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REGIONALIZATION OF RAINFALL IN NORTH-WESTERN ALGERIA

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Abstract

Our study focuses on the regionalization of rainfall in northwestern Algeria. This region is the most affected by rainfall reduction since the second half of the 1970s. The regionalization of spatial variability of precipitation is studied over two separate periods in order to improve the quality of information. Two statistical techniques were used, i.e., the Principal Components Analysis with rotation and the non-hierarchical clustering (k-means clustering). The regionalization of rainfall using 46 stations with 74 years of observations (1930-2004) allowed us to identify four groups characterizing the different climatic regions in the studied area. To refine this regionalization, we have introduced new stations (182 stations) with a shorter period of observation (36 years, from 1968 to 2003). This new procedure allowed us to highlight new regional groups. The homogeneity test of Krauss (1977) improved by Fernandez Mills et al. (1994) showed some weakness in the homogeneous structure of rainfall fields of these groups, especially the temporal component. The major element in limiting these groups is the longitude (the correlation coefficient between this parameter and rain is of the order of 0.66). To show the influence of the distance from the Mediterranean Sea and the altitude, the K-means clustering technique was applied on each one of these six groups. This procedure allowed us to divide the region into twelve groups. The homogeneity became clearer except in the groups where the temporal variability of rainfall is significant, which caused the reduction of Krauss coefficient value. When using this technique in these groups, we have demonstrated the importance of the longitude, the distance from the Mediterranean Sea and the topography characterized by its altitude in the regionalization of rainfall on an annual basis.

Key Words: *Regionalization, rainfall, North-western, Algeria.*

1. INTRODUCTION

The often tragic consequences of the persistent decrease in rainfall and flows on the economies and developments of countries justify the continued interest in the analysis of climate change. Climate variability affects the availability of water resources, which can more or less significantly fluctuate over time and across regions.

In Algeria for example, the level of satisfaction with domestic and agricultural water keeps decreasing in recent years, we talk more and more about « drought » and « drought persistence », especially in the western region of Algeria. Thus, the decrease of this resource may be due to climate change. The analysis of synoptic, weather and climate data is very important to describe the general historical developments and understand the current conditions (*Bradley et Jones, 1992*). The exploitation of agricultural resources, the supply of urban areas or meeting the ever-increasing water needs of industrial zones in general, the inventory of water resources and their rational management are closely subject to a thorough knowledge of climate elements, including rainfall that plays a prominent role

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(*Hiez G., 1977*). It is very essential to demarcate the quasi-homogeneous climatic zones and identify the climatic sub-regions in an observation network corresponding to specific weather patterns, to understand the climate of a given region. In this context, a wide variety of indices were constructed according to the ideas of the users of the influence of any climate parameter on rainfall distribution. Currently, these analyses have become finer; they use data analysis techniques and multivariate statistics. Many methods were suggested and applied in all parts of the world, unfortunately, most research in this context can't avoid a compromise between taking into account the temporal variations of a few number, or even one parameter and taking into account a maximum of climate parameters in a simplified form. The multivariate analysis is one of the most widely used techniques in the regionalization of hydrological parameters. The Principal Components Analysis has been widely used to create homogeneous groups in terms of hydrological or rainfall regime. As regards rainfall, many researchers have used this technique in many parts of the world: Steiner (1965) has used the Principal Components Analysis (with varimax rotation) on 16 climate parameters relating to 67 stations, *Wigley et al. (1984), Gregory et al. (1991)* in Britain; *Fortui et al. (1982)* in Quebec, *Goossens (1985)* in the Mediterranean, *Dyer (1975 and 1982)* in West Africa; *Gerard L. (1995)* in the Ardeche (France), *Nathali V. V. (2005)* in Fakara (Niger), *Achite M. et al. (2005), Assaba M. (2004) et Medjerab A. (2005)* in Algeria, *Stathis D. et al. (2009)* in Greece; *Baeriswyl et al. (1997)* in Switzerland ; *Sneyers R. (1989)* in Belgium; *Balafoutis C. (1991)* in Albania; *Gadgil et Iyengar (1980)* in India; *Raziei T. et al. (2008)* in Iran, *Salama H. (2011)* in Morocco and *Feki M. (2009)* in Tunisia. We have also used the k-means clustering technique to confirm the results of the Principle Components Analysis. This technique has been also used in hydrology and climatology to regionalize hydrological and climatological parameters such as maximum rainfall, maximum flows and low water levels. In addition to the PCA, the non-hierarchical clustering (k-means clustering) has been used to refine the homogeneous classes of rain. This technique has many applications in the regionalization of precipitation and extreme flows on different temporal and spatial scales *Gutierrez Lopez M.A. (2003)* in Mexico.

2. MATERIALS AND METHODS

2.1. Presentation of the study area

2.1.1. Geografical situation

The study area covers approximately 89 420 km2.. It is located between longitude 2°10'10 ''W- 3°10'11''E and latitude 34°18'54''N- 36°48'12''N (**Fig. 1**). It extends over 250 km from south to north and over 500 km from west to east.

2.1.2. Relief

The relief is the result of many factors combined especially the geological evolution and the action of erosion on a large scale (thousands or millions of years). The physical setting of the study area is characterized by the heterogeneity of the large natural units. The Tellian Atlas in the west is more divided and less imposing than that of the east. The High Plains in West Algeria are more arid than those in the East. The region can be subdivided in five different orographic groups: coastal relief; inland plains and basins, mountains and plateaus, the Tellian Plateaus and the high plains (**Fig. 1**). The hills of Oran which extend from Ain-Temouchent to Arzew Mountains, crossing the Djebel Murdjadjo form the coastal relief, where the altitude ranges from 300 to 650 m with a south-west to north-east orientation. The massif that extends from Traras to the Ouarsenis (350 to 800 metres) is an obstacle to maritime influences, their distance from the Mediterranean Sea ranges from 20 to 70 Km. the inland plains, i.e., Maghnia Plain (400 metres), Sidi Bel-Abbes Plain (470 metres) and Ghriss plain (between 400 and 600 metres) are located in the piedmont of the Tellian Plateaus. We can also distinguish the Mohammadia Plain and the Cheliff Plain in the east (between 60 and 150 metres of altitude) with a length of about 190 km. The Tellian Plateaus are expanded between the Mina high basin and the Moroccan border, at a distance of 300 km. These plateaus (with heights ranging from 900 to 1600 metres) dominate the inland basins and slope to the High Steppes (*Medjrab A., 2005*).

2.1.3. Climate and rainfall variability

The northern part of Algeria is characterized by a Mediterranean climate with a relatively cold and rainy winter and a hot and dry summer. The annual rainfall reaches 400 mm in the west, 700 mm in the centre and 1000 mm in the east for the coast. This type of climate is also found in the Tellian Atlas chains where we record totals ranging from 800 to 1600 mm in the eastern summits, while the values are lowered in the centre (700 to 1000 mm) and in the west (600 mm). In the plains of the Tellian Atlas, rainfall varies between 500 mm in the west, 450 mm in the centre and 700 mm in the east. The climate of the Saharan Atlas is very hot and dry in summer and mild in winter with lower rainfall compared to the north, owing to its distance from the sea (*Meddi H, 2001 ; Meddi M. et Meddi H, 2002*). These rainfall averages were calculated on the basis of 218 stations with observation periods from 1968 to 1998. A comparative study (*Meddi H, 2001*) with the map of the National Agency of Water Resources made by Mr. Laborde J.P in 1993 shows a drop of 13 % in the annual average rainfall in the centre and the west.

The annual average of the totals precipitated ranges between 310,6 mm in the station of Bouhanifia dam (west) and 755,1 mm in the station of Medea (centre).

2.2. Data

2.2.1. Choice of stations and the study period

To study and monitor climate change, we need long and numerous observation series. Unfortunately, we do not have data series perfectly reliable or continuous. The data used come from the two organizations responsible of rainfall network, i.e., the National Agency of Water Resources (N.A.W.R) and the National Meteorological Office (NMO). The available pluviometric data are very heterogeneous in terms of measurement reliability and observation series duration (*LABORDE JP, 1993*).In this series of weather data, errors may occur for many reasons (floppy read error, posting error, equipment derating, etc.). The lack of information is mainly concentrated during the period 1961-1968. During the data processing, some values appear to be singular compared to the rest of the time series. The existence of outliers can lead the climatologist to misinterpretations. We have tried to identify a maximum of measuring stations satisfying the following conditions:

- Information covering the last six decades
- Not more than 5 consecutive years of gaps
- Less than 10% of gaps in the whole series on the monthly scale

For the purpose of the study and for a good spatial distribution, we have filled the gaps using the technique developed by J.P. Laborde in 1998. Within these constraints, 46 stations were selected for the study (**Table no. 1** and **Fig. 1**). After review and verification of the monthly and annual data, the period 1930/31-2003/04 (74 years) was selected. The statistical analysis of annual precipitation series and all the researches have been done on rainfall amounts of the year that begins on September 1st of the year K and ends on August 31st of the year K+1. To refine the results based on 46 stations and over a long period, we will adopt a regionalization using 227 stations on a shorter period from 1968 to 2004 (36 years).

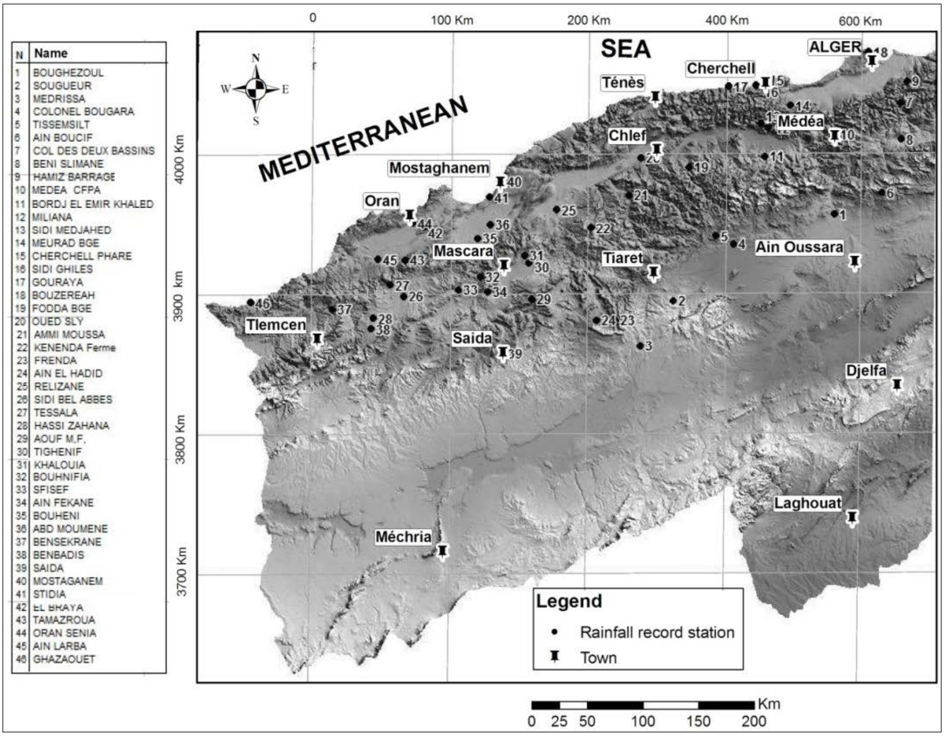

Fig. 1. Location of the study area and rainfall stations position.

2.3. Principal Components Analysis

The principal components analysis (PCA) introduced by Pearson K in 1901 and developed by Heotelling H. in 1933 is a very powerful method to explore the structure of a large number p of quantitative data by observed element: the analysis of these data must take into account their multi-dimensional character and reveal the existing connections between their components. When variables represent space and observations represent time, a PCA allows to highlight the similarities and differences in terms of temporal variability of geographical units. The components are linear combinations uncorrelated with each other, and a maximum variance of the initial variables (*Saporta*, *1990*). For regionalization purposes, *Dyer (1975)* and *Richman (1986)* have shown the contribution of the procedure of rotation, which redistribute the information contained in the K first components between K new components: the PC derived from a PCA with rotation will further individualize and stabilize spatial structures. Thus, the PCA develops new artificial variables and graphical representations, which allow visualizing the relations between variables and the possible existence of groups of elements and groups of variables. The interpretation of these representations is tricky, that is why we must pay close attention to representation qualities (measurement distance by an axis) and follow a rigorous approach. Richman in 1986 showed that a simple PCA has several defects, inter alia; the interpretation becomes difficult from the second component. Since this latter is difficult to interpret, a rotation is essential to solve the problem of the high spatial variability of rainfall. Varimax rotation is the most used in hydrology and climatology (*Messaoudi A., 1996; Basalirwa 1995; Murata 1990; Malmgren et al., 1999; Stathis, 2009*). This technique meets the criterion of orthogonality and independence between the technical axes *Kaiser (1958).*

2.3.1. Non hierarchical clustering (K-means clustering)

This method is used to divide individuals into homogeneous clusters, based on a description by a set of quantitative variables. This technique enables the processing of a large number by choosing the dominant criteria. This method of non-hierarchical clustering is implemented by decomposing a set of individuals by a number of clusters chosen a priori by an iterative process converging the selection of representatives of each cluster (one by cluster) which can be randomly initialized or by the user of the method (*Gerstengarbe et al., 1999*). Unlike the method of hierarchical clustering, we have an initial idea about the number of clusters to create. In general, the k-means clustering produce exactly k clusters as different from each other as possible (*Gutierrez Lopez M.A., 2003*). The simple regression, in our case, highlighted the explanatory parameters of the spatial distribution of precipitation in the study area. We used the geographical coordinates of the station, the altitude, the distance from the sea as defined by *Assaba (2004)* and the smooth altitude (*Laborde, 1984 et Assaba, 2004*). It was noted that the longitude explains much of the variance followed by the distance from the sea and then the altitude. These observations corroborate the results found by *Laborde (1992).*

2.3.2. Homogeneity analysis

The homogeneity of each group can be studied through the analysis of the total variance of data and that of space. If the ratio between these two variances is low, the homogeneity of the group is accepted. In this work, the scheme proposed by *Sulochana Gadgil et al. (1993)* is adopted, and the notation of *Krauss (1977)* improved upon by *Fernandez Mills et al.(1994)* was used:

r_{ij} : annual rainfall of the station i in the year j
J : number of years of the period chosen for the study
J_i : number of annual observations of the station i during the period J
I(k) : number of station in the group k
$I_j(k)$: number of stations having observations during the year j in the group k
s_i : the standard deviation of annual rainfall at the station i
ri: annual average at the station i

An annual anomaly of standardized monthly rainfall, where the group k is defined as follows:

$$Xij(k) = (r_{ij}(k) - (r_i(k)))/ s_i(k)$$

The average value of group k, where the standard index of anomaly, aj (k), in the year j is given by:

$$a_j(k) = (1/I_j(k))/ \sum_i X_{ij}(k)$$

For each group k, we divide the total sum of $X_{ij}{}^{2}$ (SST) into a spatial component (SSE) and a temporal component (SSM) (*Kraus, 1977; Wigley et al., 1984 and Fernandez Mills et al.,1994*). With this notation, we can show that:

$$SST(k) = , ,i\sum_i J_i(k) - I(k)$$

$$SSM(k) = \sum_j J_j(k)a^2{}_j(k)$$

$$SSE(k) = SST(k) - SSM(k)$$

According to *Wigley et al. (1984)*, a possible measure of the degree of homogeneity of group k can be defined as follows:

$$W(k) = SSM(k)/SST(k)$$

The high values of this index correspond to groups where the spatial component in the SST is less important than the temporal component. Therefore, these groups will be spatially coherent and the quality of regionalization is considered as satisfactory. According to *Chantez et al. (1991)* and *Fernandez Mills et al. (1994)*, an unbiased estimate of W (k) is given by:

$$Wh(k) = (SSM(k) - SSE(k)/(I(k)) - 1))/SST(k)$$

W*h* recalls the existence of missing values and at the same time avoids the problems related to the number of elements for each group. In our case, the number of observations and years are the same for all stations, so we just need the index W(k) to measure the degree of homogeneity in each group.

This approach was used by *Fernandez Mills et al. (1994)* in Spain, *Sulochana Gadgil et al. (1993)* in India, *Krauss (1977)* in Africa and India and *Wigley et al. (1984)* in England.

2.4. Regionalization of rainfall

It is very essential to demarcate the quasi-homogeneous climatic zones and identify the climatic sub-regions in an observation network corresponding to specific weather patterns to understand the climate of a given region (*Guiot J., 1986*). It is also very important to learn about the annual rainfall fields in the arid and semi-arid areas. Thus, the determination of homogeneous regions allows a better understanding of water availability (*Descroix L. et al., 2001*). Gadgil et Iyengar (1980) note that the classification of homogeneous groups of the variation in precipitation is the first step in the development of stochastic models for the prediction and the study of variability using large time scales. According to Dyer (1975 and 1976), these classifications are needed to choose an agricultural strategy and plan the use of water resources in several regions.

2.5. Results of the PCA

The regionalization we are proposing is just a test to demarcate the homogeneous spaces in terms of inter-annual variability. The application of the PCA without rotation showed that the stations (91% of the studied stations) are significantly described and positively correlated with the first component, which explains 51 % of the variance. The second component is only correlated to 4 stations that are situated in the central high plateaus. So it is difficult to accomplish a regionalization that allows the establishment of different homogeneous groups. To overcome this handicap, we are going to make a rotation of factorial axes on an annual time step. This rotation allows a clarification of the spatial structure of rainfall to characterize the different components of the relief in northwest Algeria. Richman (1986) showed the value of making a rotation of factorial axes. The rotation consists in redistributing the information contained in the k first components between k new component: the PC derived from PCA with rotation allows a better individualization and stabilization of the spatial structures (*Bouali, 2009*). We have applied on the same network of stations and for the same period a principle components analysis according to varimax method (transformation of components by rotation) which has the advantage of clarifying the spatial components of each component. The principle is then to determine in which component each station is better correlated (*Richman, 1986* et *Douguedroit, 1994*). We have selected four components based on the test of «scrée plot »for accumulation, representing 77% of the total variance. When discussing the results, the year 1975 was taken as a year of break in the stationarity of rainfall series. Many works carried out in this region have highlighted this date (*Laborde J.P., 1993; Meddi M. et al., 2002; Meddi M. et al., 2003, Talia, 2002, Meddi 2009*). The results of the PCA with Varimax rotation have generated the four following groups (**Table no. 2** and **Fig. 2**):

Table no. 1. Characteristics and results of the homogeneity study of the four groups.

	Group I	Group II	Group III	Group IV
Minimum value (mm)	194.45	393	281	336
Maximum value (mm)	398,03	838	556	422
Ratio between max and min	2,1	2,1	2	1,3
Wh	0,46	0,63	0,66	0,67
Cv spatial	21.1	18.6	17.3	7.7
Cv temporal min - max	24.7 – 47.1	22.9 – 32.5	24.3 – 45.1	26.4 – 39.3

First component : the first region (I) includes 6 stations and corresponds to the southern part of the Tellian Atlas characterized by the lowest precipitation that varies between 194 mm and 398 mm (ratio of 2,1). Five stations in this group have not had a break in the stationarity of rainfall series between 1930 and 2004, except that of Ain Boucif which is situated in the east of the group on the Tellian Atlas at1250 m of altitude. This station has experienced a reduction of 20 % after 1975. This station records the heaviest precipitation compared to other stations of Group 1 where it reaches 900 mm during the year 1933/1934.

Second component: the second region (II) includes 12 stations that receive rainfall varying between 393 and 838 mm (ratio of 2,1). The reduction in rainfall is of the order of 20 % in average. It represents the plain of the Mitidja, the central part of the Blidean Atlas and the Zekar Mountains. It is bounded on the north by the Mediterranean Sea and the Ouarsenis and on the south by the Zekar Mountains.

Third component: the third region (III) includes the Chellif, Macta and Tafna basins. These basins are characterized by the inland plains and the Tellian Atlas (Beni Chougrane, Tlemcen, Sidi Bel-Abbès and Saida mountains). This region has relatively low annual precipitation of 281 to 556 mm (ratio of 2). The reduction in rainfall is around 29 %. The ghriss plain, south Beni Chougrane Mountains, has experienced a decrease of about 34 % (the highest in Algeria).

Fourth component: includes 7 stations that receive average annual precipitation varying between 336 and 422 mm (ratio of 1,3). It is situated on the western coast of Algeria that extends from Mostaganem to Ghazaouet. It is bounded on the south by the Tessala and Taras Mountains. It is characterized by a low spatial variability (from one station to another) with a spatial variation coefficient of 7%, which shows the strong spatial homogeneity of this group. The decrease in rainfall recorded from 1975 is 20% in this region.

This regionalization based on 46 stations having a long measurement series showed the importance of the longitude in the determination of the homogeneous groups. The correlation coefficient between the average rainfall and the longitude is about 0.66. The ratio between the minimum and the maximum for each group is the double in the first three groups, except in Group 3 where the homogeneity is clearer with a ratio of only 1,3. The Wh index showed a certain homogeneity with values exceeding 60%, except in the first group (tab 2) where the value is low due to the importance of the temporal component in the SST where the variability from one year to the other is very significant as shown by the coefficient of temporal variability (**Table no. 1**) in this arid region. To check the influence of the topography and latitude, in addition to the longitude in the demarcation of homogeneous zones, we have conducted a second operation of regionalization based on 182 stations randomly distributed in space. These stations have an observation series of 36 years (1968 to 2004). The principle components analysis with rotation (Varimax) was used. The result shows the appearance of two additional regions in comparison with the first operation, that is to say 6 regional groups (**Fig. 3**). The six components explain 74 % of the variance. We noticed that the groups become more homogeneous according to the values of spatial variation coefficients of each group and the Wh homogeneity index (**Table no. 2**), except in Group 1 representative of the arid region where the coefficient of variation remains relatively high and the Wh index remains low with a value lower than 50%. The coefficient of variation is calculated from the point averages of each rainfall station (average of 36 years of measurements) in the composition of each group.

Table no. 2. Characteristics and results of the study of homogeneity of six groups.

	Group I	Group II	Group III	Group IV	Group V	Group VI
Minimum value (mm)	95.87	333,1	313,4	246,3	257,1	180,6
Maximum value (mm)	321,2	532,5	863	572,6	622,5	437,3
Coefficient of variation	29,5	15,7	19,8	22,9	19,2	17,6
Ratio between max and min	3,4	1,6	2,8	2,3	2,4	2,4
Wh	0,48	0,51	0,60	0,61	0,74	0,55

First group: this group includes 16 stations. It is situated in the south of the Saharan Atlas characterized by an arid climate. The average annual rainfall varies between 95,9 and 321,2 mm (ratio of 3.4). The coefficient of the spatial variation is of 25,2 %, which shows a moderate spatial variability, but the index of homogeneity Wh remains low, barely exceeding 48%. Which shows a strong spatial variability in this group, and makes it difficult to choose the representativity of rainfall in this region.

Second group: this group includes 8 stations. The average annual rainfall varies between 333,1 and 532,5 mm (ratio of 1.6). It is located in the massif of Ouarsenis in the east and the Tellian Atlas in the west. The coefficient of spatial variability is 15,7% and the ratio between the maximum and minimum values is the lowest compared to other groups. thus, the variability from one station to another is low. This is mainly due to the homogeneity of the topography in this region (more than 800 m of altitude). The influence of the longitude on the spatial evolution of rainfall has been reflected in the low value of Wh coefficient (0,51), this percentage (51 %) can be explained by the dispersion of rainfall stations in the westerly direction which is expressed by the negative influence on the structure of rainfall fields in the group.

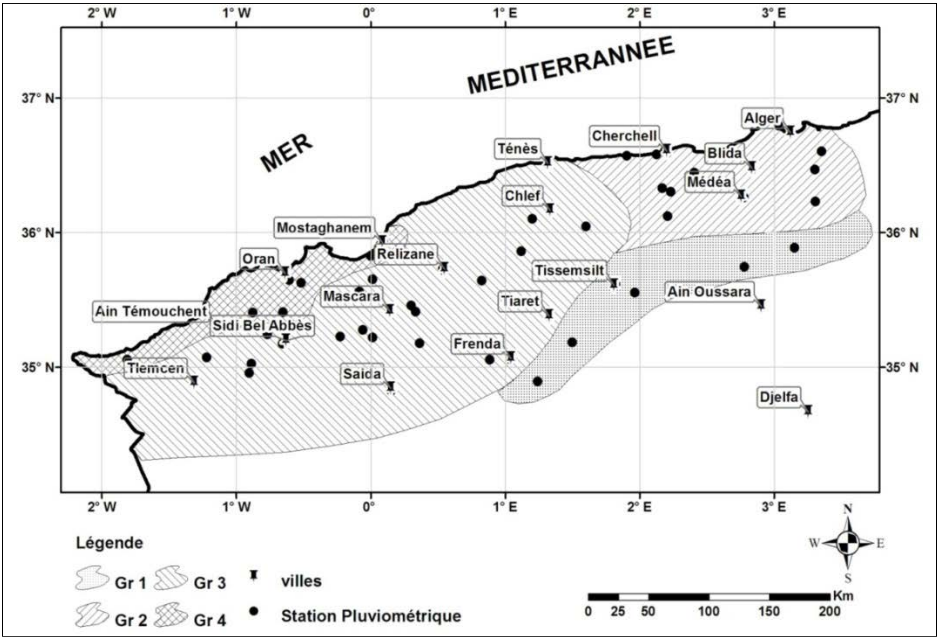

Fig. 2. Results of the PCA in 46 stations for the period 1930-2004.

Third group: includes 37 stations. They are situated in the Mitidja Plain and the Blidean Atlas. This zone ends at the summit of the Blidean Atlas and the Chenoua and Zeccar Mountains in the west. The annual rainfall varies between 313,4 and 863 mm (ratio of 2.8). The coefficient of spatial variation is about 20%. This spatial variability can be explained by the opposition of the topographic nature of this region, the plain and the mountain represented by the Atlas on which exist a number of stations having altitudes greater than 1000 m. the Wh coefficient is acceptable (61%), which shows a certain homogeneity in this group.

Fourth group: includes 51 rainfall stations. This zone is bounded on the east by the Chenoua and Zeccar Mountains, on the west by the Beni Chougrane Mountains, on the south by the Tellian Atlas. It is largely represented by the Chellif Valley. The spatial variability of rainfall is moderate (23 %). The average annual rainfall varies between 246,3 and 572,6 mm (with a ratio of 2.3) and the Wh coefficient is around 61%. These two parameters show that the group can be considered homogeneous.

Fifth group: includes 20 stations. Rainfall varies from one station to another, between 257,1 and 622,5 mm with a ratio of 2,4. The spatial variability is characterized by a coefficient of variation of 19,2. It is bounded on the north by the Mediterranean Sea, on the south by the Tellian Atlas and on the east by the Beni Chougrane Mountains. This group is the most homogeneous in the spatial evolution of rainfall fields since the Wh coefficient is around 74%.

Sixth group: includes 61 stations, rainfall varies between 180,6 and 437,3 mm with a ratio of 2,4. The region covered by this component extends from the Mediterranean Sea to Saida Mountains in the south and the limit of Chellif basin in the east. This big variety of landscape reduces the degree of homogeneity of rainfall in this group (the Wh coefficient remains low with a value of 0.55. like the first, second and sixth group, the weakness of this index is mainly due to the temporal component where this latter is important for some stations.

The introduction of new stations allows refining the regionalization of precipitation, by adding two groups. The ration between the maximum and minimum values is of the same order of those found by *Gutierrez Lopez M.A. (2007)* in the north of Mexico, and *Stathis et al. (2007)* in Greece. On the other side, in Iran the ratios are more important than those of our region (*Raziei T. et al., 2008*). To check the influence of altitude and latitude after noticing the direct influence of longitude in the determination of groups, the Wh index showed an improvement of the homogeneity of some groups without showing a balanced regionalization in all groups generated by the application of the PCA. These values are generally higher than those calculated in India by *Sulochana Gadgil et al. (1993)* and lower than those estimated in Spain by *Fernandez Mills et al. (1994)*. The non-hierarchical clustering (k-means clustering) will be applied in the interior of each of these six groups to improve the quality of the index of homogeneity (Wh). Twelve new groups (**Fig. 4**) are derived from the application of this technique where three factors explaining the spatial variability of rainfall appear to be decisive, i.e., the longitude, the distance from the sea and the altitude.

Regionalization by the k-means clustering highlighted the influence of the longitude, the distance from the sea and the altitude as determining factors in the composition of these sub groups. Thus, the first group in the arid region split into two groups under the influence of the longitude and the distance from the sea. Group 1 shows a high homogeneity with the Wh coefficient of 73%. However, Group 2 present an average coefficient of homogeneity (50%), this weakness is due to two spatial and temporal components where the variations of these two parts are high (**Table no. 3**), resulting in temporal and spatial irregularity in rainfall in this arid region with continental climate. For Group 3 and Group 4 derived from Group II, the differentiation was the results of the combination of the two previous factors, i.e, the longitude and the distance from the sea. For these two sub groups, the Wh is medium barely exceeding 52%. The temporal component is responsible for this medium percentage with a very low spatial variation, consequently the two sub groups can be considered as homogeneous. For the decomposition of groups III, IV, V and VI, three factors are critical in the separation of these sub groups: first the longitude followed by the distance from the sea and finally the altitude. We notice a clear separation between the stations of plains and those located in altitude in the Tellian Atlas and its various mountains (Tiaret, Ouarsenis, Beni Chougrane, Tlemcen and Saida).

The dominant influence of longitude confirms the spatial change of rainfall in northern Algeria, reduction in precipitation from the east to the west followed by the distance from the sea to confirm the reduction of this one, further to the south, that is to say to the inland regions. The Blidean Atlas acts as a barrier to the advancing rainy cloud masses of northerly and north-easterly directions (dominants). The Beni Chougrane Mountains (932 m) occupy much of the central zone of the study area. They extend from Saida Mountains in the east (1201 m) to Dhaya Mountains (1455 m) and the heights of the northern edge of the High Plateaus (1415 m) in the south. They form a barrier to the rainy winds of the north-west of the Azores (*Meddi, 1992* and *Aimé and al., 1988*). Group 10 includes the stations of Beni Chougrane Mountains, alluvial plains inserted in the mountains of Sidi Bel Abbès and Ghriss-Mascara of over 500 m of altitude and of Saida Mountains in the south at the limit of the Tellian Atlas. The effect of altitude has not appeared in Group 5 located in the far west of Algeria. This region is bounded on the south by the Tlemcen Mountains (1848 m) and on the north by the Mediterranean Sea. It includes the Maghnia and the middle Tafna plains. It is located away from the ridge of the middle Atlas-Rif of Morocco. Part of this area is also sheltered by the Tlemcen Mountains and another one sheltered by the Traras Massif especially Maghnia.

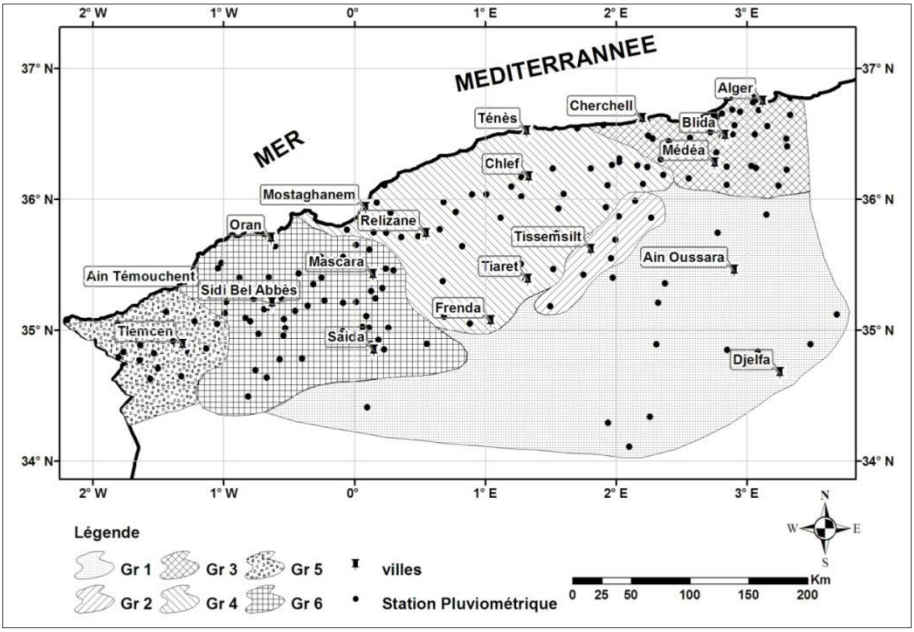

Fig. 3. Results of the PCA in182 stations for the period 1968-2004 (six groups).

It should be noted that the quality of the homogeneity index (Wh) has improved significantly (**Table no. 3**). The spatial component in the SST contributes significantly in improving this index in the groups 2, 5, 6, 8, 9, 10, 11 and 12. The temporal component weakened this index in the groups 1, 3 and 7. In these groups, the temporal variation is very significant as shown by the characteristics of the coefficient of temporal variation. Through this combined regionalization (PCA and k-means clustering), we have particularly highlighted the importance of the longitude, the distance from the sea and the topography characterized by its altitude in the regionalization of rainfall on an annual basis.

Table no. 3. Results of the homogeneity study in the twelve groups.

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Wh	0,50	0,73	0,56	0,52	0,63	0,69
Cv spatial	42.7	26	6.2	16.3	25	13.9
Cv temporal min and max	38.9 – 67.7	27.9 – 57.8	23.3 – 36.1	21 – 37.9	24.4 – 37.5	22.9 – 38.3
	Group 7	**Group 8**	**Group 9**	**Group 10**	**Group 11**	**Group 12**
Wh	0,52	0,68	0,78	0,74	0,67	0,82

3. CONCLUSION

Our analyses showed that the methods of the Principal Component Analysis and the non hierarchical clustering (k-means clustering) are particularly well adapted to the regionalization of precipitation regimes. They allowed the classification of stations having similar characteristics and the recognition of climatic regions in northwest Algeria. We undertook a first analysis taking into account the 46 rainfall stations having long measurement series (from 1930 to 2004, 74 years), and a second analysis with 182 rainfall stations applying the PCA.

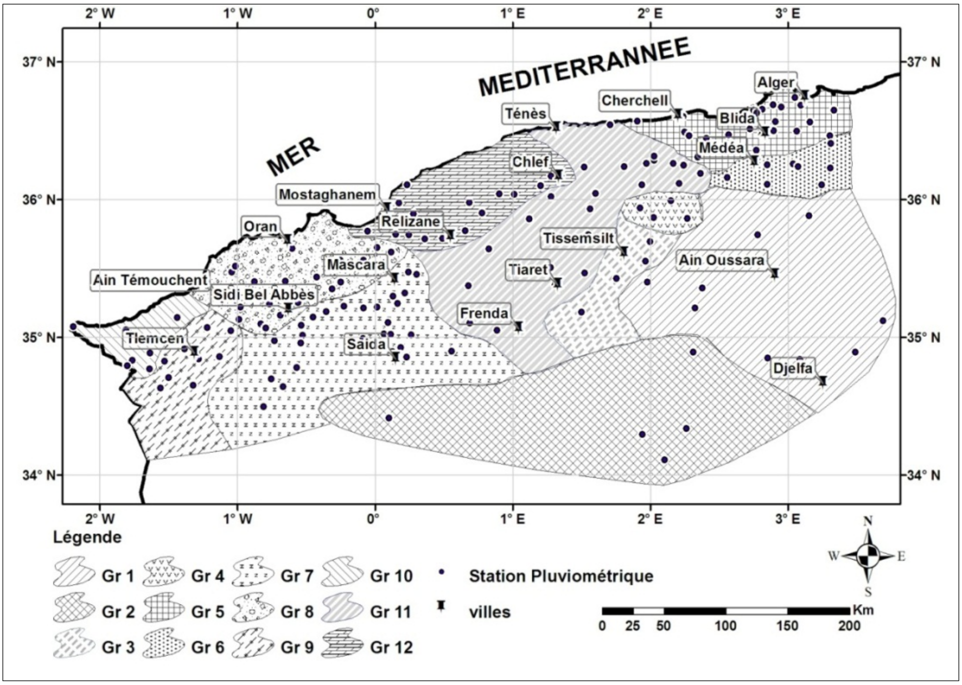

Fig. 4. Results of the PCA and the dynamic clouds for 182 stations for the period 1968 – 2004 (twelve groups)

The second analysis allowed refining the results by adding two groups to characterize the spatial variation of rainfall because of the large number of stations compared to the first one. In this case, six regions were identified. In the third analysis, the k-means clustering was used to further examine and highlight the influence of other parameters such as the distance from the sea and the altitude. Thus, we have obtained twelve groups with a better affinity in the structure of rainfall fields. We have tested the quality of homogeneity using Krauss test (1977) improved by *Fernandez Mills et al. (1994)*. This latter showed in certain groups (the High Plateaus and the Chellif Valley) a high temporal variation and an acceptable spatial homogeneity. This is valid for other groups.

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