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South Dar Fur State Integrated Water Resources

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ABSTRACT

To study integrated water resources management South Dar Fur State of Western Sudan was selected. The objective adopted the concept of integrated water resources (IWR) approach. This method required the determination of South Dar Fur 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 South Dar Fur State, to travel parallel with the expected present and future population growth.

Keywords : Resources Mean, Standard Deviations, Coefficients, Skewness.

I. INTRODUCTION

Water is basic for life and economic development. In Mar Del International Conference of 1977, it was recommended that industrial arrangement should ensure development and management of water resources. In the year 2000 Global Water Partnership (GWP) defined IWRM as a process of developed management of water to maximize economic and welfare. Dublin four guiding principles were revealed. **In** the first fresh water was considered as a finite resource, the second water management was based on a participatory approach, the third women role was described as important, and forth water management as 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, were 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 South Dar Fur State. The integration adopted the approach of (**IWR**) which required the determination of South Dar Fur State surface water, rain water and ground water quantitatively and qualitatively in the state. 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.

II. METHODS AND MATERIAL

A. Study Area

The study area is the South Dar Fur State. Figure (1), shows the map of the Sudan including Dar Fur State. South Dar Fur State is connected with high way roads with Khartoum Town and Port Sudan Town. South Dar Fur State is suffering from drought due to the desert forming most of its area. South Dar Fur State is located between longitudes 12.00,12.04 N and latitudes 24.50, 24.57 E. The total area of fertile land or arable land in South Dar Fur State is estimated as 125 thousand feddans.

South Dar Fur State is located between longitudes. In the South Dar Fur State rainfall is erratic variable and not reliable. South Dar Fur State cultivates many crops, such as beans millet, ground nut, and sorghum.

Water sources in the South Dar Fur State are mainly from Wadies one of which is Wadi Nyala.

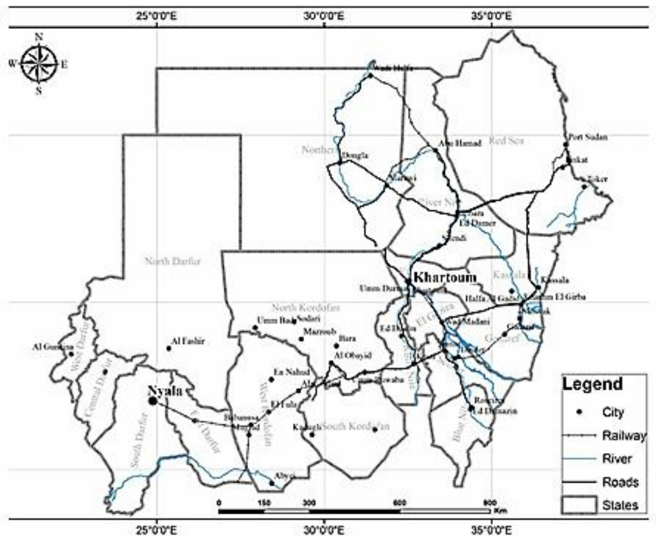

Fig. No. (1): Map of Sudan With South Dar Fur State

B. Methodology

The study area included South Dar Fur State its rural and urban areas in the vicinity of Wadi Nyala. It included metrological stations, population, geology and demography of the South Dar Fur State. It covered water resources, and geographic information system in the South Dar Fur State. The data considered precipitation, ground water, flood water, population, temperature variation, evapotranspiration and recharge the population of South Dar Fur State increased continuously with a constant rate of 10 % back to 9 %. South Dar Fur State depends on wadies including Wadi Nyala as a source of water; with its cities and villages spread along their banks. South Dar Fur State has great potentials of water that is not exploited. The state is the one that has the greatest area of desertification in the Sudan. The main required data to be collected in IWM consisted of domestic, industrial and agricultural water supply. 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 South Dar Fur State was tested according to the Sudan by laws and WHO and was perfectly suitable for use.

C.Data Collection and Analysis

Suitable programs were used to analyise the data obtained from the local and federal Government. Modeling was essential which led to the achievements of the research specific objectives. The achievements included qualitative determination of domestic and industrial water together with agricultural water in the state. It was possible to be used revealing capacity building needed to technical staff to develop the area of South Dar Fur 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 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) are that it can find both means and medians. It can also graph data on a box plot, showing both level and spread indicating any outliers. Furthermore, 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 South Dar Fur State. There was a noticed population steady increase since 2006 to date. From 2018 and future the increase is steady at the rate of 10 % then 9 %, being suitable and logical with the existing circumstances of accepted new resolution and peace.

Table No. (1): Population in South Dar Fur.

Year	Total Population Thousand	Population Growth %
2006	335	-
2013	4.65	13
2018	1522	To date.10
2023	2341	9
2025	2782	9
2028	4281	9
2033	6588	9

To improve and develop the South Dar Fur State it was found vitally necessary to use the available cultivable land properly. The people low agricultural income must be encouraged by the local and central federal governments 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 South Dar Fur State, 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 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 (I), 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 mm./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 (2)

Table No. (2) : Discharge for Recurrence Period Foster (I)

	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	$T recurrence - period$	5	20	100	1000

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

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

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.

Relation Concept Among The Three Water Resources Quality :

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

Rainwater Analysis: -

The rainfall in South Dar Fur State is always in the months June July, and August in every year, but it is little and limited. It is characterized by being unstable because sometimes it has a wide range. South Dar Fur 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 South Dar Fur and Wadi Nyala and its Hafeirs in the area.

There is painful incomplete groundwater recharge resulting from short rainfall period. However, despite of this fact there are about forty-eight 48 years of records. Table (3) presents South Dar Fur rain water data, and table (4): presents South Dar Fur State statistical analysis total rain water.

Table No. (3) : Rainfall In South Dar Fur State1971 – 2017 Millionm3

Year	Discharge	Year	Discharge	Year	Discharge
1971	30.375	1988	29.808	2004	54.837
1972	28.188	1989	29.322	2005	47.385
1973	29.322	1990	31.509	2006	45.117
1974	32.886	1991	31.185	2007	45.603
1975	33.453	1992	32.724	2008	43.983
1976	25.191	1993	30.861	2009	50.625
1977	31.023	1994	30.456	2010	56.214
1978	38.880	1995	36.207	2011	59.292
1979	25.758	1996	39.366	2012	67.230
1980	43.173	1997	44.712	2013	54.918
1981	27.459	1998	44.712	2014	35.235
1982	22.032	1999	46.413	2015	50.139
1983	26.487	2000	38.232	2016	48.762
1984	15.957	2001	38.799	2017	60.102
1985	28.512	2002	48.843		
1986	28.512	2003	57.672		
1987	22.680	2001	38.799		

Tables No. (4) : Statistical Analysis Total Rainwater Average

Population Million	P %age Probability	Years	Foster I	Foster III	Hazin	Fuller	Average
2341	20	5	48.80	48.18	48.80	60.34	51.53
4281	10	10	56.73	55.54	56.74	69.66	59.67
6588	6.7	15	58.71	58.13	58.71	75.12	62.67

5.3.2. Surface Water: -

Data collected from the five location in Wadi Nyala Basin is collected as surface water in the study area. Measurements were taken during some years. This water is also an important part of the first category of the types of water resources which is clearly referred to as **Water Resources Quality. The** analysis details are presented in the following steps. Table (9) present the total annual discharge average annual Wadi Nyala runoff. It is taken collected from five locations for a period of twenty-nine (29) years. Table (5) presents South Dar Fur surface water data, and table (6): presents South Dar Fur State statistical analysis total surface water.

Table No. (5): Average Annual Dar Fur State Surface Water Million (m3)

Year	Total discharge	Year	Total discharge	Year	Total discharge	Year	Total discharge
1977	105.53	1984	17.65	1991	0.001	2002	15.94
1978	78.73	1985	92.01	1995	122.02	2003	166.49
1979	65.86	1986	0.57	1996	59.72	2004	144.98
1980	29.17	1987	31.08	1997	141.31	2005	85.49
1981	64.14	1988	80.05	1998	186.09	2006	144.96
1982	44.54	1989	18.11	1999	150.08	2007	69.45
1983	58.27	1990	57.71	2000	57.71	2008	51.34
						2009	50.17

Tables No. (6): Statistical Analysis Total Surface Water Average

Population Million	P %age Probability	Years	Foster I	Foster III	Hazin	Fuller	Average
2341	20	5	116.78	115.72	118.29	117.70	117.12
4281	10	10	150.90	149.92	154.97	135.88	147.92
6588	6.7	15	162.60	161.62	165.17	146.51	156.98

5.3.3. Ground Water: -

The available recorded data about ground water in South Dar Fur State is from wells. No data was found about aquifers. The wells data being the only data available is taken as the ground water in South Dar Fur State.

South Dar Fur State number of wells is unknown; however, it is known that they are located in six locations. This water is also an important part of the first category of the types of water resources which is clearly referred to as **Water Resources Quality. The** analysis details are presented in table (15) as the total annual discharge average annual pumped and replenished wells water, taken from groundwater of South Dar Fur State. The recorded period was only ten (10) years. Table (7) presents South Dar Fur ground water data, and table (8): presents South Dar Fur State statistical analysis total ground water.

Table No. (7): Average Annual Dar Fur State Ground Water Milliards/Year

Year	Yield	Year	Yield
1971	4.25736	1978	2.55736
1972	4.257036	1983	13.83642
1973	6.74082	1987	5.3217
1974	6.03126	1990	3.5478
1977	13.0086	1991	2.55736

Tables No. (8): Statistical Analysis Total Ground Water Average

Population Million	P %age Probability	Years	Foster I	Foster III	Hazin	Fuller	Average
2341	20	5	9.46	8.68	8.92	9.68	9.19
4281	10	10	12,18	12.41	12.73	11.18	12.13
6588	6.7	15	13.10	13.60	14.03	12.05	13.20

Estimated Water Resources IWR: -

It is assumed that the consumption of water to be 150,150 and 1500 liters per person per day used in domestic industrial and irrigation or agricultural purposes respectively. It is logical reasonable and economical in arid and semi arid regions as that of South Dar Fur State. According to the above analysis of the three types of water rain, surface and ground, the following calculations were conducted in table (9). Volume of surface water should equal the area covered by the surface water multiplied by water or rain average depth in the area covered by the surface water as calculated from the field.However.in this study it calculated as the summation of the volumes obtained from the available local data.

Table No. (9): Estimated Water Resources Using The Concept of IWR

Item	Recurrent Period	Type of water	Probability %	Quantity m m^3	Population
1	5	Rain Water	20	51.53	2341
	10		10	59.67	4281
	15		6.7	62.67	6588
2	5	Surface Water	20	117.12	2341
	10		10	147.92	4281
	15		6.7	156.98	6588
3.	5	Ground Water	20	9.19	2341
	10		10	12.13	4281
	15		6.7	13.20	6588

Exanimation of table (9) depicts the summary of the total water available within South Dar Fur State. Table (10), is obtained from table (9) as calculated to obtain the result of **(IWRM)** from the **(IWR)** concept.

Table No. (10): Result of (IWRM) From (IWR) Concept

Item	Recurrent Period	Probability %	Total Quantity Rain + Surface + Ground m m^3	Population	Share per Person m m^3
A. 1	5	20	177.84	2341	75.97
B. 2	10	10	219.72	4281	51.32
C. 3	15	6.7	232,85	6588	35.34

It is clearly revealed that South Dar Fur State according to the available analyzed data is poor in water resources. An effort has to be endeavored by the working staff stakeholder to promate the existing situation in South Dar Fur. It is important to refer to figure (2). Sow in appendix (G) from which is detected

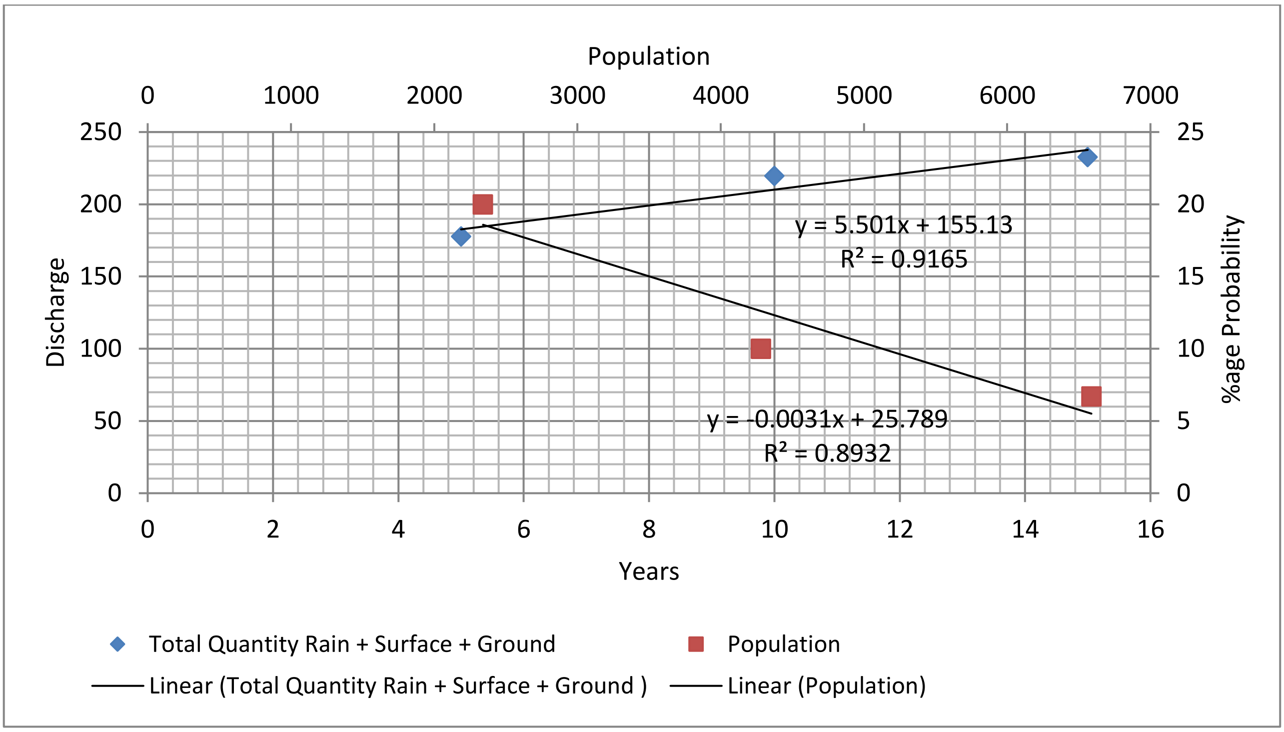

Fig.No.(2): Presentation of South Dar Fur State Water Scarcity

IV.CONCLUSION

- South Dar Fur State has 70 % 0f the Sudan total area.
- South Dar Fur State is suffering water shortage.
- South Dar Fur is very poor in minerals and industry resources, especially in cement and gold.
- Wadi Nyala annual discharge yield approach about 14 milliards, approximately about 17 % of all South Dar Fur Wadies flows.

V. RECOMMENDATIONS

- Proper management utilization of South Dar Fur State water resources can be directed to reduce desert encroachment enhance industries including gold mining.
- Lack of discharge measurement data in both Wadi Nyala and South Dar Fur State other wadies formed a bottle neck against the development of the South Dar Fur State.
- During the collection of the data it became clear that more effort must be exercised to obtain reliable data to obtain reliable results.

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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)

%age probability

C_s'	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	--	--	--

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