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**Research Article**

# TWO QUALITATIVE METHODS OF ESTIMATING THE TIME TREND OF THE ATMOSPHERIC AIR HUMIDITY CASE OF SARH, SOUTHERN PART OF CHAD PERIOD FROM 1971 TO 2004

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**Abstract**

This study concerns the time trend of the atmospheric air relative humidity over the locality of Sarh in the southern part of Chad for the period from 1971 to 2004, almost a climatic period which was divided into seven sub periods of 5 years each. Sub period monthly and yearly means have been calculated and corresponding values compared. This comparison did not reveal significant difference between the considered values; moreover the yearly trends of the sub period monthly means were slightly the same and the time trend of the yearly means indicates that the atmospheric air relative humidity was increasing with a yearly speed of 0.2%, what is relatively not significant to produce an important impact in the on-going climatic change. More attention should be paid on the environmental impacts as this could lead to the presence of more dangerous acids in the atmosphere.

**Keywords:** Atmospheric air relative humidity, monthly means, yearly means, sub periods, sub period monthly means, sub yearly means, time trend, climate change, significant difference.

## INTRODUCTION

For years we have been assisting to the degradation of climate almost all over the world. In developed countries many scientists have already been searching ways and means to prevent, reduce or even to eliminate this phenomenon. In developing countries it seems that only very few people pay attention to it. In fact, this climatic global change manifests itself in many ways. Between others, the progressive move of the boundaries of the desert of Sahara toward the equator, the drastic reduction of the duration of the rainfall seasons, the frequent droughts over many regions are some of its manifestations. Investigations of the soil water reserve and the best period of agricultural activities have been done by some researchers, (Njipouakouyou *et al.,* 2017; Njipouakouyou *et al.,* 2017). Despite the obtained results, many developing countries are under international food assistance for already many years as they are unable to produce more foods for their populations because of a severe deficit of water for agricultural activities. Moreover, new diseases registered almost allover the world have put all the human beings under permanent fear. Chad is a sahelian country and the close proximity of its northern boundaries to the Sahara desert seriously affects the air humidity not only in the region, but deeply into the south of the country where agriculture is the main activity of almost all the populations. Many foods come from this southern part to be dispatched allover the country. Thus, this southern part should be under permanent observation to avoid future humanitarian catastrophe namely hunger. Despite the fact that those inhabitants are very laborious, the quantities of foods produced are limited and not sufficient to cover the growing demands of the country. Moreover, it is frequently reported that the whole country is already under the menace of dryness. Consequently, we should hurry up to elucidate what is going on particularly with the atmospheric humidity in the country. Taking into consideration the permanent lack of meteorological data in almost all African countries, a sample method of rainfall forecast in some localities in the southern part of Chad has been elaborated by some authors, (Njipouakouyou *et al.,* 2019). Note that this situation concerns the whole equatorial zone. This paper concerns the investigation of the time trend of the atmospheric air relative humidity over Sarh, an industrial and agricultural locality in the south of Chad. Two qualitative methods are proposed. They are sample for a large number of inhabitants. The first one analyzes the time variation of the monthly means of the atmospheric air relative humidity, f, over years. Recall that $0\% \leq f \leq 100\%$. When f tends to 0%, the air is dry and when it reaches 0%, it is absolutely or completely dry. But the atmospheric air has never been absolutely dry as it always contains some quantities of water vapor. Inversely when f tends to 100% or is equal to 100%. The second method is based on the so called index of saturation of the atmospheric air with water vapor represented by the difference 100-f. It also verifies the double inequalities $0\% \leq 100 - f \leq 100\%$. When 100-f tends to 0%, the atmospheric air has a lot of water vapor. When it is 0%, the air is saturated with water vapor. Inversely when 100-f tend to 100% or is equal to 100%. Both methods are independent from one another and could not be used simultaneously as they lead to the same results. The atmospheric air relative humidity and the air temperature are the two atmospheric parameters which are very frequently registered at almost all the meteorological stations in the region. They present very few missed data. This is one of the main reasons which have pushed the authors to investigate this parameter, instead. No doubt on the importance of the problem to be solved in this paper. It is clear that the accuracy of the used data should provide better representativeness to the obtained results. This paper has five sections. The first and

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present one introduces the problematic of the work. The second exposes the data and methodology of investigation. The third presents the results of the data treatments and their analysis. The conclusion and recommendations are found in the fourth section. References in alphabetic order end the work in the fifth section.

## DATA AND METHODOLOGY

### Data

The present data was registered at the meteorological station in Sarh, southern part of Chad, from 1971 to 2004. It concerns the monthly means of the atmospheric air relative humidity. Thus, it is not primary data but already treated one and presented in tabular forms. Despite its regularity, the series have few missed data. As the station is located at the airport and recalling seriousness in its recruitment of personnel, it is obvious that the observers are well trained, theoretically and practically. Thus, the representativeness and goodness of the obtained results should not have any doubt.

### Methodology

Our methodology is sample. In fact, the whole period is divided into sub periods of five years each. Sub period monthly means and corresponding standard deviations are calculated. This last parameter has enabled us to have a correct idea on the distribution of the relative humidity around their monthly means and a judgment on the work done by observers. Missed data is replaced by the arithmetic mean of the neighboring ones. Sub period monthly means are plotted and their graphs analyzed to elucidate their yearly trends. A comparison of these trends is done to highlight their global tendencies over the considered period. Similar study is done for the standard deviations. The investigating parameters are calculated using the next formulas.

The deficit of saturation of water vapor, d, of the atmospheric air relative humidity is determined by the formula:

$$d = E-e, \tag{1}$$

where E is the saturation partial pressure and e the partial pressure of the water vapor in the air at a given temperature. Parameter E is calculated by the formula of Clausius Clapeyron. Knowing the temperature of the air, both parameters can be determined using the psychrometric tables.

Knowing E and e, the relative humidity of the air, f, is calculated by the formula:

$$f = \frac{e}{E} 100\% \tag{2}$$

The air relative humidity at meteorological stations is usually measured by the hair hygrometer. At the absence of psychrometric tables and after calculating E as indicated above, the partial pressure of the water vapor in the air can be determined by the formula:

$$e = fE \tag{3}$$

Using (2-3), formula (2-1) becomes:

$$d = E(100-f) \tag{4}$$

Factor 100-f in formula (4) is what is called the index of saturation of water vapor to be also analyzed in the text in order to qualify the quantity the atmospheric air humidity. Recall that when the atmospheric air is dry, its capacity to receive new quantities of water vapor is very high. Inversely, this capacity is very low when it is wet and null when it is saturated. Moreover, saturated atmospheric air with water vapor can quickly be developed till precipitations and other subsequent phenomena. Either dry or wet atmosphere, it sometimes has serious impacts on human beings, animals, cultures and plants in the fields particularly when the value of relative humidity in the air is out of a certain interval, depending on what species are considered.

## RESULTS AND ANALYSIS

The sub period monthly means of the atmospheric air relative humidity are presented in Table 1 and their corresponding standard deviations in Table 2. In these tables, column X indicates the yearly means of the considered parameters. Table 1 shows that during the whole period of investigation the months from January to March and December were dry with the sub period means of the atmospheric air relative humidity varying from 20% in February in the third sub period to 49% in December in the fourth sub period. February was the driest month. The remaining months were wet with sub period means mostly above 50%, highest values, between 70% and 87%, being registered from June to October. The yearly means were concentrated around 59% and its interval of variation relatively small, from 56% to 61%. No significant difference between corresponding sub period monthly means was detected during the considered period, 1971-2004. Thus, its impacts in the global climatic change should not be considerable. Table 2 shows the relatively small values, from 0% to 8%, with one order down, of the standard deviations of the monthly and yearly means of the atmospheric air relative humidity from their corresponding sub period monthly and yearly means. This indicates that the monthly and yearly means were dispatched closer to their sub period monthly and yearly means. Thus, observations might be declared accurately done. Highest values of standard deviations, mostly between 3% and 5%, were registered during the dry period and the lowest, between 1% and 4%, mostly between 1% and 3%, during the wet one. Figures 1 and 2 show the annual trends of the sub period means of the atmospheric air relative humidity and their corresponding standard deviations, respectively.

Figure 1 shows that annual trends of the atmospheric air relative humidity have almost a same tendency during all the sub periods. Figure 2 leads us to the conclusion that each sub period has its own yearly variation of the standard deviations of the atmospheric air relative humidity. For clearance, Figures 1 and 2 have been divided into two, each corresponding to the first and second halves periods, to obtain Figures 3 and 4 for the sub period monthly means and Figures 5 and 6 for their standard deviations, respectively. Concerning the first half period, Figure 3 for the four firsts sub periods shows a same tendency of the yearly variation of the sub period monthly and yearly means of the atmospheric air relative humidity. It also shows that the fourth sub period was slightly more humid than the others. During the second half period, the values of all the corresponding sub period monthly and yearly means of the atmospheric air relative humidity were almost equal, with slightly differences as indicated in Figure 4.

**Table 1. Sub period monthly and yearly means of the atmospheric air relative humidity in Sarh**

| f % | J | F | M | A | M | J | J | A | S | O | N | D | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I (1971-1975) | 28 | 26 | 34 | 50 | 60 | 70 | 78 | 81 | 79 | 73 | 52 | 38 | 56 |
| II (1976-1978) | 29 | 28 | 32 | 49 | 61 | 70 | 79 | 81 | 78 | 74 | 55 | 38 | 56 |
| III (1983-1985) | 27 | 20 | 37 | 43 | 60 | 72 | 80 | 82 | 79 | 70 | 57 | 40 | 56 |
| IV (1986-1990) | 33 | 29 | 35 | 52 | 61 | 74 | 84 | 86 | 84 | 80 | 64 | 45 | 59 |
| V (1991-1995) | 35 | 28 | 36 | 49 | 69 | 75 | 84 | 86 | 83 | 78 | 61 | 44 | 61 |
| VI (1996-2000) | 38 | 30 | 36 | 48 | 67 | 73 | 84 | 87 | 85 | 82 | 66 | 49 | 61 |
| VII (2001-2004) | 36 | 33 | 32 | 48 | 57 | 73 | 83 | 85 | 83 | 79 | 66 | 44 | 61 |
| Period | 33 | 28 | 34 | 48 | 62 | 73 | 82 | 84 | 82 | 77 | 61 | 43 | 59 |

**Table 2. Standard deviations of the sub period monthly and yearly means of the atmospheric air relative humidity in Sarh**

| s % | J | F | M | A | M | J | J | A | S | O | N | D | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I (1971-1975) | 2 | 1 | 4 | 3 | 5 | 5 | 3 | 1 | 2 | 2 | 4 | 1 | 1 |
| II (1976-1978) | 3 | 6 | 5 | 5 | 5 | 1 | 2 | 1 | 1 | 4 | 5 | 0 | 2 |
| III (1983-1985) | 2 | 1 | 8 | 6 | 3 | 2 | 6 | 6 | 6 | 3 | 8 | 7 | 2 |
| IV (1986-1990) | 5 | 4 | 6 | 3 | 4 | 2 | 1 | 3 | 4 | 3 | 5 | 8 | 2 |
| V (1991-1995) | 2 | 3 | 4 | 4 | 8 | 4 | 1 | 5 | 3 | 4 | 4 | 5 | 1 |
| VI (1996-2000) | 3 | 4 | 7 | 8 | 10 | 5 | 1 | 1 | 1 | 3 | 5 | 3 | 2 |
| VII (2001-2004) | 1 | 8 | 5 | 1 | 5 | 2 | 1 | 2 | 3 | 1 | 1 | 4 | 4 |
| Period | 5 | 5 | 5 | 5 | 7 | 4 | 3 | 4 | 4 | 5 | 7 | 6 | 3 |

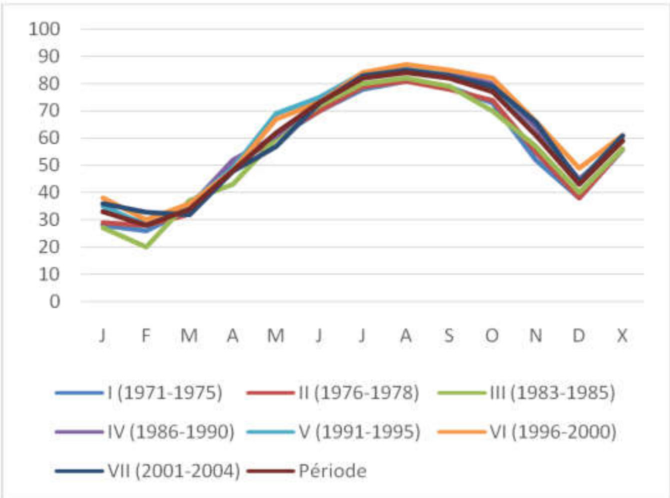


**Figure 1. Annual trends of the sub period monthly and yearly means of the atmospheric air relative humidity in Sarh**

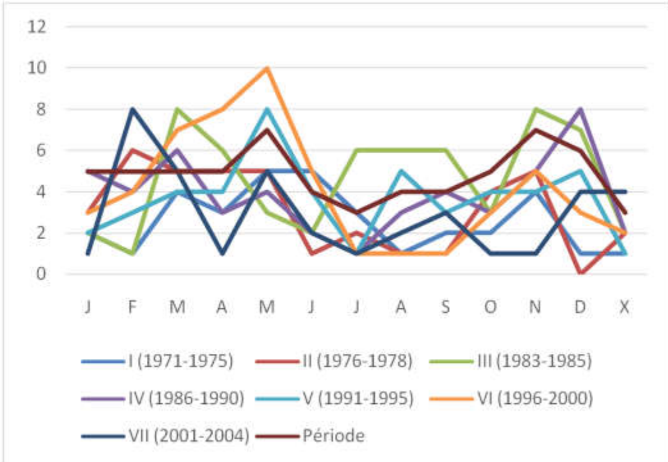


**Figure 2. Annual trends of the standard deviations of the sub period monthly and yearly means of the atmospheric air relative humidity in Sarh**

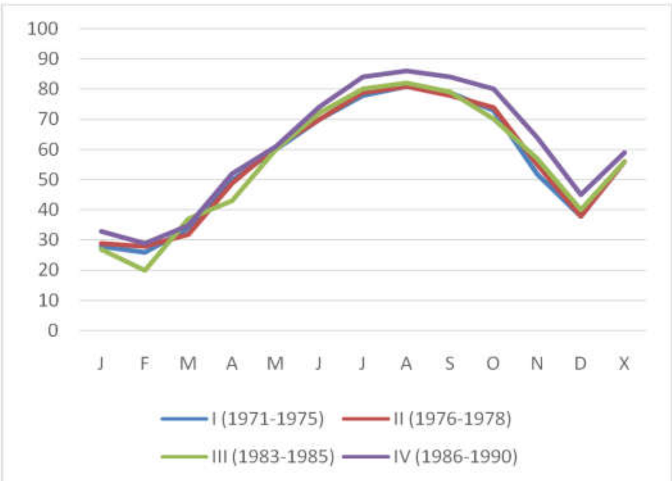


**Figure 3. Annual trends of the sub period monthly and yearly means of the atmospheric air relative humidity in Sarh during the first half period**

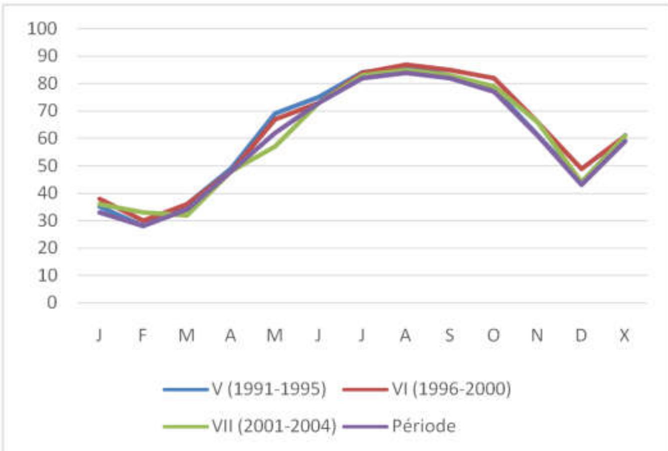


**Figure 4. Annual trends of the sub period monthly and yearly means of the atmospheric air relative humidity in Sarh during the second half period**

Figures 5 and 6 confirm the specific variability of the monthly and yearly means of the atmospheric air relative humidity around their sub period monthly and yearly means for each year. This variability was more important in the third and fourth sub periods in the first half and in the sixth sub period in the second half periods.

The interval of variation of the standard deviations in both halves periods varied from 1% to 8%. Both figures indicate important variations in the transitional seasonal period, mainly when passing from dry to rainy season. The analysis of the atmospheric air relative humidity did not reveal significant difference between the corresponding monthly means over the whole period of study.

**Table 3. Sub period monthly and yearly means of the index of saturation of the atmospheric air relative humidity in Sarh**

| 100-f in % | J | F | M | A | M | J | J | A | S | O | N | D | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I (1971-1975) | 72 | 74 | 66 | 50 | 40 | 30 | 22 | 19 | 21 | 27 | 48 | 62 | 44 |
| II (1976-1978) | 71 | 72 | 68 | 51 | 39 | 30 | 21 | 19 | 22 | 26 | 45 | 62 | 44 |
| III (1983-1985) | 73 | 80 | 63 | 57 | 40 | 28 | 20 | 18 | 21 | 30 | 43 | 60 | 44 |
| IV (1986-1990) | 67 | 71 | 65 | 57 | 39 | 26 | 16 | 14 | 16 | 20 | 36 | 55 | 41 |
| V (1991-1995) | 65 | 72 | 64 | 48 | 31 | 25 | 16 | 14 | 17 | 22 | 39 | 56 | 39 |
| VI (1996-2000) | 62 | 70 | 64 | 51 | 33 | 27 | 16 | 13 | 15 | 18 | 34 | 51 | 39 |
| VII (2001-2004) | 64 | 67 | 68 | 52 | 43 | 27 | 17 | 15 | 17 | 21 | 34 | 56 | 39 |
| Period | 67 | 72 | 66 | 52 | 38 | 27 | 18 | 16 | 18 | 23 | 39 | 57 | 41 |

Therefore, we can conclude that its impact on the global climatic change should be negligible. The results of data treatments based on the second methodology are presented in Table 3.

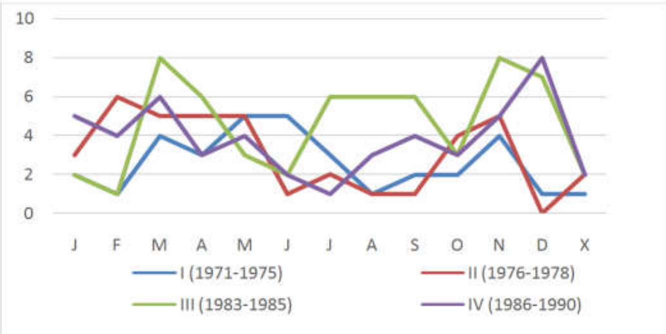


**Figure 5. Annual trends of standard deviations of the sub period monthly and yearly means of the atmospheric air relative humidity in Sarh during the first half period**

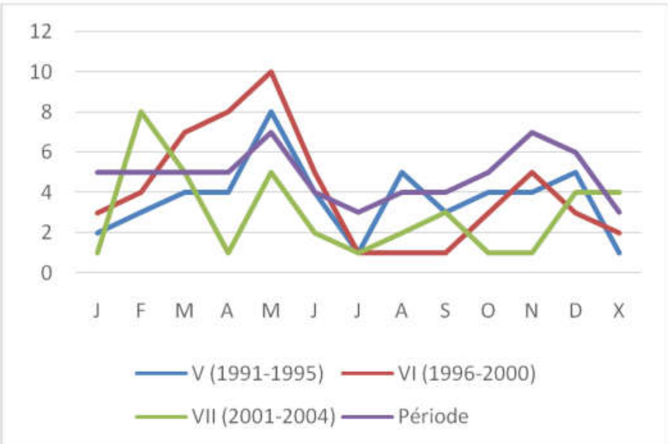


**Figure 6. Annual trends of standard deviations of the sub period monthly and yearly means of the atmospheric air relative humidity in Sarh during the second half period**

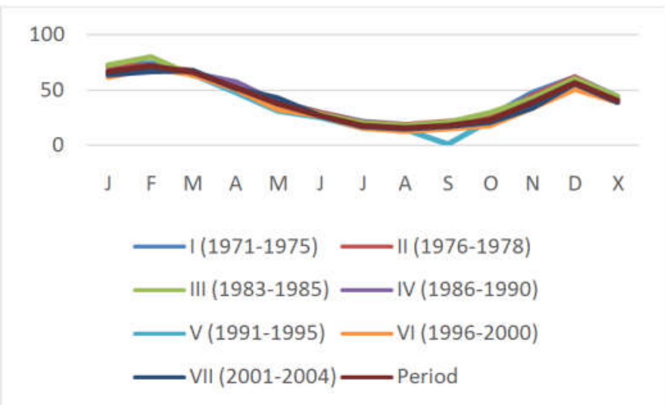


**Figure 7. Annual trends of the sub period monthly and yearly means of the index of the atmospheric air relative humidity in Sarh**

Recall that it concerns the index of saturation of the atmospheric air with water vapor represented by the factor 100-f. It is evident that when the air is dry, the relative humidity is low and the value of 1-f is high. And inversely. From Table 3, it comes that during the whole period, small values of this index were registered in the rainy season with the lowest value of 14% registered in the fourth and fifth sub periods of August. High values occurred in the dry season with a maximum of 80% in the third period of February.

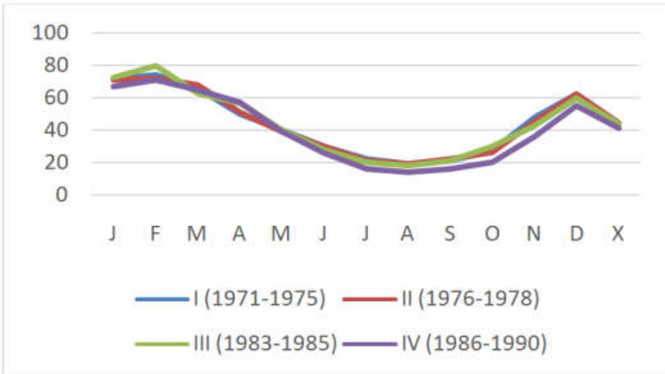


**Figure 8. Annual trends of the sub period monthly and yearly means of the index of the atmospheric air relative humidity in Sarh during the first half period**

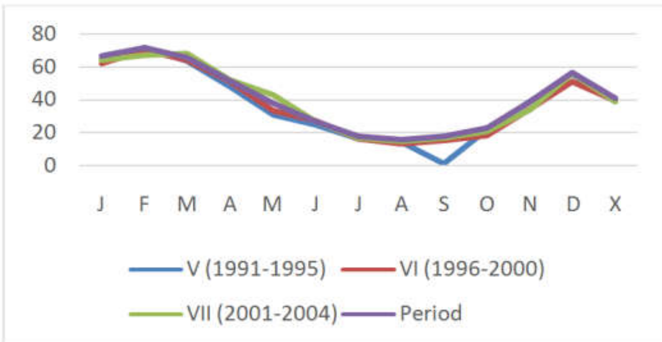


**Figure 9. Annual trends of the sub period monthly and yearly means of the index of the atmospheric air relative humidity in Sarh during the second half period**

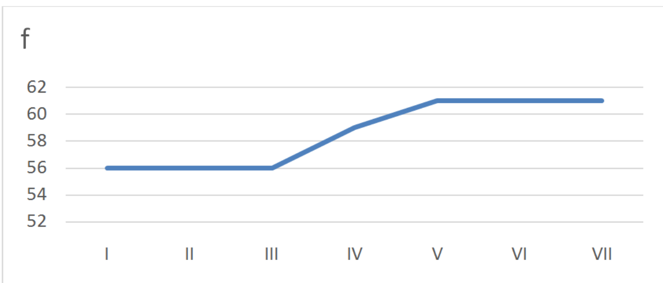


**Figure 10. Time trend of the sub period yearly means of the atmospheric air humidity in Sarh**

**Table 4. Yearly means of the atmospheric air relative humidity f in Sarh. Period from 1971 to 2004**

| t | -17 | -16 | -15 | -14 | -13 | -12 | -11 | -10 | -9 | -8 | -7 | -6 | -5 | -4 | -3 | -2 | -1 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| f | 55 | 55 | 55 | 57 | 56 | 58 | 54 | 57 | - | - | - | - | 56 | 55 | 58 | 59 | 57 | 60 |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 61 | 60 | 61 | 62 | 63 | 60 | 60 | 62 | 61 | 60 | 64 | 59 | 64 | 56 | - | 63 |

The driest month was February and the wettest, August. The sub period monthly and yearly means of this index were plotted in Figure 7. It shows high values from January to March and relatively high ones in December. In general this index decreased from February to its lowest values in July-August from where it started increasing to its relatively high values in December. No significant differences in these time tendencies were detected. Moreover, all corresponding sub period monthly and yearly means were almost equal indicating that they could not bring significant impacts on the global climatic change which is now going on in the whole region. Figures 8 and 9 for the first and second halves periods issued from Figure 7 do not indicate any significant differences neither in the corresponding values of the sub period monthly and yearly means of the index of saturation nor in their yearly trends. Using either the first or second method leads to a same conclusion. Therefore, they should not be simultaneously used. They can be implemented very easily in operational works by any technician. To avoid extra computations, the first method should be recommended as in almost all stations hygrometer is used. The time trend of the sub period yearly means is presented in Figure 10. It shows that during the three firsts sub periods the yearly means of the atmospheric air relative humidity were kept constant to 56%. Then it started increasing to 59% in the fourth sub period up to 61% in the remaining sub periods. Yearly means of the atmospheric air relative humidity contained in Table 5 were plotted to obtain a cloud of experimental points, Figure 11, whose analysis enabled the finding of the functional relationship f(t) between the time t and the relative humidity f.

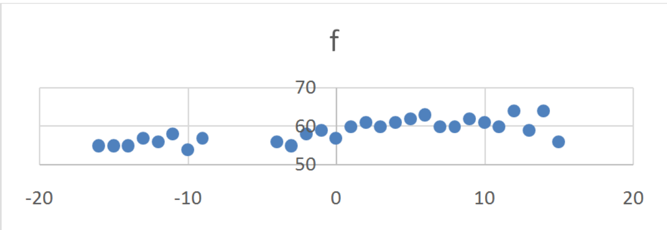


**Figure 11. Cloud of points of the yearly means of the atmospheric air relative humidity over the period from 1971 to 2004 in Sarh**

To facilitate generated computations, an auxiliary variable t is introduced such that t = 0 for year 1988. It comes from the analysis of Figure 11 that the functional relationship f(t) is linear. Let $f_{th}(t)$ be that function. Applying the least square method to Table 3-5 leads to the following searched theoretical function:

$$f_{th}(t) = 0.2t + 58.9. \qquad (5)$$

The degree of fitness of formula (5), ε(t), is the difference between the experimental and theoretical values of the yearly means of f. So we have:

$$\varepsilon(t) = f_{exp} - f_{th}, \qquad (6)$$

where $f_{exp}$ are from Table 3-5 and $f_{th}$ - from (5). Its analysis indicates that $-3 \leq \varepsilon(t) \leq 3$. Moreover, 9 points are under the regression line (5), 12 above and 7 on it. The values of ε(t) are one order down the corresponding values of the main parameter. Moreover the slightly narrow interval of variation of ε(t) leads to the conclusion that formula (6) is an acceptable representation of the time variation of the yearly means of the atmospheric air relative humidity in Sarh. This formula indicates that this parameter slightly increases with a yearly speed of 0.2%. During the considered period of investigation the atmospheric air relative humidity used to be at least 50% during 8 months in the year, from April to November, and it never reached 90%. Previous works have led to the conclusion that in the considered region, natural phenomena are not responsible of the observed climatic change, the main responsible been the population growth, (Njipouakouyou *et al.,* 2019; Njipouakouyou *et al.,* 2019).

**Conclusion and recommendation**

This study on the monthly and yearly means of the atmospheric air relative humidity has not shown significant differences between corresponding monthly means over the whole considered period. Also no substantial variation was detected in the yearly means of this parameter. During the whole period of investigation, the atmospheric air relative humidity was slightly increasing with a yearly speed of 0.2% which should not have significant impacts on the nowadays climatic change, neither on the local nor the global scale. As this parameter increases with time, attention should be paid on its environmental impacts. It is evident that the abundance of humidity in the atmosphere combined to all kinds of oxides generated by the human activities should produce different varieties of acids very dangerous for populations. Comparative studies between different climatic periods are on their way and should précised the present results.

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