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Determination of homogenous regions in the Tensift basin (Morocco).

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ABSTRACT
The aim of this study is to determine homogenous region in the Tensift basin within which the hydrological behavior is similar.
In order to do this we used two methods: The Principal components analysis on the monthly precipitation registered at the 23 rainfall stations. This resulted in setting apart 4 groups of stations. The second method is analysis of land use map, geological map, pedagogical map, vegetation map and slope map of the studied area. This method allowed us to delineate 4 homogenous areas.
The two methods yielded complementary results and the superposition of groups and regions obtained allowed us to retain 4 homogenous regions corresponding to 3 groups of stations.
Keywords – areas, flood, homogenous regions, PCA, Tensift basin.

I. INTRODUCTION

The goal of climate regionalization (or zoning) is getting a cut of a territory into homogeneous areas, within which the hydrological behavior is similar, [1].

The identification of homogeneous regions is a preliminary step for hydrological regionalization of certain methods used in practice to estimate a hydrological variable of interest (eg the annual peak flow) of a watershed for which one has no observation (ungauged watershed). Hydrological regionalization also allows completing and consolidating the observations of a site where data are uncertain or in insufficient quantity by enhancing observations throughout a region considered homogeneous at which the site belongs.

The first of homogeneous regions determination tests were based on the assumption that the nearest stations were the most geographically similar. But then came several studies to show that neighboring regions were not necessarily homogeneous. So the first approach was abandoned in favor of a classification approach based on physiographic and hydrological characteristics of the watershed that was introduced in Wiltshire [2] by examining its properties and its power using simulation tests.

In this regard, several studies have been proposed and applied to all parts of the globe using Principal Component Analysis (**PCA**) among which we cite the reference [3] for the PCA of monthly temperatures of New Zealand and the monthly precipitation, [4] for the PCA of monthly precipitation of England and [5] for the PCA on monthly precipitation in the Mediterranean region.

So in order to identify homogenous regions of our area of study, we used two methods. The first is the Principal Component Analysis on series of monthly precipitations. The second method is based on the analysis of Land use map, geological map, pedagogical map, vegetation map and slope map of the studied area. The choice of these maps is based on the fact that the PCA gives only groups of homogenous stations and does not delineate regions. Also these factors are important in the flood generation phenomenon.

II. STUDY AREA AND DATA

The Tensift basin is located between latitudes 32°10' and 30°50' North and longitudes 9°25' and 7°12' West, around the city of Marrakesh in the western center of Morocco. It is drained by the Tensift River which flows from east to west for over 260km. The basin extends over 19400km^2. Its vegetation is generally poor and depends on the topography and the nature of land. The climate is semi-arid influenced by the presence of high altitudes (the High Atlas). The altitude ranges from 0 to 4167m NGM with an average altitude of 2014m, (Fig. 3).

Rainfall is generally low and characterized by high spatial and temporal variability. The annual average rainfall is about 200mm in the plains and more than 800mm on the peaks of the Atlas, [6].

Available data used are the series of monthly series of precipitations recorded using rain gauges at the 23 rainfall stations that are located all aver the Tensift basin at altitudes ranging from 53m to 2230m NGM. The series' lengths vary from 14 years to 44 years (since 1967 until 2011). The location of these stations is shown in figure 2.

III. THE FIRST METHOD: PCA

The principal component analysis PCA method allows the description of data in an array of individuals / quantitative variables; this is the basic method of data analysis. From a more mathematical point of view, the PCA approximates a matrix (n ; p) by a matrix of the same dimensions but of rank q<p ; q is often a small value (2 or 3) for the construction of readily understandable graphics. This method allows studying the data in terms of correlation, i.e to detect stations having the same behavior [7]. The great advantage of this technique is its ability to simultaneously process a large amount of data. It allows, in addition to identifying the complex interrelationships between variables, to summarize or reduce them to a small number of indicators called factors or principal components PC. It is a linear combination of the original variables [8] such that:

$$X = UZ \text{ ou } X_{ij} = \sum_{k=1}^{p} u_{ik} z_{kj} \qquad (1)$$

With :

$X \in R^p$ The eigen values initial variables;

$Z \in R^p$ The vector of the main components;

U the orthonormal transformation matrix (U-1 = Ut).

Although the goal is generally to use only a small number of PC, this is only thereafter that we decide the number of components k to keep. This means we replace the original observations by their orthogonal projections in the subspace k defined by the first k of PC, [9].

The Principal Component define directions of space observations that are pair wise orthogonal. In other words, the PCA carries out a change of orthogonal reference, the original directions being replaced by PC. The fundamental property of PC is to be ranked in descending order of importance Thus, the best subspace k-dimensional (k <p) in which we project the observations while losing the least information is precisely that generated by the first k PC.

The most common use of the PCA is to provide data described by a large number of quantitative variables planar representations (and thus visually interpreted) as close as possible. For this, we project these data on factorial designs, each plane being defined by a pair of Principal Component taken among the first CP. In reviewing these projections, we can retrieve information on the data structure, for example:

• The existence and location of "exceptional" cases, or "aberrant", ie very far from all the other comments;

• The existence of well-marked groups, suggesting the existence of several sub-populations within the set of observations;

• The interpretation of Principal Components can be made in terms of real properties but unmeasured comments.

Before applying the method we calculated descriptive statistics in order to characterize the series, the results found are shown in the following table:

Table 1 : Descriptive statistic of the series of monthly precipitations.

Rainfall stations	Number of months used	Number of rainy months	Max	Mean	Standard deviation
Abadla	150	81	86.6	11.7	17.8
Adamna	150	101	180.1	25.5	39.0
Aghbalou	150	138	194.8	42.4	42.5
Chichaoua	150	107	90.7	14.2	19.2
Igrounzar	150	94	257	22.4	37.1
Iloudjane	150	129	180.9	26.8	30.4
Imine el hamam	150	132	184.4	29.5	34.3
Sidi Bou othmane	150	141	158.8	27.8	32.1
Sidi hssain	150	127	216	36.2	39.3
Sidi rahal	150	124	150.5	24.3	27.9
Taferiat	150	133	154.4	24.6	27.7
Tahanaout	150	139	132.7	28.6	31.0
Talmest	150	98	132	22.7	32.4
Tazitount	150	137	172.6	39.5	42.4
Agouns	150	133	128.6	30.3	28.7
Amenzal	150	130	543.7	33.1	54.9
Armed	150	142	273.6	33.3	38.7
Igouzoulen	150	90	292.6	26.6	45.0
Lalla takerkoust	150	138	132.7	25.6	29.4
Marrakech	150	115	261.3	19.3	31.6
Touirdiou	150	130	110.5	21.8	24.7
Tourcht	150	136	250.3	36.4	42.0
Iguir nkouris	150	125	177.7	19.9	26.6

The previous table shows that the number of observations is processed for 150 months for all stations. Monthly precipitations range from 0mm to 543.7mm, with averages that range between 11.7mm and 42.4mm. The number of rainy months varies from 81 to142 months.

The implementation of the PCA algorithm on all the data using the statistical software SPSS [10] gave the following results:

Table 2 : Results of PCA for the 23 stations.

Component	the initial eigenvalues		
	Total	% of variance	% cumulative
1	14.010	60.913	60.913
2	2.394	10.408	71.321
3	1.298	5.644	76.965
4	1.040	4.523	81.488
5	.688	2.992	84.480
6	.593	2.579	87.059
7	.400	1.738	88.797
8	.380	1.654	90.451
9	.343	1.489	91.940
10	.281	1.221	93.161
11	.262	1.140	94.301
12	.221	.961	95.262
13	.220	.955	96.218
14	.155	.673	96.891
15	.140	.610	97.501
16	.116	.506	98.007
17	.115	.502	98.509
18	.092	.398	98.907
19	.084	.365	99.272
20	.056	.244	99.516
21	.043	.185	99.701
22	.037	.163	99.863
23	.031	.137	100.000

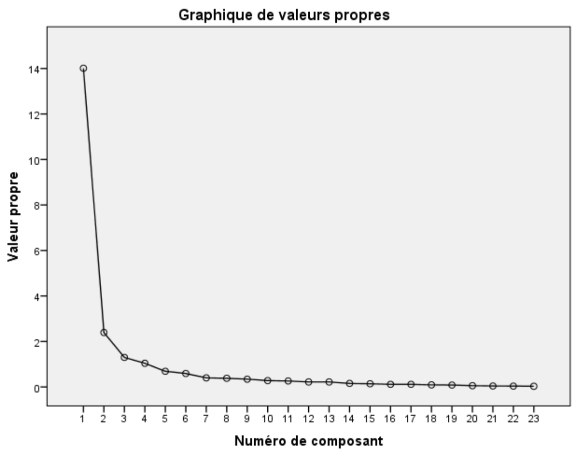

Figure 1 : Graph values for each component of the PCA for the 23 stations.

Table 2 shows the main components which are 23, their initial values, the percentage of their variances, as well as the cumulative percentage of their variance. While Figure 1 shows the representation of the eigenvalues for each component. From these results, we see that the first four components have eigenvalues greater than 1 and explain to them only about 81.5% of the total variance, so according to the Kaiser criterion which says that only components whose eigenvalues are greater than 1 should be kept. So by keeping the first four components, we will have only 18.5% of information loss, [11].

So to be able to find different groups of stations we represented the stations with their coordinates on the planes defined by the first four axes in pairs two by two. In what follows we present the results found.

Analysis of these graphs resulted in the selection of four homogeneous groups of stations divided by the axes of the plane defined by the 2nd and 3rd main axes.

The groups of stations are shown in figure 2:

- Group 1: Igrounzar, Igouzoulen, Talmest, Adamna ;
- Group 2: Abdla, Chichaoua et Marrakech ;
- Group 3: Agouns, Tourcht, Touirdiou, Armed, Amenzal, Iguir N'kouris, Tazitount ;
- Group 4: Sidi Hsain, Imin El Hamam, Sidi Bou Othmane, Aghbalou, Tahanaout, Iloudjane, Lalla Takerkoust, Sidi Rahal, Tafériat.

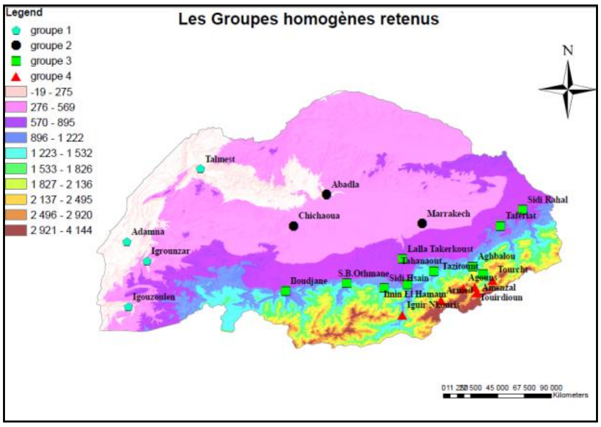

Figure 2 : Selected homogenous groups by the PCA method.

IV. THE SECOND METHOD: MAPS ANALYSIS

In this sense, we used a set of downloaded maps as shown in figure 3.

- The land use and vegetation map downloaded from the FAO website, [12] ;
- The geological and soil map from the site of Hydraulic Basin Agency of Tensift, [13] ;
- The slope map of the basin, developed by Spatial Analyst Extension of Arcgis (ESRI, 2014) from the DTM (creating classes of slopes ranging from 0% to over 35%).

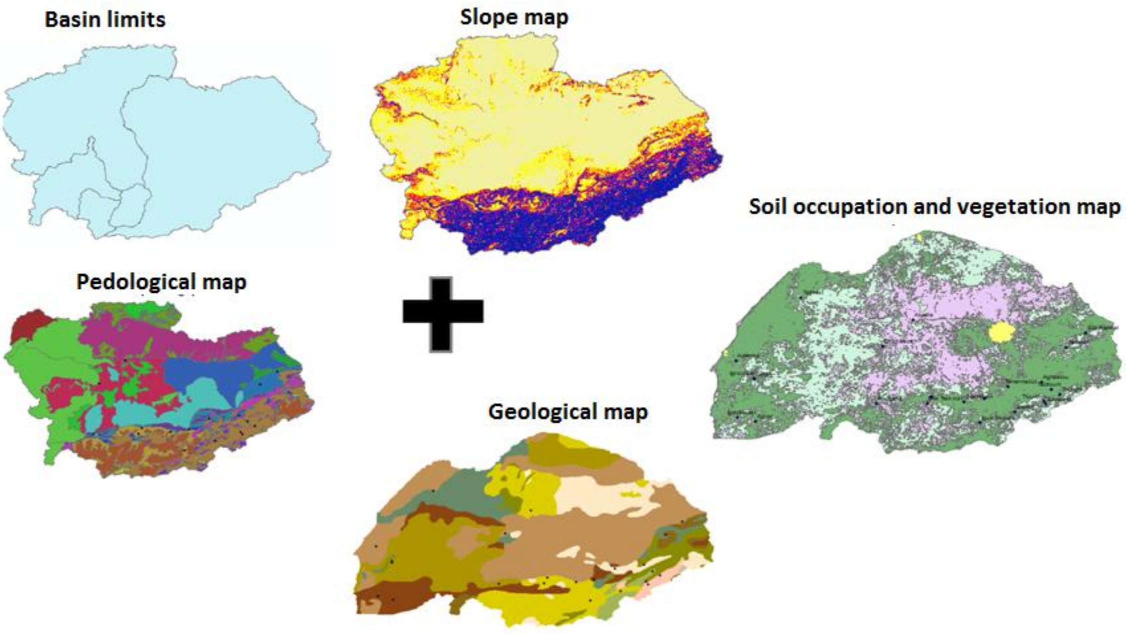

Figure 3 : Maps used in defining homogenous regions.

In order to delimit homogeneous areas on the Tensift basin, we tried to analyze each map and subdivide it in relatively homogenous regions:

- According to the classified slopes map there are three areas: a mountain area with very acute slopes (> 35%), a second zone with average slopes (between 15% and 35%) and third plain area with fairly gentle slopes (<5%) ;
- According to the soil map, 3 homogeneous regions can be distinguished: A region in mountain areas made by skeletal soils and sandy soils (brown part). A second area in the North West of the basin, formed by the soil on limestone plateau. A third area in the central and northwest of the basin, formed by fersiallitic floors, slate floors, chestnut soils and Siorozems soil (same source rock) ;
- According to the geological map four homogeneous areas can be distinguished: An area in the High Atlas made largely by impermeable formations. A second zone in the central part of the basin formed by Neocene and quaternary formations with an average permeability. A third area in the northern part of the basin formed by the Paleozoic formations characterized by a relatively low permeability. A fourth area in the western part of the basin with highly permeable formations ;
- According to the land use and vegetation map under 4 different homogeneous areas: an area in the High Atlas characterized by its low density and scattered plants, a second in the central part surrounding the Marrakech with high urban density, a third in the northern part characterized by meadows and forests, a fourth in the western part in the plain of Essaouira which is characterized by a relatively high density of inhabitants and its scattered vegetation.

The superposition of all these maps, made it possible to distinguish roughly 4 homogeneous areas, “Fig.4”:

- An area in the north of the basin with relatively gentle slopes and tight formations and vegetation sufficiently developed;
- A central area with medium to low slopes and average permeability formations, with a high density of population;
- An area south of the basin in the High Atlas area with fairly acute slopes and low permeability soil and a plant formation formed of bushes or shrubs;
- A western area of the basin with average slopes and very permeable formations and farmland.

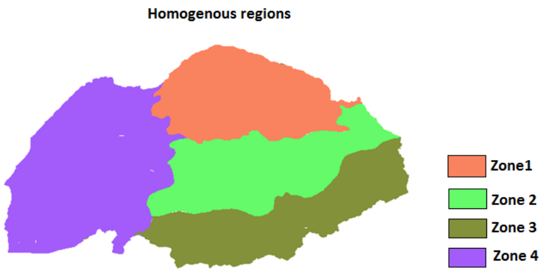

Figure 4 : Homogenous regions on the Tensift basin.

V. Conclusion

Both methods yielded complementary results. The overlay of the map of homogeneous groups and that of the homogeneous regions shows that we can distinguish, “Fig.5”:

- The homogeneous zone 1 (red part) north of the basin that contains no rainfall station;

• The homogeneous zone 2 at the center of the basin (green part) which includes all stations in the homogeneous group 2;

• The homogeneous zone 3 souths in the region of the medium and high Atlas of scolding elevations (partly brown). It includes the rainfall stations in groups 3 and 4;

• The homogeneous zone 4 west basin (purple part) that contains the rainfall stations in Group 1.

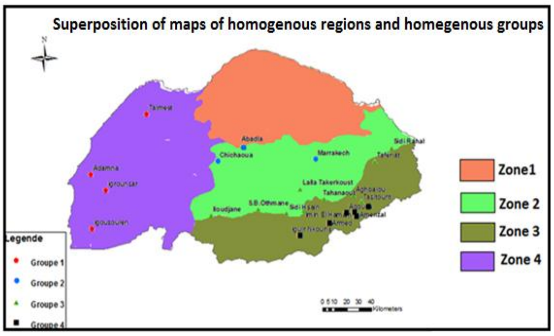

Figure 5 : Superposition of homogenous regions and homogenous groups.

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