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DECLARATION

I, Selemani M, Chillo do here by declare to the Senate of University of Nairobi that this Research is my own original work and has never been submitted nor is currently being submitted for a degree award in any other University.

Signature.................................

SELEMANI M. CHILLO

Date. 13rd 10 - 2009

Supervisor's signatures

1...

DR. CHRISTOPHER OLUDHE

Date. 14/10/2009

2...

DR. JOSEPH MUTEMI

Date. 14/10/09

DEDICATION

This work is dedicated to the Almighty ALLAH (SWT), from him comes knowledge, understanding and wisdom to those who worship him.

I also dedicate the precious moment to my parents, my family and all my friends as a whole.

ABSTRACT

Industrial production is gradually playing a strategic role in the socio-economic development of the country. This sector is heavily dependent on electrical power generated to a large extent from hydro-electric-power it has been observed that the amount of water in the storage reservoirs fluctuates considerably between different years. There have been drought situations as well as flood in some part of Tanzania which had a negative impact on the electricity generation to operate efficiently. Load shedding might continue to be a problem in the future due to the climatic change, not only due to drought, but also flood that might increase demands for hydropower plants.

This research therefore tries to identify the possibility of capturing or exploiting seasonal rainfall as predicted and put into use onto a decision making process for hydropower production based on the interpretation of such available forecasts. While floods or droughts cannot be prevented, but timely availability of scientifically early indication of the most probable rainfall may contribute a lot toward forecasting dam levels well in advance and thus planning to address shortfalls that may be anticipated due to predicted rainfall.

The United Republic of Tanzania is located on the East coast of Africa between parallels 1^0S and 12^0S and meridians 30^0E and 40^0E.electricity supply is primarily from hydroelectric power (60%), with thermal (gas and diesel) and imports from neighboring countries (Uganda and Zambia) making up the remaining supply (40%). Mtera reservoir is the biggest in Tanzania, with 660 km^2 at full capacity. Depending on rainfall and the amount of water fed to the power plants the level of Nyumba ya Mungu Dam vary with more than 10m and as a result of this the surface area is between $50km^2$ and $160km^2$.

The overall objective of this study is to assess the impacts of rainfall variability on hydropower generation in Tanzania. Examine, the years of rainfall variability in Tanzania as well as Impact of rainfall variability on discharge and dam levels.

Data was collected from rain gauge station within the catchments area of the rivers that flow to generate the hydropower stations in Tanzania.. The data used consist of more than 30 years of monthly rainfall from TMA and 25 years of dam level and Discharge from

TANESCO. Rainfall data used in this study derived from 10 rain gauges with the best series for at least 30 years in the period 1978 to 2008.

Mass curve was used to check the quality of the data of the area which shows positively and the annual circles was employed to check the homogeneity of the area which also shows positively, Results from correlation analysis between two rain season that is MAM and OND with dam levels and discharge shows some significance correlation where by this help to formulate the relationship with those month of high significance to forecasting the dam level as well as discharge.

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CHAPTER I

1.0 INTRODUCTION

Mainland Tanzania has an area of about 939,702 square kilometers and the Islands of Zanzibar and Pemba, in the Indian Ocean, occupy an area of 2,643 square kilometers. The majority of the population lives in rural areas depending mostly on rain fed agriculture. Industrial production is also gradually playing a strategic role in the socio-economic development of the country. This sector is heavily dependent on electrical power generated to a large extent from hydro-electric-power. Spatial and temporal distribution of rainfall is sometimes poor while the intensity becomes varied in such a manner that ends up in extremes, such as droughts or floods. The generation of power is thus seriously affected by such extreme events. This makes seasonal rainfall forecasts very important to hydropower generation.Global warming and changes in precipitation patterns will alter the timing and magnitude of river flows. This will affect the ability of hydropower stations to harness the resource, and may reduce production, implying lower revenues and poorer returns.

.In Tanzania electricity supply is primarily from hydroelectric power (60%), with thermal (gas and diesel) and imports from neighboring countries (Uganda and Zambia) making up the remaining supply (40%). The electricity supply consists of both interconnected and isolated grid systems. The installed capacity is 959 MW out of which 561 MW is from hydro and 398 MW is thermal. The suppressed demand is about 620 MW. The annual growth in demand is assumed to be roughly 8% up to year 2015 (according to power demand forecast in the power system master plan). The annual electricity generation of TANESCO for year 2006 was 2,662,027,682 kWh, an annual consumption of 76kWh per person.

1.1 Study area

The United Republic of Tanzania is located on the East coast of Africa between parallels 1^0S and 12^0S and meridians 30^0E and 40^0E. It extends from Lake Tanganyika in the West, to the Indian Ocean in the East; Lake Victoria in the North, to Lake Nyasa and River Ruvuma in the South. It borders Kenya and Uganda in the North, Rwanda and Burundi in the North-west, Democratic Republic of Congo to the West, Zambia to the South-west and Malawi and Mozambique to the South.

Mainland Tanzania has an area of about 939,702 square kilometers and the Islands of Zanzibar and Pemba, in the Indian Ocean, occupy an area of 2,643 square kilometers. The average temperature is between $20.^0$C and $32.^0$C. Average annual rainfall is approximately ranges from 600mm to 1,800mm per year under normal conditions and depending on the elevation of a place from sea level. The average duration of the dry season is 5 to 6 months.

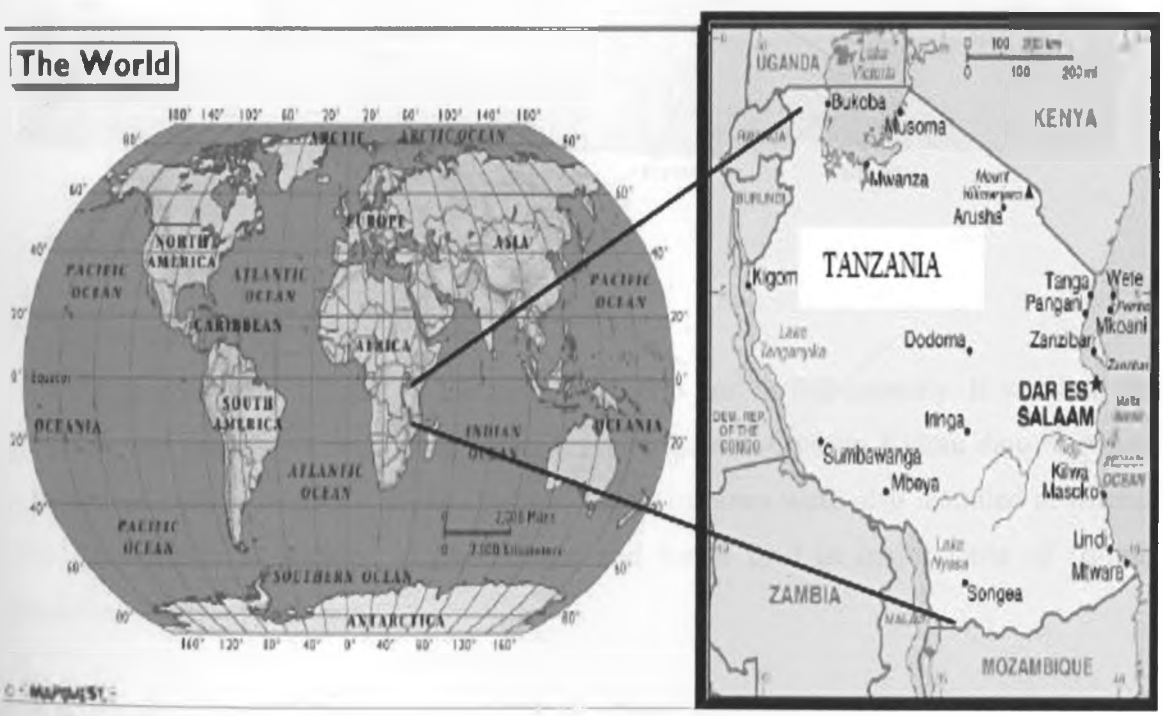


Fig: 1 Map shows the position of Tanzania in the world.

1.2 Profile of main hydropower dams in Tanzania

Below illustrates a general design of a hydropower generating system. It shows how a dam's stored water flows down a penstock to the turbines where the water rotates turbine blades to generate electricity, which is carried by
Transmission lines to consumers.

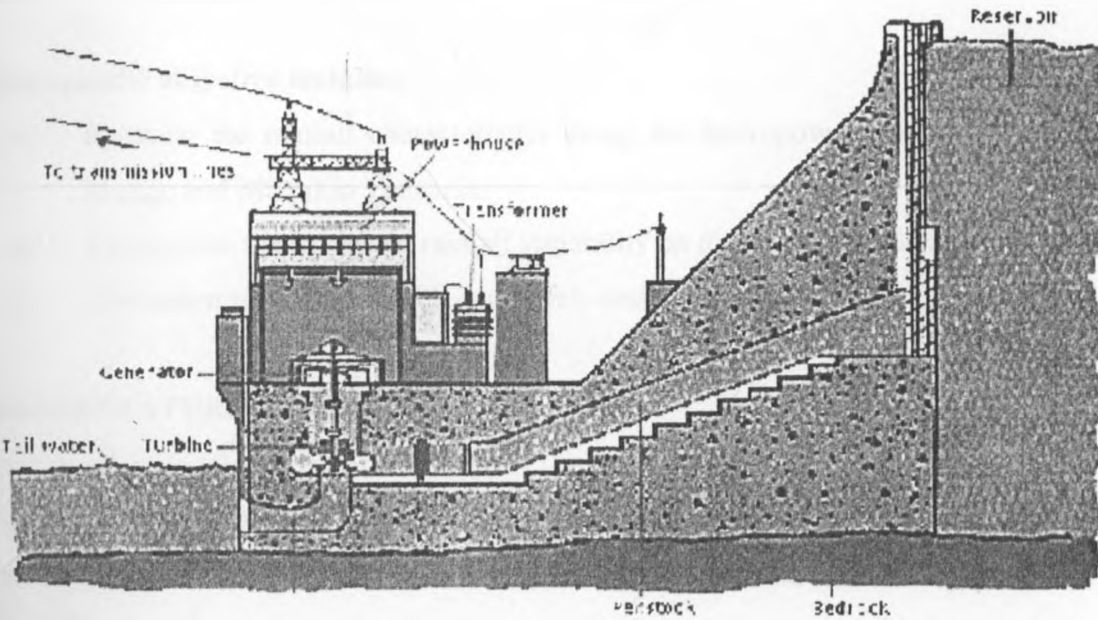


Figure 1: Hydropower generating system

1.3 Mtera Dam [1]

Mtera reservoir is the biggest in Tanzania, with 660 km^2 at full capacity. It was built in 1979 for the purpose of regulating water level at the downstream Kidatu dam; a major supplier of hydro electricity in the country. Later, turbines were also installed at Mtera. The dam drains 68,000km^2 of agricultural and forest land in major parts of Iringa, Dodoma and Mbeya Regions.

1.4 Nyumba ya Mungu Dam

This dam is a reservoir both for the power plant at Nyumba ya Mungu itself and for the power plants in Hale located downstream more than 400km closer to the outlet of the Pangani river. Depending on rainfall and the amount of water fed to the power plants the level of Nyumba ya Mungu vary with more than 10m and as a result of this the surface area is between 50km^2 and 160km^2.

2.0 OBJECTIVES OF THE STUDY

The overall objective of this study is to assess the impacts of rainfall variability on hydropower generation in Tanzania.

The specific objective includes:

i. Examine the rainfall characteristics along the hydropower station (Nyumba ya Mungu and Mtera) in Tanzania.

ii. To examine the Impact of rainfall variability on discharge and dam levels.

iii. Evaluation rain seasons with dam levels and discharge.

3.0 LITERATURE REVIEW

Two rainfall regimes exist over Tanzania. One is unimodal (December - April) and the other is bimodal (October -December and March - May). The former is experienced in southern, south-west, central and western parts of the country, and the later is found to the north and northern coast. In the bimodal regime the March - May rains are referred to as the long rains or Masika, whereas the October - December rains are generally known as short rains or Vuli.

Hydropower potential is defined by the river flow, and therefore changes in flow due to climate change will alter the energy potential (GMS, 2008). In recent years eastern tropical Africa Including Tanzania has experienced recurring dry spells, when deficits in hydroelectricity and agriculture production hampered economic growth. Thus the need arises to better understand and predict rainfall over the region to better ensure the viability of natural resources and to minimize the impact of adverse climate (Kabanda T. A. *et al*, 1999). According to scientists, Tanzania will be warmer by 1.9-2.6 degrees in the next four years and that rainfall will decrease by 10-15 per cent in many parts of the country (Second Scientific Conference on Environmental Sustainability in Tanzania in Moshi

Tanzania has been relying on hydropower for the past four decades, with seven hydropower plants combining to boast of an installed electricity generating capacity of 656 megawatts. Yet due to the failure of rainfall in the short rain season late last year and early this year, these hydropower plants were only operating at 30 percent of their capacity, thus causing a nationwide power rationing that at one time lasted for as long as 16 hours a day in Dar es Salaam. Tanzania's demand for electricity is 550 megawatts while its actual power consumption is around 400 megawatts for the time being. The steadily decreasing rainfall in recent years have forced the Tanzanian authorities to consider diversifying electricity generation so as to reduce sole reliance on hydropower, though affluent in the country but unreliable. This forced Tanzania Electric Supply Company, TANESCO, to make use of high cost thermal generation instead of the normal low cost hydro power generation (16 Jan 2008).

In Washington the study was done to check in what extent do the hydropower sector affected by the climatic change due to rainfall variability where by the operation of these reservoirs and dams for production of hydroelectricity has been tuned to the historical seasonal variations in electricity demand and the timing and volume of stream flow. In the 21st century, however, projected climatic and hydrologic changes will likely alter the annual patterns of electricity demand and stream flow, posing challenges to the current management of the PNW's hydroelectric power network, (Joseph H. C. *et al*, 2005).

(Mhita M.S *et al*) was also done the study to Develop Methodologies for Forecast Dissemination and Use in Hydropower Sector in Tanzania, experience shows that the amount of water in the storage reservoirs fluctuates considerably between different years. There have been drought situations in the 1990s forcing TANESCO to impose load shedding, which had a negative impact on the industries to operate efficiently. Load shedding might continue to be a problem in the future, not only due to drought, but also following the increased demand for irrigation water upstream the hydropower plants. It calls for compromise among the stakeholders to chart out a resolve/understanding strategy on the water management. A great challenge for the future lies in finding methods for development of lasting solution. A solution, which will also arrest the current trend of wood fuel depletion by evolving more appropriate land management practices and more efficient wood fuel technologies.

In Nepal the study was done to identify two critical impacts of climate change – GLOFs and variability of river runoff – both of which pose significant impacts on hydropower, and agriculture. A preliminary discussion on prioritization of adaptation responses highlights potential for both synergies and conflict with development priorities. Micro-hydro, for example, serves multiple rural development objectives, and could also help diversify GLOF hazards. On the other hand, storage hydro might conflict with development and environmental objectives, but might be a potential adaptation response to increased variability in stream-flow and reduced dry season flows which are anticipated under climate change. (GLOFs), as the breach of a dam following a GLOF might result in a second flooding event, (Shardul Agrawala *et al*, 2003).

In California Sierra Nevada the results of the related study shows that hydropower generation, in terms of energy generated and revenues, drops in all climate change scenarios as a consequence of drier hydrologic conditions. The drop is greater in terms of energy generation than in terms of energy revenues, reflecting the ability of the system to store water when energy prices are low, and then release water when electricity demand and prices are high (July through September). Contrary to our expectations, we found no clear effect on annual energy generation associated with either changes in the timing of inflows or the magnitude and occurrence of high flows, (Sebastian Vicuña *at el*, 2005).

Studying on the variability of rainfall was done by (Declan Conway *at* el, 2005),where he observe that rainfall and water resources in Africa display high levels of variability across a range of spatial and temporal scales with important consequences for the management of variability and risk in water resource systems. Studies by Sutcliffe and Knott (1987), Grove (1996) and Conway (2002) demonstrate these high levels of interannual variability in many river basins of Africa. Examples include prolonged periods of high flows for rivers draining large parts of East (White Nile and Tana) and Central Africa (Congo and Oubangui), where during one particularly humid period (1961 to 1964) the cumulative excess volume of flow above the 1961-1990 mean of all the rivers analyzed was 30 percent (Conway, 2002). Detailed studies of smaller size river basins in East Africa highlight changes in daily flow characteristics; for example, in Tanzania, Valimba *et al.* identified the effects of human activities on the land surface and their influence on flow regimes in the Mara river basin. In a similar study in the Pangani river basin Valimba *et al* highlight the difficulties of describing and explaining the causes of spatial and temporal variability in rainfall and river flows due to the sparsely and quality of river flow records.

In recent years eastern tropical Africa has experienced recurring dry spells, when deficits in hydroelectricity and agriculture production hampered economic growth. Thus the need arises to better understand and predict rainfall over the region to better ensure the viability of natural resources and to minimize the impact of adverse climate (Kabanda T. A. *et al*, 1999).

Dr. Otto Pirker *et al*,(2007) on the study of Climate Change & Hydropower Consequences and challenges he conclude that Climate Change is a serious issue for the whole electricity industry the new Package for Energy by the commission is an important step for future developments in Europe, the role of renewable energy sources will further increase Hydropower is still the most important renewable energy source worldwide and in Europe Hydropower operators must have a strong focus on climate change Climate Change is a big challenge for the future.

The same problem face Tanzania that the variability of rainfall affects the hydropower sector this is when we have low rainfall amount in a certain year which results into low water discharge into the river, and also we have el-Niño year which cause flood to some of the Tanzania Rivers of hydropower potential this will also affect the river discharge. This study will help the hydropower sector to mark the dry yeas as well as the flood year's which in turn help to develop the forecasting model for the fluctuation the river discharge and hydropower generation including the structure design of the dams to tackle the problem of the low and high river discharge

4.0 PROBLEM STATEMENTS

It has been observed that the amount of water in the storage reservoirs fluctuates considerably between different years. There have been drought situations as well as flood in some part of Tanzania which had a negative impact on the electricity generation to operate efficiently. Load shedding might continue to be a problem in the future due to the climatic change, not only due to drought, but also flood that might increase demands for hydropower plants.

Second Scientific Conference on Environmental Sustainability in Tanzania in Moshi, Professor Mark Mwandosya cautioned Tanzanians to prepare themselves for possible warmer temperatures and *lack of rainfall.* He said climate change in the world could lead to warmer weather and *poor rains* in parts of Africa including Tanzania.

CHAPTER II

5.0 DATA AND METHODOLOGY

5.1 DATA

Data will be collected from rain gauge station within the catchments area of the rivers that flow to generate the hydropower stations in Tanzania. This data are taken from 1978-2008 in order to notice the variation of rain in those years. The highest amount of rainfall and the lowest are noted to correlate with

- Power generation to users
- Dam level filling
- The river discharge Q

The data used will consist of more than 30 years of monthly rainfall and 30 years of dam level totals. They were obtained from Tanzania Meteorological Agency (TMA) and Tanzania Electric Supply Company (TANESCO) respectively. Dam levels data measuring in metres unlike rainfall which measures in millimeters will be derived from the two dams, Nyumba ya Mungu and Mtera. In the case of rainfall, The distribution of the rain gauges in both Nyumba ya Mungu and Mtera.

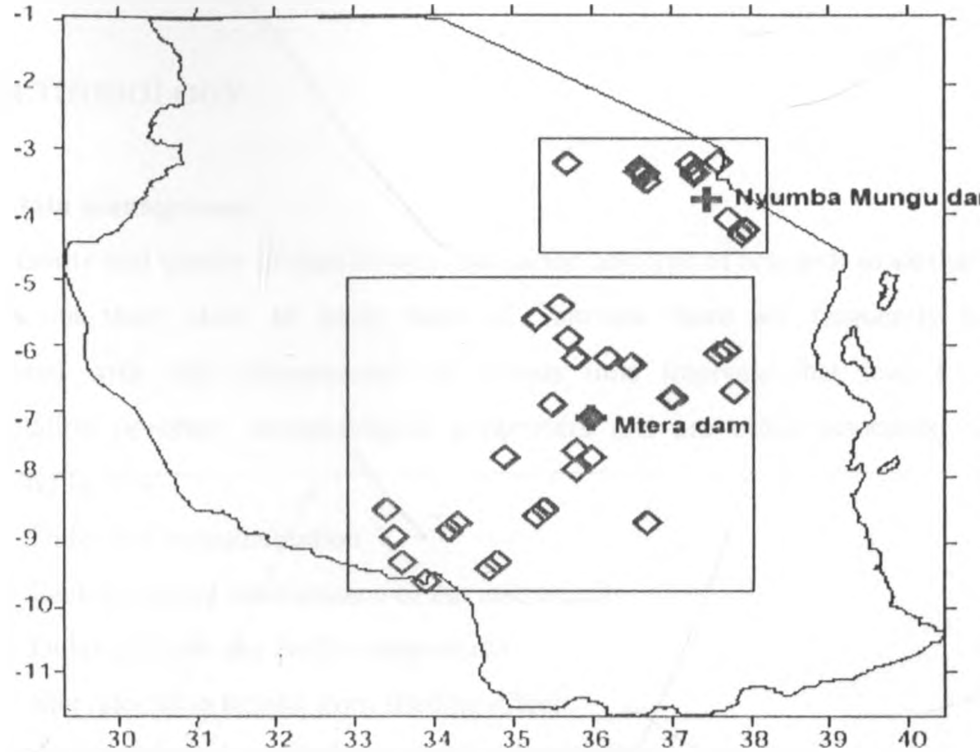


Figure 2. Distribution of rain gauges with respect to the dams

5.1.1 Nyumba ya Mungu Dam

Rainfall data used in this study will be derived from 12 rain gauges with the best series for at least 30 years in the period 1978 to 2008 selected from a network of rain gauges forming upstream of Nyumba ya Mungu catchment Basin from the slopes of Kilimanjaro, Meru and Pare mountains. The basin is between latitudes 3° and 4°S and longitudes 35° and 38°E.

5.1.2 Mtera Dam

Rainfall data used in this analysis will be drawn from 30 rain gauges with continuous series of more than 30 years in the period 1978 to 2008 selected from a network of rain gauges forming upstream of the dam mainly from Iringa,Dodoma, Mbeya and Singida regions through Great Ruaha and Kisigo rivers. On average the catchment basin is between latitudes 5° to 9°S and longitudes 33° to 37°E

5.2 METHODOLOGY

5.2.1 Data management

The quantity and quality of data is very crucial for any type of research work that is to be carried out there after. In many parts of Tanzania there are frequently problems associated with data discontinuity at various time intervals that lead ta missing precipitation or other meteorological parameters this are often associated with the following factors

1. Defective instrumentation
2. Lack of proper maintenance of the instruments
3. Delay in replacing faulty components
4. Site relocation results from shading effects
5. Communication break down or site inaccessibility
6. Negligence or sickness of the part of the observer
7. Out break of the civil war
8. Vandalism or theft of the instruments
9. Lack of competent observer

Then following steps will be taken if it is observed during data collection.

- In case for missing data this will be solved by obtained using applying correlation method. Formula:

$$x = \frac{y}{\bar{y}} \times \bar{x}$$

Whereas:

x: Missing data

y: Available complete data of the station having highest correlation with the data of the missing station.

$\bar{y}$: Available mean value of the station with complete data.

- In case for data quality assurances

This is done in order to ensure that the data I have collected is consistent. Data inconsistency may arise due to several factors which include:

1. Changes of observing instrument.
2. Change of location of observing instrument.
3. Change of an observer

In order to solve the above problem I will use homogeneity test, single or double mass curve

5.2.2 Data analysis

The analysis will employ me to use several processes which will help me to develop a relationship between variables I have in my objectives. In accomplish this several methods can be used such as, Time analysis and statistical analysis (mean, variance, standard deviation, correlation analysis, regression analysis)

5.2.3 Time series analysis

Times series is a collection of observation taken at specified time and is usually at equal intervals.Observations are subjected to a time series analysis, using the same interval, to observe the trend taken Over a certain period of time. The trend found can be used to anticipate the parameter over time.

5.2.4 Correlation Analysis

In the correlation methods pairs of nearby station are selected and their correlation coefficients are computed in relation to the station with missing precipitation records. The data using in this case must be correspond values of equal data period. Relationship between the variables is usually established by the degree of linear association between the variables. To study the relationship between the rainfall and other parameters like

Dam level filling and hydropower generation, the sample correlation coefficient r between variable X and variable Y is given as

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

Where

x_i =the i-th value of variable X

y_i =the i-th value of variable Y

$\bar{x}$ =the mean of variable X

$\bar{y}$ =the mean variable Y

n=the total number of observation

The statistical significance of **r** will be tested using the t-test. The disadvantage of the sample correlation is that it only picks up the linear relationship between the variables. It is however an easier and useful method of identifying the nature of association between variables. But this method has the disadvantage of not taking topography into account and assumes that the variation of rain fall over the area is liner which may not be the case.

5.2.5 Determination of the areal rainfall average

Because of high degree of space-time variability of rainfall, the development of the empirical forecasting techniques using statistical model or otherwise use regional averaging rain fall record to generate model that may be adopted over a homogeneous region this will have an advantage of removing or filter out random error (variation)associated with the record from individual stations.

CHAPTER III

6.0 RESULTS

6.1 NYUMBA YA MUNGU HYDROPOWER STATION

6.1.1 MASS CURVE

Mass curve for nyumba ya mungu dam level and discharge

Fig 4. Mass curve for NYM Dam discharge

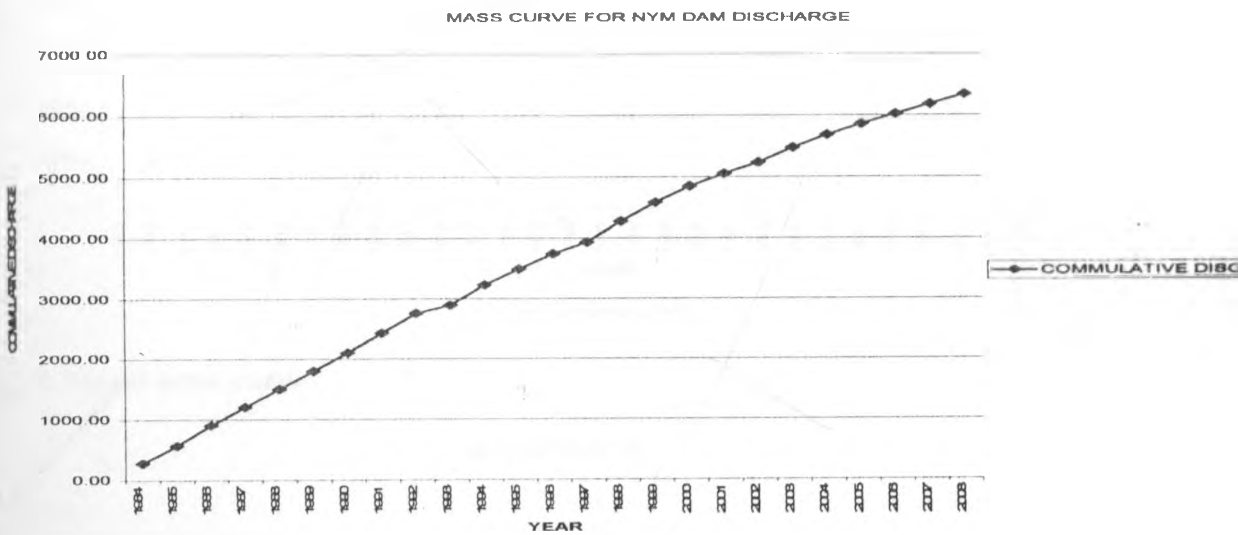


Fig 6. Arusha mass curve

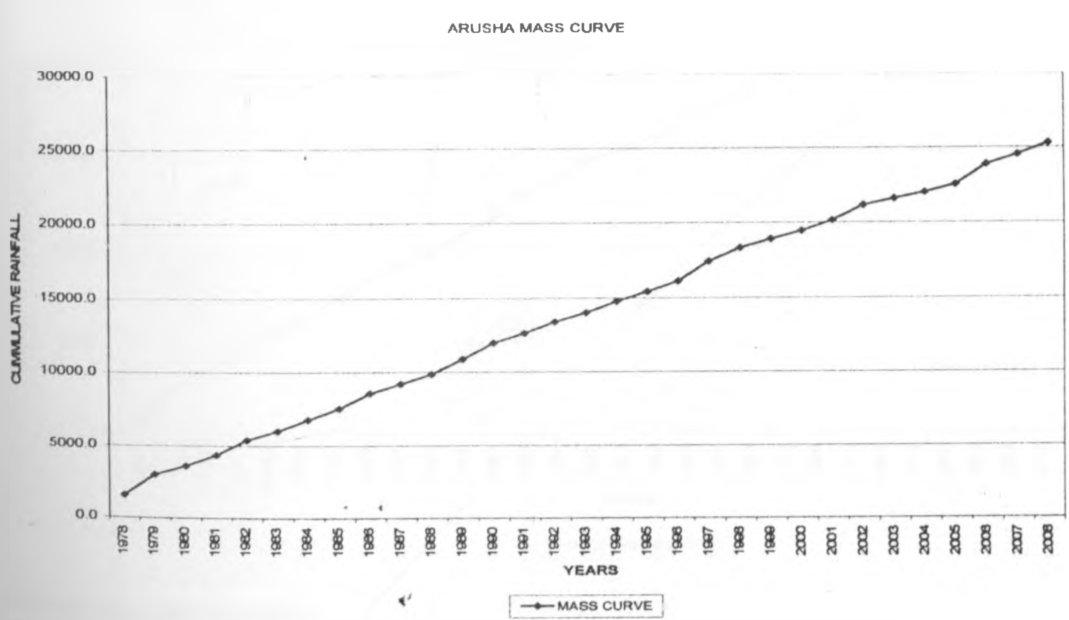


Fig 7. Kia mass curve

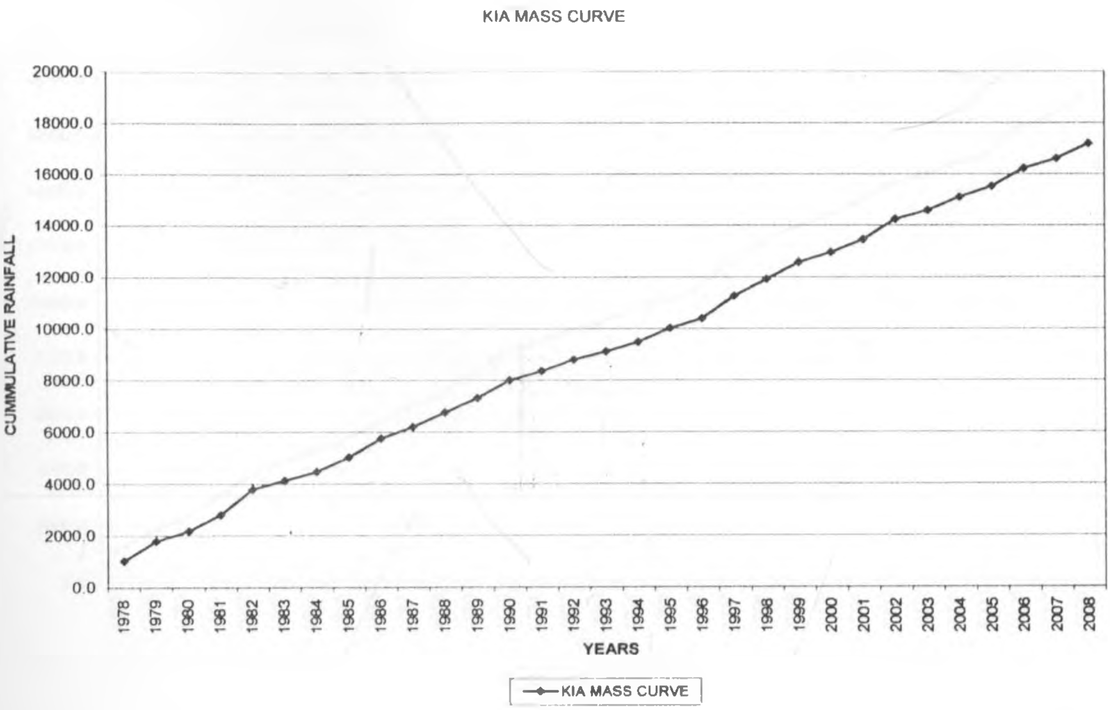


Fig 8. Moshi mass curve

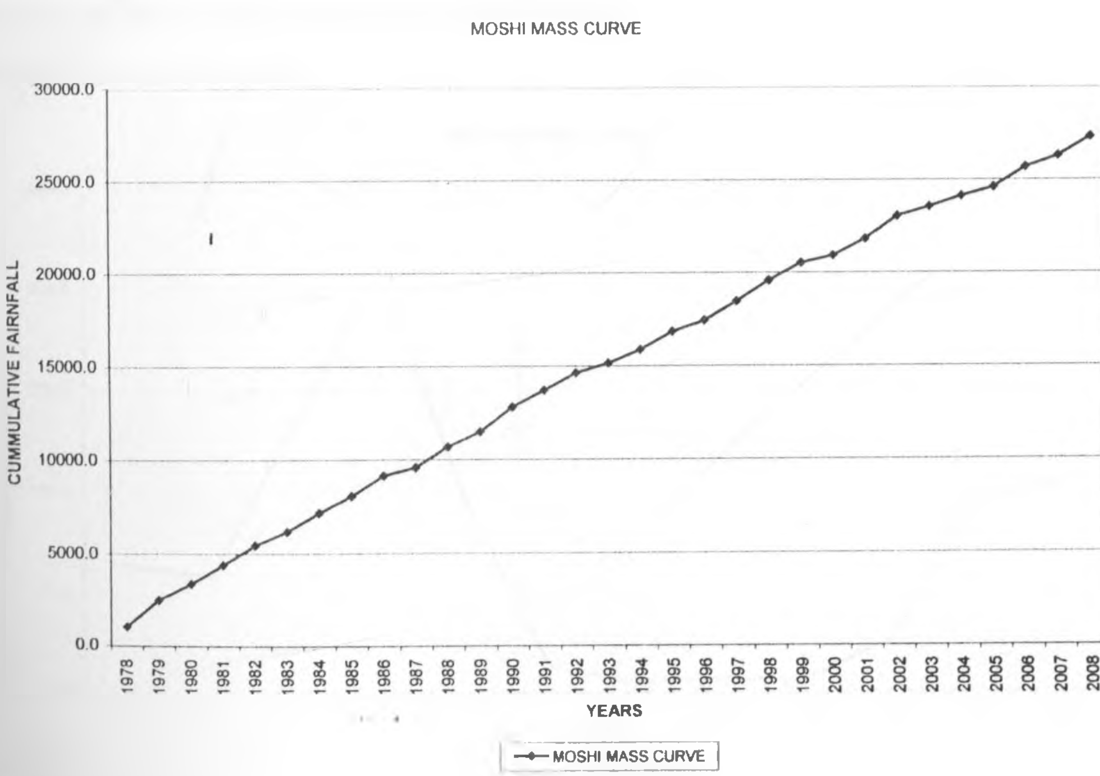
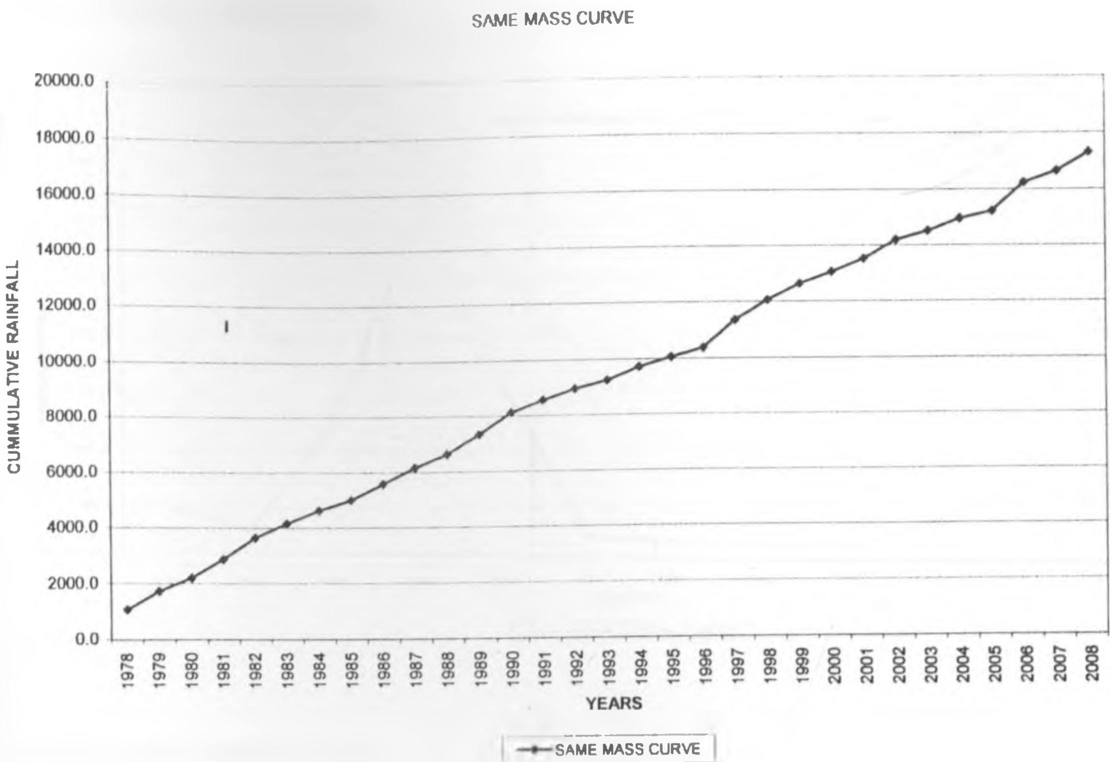


Fig 9. Same mass curve



6.1.2 ANNUAL CIRCLES

Annual circles to mark the bimodal rainfall seasons.

Fig 10. Kia annual circle

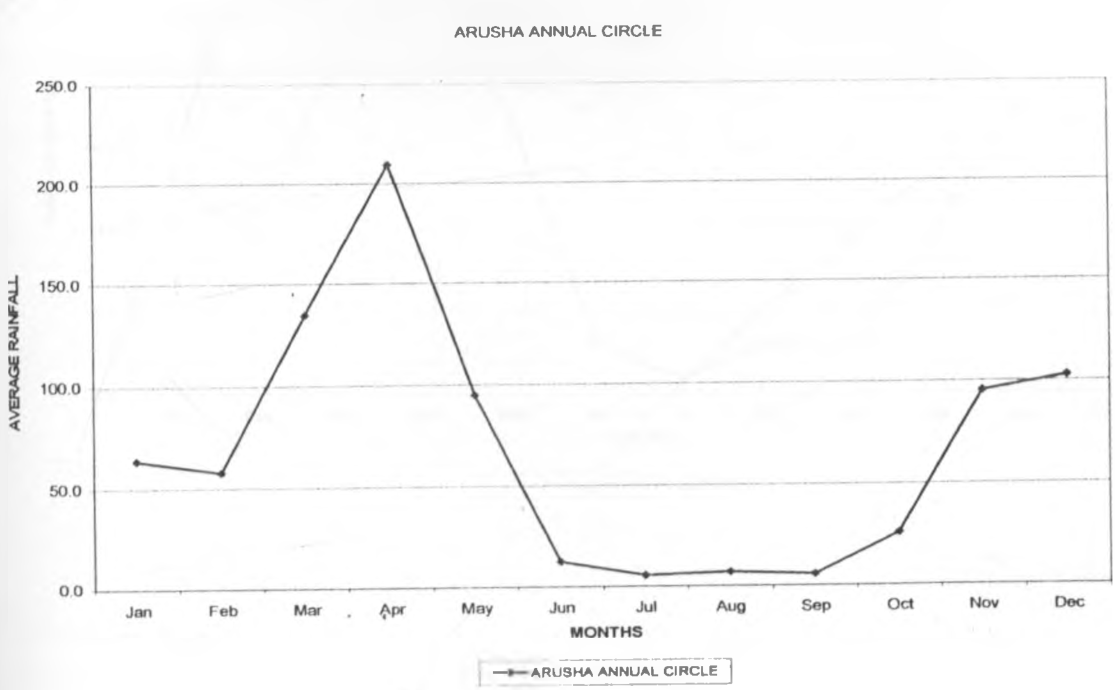


Fig 11.Moshi annual circle

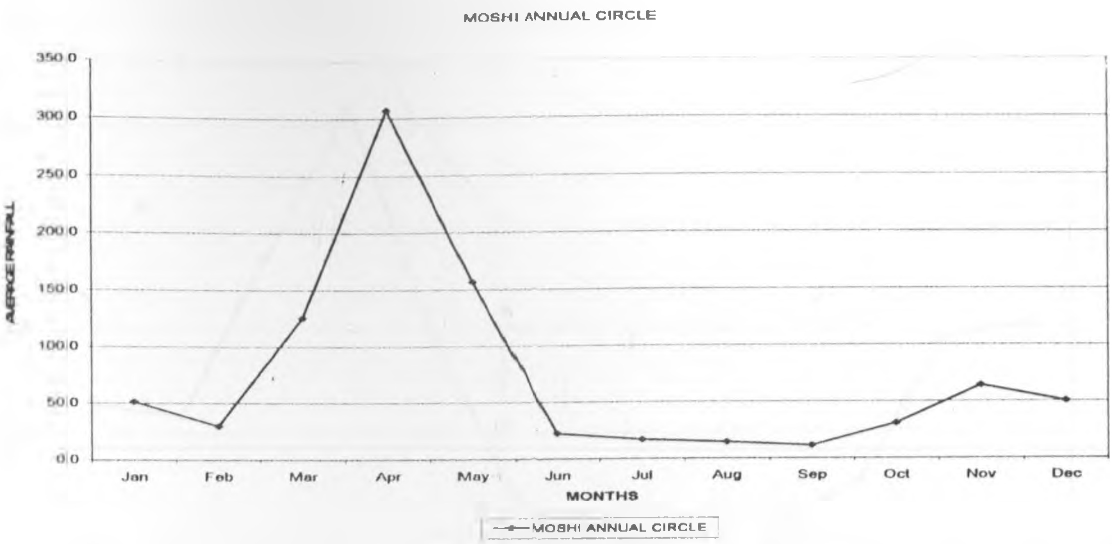


Fig 12.Same annual circle

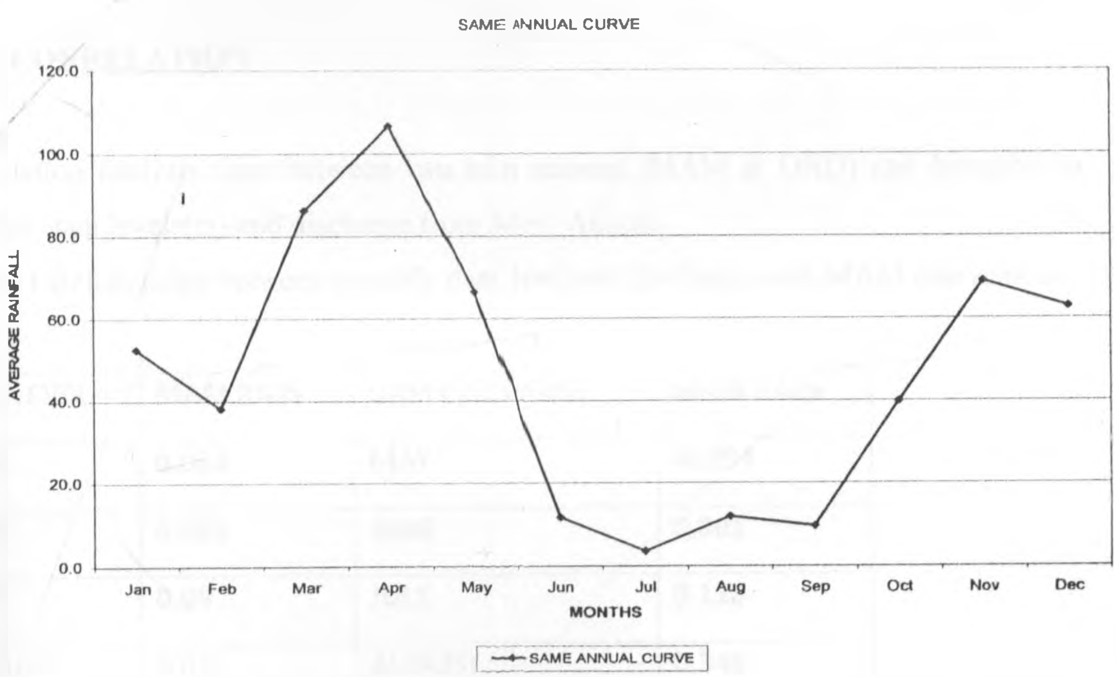
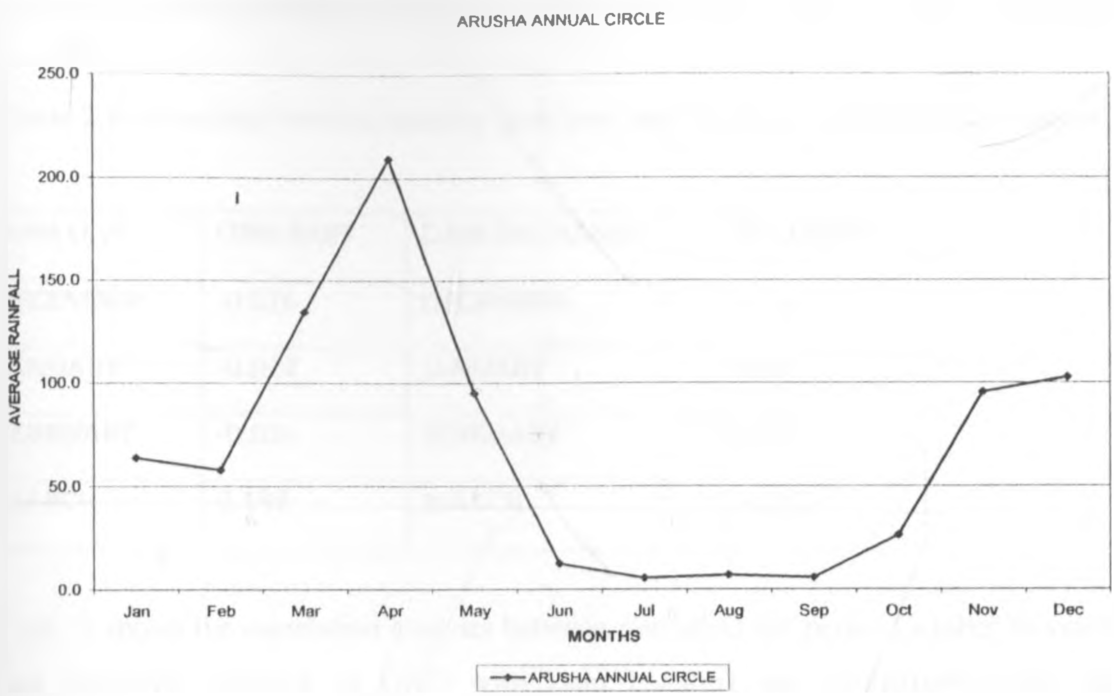


Fig 13. Arusha annual circle



6.1.3 CORRELATION

Correlation analysis done between two rain seasons (MAM & OND) and Nyumba ya Mungu Dam levels(m) and discharge from May- August.

Table 1.Relationship between monthly dam level and discharge with MAM rain season

DAM LEVEL	**MAM RAIN**	DAM DISCHARGE	**MAM RAIN**
MAY	**0.084**	**MAY**	**-0.094**
JUNE	**0.085**	**JUNE**	**0.001**
JULY	**0.09**	**JULY**	**0.128**
AUGUST	0.025	**AUGUST**	**0.349**

Table 1 shows the correlation analysis between rainfall in the period March, april and May seasons denoted as MAM with dam levels and discharge from June to August at Nyumba ya Mungu Hydropower Station. The seasonal rainfall are collected through downstream of the catchment basins at Nyumba ya Mungu. Statistical associations between these two variables of at least 0.1 are accepted in this study as being significant.

Table 2.Relationship between monthly dam level and discharge with OND rain season

DAM LEVEL	OND RAIN	DAM DISCHARGE	OND RAIN
DECEMBER	-0.026	**DECEMBER**	-0.142
JANUARY	-0.024	**JANUARY**	**0.10**
FEBRUARY	-0.024	**FEBRUARY**	0.05
MARCH	**0.132**	**MARCH**	-0.095

Table 2 shows the correlation analysis between rainfall in the period October,November and December denoted as OND with Dam level(m) and Discharge(m^3/sec) from December to March at Nyumba ya Mungu Hydropower Station.

The seasonal rainfall are collected through downstream of the catchment basins at Nyumba ya Mungu. Statistical associations between these two variables of at least 0.1 are accepted in this study as being significant.

6.1.4 LINEAR REGRESSION

Linear relationship between rain seasons (MAM, OND) with dam discharge at Nyumba ya Mungu station

Fig 14.Relationship between July discharge and MAM rain.

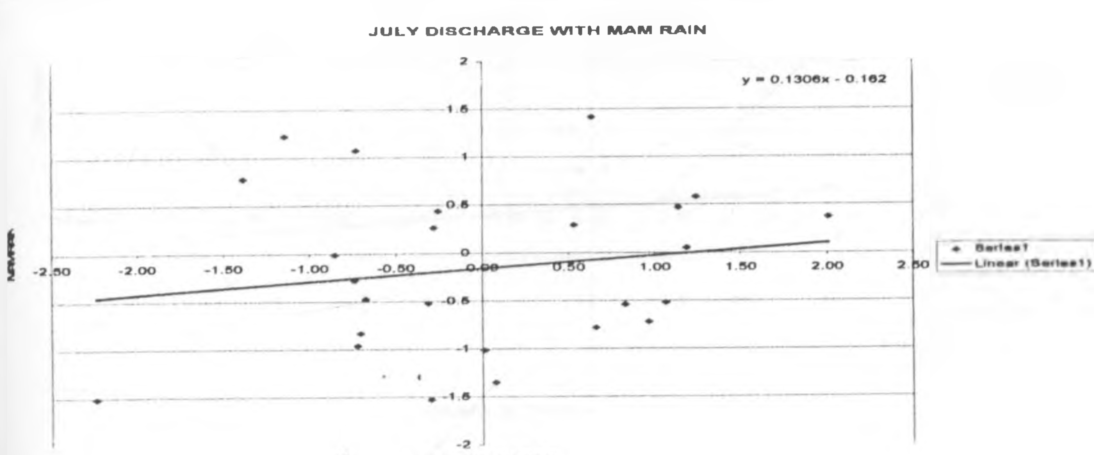


Fig 15. Relationship between August discharge and MAM rain

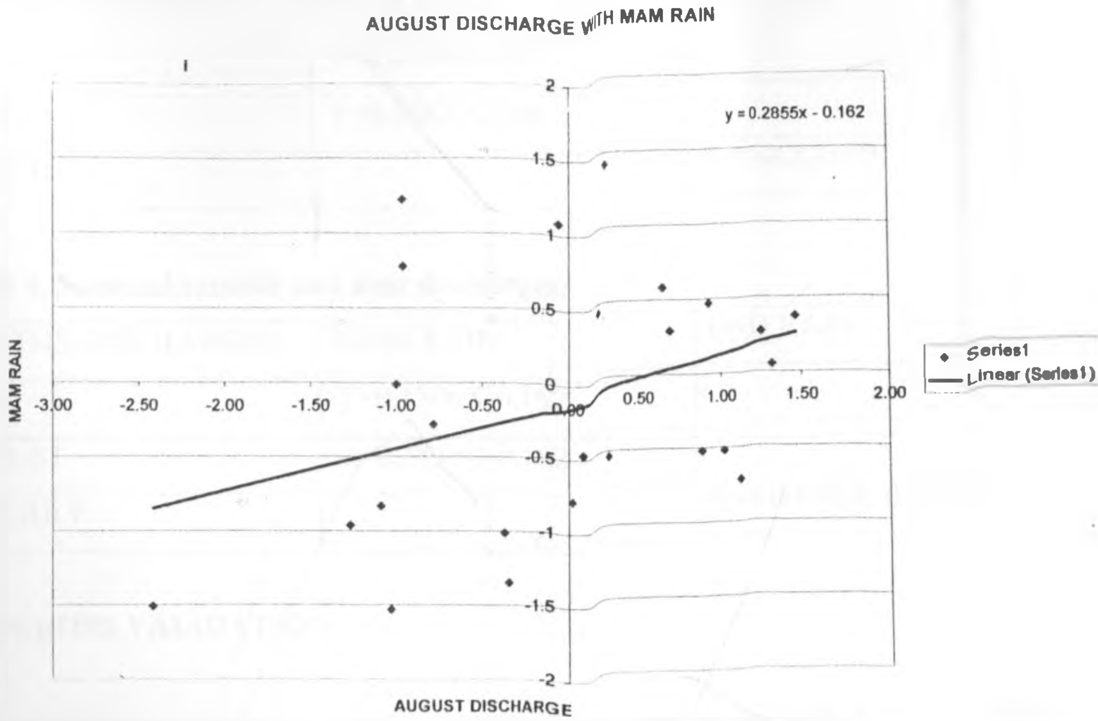
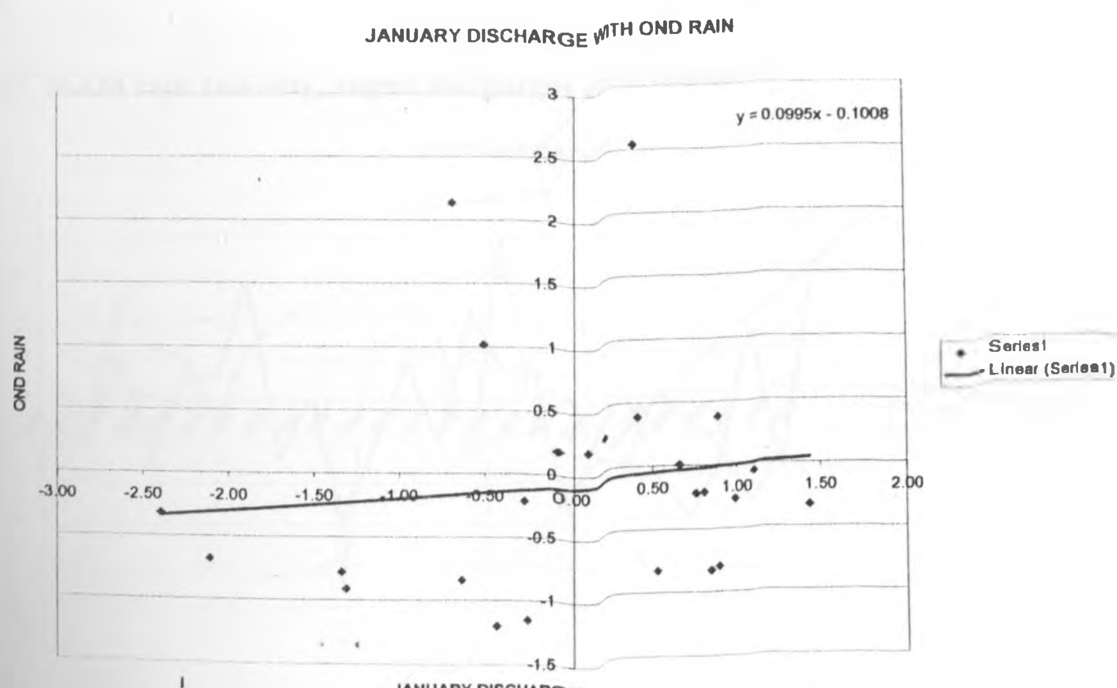


Fig 16.Relationship between January discharge and OND rain



Linear regression of levels, discharge seasonal rainfall is summarized as follow.

Table 3. Seasonal rainfall and dam levels.

MONTHS LEVELS	MAM RAIN	OND RAIN
JUNE	Y=0.243X-0.57	
JULY	Y=0.258X-0.566	
MARCH		Y=0.44X-0.39

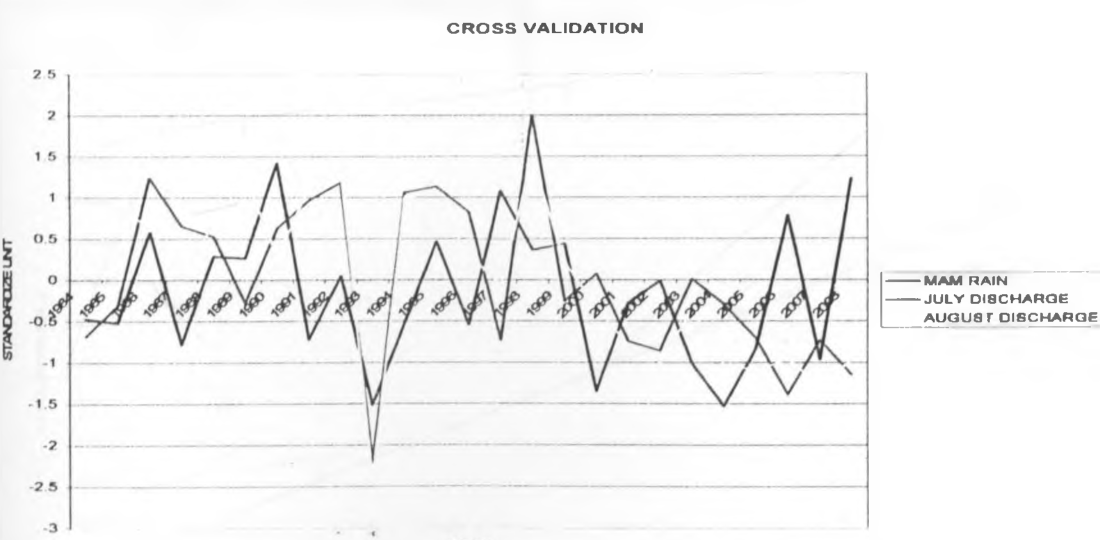
Table 4. Seasonal rainfall and dam discharges.

MONTHS DISCHARGES	MAM RAIN	OND RAIN
JULY	Y=0.1306X-0.162	
AUGUST	Y=0.2855X-0.162	
JANUARY		Y=0.00995X-0.1008

6.1.5 CROSS VALIDATION

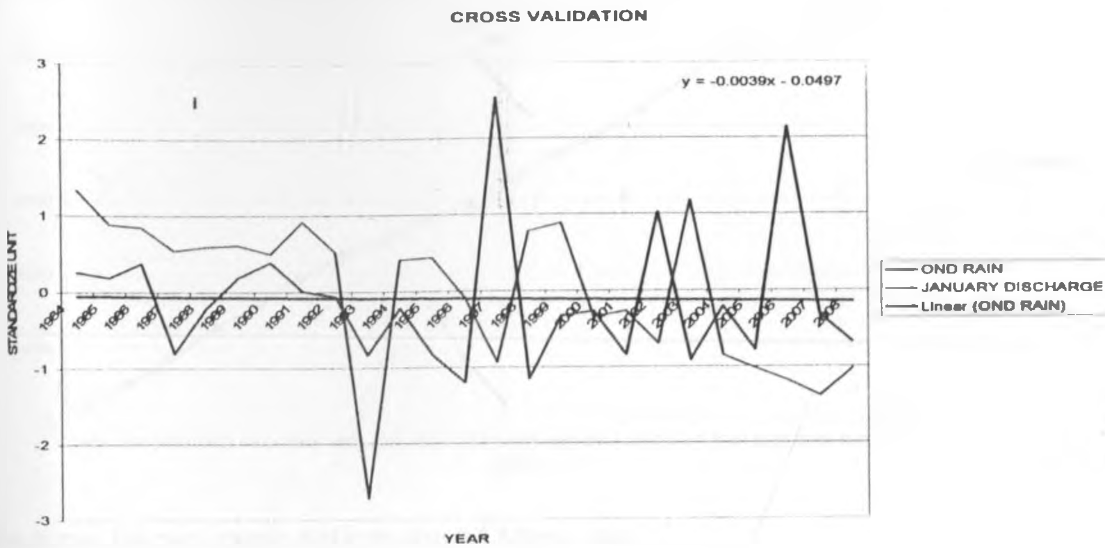
The cross validation between March, April and May rain season with July and August water discharge shows some relation but slightly diverge due to the time lag period.

Fig 17. MAM rain and July, august discharges cross validation



The cross validation is also done for October, November and December rain seasons with January water discharge shows some relation but slightly diverge due to the time lag period.

Fig 18. OND rain and January discharge cross validation



6.2 MTERA HYDROPOWER STATION

6.2.1 MASS CURVE

Mass curve for Mtera dam level and discharge

Fig 19.Mass curve for Mtera dam level

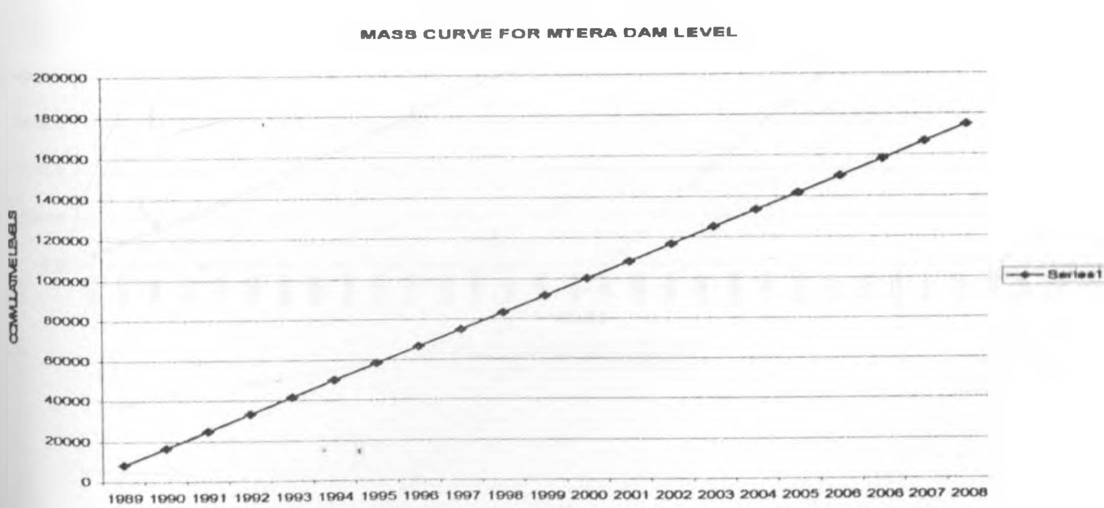
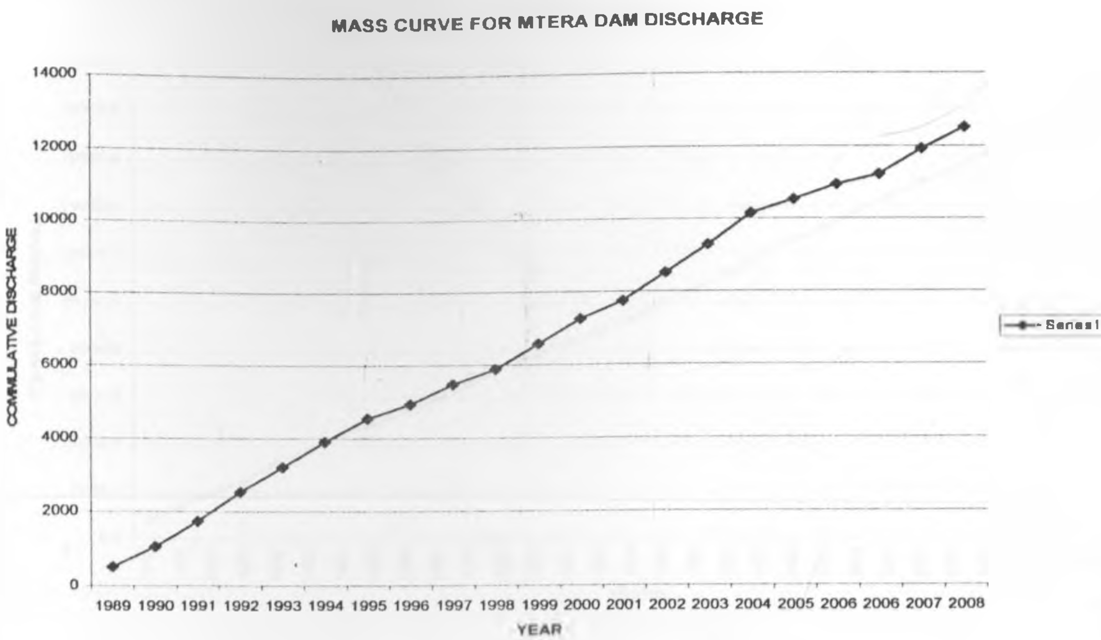


Fig 20.Mass curve for Mtera dam discharge



Mass curve for rain gauge stations around Mtera dam.

Fig 21. Dodoma mass curve

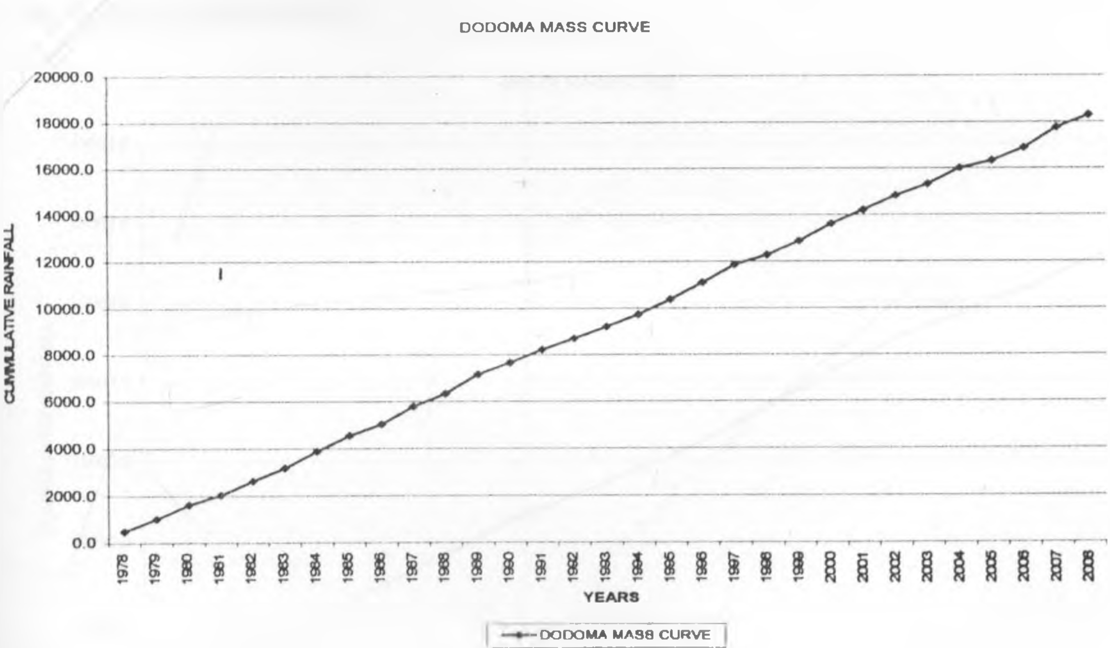


Fig 22.Iringa mass curve

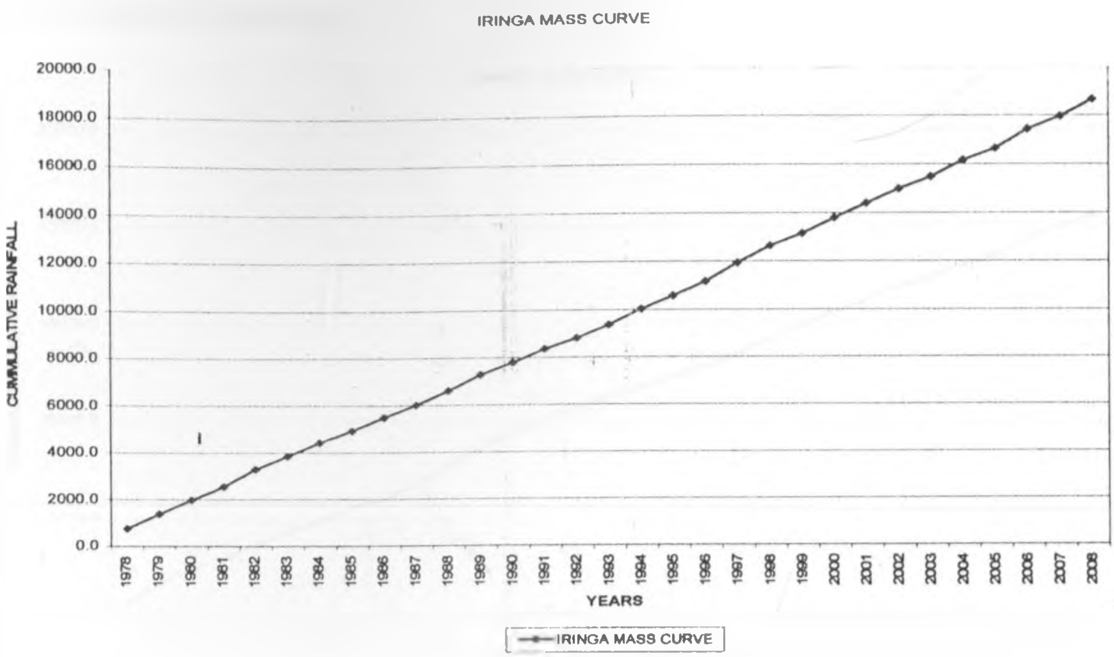


Fig 23.Mbeya mass curve

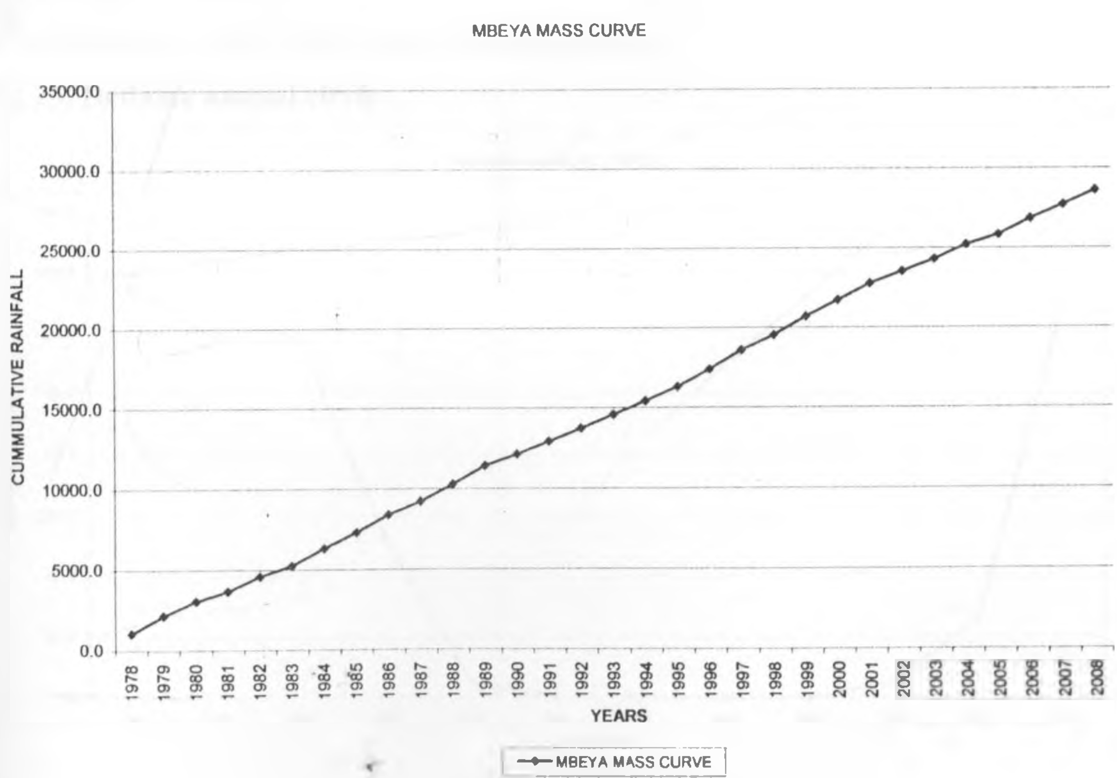
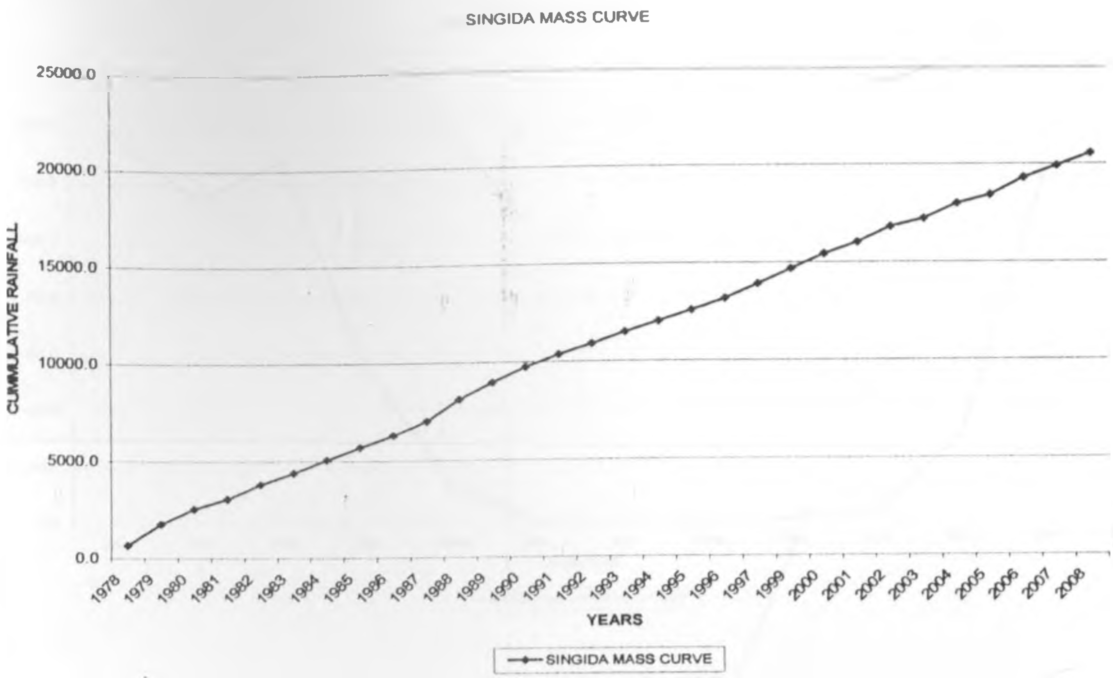


Fig. 24. Singida mass curve



6.2.2 ANNUAL CIRCLES

Annual circles to mark the unimodal rainfall seasons.

Fig 25. Dodoma annual circle

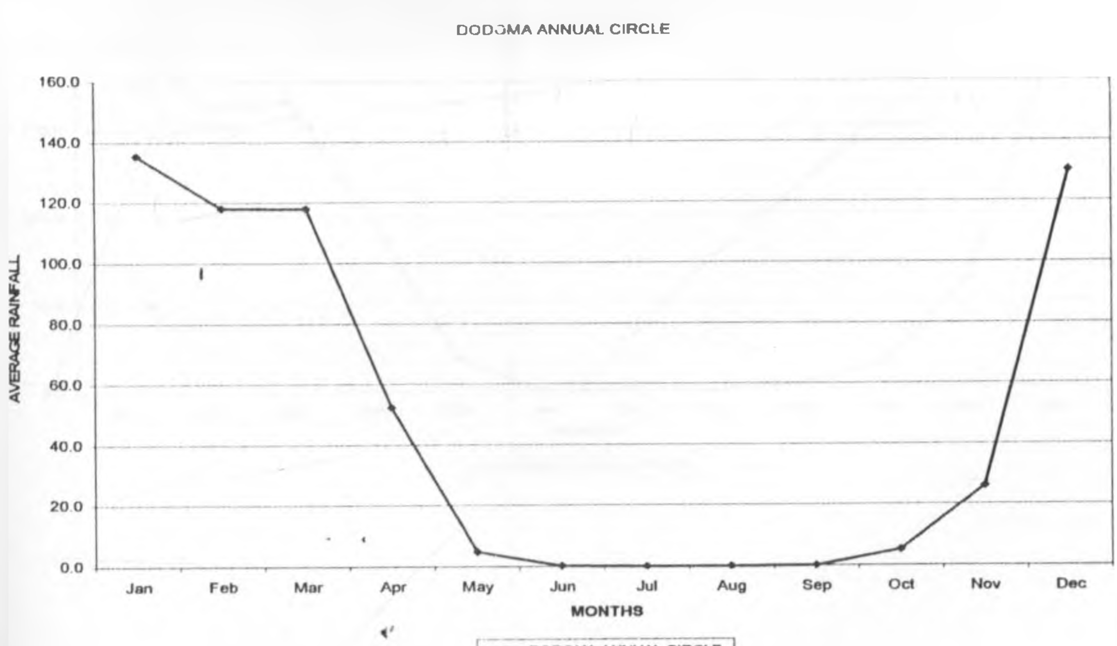


Fig 26. Iringa annual circle

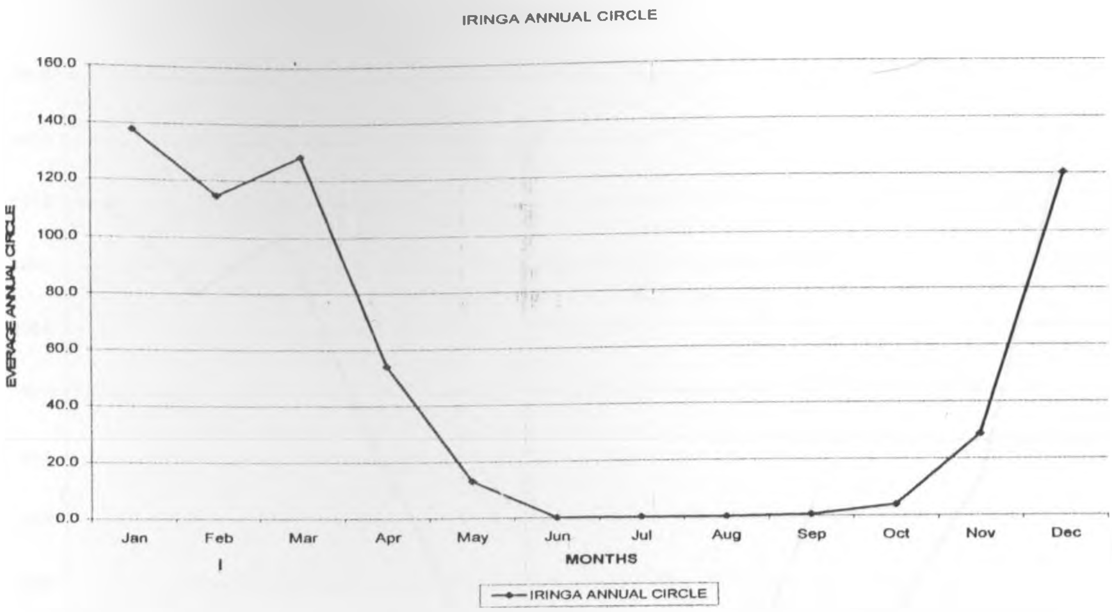


Fig 27. Mbeya annual circle

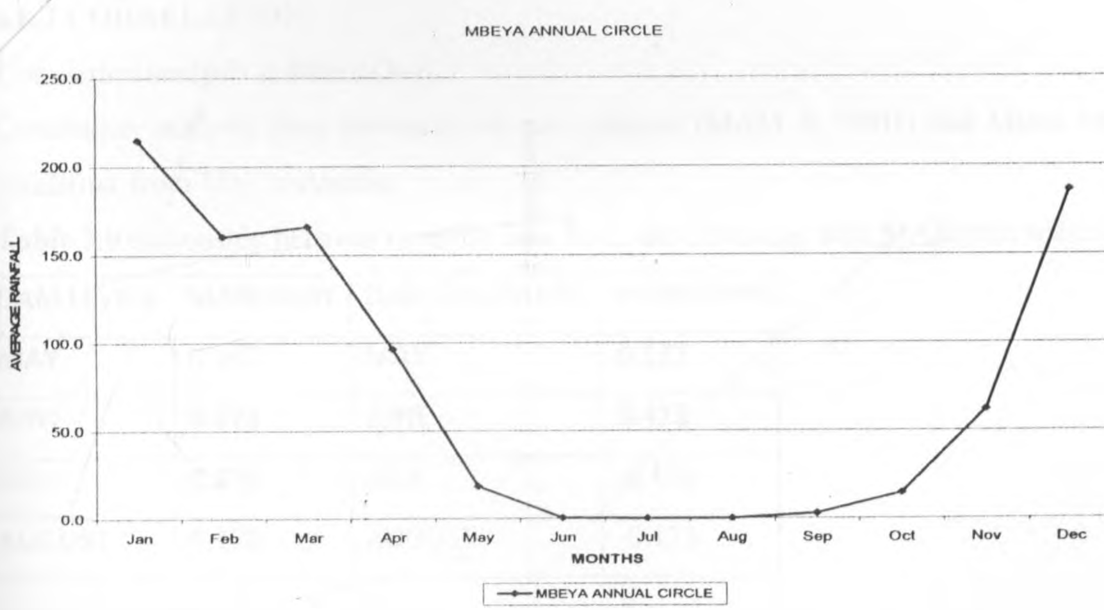


Fig 26. Iringa annual circle

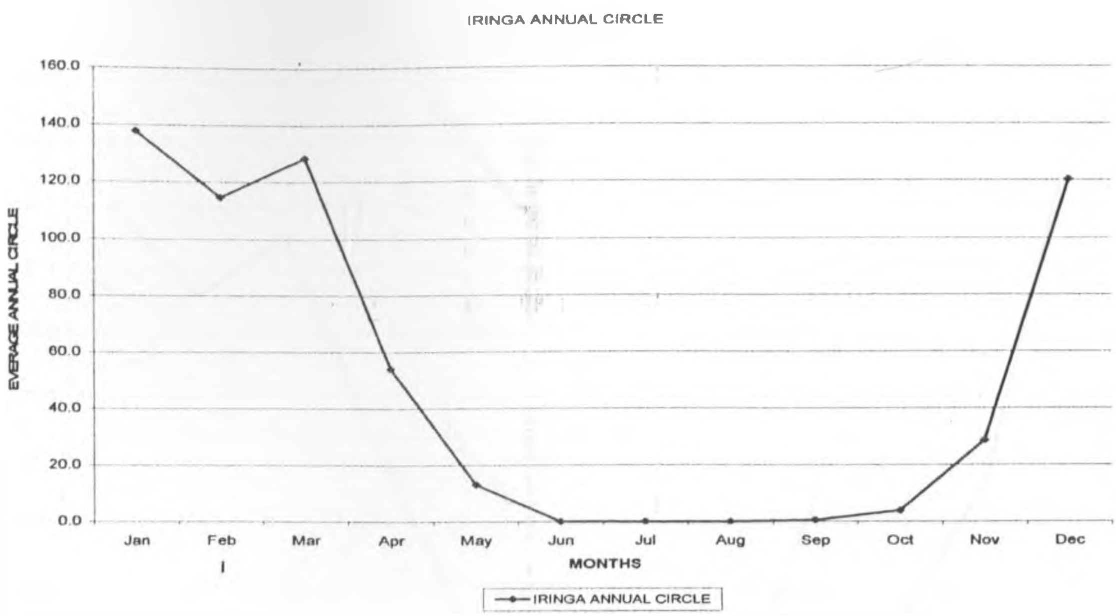


Fig 27. Mbeya annual circle

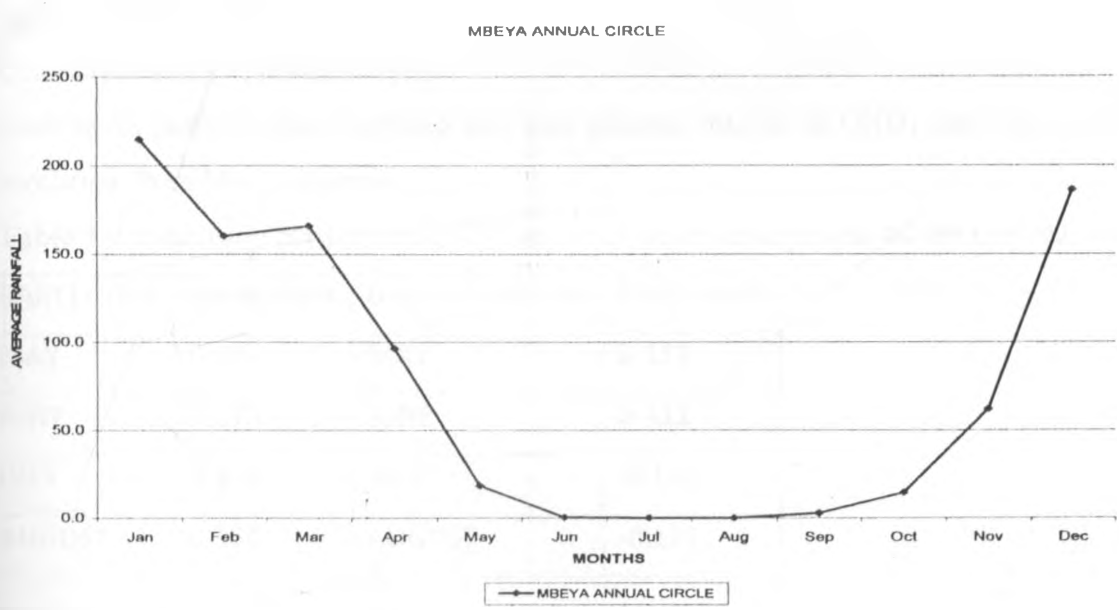
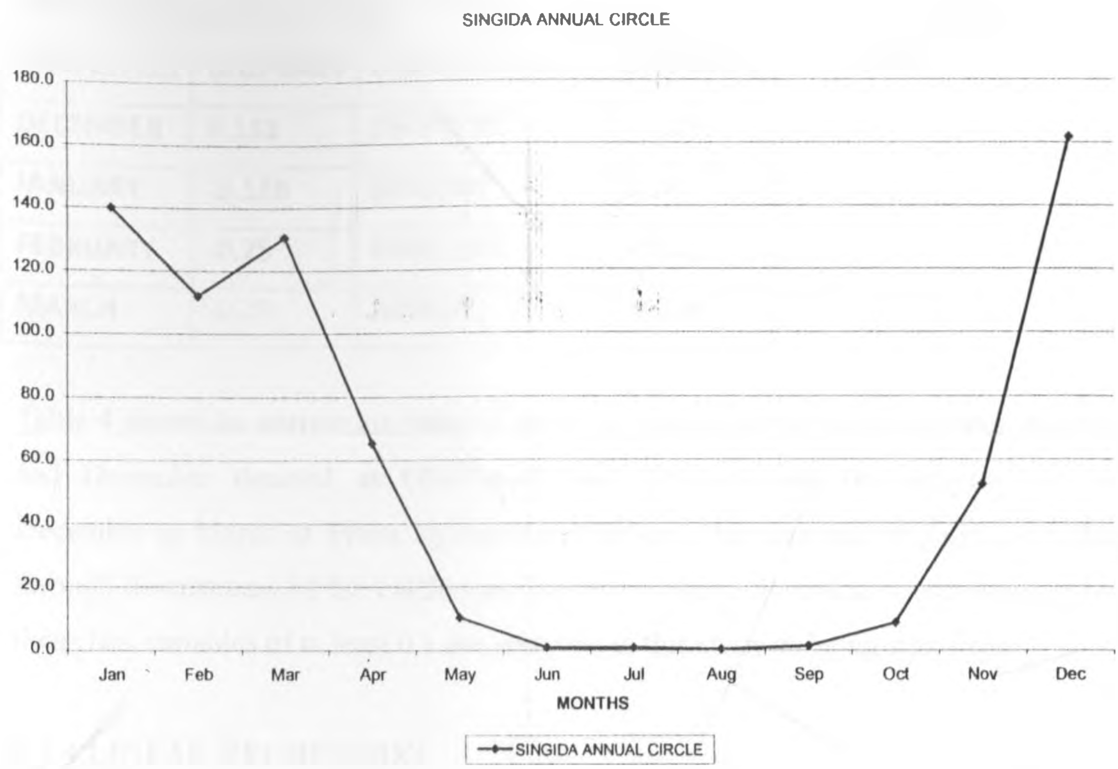


Fig 28. Singida annual circle



6.2.3 CORRELATION

Correlation analysis at Mtera Dam.

Correlation analysis done between two rain seasons (MAM & OND) and Mtera Dam levels(m) from May to August.

Table 5.Relationship between monthly dam level and discharge with MAM rain season

DAM LEVELS	**MAM RAIN**	DAM DISCHARGE	**MAM RAIN**
MAY	0.147	MAY	**0.132**
JUNE	**0.173**	JUNE	**0.411**
JULY	**0.170**	JULY	-0.132
AUGUST	**0.170**	AUGUST	-0.122

Table 3 shows the correlation analysis between rainfall in the period March, April and May seasons denoted as MAM with dam levels and discharge from May to August at Mtera Hydropower Station. The seasonal rainfalls are collected through downstream of the catchments basins at Mtera. Statistical associations between these two variables of at least 0.1 are accepted in this study as being significant.

Table 6.Relationship between monthly dam level and discharge with OND rain season

DAM LEVELS	**OND RAIN**	DAM DISCHARGE	**OND RAIN**
DECEMBER	**0.132**	DECEMBER	-0.129
JANUARY	-0.188	JANUARY	**0.18**
FEBRUARY	-0.25	FEBRUARY	-0.071
MARCH	-0.29	MARCH	-0.284

Table 4 shows the correlation analysis between rainfall in the period October, November and December denoted as OND with dam level(m) and Discharge(m^3/sec) from December to March at Mtera Hydropower Station. The seasonal rainfalls are collected through downstream of the catchments basins at Mtera. Statistical associations between these two variables of at least 0.1 are accepted in this study as being significant.

6.2.4 LINEAR REGRESSION

Mtera seasonal rainfall

The following linear regression has been established:

Fig 29. Relationship between MAM rain and June levels.

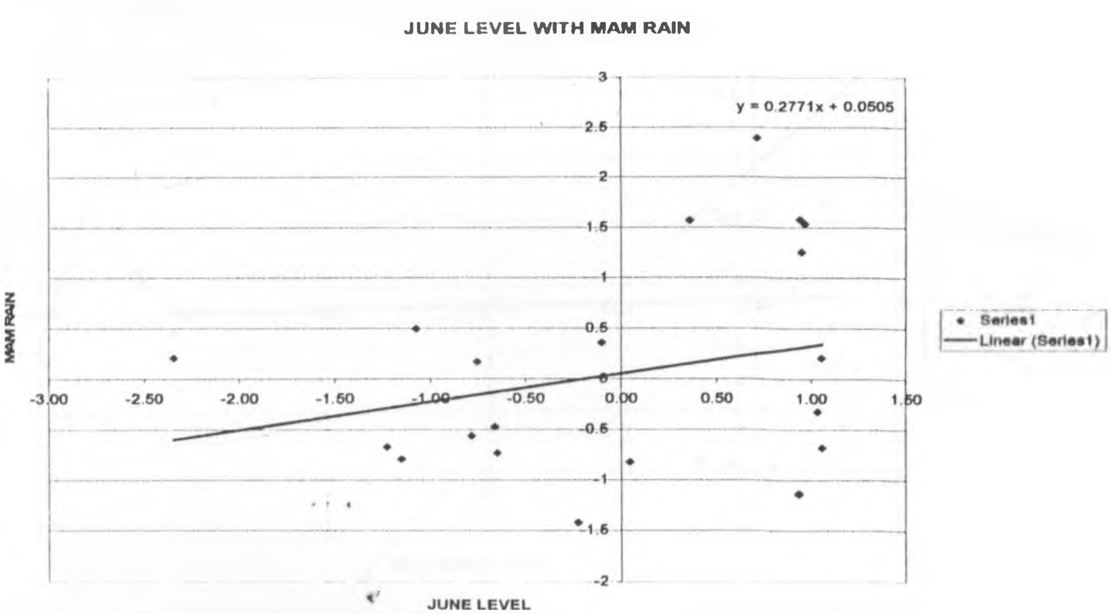


Fig 30. MAM rain and July levels.

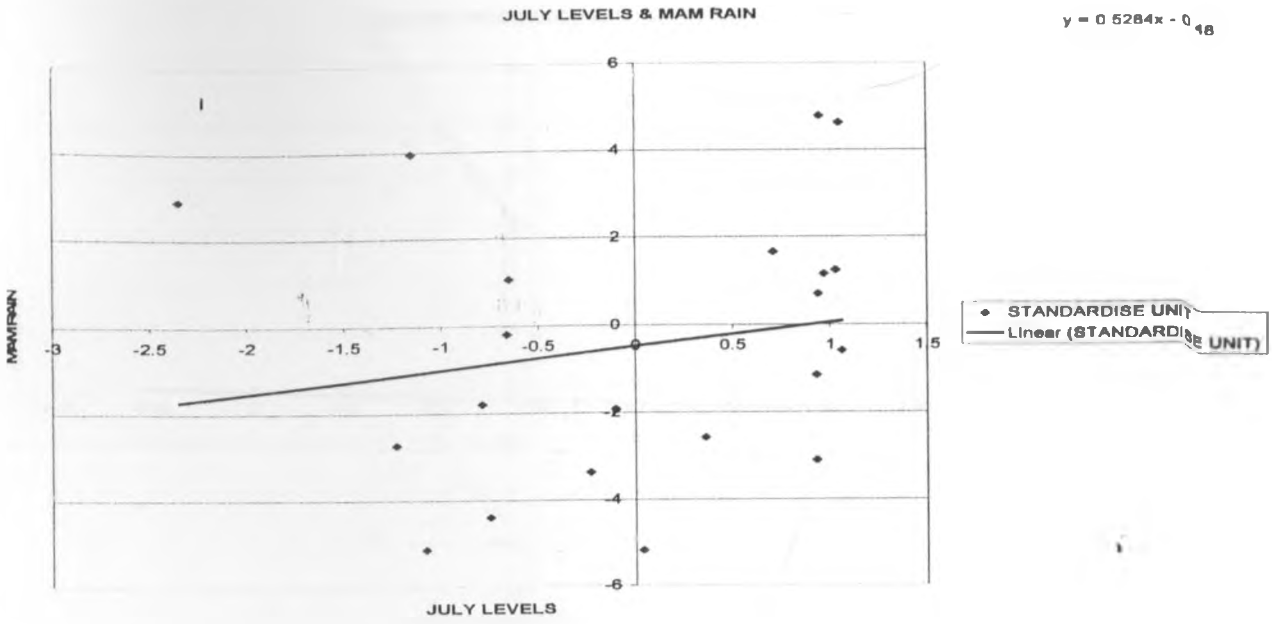


Fig 31.Relationship between OND rain and December levels.

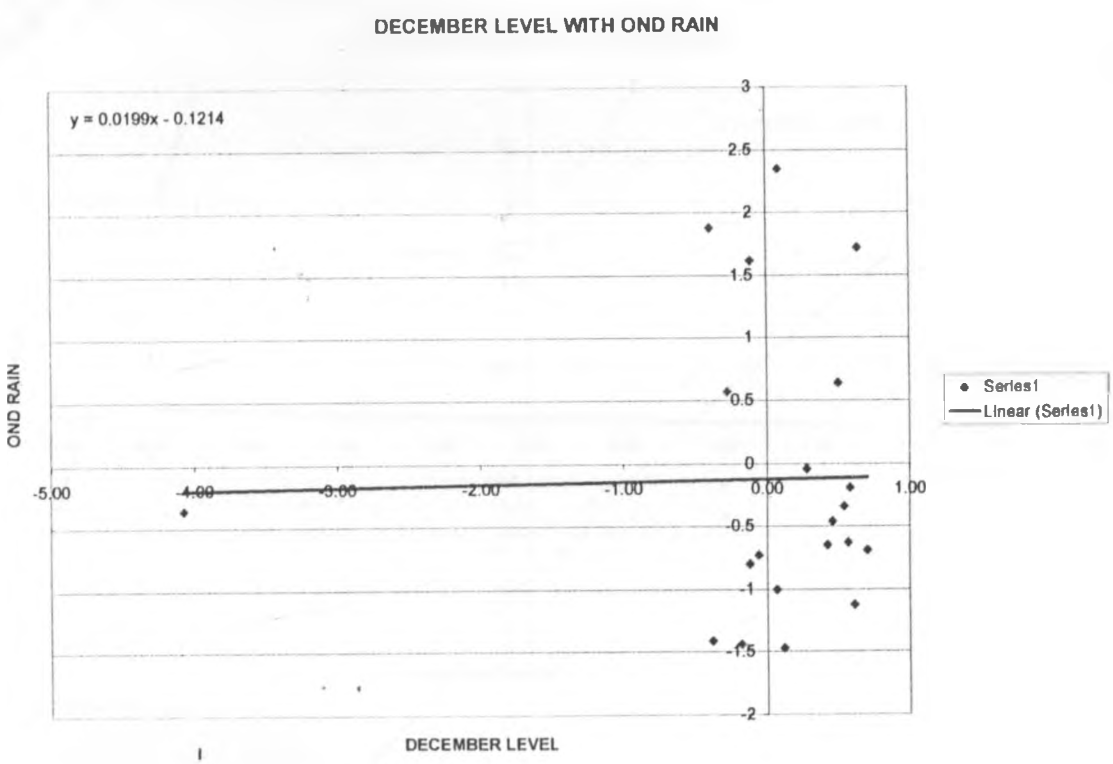


Fig 32. Relationship between OND rain and January discharge.

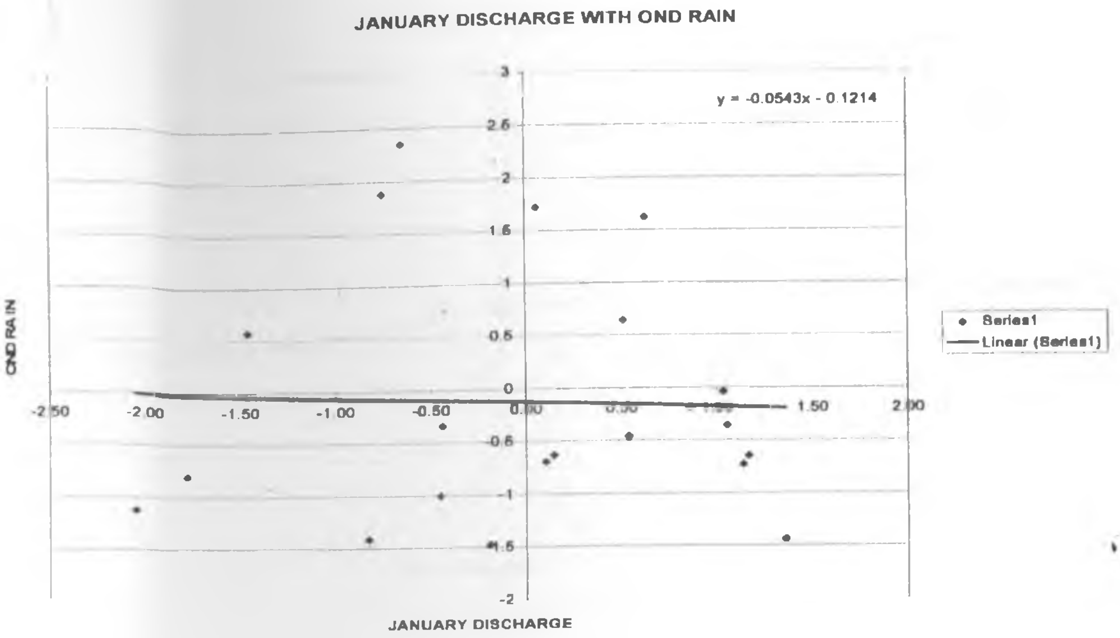


Fig 33. Relationship between MAM rain and June discharge.

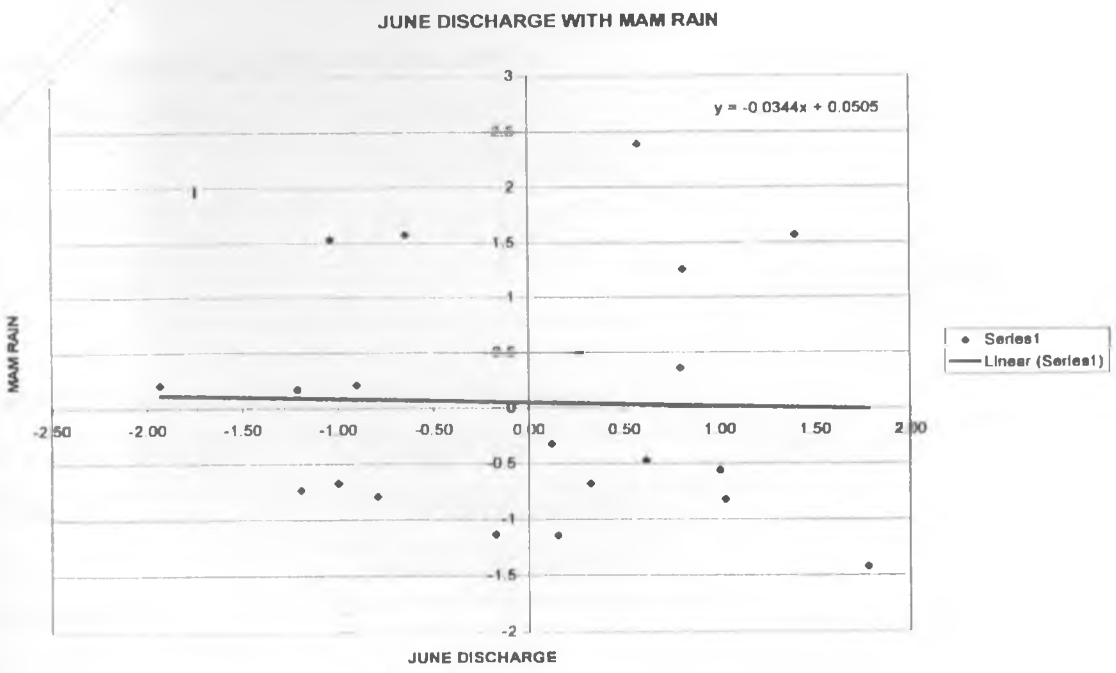
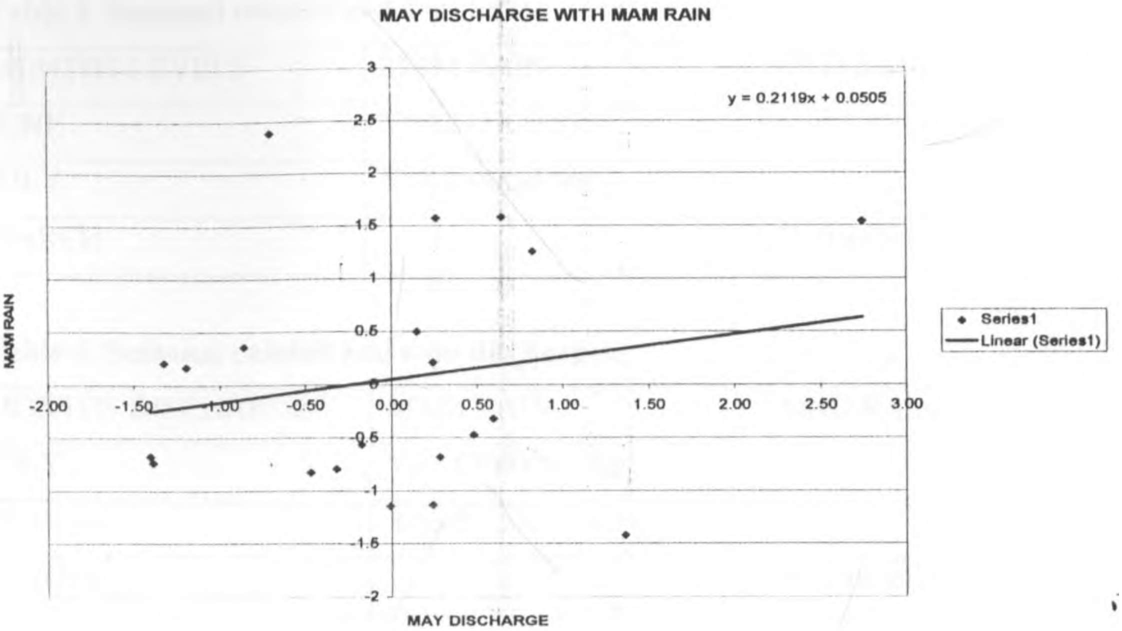


Fig 34. Relationship between MAM rain and May discharge.



Linear regression of levels seasonal rainfall is summarized as follow.

Table 7. Seasonal rainfall and dam levels.

MONTHS LEVELS	MAM RAIN	OND RAIN
JUNE	Y=0.2771X+0.0505	
JULY	Y=0.528X-0.48	
DECEMBER		Y=0.0199X-0.121

Table 8. Seasonal rainfall and dam discharges.

MONTHS LEVELS	MAM RAIN	OND RAIN
JUNE	Y=-0.0344X+0.0505	
MAY	Y=0.2119X+0.0505	
JANUARY		-0.0543X-0.121

Linear regression of levels, discharge seasonal rainfall is summarized as follow.

Table 3. Seasonal rainfall and dam levels.

MONTHS LEVELS	MAM RAIN	OND RAIN
JUNE	Y=0.243X-0.57	
JULY	Y=0.258X-0.566	
MARCH		Y=0.44X-0.39

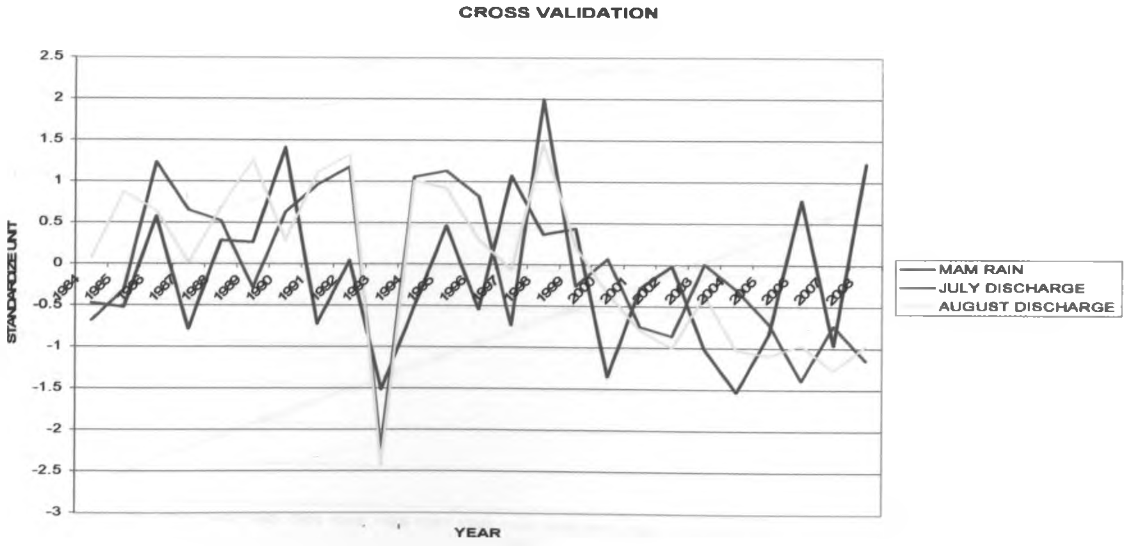
Table 4. Seasonal rainfall and dam discharges.

MONTHS DISCHARGES	MAM RAIN	OND RAIN
JULY	Y=0.1306X-0.162	
AUGUST	Y=0.2855X-0.162	
JANUARY		Y=0.00995X-0.1008

6.1.5 CROSS VALIDATION

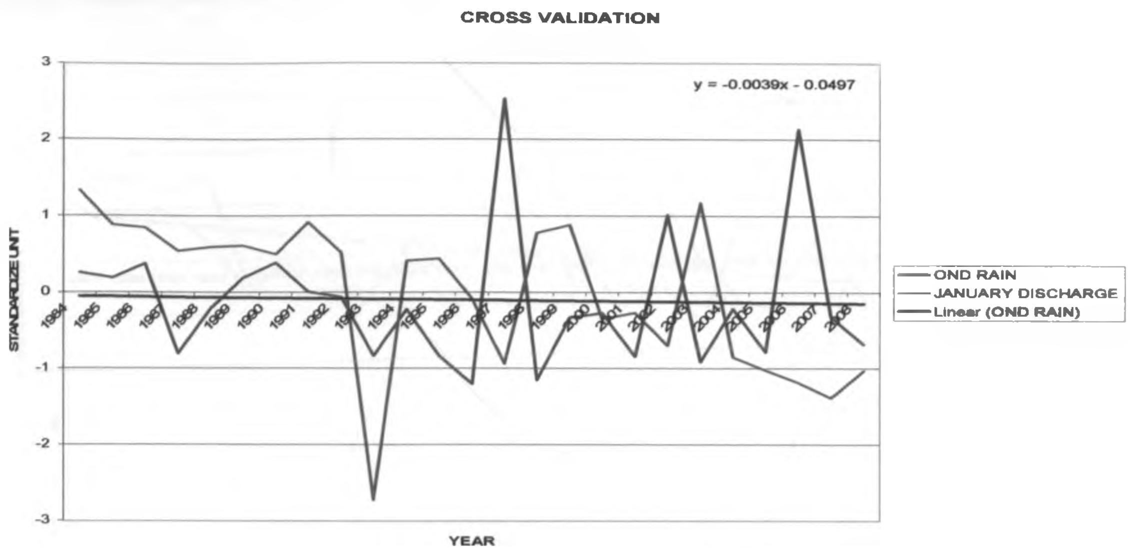
The cross validation between March, April and May rain season with July and August water discharge shows some relation but slightly diverge due to the time lag period.

Fig 17. MAM rain and July, august discharges cross validation



The cross validation is also done for October, November and December rain seasons with January water discharge shows some relation but slightly diverge due to the time lag period.

Fig 18. OND rain and January discharge cross validation

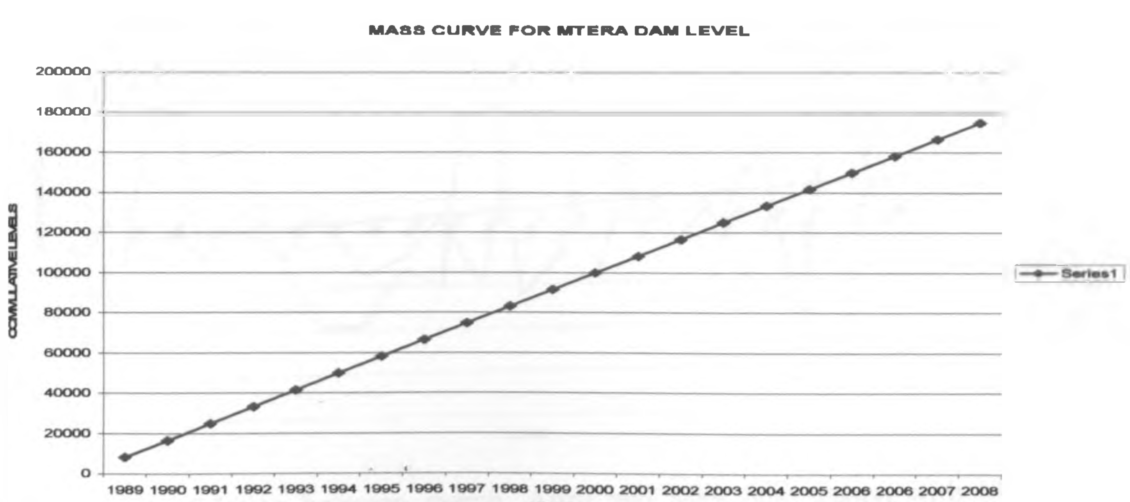


6.2 MTERA HYDROPOWER STATION

6.2.1 MASS CURVE

Mass curve for Mtera dam level and discharge

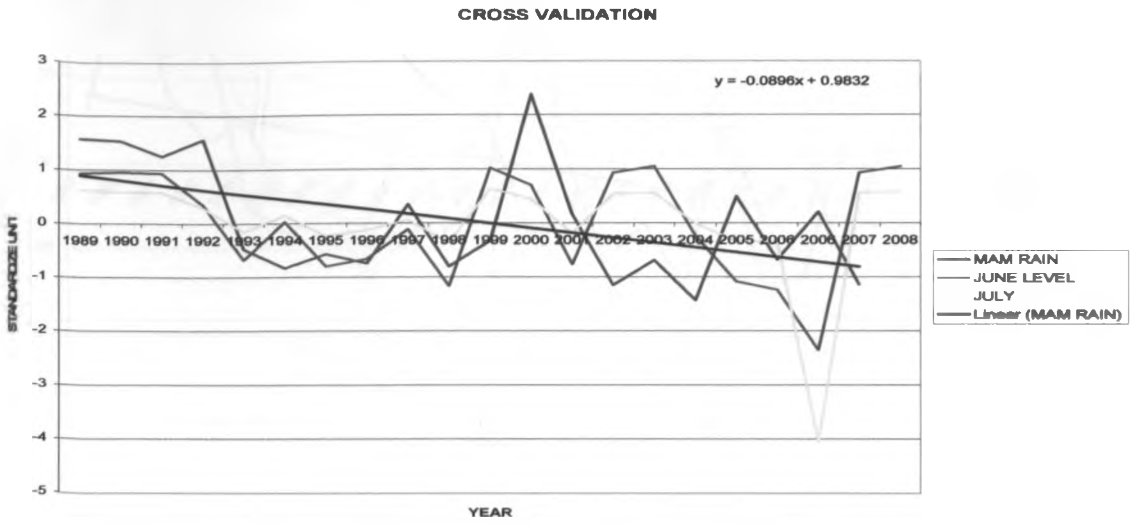
Fig 19.Mass curve for Mtera dam level



6.2.5 CROSS VALIDATION

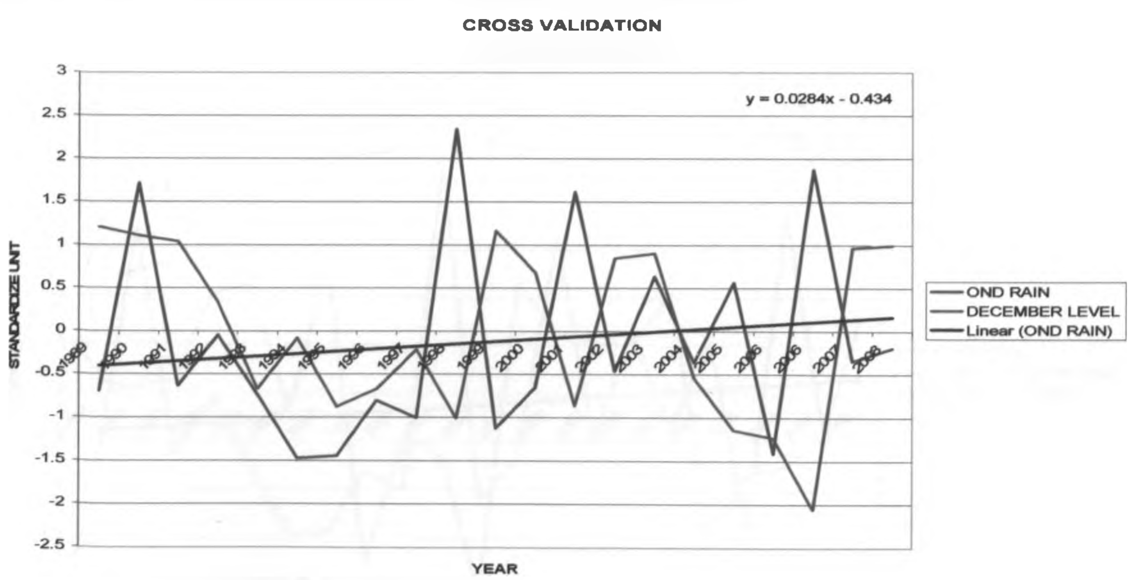
The cross validation between March, April and May rain season with June and July levels shows some relation but slightly diverge due to the time lag period.

Fig 35. MAM rain and June, July levels cross validation



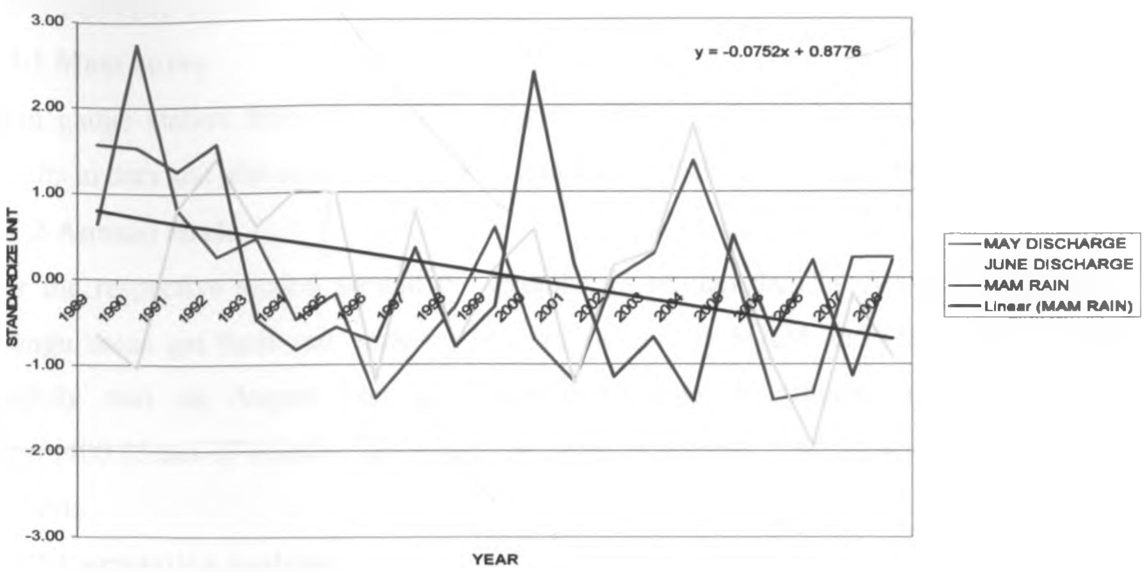
The cross validation between October, November and December rain season with December levels shows some relation but slightly diverge due to the time lag period.

Fig 36. OND rain and December cross validation.



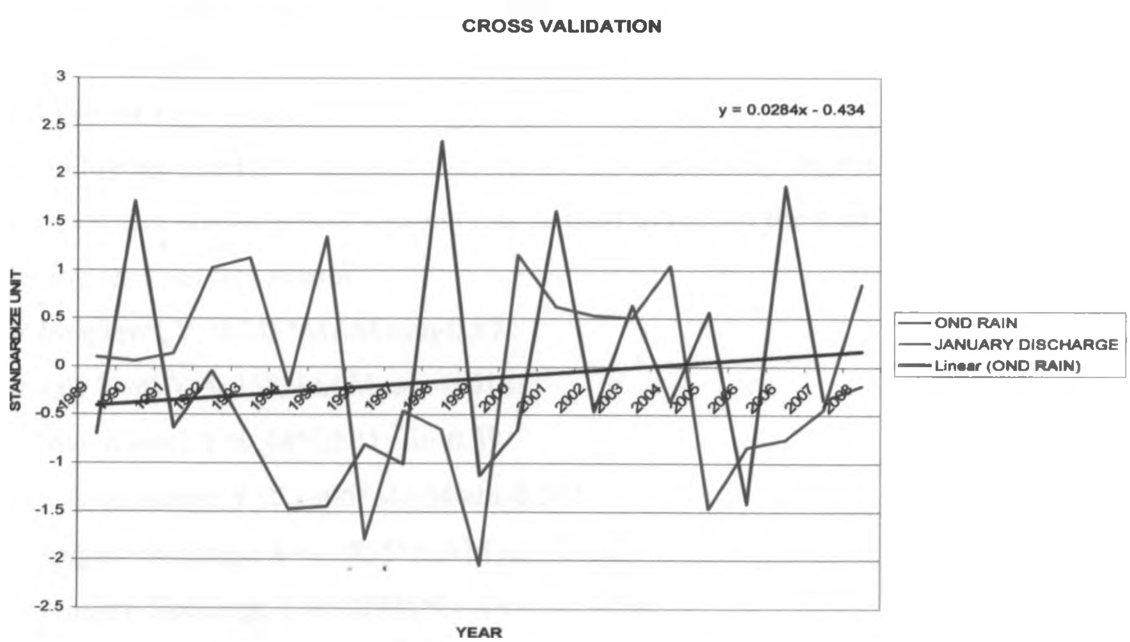
The cross validation between march, April and May rain season with May and June discharge shows some relation but slightly diverge due to the time lag period.

Fig 37. MAM rain and May June, cross validation.



The cross validation between October, November and December rain season with January discharge shows some relation but slightly diverge due to the time lag period.

Fig 38. OND rain and January discharges cross validation.



7.0 DISCUSSION

7.1 NYUMBA YA MUNGU DAM

7.1.1 Mass curve

Rain gauge station from fig 12-16. ie.Arusha, Kia, Moshi and Same, shows positive results in data and also data for dam level and water discharge are also ok.

7.1.2 Annual circle

For the respective station around the nyumba ya mungu dam, shows that nyumba ya mungu areas get their rain most in two season that is MAM and OND, but there is slightly rain on August but not much remarkable. Maximum rain observed on April(400.85mm of rain)for MAM season, And November (166.2mm of rain)for OND season.

7.1.3 Correlation analysis

Correlation analysis shows that MAM rain season have a correlation with May, June and July levels by R^2=0.084, 0.085 and 0.09 respectively. Also shows some relation with dam discharge with June and July by R^2=0.128 and 0.349 respectively. Hence during these related months the generation of electricity is at normal condition due to the availability of water from rain.

During OND rain season, dam level on March shows relation than the other months and January dam discharge of about R^2=0.132 and 0.10.

7.1.4 Linear regression

The following formula obtained from the linear relationship between rain season with dam level and discharge this formula can be used to predict the dam level and discharge after the sessions rain season

For June level Y=0.243*MAM rain-0.57

For July level Y=0.258*MAM rain-0.518

For March level Y=0.44*OND rain-0.39

For July discharge Y=0.1306*MAMrain-0.162

For August discharge Y=0.2855*MAM rain-0.162

For January discharge Y=0.00995*ONDrain-0.1008.

7.1.5 Cross validation

Figure 17-18 shows validation trends of MAM rain seasons with June and August discharge. Same slightly difference on time of pick start and value on standardized unit but they have the same feature, the time difference is due to time lag. This trend is decreasing in both rain fall and discharge from the dam this can be accounted due to the problem of climatic change the rain fall amount is decreasing and hence discharge will also need to decreasing in order to counter balance the effect

7.2 MTERA DAM

7.1.1 Mass curve

Rain gauge station from fig 19-24. Ie.Mtera Dodoma, Iringa, Mbeya and Singida shows positive results in data and also data for dam level and water discharge are also ok.

7.1.2 Annual circle

For the respective station fig 25-28 around the Mtera dam, shows that areas get their rain most in one season that is long season but the rain are within the OND and MAM season,

7.1.3 Correlation analysis

Correlation analysis fig 29-34 shows that MAM rain season have a correlation with June and July and august levels by R^2=0.173, 0.170 and 0.170 respectively. Also shows some relation with dam discharge with June and May by R^2=0.132 and 0.411 respectively. Hence during these related months the generation of electricity is at normal condition due to the availability of water from rain.

During OND rain season, dam level on December shows relation than the other months and January dam discharge of about R^2=0.132 and 0.18.

7.1.4 Linear regression

The following formula obtained from the linear relationship between rain season with dam level and discharge this formula can be used to predict the dam level and discharge after the sessions rain season

For June level Y=0.2771*MAM RAIN+0.0505

For July level Y=0.5284*MAM RAIN-0.48

For December level Y=0.0199*OND rain-0.121

For January discharge Y=-0.0543*OND rain-0.121

For June discharge Y=-0.0344MAMrain+0.0505

7.1.5 Cross validation

Figure 17-18 shows validation trends of MAM rain seasons with June and July discharge. Same slightly difference on time of pick start and value on standardized unit but they have the same feature, the time difference is due to time lag. This trend is decreasing in both rain fall and discharge from the dam this can be accounted due to the problem of climatic change the rain fall amount is decreasing and hence discharge will also need to decreasing in order to counter balance the effect

8.0 CONCLUSION

This study has given the impression that it is possible to simulate dam levels after the rainfall season, a move that ensures decision-making on Hydropower generation. This will also reflect a comprehensive approach to integrating social, environmental and economic dimensions of development; create greater levels of transparency and certainty for all involved and increase levels of confidence in the ability of communities to meet their future electricity needs.

However, experience shows that the amount of water in the storage reservoirs fluctuates considerably between different years, which had a negative impact on hydropower generation. It calls for compromise among the stakeholders to chart out a resolve/understanding strategy on the water management. A great challenge for the future lies in finding methods for development of lasting solution. A solution, which will also arrest the current trend of wood fuel depletion by evolving more appropriate land management practices and more efficient wood fuel technologies.

The wind-based project to exploit wind energy to generate electricity, Feasibility studies have shown that the wind power project in the few areas selected along the Tanzanian coastal strip and north eastern highlands is economically and financially viable as a precondition for obtaining sustainability of the project. Other areas may include developing other sources of energy like geothermal and solar-based energy. The mean solar energy density in Tanzania is of the order of 4.5 kW per square metre per day, which is an indication of a good potential for use as an energy source. However, lack of incentives to disseminate technical cost effective locally based innovations may hamper the development. There are at present, for example, heavy taxes on imported solar panels.

Future research will involve relating seasonal/climate forecast tercile indices with aerial rainfall amounts in the relevant catchments. It will also incorporate evaporation and characteristics of soils upstream of the dams to allow for water losses as a result of the two and at a time when the dam level series are long enough to ensure stable statistics particularly over Mtera.

AKNOWLEDGMENT

I would like to thank ALLAH Almighty to the merciful and all protection he gave me during my studies in the University Of Nairobi.

Similarly I wish to extend my sincere gratitude to my Director General of Tanzania Meteorological Agency (TMA) for giving me this opportunity to pursue studies leading to Postgraduate Degree in Meteorology.

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Finally I thank my entire Staffs of Tanzania Meteorological Agency for their cooperation.

ALLAH (Almighty) BLESSES YOU ALL!!

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