International Journal of Scientific Research in Computer Science, Engineering and Information Technology
© 2018 IJSRCSEIT | Volume 3 | Issue 1 | ISSN : 2456-3307

Sudanese River Nile State Integrated Water Resources

Jehan Mohmed Sharief*[1], Abbas Abd Alla Ibrahim[2], El Sadig El Hadi El Hassan[3]
*[1]Faculty of Civil engineering, Sudan University of science & Technology, Khartoum , Khartoum North, Sudan
[2]Faculty of Water & Environmental Engineering, Sudan University of science & Technology, Khartoum , Khartoum North, Sudan
[3,1]Faculty of Civil engineering, Sudan University of science & Technology, Khartoum, Khartoum South, Sudan

ABSTRACT

With the objective to study integrated water resources management River Nile State of Northern Sudan was taken as a pilot area. The integration adopted the approach concept of **integrated water resources (IWR**) which required the determination of River Nile State surface water, rain water and ground water quantitatively and qualitatively. Simple statistical models as well as sophisticated softwares and advanced statistical models were applied. These included beside the means, standard deviations, the more sophisticated statistical parameters such as coefficient of variation, skewness and their corrections. These adopted softwares in this research are considered the keys leading to solution of the problems and fulfilling the objectives to create an integrated water resources management body in the River Nile State pilot area, to travel parallel with the expected present and future population growth.

Keywords : integrated water resources means, standard deviations, coefficient of variation, skewness.

I. INTRODUCTION

Water is basic for life and economic development. Mar Del International Conference in 1977 recommended that industrial arrangement should ensure development and management of water resources. In 2000 Global Water Partnership (GWP) defined IWRM as a process of developed management of water to maximize economic and welfare. In Dublin guiding principles four principles were revealed. The first used fresh water as a finite resource, the second water management based on a participatory approach, third women important role, and forth water management an economic good. Water Resources Management (WRM) started a long time ago, while Integrated Water Resources Management IWRM is a recent technique. However it is well known that water demand and supply are unbalanced. Water supply management without social, ecosystem economics, impacts are insufficient. This wide spectrum of the integrated water resources management tackled by many different international intellectual organizations and genuine stake holder can be broadly divided into two parts. The first part face or side can deal with the Integrated Water Resources (IWR) .It can conceptionally deal with the integration of rain water, surface water, and ground water qualitatively and quantitatively, which is the objective of this research. The second or other face of the coin can conceptionally deal with the Water Resources Management (WRM), the main three different types of water namely domestic use, industrial use and agricultural use, which will be dealt with in a separate research. The two roads or the two approaches lead to Rome. One can manage the resources if he found the available integrated water resources. Like wise one can integrate his water resources if he was able to manage his available domestic industrial and agricultural water resources.

The main objective of this research is to suggest an integrated water management methodology in the River Nile State pilot area. The integration adopted the approach of (IWR) which required the determination of River Nile State surface water, rain water and ground water quantitatively and qualitatively in the pilot area. The concept of Integrated Water Resources Management (IWRM) and its relations with the type of the source of water whether ground, surface or rain water is inherently knitted with the study objectives and problems. Likewise the different uses of water whether domestic, industrial or agricultural are also inherently knitted with the objectives and problems. Therefore simple statistical models as well as sophisticated analyses are pivotal to reveal the fulfillment of the objectives and the solution of their associated problems.

These are dealt with in succession starting with first category of the types of water resources which is conventionally and clearly referred to as Integrated Water Resources (IWR) .This was then followed by the use of the models in the second category of the resources conventionally referred to as Water Resources Management (WRM).The integration lead to solution of desertification drought, and undesired man activities. It attracted people who previously left their farms to travel back to their lands. This in tern enhanced development management program policies. It stopped bank erosion and flooding inundations.

II. METHODS AND MATERIAL

A. Study Area

The study area is the River Nile State. Figure (1), shows the map of the Sudan including River Nile State. The River Nile State is connected with high way roads with Khartoum Town and Port Sudan Town. River Nile State is suffering from drought due to the desert forming most of its area. The River Nile State is located between longitudes 15 and 30 east and latitudes 22 and 16 north. The total area of fertile land or arable land in the River Nile State is estimated as 3.289 million feddans. In the River Nile State rainfall is erratic variable and not reliable. River Nile State cultivates many crops, such as palms, citrus, wheat and broad beans. Water sources in the River Nile State are mainly from the River Nile.

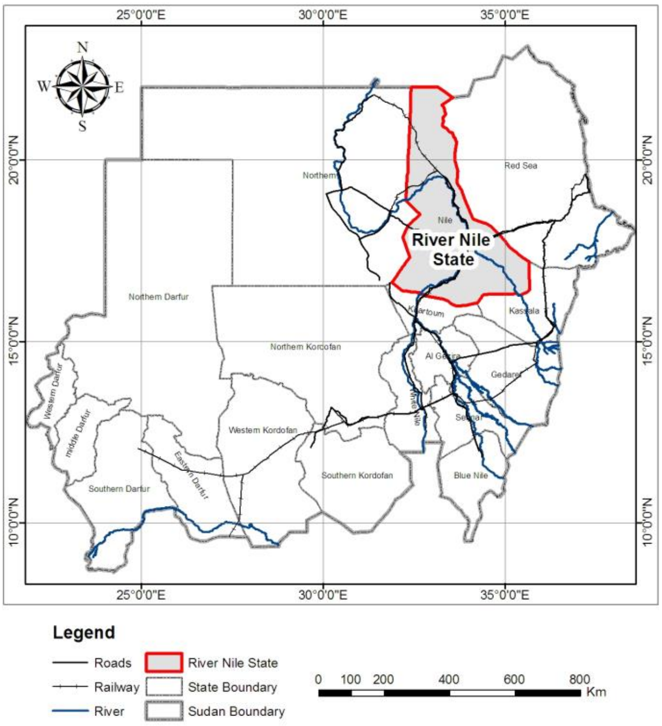


Figure 1 : Map of Sudan With River Nile State

B. Methodology

The pilot area included the River Nile its rural and urban areas in the vicinity of River Nile State. It included metrological stations, population, geology and demography of the River Nile State. It covered water resources, and geographic information system in the River Nile State. The data considered precipitation, ground water, flood water, population, temperature variation, evapotranspiration and recharge. The distribution of population in Sudan especially in the River Nile State is concentrated on the River Nile and Atbara River banks. From 2008 to

2013 population of the River Nile State increased continuously, that required revision of water management. Food and Agricultural Organization (FAO) water report 2005 indicated that there was a problem in water in the River Nile State. The River Nile State depends on the Nile River as a source of water; with its cities and villages spread along its banks.

The River Nile State has great potentials of water that is not exploited. The River Nile State is the state that has the greatest area of desertification in the Sudan. The data to be collected in IWR consisted of and included precipitation data, ground water level,drawdown or pumping lift data, and flood or discharge measurement data. The population data is essential forming the main beneficiaries of the study objective. It is fortunate that the quality of the three types of water rain surface and ground water in the River Nile State was tested according to the Sudan by laws and World Health Organization (WHO) and was perfectly suitable for use.

C. Data Collection and Analysis

The data obtained from Meteorological Authority and the Ministry Of Irrigation, was analyzed by suitable programs to obtain the results. Modeling the data was very essential which led to the achievements of the research specific objectives. The achievements included quantitative determination of surface and ground water together with rain water in the pilot area. The same approach could be used to estimate production of isohyetal rainfall map of River Nile State area, together with rehabilitation of meteorological stations for early warning system against floods, and droughts. It could also be used to reveal capacity building needed to technical staff to develop the area of the River Nile State. However, care was focused on water estimation only, forming the part of the objectives. This study involved using Statistical Package of Social Sciences (SPSS). (SPSS) is a software that can analyze most types of data. It can take two mutually exclusive values of a variable in two aspects. It could also be original scaled data, usually programmed as questionnaires, interval or, ratio data. The data used in this study are interval and ratio data. (SPSS) is suitable software, because it is easy and accurate (Andrew Garth-2008).Some advantages of (SPSS) can find both means and medians. It can also graph data on a box plot, showing both level and spread indicating any outliers.Furthemore it also reveals the differences or correlation between elements of the available data.

III. RESULTS AND DISCUSSION

Table (1) shows the population growth and future forecast of the River Nile State .There was a noticed population decrease after 1983 due to the population movements to other jobs such as gold mining and attractive salaries of the then new cement factories.

Year	Total Population	Population Growth
1956	874000	-
1973	1198000	1.07
1983	1378000	1.41
1993	1551000	1.19
2008	1808700	1.03
2010	1856250	1.50
2013	1903800	1.50
2017	2020600	1.80
2050	3640000	

Table 1 : Population in River Nile State

To improve and develop the River Nile State it was found vitally necessary to use the available cultivable land properly. The people leaving their homes due to drought and low agricultural income must be encouraged by the local and central federal governments to stay with the challenge that they must enjoy better chances of living using the (**IWRM)** as an effective tool. That must be supplemented by balanced development in urban and rural religions in the state. Use of software such as **Hec-HMS** or simple and advanced statistical models should be applied. These ambitious suggestions must be strengthened with adoption of a policy directed against desertification through stakeholders, including **None Governmental Organizations (NGOs)** and association with awareness spread, being the well known tools that help in (**IWRM**) in the state. These last ambitious changes which are adopted in this research are considered the keys leading to solution of the problems and fulfilling the objectives to create an integrated water management body in the River Nile State pilot area, to travel parallel with the expected present and future population growth. Using the collected data and analysis, applying simple correlation regressions analyzing the results of the analysis and its effects on the River Nile State problems, further in depth discussion was found necessary. More advanced analysis was conducted, and discussed in relation with (**IWRM**). The advanced discussion included some simple and advanced statistical model analysis. These included beside the means, standard deviations, the more sophisticated statistical parameters such as coefficient of variation, skewness and their corrections. They involved use of the famous statistical tables of Foster Hazin and Fuller equations. The use of these model equations together with the known statistical coefficient and parameters has paved the road of fulfilling the study objective together with their inherently knitted problems.(Murray R.Spiegel,1972,New York,Schaums Series).Table Hazin ,together with Foster table (I) and Foster table (III),are given in appendix (A),are available in many hydrological text books.

The average value of any statistical relevant parameter given as for example the discharge (Q), by the equation:-

$$\textit{Average}\ \text{Discharge}\ (\text{Q}) = \frac{\text{Sum of the Q s}}{\text{n}} = \bar{Q}\ ---(1)$$

Or

$$\textit{Average}\ \text{Rainfall}\ (\text{P}) = \frac{\text{Sum of the P s}}{\text{n}} = \bar{P}\ ---(1)$$

Where:-

$\bar{Q}$ = The average discharge per year $m^3 / year$ or average rainfall in m m./year.

$n =$ The number of years of records.

$$S\tan dard\ \text{Deviation}\ \ \sigma = \sqrt{s} = \sqrt{\frac{\sum_{i=1}^{20}(Q_i - \bar{Q})^2}{20-1}}\ ---(2)$$

for rains Q is substituted by P

(Murray R.Spiegel, 1972, New York, Schaums Series)

$$\textit{Coefficient}\ \text{of variation}\ = C_v = \frac{\sigma}{\bar{Q}} ---(3)$$

$$\textit{Skewness}\ \text{coefficient}\ C_s = \frac{\sum_{i=1}^{20}\left[\frac{Q_i}{\bar{Q}} - 1\right]^3}{(20-1)C_v^3} ---(4)$$

Correction factor to skewness coefficient =

In Foster Table (I) $F = 1 + \frac{6}{n} ---(5a)$

In Hazin Table and Foster Table (III)

$$F = 1 + \frac{8.5}{n} ---(5b)$$

$$\textit{Corrected}\ \text{skewness factor}\ C_s' = F \times C_s ---(6)$$

(Murray R.Spiegel,1972,New York,Schaums Series)

The discharge for recurrent return periods is obtained by the equation:-

$$Q = \bar{Q}(P_m C_v + 1) ---(7)$$

As in the table below

Best solution in the table

P	%age Probability	20	5	1	0.1
I	$C_s' =$				
II	$I \times C_v$				
III	$II + 1$				
IV	$III \times \bar{Q}$				
V	$Trecurrence - period$	5	20	100	1000

$$T\ \text{- Recurrence} - period = \frac{100}{P_m} \rightarrow e.g. \frac{100}{20} = 5\ \text{years}\ ---(8)$$

$$\textit{and}\ \text{P \% age Probability} = \frac{100}{\text{T}} \rightarrow \text{e.g.} \frac{100}{5} = 20\ \% ---(9)$$

The above is the application of Foster table (1); the same is applied on Foster (III) and Hazin table.

Fuller equation is expressed as :- (Murray R.Spiegel, 1972, New York, Schaums Series)

$$Q_T = \bar{Q}[1 + 0.80 \log\ \text{T}] ---(10)$$

$Q_T = \textit{Expected}$ discharge after (T) years.

$\bar{Q} = \textit{Average}$ discharge during (t), *years* of records.

- **Application of the Concept Relation Among the Three Water Resources IWR:-**

According to the data collection in the River Nile State the three types of water rain water, surface water, and ground water are available. The statistical analyses were applied on the three of them.

Rain Water:- The three metrological stations Atbara, Hudiba and Shendi of River Nile State are studied using the concept relation among the three water resources and IWR. There is always rainfall in the River Nile State in the months June July, and August in every year, but it is frequently very little and very limited, usually characterized by being unstable .The River Nile State swings between repeated droughts. This is translated into harmful effects on grazing rainfall agriculture. It has also deep and profound effects on surface water recharge in River Nile River Atbara and Hafiers, together with painful low groundwater recharge resulting from short rainfall periods. The application is conducted in the three stations:-

- **Atbara Station:-**

Table 2. Total Rainfall Atbara Station 1981 to 2010

Year	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Attabra	27	18	15.5	1.1	33.3	41.3	71	239.7	50.5	0	9.5	37.4	31.9	71.7	96.7
Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Attabra	32.2	68.5	35.1	162.3	0	18.1	5.6	89.5	15	74.9	53.2	63.1	15.7	32.3	19.8

Foster I

Table 3. Total Rainfall Atbara Station Parmeters Values1981 to 2010

Parameter	Value
$Average\ \text{Rainfall}\ \bar{P} =$	47.66 $m.m.$
$S\tan dard\ \text{Deviation}\ \sigma = \sqrt{s} =$	50.52
$Coefficient\ \text{of variation} = C_v =$	1.06
$Skewness\ \text{coefficient}\ C_s =$	2.35
$Correction$ factor to skewness coefficient = Foster Table (I) $F = 1 + \frac{6}{n}$	1.2
$Corrected$ skewness factor $C_s' =$	2.82

P	%age Probability	20	5	1	0.1
I	$C_S' = 2.82$	0.446	2.089	4.912	11.31
II	$I \times C_v\ (1.06)$	0.47	2.21	5.21	11.99
III	$II + 1$	1.47	3.21	6.21	12.99
IV	$III \times \bar{Q}$	70.19	153.19	295.79	618.99
V	$Trecurrence - period$	5	20	100	1000

Log – Log

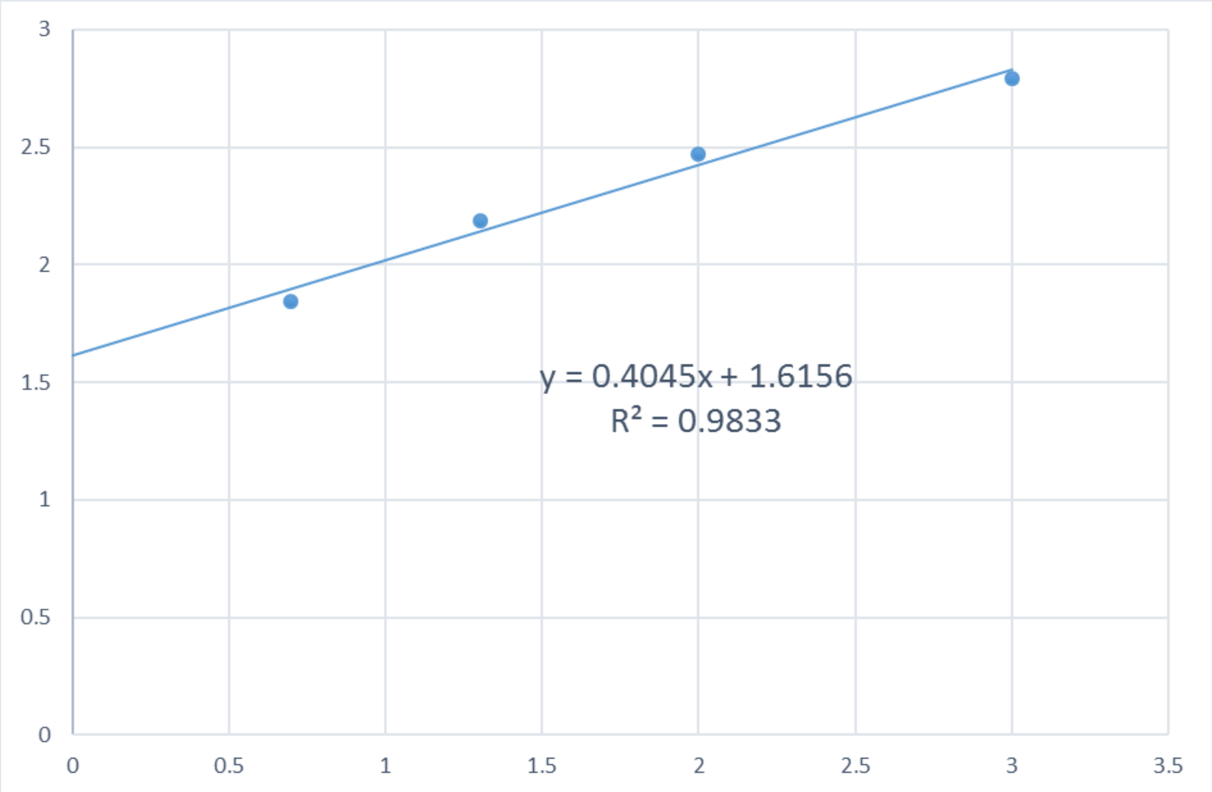


Fig 2. Log Log Total Rainfall Atbara Station Foster I

Foster III

Table 4. Total Rainfall Atbara Station Parmeters Values1981 to 2010

Parameter	Value
$Average$ Rainfall $\bar{P}$ =	47.66 $m.m.$
$Standard$ Deviation $\sigma = \sqrt{s} =$	50.52
$Coefficient$ of variation $= C_v =$	1.06
$Skewness$ coefficient C_s =	2.35
$Correction$ factor to skewness coefficient = Foster Table (I) $F = 1 + \frac{8.5}{n} =$	1.28
$Corrected$ skewness factor $C_s' =$	3.01

Corrected skewness= 3.01

P	%age Probability	20	5	1	0.1
I	$C_S' = 3.01$	0.42	2.02	4.02	7.25
II	$I \times C_v\ (1.06)$	0.45	2.14	4.26	7.68
III	$II + 1$	1.45	3.14	5.26	8.68
IV	$III \times \bar{Q}$	68.88	149.70	250.73	413.90
V	$Trecurrence - period$	5	20	100	1000

Log – Log

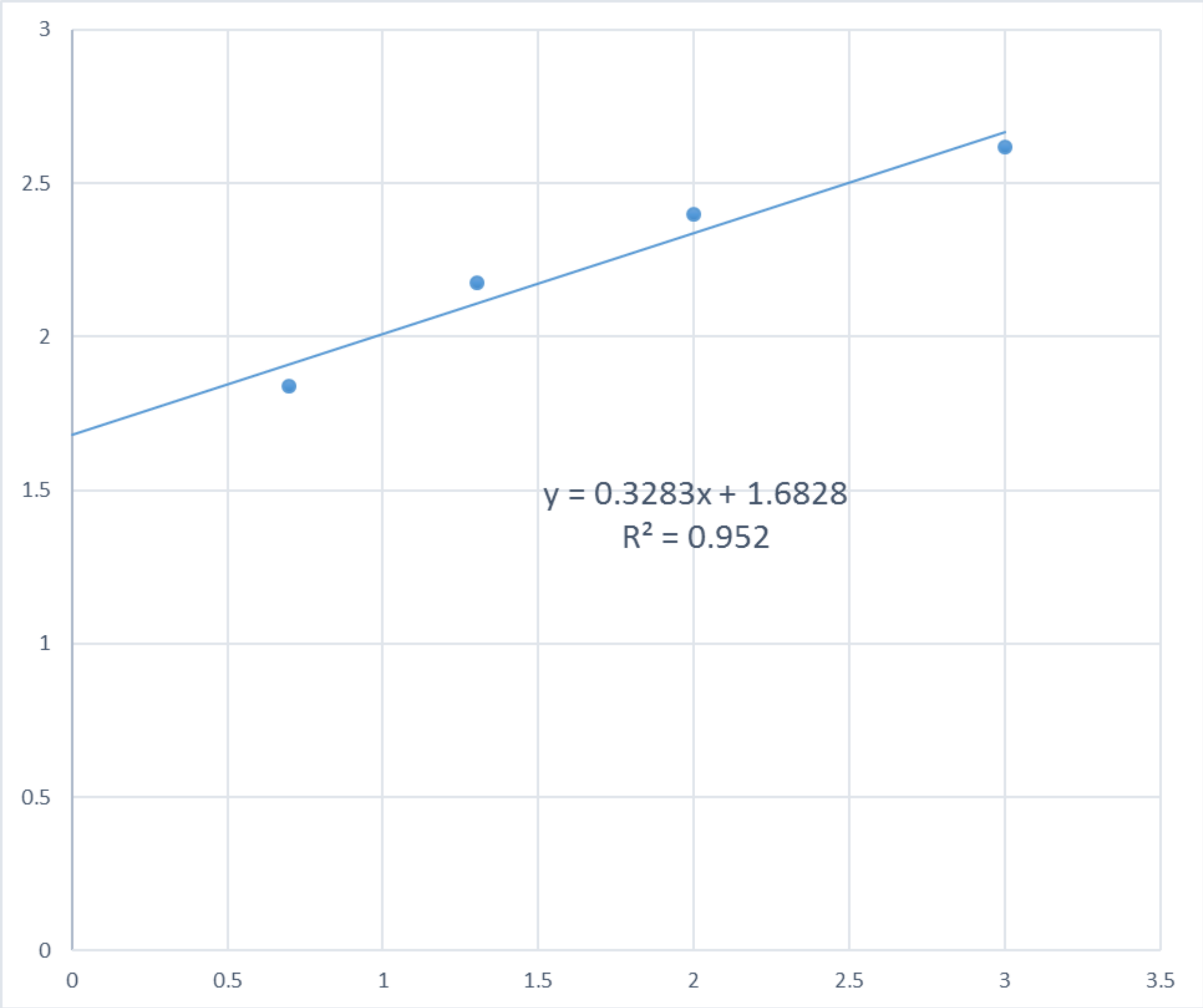


Fig 3. Log Log Total Rainfall Atbara Station Foster III

Hazin

Corrected skewness= 3.01

P	%age Probability	20	5	1	0.1
I	3.01	0.42	2.02	4.02	7.25
II	$I \times C_v\ (1.06)$	0.45	2.14	4.26	7.68
III	$II + 1$	1.45	3.14	5.26	8.68
IV	$III \times \bar{Q}$	68.88	149.70	250.73	413.90
V	$Trecurrence - period$	5	20	100	1000

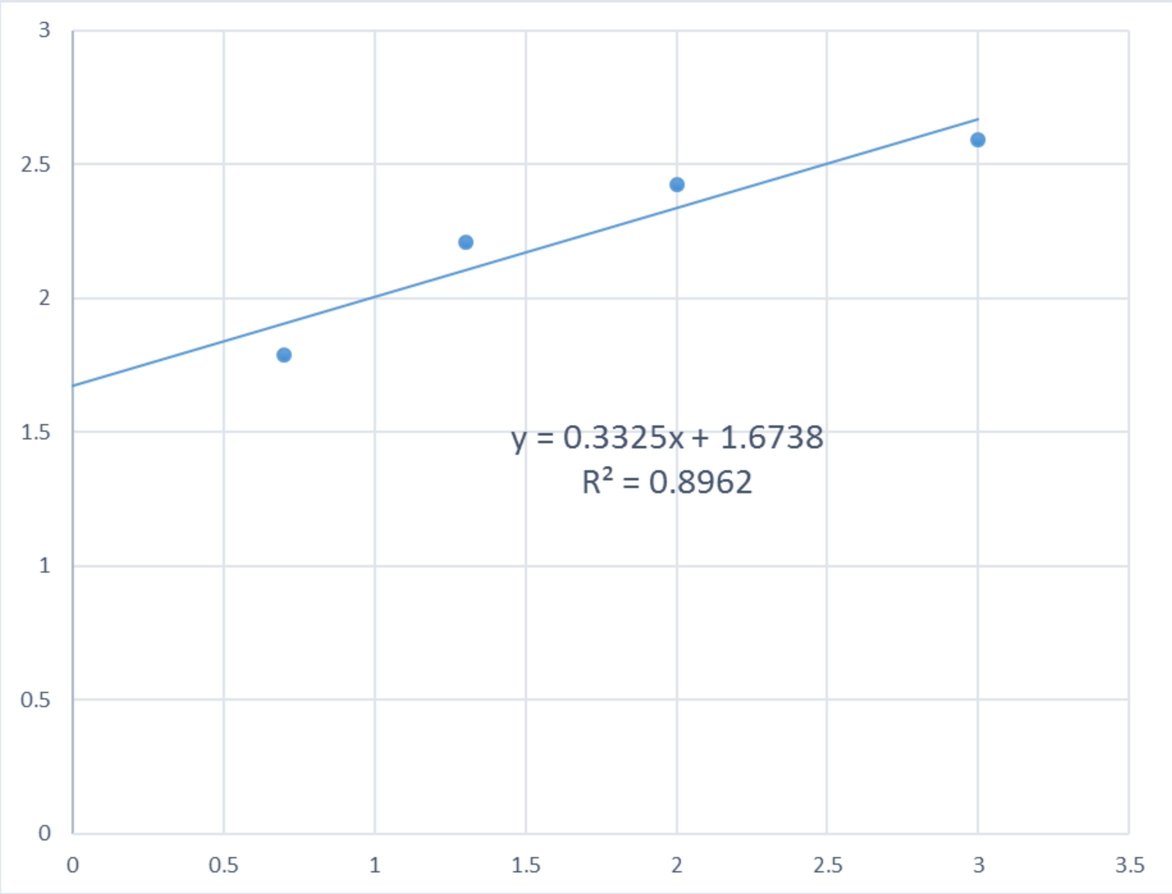


Fig 4. Log Log Total Rainfall Atbara Station Hazin

Fuller

$$Q_T = \bar{Q}[1 + 0.80\log\ T]$$

Table 5. Total Rainfall Atbara Station Parmeters

Values1981 to 2010

Years	Value
$\bar{P}$	47.66 *m.m.*
5	74.31553
20	97.27247
100	123.9247
1000	162.0553

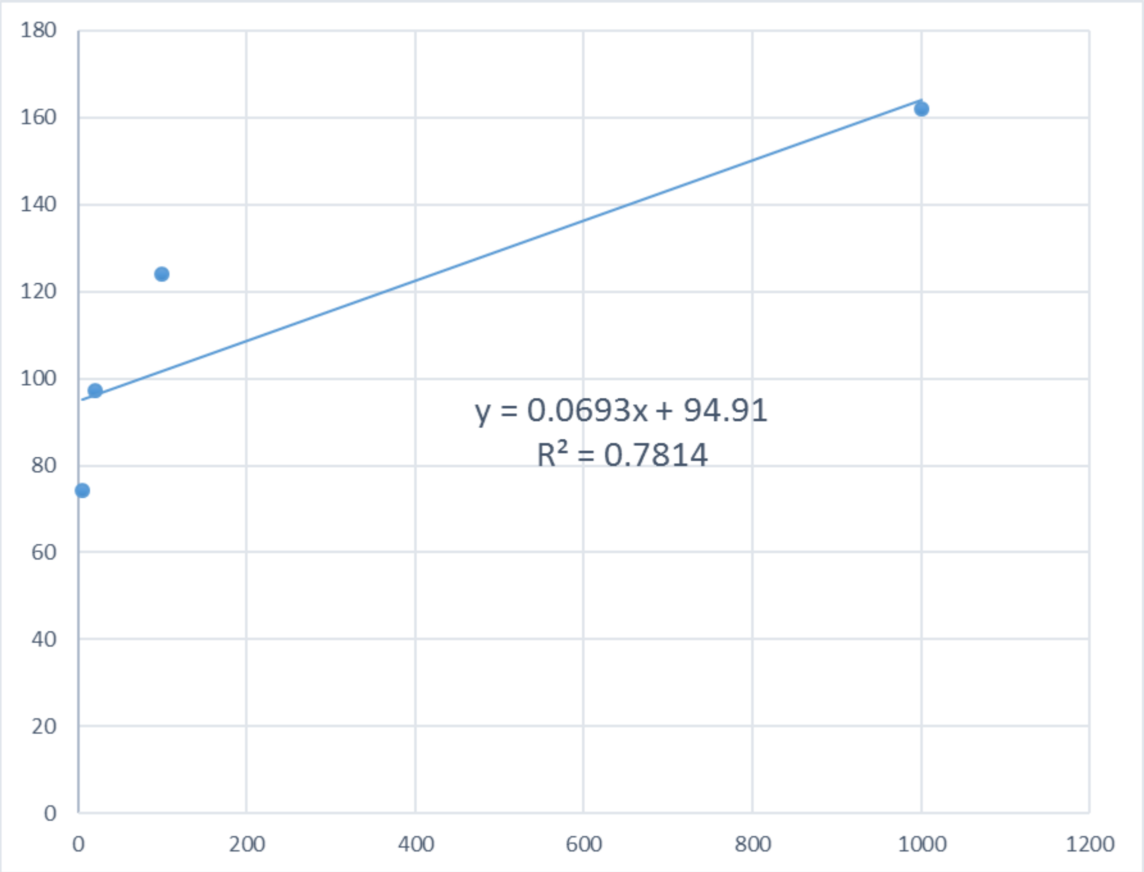


Fig 5. Log Log Total Rainfall Atbara Station Fuller

Tables 6. Statistical Analysis Total Rainfall Atbara Station

Expected Population	P %age Probability	Years	Foster I	Foster III	Hazin	Fuller	Average
2209122	20	5	70.2	68.9	61.8	74.3	68.8
2886931	5	20	153.2	149.7	162.8	97.3	140.8
12029844	1	100	295.8	250.7	265.9	123.9	234.1
113046820	0.1	1000	619.0	413.9	393.7	162.1	397.2

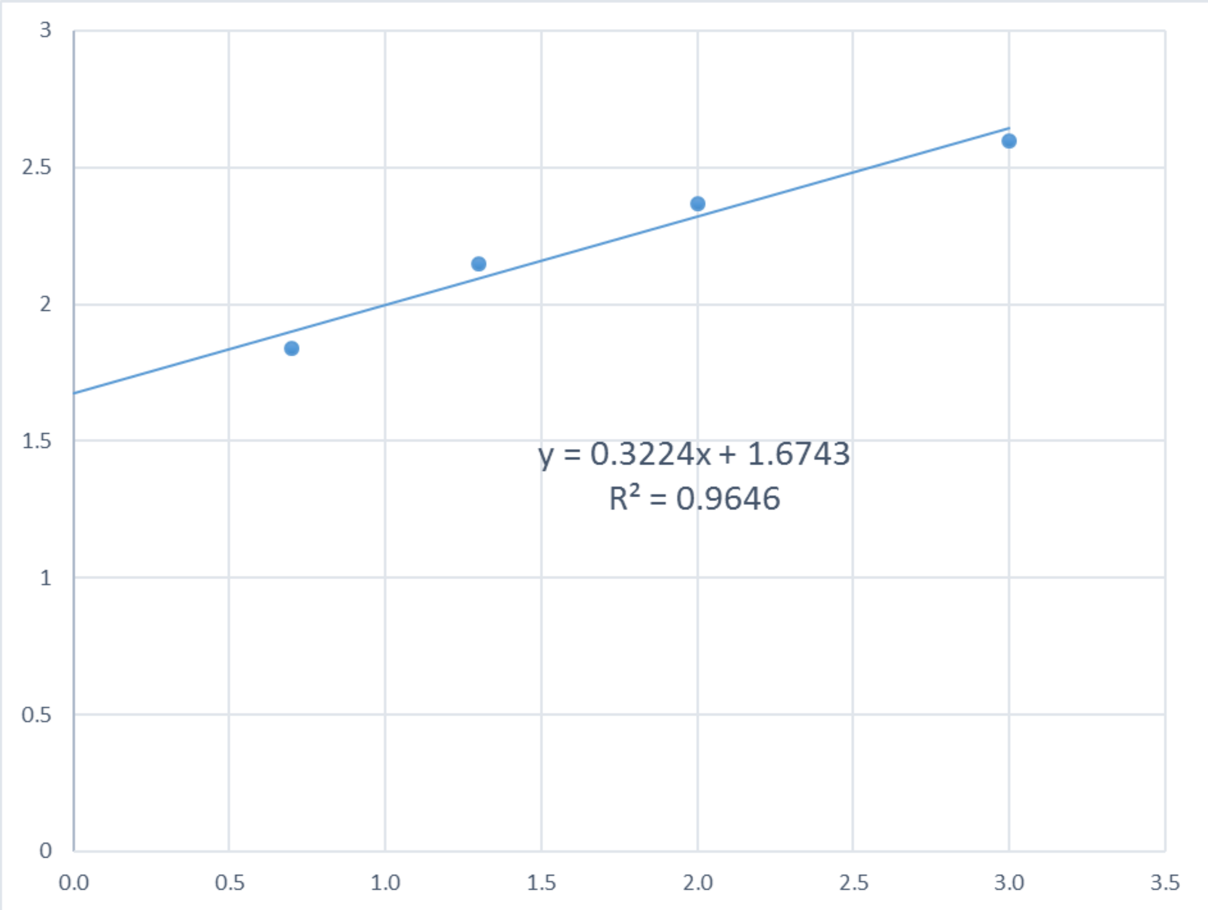


Fig 6. Log Log Total Rainfall Atbara Station Average of Foster I,III,Hazin and Fuller

Conducting the same approach for the other two rainfall stations namely Hudiba and Shendi Stations,applying the equations from (1) to (10) to each .Tables (7),for Hudiba Station and table(8) for Shandi station are shown. Also table 9):Log Log Total Rainfall for Hudiba Station Average of Foster I,III,Hazin and Fuller,together with table 10):Log Log Total Rainfall for Shendi Station Average of Foster I,III,Hazin and Fuller are shown.Figures (7),and (8),are log log presentations for Hudiba and Shendi Stations

Table 7. Total Rainfall Hudiba Station 1981 to 2010

Year	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Rain Fall	11.1	18	18	22.8	11.6	36	51	240.2	52.9	1.5	1	81.6	8.5	82.2	71.4
Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Rain Fall	36.5	40.6	72.2	114.6	4.8	6.6	19.5	52.4	18	67.4	49.3	52.5	53.9	84.2	25.2

Table 8. Total Rainfall Shendi Station 1981 to 2010

Year	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Shindi	56.6	7.6	32.6	3	19.8	34.6	72.1	205.4	15.8	37.8	31.7	86.8	5.8	108	83.1
Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Shindi 1	43.6	42.2	227.6	229.4	0.8	37.3	23.1	157.3	50.6	41.7	145.8	158.5	60.6	106.9	114.8

Tables 9. Statistical Analysis Total Rainfall Hudiba Station

Expected Population	P %age Probability	Years	Foster I	Foster III	Hazin	Fuller	Average
2209122	20	5	65.51	63.26	56.04	73.05	64.47
2886931	5	20	144.10	141.57	155.73	95.61	134.25
12029844	1	100	289.83	239.94	257.95	121.81	227.38
113046820	0.1	1000	640.47	403.87	387.74	159.29	397.84

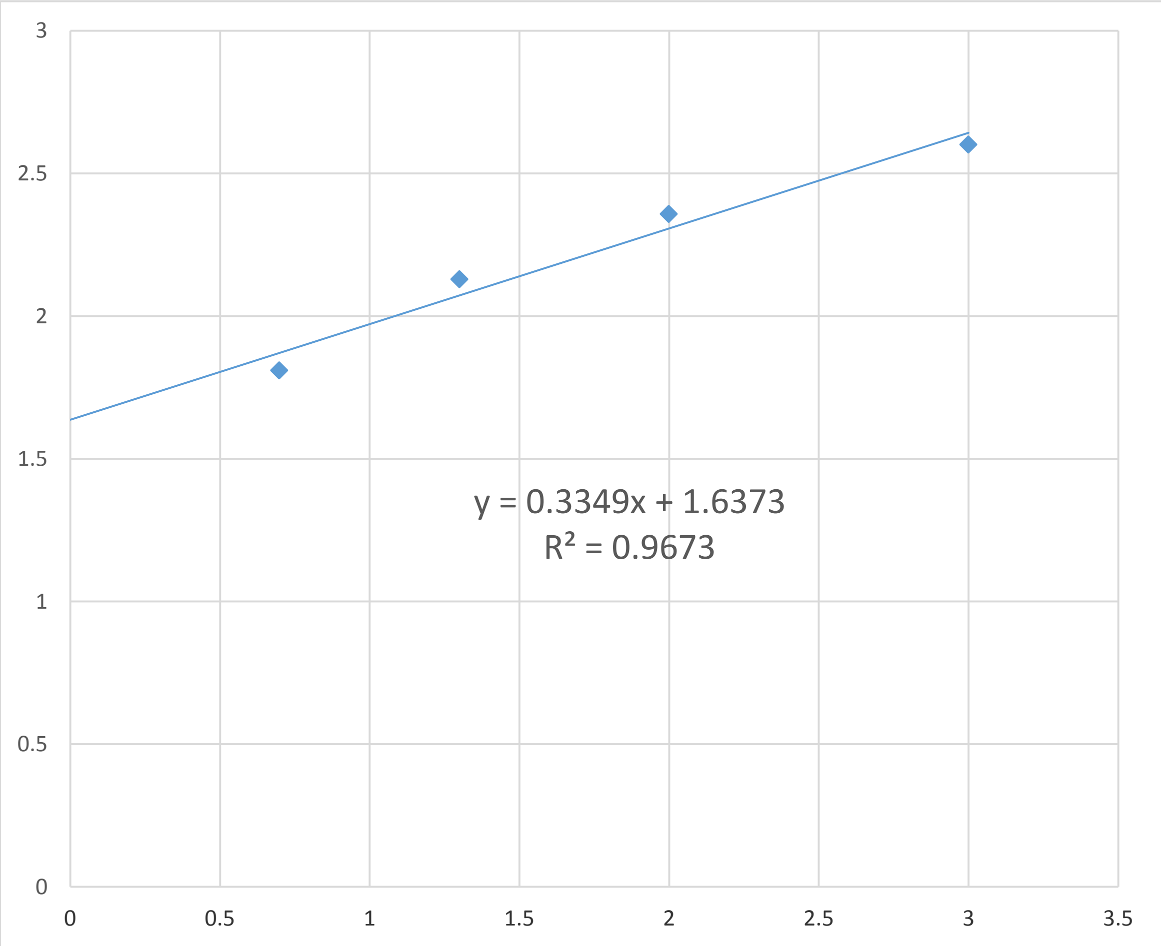


Fig 7. Log Log Total Rainfall Hudiba Station Average of Foster I,III,Hazin and Fuller

Tables 10. Statistical Analysis Total Rainfall Shandi Station

Expected Population	P %age Probability	Years	Foster I	Foster III	Hazin	Fuller	Average
2209122	20	5	122.75	121.75	123.02	116.47	121.00
2886931	5	20	205.42	203.36	210.08	152.44	192.83
12029844	1	100	303.13	293.81	292.02	194.21	270.79
113046820	0.1	1000	454.49	416.68	372.89	253.97	374.51

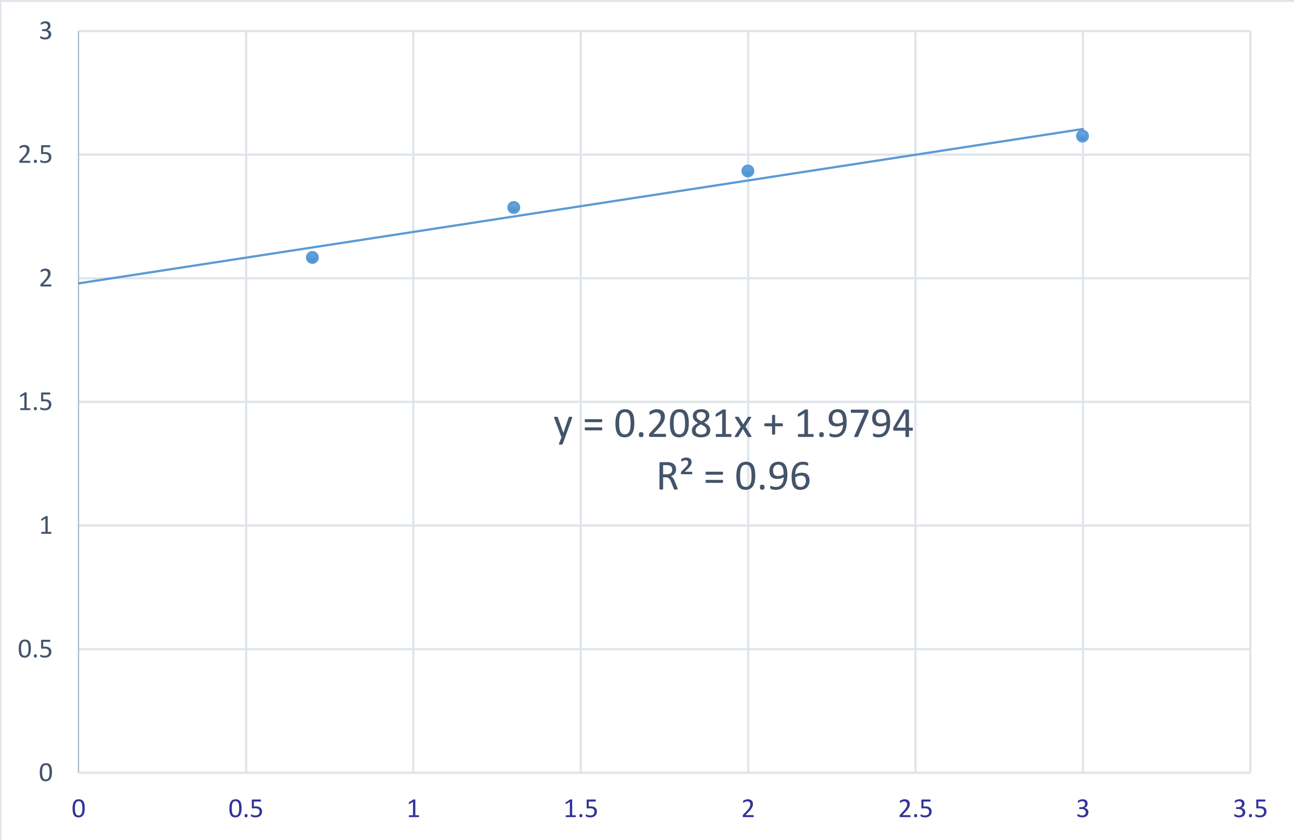


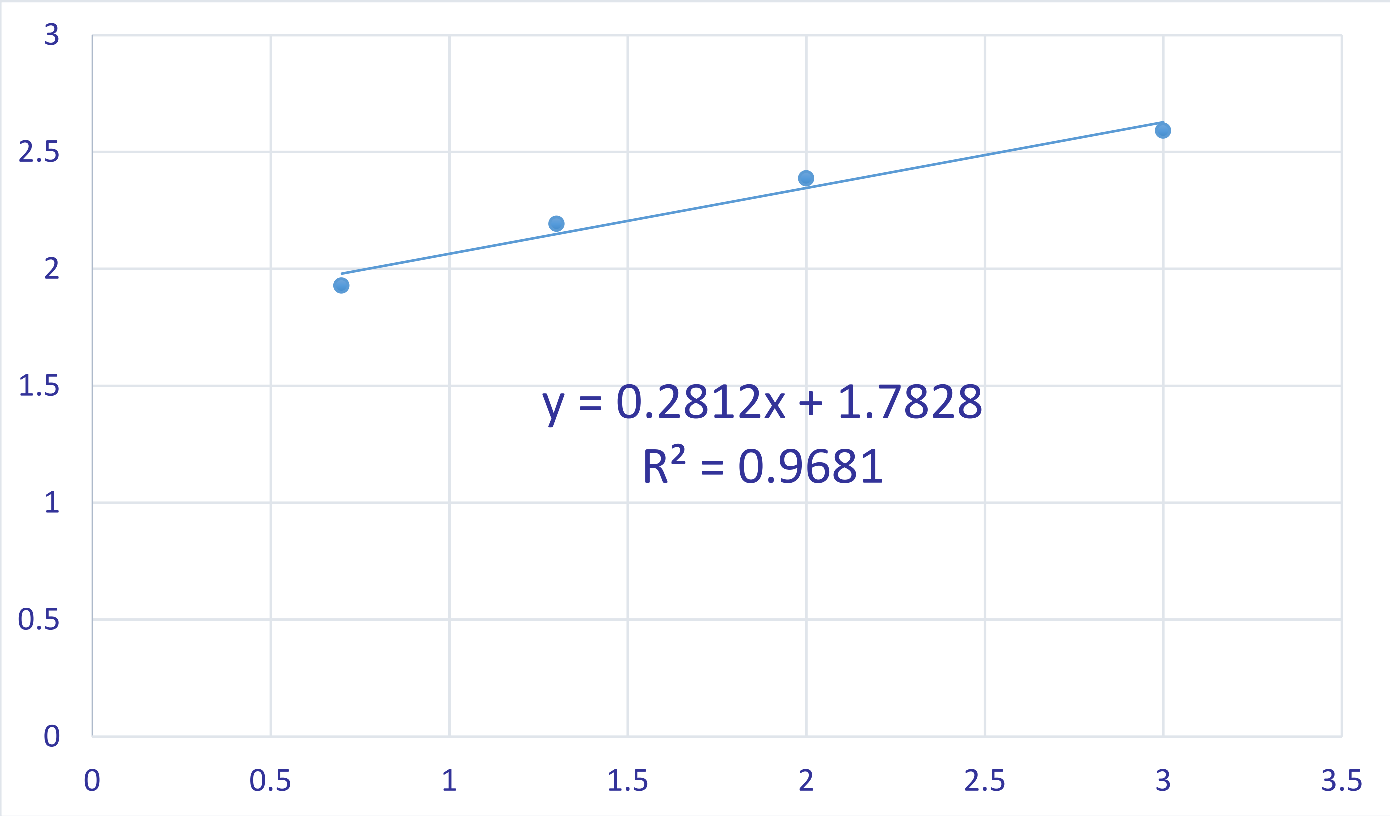
Fig 8. Log Log Total Rainfall Shendi Station Average of Foster I,III,Hazin and Fuller

The rain analysis being part of the first category of the types of water was carried out. It was conventionally referred to as **Integrated Water Resources (IWR)** .The average value of the statistical relevant parameter given as the total rainfall instead of the discharge (Q), was obtained using equation (1).The steps of the analysis conducted the remainder of the other equations, the last one of which was Fuller equation (10).

The application of the statistical analysis leading to the results for rain water in the River Nile State for the three rainfall stations are given in table (11) , and graph in figures (9),together with population growth.

Tables 11 : Statistical Analysis Total Rainfall River Nile State

P %age Probability	20	5	1	0.1	Remark
Expected Total Rainfall	84.76	155.96	244.10	389.85	Average
$T - Recurrence\ Period$	5	20	100	1000	
Expected Population	2209122	2886931	12029844	113046820	



Rainfall Stations.

The application of the statistical analysis led to the results for surface water in the River Nile State. This was obtained by adding the differences in discharges between Tamaniat and Hasanab Stations, to that between Girba and K3 Atbara Stations. Their detailed data are not shown in this paper, but the conducted statistical analysis is shown in table (12), with the total State surface water in figure (10). Beside giving the statistical analysis for the addions of these differences table (12) gave the expected population increase.

Tables 12 : Statistical Analysis Total Surface Water River Nile State

Expected Population	P %age Probability	Years	Foster I	Foster III	Hazin	Fuller	Average
2209122	20	5	25.67	25.51	25.69	30.03	26.72
2886931	5	20	36.41	36.19	37.06	39.31	37.24
12029844	1	100	49.01	47.99	47.72	50.08	48.70
113046820	0.1	1000	68.22	63.98	58.19	65.49	63.97

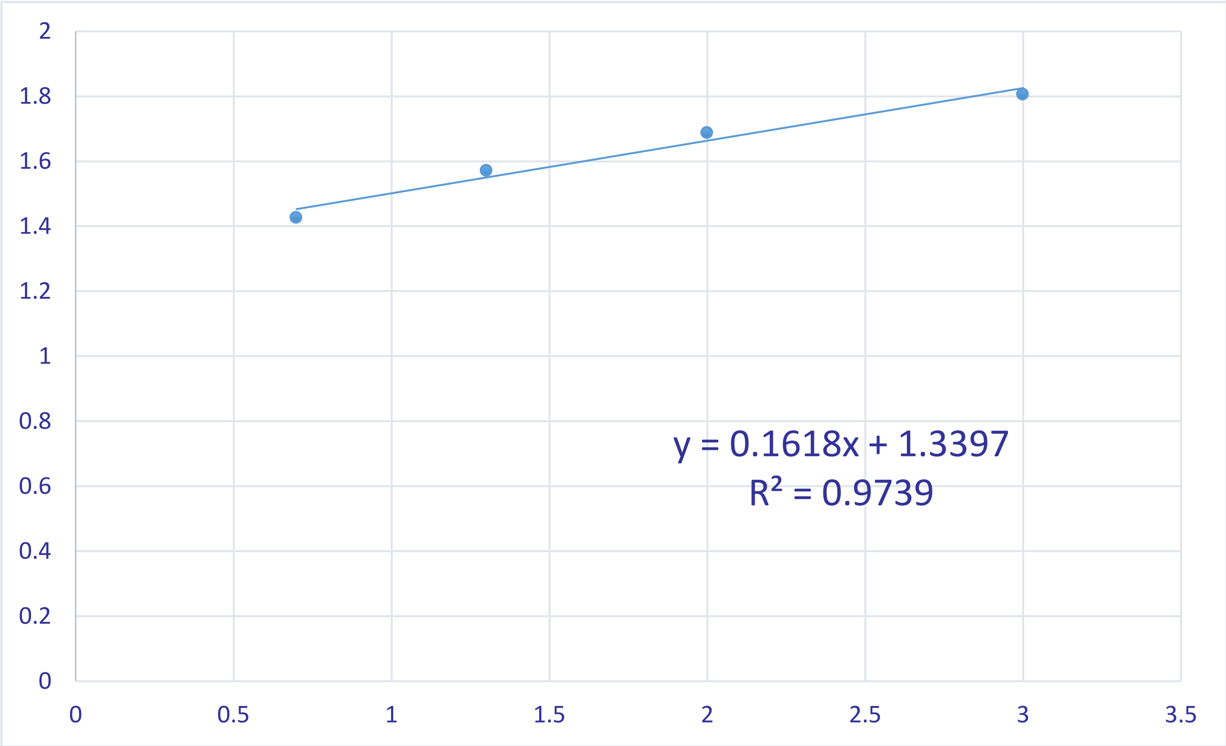


Fig 10. Total Surface Water River Nile State Average

Ground Water :-

The River Nile State underground water is not replenished, while the available ground water is taped from wells. The ground water data is treated in the same way as that of the surface water. There is no recharge occurring in the River Nile State Table (13),shows statistical analysis total ground water in River Nile State, and figure (11),gave the statistical analysis total groundwater in River Nile State

Tables 13 : Statistical Analysis Total Ground Water River Nile State

Expected Population	P %age Probability	Years	Foster I	Foster III	Hazin	Fuller	Average
2209122	20	5	3.18	3.18	3.25	3.46	3.26
2886931	5	20	4.15	4.14	4.16	4.53	4.25
12029844	1	100	5.00	5.01	4.73	5.77	5.13
113046820	0.1	1000	5.99	5.99	5.17	7.54	6.17

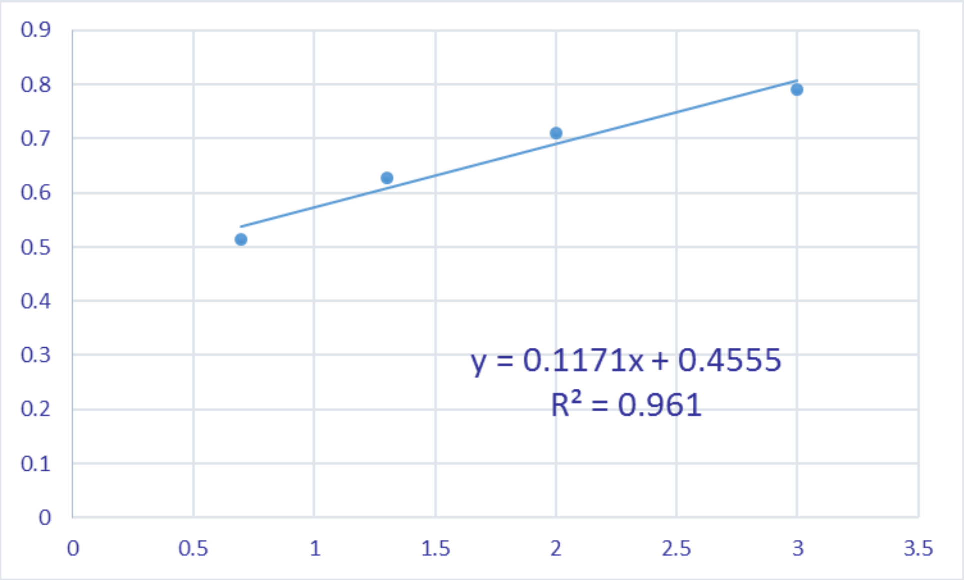


Fig 11. Statistical Analysis Total GroundWater ln River Nile State

- **Estimated Water Resources IWR:-**

It is well known and logical to assume that the consumption of water to be 137.5,137.5 and 1375 liters per person per day respectively in arid and semi arid regions as that of the River Nile State.

According to the above analysis of the three types of water rain, surface and ground, the following calculations are conducted as shown in table (14).

Volume of surface water = area covered by the surface water X water or rain depth. area covered by the surface water as calculated from the field $= 40 \times 10^6\ m^2$

Table 14. Estimated Water ResourcesUsing the Concept of IWR

Item	Recurrent Period	Type of water	Probability %	Quantity m m^3	Population
1	5	Rain Water	20	3.400	2209122
	20		5	6.200	2886931
	100		1	9.760	12029844
	1000		0.01	15.600	113046820
2	5	Surface Water	20	26.72	2209122
	20		5	37.24	2886931
	100		1	48.70	12029844
	1000		0.01	63.97	113046820
3.	5		20	3.26	2209122
	20		5	4.25	2886931
	100		1	5.13	12029844
	1000		0.01	6.17	113046820

Exanimation of table (14) depicts the summary of the total water available within the River Nile State.Table (15),is obtained from table (14) as calculated to obtain the result of **(IWRM)** from the **(IWR)** concept.

Table 15. Result of (IWRM) From (IWR) Concept

Item	Recurrent Period	Probabilty %	Total Quantity Rain + Surface + Ground m m^3	Population	Share per Person m m^3
A.	5	20	33.38	2209122	15.15
B.	20	5	47.69	2886931	16.52
C.	100	1	63.53	12029844	5.30
D.	1000	0.01	85.74	113046820	0.758

It should be clearly stated the surface water included the transboundary that pass to Egypt which is 55.5 *Milliards* per year. Table (14),has a minimum of 26.72 being less than Egypt and a maximum of 85.74 greater than Egypt share, which can be attributed to calculation errors due to incomplete and unreliable data.

IV. CONCLUSION

- ✓ River Nile State has an area equal to about 7 % of the Sudan area with water resources about 50 % of the Sudan water resources.
- ✓ Despite of its vast desert area in the River Nile State yet it is rich in cement industry and gold mining.
- ✓ Atbara River annual discharge yield approach about 14 milliards.
- ✓ After the construction of Tekazi dam the discharge at Girba Gauging Station has an unmeasured increase,the flow became continuous all the year while there was no flow in the perion from February to May.

V. RECOMMENDATIONS

- ✓ Proper management utilization of the River Nile State water resources can reduce desert encroachment enhance cement industries and gold mining.
- ✓ Lack of accurate discharge measurement data in both the main Nile and Atbara River formed a bottle neck against the development of the River Nile State.
- ✓ The increased discharge from Tekazi dam has improved the situation at both New Halfa Scheme especially during May for sugar demand and increasing the potentiality dpownstrean in the River Nile State.
- ✓ Evapotranspiration being greater than effective rain is a problem that requires future research and solution.
- ✓ Considering the population of the River Nile State and the available rain water,surface water and ground water it is apparent that these waters lead to a good comfortablle integrated water resources in the pilot area state.

VI. REFERENCES

[1]. Diana Rizzolio Karyabwite -Water Sharing in the Nile River Valley - UNEP/DEWA/GRID - Geneva -January -March 1999 January-June 2000

[2]. Essam Hassan Mohamed Ahmed PhD Lead Author, Nubian sandstone aquifer system-, August 27, 2013

[3]. Andrew Garth, Analyzing data using SPSS- Sheffield Hallam University, 2008

[4]. Central Bureau of Statistics cbs -Sudan in figurers -2014 source

[5]. Dr: Isam Mohamamed Abd Elmagid-Prof Abbas Abdalla -Hydrology- Published by Sudan Uneversity of science -2002

[6]. H.A.J. Van Lanen, N. Wanders, L.M. Thllaksen, and A.F. Hydrological drought across the world: impact of climate and physical catchment structure- Van Loon-May 2013

Appendix I
Hazen Table

C_s'	%age probability									
	99	95	80	50	20	5	1	0.1	0.01	0.001	0.0001
0	-2.11	-1.64	-0.92	0	0.92	1.64	2.08	2.39	2.53	2.59	2.62
0.2	-1.91	-1.56	-0.93	-0.05	0.89	1.72	2.25	2.66	2.83	2.94	3.00
0.4	-1.75	-1.47	-0.93	-0.09	0.87	1.79	2.42	2.95	3.18	3.35	3.44
0.6	-1.59	-1.38	-0.92	-0.13	0.85	1.85	2.58	3.24	3.59	3.80	3.92
0.8	-1.44	-1.30	-0.91	-0.17	0.83	1.90	2.75	3.55	4.00	4.27	4.34
1.0	-1.30	-1.21	-0.89	-0.21	0.80	1.95	2.92	3.85	4.42	4.75	4.95
1.2	-1.17	-1.12	-0.86	-0.25	0.77	1.99	3.09	4.15	4.83	5.25	5.50
1.4	-1.06	-1.03	-0.83	-0.29	0.73	2.03	3.25	4.45	5.25	5.75	6.05
1.6	-0.96	-0.95	-0.80	-0.32	0.69	2.07	3.40	4.75	5.67	6.25	6.65
1.8	-0.87	-0.87	-0.76	-0.35	0.64	2.10	3.54	5.05	6.08	6.75	7.20
2.0	-0.80	-0.79	-0.71	-0.37	0.58	2.13	3.67	5.35	6.50	7.25	7.80

Foster Table (I)

C_s'	%age probability								
	99	95	80	50	20	5	1	0.1	0.01
0	-2.32	-1.64	-0.84	0	0.84	1.64	2.32	3.09	3.70
0.2	-2.18	-1.59	-0.85	-0.03	0.83	1.71	2.48	3.39	4.20
0.4	-2.04	-1.53	-0.85	-0.06	0.82	1.76	2.64	3.72	4.72
0.6	-1.92	-1.47	-0.85	-0.09	0.81	1.81	2.80	4.08	5.30
0.8	-1.80	-1.41	-0.85	-0.12	0.79	1.86	2.97	4.48	6.00
1.0	-1.68	-1.34	-0.84	-0.15	0.76	1.90	3.15	4.92	6.74
1.2	-1.56	-1.28	-.83	-0.18	0.74	1.94	3.33	5.40	7.66
1.4	-1.46	-1.22	-0.82	-0.20	0.71	1.98	3.50	5.91	8.66
1.6	-1.36	-1.16	-0.81	-0.23	0.67	2.01	3.69	6.48	9.79
1.8	-1.27	-1.10	-0.79	-0.25	0.64	2.03	3.88	7.09	11.00
2.0	-1.19	-1.05	-0.77	-0.27	0.61	2.05	4.07	7.78	12.60
2.2	-1.11	-0.99	-0.75	-0.29	0.57	2.07	4.27	8.54	14.30
2.4	-1.03	-0.94	-0.73	-0.31	0.53	2.08	4.48	9.35	--
2.6	-0.97	-0.89	-0.71	-0.32	0.49	2.09	4.68	10.15	--
2.8	-0.91	-0.84	-0.68	-0.33	0.45	2.09	4.89	11.20	--
3.0	-0.84	-0.79	0.66	-0.34	0.41	2.08	5.11	12.30	--
3.2	-0.78	-0.74	-0.64	-0.35	0.37	2.06	5.35	13.50	--
3.4	-0.73	-0.69	-0.61	-0.36	0.32	2.04	5.58	--	--
3.6	-0.67	-0.65	-0.58	-0.36	0.28	2.02	5.80	--	--
3.8	-0.62	-0.61	-0.55	-0.36	0.23	1.98	6.10	--	--
4.0	-0.58	-0.56	-0.52	-0.36	0.19	1.95	6.50	--	--
4.5	-0.48	-0.47	-0.45	-0.35	0.10	1.79	7.30	--	--
5.0	-0.40	-0.40	-0.39	-0.34	0.00	1.60	8.20	--	--

Foster Table (III)

C_s'	%age probability									
	99	95	80	50	20	5	1	0.1	0.01	0.001	0.0001
0	-2.33	-1.64	-0.84	0	0.84	1.64	2.33	3.09	3.73	4.27	4.76
0.2	-2.18	-1.58	-0.85	-0.03	0.83	1.69	2.48	3.38	4.16	4.84	5.48
0.4	-2.03	-1.51	-0.85	-0.06	0.82	1.74	2.62	3.67	4.60	5.42	6.24
0.6	-1.88	-1.45	-0.86	-0.09	0.80	1.79	2.77	3.96	5.04	6.01	7.02
0.8	-1.74	-1.38	-0.86	-0.13	0.78	1.83	2.90	4.25	5.48	6.61	7.82
1.0	-1.59	-1.31	-0.86	-0.16	0.76	1.87	3.03	4.54	5.92	7.22	8.63
1.2	-1.45	-1.25	-0.85	-0.19	0.74	1.90	3.15	4.82	6.37	7.85	9.45
1.4	-1.32	-1.18	-0.84	-0.22	0.71	1.93	3.28	5.11	6.82	8.50	10.28
1.6	-1.19	-1.11	-0.82	-0.25	0.68	1.96	3.40	5.39	7.28	9.17	11.21
1.8	-1.08	-1.03	-0.80	-0.28	0.61	1.98	3.50	5.66	7.75	9.84	11.96
2.0	-0.99	-0.95	-0.78	-0.31	0.61	2.00	3.60	5.91	8.21	10.51	12.81
2.2	-0.90	-0.89	-.75	-0.33	0.58	2.01	3.70	6.20	--	--	--
2.4	-0.83	-0.82	-0.71	-0.35	0.54	2.01	3.78	6.47	--	--	--
2.6	-0.77	-0.82	-0.68	-0.37	0.51	2.01	3.87	6.73	--	--	--
2.8	-0.71	-0.71	-0.65	-0.38	0.47	2.02	3.95	6.99	--	--	--
3.0	-.67	-.66	-0.62	-0.40	0.42	2.02	4.02	7.25	--	--	--