IMPACTS OF RAINFALL ON AIRCRAFT OPERATIONS AT JULIUS NYERERE INTERNATIONAL AIRPORT AND SHINYANGA AIRPORT, TANZANIA.

BY

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DEDICATION:

This project work is dedicated to the entire members of my family for their endless support and encouragement throughout my study. Were it not for their support, I would not be where and who I am today.

DECLARATION:

I declare that this project is my own work and has not been submitted to any other institutions for the award of diploma in Meteorology, or Bachelor of Science (BSc) in Meteorology, or any other degree course.

The project was carried out and presented for Examination by:

.... on .... of 2009
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The project has been submitted for Examination with our approval as University Supervisors:

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ABSTRACT

Although air transportation seems to be the best way of travels in Tanzania sometimes it became unsafely and unreliable due to the different factors including bad weather such as heavy rains. Bad weather may lead to aircraft accidents, delays, cancellations of flight, and diversions of flights to other alternate aerodromes. The present study examined the impacts of rainfall on air transportation at Julius Nyerere International Airport (JNIA) and Shinyanga airport (HTSY).

The methods that were employed in this study include; time series analysis, graphical analysis and correlation analysis that used to Study the impacts of rainfall on air transportation at Julius Nyerere International Airport and Shinyanga airport. In order to archive this objective the following specific objectives were addressed; to examine the temporal characteristic of rainfall at JNIA, to identify cases of delaying, cancellation, diversions of flights due to heavy rainfall and to study the wet spells during a wet season (Intra Seasonal Oscillations-ISO).

Two data sets were used in this study; Rainfall data and charts of each day for three months, March, April, and May from 1996 to 2005 and Flight accident reports which obtained through accidents report files in operation office of Precision Air.

Rainfall analysis used in this study shows that; The wettest season was 2002 for both stations(JNIA and HTSY) while driest season was 2003 for JNIA and 2000 for HTSY. April was the wettest month at JNIA But March was the wettest month at HTSY, while May was the driest month at both stations (JNIA and HTSY). Also rainfall season(MAM) show that; the mean onset starts on 3rd week of March at both JNIA and HTSY, while the mean cessation at JNIA is on 4th week of May and at HTSY is on 2nd week of May.

More analysis was done on operation of aircraft on both stations, at JNIA more delays were in April (5) while at HTSY more delays were observed in March (6), and maximum number of cancellation (39) occurred at HTSY.

Although rains cause some cancellations and delays of flights, but it is not a main cause of aircraft accidents in Tanzania.

The results obtained from rain data and operation of aircraft showed there are more correlations between rain days and delays of flights at both airports (JNIA &HTSY), also some correlations are observed on rain days and cancellations of flights at HTSY.

In order to solve the problems of most cancellations, the construction of paved (tarmac) runways is required; also the problem of delays of flights can be solved by relating flights planning with daily weather forecasts and Terminal Aerodromes Forecasts (TAF).

CHAPTER ONE

1.0 Introduction

The operation of aircrafts at Julius Nyerere International airport (JNIA) formally (Dar es salaam International Airport) and Shinyanga Airport sometimes falls under risk because of heavy rain (+RA), heavy thunderstorm with rain (+TSRA) which are always associated with strong wind, the thunderstorm with heavy rains reduces vertical and horizontal visibility.

Aircrafts accidents which occur during landing and take-off stages in most aerodromes are caused by either severe weather or technical problems in aircraft itself. Heavy Rainfall is a major cause of accidents as it can reduces visibility up zero, this makes it difficult for pilots to see the runway clearly, if pilot decide to take off or landing in such condition it can lead to aircraft crushing which result in damage of aircraft and loss of lives.

Also heavy rainfall can cause accidents through damaging air navigation system on board the aircraft which is very important during landing of aircrafts; therefore pilot can loose communication and making landing to be risky. The possibility of an accident to occur is high if pilot forced to land in such conditions.

Heavy rainfall also causes interruption in operation of an aircraft due to floods and maintenance on its infrastructure such as runway, this may lead to delay on take off or landing, cancellation of flights, and diversion of flight to alternate aerodromes.

The present study will concentrate on the heavy rain which falls during long rain season of March, April and May (MAM) in each year on Julius Nyerere International Airport and Shinyanga Airport as the area of study.

The aim of research is to investigate the impacts of heavy rainfall on aircraft operation at Julius Nyerere International Airport and Shinyanga Airport.

1.1 Problem statement

Although air transportation seems to be the best way of travels in Tanzania sometimes it became unsafely and unreliable due to the different factors including bad weather such as heavy rains. Bad weather may lead to aircraft crashing, delaying, cancellation of flight, diversion of flights to other alternate aerodromes. If crashing occurs it expose passengers and crew in the high risk and damage to the aircraft, therefore the loss of income for the owner of that damaged aircraft as well as government though taxes.

In Tanzania many cases of flight accidents are reported which associated with weather, also many cases of delay, cancellation of flight are still reported much during long and short rain seasons.

1.2 Rainfall Climatology of the study area

1.2.1 Area of study

Julius Nyerere International airport (JNIA) is the largest and busiest airport in Tanzania (category A) therefore it shall represent other large airports in the region. JNIA is located in coastal zone of Tanzania therefore also it shall represent other airports along the coastal strip of Tanzania by assumptions of having the same characters of weather.

Shinyanga Airport is the regional airport located near Lake Victoria basin, this airport classified as category C which has unpaved runway (dimension 2000x30m and its strength is 5700kg), no taxiway, apron surface strength is gravel, rescue aid from fire brigade is category five(5) so during rain seasons the problems of cancellation, delaying and diversions are common. Therefore this airport will represent other airports around Lake Victoria basin and also it represents other airports which classified the same category.

The United Republic of Tanzania is located on the East coast of Africa between parallels 10°S and 12°S and meridians 30°E and 40°E (Figure 1). 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.

The Julius Nyerere International Airport is located at latitude 06.53°S and longitude 39.12°E, its height above mean sea level is about 55 meters and Shinyanga Airport is about seven(7) kilometers North East of Shinyanga town, it located at latitude   S and longitude   E, its height above mean sea level is 3800 feet.

1.2.2 Synoptic Circulation systems that control the climate over coastal area of Tanzania include ;

(a)The Inter-Tropical Convergence Zone (ITCZ):-
This is a region where the air masses originating from the tropics of cancer and Capricorn converges and lift. The ITCZ governs the occurrence of wet and dry seasons. The convergence zone moves with the overhead sun.
(b)Sub-Tropical Anticyclones:-
 These are Mascarine High,St Helena High,Azores High snd The Arabian Ridge.
(c)Tropical Cyclones:-
This is low pressure centres that move Westward or Southward from Eastern Indian Ocean.
(d)Sea Surface Temperatures over SW Indian Ocean
(e)Easterly Waves and Monsoons.
(f)The Congo Airmass:-
This is an airmass originating from moist and cold Congo Forests
(g)Lake Victoria Influence:-

This is a Local effects from Lake Victoria.
Mean annual rainfall ranges from 731mm to 1,733mm with a mean of 1134mm 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

Figure 1; Red ovals are the location of study area.

Data for monthly mean rainfall at Dar es salaam (Julius Nyerere International Airport) for the last two decades are show in the table 1 below;

MONTHS	MEAN MONTHLY RAINFALL (mm)
JANUARY	74
FEBRUARY	83
MARCH	143
APRIL	273
MAY	152
JUNE	34
JULY	32
AUGUST	28
SEPTEMBER	26
OCTOBER	60
NOVEMBER	122
DECEMBER	108
TOTAL	1134

Table 1; Mean monthly rainfall for Dar es salaam Airport

The following histogram is for the months from January up to December versus monthly mean rainfalls of Julius Nyerere International Airport (JNIA), the data was obtained as an average of two past decades.
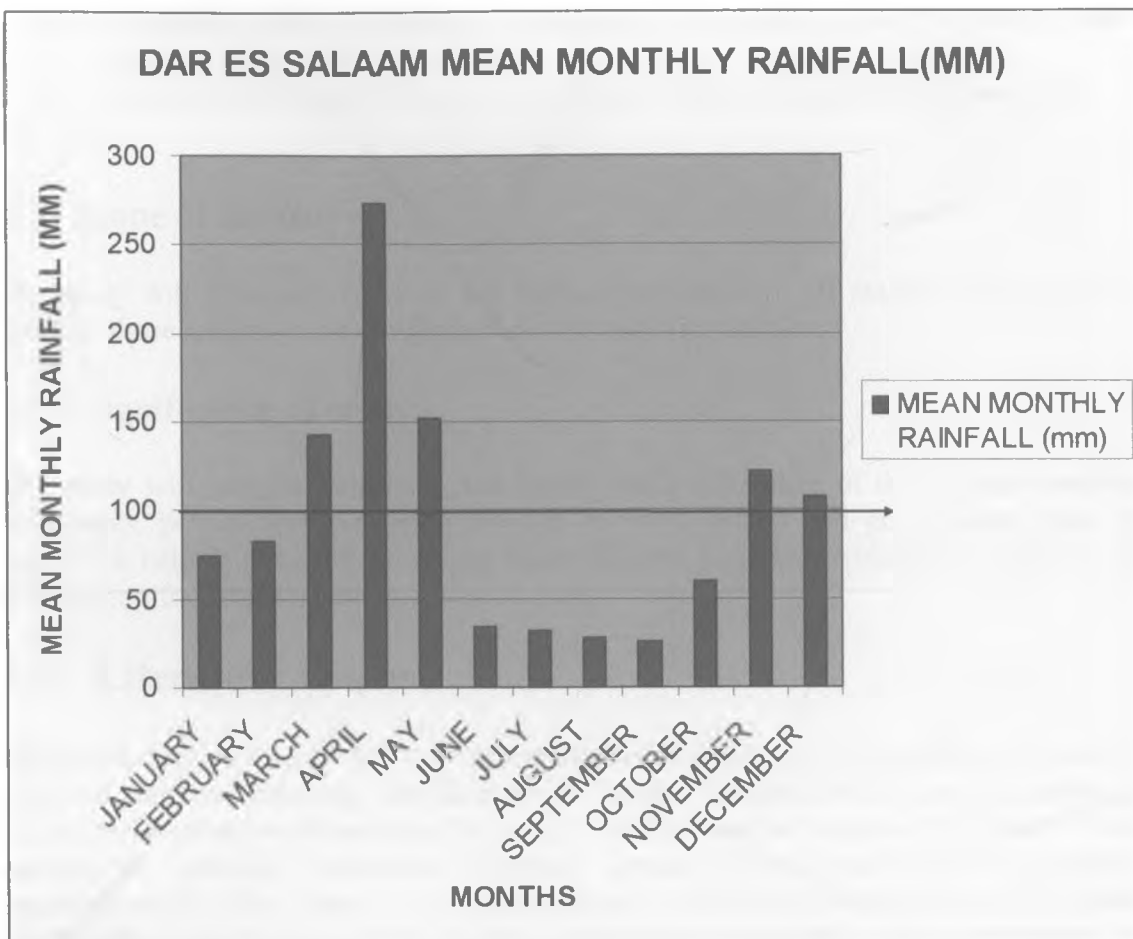
DAR ES SALAAM MEAN MONTHLY RAINFALL(MM)

Figure 2; Mean monthly rainfall (mm) plot for Dar es salaam.

While Table 1 and Figure 2 above show the rainfall climatology of Dar es Salaam is bimodal (MAM and OND), but MAM shows the highest rainfall compared to OND. Noted that mean monthly rainfall is greater than 100mm for all MAM months. These months are classified as high rainfall months. (Okoola and Ambenje, 2003).

Therefore this will justify the using of MAM in my research as the one which having much impacts on aircraft operations at JNIA.

1.3 Objectives;

Main objective;
The overall objective is to Study the impacts of rainfall on air transportation at Julius Nyerere International Airport.

The Specific objectives include;
  a) To examine the temporal characteristic of rainfall at JNIA and Shinyanga Airport.

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b) To identify cases of delays, cancellations, diversions of flights due to heavy rainfall.

c) To study the wet spells during a wet season (Intra Seasonal Oscillations-ISO)

1.4 Scope of the study;

The study will concentrate mainly on the landing and take off stages of an aircraft at JNIA as these are the phases of flight for which data is available.

1.5 Significance of study;

The study will help in improving the safety and profitability of the air transportation companies, people who are using airways for their safaris and government. Also the study will help in reducing accidents, understanding local climatology and will provide information for future planning.

1.6 Literature review

During landing of aircraft the microwave landing system is very important in order to avoid an accident/ crashing, The Microwave Landing System (MLS) is in the process of being implemented worldwide as the new all weather landing system for aircraft. It will replace the existing Instrument Landing System (ILS). One of the operational requirements for the system is to guide aircraft to runway touchdown in all weather conditions (termed Category III). Testing conducted in recent years has demonstrated the sensitivity of the performance of the microwave antennas to the presence of water on the antenna radome.

The effects can include not only degradation of the radiated signal but also degradation of system monitoring. Research has been conducted to find a radome material with hydrophobic (water shedding) properties sufficient to prevent the accumulation of water on the radomes and thereby eliminate its effects. The radome material also needs to have a sufficient lifetime that it does not create maintenance problem. Testing conducted in recent years has demonstrate that, during rainfall the sensitivity of the performance of the microwave antennas are very poor due to present of water on antenna radome, because water on antenna radome of aircraft causes loss of accuracy, effective radiated power and system monitoring. (Cassell R. 1990).

Rainfall presents major problems on flight plans in different areas around the world, rain is the most weather cases reported in many countries in which causes interruptions of flights especially when it is associated with poor visibility In such poor visibility operation must be stopped by ICAO recommendations, therefore no aircraft allowed to land or take off until improvement achieved.

Burgauer D. (2000). Airline flight schedules and delays for one specific route from Los Angeles to San Francisco during the month of September, He found that airlines do tend to pad their schedules to give the appearance that flights arrive on time more frequently

than they actually do. Delays have thus become a standard element of air travel. The sample used in their report has a mean delay of almost sixteen minutes. However the median delay, counting early arrivals as negative numbers, is zero minutes. So, just how common are delays? It is common to hear the pilot announce to the passengers that even though the plane was delayed in taking off and possibly leaving the gate, the lost time will be made up in the air for an early arrival. Surely, there is a limit to the amount of time that can be made up in-flight as each plane flies at a specific cruising speed.

Weather has been attributed to be a major factor in most fatal accidents: over 80% of Controlled Flight into Terrain (CFIT) accidents happened when the pilot either continued flying into adverse weather or did not appreciate the effects of the weather conditions (The Safety Link, Vol.1 No 5, Nov/Dec 2001).

MSG satellite view with RGB color combinations is the most useful now-casting and forecasting tool for the operational and research forecasters. With RGB color combinations it becomes much easier to detect severe thunderstorms, microburst, gravity waves, Rain and mountain waves, fog at night and early hours of the morning which was difficult to detect using Meteosat 7.

The summer of 2005 has been named the 'Black Summer' for aviation; this followed the several deadly air crashes for different airlines in which close to 500 people were killed from July 2005. (News24.com, 05 September 2005).

In severe thunderstorms with rain (+TSRA) many accidents occurred due to poor visibility, destruction of electric equipments on aircraft and wet runway. Therefore it is more risk to take flight during +TSRA because when crushing occurs the following are expected; Loss of lives, Damage to aircraft and other properties, Loss of income to airline companies as well as Government through tax.

Among the most hazardous weather for aviation is +TSRA. Weather is regarded amongst others as one of the main cause of aircraft accidents and incidents. Different weather hazards such as Thunderstorms, Microburst from Thunderstorms, Mountain Wave turbulence, Clear air turbulence (CAT), Wind shear, Poor visibility and Fog, etc. have been the cause for numerous aircrafts accidents and incidents. In some instances passengers were injured, some even lost their lives and some aircrafts suffered structural damages. CAT has been the cause of numerous incidents where commercial aircraft passengers have been injured and sometimes died (DeVilliers 1998).

Aircrafts accidents also impact financial on the aviation industry. In its financial year 2004/2005, the South African Civil Aviation Authority (SACAA) spent R6 million on accidents and incidents Investigations (Rudzana Malala, 2005)

In his annual update on air show accidents worldwide, Des Barker (2006) has established that the year 2005 was the worst for more than a decade and that the accident rate worldwide has shown a definite increasing trend during the past five years (World Air news, February 2006, by Des Barker).

Operationally today for manned and unmanned aircraft flights, mission planning and flight route weather information in the U S. Army and across much of the Department of Defense (DoD) are conveyed to the planners and pilots via a standard pilot weather briefing form. This form presents information primarily in text format or with simple map sketches covering broad flying regions and across extended timeframes. It is left to the mission planners and pilots to infer the specific meteorological conditions along the intended route at the time the aircraft arrives at particular route waypoints and enroute stops, and the impact of those conditions on the mission. The degree of acceptable risk can be user-defined and determines the relative weight assigned to weather impacts as opposed to flight time. So a "careful" path will take more time to avoid weather impacts, while a more "risky" path will attempt to save time by cutting through small patches of harsher weather. Distance traveled is a cost that tends to decrease the length of the resulting optimized path. Or each aircraft based on the aircraft's specific weather sensitivity thresholds (Knapp, 2006).

The financial implication of the weather on aircrafts accidents is a persisting problem even in fully developed countries. Weather is a factor in roughly 23% of all aviation accidents and annually costs the US an estimated $3 billion for accident damage and injuries, delays, and unexpected operating costs (Office of the Federal Coordinator for Meteorology, 1999).

CHAPTER TWO

2.0 Data and Methodology

2.1   Data, Data source and data quality control

2.1.1 Data

This research utilizes focus on the three months period from March to May, which are rainy period, and it covers period of 1996-2005.

Two data set are used in the study;
Rainfall data and charts of each day for three months, March, April, and May from 1996 to 2005. These data and charts were used to show and indicate the time at which rain was falling in the station.

Data of rainfall

(a) Daily rainfall data (mm) for the MAM rain season for the five months (February-June) on both stations Julius Nyerere International Airport and Shinyanga Airport for the period of ten years (1996-2005).

(b) Monthly mean rainfall for the MAM rain season for the five months (February-June) on both stations Julius Nyerere International Airport and Shinyanga Airport for the period of ten years (1996-2005).

(c) There are 11(HTSY) and 27(JNIA) rain days (hard days $>/= 50$ mm), no heavy rain days (harder rain day $>/=100$ mm) reported and also no Extreme rain days (hardest rain days $>= 200$ mm) was reported for the whole period of ten years of study (1996-2005).

Flight accident reports are obtained through accidents report files in operation office of Precision Air; also reports of delay, cancellation are obtained in compiled files of mayfly of each day in operation offices of Precision Air.

Data of aircraft operations

(a) Cancellations of flights due to heavy rains have being reported in Shinyanga Airport, 157 cases were reported (March -98, and April -56 May- 3) and no case was reported at Julius Nyerere International Airport. Because during that particular time the aerodrome was closed due to floods and damaged of its runway.

(b) Delays of flights due to heavy rains have reported on both aerodromes, at Julius Nyerere International Airport 9 cases were reported (April-8 and May-1) while in Shinyanga Airport 8 cases were reported (March-6, and April-2).

(c) No Diversions of flights due to heavy rains reported at Shinyanga Airport and at Julius Nyerere International Airport for the whole period of ten years (1996-2005).

(d) Cancellations of flights due to heavy rains have being reported in Shinyanga Airport, 157 cases were reported (March -98, and April -56 May- 3) and no case was reported at Julius Nyerere International Airport. Because during that particular time the aerodrome was closed due to floods and damaged of its runway.

(e) Delays of flights due to heavy rains have reported on both aerodromes, at Julius Nyerere International Airport 9 cases were reported (April-8 and May-1) while in Shinyanga Airport 8 cases were reported (March-6, and April-2).

(f) No Diversions of flights due to heavy rains reported at Shinyanga Airport and at Julius Nyerere International Airport for the whole period of ten years (1996-2005).

(g) No aircraft accidents reported on both airports Julius Nyerere International Airport and Shinyanga Airport which are caused by heavy rains for the period of ten years (1996-2005).

(h) Shinyanga airport doesn't have good facilities and systems for landing and take off during night time, it lack some important facilities such as second power supply and Approach Runway lighter, no ATS Airspace, no ATS communication system, no Radio Navigation Aids.

2.1.2 The data Source;

The data of weather parameter (Rain) are obtained from TMA offices at Tanzania Meteorological Agency Head Quarter, Julius Nyerere International Airport (JNIA) previously called Dar es salaam International Airport (DIA) and Shinyanga airport.

Precision Air is the private airline company has been operating in Tanzania for several years (more than ten years). This airline company takes about 70% of flights operates in Tanzania every day, therefore its performance is high compared to any other local companies such as Air Tanzania Cooperation (ATC), TanzanAIR, and Community Air etc.

It is better to use data from Precision Air because;
. It has different types of aircrafts
. It travels at most routes in Tanzania
. It has daily flights at most routes in Tanzania
Therefore the required data of delays, Cancellations of flights were obtained at optimum number.

2.1.3 Data Quality control

(i) For homogeneity test, a single mass curve method was applied to test the rainfall data, starting the most current going backwards from both stations Julius Nyerere International Airport and Shinyanga Airport as shown below;

1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
792.3	1515.3	2309	2992.1	3694.1	4377.6	5003.2	5663.4	6307.3	6851.2

Table 2; JNIA MAM Cumulative rainfall.
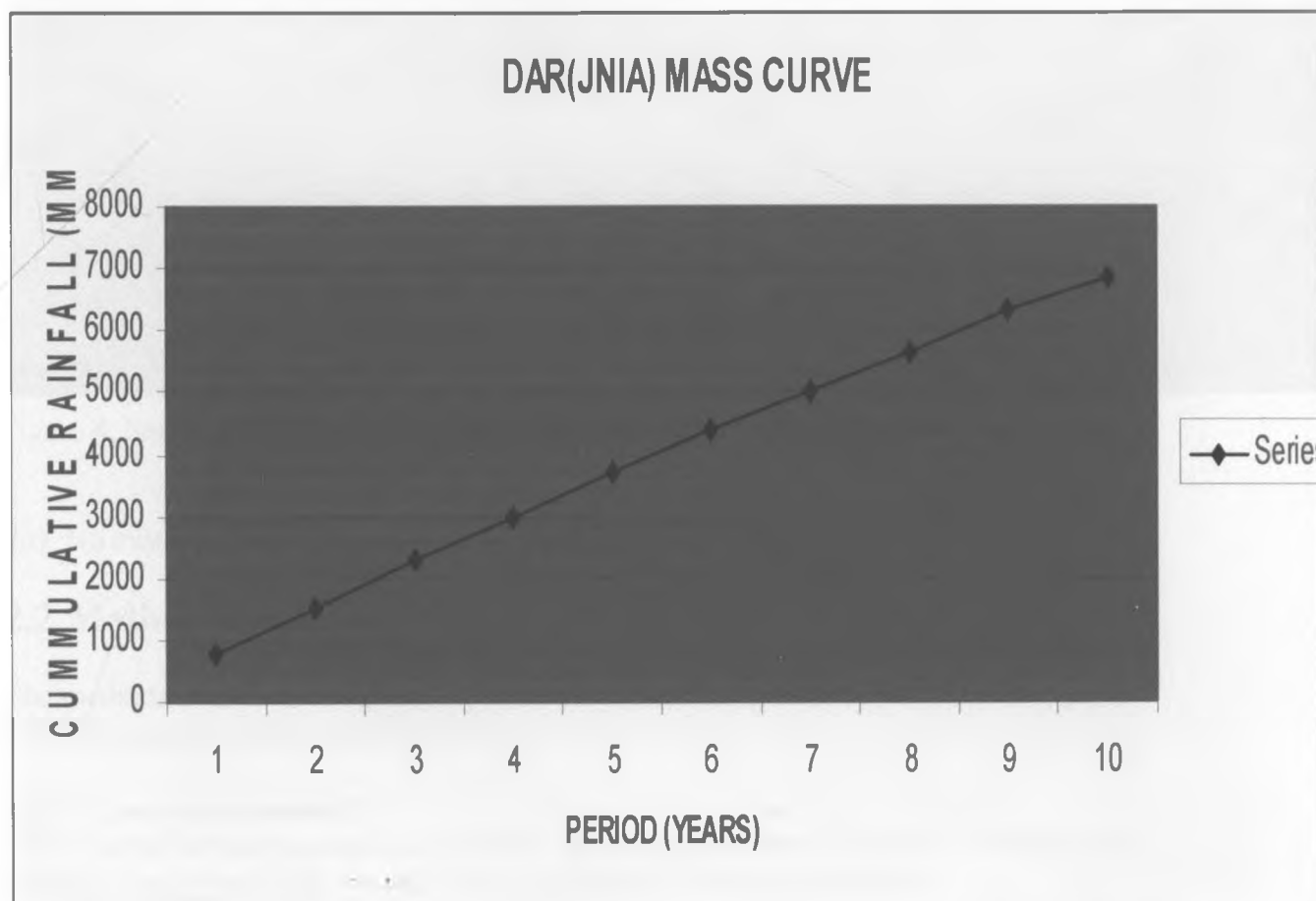
Figure 3; JNIA mass curve.

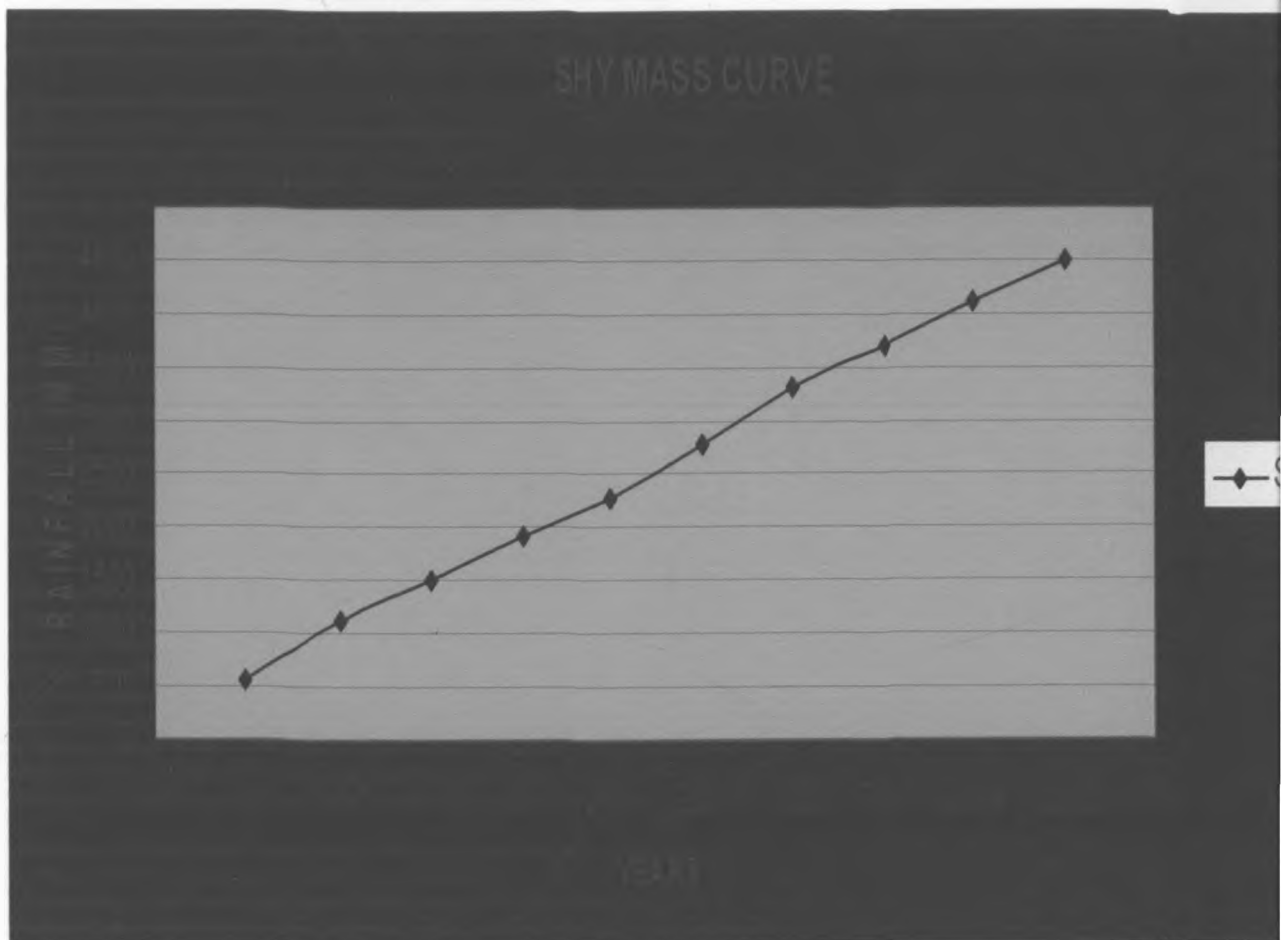| 1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
574.8	1121.6	1521.6	1919.6	2279	2769.8	3318.1	3709.4	4115.9	4489.9

Table 3; Shinyanga airport MAM Cumulative rainfall.

Figure 4; Shinyanga airport mass curve.

(ii) No missing data on both data sets, therefore no statistical method was employed.

2.2 Methodology

The methods that have being employed in the present study include; time series analysis graphical analysis and correlation analysis,

2.2.1 Time series analysis

The time series analyses are used to study the temporal pattern of rainfall. Therefore the season, monthly and daily rainfalls were subjected to time series analysis.

2.2.2 Graphical method

The Graphical method was used to study the relationship between rainfall and events such as;

- Rainfall period(time) versus aircraft delaying
- Rainfall period(time) versus aircraft cancellation

2.2.3 Correlation Analysis

It was used to quantify the relationships between long rain season (March, April and May-MAM) and aircrafts operations for the whole period of 10 years (1996-2005).
If it was rain day, what happened to aircrafts operations at JNIA and Shinyanga airport

CHAPTER THREE

3.0 RESULTS AND DISCUSSIONS

3.1 Results from Time series Analysis;

3.1.1 Season rainfall (MAM) Analysis

3.1.1.1 JNIA season rain (MAM) Analysis

1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	
555.5	567.9	640.1	624.4	439.6	598.2	796.7	266.9	451.4	502.2	**5442.9**

Table 4; JNIA MAM- total rainfall (mm).
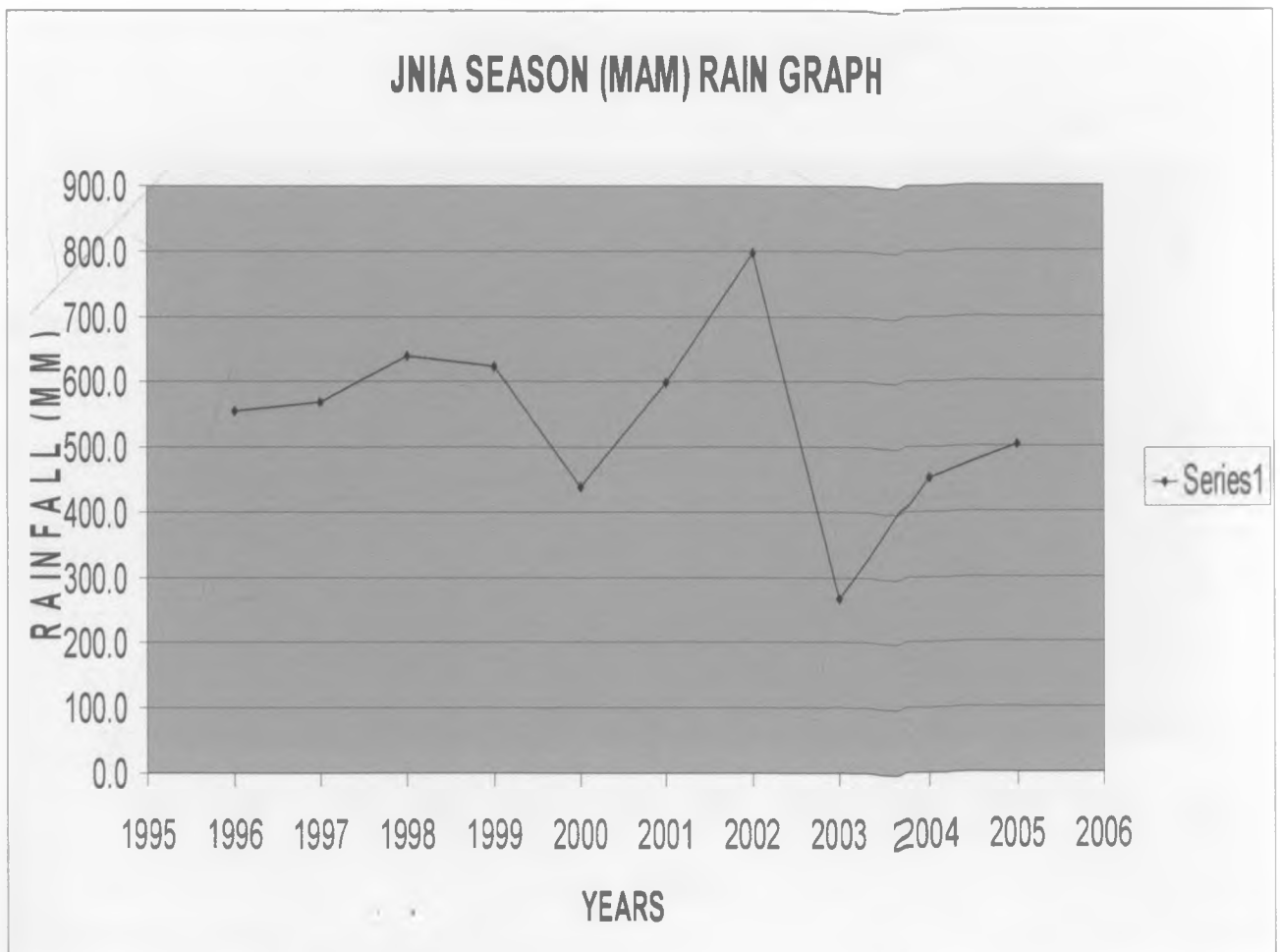
Figure 5; JNIA MAM total rainfall graph.

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The results from above JNIA Table 4 and Figure 5 show that;

(i) The year 2002 had the wettest season (796.7 mm) among the ten years of study (1996 -2005).

(ii) The year 2003 had the driest season (266.9 mm) among the ten years of study (1996-2005).

3.1.1.2 HTSY season rain (MAM) Analysis

1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
353.3	386.7	270.8	346.2	261.6	281.6	447.5	278.1	269.0	307.4

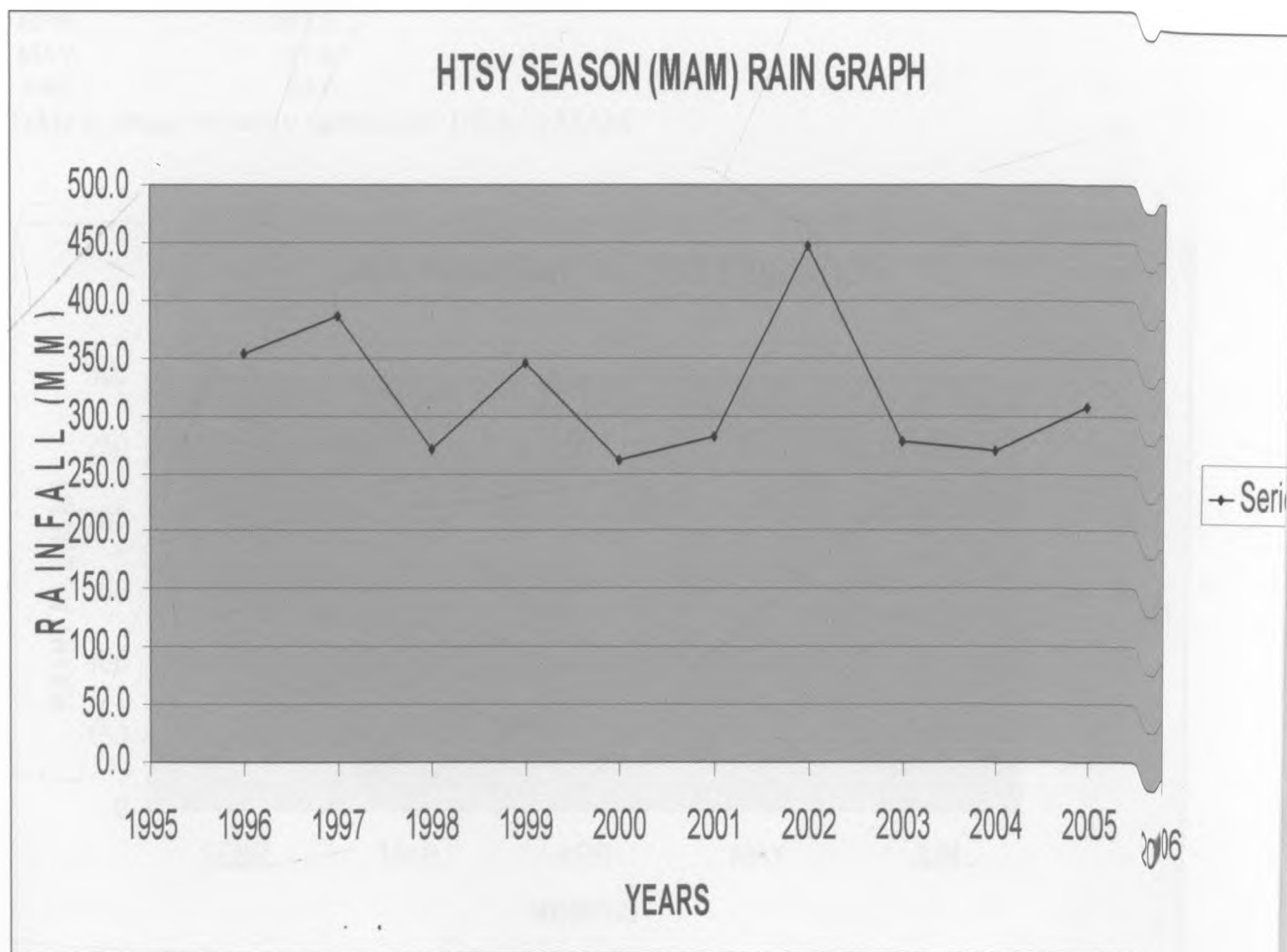Table 5: Shinyanga airport MAM- total rainfall (mm)

Figure 6; Shinyanga airport MAM total rainfall graph.

The results from HTSY Table 5 and Figure 6 above show that;

(i)   The year 2002 is the wettest year (447.5 mm) for the period of ten years (1996-2005).

(ii)   While 2000 year indicated as the driest year (261.6 mm) over the ten years of study.

3.1.2 Monthly rainfall data Analysis

3.1.2.1 JNIA Monthly rainfall data Analysis

MONTH	MEAN MONTHLY RAINFALL(MM)
FEBR	82.8
MAR	173.6
APR	248.9
MAY	121.8
JUN	58.0

Table 6; Mean monthly rainfall for JNIA in MAM
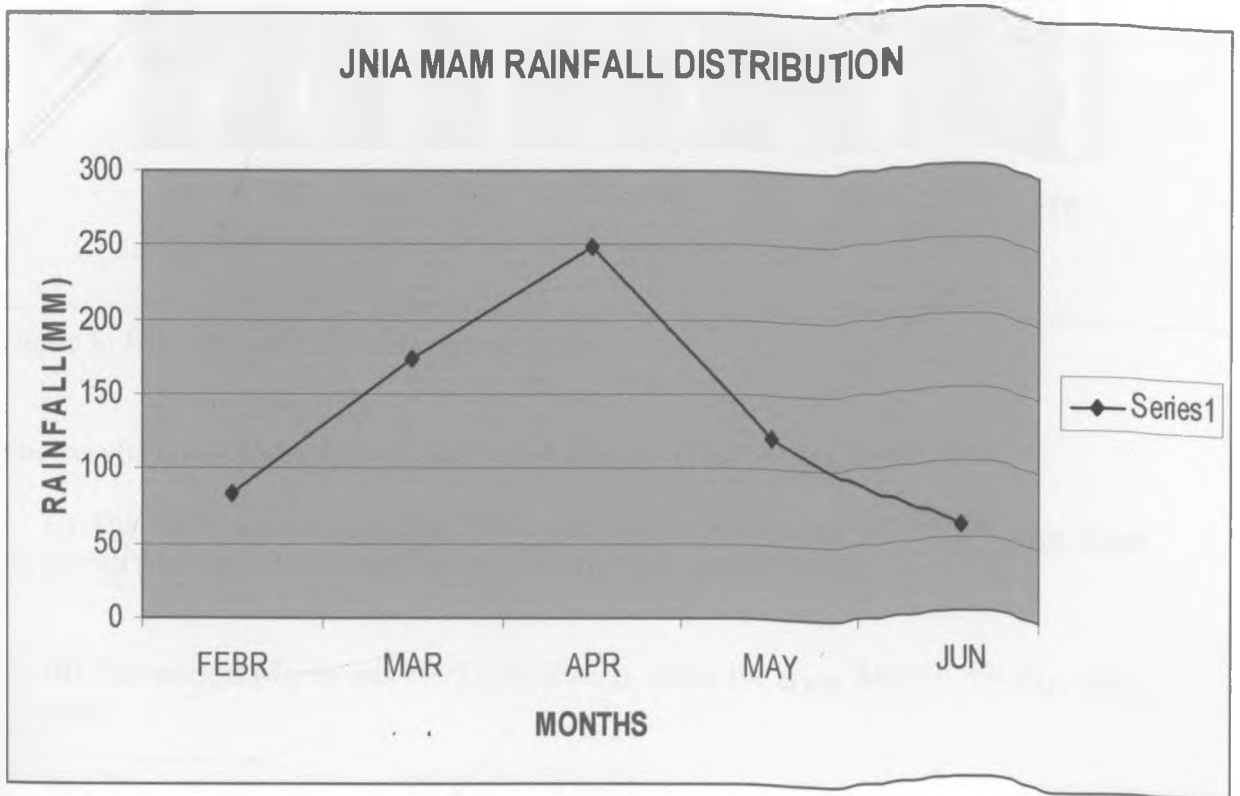
Figure 7; JNIA monthly rainfall distribution in MAM.

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	TOTAL
MARCH	233.1	282.8	155.2	222.1	169.9	139.0	197.2	122.4	134.5	80.2	1736.4
APRIL	223.2	167.7	319.9	258.9	222.1	296.7	569.4	13.7	297.6	119.4	2488.6
MAY	99.2	117.4	165.0	143.4	47.6	162.5	30.1	130.8	19.3	302.6	1217.9

Table 7; JNIA March, April and May rainfall (mm)
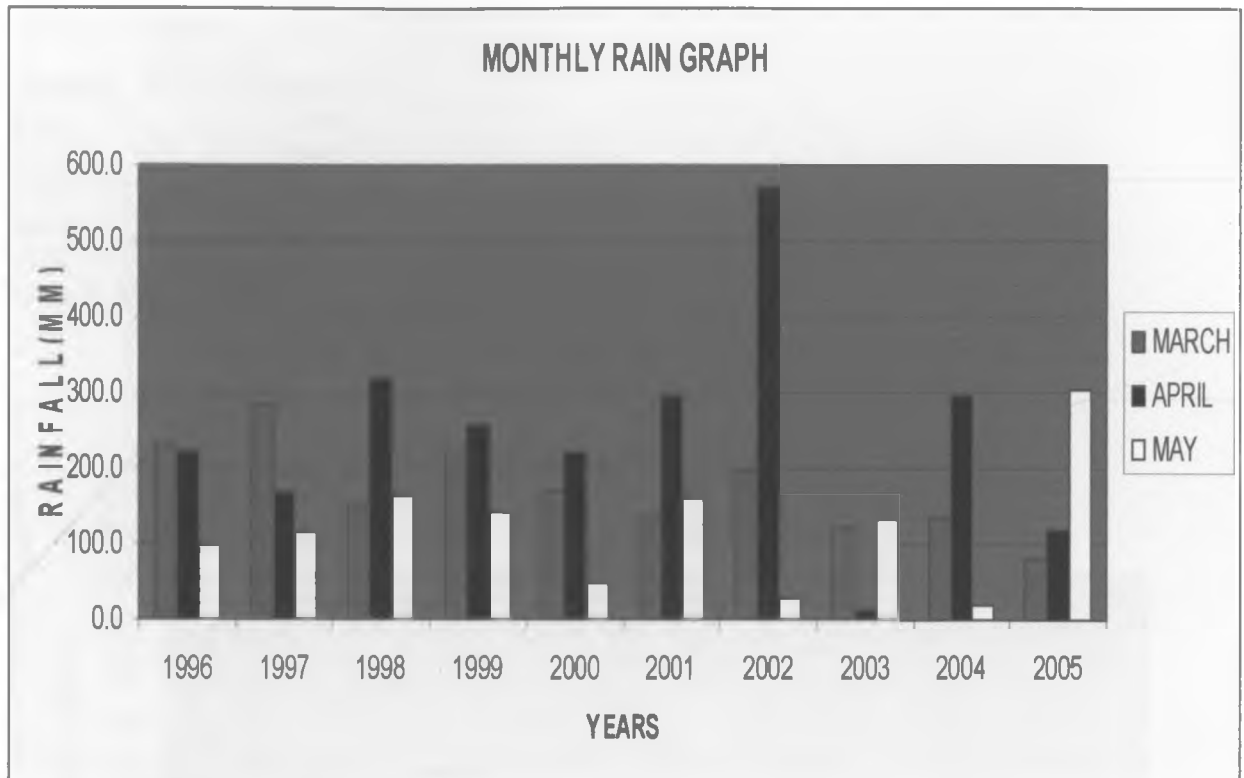
Figure 8; JNIA Monthly (MAM) rainfall graph.

The results from JNIA Tables (6&7) and Figures (7&8) above show that;

(i) The mean wettest month at JNIA was April (248.9 mm), while the mean driest month was May (121.8 mm) for the period of ten years (1996-2005).

(ii) The wettest March was 1997 (282.8 mm), while the driest March was 2005 (80.2 mm).

(iii) The wettest April was 2002 (569.4 mm), while the driest April was 2003 (13.7 mm).

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(iv)The wettest May was 2005 (302.6 mm), while the driest May was 2004 (19.3 mm).

(v) The highest rainfall month was April (2002, 569.4 mm), while the lowest rainfall month was April (2003, 13.7 mm).

3.1.2.2 HTSY Monthly rainfall data Analysis

MONTH	MEAN MONTHLY RAINFALL(MM)
FEB	127
MAR	179.1
APR	104.4
MAY	36.7
JUN	1.0

Table 8; Mean monthly rainfall for HTSY in MAM
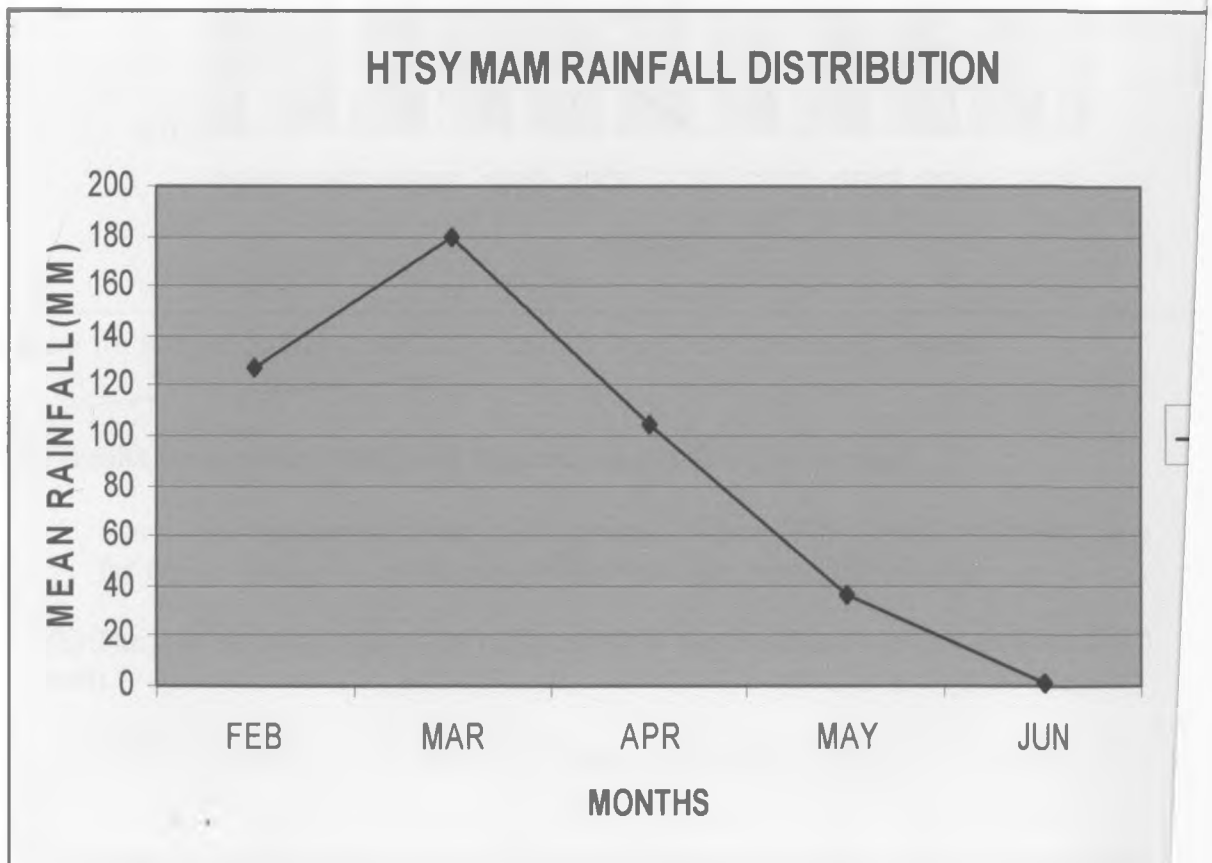
Figure 9: Shinyanga airport monthly rainfall distribution in MAM.

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	TO
AR	266.8	139.4	112.5	289.7	183.1	171.5	224.9	80.0	175.7	147.5	1
PR	49.2	184.7	102.8	54.1	78.5	92.0	142.4	159.4	93.3	87.8	1
AY	37.3	62.6	55.5	2.4	0.0	18.1	80.2	38.7	0.0	72.1	

Table 9: Shinyanga airport March, April and May rainfall (mm)
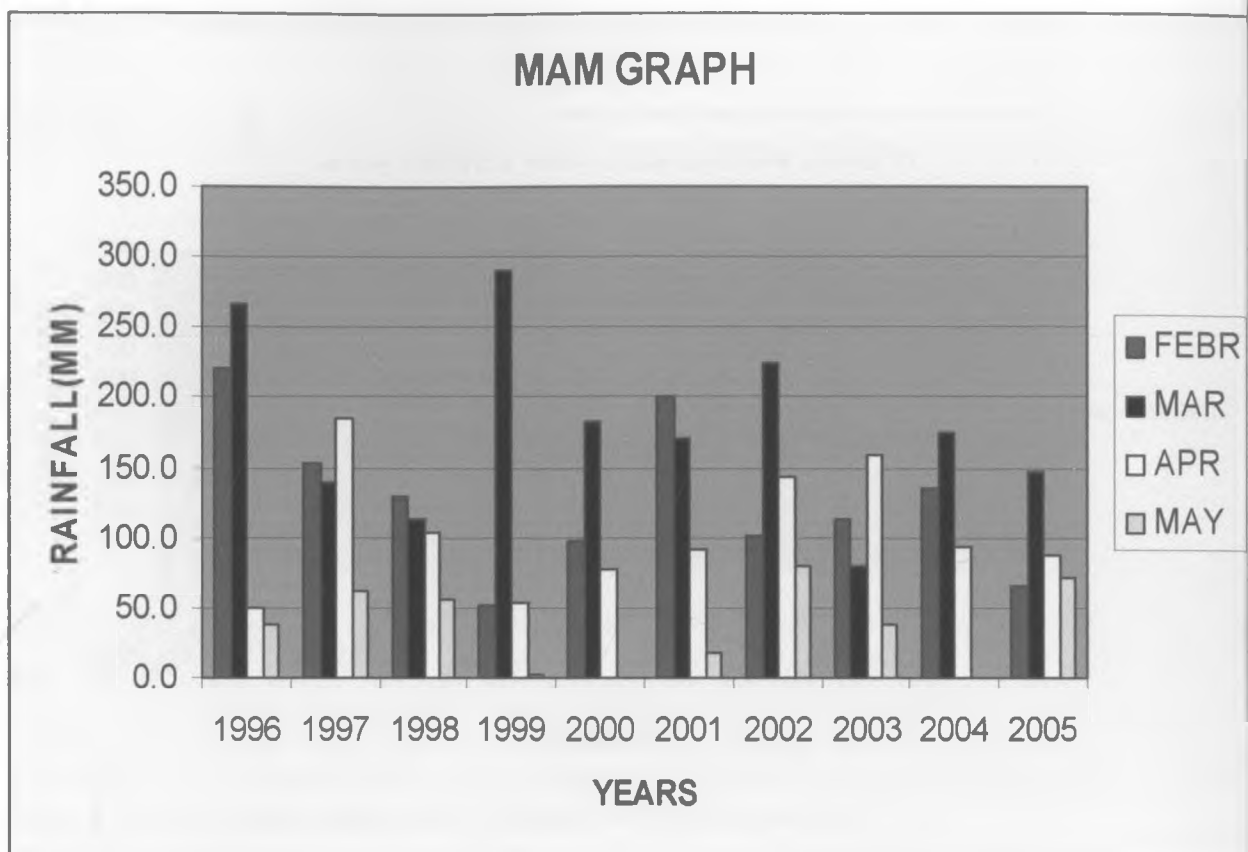
Figure 10: Shinyanga airport February, March, April and May rainfall graph

The results from tables (8&9) and Figures (9&10) above show that;

(i) March was the wettest month at Shinyanga Airport (179.1 mm), while May was the driest month (36.7 mm) over the period of ten years (1996-2005).

(ii) The wettest March was 1999 (289.7 mm), while the driest March was 2003 (80.0 mm).

(iii) The wettest April was 1997 (184.7 mm), while the driest April was 1996 (49.2 mm).

(iv)The wettest May was 2002 (80.2 mm), while the driest May was 2000 and 2004 (0.0 mm).

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(v) The highest rainfall month was March (1999, 289.7 mm), while the lowest rainfall month was May (2000 and 2004, 0.0 mm).

3.1.3 Daily rainfall data analysis

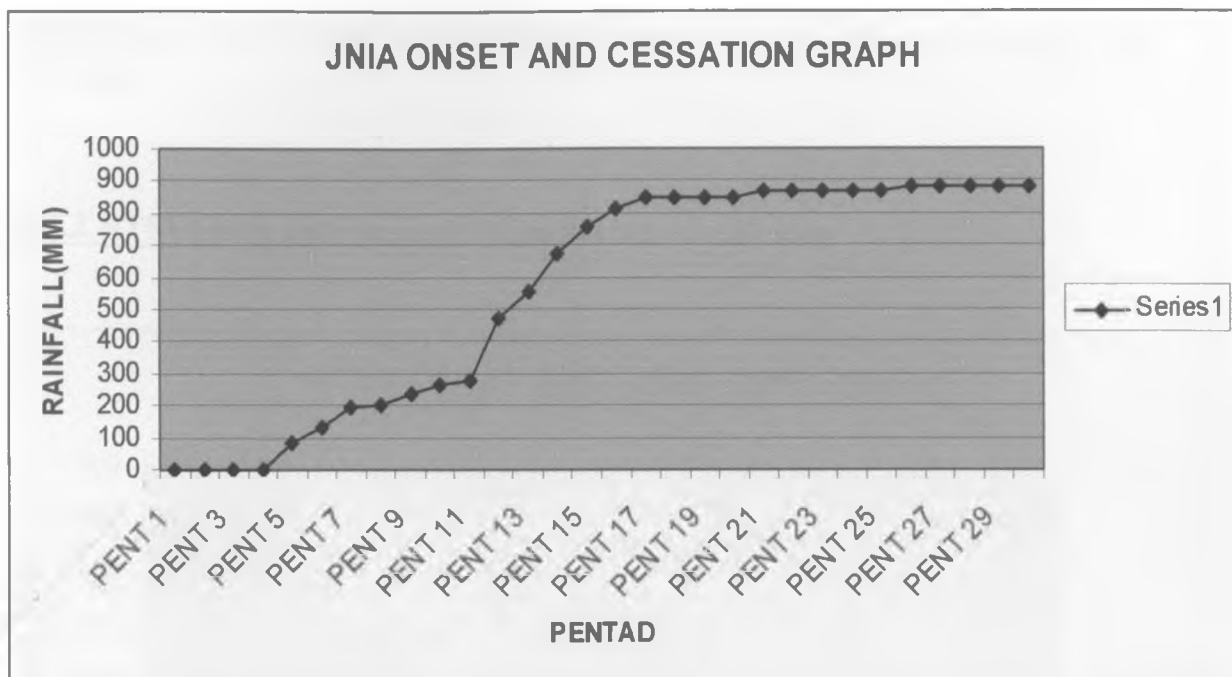### 3.1.3.1 JNIA Onset and Cessation from Pentad rainfall data

Figure 11; JNIA pentads graph show the mean onset and cessation.

The pentad of onset /cessation is the time when there is a sudden increase/decrease in rainfall values (Ogallo, *1994*).

The results from figure 11 above of JNIA during MAM rain season have showed that;

(i) The mean onset normally starts in the third week of March (Pentad 11).

(ii) April have much rains compared to March and May during MAM season.

(iii) The mean cessation of MAM rain season at JNIA is in the fourth week of May (Pentad 25).

Analysis from daily rain charts of JNIA for the period of ten years (1996-2005) during MAM rain season shows that;

(i) Between 12.00 noon and 04.00 pm, it seems to be the most dominant time for rains at JNIA especially during March and April.

(ii) Between 03.00am and 10.00am, it is the time at which more rains dominates at the end of April and mid of May.

(iii) Charts have showed that, there are much dry spells between 09.00pm and 02.00am.

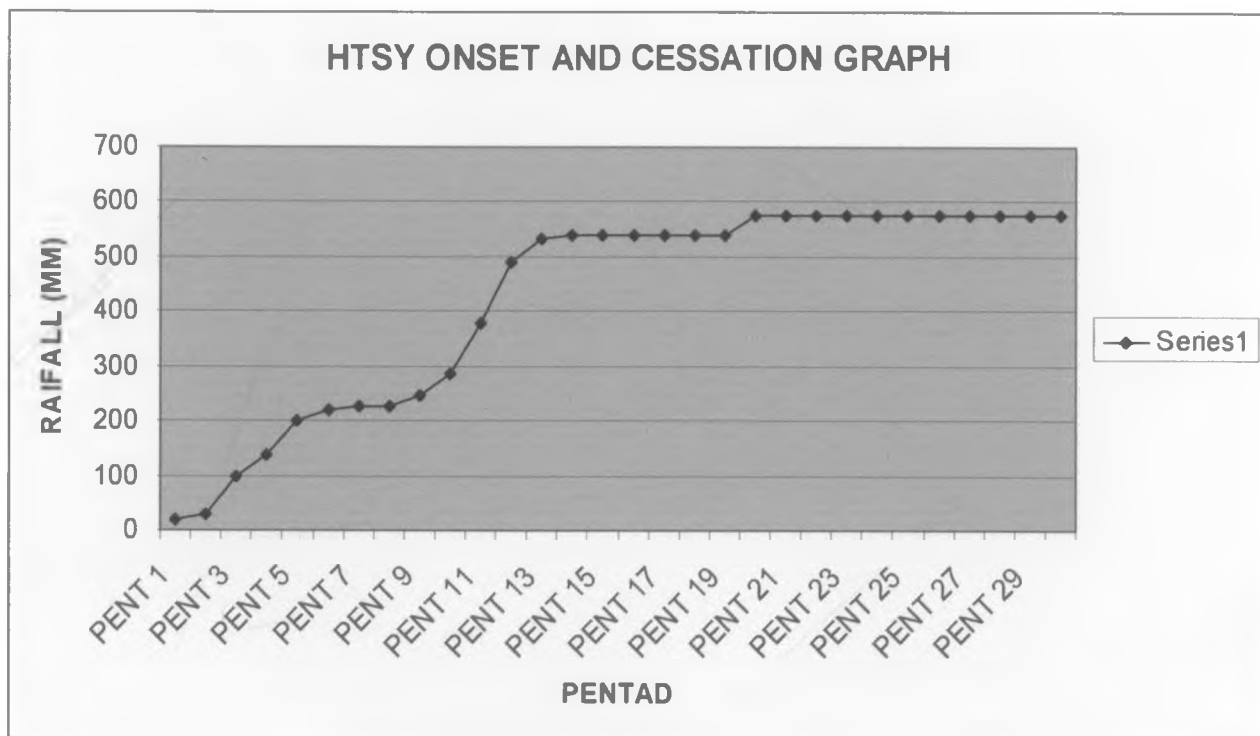### 3.1.3.2 HTSY Onset and Cessation from Pentad rainfall data

Figure 12; HTSY pentads graph show the mean onset and cessation.

The results from figure 12 above of HTSY during MAM rain season have showed that;

(a) The mean onset normally starts at the third week of March (Pentad 11).

(b) March have much rains compared to April and May.

(c) May is the month of low amount of rainfall in MAM rain season.

(d) The mean cessation is on second week of May (Pentad 21).

Analysis from daily rain charts of HTSY for the period of ten years (1996-2005) during MAM rain season shows that;

(a) Between 06.00 pm and 11.00 pm is the time at which most rain reported (wet spells) during March and April.

(b) Between 00.00 mid night and 05.00 am is the time (active time) at which most rains reported at the third week of February and second week of May.

(c) Between 06.00 am and 00.00 noon is the most dry spells period.

3.2 Results from Graphical method (histogram) Analysis;

3.2.1 JNIA Aircraft operations data Analysis

SERIAL NUMBER	DATE	AMMOUNT OF RAINFALL (MM)- RAINDAY (>50MM)
1	March 18th 1996	78.1
2	March 25th 1996	60.9
3	March 26th 1997	69.0
4	March 23rd 1998	50.1
5	April 28th 1998	67.1
6	May 02nd 1998	69.9
7	May 03rd 1998	69.5
8	March 16th 1999	56.2
9	March 25th 1999	54.4
10	May 13th 1999	57.3
11	March 31st 2000	61.6
12	March 26th 2001	65.3
13	April 02nd 2001	58.1
14	April 20th 2001	59.3
15	May 20th 2001	62.5
16	March 10th 2002	50.8
17	April 01st 2002	75.9
18	April 04th 2002	50.6
19	April 11th 2002	64.4
20	April 03rd 2004	56.2
21	April 04th 2004	66.1
22	April 12th 2004	64.0
23	May 20th 2005	95.7

Table 10; Show the number and date of rain days at JNIA, the red number on the table indicate also the days of delays.

Note; It reported as rain day (hard day) if the total amount of rainfall measured within 24 hours beginning at 09.00 am (0600 GMT) of the first day up to the same time in the next day is equal or exceed 50 mm, and heavy rain day (harder day) reported if it is greater or equal to 100 mm, while Extreme rain day (hardest day) reported if it is greater or equal to 200 mm. (Lu Han Cheng and Yang Xinvier, 1996).

Therefore no heavy rain days or extreme rain days were reported at JNIA in all ten years
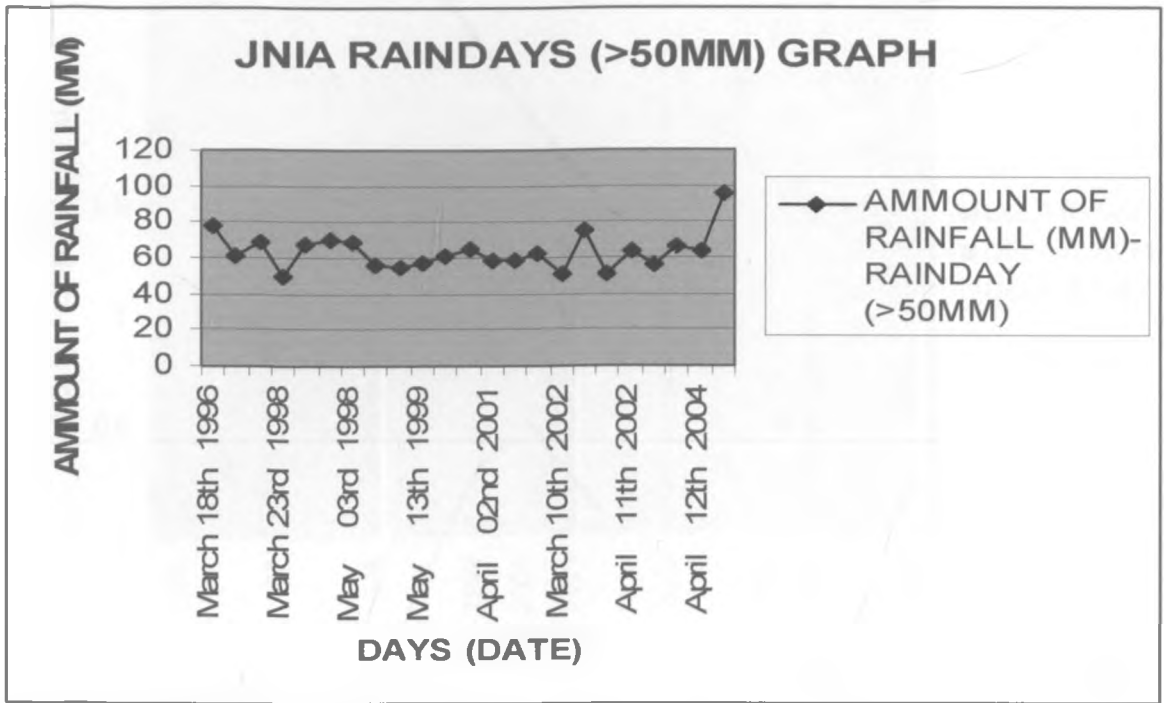of this study

Figure 13; Show the rain days at JNIA

SERIAL NUMBER	DATE	NO. OF DELAY (>1HOUR)
1	March 18th 1996	1
2	March 26th 1997	1
3	April 28th 1998	1
4	May 02nd 1998	1
5	April 02nd 2001	1
6	May 20th 2001	1
7	April 01st 2002	1
8	April 11th 2002	1
9	April 12th 2004	1
10	May 20th 2005	1

Table 11; Show the number and date of Delays at JNIA
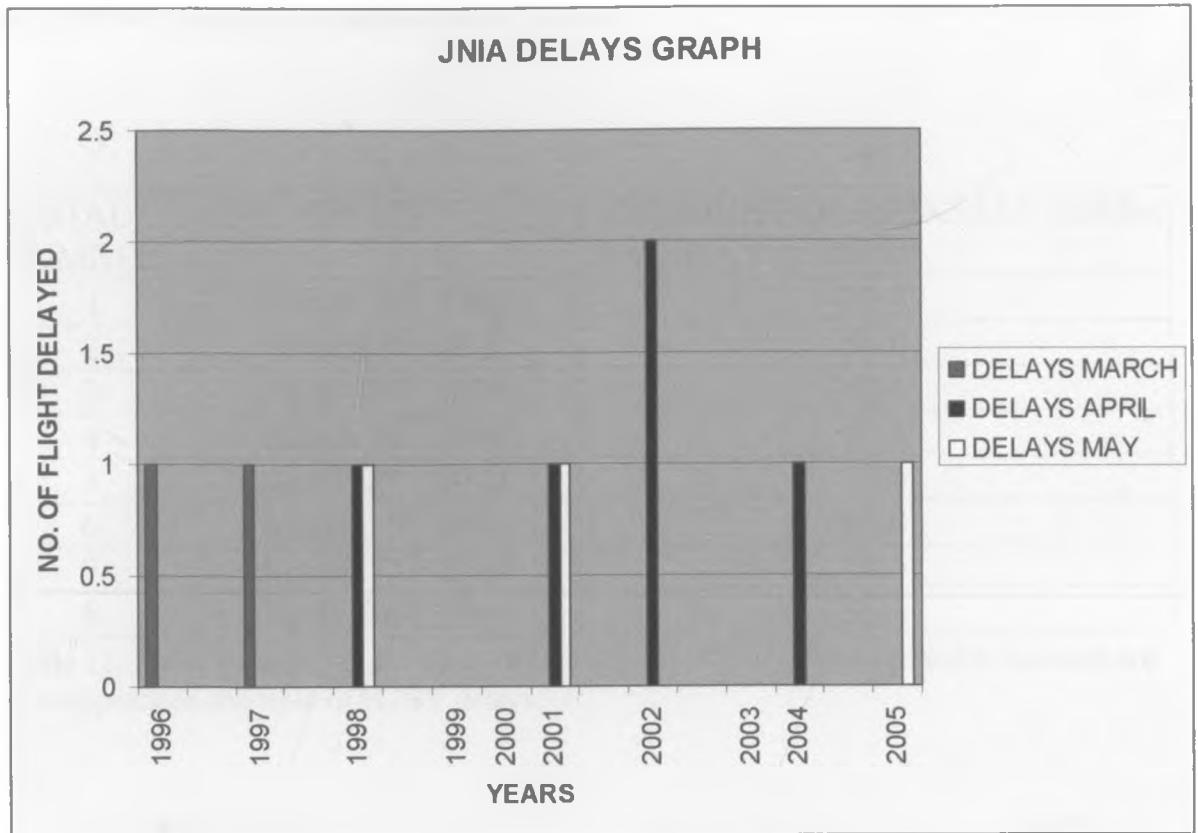
Figure 14; Show the number of flights delayed at JNIA.

Note; Delay(s) of flight reported if an aircraft failed to take off for some hours (>1 hour) from its required time (Departure Time), the operations have stopped for sometime until the improvement of weather parameters (e.g. vertical and horizontal visibility) within and around that particular aerodrome.

From Julius Nyerere International airport histograms above (Fig.13 & 14), it showed that;

(a)   Most delays occurred in April (5), it followed by May (3) and then March (2) for the ten years (1996-2005) of this study.

(b)   No flight delay was reported in 1999, 2000 and 2003, but highest numbers of delays (2) were reported in 1998, 2001 and 2002.

(c)   April 2002 was only month at which highest (2) delays were reported in this study.

The result from the tables (10&11), it shows that;

At JNIA there are correlations between days of delays and rain days, since there are 23 rain days and 10 flights delays where by those 10 days of delays occurred within those 23 rain days.

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3.2.2 HTSY Aircraft operations data Analysis

SERIAL NUMBER	DATE	AMMOUNT OF RAINFALL (MM)- RAINDAY (>50MM)
1	March 29th 1997	81.4
2	March 9th 1998	54.0
3	April 2nd 1998	62.6
4	March 14th 1999	62.4
5	April 2nd 2003	93.6
6	March 9th 2004	60.0
7	March 11th 2004	54.6
8	April 08th 2005	56.8

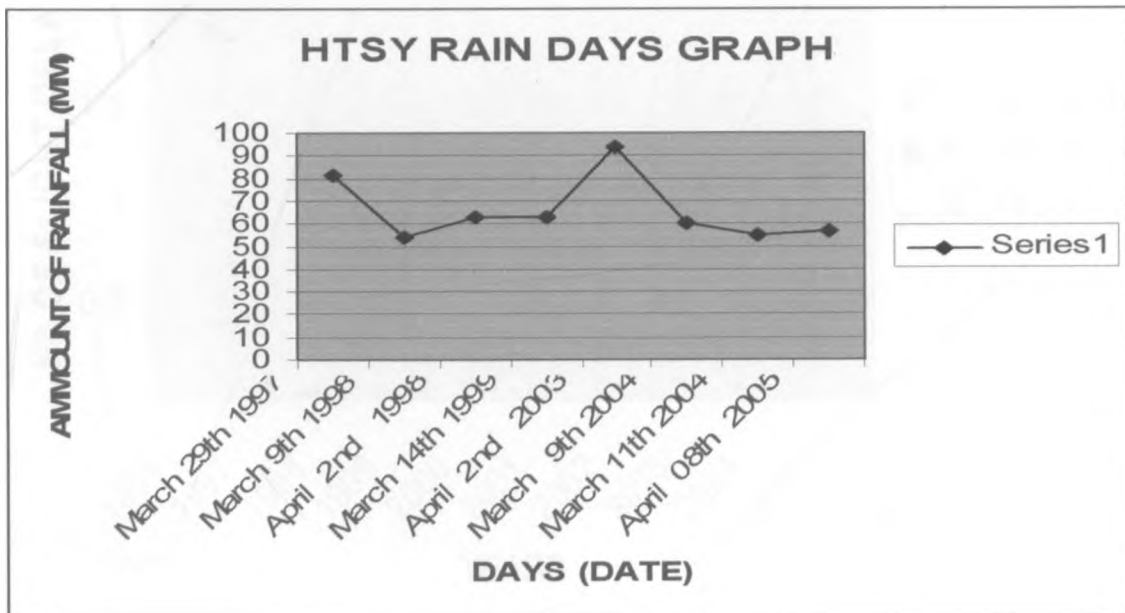Table 12; Show the number and dates of rain days at HTSY, where red color numbers are also appears on the table of HTSY delays.

Figure 15; Show the rain days at HTSY.

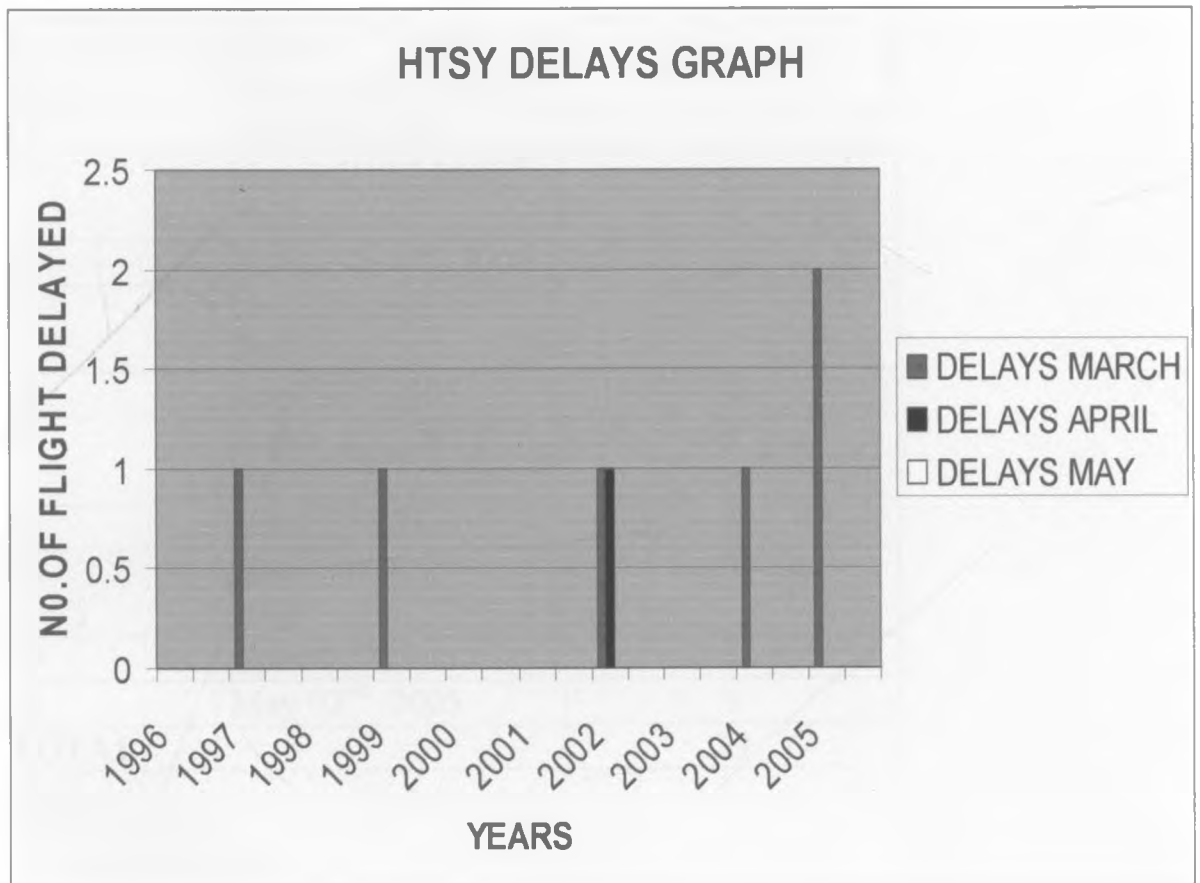| SERIAL NUMBER	DATE	NO. OF DELAY (>1HOUR)
1	March 29th 1997	1
2	March 9th 1998	1
3	March 14th 1999	1
4	April 2nd 2003	1
5	March 9th 2004	1
6	March 11th 2004	1
7	April 08th 2005	1

Table 13; Show the number and dates of delays at HTSY

Figure 14; Show the number of flights delayed at HTSY.

Table 14; Show the number and dates of Cancellations at HTSY

| SERIAL NUMBER	DATE	NO. OF CANCELLATION
1	March 27th &29th 1996	3
2	April 04th 1996	1
3	March15,17,29&31 1997	4
4	April 03rd 1997	1
5	March 7,10 &28 1998	3
6	April 05 1998	1
7	March 06,13,15&26 1999	4
8	April 02nd 1999	1
9	March 12th 2000	1
10	March 06&11 2001	2
11	April 09th 2001	1
12	March 5,12,24&28th 2002	4
13	April 21&30th 2002	2
14	March24,26&31st 2003	3
15	April 22nd 2003	1
16	March 10,12&14th 2004	3
17	April 05th 2004	1
18	March 07&20th 2005	2
19	April 09th 2005	1
20	May 02nd 2005	1
TOTAL		39

HTSY CANCELLATIONS GRAPH
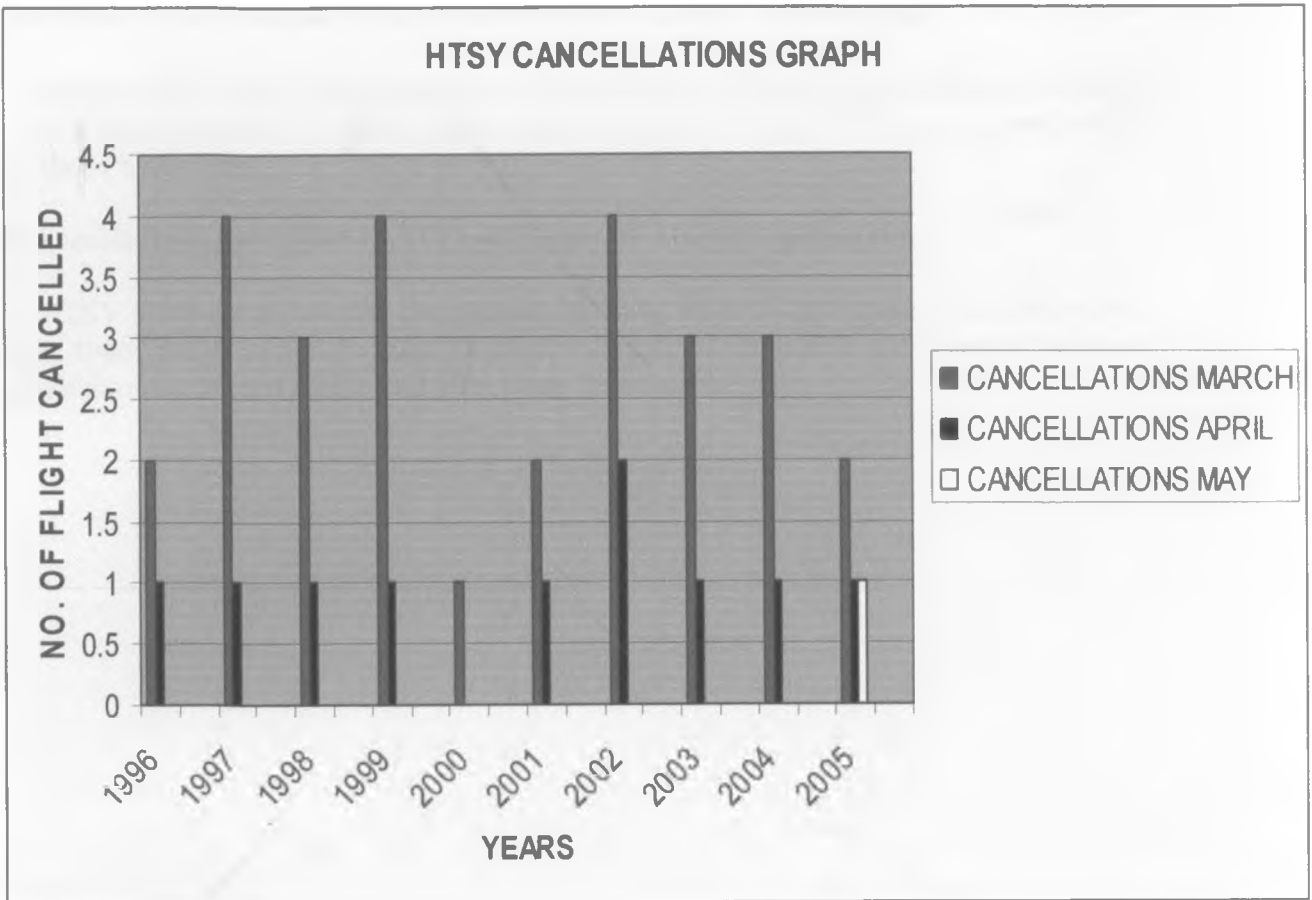
Figure 15; Show the number of flights Cancelled at HTSY.

Note; Cancellation(s) of flight reported if an aircraft failed to take off from one airport to another.(E.g. from JNIA to HTSY). The most operations of aircrafts in many aerodromes in Tanzania are affected by rain (rain days) especially for those aerodromes which having an unpaved runway.

From Shinyanga airport histograms above (Fig. 14&15), it showed that;

(a) Most cancellations occurred on March (28), it followed by April (10) and then May (1).

(b) Most delays occurred in March (6), it followed by April (1) and no delayed was reported in May.

© The highest number of delays was reported in May 2005(2), but no delayed was reported in 1996, 1998, 2000, 2001 and 2003.

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The result from the tables 12&13 and Figure 14 above, it shows that;

Also at HTSY there are correlations between days of delays and rain days, since there are 8 rain days and 7 flights delays where by those 7 days of delays occurred within those 8 rain days.

The result from the tables 12&14 and Figure 15 above, it shows that;

At HTSY there are also some correlations between days of cancellations and rain days, since there are 8 rain days and 39 flights cancellations where by those 39 days of cancellations occurred within and after those 8 rain days

CHAPTER FOUR

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

(i) Heavy rains cause some cancellations of flights particularly at Shinyanga airport.

(ii)The aerodrome at Shinyanga airport was closed due to Aviation Safety Regulations which does not allow the take off and landing of aircrafts in the floods runways.

(iii) Delays observed in both airports, Julius Nyerere International Airport and Shinyanga Airport.

(iv) April is the wettest month at Julius Nyerere International Airport, while March is the wettest month at Shinyanga Airport.

(v) Onset of MAM rain season at Shinyanga airport and Julius Nyerere International Airport are on third week of March.

(vi) Cessation of MAM rain season is on second week of May at Shinyanga airport while at Julius Nyerere International Airport is on fourth week of May.

4.2 RECOMMENDATIONS

(i) Shinyanga airport should be Constructed to be either Category A or B in order remove the problem of cancellations of flights which have caused by rains.

(ii) Flights planning should use daily weather forecasts and Terminal Aerodromes Forecasts (TAF) in order to minimize the problems of flight delays in different aerodromes.

(iii)The suggestion for further study;   It is important to know why at Shinyanga the mean onset is on third week of March and data says the highest rainfall month is March as well.

ACKNOWLEDGEMENTS;

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