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Research Article

STATISTICAL ANALYSIS, TIME TENDENCIES OF REAL EVAPOTRANSPIRATION AND DIAGNOSTIC OF A FUNCTIONAL RELATIONSHIP BETWEEN INSOLATION AND EVAPOTRANSPIRATION. CASE OF NDJAMENA-CHAD. PERIOD FROM 1986 TO 2010

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Abstract

This work particularly concerns statistical distribution and time tendencies of the evapotranspiration in Ndjamena and surroundings for the period from 1951 to 2010 included. As solar radiation is the main cause of the evapotranspiration and keeping in mind that Chad and particularly Ndjamena are closer to the desert of Sahara, the authors at first have paid their attention to the insolation, e.i. the duration of the solar radiation on the earth surface which, measured using the heliograph Campbell-Stokes. Concerning the evapotranspiration, it is usually estimated by empirical formulas elaborated for some specific zones. Moreover, these formulas need information on some atmospheric parameters which are not currently measured in many meteorological stations, particularly in developing countries. Thus, in this paper was analyzed real evapotranspiration measured with the bac of evapotranspiration installed according to the World Meteorological Organization prescriptions. The authors have diagnosed a relationship between insolation and evapotranspiration. It would enable users to faster estimate the second parameter knowing the first as it is measured in almost all the meteorological stations. To do the study, 1951-2010 was divided into five years sub periods. In each one, monthly means and standard deviation were calculated, corresponding values in other sub periods were compared between themselves. This permitted us to analyze their statistical distribution and to deduce their time trends. According to the analysis, the main results were that highest values of both parameters were registered during the dry season, particularly in March-April, and lowest values – in the rainy season, mostly in August. The values of insolation were dispatched closer their mathematical means than what was observed for the evapotranspiration. For the moment, establishing a relationship between the two parameters seems to be difficult as all requested information is not yet available. Effort should be done to complete the bank off data with missing one.

Keywords: Solar radiation, Insolation, Evapotranspiration, Statistical distribution, Time trend.

INTRODUCTION

Evapotranspiration combines two natural phenomena which play a very important role in our daily activities. They are evaporation of water from the soil and the loss of water through transpiration by plants. Separating one phenomenon from another is practically impossible. Consequently, both are always taken together. Note that evaporated water can come from the depth of ground as well as from the earth surface. In general, water in the soil and plants comes from the rain. The first is infiltrated into the ground. The second is carried by different fluxes from the soil to the roots of plants in the soil. The quantities and intensities of water infiltrated into the ground depends on the quality and texture of the soil. For Ndjamena, the quality of its soil is not favorable for the infiltration of water. Therefore, important quantities of rain water are accumulated on the earth surface. Moreover, Chad is a Sahelian country. Thus, the influence of the desert of Sahara is very important all over the country. The solar radiation is very intensive and their impacts on the environment included the vegetations very important. When the solar radiation increases, the evaporation and quantities of water lost by the soil also increase. Similar phenomenon is observed with the transpiration ofvegetations over the land. Few methods have been elaborated to estimate at once both components, whence the terminology: Evapotranspiration which takes into account evaporation from the soil and transpiration from the vegetations. The present paper investigates these combined phenomena. Estimating the evapotranspiration need sufficient long chronological data on specific atmospheric parameters some of which are not usually observed in many meteorological stations, particularly in developing countries. This absence of data makes such investigations practically impossible. Chad belongs to them. Moreover, existing methods are empirical and applicable only for some geographic zones. Extending them to other localities is not very recommended. It is then clear that each zone should develop its proper methods of estimation evapotranspiration. It is clear that evapotranspiration is firmly linked to solar radiation. Thus, there should exist a relationship between the two phenomena. Clarification of their statistical distribution and time trends and finding out their relationship are the goals of the present work. Our study should be divided into two main parts. The first and present one concerns the statistical distribution and time trends of these phenomena. For this locality, this investigation could be classified among the firsts on this domain. Because of the lack of data, the second part, establishment of the relationship, should be carried later. Very few of such investigations have been recently done for Ndjamena. These ones be indicated. Some preliminary methods of estimating the soil water reserve in Ndjamena has been done, (Njipouakouyou *et al.,* July 2017). The periods of agricultural activities in Ndjamena based on the estimation of the soil water reserve have been determined, (Njipouakouyou *et al.,* September 2017). Statistical analysis, time tendencies and eventual relationship between insolation

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and evapotranspiration has been investigated for Ndjamena for the period from 1986 to 2010, (Abdelkerim, 2023). All these works should be considered as preliminaries and must be completed. Obviously, without sufficient quantities of soil water reserve, agricultural activities are practically impossible. There must be a certain amount of water in the soil for the agriculture to be prosperous. No doubt that these amounts depend on the agricultural species. Some of them need much water, others–less. It is understandable that this investigation will bring a considerable contribution in solving one of the more important and actual problems of the human beings: the hunger. Whence its importance. This work is structured into five parts. The first and present one introduces the problematic of the investigation. The second one presents and comments the chronological data. It also exposes the methodology used for their treatment. The results and their analysis are in the third part. The conclusion and some recommendations are contained the fourth part while the references in alphabetical order are found in fifth.

DATA AND METHODOLOGY

Data

Our data covers the period from 1986 to 2010 included. It was registered at the international airport of Ndjamena. As an international airport where many kinds of airliners land and take off every day, flights should be well secured. Thus, its meteorological station should be well equipped with modern instruments andits personnel - well trained. Chad, a Sahelian country, is situated almost at the center of Africa. Ndjamena, its political capital and main city, is in the south-west, on one bank of the Logone river. The country is limited in the north with Libya, in the east with Sudan, in the south with Central African Republic in its eastern part and Cameroon in its western part, in the west with Nigeria in its southern part and Niger in its northern part.

These data were obtained using the heliograph Campbell Stokesfor the duration of solar radiation, insolation, and a standard vessel, bac of evapotranspiration, according to the World Meteorological Organization. All these instruments were installed according to the international norms and prescriptions. Thus, our data should be considered as representative. They are not primary ones, but already treated and presented in tabular forms as monthly average daily durations of solar radiation and monthly amounts of evapotranspiration. Because these values were observed and not calculated by one of the empirical formulas, it is clear that our investigation is on real evapotranspiration. These data are respectively presented in Tables 1 and 2.

Because of the geographic situation of Chad, the solar activities allover the country should be intensive and consequently the evapotranspiration, too. Moreover, because of the desert around, the amount of the atmospheric humidity should be low, meaning that the atmosphere should be always ready to receive new quantities of water vapor from the evapotranspiration.

Methodology

The whole period of investigation was divided into five equal sub periods of five years each noted P_i, i=1, 2, 3, 4 and 5. For each parameter and each sub period average amounts and corresponding standard deviations were determined. This enabled us to investigate their time trends and variabilities. This has also enabled us to find out the periods when these phenomena were very active, and inversely. Based on these knowledges, inhabitants should be aware of the periods of soil dryness to get themselves ready for irrigation.

RESULTS AND THEIR ANALYSIS

These results are in tabular forms as presented below.

Tableau 1. Average daily duration of solar radiation over the earth surface. Period from 1986 to 2010

Average durations of solar radiation over the earth surface (in hours/day) in Ndjamena												
1986	Jan	Feb	Marc	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly means
1987	10	9.6	8.2	9.1	10.1	9	8.6	6.4	8.6	9.4	10	9.6	9.1
1988	8.9	9.7	8.9	**	8.4	8.6	6.7	5.4	6.6	9.9	10.2	8.8	8.4
1989	10	10	9.9	10	7.6	8.9	6.9	7.4	7.4	9.5	10	9.6	8.9
1990	9.4	9.8	9.9	10.1	9.8	9.1	5.6	8.5	8.2	9.1	9.3	9.2	9
1991	9.8	10	8.9	8.6	6.6	9	7.3	6.4	8.8	8.9	9.8	9.3	8.6
1992	8.8	9.6	7.3	6.5	7.3	7.1	5.8	4.6	7.4	9.8	9.4	10	7.8
1993	9.5	10	8.9	9	9.3	9	7.4	7.4	7.6	9.4	9.9	9.7	8.9
1994	9.5	9.3	10.2	7.8	9.7	8.8	7.2	6	7.6	9.2	10.2	9.8	8.8
1995	9.7	10.3	9.1	8.6	9.7	8.7	7.2	6.5	8.3	8.9	10.1	10.5	9.0
1996	10.3	10.1	8.8	9.3	9.1	8.8	7.7	7.2	6.9	9.1	10.2	10.3	9.0
1997	**	9.4	8.5	7.6	8.8	7.3	7.5	7.3	7.9	8	9.6	9.8	8.3
1998	9.6	9.5	8.7	9.1	9.4	8.5	5.8	5.7	6.8	9.2	10	9.8	8.5
1999	10.1	9.8	10.4	9.9	8.8	9.1	6.1	6.9	6.4	8.8	9.9	10.3	8.9
2000	10.1	9.8	10.1	10.2	10	9.3	7	7.5	8.4	9	10.5	10.1	9.3
2001	10.5	9.7	10.2	9.1	9.1	7.4	7.1	6.1	8.3	9.8	10.7	10.5	9.0
2002	9.8	9.6	9.1	9.1	10	8	7.1	7.2	7.9	8.7	9.8	10.3	8.9
2003	10.2	9.7	8.7	8.6	9.4	8.1	7.2	5.7	7.8	9.1	9.9	9.6	8.7
2004	9.3	9.6	8.7	9.8	9.2	7.9	6.9	6.7	8.5	9.1	10	9.9	8.8
2005	9.1	8.9	8.3	8.1	7.6	6.8	7.4	7.1	7.6	9.5	10.4	10.2	8.4
2006	9.9	9.5	7.9	9.6	7.5	8.1	7.9	6.2	6.6	9.1	10.1	10.3	8.6
2007	9.7	10	9.6	8.6	7.7	**	**	5.4	7.3	9.9	10.1	10.1	8.8
2008	9.5	**	9.9	7.5	9.6	8.7	8.2	5.9	6.6	9.1	10.3	10	8.7
2009	9.6	9.5	8.6	7.3	8.1	8.1	7.4	6.3	8.1	7.7	9.7	10.4	8.4
2010	10.2	10.1	8	8.7	8.7	7.5	5.5	5.9	7.4	8.5	10.2	10.3	8.4

Table 2. Monthly amounts of evapotranspiration (in mm/month) in Ndjamena. Period from 1986 to 2010

Years	Jan	Feb	Marc	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Yearly sums
1986	292.7	374.8	475.4	493.6	437.8	347.9	242.7	205.8	**	285.6	306.6	303.2	3766.1
1987	331.6	**	456.5	580.2	473.3	289.4	295.3	184.7	235.7	354.9	353.3	346.7	3901.6
1988	328.2	394.4	531.2	463.7	408.3	286.9	228.3	142.9	161.8	253.4	297.7	312.2	3809
1989	358.1	406.4	524.7	429.3	381.8	317.9	219.4	156.1	**	303.9	**	327.2	3424.8
1990	401.3	416.9	572.5	477.5	432.9	369.3	236.7	209.3	251.8	395.6	393	**	4156.8
1991	411.7	**	494.7	**	300.2	310.1	225.1	148.9	198.1	283.1	353.6	340.6	3066.1
1992	337.6	452	495.3	471.3	385.3	358.3	212.2	133.6	180.3	253.9	345.6	333.8	3959.2
1993	370.1	364.6	490.3	420.2	370.6	309.9	250.4	210.1	194.8	311.9	349.9	341.5	3984.3
1994	346.5	399.8	553.6	408.2	430.6	358.2	220.5	162.1	170.3	243	324.7	328.9	3946.4
1995	314.4	379.2	502.6	444.2	402.5	345.2	277.1	174.6	188.4	250.8	340.3	343.5	3962.8
1996	355.5	417.3	540.8	464.2	385.1	331.7	280	206.1	187.2	285.2	376.8	341.5	4171.4
1997	389.4	434.8	529.9	406.1	385.4	289.8	225.5	187.1	249	274.5	362	356.7	4090.2
1998	401	467.2	556.9	513.6	473.6	355.3	**	156	169.6	274.8	371	339.9	4078.9
1999	332.7	373.7	495.9	527.9	419	355.7	207.1	176.8	159.8	251.6	352.1	330.1	3982.4
2000	386.2	400.6	531.7	463.3	445.5	319.1	214.6	149.6	209.9	280.7	393.3	349.9	4144.4
2001	359.3	370.8	520.8	446.1	407.8	278.2	239.1	153.8	168.8	306.8	351.3	344.8	3947.6
2002	337.2	355.4	498.6	443	453.5	335.4	263.5	166.2	203.3	255.1	327.9	346.7	3985.8
2003	244.6	272.1	376.1	377.5	426.3	178.4	130.1	62.6	74.5	162.1	273.8	274.4	2852.5
2004	347.5	419.1	547.3	477.2	383.4	321.5	230.8	181.8	231.6	321	363.4	332.7	4157.3
2005	348.9	431.3	582	511.6	439.4	297.9	218.8	161.1	176	276.9	336.1	322.7	4102.7
2006	335.1	346.5	488.5	487.3	349.9	305.5	258.4	166.2	166.5	263.7	340.9	317.6	3826.1
2007	362.4	386.7	504.1	426.9	399.6	335	244.1	157.6	181.7	281.4	351.6	360.6	3991.7
2008	326.6	**	519.1	431.8	387	334.1	243	170.9	179.9	310.9	355.1	323.8	3582.2
2009	341.8	397.6	501.5	360.5	366.6	350.7	**	200.2	215.7	267	316.3	339.3	3657.2
2010	331.7	391.4	463.4	464.6	416.8	324.6	237.5	169.6	191.7	255.2	332.3	331.7	3910.5
2011	352.4	392.8	535.5	520	419.9	326.6	250.3	212.9	219.4	279.6	322.9	349.2	4181.5

Table 3. Sub period cumulative daily means duration of solar radiation, h, daily mean durations, $\bar{h}$, and corresponding standard deviations, s. Period from 1986 to 2010

P_i	Par	Jan	Feb	Mar	April	May	June	July.	Aug	Sept.	Oct.	Nov.	Dec.	Y.M.
P_1	h	48.1	48.8	45.6	48.8	45.0	44.4	34.4	34.5	38.8	47.5	49.1	46.0	44.2
	$\bar{h}$	9.6	9.8	9.1	9.8	9.0	8.9	6.9	6.9	7.8	9.5	9.8	8.8	8.8
	s	0.5	0.2	0.8	0.4	1.0	0.2	1.1	1.2	0.8	0.3	0.4	0.3	0.3
P_2	h	47.3	49.2	44.4	40.5	42.6	42.6	34.9	30.9	39.7	46.2	49.4	43.1	43.1
	$\bar{h}$	9.5	9.8	8.9	8.1	8.5	8.5	7.0	6.2	7.9	9.2	9.9	8.6	8.6
	s	0.4	0.4	1.0	1.0	1.5	0.8	0.7	1.0	0.6	0.4	0.3	0.5	0.5
P_3	h	50.1	48.6	46.5	46.1	46.1	43.0	34.1	34.6	36.4	44.1	50.5	44.0	44.0
	$\bar{h}$	10.0	9.7	9.3	9.2	9.2	8.6	6.8	6.9	7.3	8.8	10.0	8.8	8.8
	s	0.3	0.3	0.9	1.0	0.5	0.8	0.8	0.7	0.8	0.5	0.3	0.4	0.4
P_4	h	48.9	47.5	45.0	44.7	45.3	38.2	35.7	32.8	40.1	46.2	50.3	43.8	43.8
	$\bar{h}$	9.8	9.5	9.0	8.9	9.1	7.6	7.1	6.6	8.0	9.2	10.2	8.8	8.8
	s	0.6	0.3	0.7	0.6	0.9	0.5	0.2	0.6	0.4	0.4	0.4	0.2	0.2
P_5	h	48.9	48.9	44.0	41.7	41.6	40.8	37.1	29.7	36.0	44.3	50.4	42.9	42.9
	$\bar{h}$	9.8	9.8	8.8	8.3	8.3	8.2	7.4	5.9	7.2	8.9	10.1	8.6	8.6
	s	0.3	0.3	0.9	0.9	0.8	0.4	1.1	0.4	0.6	0.8	0.2	0.2	0.2
P	h	243.3	243.0	225.5	221.8	220.6	209.0	176.2	162.5	191.0	228.2	250.2	218.0	218.0
	$\bar{h}$	48.7	48.6	45.1	44.4	44.1	41.8	35.2	32.2	38.2	45.6	50.0	43.6	43.6
		(9.7)	(9.7)	(9.0)	(8.9)	(8.8)	(8.4)	(7.0)	(6.5)	(7.6)	(9.1)	(10.0)	(9.5)	(8.7)
	s	1.0	0.7	1.0	3.3	1.9	2.4	1.2	2.2	1.9	1.5	0.7	0.6	0.6

Table 3. Shows sub period cumulative daily means duration, h, of solar radiation (in hours/(sub period)), daily mean durations, $\bar{h}$, of solar radiation in a sub period (in hours/day) and corresponding standard deviations, s, relatively to the sub period (in hours/(sub period)). Recall that in table 3., P_i stands for the sub periods, Par-for the parameters and MY.- for the yearly means. From this table, it comes that the sub period cumulative daily mean durations of solar radiation in Ndjamena and surroundings were included in the intervals: 34.4-48.8 hours for the first sub period, 30.9-49.4 hours for the second sub period, 34.1- 50.5 hours for the third sub period, 32.8-50.3 hours for the fourth sub period, 29.7-50.4 hours for the fifth sub period. For the whole period cumulative daily mean durations of solar radiation in the city varied in the interval from 162.5 to 250.2 hours, conferred the last rows under indication P. Table 3. also indicates that the daily longest durations of solar radiation in Ndjamena and surroundings were observed during the dry season, i.e. from January to June and from November to December.

This is due to the fact that by this time the sky is almost cloudless while in the remaining period of the year, rainy season, a lot of clouds from surrounding geographical regions in the sky block important parts the solar radiation to reach the earth surface. Moreover, it comes from Table 3. that the duration of solar radiation on the earth surface is a less variable parameter. This is due to the fact that their corresponding standard deviations were almost one order less than the main values and less than one hour. Dividing the insolation into intervals of equal length of five hours led to the next table of distribution, conferred Table 4. From Table 4, it comes that the most frequent sub period average durations of solar radiation in Ndjamena and surroundings were included in the interval from 40.0 to 50.0 hours. It also indicates the time variability of this parameter which was slowly decreasing from interval 45.0-50.0 to 40.0-45.0 hours per sub period. This tendency was probably due to the growth of the atmospheric pollution in the city due to the high increase of demography, vehicles and other engines and also the intensive destruction of the environment.

Table 3.2. Distribution per intervals of the sub period cumulative means duration of solar radiation in Ndjamena. Period from 1986 to 2010

Sub periods	[25.0,30.0[	[30.0,35.0[	[35.0,40.0[	[40.0,45.0[	[45.0,50.0[	[50.0,55.0[	years
P_1	0	2	1	1	8	0	1986-1990
P_2	0	2	1	5	4	0	1991-1995
P_3	0	2	1	3	4	2	1996-2000
P_4	0	1	2	3	5	1	2001-2005
P_5	1	0	2	6	2	1	2006-2010

Table 3.3.Sub period cumulative monthly means of evapotranspiration, ET, monthly means of evapotranspiration,$\overline{(ET)}$, and corresponding standard deviations, s. Period from 1986 to 2010

P_i	Parameters	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Yearly cumul
P_1	ET	1711.9	1977.1	2506.3	2444.3	2134	1611	1224.4	1222.4	1054.9	1593.4	1696	1623.2	19058.3
	$\overline{ET}$	342.4	395.4	512.1	488.9	426.8	322.2	244.5	244.5	211	318.7	338.2	324.6	3811.7
	s	40.3	16.8	46.4	56.3	34.2	36.1	29.7	29.7	34.9	56.6	38.5	17.3	264.1
P_2	ET	1780.3	2030.1	2536.5	2218.3	1889.2	1681	1185.3	830	931.9	1342.7	1714.1	1688.3	18918.8
	$\overline{ET}$	356.1	406	507.3	443.7	377.8	336.2	237.1	166	186.4	268.5	342.8	337.7	3783.8
	s	36.9	36.7	26.3	29.7	48.8	24.5	26.5	28.9	11.3	28.6	11.3	6.1	401.4
P_3	ET	1864.8	2093.6	2655.2	2375.1	2108.6	1652	1143.5	876	975.5	1366.8	1855.2	1718.1	20467.3
	$\overline{ET}$	373	418.7	531	475	421.7	330.4	228.7	175.2	195.1	273.4	371	343.6	4093.5
	s	28.1	35.2	22.4	48.2	38.5	27.5	29.4	22.9	35.6	13	15.6	10.1	72.8
P_4	ET	1637.1	1848.7	2524.8	2255.4	2110.4	1411	1982.3	725.6	854.2	1321.9	1652.5	1621.3	19045.9
	$\overline{ET}$	327.5	369.7	505	451.1	422.1	282.2	216.5	145.1	170.8	264.4	330.5	324.3	3809.2
	s	47	63.2	78.5	49.6	27.4	62.2	51	47.3	59.3	62.7	34.5	29.5	541.5
P_5	ET	1696.6	1914.4	2476.6	2171.1	1919.9	1651	1223.3	865	935.5	1378.2	1696.2	1673	18967.7
	$\overline{ET}$	339.5	382.9	495.3	434.2	384	330.2	244.7	173	187.1	275.6	339.2	334.6	3793.5
	s	13.9	20.7	20.9	48	26.4	16.5	8.1	15.9	18.3	21.9	15.7	16.7	171.2
P	ET	8692.1	9863.9	12753.4	11464.2	10162.2	8006	5856.8	4519	4752	7003	8614	8323.9	96458
	$\overline{ET}$	1738.4	1972.8	2550.7	2292.8	2032.4	1601.2	1171.4	903.8	950.4	1400.6	1722.8	1664.8	19291.6
	s	87	95.8	65.9	113.5	117.7	109.2	59.6	187.7	73.1	110	77.4	42.1	659.7

Table 3.4. Distribution per intervals of the sub period cumulative means evapotranspiration in Ndjamena. Period from 1986 to 2010. The values of the intervals must be multiplied by 100

Sub periods	[5.0,10.0[	[10.0,15.0[	[15.0,20.0[	[20.0,25.0[	[25.0,30.0[	Years
P_1	0	3	6	2	1	1986-1990
P_2	2	2	5	2	1	1991-1995
P_3	2	2	4	3	1	1996-2000
P_4	2	2	5	2	1	2001-2005
P_5	2	2	6	2	0	2006-2010

No doubt that the solar radiation has determinant impacts on the evapotranspiration. Thus, next coming concerns similar investigation of this phenomenon. The results of its treatment are shown in Table 5 where monthly sub period cumulative amounts of the evapotranspiration are presented. Clearly seen that this phenomenon is very intensive during the dry season, particularly in the period from February to May where very high values were registered. Lower values occurred during the rainy season. For the first sub period, the amount of the evapotranspiration was included in the interval from 1054.9 mm (in September) to 2506.3 mm (in March). For the second sub period, from 830.0 mm (in August) to 2536.5 mm (in March). For the third sub period, from 876.0 mm (in August) to 2655.2 mm (in March). For the fourth sub period, from 725.6 mm (in August) to 2524.8 mm (in March). For the fifth sub period, from 865.0 mm (in August) to 2476.6 mm (in March). It is obvious that the soil water reserve should be at its lowest level by the middle of the dry season, in particular in March. Consequently, agricultural activities during this period should be very difficult except with the intensive practice of irrigation. For what concerns the values of the monthly means of the evapotranspiration, $\overline{ET}$, their sub period intervals of variation were as follows. For the first sub period, it was from 211.0 to 512.1 mm per month, for the second sub period, from 166.0 to 507.3 mm per month, for the third sub period, from 175.2 to 531.0 mm per month, for the fourth sub period, from 145.1 to 505.0 mm per month and for fifth sub period, from 173.0 to 495.3 mm per month.

The analysis of the time tendency of this parameter indicates that it was decreasing when passing from a sub period up to the next. Obvious that this result is coherent with what obtained for the insolation. Thus, it could be clearly confirmed that the time tendencies of the insolation and evapotranspiration occur the same way. Going further to the time variability of the evapotranspiration, let us consider the values of standard deviation. Table 5 indicates that these values were two orders less the amounts of the sub period evapotranspiration, ET, and one order less the monthly means of the evapotranspiration, $\overline{ET}$. We may conclude that the time distribution of the evapotranspiration in Ndjamena and surroundings was closer to their main values. Therefore, evapotranspiration could be classified as a less variable atmospheric phenomenon compare for example to rainfall. To complete our investigation on the time trends of the evapotranspiration in Ndjamena, we consider the distribution per intervals of the sub period cumulative means evapotranspiration. The full interval of variation of this parameter as divided into sub equal intervals of length 500 mm/(sub period). Then the number of occurrences of each interval in the considered sub period was determined. This has enabled us to build Table 6. Table 6 informs us that the most frequent amounts of the evapotranspiration occurred in the interval from 1000.0 to 2500.0 mm per sub period. Moreover, the highest frequencies were observed in the interval from 1500.0 to 2000.0 mm per sub period. Or the whole period of investigation; these frequencies were decreasing from the first to the third sub period, then started increasing till the fifth sub period. Concerning the relationship between insolation and evapotranspiration, a qualitative one has been already established according to which both phenomena vary in the same direction. The main problem is to find out the quantitative relationship, the one which would enable user to determine the amount of the evapotranspiration knowing the value of insolation. This work needs tools which should go out of the proposed goals of the present study and for this reason, it should be done later and publish in the next authors' scientific paper. Obvious that knowing the amounts of evapotranspiration, it is then possible to evaluate the quantities of water to be provided to the soil through irrigation during the period of agricultural activities. Progressing this way, the problem of hunger will find a solution through the world. While waiting for a functional relationshipto be established between insolation and evapotranspiration, users should continue operating with the evapotranspiration vessel as done today.

Conclusion and recommendations

This investigation has shown that the daily insolation in Ndjamena varies from 6 to 10 hours, mostly from 8.5 to 9.7 hours. From the observations, it comes that the intensity of the solar radiation (parameter not available in this station) is usually very high, if judging by the way inhabitants swear in- and out-doors. Highest values of insolation arise during the dry season corresponding to the period between March and April. It is clear that during the dry season and particularly the above indicated laps of time, the phenomenon of evapotranspiration should be very intensive. Consequently, the soil water reserve should progressively decrease to their lower values by the end of the dry season.

It is obvious that the time trend of the evapotranspiration is similar to the time trend of the insolation. From this similarity, the author have set a question if it should be possible to elaborate a mathematical formula which could enable the different users to easily estimate the amount of the evapotranspiration without running to the classic methods of Thornwhaite, Penmann, Turc or Boucher which need a lot of information that are not measured in almost all our meteorological stations. Thus, further investigations of the authors should be focused in solving this problem.

REFERENCES

1. Njipouakouyou Samuel, Aoudou Doua Sylvain, Galmai Orozi: Investigating the minimal quantity of soil water reserve and its tendency in Ndjamena and surroundings-Chad. *IJCR*, vol. 09, Is. 07, July 2017, pp. 54482-54485.
2. Njipouakouyou Samuel, GalmaiOrozi, AoudouDoua Sylvain, Yacoub Idriss Halawlaw and Dokoubou Joseph Rodolphe: Determining the best seeding and duration of the cultivation period in Ndjamena and surroundings-Chad. *IJCR*, vol. 09, Is. 09, September 2017, pp. 56894-56897.
3. Abdelkerim Brahim Adam: Analyse statistique et tendancielle temporelle de l'évapotranspiration réelle et diagnostique d'un lien fonctionnel ensoleillement-évapotranspiration à Ndjamena, Tchad. Période 1986-2010. Mémoire présenté sous l'encadrement de Njipouakouyou Samuel pour l'obtention du Diplôme de Master en Physique, option Physique de l'Atmosphère et du Climat. Département de Physique, Faculté des Sciences, Université de Ndjamena ; 2e promotion, 2023, 21p.

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