vegetable crops such as onions and tomatoes are grown under both rainfed and irrigated conditions. Supplementary irrigation is practiced in all crops except paddy and sorghum, which rely entirely on rainfall and runoff harvesting.

Table 32: Cropping calendar for the middle MSC

Crops \Months	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Cropping system	Production Domain
Maize	Weeding			Harvest/Ploughing/Planting						Ploughing and Sowing		Weeding	Mono/ Mixed	Rainfed
Beans			Harvest / Planting	Planting			Harvest/Planting				Ploughing and planting		Mono/ Mixed	Rainfed/ Intermediate /Irrigation
Paddy	Transplanting		Weeding			Harvest					Land preparation and ploughing		Mono cropping	Rainfed
Sorghum			Weeding			Harvest					Ploughing and Planting		Mono cropping	Rainfed
Onions			Ploughing/ Planting					Harvest/Planting			Harvest		Mono cropping	Intermediate / Irrigation

Source: Survey, 2003

(ii) Cropping sequences

There are three major cropping sequences in the middle MSC. These are:

a) Maize - beans

In this sequence either beans or maize normally follows maize-beans intercrop, which is planted in December-January and harvested in April-May. The latter second crop is grown under irrigated conditions.

b) Vegetables (tomatoes and leafy vegetables)

This cropping sequence is normally practiced in irrigated plots whereby tomatoes, onions and sometimes beans are planted in November and December and harvested in March. In most cases, there can be more than two leafy vegetables growing cycles following the first crop. The sequence is subsequently repeated.

c) Beans-vegetables

This cropping sequence is more or less similar to the vegetable sequence. Beans are planted as monocrop at the onset of the rainy season in November and followed either by beans or tomatoes and leafy vegetables in March. The second crop, which is harvested three months later, is normally followed by vegetables. In total there can be at least three cropping cycles.

(iii) Cropping patterns

For the middle MSC there is only one major cropping pattern, which is maize-beans intercrop. Other crops are normally grown as monocrops.

4.5 Lower Mkoji sub catchment

Crop production activities in the lower MSC rely entirely on rainfall, therefore farming activities are concentrated only in five months of the year. This follows the annual rainfall distribution resulting into a single cropping season. Major crops grown are maize, millet paddy and groundnuts.

(i) Cropping Calendar

Table 33 shows the cropping calendar for the lower Mkoji zone. Since farming is purely rainfed, all major crops, namely, maize, millet, paddy and groundnuts are planted in December. Except for groundnuts, which are harvested in April, other crops are harvested in June. There is a potential for growing sesame and sunflower in the area, however, these crops are not grown due to lack of markets and knowledge.

Table 33: Cropping calendar for lower MSC

Crops\ Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Cropping System	Production Domain
Maize		Weeding				Harvest					Ploughing and Planting		Mono /Mixed	Rainfed
Sorghum		Weeding				Harvest					Ploughing and Planting		Mono Cropping	Rainfed
Paddy	Transplanting		Weeding			Harvest					Land preparation and ploughing		Mono Cropping	Rainfed
Chick peas					Planting			Harvest						
Ground Nuts		Weeding		Harvest							Ploughing and Planting		Mono /Mixed	Rainfed

Source: Survey data, 2003

(ii) Cropping sequence

In this zone there is only one cropping sequence which is basically paddy followed by chickpeas. The latter crop is planted soon after harvesting paddy and utilizes the residual soil moisture.

(iii) Cropping patterns

The cropping pattern in the lower MSC is mainly maize-groundnut intercropping.

5 WATER PRODUCTIVITY

5.1 Crop Water Productivity Modelling

This section of the report describes the results for crop water productivity (CWP) modelling of the Mkoji sub-catchment. The results represent crop water productivity of the three agricultural production domains (rainfed, irrigated and intermediate) in the upper, middle and lower MSC. The results for the rainfed crops are for the last wet season (2002/2003), while the results for the irrigated crops are for the current (2003) dry season. The CROPWAT Model (7.0) was used to simulate the crop water requirement and the crop water use during irrigation. The input for the model included climatic, soils, and crop data. Crop yield data from the questionnaire survey were used to compute the CWP for different crops grown in the MSC.

Appendixces 4 Tables A4-1, A4-2 and A4-3 show the mean monthly weather data for the three zones of the MSC for five years. Appendix 4 Table A4-4 shows soil data used in the CROPWAT model. The soils in the upper MSC are generally medium, while the soils in the middle and lower MSc were heavy with high percentage of clay. The total available soil moisture in the two types of soils was 120 and 140mm/m, respectively. Crop data used in the simulation include crop development stages, crop coefficients; planting dates, yield response factors, rooting depth, plant height, and level of depletion factors.

5.2 Productivity of water in crop production system

(i) Rainfed crops

Tables 34, 35 and 36 show the crop water productivity for rainfed crops in the upper, middle and lower MSC, respectively. Major crops grown under rainfed conditions include maize, millet, dry beans, Irish potatoes, tomatoes, wheat, sorghum and onions. Wheat and Irish potatoes are grown only in the upper MSC while groundnuts and sorghum are grown in the middle and lower MSC.

Onions and tomatoes are the only high value crops grown in the middle and upper MSC under rainfed conditions. The crops were planted during February/March before the cessation of the rains and utilize residual soil moisture at the end of the wet season.

The average rainfall utilization efficiency for most crops was 50%. Average rainfall losses accounted for the remaining 50% of the total rainfall amount. These losses are mainly through surface runoff and deep percolation. The crop water productivity (CWP) for effective rainfall (PWEFR) and actual evapotranspiration (PWDP) were twice the CWP of the total rainfall (PWRF). This is so because the rainfall utilization efficiency is 50%. The CWP for high value crops (tomatoes, onions) and Irish potatoes for upper and middle MSC is comparably higher than CWP for grain crops. There is also a difference in CWP for cereals between the three zones of MSC. Crop water productivity for dry beans and sorghum is less (up to 15%) in the middle compared to upper MSC. However, in the upper MSC, CWP for dry beans (0.64kg/m3) is higher compared to middle and lower MSC (0.23 and 0.21kg/m3) based on actual rainfall water depleted. For maize, CWP (0.42kg/m3) is 64% and 30% higher in the lower compared to CWP (0.21 and 0.41kg/m3) in the middle and upper Mkoji respectively.

Generally CWP under rainfed is higher in the lower MSC for most cereals compared to the middle and upper MSC. The CWP for high value crops on the other hand is higher when compared to cereal crops.

Table 34: Crop Water Productivity for different crops in the rainfed upper MSC

Crop	CWR (mm)	ETa (mm)	RF (mm)	ERF (mm)	TRL (mm)	RE (%)	MD (mm)	CY (Mg/ha)	PW_{RF} (Kg/m^3)	PW_{ERF} (Kg/m^3)	PW_{DP} (Kg/m^3)
Maize	487.9	487.9	926.5	474.6	452.3	51.2	13.7	2.00	0.22	0.42	0.41
Millet	441.2	441.2	954.6	433.6	521.0	45.4	7.5	2.00	0.21	0.46	0.45
Dry Beans	313.5	313.5	706.0	312.0	394.0	44.2	1.5	2.01	0.28	0.64	0.64
Irish Potato	455.2	447.5	843.7	441.6	402.1	52.3	5.9	9.14	1.08	2.07	2.04
Tomato	386.1	364.4	553.6	288.6	264.4	52.2	75.9	7.2	1.30	2.50	1.98
Spring Wheat	341.0	236.6	370.3	147.4	222.9	39.8	89.3	1.50	0.41	1.02	0.41

Table 35: Crop Water Productivity for for different crops in the rainfed middle MSC

Crop	CWR (mm)	ETa (mm)	RF (mm)	ERF (mm)	TRL (mm)	RE (%)	MD (mm)	CY (Mg/ha)	PW_{RF} (Kg/m^3)	PW_{ERF} (Kg/m^3)	PW_{DP} (Kg/m^3)
Maize	350.7	350.7	657.9	348.4	309.5	53.0	2.4	0.73	0.11	0.21	0.21
Sorghum	334.5	334.5	710.4	332.7	337.7	46.8	1.8	0.32	0.05	0.10	0.10
Dry Beans	281.3	281.3	607.8	276.1	331.7	45.4	5.1	0.64	0.11	0.23	0.23
G/nut	338.3	338.3	742.6	383.9	358.7	51.7	4.4	0.41	0.05	0.11	0.12
Tomato	331.0	324.7	486.7	252.3	234.3	51.8	72.4	3.64	0.75	1.44	1.12
Onion	229.8	203.6	269.0	148.7	120.4	55.3	54.9	2.73	1.01	1.84	1.34

Table 36: Crop Water Productivity for different crops in the rainfed lower MSC

Crop	CWR (mm)	ETa (mm)	RF (mm)	ERF (mm)	TRL (mm)	RE (%)	MD (mm)	CY (Mg/ha)	PW_{RF} (Kg/m^3)	PW_{ERF} (Kg/m^3)	PW_{DP} (Kg/m^3)
Maize	339.5	339.5	461.2	303.5	157.7	65.89	92.3	1.41	0.31	0.46	0.42
Sorghum	379.3	363.2	441.5	260.1	180.4	58.9	103.9	0.89	0.20	0.34	0.25
Dry Beans	310.7	274.1	357.8	179.1	178.7	50.1	95.0	0.58	0.16	0.32	0.21
G/nuts	365.6	349.5	461.2	285.0	175.3	62.0	67.3	0.59	0.13	0.21	0.17

ii) Irrigated Crops

Tables 37 and 38 show the crop water productivity for irrigated crops in the Upper and Middle MSC, respectively. As a result of water abstraction for irrigation by the upper and middle villages, the streams at the lower MSC are always dry during the dry season. So no irrigation farming is practiced in this part of the sub catchment. Major crops grown under irrigation include maize, dry beans, tomatoes and onions. Irish potatoes are grown under irrigation only at the upper part of the sub catchment. Tomatoes are cultivated in the two zones throughout the dry season, which spans from late April to first decad of November. Planting during the early part of the dry season is in May, while the late season planting is done in September.

A fixed irrigation interval of 7-days is practiced for all the crops grown under irrigation in the two locations. The depth of water applied is not measured, but fields are flooded such that the soil moisture content is restored to field capacity at irrigation. As a result of fixed interval irrigation, the total net irrigation requirement (NIR) for maize was less than the actual irrigation requirement (AIR), leading to moisture deficits of 2.9 mm and 18.2 mm at the upper and middle zones respectively. This deficit occurs at the latter part of the crop-growing season, which leads to reduction in cop yields. Moisture deficits of 24.2 mm and 18.2 mm were also noticed for onions at the upper and lower zone respectively. This deficit occurs during the bulb formation to maturity growth stages. At the upper zone, where rainfall starts in the second decad of November, the late dry season tomatoes (planted in September), Irish potatoes, and onions receive effective rainfall of 146.4 mm, 24.5 mm, and 13.6 mm respectively. This may have been responsible for the higher yields for late tomatoes and onions in the upper zone compared to the middle zone.

Crop water productivity for irrigated tomatoes onions and potatoes were noticed to be higher compared to irrigated grain crops. With the exception of irrigated maize and dry beans, the crop water productivity for the irrigated crops in the middle zone was higher compared to the upper zone.

Crop water productivity for irrigated maize, dry beans, tomato and onions in the MSC were found to be higher compared to the same crops grown under rainfed conditions. The average values for crop water productivity (CWPdepleted) were 0.36 Kg/m3, 0.64 Kg/m3, 1.99 Kg/m3, and 2.37 Kg/m3 for irrigated maize, dry beans, tomato, and onions respectively; and 0.34 Kg/m3, 0.45 Kg/m3, 1.32 Kg/m3, and 1.77 Kg/m3 respectively, for the same crops under rainfed conditions.

Table 37: Crop water productivity for irrigated crops in upper MSC

Crop	CWR (mm)	ETa (mm)	RF (mm)	ERF (mm)	TGI (mm)	TNI (mm)	AIR (mm)	MD (mm)	CY (Mg/ha)	PW_W (Kg/m^3)	PW_{DP} (Kg/m^3)
Maize	470.1	470.1	2.8	2.3	632.7	442.9	467.8	24.9	1.71	0.27	0.36
Dry Beans	325.8	325.8	8.8	4.7	449.3	314.5	321.0	6.5	3.22	0.70	0.99
Tomato (Early)	414.5	414.2	2.1	1.8	634.4	412.4	412.7	0.0	9.34	1.47	2.25
Tomato (Mid)	509.7	506.0	4.9	3.6	764.1	496.6	506.1	5.7	8.50	1.11	1.68
Tomato (Late)	568.6	568.6	117.2	146.4	591.8	414.3	422.2	7.9	7.97	1.12	1.40
Irish Potato	501.6	488.0	81.2	24.5	638.5	447.0	477.1	16.5	5.96	0.83	1.22
Onions	506.2	453.1	14.7	13.6	593.1	415.2	492.7	24.4	10.73	1.77	2.37

Table 38: Crop water productivity for Irrigated crops in middle MSC

Crop	CWR (mm)	ETa (mm)	RF (mm)	ERF (mm)	TGI (mm)	TNI (mm)	AIR (mm)	MD (mm)	CY (Mg/ha)	PW_W (Kg/m^3)	PW_{DP} (Kg/m^3)
Maize	**360.3**	**360.3**	**0.6**	**0.6**	**487.8**	**431.5**	**359.6**	**18.2**	**1.3**	**0.27**	**0.36**
Dry Beans	**266.6**	**266.6**	**14.0**	**19.1**	**360.4**	**252.3**	**257.4**	**5.1**	**0.75**	**0.20**	**0.28**
Tomato (Early)	**335.1**	**335.1**	**5.0**	**4.9**	**471.7**	**330.2**	**330.2**	**0.0**	**8.34**	**1.75**	**2.49**
Tomato (Mid)	**392.5**	**292.5**	**1.4**	**1.0**	**559.3**	**391.5**	**391.5**	**0.0**	**7.50**	**1.34**	**2.56**
Tomato (Late)	**441.9**	**441.7**	**81.6**	**65.8**	**536.9**	**375.8**	**376.0**	**0.0**	**6.97**	**1.13**	**1.58**
Onions	**385.7**	**379.1**	**6.0**	**5.7**	**507.6**	**355.3**	**380.1**	**18.2**	**9.73**	**1.89**	**2.57**

(iii) Intermediate

Table 39 shows the CWP for paddy rice under supplementary irrigation (intermediate). Paddy rice is cultivated in the middle and lower parts of the MSC. The estimated total area grown under paddy rice in the wet season for MSC is above 12,000ha (SMUWC, 2001) practiced in both improved and traditional smallholder irrigation systems. The crop is grown during the rainy season but land preparation starts earlier in November for middle MSC because of easier accessibility to water from irrigation canals. Paddy rice transplanting in the lower MSC starts in late January because of water delay from upper MSC until when river water flowing from upper to lower MSC has increased substantially from rains in the upper catchment.

Table 39: Crop water productivity for paddy rice under supplementary irrigation

Location	CWR (mm)	Perc (mm)	Lprep (mm)	RiceRq (mm)	ERF (mm)	IrReq (mm)	Kg/ha	PW_w (Kg/m3)	PW_{ET} (kg/m3)
Middle	**515**	**2305**	**200**	**3020**	**453**	**2567.2**	**1727.79**	**0.057**	**0.34**
Lower	**529**	**2281**	**197**	**3007**	**290**	**2715.0**	**2060.86**	**0.068**	**0.39**

A large area under paddy rice in the MSC is either irrigated and rainfall supplemented or rainfed and supplemented with runoff irrigation. The water requirements for paddy are 3020mm and 3007mm for middle and lower MSC respectively. Water lost through percolation accounts for 76% of the crop water requirement both in the middle and lower MSC. The water used for land preparation is only 6% of the total water used for paddy production. The CWP for paddy is 0.057kg/m^3 and 0.068kg/m^3 for middle and lower MSC respectively. When only actual paddy crop water use is considered, CWP increases by 83% in both middle and lower MSC. These CWP values are lower compared to the average CWP for paddy rice in the Usangu plain (0.18kg/m^3) (SMUWC, 2001).

When the CWP for irrigated maize and paddy rice in the middle and upper MSC were compared based on gross water requirements, it was found that the CWP for maize is 79% higher than that for paddy rice. But when actual crop water use is considered, CWP for paddy rice and irrigated maize are almost equal, i.e. 0.34kg/m3, 0.39kg/m3, and 0.36kg/m3 for middle, lower and upper MSC respectively. The low values of CWP may be attributed to factors such as water loss through deep percolation, crop varieties, low use of fertilizers and pesticides, weather variability, and poor timing of crop planting.

Trials conducted by the Usangu village irrigation project between 1994/85-1986/87 for rice varieties and fertilizer in the middle MSC indicated that a maximum yield of up to 10tons/ha could be attained for improved varieties such as Katrin and ITA and 8tons/ha for local adopted varieties such as Kibibi and Kilombero (Macapugay et al., 1987). The reported yield for local varieties is possible with fertilizer application at the rate of 50kgN/ha and 80kgP2O5/ha. The use of insecticides and herbicides also contributed to the reported high yields. On average, paddy rice yield in the Usangu plains is 3ton/ha and therefore, with its current CWP of 0.18kg/m3, the potential for improving CPW for paddy is 45% without taking into account the contribution of other inputs such as fertilizers, herbicides, and insecticides. Although the potential for increasing CWP for paddy is high, low yielding local varieties, are mostly preferred by farmers because of good aroma that attract buyers.

5.3 Value of domestic water

The value of water in the domestic sector was estimated using two methods, the first one entailed the use of market prices for water and the second one used the Contingent Valuation (CV) approach. The first method has used the current market prices as charged by local sellers, who carry water from sources to the villages (as at Uyole which represent the upper MSC), at Tsh 20 per bucket of 20 litres (equivalent to Tsh 1000 per m3). The same price is also charged to cover the maintenance and operation costs for a well that was drilled by the SMUWC project in the Ukwaheri village (lower MSC).

In the second method the study adopted the use of the Willingness To Pay (WTP) approach. Households were asked individually how much they are willing to pay for an improved water supply. This involved the use of a direct, open-ended question such as: “What is the maximum amount of money they would be willing to pay (for improved domestic water supply)?” In addition, the respondents were given specific choices requiring a yes or no answer. The questionnaire was designed in the form of a bidding game with several options of combining open-ended and yes or no questions. This approach was specifically used in the lower MSC where water resources are scarce especially during the dry season and where villagers often walk long distances in search of water for their domestic needs. Fortunately, the average amount that respondents were willing to pay per bucket was found to be Tsh 20 (the same as for the first method). The price of Tsh 1000 per m3 was therefore adopted in the calculation of the value of water in the domestic sector. The value was estimated at Tsh 1.7 billion per year, equivalent to Tsh 12000 per person per year for the whole of MSC (Table 40).

Table 40: Values of water used for domestic purposes in MSC

Mkoji zones	Household consumption (m^3/hh/day)	Domestic water (Mm^3/year)	Total Volume of used in MSC (Mm^3/year)	Value of water (Tsh/m^3)	Total value of Domestic water used in MSC (billion Tsh/year)	Value of domestic water per year (TSh/person/year)
Upper	0.131	0.76	1.7	1000	1.7	12 000
Middle	0.175	0.73				
Lower	0.143	0.23				

Source: Survey, 2003

5.4 Productivity of water in the livestock sector

The productivity of water used in the livestock sector was calculated using the shadow price of Tsh 1 per litre, as deduced from the domestic sector. The Profit Margin Approach was then used to estimate the productivity of water in this sector. Livestock production in the study area can generally be defined as that of low input category involving family labour (for herding) as the major input, mostly provided by young members of the family. Labour was valued at Tsh 5000 per month, which is the average wage paid to herdsmen in other parts of the Usangu plains. Water productivity in the livestock sector was estimated at Tsh 5.25; 5.75; and 6.32 per m^3 equivalent to Tsh 2.19; 1.11; and 0.13 per TLU per m^3 for upper, middle and lower MSC respectively (Tables 41 to 43).

Table 41: Water productivity per annum in the livestock sector in upper MSC

Variable	Units	Price (TSh/Unit)	Value (TSh)
REVENUE:			
TLU	2.4		303,621.25
Total revenue per year			303,621.25
VARIABLE COSTS:			
Herding	12	5,000.00	60,000.00
Water consumed per year	37543	1.00	37,543.00
Other variable costs			9,051.00
Total Variable costs (Tsh/year)			106,594.00
Profit Margin (TSh/year)			197,027.25
Productivity of water (Shs/m3)			5.25
Productivity of water (TSh/TLU/m3)			2.19

Source: Survey data, 2003

Table 42: Water productivity per annum in the livestock sector in the middle MSC

Variable	Units	Price (TSh/Unit)	Value (TSh)
REVENUE:			
TLU	4.9		616,266.67
Total revenue per year			616,266.67
VARIABLE COSTS:			
Herding	12	5,000.00	60,000.00
Water consumed per year	81868	1.00	81,868.37
Other variable costs			3,619.66
Total variable costs (TSh/year)			145,488.02
Profit margin (TSh/year)			470,778.64
Productivity of water (TSh/m3)			5.75
Productivity of water (TSh/TLU/m3)			1.11

Source: Survey data, 2003

Table 43: Water productivity per annum in the livestock sector in the lower MSC

Variable	Units	Price (TSh/Unit)	Value (TSh)
REVENUE:			
TLU	47.5		5,518,797.85
Total revenue per year			5,518,797.85
VARIABLE COSTS:			
Herding	12	5,000.00	60,000.00
Water consumed per year	745004	1.00	745,003.90
Other variable costs			4,598.73
Total variable costs (TSh/year)			809,602.64

Profit Margin (TSh/year)	**4,709,195.21**
Productivity of water (TSh/m^3)	**6.32**
Productivity of water (TSh/TLU/m^3)	**0.13**

Source: Survey data, 2003

5.5 Productivity of water in brick making

The Profit Margin Approach was used in calculating water productivity in brick making. The market price was reported to average Tsh 20 per brick during the dry season. Although the price can go up to Tsh 35 per brick particularly during the wet season when brick supply is limited to the quantity carried forward from the last dry season, most of the bricks are normally sold during the dry season when weather allows construction of houses. Therefore the dry season prices were used to value productivity of water. According to the estimates done, water productivity for brick making was estimated at Tsh 2.18, 1.41 and 1.32 per m^3 for the upper, middle and lower MSC (Tables 44 – 46) respectively.

Table 44: Productivity of water for brick making in the upper zone of MSC

Variable	Units	Price (TSh/Unit)	Value (TSh)
REVENUE:			
Brick	971	20.00	19,420.00
Total revenue			19,420.00
VARIABLE COSTS:			
Water consumed	2428	1.00	2,427.50
Man days	20	166.67	3,333.40
Other variable costs	971	8.625	8,374.88
Total variable costs (TSh/year)			14,135.78
Profit Margin (TSh/year)			5,284.23
Productivity of water (TSh/m^3)			2.18
Productivity of water (TSh/brick/m^3)			0.0022

Source: Survey data, 2003

Table 45: Productivity of water for brick making in the middle zone of MSC

Variable	Units	Price (TSh/Unit)	Value (TSh)
REVENUE:			
Brick	507	20.00	10,140.00
Total revenue			10,140.00
VARIABLE COSTS:			
Water consumed	1268	1.00	1,267.50
Man days	10	166.67	1,666.70
Other variable costs	507	10.68	5,414.04
Total variable costs (TSh/year)			8,348.24
Profit Margin (TSh/year)			1,791.76
Productivity of water for 507 (TSh/m3)			1.41
Productivity of water (TSh/brick/m3)			0.0028

Source: Survey data, 2003

Table 46: Productivity of water for brick making in the lower zones of MSC

Variable	Units	Price (TSh/Unit)	Value (TSh)
REVENUE:			
Brick	**422**	**20.00**	**8,438.00**
Total revenue			**8,438.00**
VARIABLE COSTS:			
Water consumed	**1055**	**1.00**	**1,054.87**
Man days	**8**	**166.67**	**1,333.36**
Other variable costs	**422**	**11.04**	**4,657.52**
Total variable costs (TSh/year)			**7,045.75**
Profit Margin (TSh/year)			**1,393.24**
Productivity of water (TSh/m^3)			**1.32**
Productivity of water (TSh/brick/m^3)			**0.0031**

Source: Survey data, 2003

6 CONCLUSIONS AND KEY POLICY IMPLICATION

6.1 Conclusions

From this study, the following conclusions can be drawn.

1. During the dry season, the water resources in the MSC are inadequate in meeting the domestic, livestock and crop production requirements. However, the highlands receive fairly more rainfall (than the lowlands), which is adequate to meet crop water requirements under rain fed conditions. The potential for using ground water exists but but it has not been adequately studied and exploited.

2. The average households size (6) in MSC is relatively higher than that of the national average of 4.9. Female-headed households constitute about 16% of the total households, somewhat lower than the national figure of 20%. The adult labour equivalent for an average farming household is 4 and the dependency ratio is 0.40 (slightly lower than the national ratio of 0.42). There is wide income disparity among households. The average net mean income was US $ 495.00 per annum, which is more than twice as much as that of the national average (US $ 208.87). Only 13% of the total households were grouped as rich ("very rich" and "rich") and the poor categories ("poor" or "very poor") constitute about 20% of the total households in the area. In general, the family incomes in MSC are almost entirely dependent on natural resources and cultivation is the primary activity, both in terms of numbers employed and total income generated. Together with the adaptation to resource opportunities this determines the types of farming systems and livelihood outcomes.

3. Livelihood strategies and coping mechanisms in MSC are diverse and vary. Livelihood strategies relate to farming practices, business market, social and cultural relations. Coping strategies resolve mainly around sale of assets, sale of labour and support from clubs and credit arrangements.

4. There is little strict gender differentiation between livelihood activities in MSC. Gender specializations in certain tasks are common and women have variable degrees of command over household resources and livelihood decision-making and independent command over resources. However, others are severely constrained by marriage and cultural norms.

5. The vulnerable groups in MSC are the poor who get an income of less than US$1 per day per person. They include poor women. They are at risk of food security and their households fall under the bottom income quintile for different family types.

6. The cropping calendars, patterns and sequences in MSC are quite diverse. More intensive farming activities are found in the upper and middle parts of the subcatchment. This is made possible by use of residual soil moisture and irrigation. Both maize and beans are extensively in the MSC. Paddy is mostly grown in the middle and lower MSC.

7. Among the different water users in the MSC, agriculture is the leading consumer under both rain-fed and irrigated production systems. Under these two domains, it was estimated that they use 66.63 million cubic meters of water during the wet season. The other major water users include livestock (1.7 x 10^6 m^3) and domestic (0.9 X10^6). During the dry season, total water use by the different sectors (agriculture, livestock, domestic and brick making) was 12.89x10^6 m^3.

8. Generally, the crop water productivity under rain-fed crop production was higher in the lower MSC for most cereals compared to the middle and upper MSC. However, vegetables (high value crops) had higher crop water productivity than cereal crops (e.g. maize).

9. Under irrigation conditions, crop water productivity for irrigated maize, beans, tomatoes and anions in the MSC were found to be higher than same crops when grown under rainfed conditions.

6.2 Key Implications

The following key policy implications are derived from the assessment of livelihoods farming systems and vulnerable context.

1. Given the shrinking natural resources base, the need to implement improved resource management over areas wider than the village raises questions of the appropriate authority and monitoring mechanisms. Improved resource management has the potential to benefit the poor (e.g. through improved supply of water to irrigation tai-lenders) but will not necessarily do so. Poor people are likely to be differentially affected by new resource arrangements and this should be taken into account at the grass-root level of planning.

2. Poor people are unlikely to be able to change their resource use patterns unless their extreme labour shortages are addressed. A useful focus of community engagement activities could be on the development of village specific poverty indicators related to natural resource use and management.

3. Traditional resource management arrangements should not be ignored in planning.

4. The high levels of seasonal stress on households and the shortage of labour mean that the opportunity costs of participation in public decision-making are high, particularly for poor people (a potential constraint to community engagement activities and a challenge to development of local strategies, which do not disadvantage the poor).

5. Due to the high opportunity costs of participation people are more likely to prefer institutional arrangements for resource management, that economize on transaction costs. In designing such arrangements it should be noted that the people making public decisions about regulations (mostly adult male household heads) are not necessarily those actually using the resource (children, hired labourers, women).

6. Gender role flexibility suggests a scope for greater women's involvement in public decision-making about natural resource management. However, women are currently unlikely to substantially contribute above hamlet level, possibly because the decision-making fora at village level and above are not perceived by them as "women-friendly."

7. Due to strong inter-linkages in rural livelihoods and common cultural principles emphasizing respect and accommodation, there should be scope for building strong inter-ethnic co-operation over resource management. The need to build trust between pastoralists and government is vital and will be critical to improved resource management and development activities.

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8 APPENDICES

Appendix 1: Average Monthly Rainfall at different weather stations in MSC

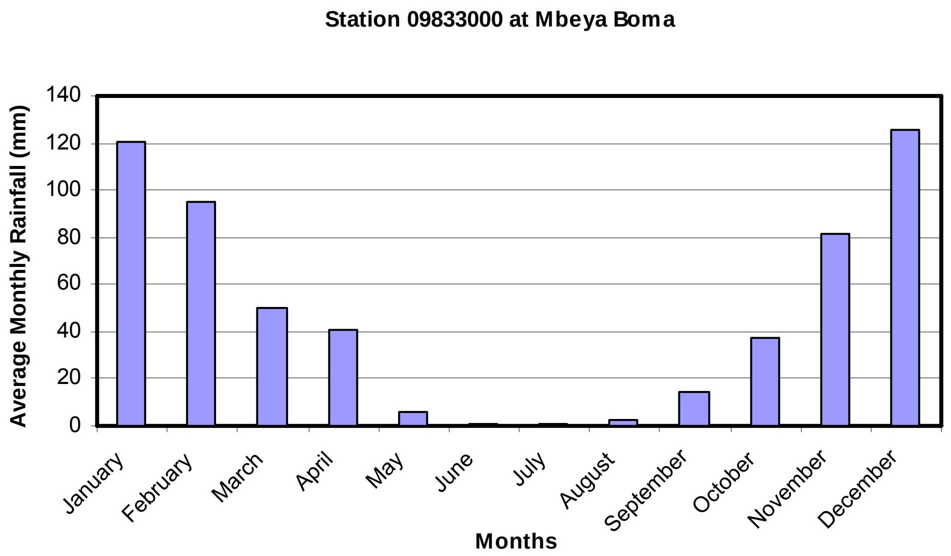

Figure A1-1: Average Monthly Rainfall at Mbeya Boma station

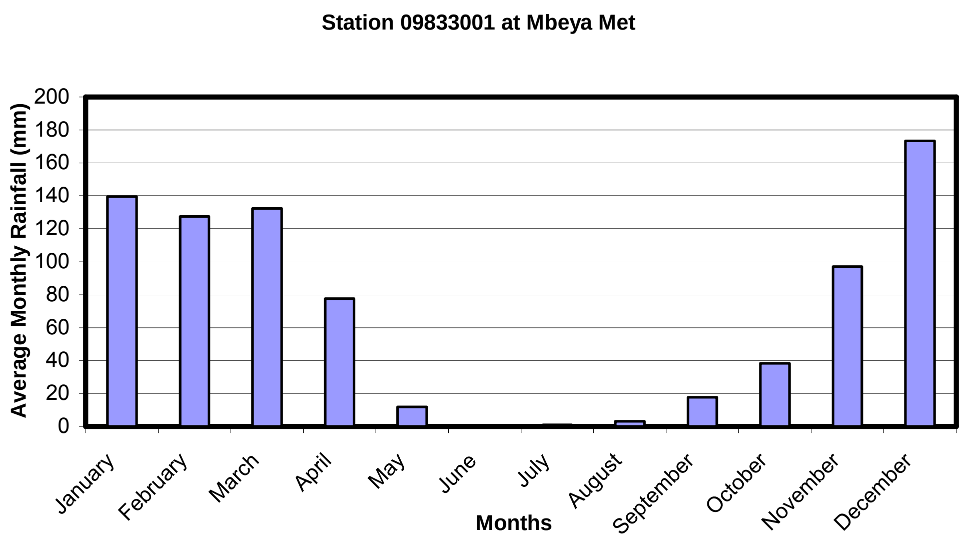

Figure A1-2 Average Monthly Rainfall at Mbeya Metrological station

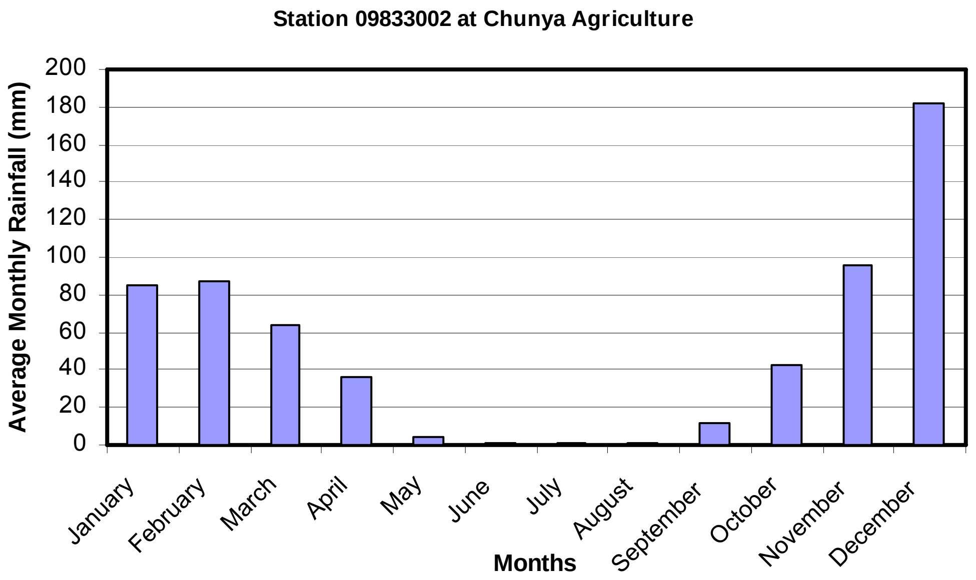

Figure A1-3 Average Monthly Rainfall at Chunya station

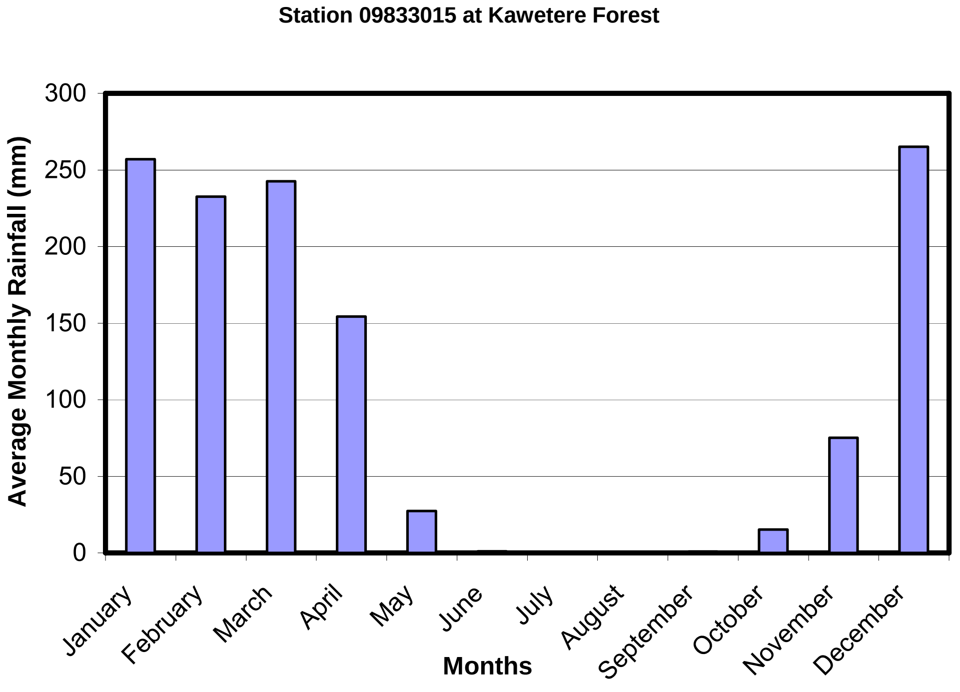

Figure A1-4 Average Monthly Rainfall at Kawetere Forest station

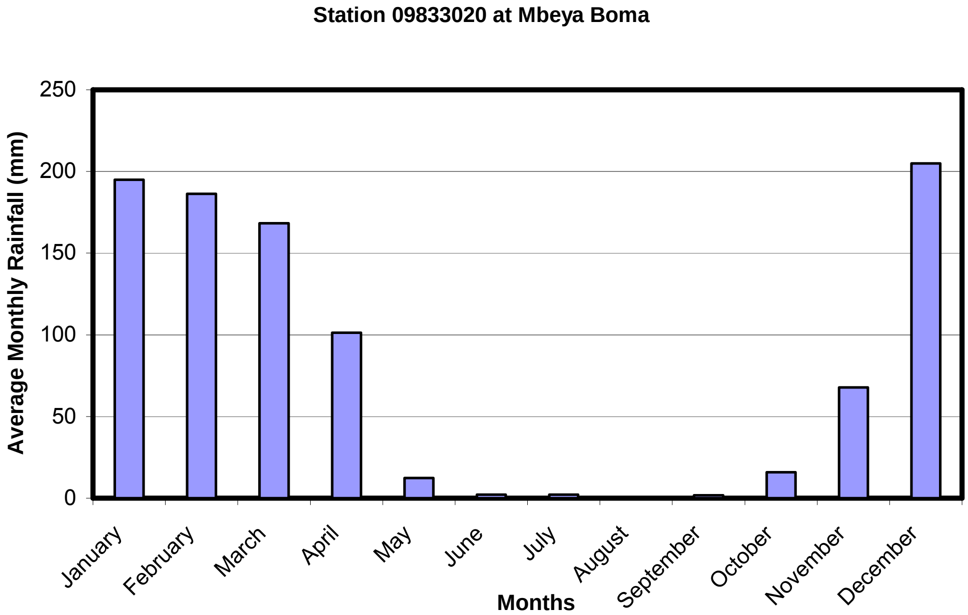

Figure A1-5 Average Monthly Rainfall at station 08833020 Mbeya Boma

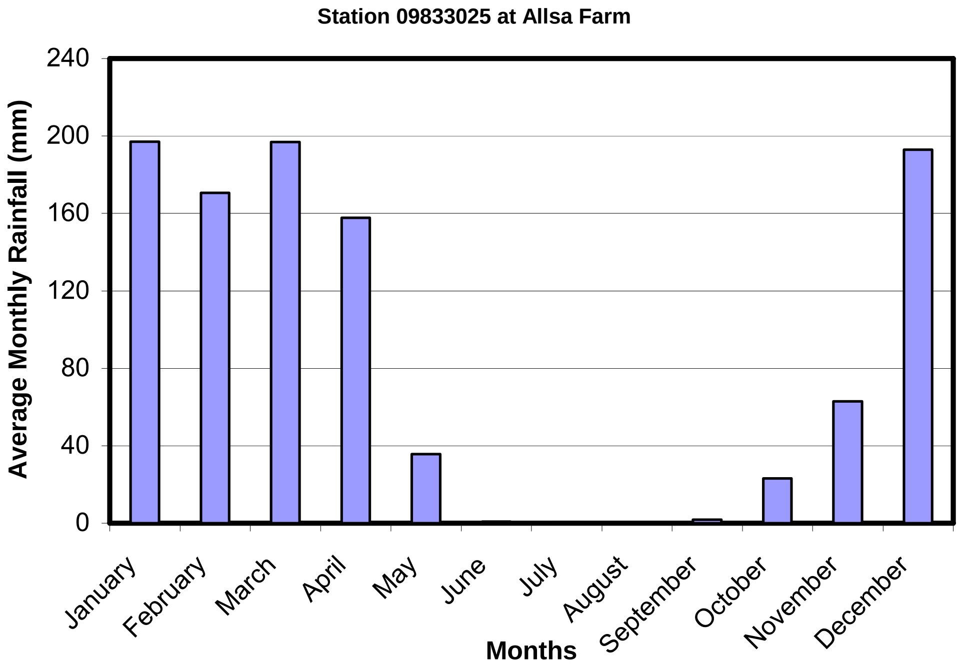

Figure A1-6 Average Monthly Rainfall at Allsa Farm station

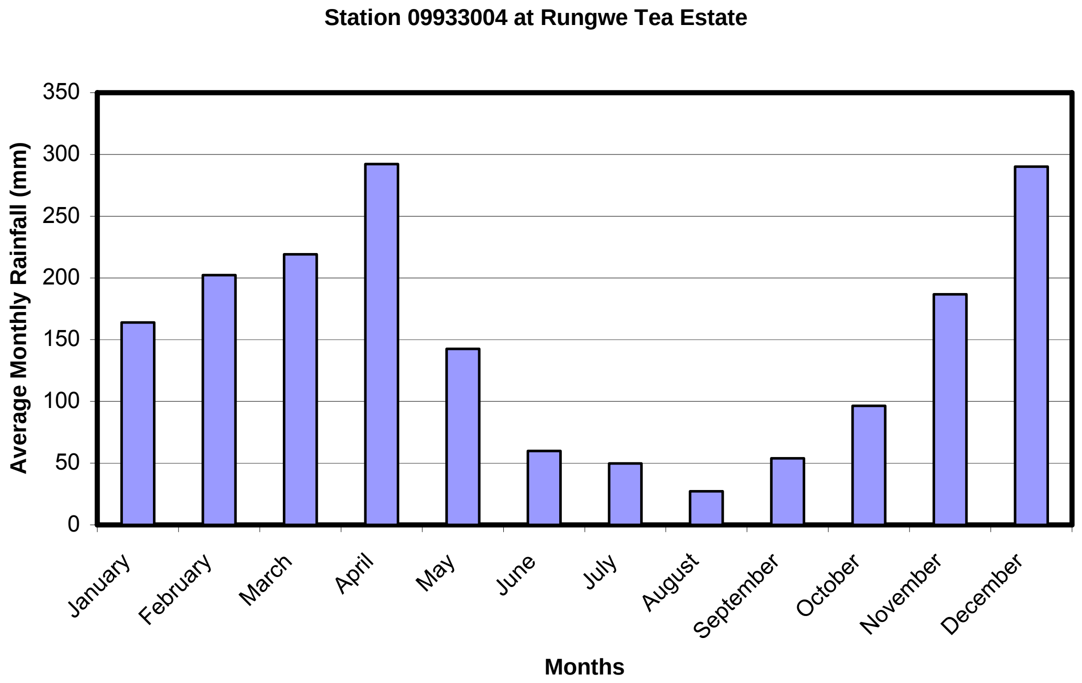

Figure A1-7 Average Monthly Rainfall at Rungwe Tea Estate

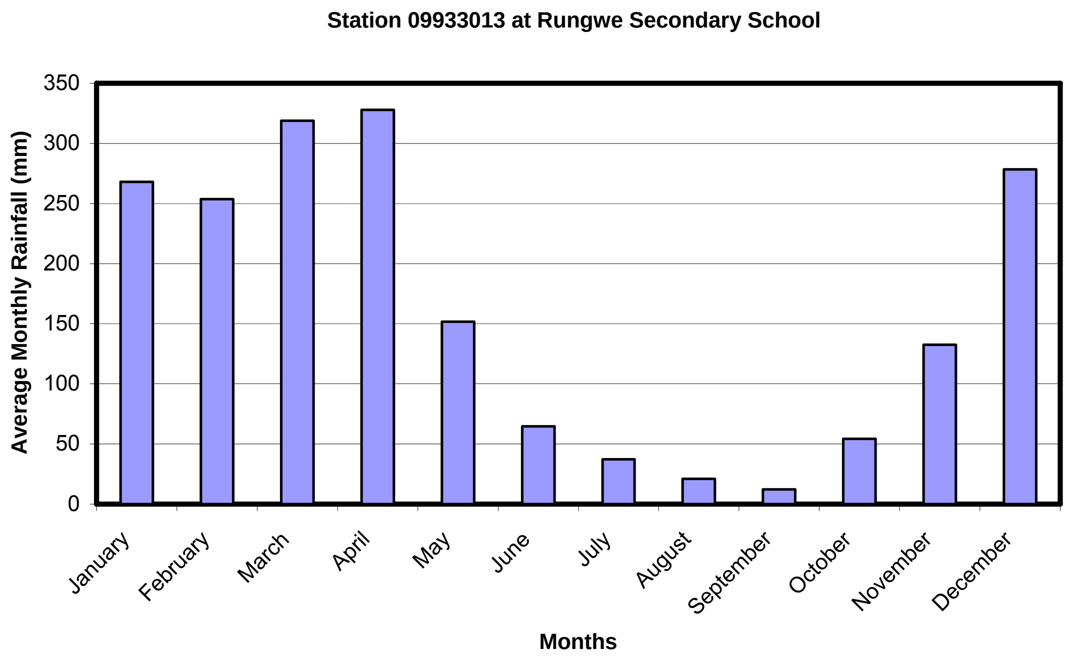

Figure A1-9 Average Monthly Rainfall at Rungwe Secondary School station

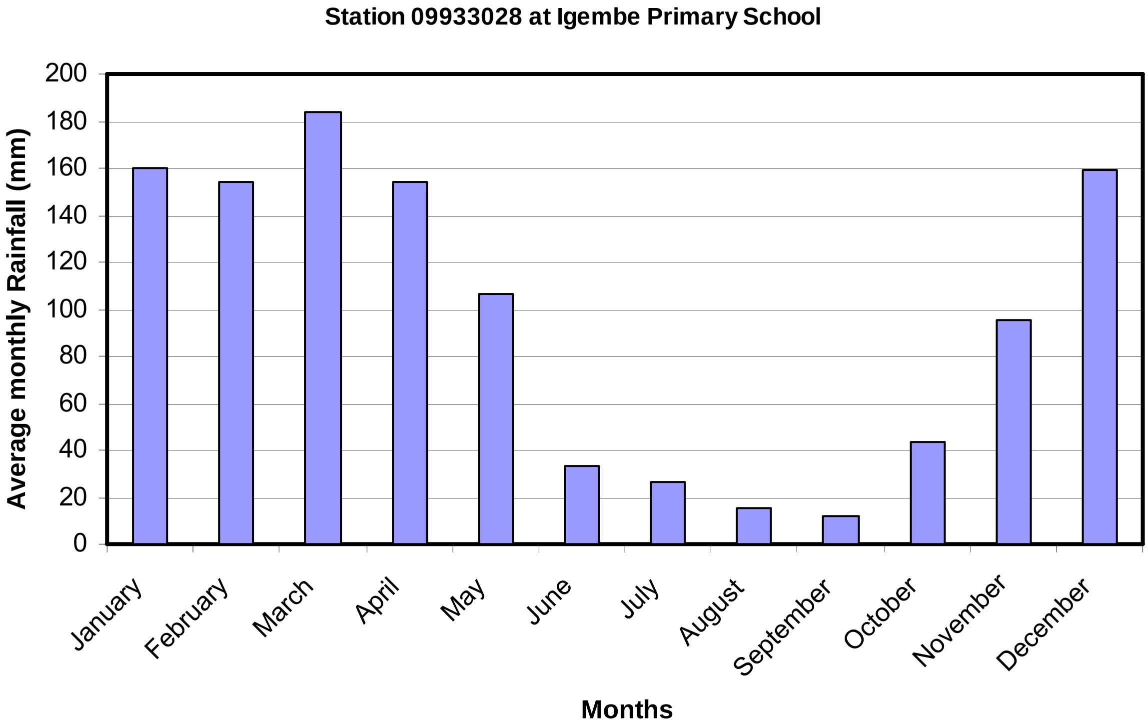

Figure A1-9 Average Monthly Rainfall at Igembe Primary School station

Appendix 2: Mean monthly and annual flows for different rivers in the MSC

Table A2-1 Mean monthly and annual flows (m^3/s) for Umrobo River (1KA51a)

Year/month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
1954	**16.6**	**17.7**	**35.9**	**42.4**	**29.9**	**12.2**	**10.1**	**10.6**	**10.6**	**8.3**	**4.7**	**7.8**	**206.8**
1955	**11.9**	**23.5**	**37.0**	**47.2**	**30.8**	**12.4**	**10.1**	**10.6**	**10.4**	**8.3**	**4.9**	**8.0**	**215.1**
1956	**19.9**	**23.0**	**36.7**	**48.4**	**31.7**	**12.2**	**10.1**	**10.6**	**10.3**	**8.3**	**5.2**	**5.8**	**222.2**
1957	**18.0**	**25.5**	**36.6**	**49.8**	**30.8**	**12.4**	**10.1**	**10.6**	**10.4**	**8.4**	**5.3**	**6.3**	**224.2**
1958	**13.7**	**21.4**	**40.0**	**43.5**	**29.6**	**12.1**	**10.1**	**10.6**	**10.5**	**8.5**	**5.6**	**7.9**	**213.5**
1959	**14.9**	**19.1**	**38.1**	**47.4**	**30.5**	**12.1**	**10.2**	**10.6**	**10.4**	**10.0**	**8.0**	**8.1**	**219.4**
1960	**15.7**	**20.8**	**42.4**	**49.4**	**29.6**	**12.1**	**10.3**	**10.6**	**10.7**	**8.4**	**4.8**	**5.3**	**220.1**
1961	**11.7**	**20.9**	**36.9**	**44.6**	**31.5**	**12.1**	**10.1**	**10.6**	**10.5**	**9.9**	**8.6**	**17.2**	**224.6**
1962	**20.1**	**20.6**	**41.5**	**44.5**	**30.0**	**12.2**	**10.1**	**10.6**	**10.4**	**10.0**	**5.8**	**5.7**	**221.5**
1963	**26.6**	**23.2**	**40.9**	**49.8**	**29.4**	**12.1**	**10.2**	**10.6**	**10.3**	**9.0**	**12.2**	**12.6**	**246.9**
1964	**21.2**	**23.2**	**38.2**	**43.6**	**29.7**	**12.2**	**10.1**	**10.6**	**10.3**	**8.3**	**5.8**	**5.5**	**218.7**
1965	**18.5**	**22.3**	**37.2**	**44.5**	**28.7**	**12.5**	**10.1**	**12.1**	**11.7**	**11.2**	**8.1**	**9.5**	**226.4**
1966	**20.3**	**27.9**	**67.9**	**69.0**	**24.8**	**13.7**	**13.8**	**13.5**	**14.8**	**14.4**	**11.9**	**15.7**	**307.7**
1967	**12.5**	**14.2**	**20.9**	**49.2**	**27.9**	**13.7**	**10.7**	**9.3**	**8.8**	**8.0**	**8.0**	**26.6**	**209.8**
1968	**48.9**	**34.0**	**61.0**	**57.5**	**28.9**	**12.6**	**10.9**	**11.9**	**13.6**	**7.3**	**7.8**	**10.3**	**304.7**
1969	**12.4**	**33.6**	**23.5**	**20.1**	**18.4**	**10.3**	**9.9**	**11.0**	**11.1**	**9.4**	**7.8**	**8.2**	**175.7**
1970	**13.8**	**25.0**	**63.6**	**47.2**	**23.5**	**10.7**	**11.0**	**13.0**	**12.9**	**13.2**	**7.6**	**9.7**	**251.2**
1971	**17.7**	**30.8**	**39.0**	**30.4**	**39.0**	**11.9**	**10.1**	**8.9**	**8.6**	**8.9**	**5.7**	**7.5**	**218.5**
1972	**8.8**	**4.1**	**56.5**	**53.4**	**30.5**	**12.9**	**9.0**	**8.8**	**8.1**	**7.6**	**8.2**	**9.7**	**217.6**
1973	**15.1**	**27.3**	**36.3**	**38.8**	**25.4**	**12.3**	**9.8**	**8.5**	**7.5**	**5.1**	**4.9**	**6.0**	**197.0**
1974	**11.0**	**14.8**	**13.4**	**74.9**	**58.0**	**14.2**	**9.7**	**7.8**	**8.6**	**8.9**	**7.3**	**10.1**	**238.7**
1975	**15.3**	**16.1**	**43.5**	**51.5**	**38.3**	**15.0**	**12.2**	**12.6**	**11.7**	**10.0**	**5.6**	**7.5**	**239.3**
1976	**11.8**	**14.3**	**41.8**	**53.4**	**34.8**	**14.5**	**12.3**	**11.1**	**8.6**	**9.6**	**7.6**	**8.8**	**228.6**
1977	**14.0**	**12.8**	**9.8**	**26.9**	**22.7**	**8.9**	**6.1**	**5.4**	**5.4**	**4.5**	**4.1**	**7.2**	**127.8**
1978	**7.4**	**10.8**	**65.6**	**38.4**	**13.5**	**8.6**	**8.5**	**8.0**	**6.4**	**5.2**	**4.0**	**7.9**	**184.3**
1979	**20.6**	**59.0**	**119.2**	**117.5**	**37.4**	**12.5**	**10.2**	**10.6**	**12.7**	**14.5**	**12.6**	**13.7**	**440.5**
1980	**12.3**	**11.4**	**17.5**	**28.3**	**29.2**	**9.4**	**7.2**	**10.4**	**10.6**	**9.4**	**9.6**	**21.8**	**177.1**
1981	**17.4**	**46.7**	**33.5**	**34.1**	**18.3**	**7.2**	**8.7**	**8.3**	**6.5**	**6.2**	**4.7**	**6.9**	**198.5**
1982	**6.2**	**16.8**	**10.5**	**17.8**	**25.2**	**6.1**	**4.1**	**3.5**	**3.8**	**4.1**	**6.2**	**18.1**	**122.4**
1983	**75.7**	**38.2**	**36.1**	**38.3**	**15.0**	**4.8**	**3.9**	**4.2**	**4.1**	**4.5**	**4.1**	**6.5**	**235.4**
1984	**13.7**	**24.8**	**51.3**	**31.7**	**18.3**	**5.7**	**4.4**	**4.6**	**3.9**	**3.7**	**3.5**	**28.9**	**194.5**
1985	**9.6**	**31.1**	**55.6**	**78.1**	**25.8**	**6.2**	**5.2**	**5.0**	**4.5**	**3.7**	**6.2**	**13.2**	**244.2**
1986	**23.0**	**36.5**	**47.5**	**60.4**	**23.1**	**13.0**	**10.4**	**8.9**	**5.4**	**5.2**	**5.0**	**43.5**	**281.9**
1987	**60.3**	**84.0**	**82.5**	**59.3**	**35.3**	**17.5**	**14.0**	**12.2**	**10.9**	**8.1**	**7.9**	**7.6**	**399.6**
1988	**15.7**	**38.8**	**46.0**	**89.9**	**44.3**	**16.8**	**14.5**	**12.7**	**10.8**	**8.3**	**10.8**	**27.2**	**335.8**
1989	**26.8**	**42.3**	**49.3**	**68.7**	**46.1**	**25.8**	**23.7**	**17.9**	**14.7**	**13.2**	**12.7**	**33.3**	**374.5**
1990	**34.1**	**26.3**	**47.3**	**56.0**	**29.5**	**17.4**	**14.6**	**14.5**	**11.4**	**11.3**	**10.0**	**10.1**	**282.5**
1991	**29.6**	**14.1**	**20.2**	**45.2**	**18.8**	**8.0**	**8.7**	**10.0**	**9.5**	**9.6**	**7.9**	**9.8**	**191.4**
1992	**16.5**	**17.8**	**50.0**	**44.8**	**40.8**	**25.5**	**23.9**	**20.8**	**19.0**	**17.3**	**19.1**	**22.1**	**317.6**
1993	**48.0**	**55.4**	**67.1**	**50.8**	**43.9**	**30.4**	**28.1**	**22.6**	**19.9**	**19.3**	**19.9**	**18.8**	**424.2**
1994	**25.2**	**39.5**	**68.6**	**47.2**	**31.6**	**22.6**	**19.9**	**18.1**	**15.1**	**15.6**	**5.8**	**10.0**	**319.2**
1995	**18.1**	**10.1**	**43.2**	**44.4**	**30.1**	**16.1**	**15.2**	**10.6**	**10.3**	**8.5**	**5.5**	**3.5**	**215.6**
1996	**22.4**	**38.2**	**50.6**	**76.4**	**29.1**	**12.2**	**10.1**	**10.6**	**10.4**	**8.8**	**5.5**	**8.7**	**283.0**

1997	**10.2**	**18.4**	**31.1**	**48.1**	**28.2**	**12.1**	**11.1**	**10.6**	**10.3**	**8.7**	**7.6**	**19.5**	**215.9**
1998	**15.3**	**23.4**	**36.2**	**46.2**	**28.7**	**12.1**	**10.2**	**10.7**	**10.5**	**8.6**	**5.2**	**2.2**	**209.1**
1999	**15.0**	**18.0**	**40.4**	**71.3**	**36.1**	**19.1**	**15.7**	**12.1**	**6.5**	**6.4**	**6.1**	**7.3**	**254.1**
Mean (m^3/s)	**20.3**	**26.5**	**43.7**	**50.4**	**30.1**	**13.2**	**11.3**	**10.8**	**10.1**	**9.0**	**7.5**	**12.3**	**245.2**

Table A2-2 Mean monthly and annual flows (m^3/s) for Mswiswi River (1KA50a)

Year/month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
1954	**34.0**	**50.3**	**94.3**	**113.9**	**75.9**	**18.6**	**6.9**	**4.3**	**3.3**	**0.0**	**0.0**	**13.8**	**415.3**
1955	**15.0**	**61.1**	**104.1**	**127.1**	**79.8**	**20.1**	**6.9**	**4.1**	**1.6**	**0.0**	**0.0**	**6.9**	**426.7**
1956	**46.5**	**60.2**	**100.2**	**128.2**	**79.4**	**18.8**	**6.9**	**4.1**	**1.6**	**0.0**	**0.0**	**1.3**	**447.2**
1957	**39.6**	**76.6**	**91.5**	**134.3**	**74.6**	**19.3**	**6.9**	**4.1**	**1.6**	**0.0**	**0.0**	**4.4**	**452.9**
1958	**18.2**	**57.2**	**110.1**	**107.7**	**68.6**	**18.2**	**6.9**	**4.1**	**2.1**	**0.1**	**0.0**	**8.1**	**401.3**
1959	**24.8**	**48.7**	**100.1**	**123.4**	**79.8**	**19.1**	**12.5**	**4.1**	**1.7**	**4.4**	**3.0**	**2.9**	**424.5**
1960	**22.4**	**49.7**	**110.0**	**125.1**	**68.9**	**19.6**	**7.6**	**4.1**	**2.7**	**0.0**	**0.0**	**3.0**	**413.1**
1961	**12.5**	**53.1**	**99.3**	**112.8**	**79.2**	**18.8**	**11.9**	**5.9**	**3.0**	**2.4**	**4.9**	**26.9**	**430.7**
1962	**35.7**	**55.9**	**113.4**	**112.9**	**76.7**	**19.3**	**7.7**	**4.9**	**1.7**	**2.9**	**1.4**	**2.7**	**435.2**
1963	**69.5**	**67.6**	**123.0**	**144.5**	**74.1**	**19.7**	**7.2**	**4.3**	**1.9**	**0.7**	**21.8**	**22.0**	**556.3**
1964	**50.4**	**66.2**	**110.8**	**125.0**	**71.5**	**18.6**	**7.9**	**4.3**	**1.6**	**0.0**	**0.0**	**4.6**	**460.9**
1965	**34.7**	**60.6**	**106.4**	**120.7**	**69.9**	**22.9**	**7.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**422.2**
1966	**7.7**	**31.8**	**162.8**	**164.6**	**45.0**	**6.6**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**17.8**	**436.3**
1967	**7.7**	**21.4**	**48.4**	**137.5**	**79.3**	**27.8**	**10.1**	**3.1**	**0.7**	**0.3**	**3.5**	**86.5**	**426.3**
1968	**143.4**	**129.6**	**185.1**	**191.6**	**109.6**	**39.8**	**21.8**	**14.8**	**8.7**	**0.3**	**0.1**	**1.6**	**846.4**
1969	**10.0**	**77.7**	**68.8**	**69.8**	**43.5**	**14.5**	**3.7**	**0.3**	**0.0**	**0.0**	**0.0**	**0.0**	**288.3**
1970	**2.6**	**60.6**	**189.3**	**129.5**	**39.2**	**7.2**	**1.5**	**1.0**	**0.0**	**0.0**	**0.0**	**11.4**	**442.3**
1971	**33.0**	**102.5**	**64.8**	**72.3**	**55.0**	**0.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**1.0**	**328.7**
1972	**7.1**	**28.6**	**190.3**	**139.0**	**71.9**	**22.0**	**5.1**	**1.5**	**0.1**	**1.2**	**3.3**	**8.0**	**478.1**
1973	**70.7**	**131.0**	**166.7**	**138.7**	**58.0**	**19.1**	**5.9**	**1.3**	**0.0**	**0.0**	**0.0**	**0.4**	**591.8**
1974	**14.3**	**41.1**	**41.0**	**178.1**	**175.0**	**63.0**	**36.3**	**22.8**	**15.1**	**11.0**	**10.9**	**13.6**	**622.2**
1975	**44.3**	**16.5**	**93.7**	**131.3**	**93.0**	**24.6**	**9.9**	**7.8**	**2.7**	**1.2**	**0.4**	**2.7**	**428.1**
1976	**13.1**	**24.8**	**103.0**	**111.0**	**65.1**	**19.2**	**9.3**	**4.1**	**2.1**	**1.1**	**0.0**	**0.0**	**352.8**
1977	**14.3**	**25.4**	**25.2**	**63.5**	**84.9**	**6.4**	**0.0**	**0.0**	**0.0**	**0.2**	**0.0**	**0.2**	**220.1**
1978	**3.5**	**33.8**	**201.9**	**100.8**	**22.6**	**2.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.1**	**1.5**	**366.3**
1979	**39.8**	**143.7**	**267.4**	**195.7**	**101.7**	**19.3**	**7.0**	**4.1**	**1.9**	**0.0**	**0.0**	**0.0**	**780.6**
1980	**3.8**	**0.3**	**1.9**	**54.8**	**16.4**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**2.2**	**79.4**
1981	**7.4**	**76.8**	**46.7**	**77.8**	**9.6**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**218.3**
1982	**0.4**	**14.8**	**3.1**	**24.3**	**63.4**	**1.3**	**0.0**	**0.0**	**0.0**	**0.0**	**0.8**	**15.5**	**123.6**
1983	**138.0**	**40.1**	**67.7**	**65.3**	**15.2**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.2**	**0.0**	**326.5**
1984	**0.9**	**10.1**	**65.1**	**17.6**	**4.6**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**1.5**	**99.8**
1985	**0.0**	**81.3**	**92.1**	**117.3**	**44.1**	**7.9**	**1.0**	**0.0**	**0.0**	**0.0**	**1.4**	**1.0**	**346.1**
1986	**13.6**	**76.9**	**91.1**	**83.1**	**31.3**	**4.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.4**	**46.5**	**346.9**
1987	**104.8**	**121.2**	**147.8**	**52.6**	**31.7**	**1.4**	**0.0**	**5.1**	**0.0**	**0.0**	**0.0**	**0.0**	**464.6**
1988	**11.0**	**34.8**	**73.7**	**142.1**	**39.9**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**1.3**	**15.9**	**318.7**
1989	**26.9**	**84.8**	**110.7**	**182.6**	**37.4**	**8.6**	**0.2**	**0.0**	**0.0**	**0.0**	**0.0**	**2.5**	**453.7**
1990	**33.0**	**19.2**	**70.9**	**155.0**	**55.1**	**16.1**	**4.4**	**0.0**	**0.0**	**0.0**	**7.5**	**8.9**	**370.1**
1991	**22.2**	**25.8**	**19.7**	**115.4**	**21.7**	**0.5**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**8.2**	**213.5**
1992	**135.6**	**27.4**	**2.3**	**110.3**	**126.4**	**44.4**	**24.3**	**0.0**	**6.0**	**1.1**	**7.1**	**8.3**	**493.2**

1993	**65.4**	**101.6**	**141.5**	**101.1**	**75.1**	**19.7**	**10.0**	**1.2**	**0.0**	**0.0**	**0.0**	**0.5**	**516.1**
1994	**22.1**	**50.4**	**140.2**	**126.5**	**79.3**	**43.0**	**29.7**	**22.6**	**12.5**	**14.9**	**0.0**	**10.9**	**552.1**
1995	**5.2**	**7.3**	**176.4**	**139.4**	**68.1**	**12.5**	**19.0**	**5.9**	**1.6**	**0.0**	**0.0**	**0.9**	**436.3**
1996	**4.8**	**81.3**	**150.4**	**257.8**	**68.1**	**18.8**	**6.9**	**4.1**	**1.6**	**0.7**	**0.1**	**10.1**	**604.7**
1997	**12.1**	**42.7**	**75.3**	**119.0**	**62.9**	**18.2**	**7.0**	**4.1**	**1.6**	**0.4**	**2.9**	**44.6**	**390.8**
1998	**23.3**	**62.4**	**90.6**	**117.1**	**65.7**	**18.2**	**6.9**	**4.1**	**1.6**	**0.0**	**0.0**	**0.0**	**389.9**
1999	**24.8**	**44.6**	**111.9**	**147.2**	**5.6**	**1.7**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**3.0**	**338.7**
Mean (m^3/s)	**32.0**	**56.1**	**103.3**	**119.7**	**62.3**	**15.7**	**6.9**	**3.4**	**1.7**	**0.9**	**1.5**	**9.2**	**412.6**

Table A2-3 Mean monthly and annual flows (m^3/s) for Lunwa River (1KA51a)

Year/month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
1954	**40.4**	**38.1**	**89.6**	**75.2**	**34.9**	**9.6**	**5.2**	**5.2**	**4.3**	**0.0**	**0.0**	**1.9**	**304.4**
1955	**18.0**	**83.4**	**102.5**	**109.4**	**41.8**	**11.1**	**5.2**	**4.9**	**2.3**	**0.0**	**0.0**	**12.5**	**391.1**
1956	**68.4**	**71.7**	**100.4**	**119.9**	**47.9**	**10.1**	**5.2**	**4.9**	**2.1**	**0.0**	**0.0**	**0.0**	**430.6**
1957	**54.2**	**94.7**	**101.3**	**130.5**	**40.6**	**11.3**	**5.2**	**4.9**	**2.2**	**0.0**	**0.0**	**4.5**	**449.4**
1958	**25.1**	**65.4**	**127.3**	**80.1**	**31.7**	**9.3**	**5.2**	**4.9**	**3.2**	**0.2**	**0.0**	**10.4**	**362.8**
1959	**33.8**	**49.7**	**106.7**	**114.7**	**52.5**	**11.1**	**16.5**	**4.9**	**2.3**	**9.6**	**7.5**	**3.1**	**412.4**
1960	**31.1**	**47.4**	**125.5**	**116.7**	**33.8**	**12.0**	**6.4**	**4.9**	**4.3**	**0.0**	**0.0**	**2.3**	**384.4**
1961	**14.8**	**57.8**	**102.1**	**95.3**	**52.0**	**10.5**	**15.4**	**8.7**	**4.9**	**6.2**	**11.6**	**45.1**	**424.4**
1962	**52.9**	**63.9**	**133.2**	**92.5**	**47.6**	**11.4**	**6.8**	**6.7**	**2.4**	**7.3**	**2.8**	**3.5**	**431.0**
1963	**108.7**	**81.4**	**141.4**	**142.2**	**38.7**	**11.9**	**5.6**	**5.3**	**2.7**	**1.5**	**43.1**	**33.9**	**616.4**
1964	**76.6**	**80.1**	**128.3**	**115.1**	**38.2**	**10.1**	**7.2**	**5.3**	**2.1**	**0.0**	**0.0**	**9.3**	**472.3**
1965	**46.8**	**74.9**	**120.6**	**105.2**	**35.6**	**18.4**	**5.2**	**3.3**	**3.0**	**2.4**	**1.4**	**14.5**	**431.3**
1966	**30.7**	**40.7**	**254.2**	**223.7**	**32.5**	**21.3**	**17.6**	**15.3**	**12.5**	**10.1**	**12.8**	**15.3**	**686.7**
1967	**10.2**	**52.4**	**54.3**	**281.6**	**34.1**	**17.3**	**16.8**	**11.5**	**9.8**	**9.3**	**3.9**	**91.3**	**592.5**
1968	**148.9**	**136.7**	**198.2**	**183.5**	**82.7**	**27.4**	**9.9**	**7.3**	**4.2**	**3.6**	**3.1**	**3.2**	**808.7**
1969	**37.2**	**127.9**	**71.1**	**66.7**	**33.7**	**10.7**	**4.4**	**2.9**	**2.5**	**2.0**	**2.5**	**3.7**	**365.3**
1970	**31.8**	**87.0**	**378.5**	**117.1**	**10.1**	**1.1**	**4.3**	**2.3**	**1.5**	**1.1**	**0.8**	**7.2**	**642.8**
1971	**20.5**	**54.1**	**32.1**	**21.5**	**18.1**	**3.8**	**3.9**	**2.5**	**1.6**	**1.2**	**0.9**	**4.4**	**164.6**
1972	**24.2**	**31.0**	**59.3**	**20.6**	**9.6**	**5.1**	**2.6**	**1.9**	**1.9**	**0.9**	**2.0**	**21.4**	**180.5**
1973	**93.5**	**70.8**	**146.1**	**91.5**	**25.7**	**15.1**	**8.4**	**4.2**	**2.6**	**3.2**	**1.4**	**2.5**	**465.0**
1974	**20.9**	**51.9**	**34.5**	**139.8**	**116.0**	**17.8**	**8.7**	**11.9**	**2.9**	**2.0**	**5.4**	**4.6**	**416.4**
1975	**38.1**	**25.5**	**66.4**	**68.1**	**62.7**	**11.7**	**5.4**	**3.4**	**2.6**	**2.2**	**1.8**	**2.5**	**290.4**
1976	**16.1**	**24.9**	**136.3**	**71.3**	**36.2**	**17.1**	**12.2**	**7.0**	**4.8**	**4.3**	**3.6**	**7.2**	**341.0**
1977	**21.5**	**72.2**	**103.1**	**151.3**	**113.1**	**24.2**	**9.7**	**9.4**	**9.2**	**4.0**	**6.8**	**15.9**	**540.4**
1978	**62.4**	**119.2**	**551.6**	**143.0**	**13.1**	**4.9**	**3.6**	**4.2**	**3.4**	**0.5**	**1.1**	**3.9**	**910.9**
1979	**35.3**	**83.9**	**509.6**	**693.9**	**118.2**	**13.0**	**5.7**	**2.9**	**2.0**	**1.9**	**1.8**	**10.4**	**1478.6**
1980	**42.7**	**21.4**	**21.9**	**49.9**	**31.8**	**8.0**	**3.6**	**1.4**	**1.7**	**1.8**	**2.1**	**12.0**	**198.3**
1981	**14.6**	**18.8**	**21.9**	**28.8**	**13.1**	**6.0**	**4.5**	**5.3**	**4.2**	**1.0**	**0.7**	**2.6**	**121.5**
1982	**6.2**	**40.4**	**97.4**	**44.7**	**48.9**	**21.7**	**9.6**	**4.5**	**3.3**	**3.4**	**147.5**	**144.1**	**571.7**
1983	**38.3**	**39.2**	**122.5**	**241.2**	**25.2**	**20.7**	**11.0**	**8.3**	**5.1**	**2.8**	**5.3**	**43.4**	**563.0**
1984	**116.8**	**194.1**	**104.0**	**69.2**	**33.2**	**8.9**	**2.9**	**4.9**	**3.3**	**3.4**	**0.4**	**26.3**	**567.4**
1985	**14.6**	**97.8**	**98.8**	**104.0**	**28.4**	**6.7**	**4.0**	**4.9**	**3.3**	**3.4**	**14.4**	**5.3**	**385.6**
1986	**24.1**	**80.4**	**97.7**	**67.6**	**20.8**	**9.5**	**2.9**	**4.9**	**3.3**	**3.4**	**20.1**	**55.8**	**390.5**
1987	**107.7**	**127.7**	**158.3**	**34.9**	**22.6**	**9.2**	**2.9**	**7.3**	**3.4**	**2.4**	**0.0**	**0.7**	**477.1**
1988	**39.7**	**42.3**	**79.1**	**130.6**	**20.6**	**9.6**	**2.9**	**4.9**	**3.3**	**3.4**	**2.9**	**17.0**	**356.3**

1989	24.4	88.8	118.7	173.9	21.9	9.9	3.3	1.9	2.5	0.7	4.3	18.1	468.4
1990	32.1	18.6	76.1	144.4	136.1	89.8	52.6	30.6	13.8	25.7	0.1	3.3	623.2
1991	30.2	25.6	36.9	102.0	28.5	9.7	2.9	4.9	3.3	3.4	5.9	16.1	269.4
1992	140.6	48.1	51.9	96.6	100.6	37.4	28.8	5.6	8.8	4.6	7.1	12.8	542.9
1993	66.7	106.7	150.1	86.7	60.2	14.8	13.7	6.2	3.8	3.4	16.2	0.4	528.9
1994	37.6	63.6	129.4	137.2	141.8	113.5	97.5	6.6	2.9	9.9	0.2	14.7	754.9
1995	31.7	63.6	128.9	138.2	134.9	118.2	97.2	5.2	2.2	0.0	0.2	0.3	720.6
1996	49.2	172.1	168.4	286.6	30.4	10.0	5.2	4.9	2.2	1.5	0.4	13.3	744.2
1997	13.8	36.3	53.5	105.3	21.6	9.3	40.6	33.5	2.1	1.3	34.2	326.7	678.2
1998	317.2	243.3	205.4	300.0	106.1	49.73	34.73	24.69	2.15	0.02	0.07	0	1283.6
1999	37.88	11.23	112.2	180.2	89.07	40.37	11.46	8.71	7.69	7.74	6.59	5.57	518.7
Mean (m^3/s)	51.0	72.3	130.6	132.4	50.4	20.2	13.8	7.2	3.9	3.4	8.3	22.9	516.5

Appendix 3: Mean monthly rainfall for Igurusi and Kapunga climatic station

Table A3-1: Mean monthly rainfall for Igurusi climatic station

Year/Month	Jan.	Feb.	March	April	May	June	July	August	Sept.	October	Nov.	Dec.	Total
1985	**91.70**	**249.20**	**111.90**	**88.40**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**3.00**	**149.20**	**89.40**	**782.80**
1986	**88.80**	**153.50**	**153.20**	**39.60**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**7.80**	**17.10**	**450.80**	**910.80**
1987	**392.80**	**186.60**	**130.70**	**87.70**	**0.00**	**0.00**	**0.00**	**0.00**	**2.40**	**0.00**	**35.50**	**43.20**	**878.90**
1988	**222.00**	**85.40**	**212.30**	**65.60**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**6.00**	**47.50**	**218.40**	**857.20**
1989	**206.50**	**344.70**	**202.40**	**154.70**	**11.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**63.00**	**135.70**	**1119.00**
1990	**152.00**	**128.50**	**86.00**	**104.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**8.80**	**5.40**	**104.80**	**589.50**
1991	**274.90**	**136.90**	**89.80**	**204.80**	**2.40**	**0.00**	**0.00**	**0.00**	**7.30**	**10.00**	**9.00**	**150.80**	**885.90**
1992	**130.90**	**181.10**	**115.50**	**59.40**	**66.50**	**6.50**	**0.00**	**0.00**	**0.00**	**3.00**	**79.00**	**80.60**	**722.50**
1993	**211.80**	**119.00**	**150.50**	**62.00**	**19.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**20.00**	**29.00**	**611.30**
1994	**238.70**	**193.90**	**298.70**	**27.50**	**3.00**	**0.00**	**0.00**	**NR**	**0.00**	**NR**	**18.50**	**NR**	**780.30**
2000	**113.00**	**110.90**	**116.20**	**89.30**	**112.10**	**0.00**	**0.00**	**0.00**	**6.60**	**0.00**	**114.50**	**321.50**	**984.10**
2001	**396.40**	**115.70**	**164.60**	**69.80**	**13.30**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**252.70**	**1012.50**
2002	**NR**	**114.50**	**145.40**	**46.10**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**	**0.00**	**4.70**	**117.50**	**429.20**
Total	**2519.50**	**2119.90**	**1977.20**	**1098.90**	**227.30**	**7.50**	**0.00**	**0.00**	**17.30**	**38.60**	**563.40**	**1994.40**	**10564.00**
Mean	**209.96**	**163.07**	**152.09**	**84.53**	**17.48**	**0.58**	**0.00**	**0.00**	**1.33**	**3.22**	**43.34**	**166.20**	**841.80**
STD	**104.91**	**70.42**	**58.31**	**48.54**	**33.77**	**1.80**	**0.00**	**0.00**	**2.59**	**3.91**	**46.41**	**124.25**	**189.74**
CV	**0.50**	**0.43**	**0.38**	**0.57**	**1.93**	**3.12**	**0.00**	**0.00**	**1.95**	**1.22**	**1.07**	**0.75**	**0.23**

NR = No Record

Table A3-2: Mean monthly rainfall for Kapunga climatic station

Year/Month	**Jan.**	**Feb.**	**March**	**April**	**May**	**June**	**July**	**August**	**Sept.**	**October**	**Nov.**	**Dec.**	**Total**
1993	**192.60**	**225.20**	**142.00**	**1.30**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**13.40**	**2.20**	**576.70**
1994	**73.80**	**122.90**	**104.80**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.30**	**0.40**	**15.30**	**60.70**	**379.20**
1995	**137.50**	**140.40**	**84.60**	**15.40**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**189.10**	**567.00**
1996	**161.10**	**216.70**	**79.40**	**67.30**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**98.00**	**622.50**
1997	**130.50**	**131.50**	**18.50**	**43.50**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**245.10**	**569.10**
1998	**228.50**	**120.20**	**39.90**	**77.40**	**23.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**48.90**	**537.90**
1999	**116.30**	**45.60**	**152.70**	**87.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**401.60**
Total	**1040.30**	**1002.50**	**621.90**	**291.90**	**23.00**	**0.00**	**0.00**	**0.00**	**1.30**	**0.40**	**28.70**	**644.00**	**3654.00**
Mean	**148.61**	**143.21**	**88.84**	**41.70**	**3.29**	**0.00**	**0.00**	**0.00**	**0.19**	**0.06**	**4.10**	**92.00**	**522.00**
STD	**50.93**	**61.56**	**49.34**	**36.62**	**8.69**	**0.00**	**0.00**	**0.00**	**0.49**	**0.15**	**7.02**	**93.34**	**84.34**
CV	**0.34**	**0.43**	**0.56**	**0.88**	**2.65**	**0.00**	**0.00**	**0.00**	**2.65**	**2.65**	**1.71**	**1.01**	**0.18**

Appendix 4: Weather and soil data for MSC (1998-2002)

Table A4-1: Table 33: Mean Monthly weather data for Upper MSC (1998-2002)

Month	Max. Temp (^{0}C)	Min. Temp (^{0}C)	RH (%)	Sunshine hours (hrs)	Wind speed (km/day)	Rainfall (mm)
January	24.5	14.6	66.9	4.8	163.0	232.16
February	23.8	14.5	66.1	5.3	134.7	218.04
March	23.6	14.2	66.4	6.3	148.9	173.32
April	23.2	12.4	61.6	7.0	163.3	147.8
May	22.8	7.6	60.8	9.5	176.6	14.16
June	21.4	6.3	54.7	10.1	194.8	0.5
July	21.7	6.5	50.3	10.2	228.9	0.52
August	23.1	8.4	51.0	9.5	252.3	0.98
September	25.5	10.6	44.1	9.1	292.4	0.44
October	26.7	12.2	38.7	9.5	299.5	12.94
November	26.3	14.4	45.3	7.5	283.8	64.56
December	25.2	14.6	52.2	6.3	198.9	204.76

Table A4-2: Monthly mean weather data for Middle MSC (1998-2002)

Month	Max. Temp (^{0}C)	Min. Temp (^{0}C)	RH (%)	Sunshine hours (hrs)	Wind speed (km/day)	Rainfall (mm)
January	27.4	17.6	79.1	4.8	67.2	199.22
February	27.3	17.8	81.5	5.1	52.3	219.12
March	27.8	17.4	80.8	5.7	56.6	128.24
April	27.9	16.6	79.9	6.8	61.9	119.38
May	28.2	14.7	71.2	7.9	64.3	19.78
June	27.5	12.0	66.4	9.3	69.6	1.3
July	26.9	10.3	59.6	9.2	82.1	0
August	27.7	11.7	59.0	8.7	77.1	0
September	29.6	13.2	58.9	8.5	104.6	0
October	31.1	15.3	55.6	8.4	108.5	5.76
November	31.7	17.4	56.7	7.1	103.7	33.48
December	30.0	18.2	67.4	5.8	73.9	102.18

Table A4-3: Monthly mean weather data for Lower MSC (1998-2002)

Month	Max. Temp (^{0}C)	Min. Temp (^{0}C)	RH (%)	Sunshine hours (hrs)	Wind speed (km/day)	Rainfall (mm)
January	28.7	18.04	74.5	6.1	75.1	121.3
February	28.12	17.98	81.0	4.6	47.5	173.6
March	28.98	17.72	76.5	9.2	59.9	88.6
April	28.74	16.48	74.2	8.2	75.4	15.9
May	28.18	13.6	71.1	9.3	83.3	0.3
June	26.48	10.46	67.7	12.6	96.5	0.0
July	26.3	8.84	65.0	12.8	114.5	0.0
August	27.04	10.48	58.2	16.7	143.3	0.0
September	30.44	15.22	55.9	12.2	163.5	0.3
October	30.7	17.08	51.2	12.1	196.5	0.1

November	**27.96**	**19.2**	**55.6**	**11.3**	**198.4**	**11.9**
December	**29.88**	**18.8**	**60.2**	**8.9**	**107.6**	**121.5**

Table A4-4: Soil data used in the water productivity modelling

Zone	Soil type (Texture)	Total available moisture (mm/m)	Maximum Rain Infiltration rate (mm/day)	Max. Rooting depth (mm)
Upper MSC	**Medium**	**120**	**44**	**200**
Middle MSC	**Heavy**	**140**	**32**	**180**
Lower MSC	**Heavy**	**140**	**32**	**180**

Appendix 5: Checklist for PRA

Wealth ranking

- Local perceptions among groups (age, gender, etc.) of wealth differences and inequalities,
- Local indicators and criteria of wealth and well-being:
  - Amount of land owned, cultivated?
  - Number of livestock owned?
  - Type/size of house?
  - Types of other assets owned (e.g., farm implements, milling machine, sewing machine, refrigerator, bicycles, TV, radio, private source of water etc.)?
  - Earnings from other non-farm activities (e.g., shops, lodgings, bars, trading etc.)?
  - Food security status?
  - Labour use (ability to hire in labour)?
  - Level of education?
  - Consumption of goods (e.g. clothes and other merchandizes)?
  - Ability to pay for health/medical services?
  - Respect and powerfulness in the society?
  - Other criteria?
- Relative position of households in the community and the range of socio-economic situation, and
- Proportion of households in each worth group.

Farming Systems and Livelihood Analysis

- Types of farming system
- Major crops grown and yields
- Present livelihood groups and income sources (farm and non-farm)
- Mutually shaping interactions of livelihood, farming and other production systems
- Behaviours, decisions and coping strategies

Activity and Time Charts

- Daily pattern of activities in space and time
- Routines and activities of different groups (e.g., women, men, young, old, employed, unemployed, wealthy, poor) – including activities at different times of the year

Labour Profiles

- Labour resource availability (family and hired) – access and control
- Who does what and when (at the household level)?

Mobility and Social Maps

- Patterns of spatial mobility within and between communities
- Linkages of different groups (e.g. old men, young men, old women, young women, children, educated, non-educated, wealthy, poor)
- Differences within and between households (e.g. in terms of education and literary status, school-going children, health, wealth, size of landholding, household assets, access to resources, etc.)

Historical Profiles

- Key historical events (crises) in the community and their importance for the present situation
- Coping strategies against the crises
- Processes underpinning the current changes or stasis

Food Calendar

- Seasonal variability in food availability
- Food insecurity crisis
- Vulnerable groups in the community
- Reasons for vulnerability
- Main activities enhancing food security, problems and opportunities through the annual cycle, and key linkages between the various components
- Months of greatest difficulty and vulnerability
- Coping strategies in times of crisis
- How effective are the coping strategies?

Appendix 6: Checklist for Semi-structured Interviews

Local definition and characteristics of the household (for all focus groups – representing a wide range of socio-economic dimensions (wealth, livelihoods, farming/production systems, age and gender)

- Household size and composition
- Other characteristics

Land resources, assets, sources of income, wealth groups, livelihood typologies, farming systems and coping strategies (for all focus groups as above) including:

- Amount of land owned, cultivated (rainfed and irrigated)
- Number of livestock owned
- Other non-farm activities
- Other assets owned
- Labour (family and hired labour)
- Major crops grown and harvest
- Major sources of income (both farm and non-farm)
- Proportion of income by sources and relative income
- Consumption and expenditure
- Level of education and ability to pay school fees for children
- Health status and ability to pay for medical services
- Credits and debt status
- Household food security
- Other indicators and criteria

Vulnerability analysis (for all focus groups as above)

- Groups of people perceived as vulnerable groups in the community
- Reasons for their vulnerability
- Coping strategies they use in times of crisis
- Effectiveness of the coping strategies

Gender dimensions (only for women focus groups)

- What access do women have to land/agricultural fields?
- Extent and nature of this access
    - Cultivated and owned by women?
    - How was the access acquired (purchasing, borrowing, renting, purchasing etc.)?
    - Do women control the output from these plots?
- What livestock and other assets do women own or control?
- The role of women in family decision-making?
    - About incomes and spending
    - About allocation of women's labour
    - About sale of products?
    - About the family's food security?
- Activities that women cannot do?
- Activities that women must do?
- Reasons behind these activities (religion, class, ethnicity, cultural norms, etc?)
- Flexibility for changing the workloads of men and women or for sharing tasks?
- Do women rely on social networks to share burdens and workloads?
- If yes, how?
- Resources that women consider they are most short of to help the family gain a food secured situation?
- What would women like to be doing in the future (in terms of gaining a living and enhancing food security at the household level)?

- What are the factors that prevent them, or could help them, to achieve their stated goals?