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Statistical Study of Rainfall Pattern in Gombe Metropolis, and its Implication on the Attainment of Sustainable Development Goals (SDGs)

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Abstract- This paper examines the statistical rainfall pattern in Gombe metropolis and its implications on the attainment of sustainable development goals (SDGs). Adopting statistical tools commonly used to describe climate such as mean, standard deviation, coefficient of variation, standardized coefficient of skewness and kurtosis, linear trends and Standardized Anomaly Index were used to examine the recent trends and pattern. The trend of rainfall in the study area in the last three decades shows that inter-annual fluctuation responsible for dryness and recent wetness in the study area. The results of the standardized anomaly index, 3- year running moving average and the linear trend revealed that rainfall total is increasing in the study area; the increase in the annual total is predominantly as a result of the increase of August and October, which are critical months for agricultural production in the area. The research recommend that there is need for total commitment and integrated approach towards attainment of SDGs and monitoring rainfall trend as its plays a significant role in the interface of economy, means of livelihood, poverty index and attainment of food security for the benefit of the present and future generation.

Index Terms- Gombe Metropolis, Implication on the attainment, Rainfall Pattern, Statistical Study, Sustainable Development Goals

I. Introduction

Globally, it has been observed that changes are occurring in the amount, intensity, frequencies and type of rainfall. In Africa, rainfall exhibits high spatial and temporal variability. Mean annual rainfall ranges from as low as 10 mm in the innermost core of the Sahara region to more than 2000 mm in parts of the equatorial region. The rainfall gradient is largest along the southern margins of the Sahara (i.e. the Sahel) where the mean annual rainfall varies by more than 1000mm over about 750km. As a result of the tight rainfall gradient, a slight change in the position of the ITCZ can have large consequences for rainfall in the Sahel region; thus, this region is a sensitive indicator of climate change in Africa. The coefficients of rainfall variability in Africa is above 200% in the deserts, about 40% in most semiarid regions and between 5% and 20% in the wettest areas (Watson, Zinyowera, Moss, & Dokken, 2001).

Several studies in sub-sahara Africa used time series data from different parts to analyze trend of rainfall. Findings from the analysis of the studies showed that inter-annual rainfall variability was large over most Africa, and in some regions multi-decadal variability was also substantial. In West Africa, a decline in annual rainfall has been observed since the end of 1960s, with decrease of 20% to 40% noted between 1931-1960 and 1968-1990 (Mithcell and Jones, 2005; Nicholson 2013;). In the tropical rainforest zone, decline in the mean annual precipitation of around 4% in west Africa, 3% in north Congo and 2% in southern Congo for the period 1960 to 1998 was noted (Malhi & Wright, 2004). A 10% increase in annual rainfall along the Guinea coast during the long-term trend was noted. However, increased inter-annual variability was observed in the post-1970 period, with higher rainfall anomalies and more intense and wide spread droughts reported (Fauchereau et al., 2003).

In Nigeria, a downward shifts of 8.8% rainfall from the long-term mean of 1968 to 2008 was recorded in the north-Western Nigeria (Ekpoh and Nsa 2011), also a consistent decrease in annual rainfall of 8mm $year^{-1}$ in the north-Eastern part has been reported (Hess et al., 1995), also a significant positive increase of 2.16mm in rainfall was recorded in the entire northern Nigeria within the period of 1970-2012 (Abdullah et at., 2015). Also a positive increase of annual rainfall of 17.1mm was observed in North-Eastern Nigeria for the period of 1984-2013 (Yahaya, 2015).

Rainfall is one of the key climatic resources of Gombe, hence the need to foster and examine its implications toward achieving the (SDGS). As of 2014 about 795 million people are estimated to be chronically undernourished. And still one person in every four still goes hungry in Africa. About 6 million still die before their fifth birthday, 16,000 children die each day in developing regions. Water scarcity affects more than 40% of people globally and said to be on alarming increase due to consequences of climate- change. Greenhouse gas emission continous to rise, and are now more than 50% higher than their 1990 level.

Today we are seeing unprecedented land degradation, and loss of arable land, drought and desertification is also on the rise each year, amounting to the loss of 12 million hectares globally. The goals will only be achieved through strong commitment partnership and cooperation, by coordinating policies to help developing nation managed their debt; and more investment opportunities. http://www.un.org/sustainabledevelopment-goals

It is against these highlight for the post- 2015 (MDGs) goals and recently flood of 2004, 2007 and 2014 that rendered thousands of people homeless and their means of livelihood destroyed in the study area have shown how important to analyzed the trend in rainfall towards achieving the recently 2016 sustainable development goals (SDGs).

II. Study Area

Gombe town (Jewel in the Savannah) is located in the Sudan savannah region of the country at the north-east of river Benue and east of Yankari Game Reserve bordering with Adamawa, Bauchi, Borno and Yobe states covering the total area of 52sq/km with a population of 268.000 at 2006 census. The approximate altitude of Gombe ranges from 400-500m above mean sea level. Topography is mainly moutaineous, undulating and hilly to the southeast and open plains in the central north east,west and northwest.(Bello, 2009).

Gombe town is located between latitudes $10^0 18^1 25.0^{11}$N and longitude $11^0 10^1 29.6^{11}$E (Figure 1). It shares common boundary with Akko LGA in the South and West; Yamaltu-Deba to the East and Kwami to the North. It is the capital of Gombe State and occupies an area of about $45km^2$ (Ministry of Land and Survey, Gombe, 2008). Gombe town is well linked by road to other regional centres like Biu / Maiduguri, Potiskum / Damaturu, Bauchi /Jos and Yola /Jalingo. A single gauge railway line on the Bauchi – Maiduguri route also links the town, in addition to an international airport. (Mbaya, et.al 2012)

The climate of Gombe is characterized by a dry season of six months, alternating with a six months rainy season. As in other parts of the Nigerian Savanna this precipitation distribution is mainly triggered by a seasonal shift of the Inter -Tropical Convergence Zone (ITCZ). For the years 1984 to 2013, the mean annual precipitation is 969.7mm the arrival of the rainy season starts around April or May; however, heavy rainfall may put in an appearance until June or even July. By October, the amounts of rainfall begin to decrease. (Yahaya, 2015). The mean annual temperature is about 32^0C weather tends to be very hot between November and March with average high temperature can reach 32^0C or more. The hamattan wind from around Febuary makes the temperature cooler, although with dusty conditions, where as relative humidity has some pattern being 90% in August and dropping to less than 10% during the hamattan period (Balzerek et,al 2003).

Figure 2.Gombe town area is divided into different residential quarters which include, GRA, Federal Low Coast, Arawa, State Low Coast, Kumbiya- Kumbiya, Pantami, Jekadafari, Tudunwada, Madaki, Dawaki, Bolari, Yalanguruza, Shamaki. etc (Bello, 2014)

The natural vegetation cover consist of complex, composite of thick acacia shrub and open grassland, however, the vegetation has been altered with very much degraded as a result of several human activities such as urbanization, cultivation, livestock grazing etc. feeling of trees as a means of employment which serves as a major source of fuel (charcoal and firewood) for the inhabitants by the unemployed youths without any plan to replace them. The predominant species consist of fine leaf, thorny trees such as *bulaniteagytica* (Aduwa), *TamarindusIndica* (Tsamiya), *adasoniadegitata* (Kuka) and *Parkiabuglungosa* (Daurowa).

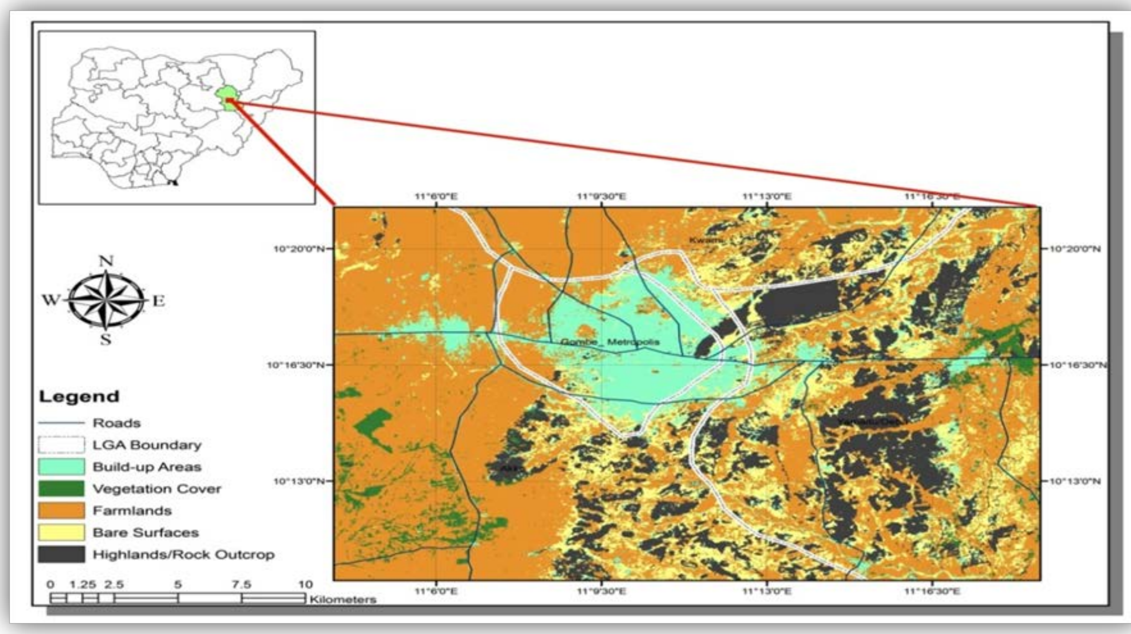
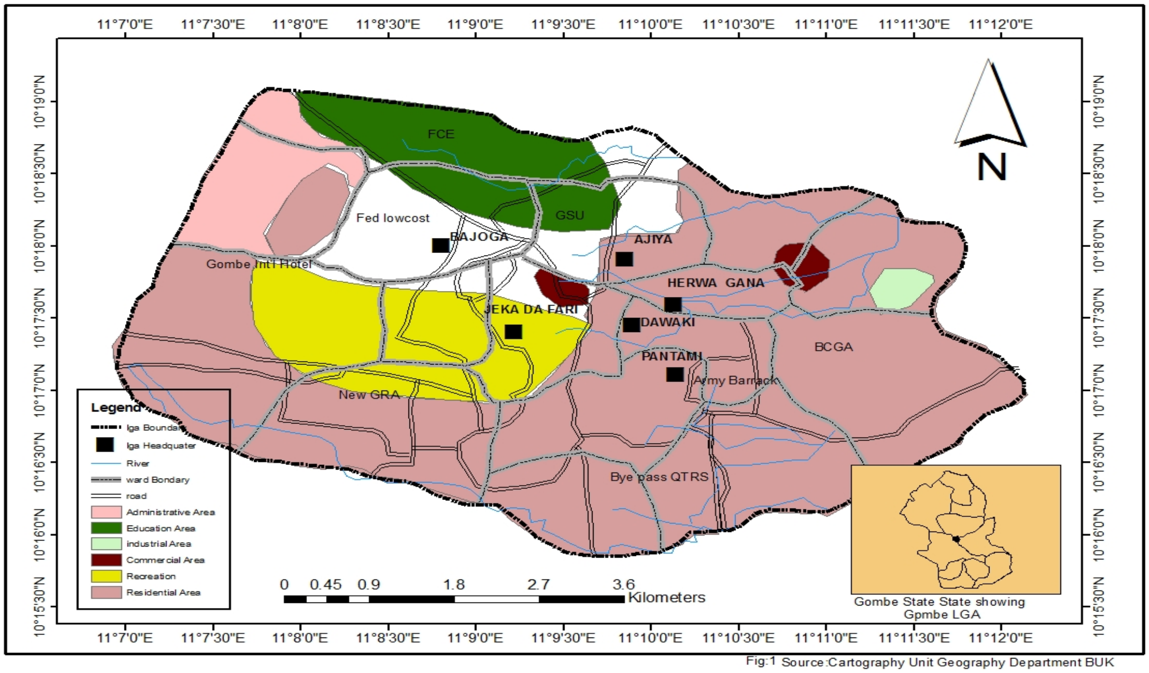


Figure 1: Map of Gombe showing study area
Source: Adopted from B.L Gadiga, (2015)



Figure, 2 Map of Gombe Metropolis
Source: Adopted from M.B. Bashir (2014)

Today there is no country in the world that is not seeing first-hand drastic effects of climate change, which raised the question of more to be done than ever before, by improving access to technology and knowledge being an important way to share ideas and foster innovation to reduce the magnitude of climate related disasters. http://www.un.org/sustainabledevelopment-goals

III. Materials and Methods

Rainfall data for Gombe station from 1984-2013 (30 years) were collected from the Nigerian Meteorological Agency. NIMET is vested with the responsibility of documenting meteorological and climatological data in the country. In this study, the standardized coefficient of Skewness (Z_1) and Kurtosis (Z_2) statistics as defined by Brazel and Balling (1986) were used to test for the normality in rainfall totals for the study area. The standardized coefficient of Skewness (Z_1) was calculated as:

$$Z_1 = \left[\left(\sum_{i=1}^{N} (x_i - \bar{x})^3 / N \right) \Big/ \left(\sum_{i=1}^{N} (x_i - \bar{x})^2 / N \right)^{3/2} \right] \Big/ (6/N)^{1/2}$$

And the standardized coefficient of Kurtosis (Z_2) will be determined as:

$$Z_2 = \left[\left(\sum_{i=1}^{N} (x_i - \bar{x})^4 / N \right) \Big/ \left(\sum_{i=1}^{N} (x_i - \bar{x})^2 / N \right)^{2} \right] - 3 \Big/ (24/N)^{1/2}$$

Where: $\bar{X}$ represents the long term mean of X_1 values, and N is the number of years in the samples. These statistics were used to test the null hypothesis that the individual temporal samples came from a population with a normal (Gaussian) distribution. If the absolute value of Z_1 or Z_2 is greater than 1.96, a significant deviation from the normal curve is indicated at the 95% confidence level.

To examine the nature of the rainfall pattern, the standardized Anomaly index (SAI) is then used. It was calculated as:

$$Z = \frac{X - \bar{X}}{S}$$

Where **X** is the rainfall observation for the year and, $\bar{X}$ and S is the mean and standard deviation of the entire series respectively in the study area. This statistic enable the researcher to determine the dry (-ve values) and wet (+ve values) years in the record as reported by Hulme, (1990). It was then smoothened with 3-year running mean.

To further examine the nature of the trends in the rainfall series, linear trend lines were also plotted for the annuals and for the months of April to October using Microsoft Excel statistical tool, and estimation of changes in the rainfall series was determined. Comparisons were then made with the long-term mean totals.

The linear regression method has been used to investigate trends in many climatic time series (e.g Abaje et., al 2009

Sabbaramayya and Kumar 1987; Hutchinson 1985; Ayoade 1973).

Result and Discussion

The mean ($\overline{X}$), standard deviation (*SD*), coefficients of variation (*CV*), standardized coefficients of Skewness (Z_1) and Kurtosis (Z_2), Minimum, Maximum and range of rainfall for Gombe are presented in Table 2 for the months of April to October and the annual.

Table 2: General statistics of monthly and annual rainfall for Gombe.

Statistics	April	May	June	July	August	September	October	Annual
X	27.74	81.37	135.93	223.77	289.56	168.54	39.54	969.67
SD	26.21	36.82	49.37	77.47	87.98	72.85	30.47	149.25
CV	94.48	45.25	36.32	34.62	30.38	43.22	77.06	15.39
Min	00	25.10	56.40	107.30	162.20	31.20	00	725.60
Max	106.90	149.10	236.10	440.00	578.30	300.50	113.10	1283.50
Range	106.90	124.00	179.70	332.70	416.10	269.30	113.10	557.90
Z_1	1.46	0.40	0.51	0.77	1.31	0.14	0.95	0.32
Z_2	2.01*	-0.84	-0.51	0.50	2.89*	-0.50	0.40	-0.48

* Statistically significant at 95% confidence level

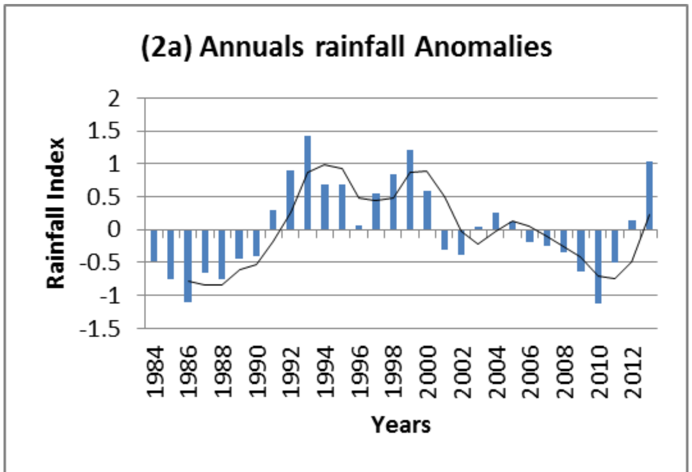
The results of the standardized coefficients of Skewness (Z_1) and Kurtosis (Z_2) show that all the months and the annual were accepted as indicative of normality at the 95% significant level, with the exception of Z_2 for the months of April and August that show a significant deviation from normal. Based on this no transformation was done to the data. Therefore, the data were not transformed.

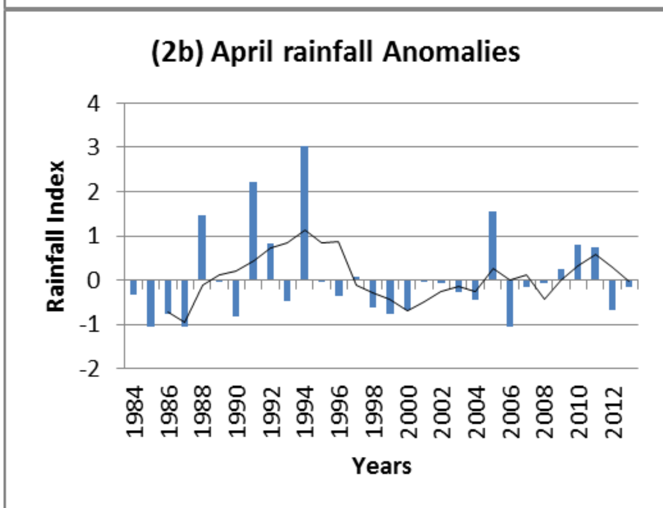
Fig. 2 shows the graphical presentation of the standardized anomaly index for both the annual and monthly rainfall smoothened out with 3- year running mean. It is clear from these results that rainfall yield is increasing in the study area. (Fig 2a) shows that the highest rainfall was recorded in 1993, whereas 1986 was a year of extremely low rainfall. This was the period of the intense drought that ravages the Northern Nigeria. The 3-year running mean shows that the recent increasing total of annual rainfall started from early 1990s to date. The increase does not show a distinct trend because there are fluctuations.

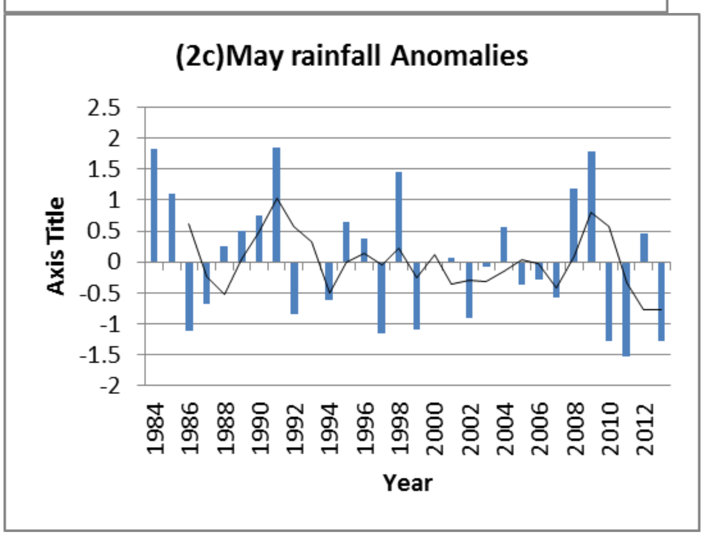
Monthly rainfall total reach their maximum between July and September. (Fig.2b-h). It is clear from these results that the substantial increase in the annual rainfall yield is predominantly as a result of the increase in August and September rainfall. This result seems to be in good agreement with the study of Nafisat (2011) for Kumo Area in Gombe state that the rainfall yield is increasing in the area.

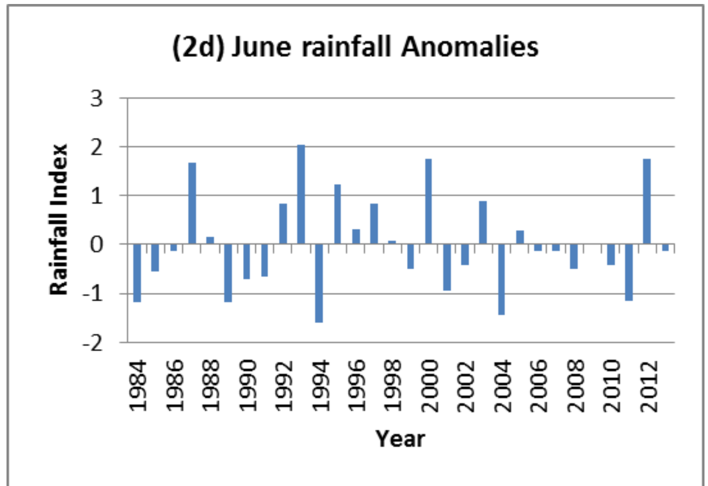
The result of the linear trend lines for the period of study (1984-2013) clearly demonstrates a general tendency for an increase in rainfall in the area (Fig 3). From the linear trend lines of the monthly rainfall there is a clear indication of an increase in rainfall amounts over time. Estimation of changes in the monthly expressed in mm for the period of study shows little or no change in the month of April. For the month of May, there is a decrease of approximately 131.4mm at the rate of 4.38 mm year^{-1}. Compared with the long-term mean, it means that May rainfall was decreasing at the rate of 9.8% per year. The month of June also shows little or no change. (See fig 3). The month of July show a significant decrease in rainfall of approximately 155mm at the rate of 5.2 mm per year -1. When compared with the long-term mean, it means that July rainfall was decreasing at the rate of 3.1% per year. There is a significant increase in rainfall of approximately 325.3 mm at the rate of 10.8 mm year^{-1} for the month of August, a decrease of approximately 14.1 mm at the rate of 0.5 mm year^{-1} for the month of September, an increase of approximately 141.8 mm at the rate of 4.7 mm year^{-1} for the month of October. When compared with the long-term mean totals, it is also clear that the monthly rainfall was increasing at the rate of 10.6% per year in August, decrease of 0% per in September and increase of 16.8% per year in October.From the result the maxima of rainfall in June and September is still very much established, while April that use to be the beginning of the rainy season is tending towards dry month and October that used to be the beginning of dry season is also tending toward raining month. The shift in the beginning of rainfall from April/March and ending of raining season from October/November has significant implication on the ecosystem. These are critical months for annual agricultural cycles where early and late crops are planted, causes crop failure, food shortages and more prone to pest attacks.

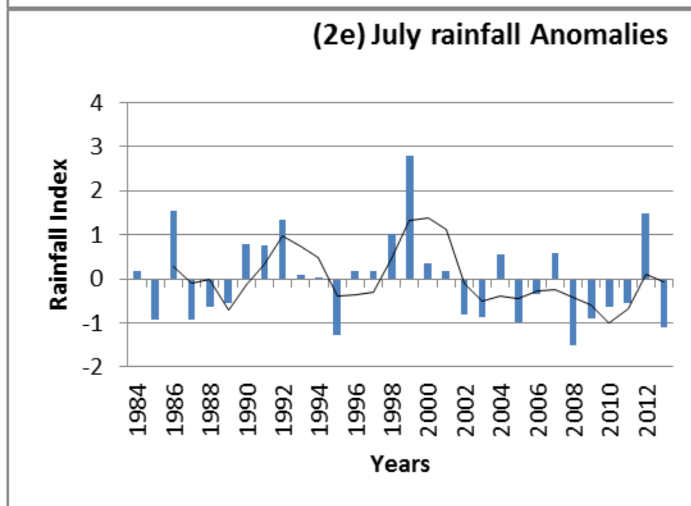
Estimation of changes of the annual rainfall for the period of study indicates an increase of approximately 140.4mm at the rate of 4.6 mm year^{-1}. Compared with the long-term average totals, it means that the annual rainfall was increasing at the rate of 0.6% per year^{-1}. It is clear from the result of the linear trend lines that the increase in the annual rainfall yield is predominantly as a result of the substantial increase in August and October rainfall

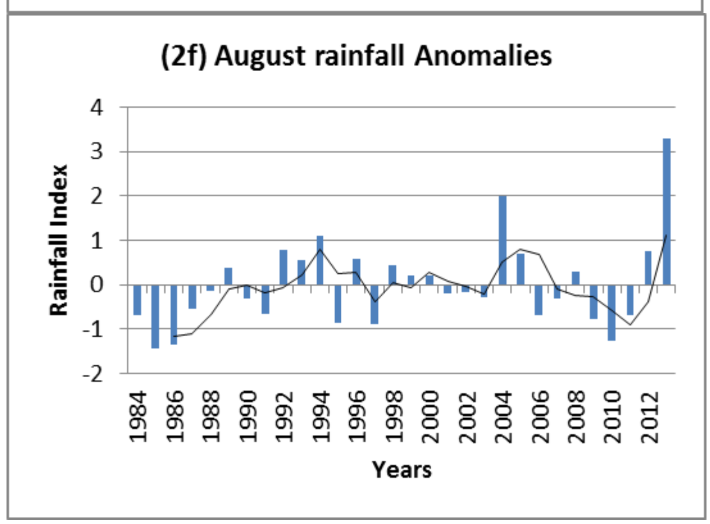

(2a) Annuals rainfall Anomalies
Rainfall Index
2
1.5
1
0.5
0
-0.5
-1
-1.5
1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012
Years

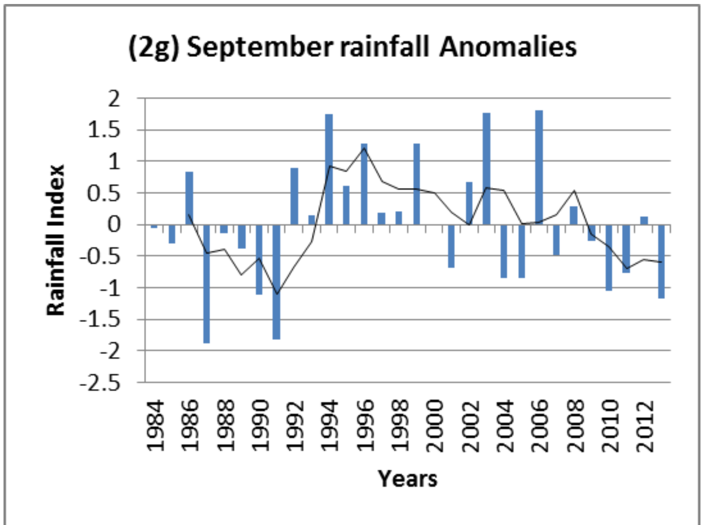

(2b) April rainfall Anomalies
Rainfall Index
4
3
2
1
0
-1
-2
1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012
Years

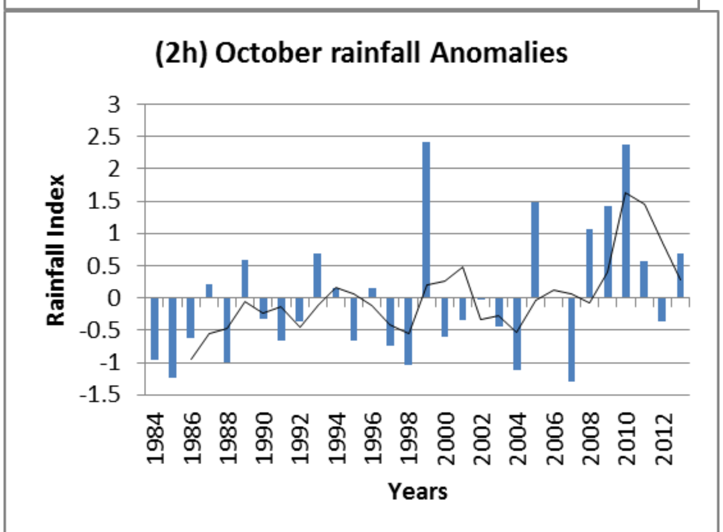

(2c)May rainfall Anomalies
Axis Title
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012
Year

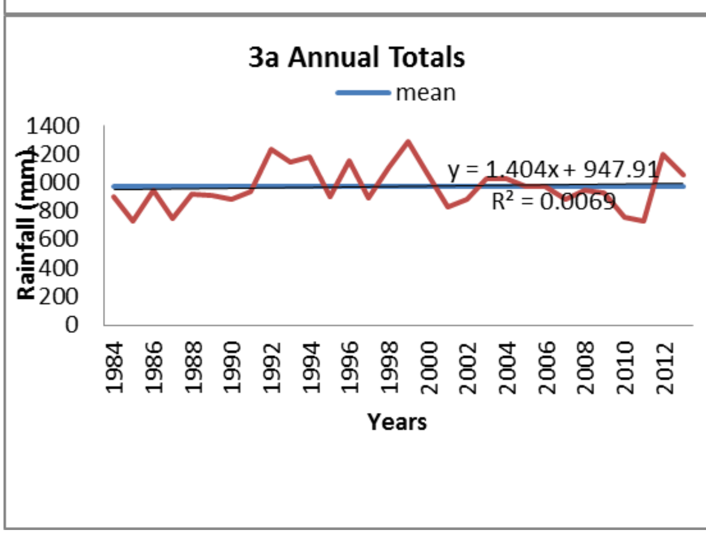

(2d) June rainfall Anomalies
Rainfall Index
3
2
1
0
-1
-2
1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012
Year

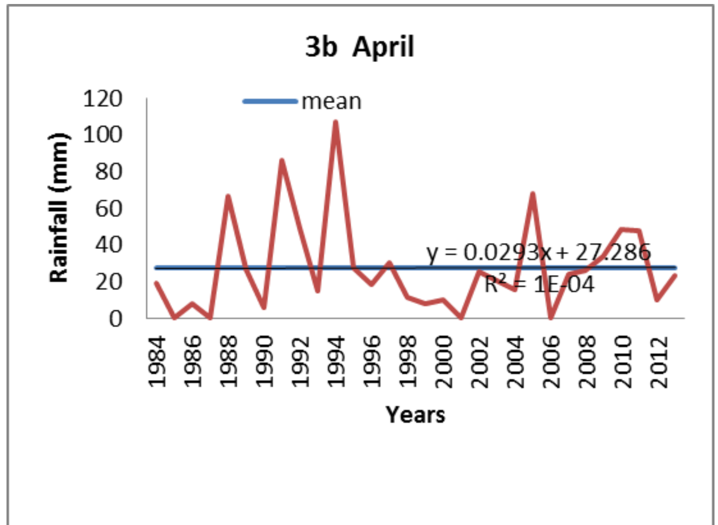

(2e) July rainfall Anomalies
Rainfall Index
4
3
2
1
0
-1
-2
1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012
Years

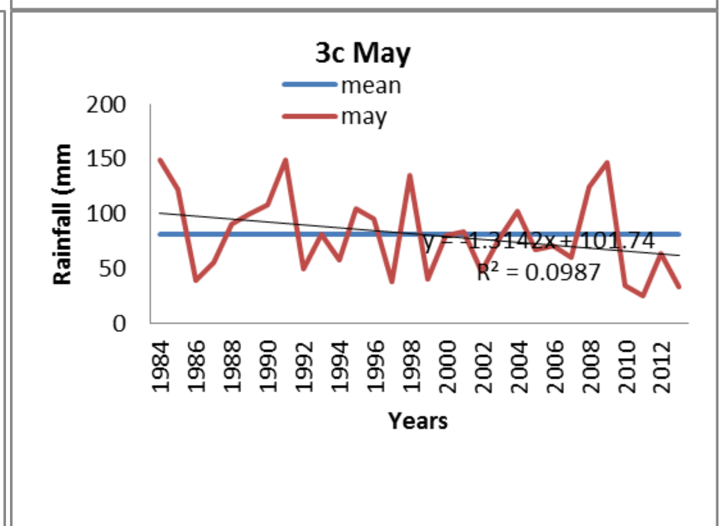

(2f) August rainfall Anomalies
Rainfall Index
4
3
2
1
0
-1
-2
1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012
Years

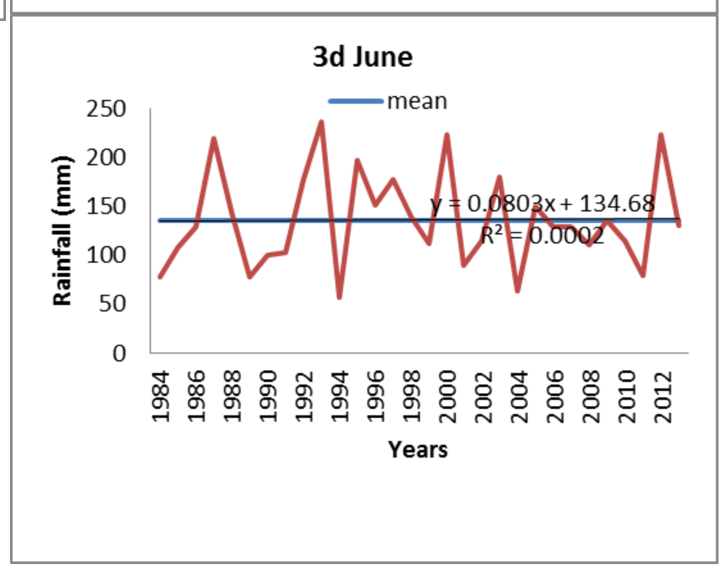

(2g) September rainfall Anomalies
Rainfall Index
Years
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012


(2h) October rainfall Anomalies
Rainfall Index
Years
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012


3a Annual Totals
mean
Rainfall (mm)
Years
y = 1.404x + 947.91
R² = 0.0069
1400
1200
1000
800
600
400
200
0
1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012


3b April
mean
Rainfall (mm)
Years
y = 0.0293x + 27.286
R² = 1E-04
120
100
80
60
40
20
0
1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012


3c May
mean
may
Rainfall (mm
Years
y = -1.3142x + 101.74
R² = 0.0987
200
150
100
50
0
1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012


3d June
mean
Rainfall (mm)
Years
y = 0.0803x + 134.68
R² = 0.0002
250
200
150
100
50
0
1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012

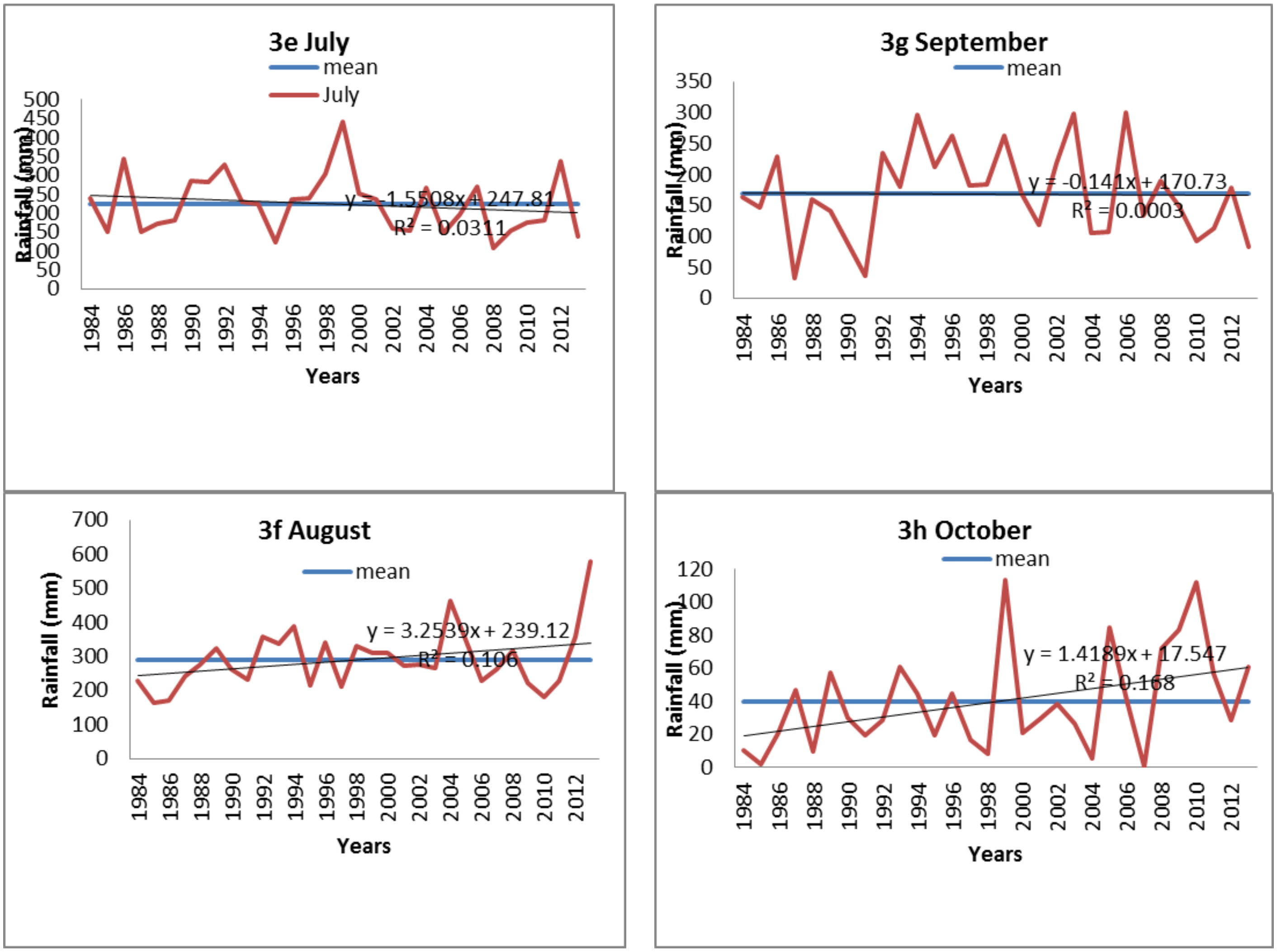


Fig. 2: Rainfall anomalies for (2a) Annual totals, (2b) April, (2c) May, (2d) June, (2e) July, (2f) August, (2g) September, (2h) October

Fig.3 Monthly and Annual Rainfall Trend and Fluctuations (2a) Annual totals, (2b) April, (2c) May, (2d) June, (2e) July, (2f) August, (2g) September, (2h) October

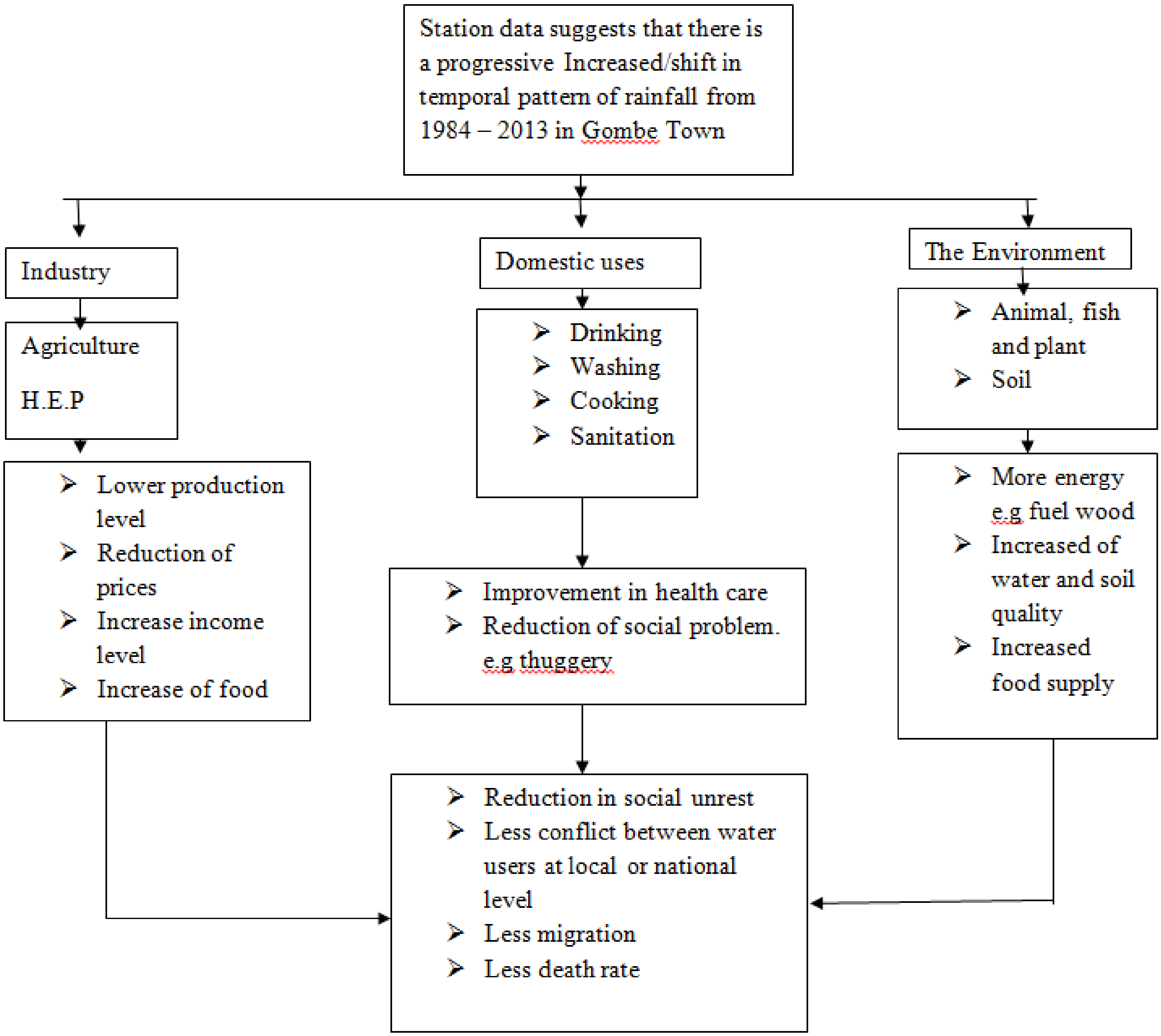


Fig (4) Illustrating some of the implications of increased of rainfall total on the environment and the society

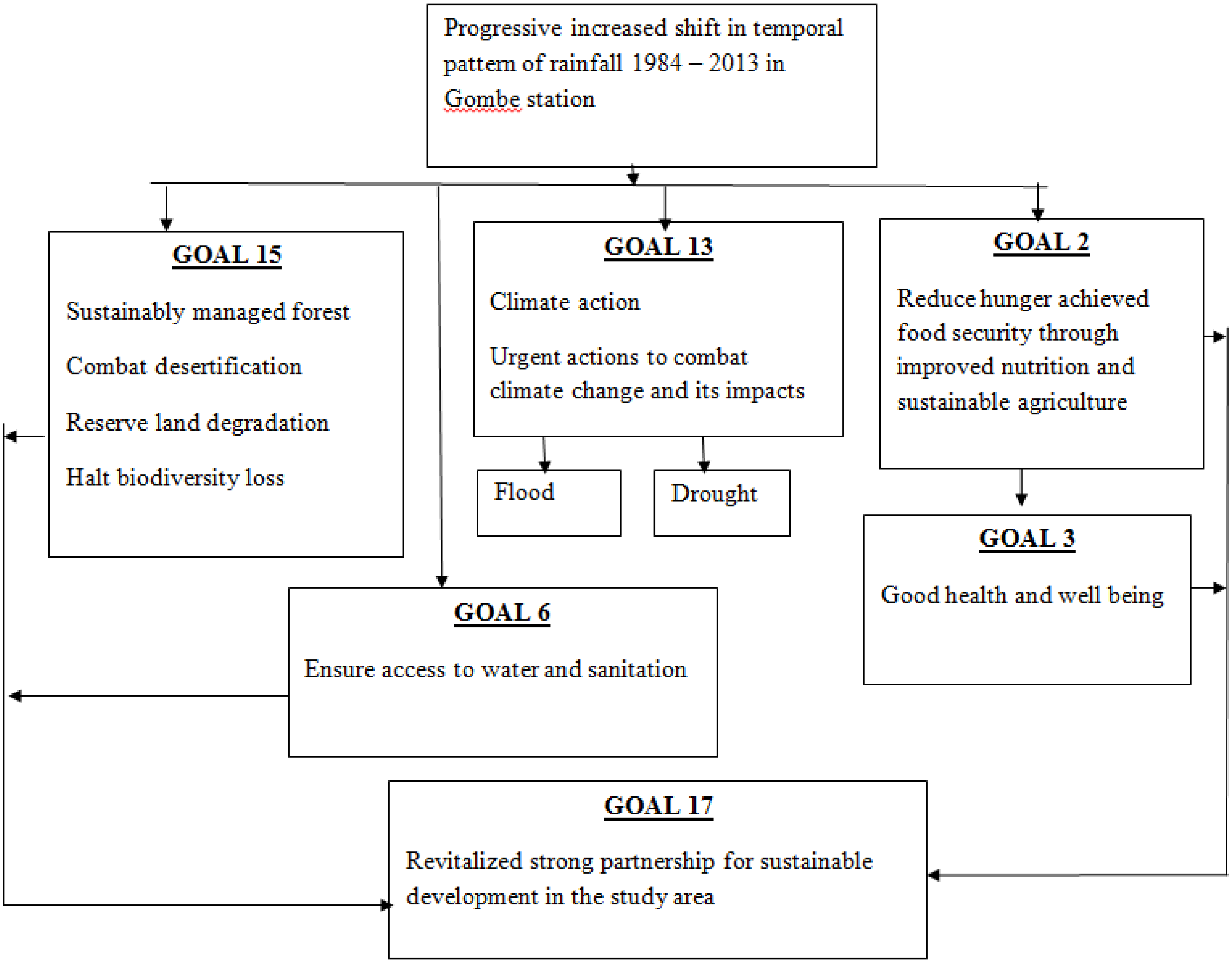


Fig (5) Illustration of some implications of rainfall trend for sustainable development goals (SDGs)

Fig 4 and 5 highlight some of the implications of the increased rainfall totals on the environment and society and the sustainable development goals (SDGs). Hence, the present study reveals the progressive increased shift in temporal pattern of rainfall in Gombe station that has a multiplying factor at local level towards achieving the (SDGs).

According to Oladipo, (2016) argue that extreme weather event are already impacting negatively on the country economy, social, environmental and infrastructural fabrics. Since there is a paradigm shift from the post-2015 MDGs for the achievement of SDGs, Nigeria need to move its economy toward a more environmentally friendly, low carbon, climate resilient, green and sustainable path.

IV. Conclusion

Evidence of change in the distribution and characteristics of rainfall can be examined in terms of frequency, intensity and amounts e.t.c. Present study brings out some of the interesting and also significant changes in the rainfall pattern of Gombe town. The monthly and annual series have been examined for fluctuations, trend and its implication on sustainable development goals (SDGs) based on data collected from 1984-2013 period.

It is clear from the results of the analysis that the trend in the rainfall total is increasing on annual basis. The recent increase in the annual rainfall totals is predominantly as a result of the increase in August and October rainfall.

The result of the standardized anomaly index shows a fluctuating rainfall pattern across the months under consideration; the delay in rainfall till April and the high rainfall in October might have serious agricultural implications because most agricultural activities in this area rely on rainfall of this period might cause flooding and food production in the area to be late e.g maize, beans and millet. e.t.c

Base on the findings from this study it is recommended that, there is need for government to embark on total commitment and integrated approach toward achieving the SDGs and monitoring of rainfall trend as its plays a significant role in the interface of economy, means of livelihood, poverty index and food security.

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