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Characterization of precipitation patterns in the Anzoátegui state, Venezuela

INTRODUCTION

The characterization of rainfall represents, largely, a way to describe the rainfall regime in the area, being useful for agricultural planning and research. This is why classifying and describing zones with homogeneous patterns of this climatic element is a first approximation in the development of models for diverse predictions (Demey et al., 1995, Guenni et al., 2008, De Luis et al., 2010; Martin Vide, 2011; Miró et al., 2015).

There are several methods of climate classification. Among these various methods (Pla, 1986, Demey et al., 1995, Olguin et al., 2011, Pradere, 1999) there is an agreement that the Principal Components Analysis (PCA) is a useful tool in climatology. It allows the original data to be simplified, representing them in a smaller number of variables, which contain most of the information, widely used by professionals in the meteorological area for the delineation of patterns of climatic variables. This is a multivariate technique that can be applied to a variety of problems in the sciences, being very useful for diagnostic or prediction tasks (Zambrano et al., 1995).

This method has been applied in the determination of homogeneous areas of precipitation (Demey et al., 1995); in the spatial distribution of rain (Demey and Pradere, 1996); in the definition of homogeneous patterns of rainfall in the Venezuelan central plains through factorial kriging (Pradere, 1999) and in the application of the multiple homogeneity index to climatic data of Venezuela (Pineda et al., 2006).

The spatial analysis of climatic variables is of great importance in order to understand the behavior of natural phenomena that vary spatially influenced by the physical environment that surrounds them; it is a very useful tool for various disciplines and serves to make decisions that can affect human activities.

Knowledge of the spatial distribution of rainfall represents an essential aspect to understand descriptively the precipitation regimes, as well as obtaining the classification of areas according to the similarity between neighboring rainfall stations. The objective of this work was to characterize precipitation patterns, through the use of Principal Component Analysis (PCA) and hierarchical grouping analysis.

METHODOLOGY

The study area corresponds to the Anzoátegui state in Venezuela. Much of the state has a tropical dry forest, with the exception of the northwest of the state which has a narrow semi-arid strip called the very dry tropical forest. To the northeast, a climate of dry premontane forest and humid premontane forest characteristic of high areas bordering the Monagas state.

The monthly precipitation values used for this study correspond to 40 rainfall stations located in the Anzoátegui state during the 1970-2000 registration periods. After the selection of these stations, the data quality control tests recommended by Parra and Cortez (2005) and Olivares et al., (2013) were applied, represented by the determination of gaps, the calculation of descriptive statistics, analysis of dispersion and homogeneity of the time series of precipitation.

For the determination of the homogeneous groups, the hierarchical clustering analysis was applied, designed to reveal the natural groupings (the conglomerates) within a data set. We used Ward's minimum variance method, where the distance between the two groups is the sum of the squares of analysis of variance between the two groups added along all the variables (SAS, 2010). Both analyzes are described with greater emphasis in the previous study called: Group of climatic stations with homogeneous rainfall patterns in the Anzoátegui state according to Olivares et al. (2012).

The statistical analysis was carried out through the Principal Component Analysis (PCA) described by Pla (1986). The data matrix X is constituted by the set of vectors of the observations X [ij], j = 1, ..., p and where each vector X [ij] presents the variable j-th for all the observations and where X, is the data matrix formed by "n" observations with "p" variables (40 observations with 24 variables corresponding to the average and standard deviation of each month).

The Geographic Information System (GIS) ArcView 3.2 (ESRI, 1996) was used to spatialize the climatic stations with their attributive information that provide data of the responsible organism, name of the station, state, station code, type of station, geographic coordinates and altitude (Metada).

The average monthly and annual precipitation data were subjected to an exploratory data analysis (AED) for which the statistical program Infostat (Infostat, 2008) was used. The basic statistics were obtained (mean, variance, standard deviation, coefficient of variation, kurtosis, asymmetry, maximum and minimum values and quartiles) and the presence of outliers.

According to the results of the AED, this study was based on the use of a position statistic such as Percentile 75 (P75) which indicates the amount below which 75% of the precipitation sheets are found.

For the temporal analysis of precipitation the data of P75% was used, later it was specialized using geostatistics. In this sense, the experimental semivariograms were constructed, and they were adjusted to theoretical models, as a basis for the interpolation and generation of precipitation isolines maps of the Anzoátegui state, by means of the Ordinary Kriging (KO) method. Finally, the maps of the annual precipitation sheets and the number of wet months for the state were generated and edited.

RESULTS AND DISCUSSION

With respect to the ACP, the eigenvalues of the first five Principal Components (CP) were higher than the average according to the Kaisser criterion which includes only those components whose eigenvalues are above average. These five CPs explain 79.98% of the total variance, which is considered a significantly high percentage, while the rest of the 19 components only explain 21.10% of the existing variation.

According to the characterization of the first component, this group is the one that presented the highest variance, therefore the highest explanatory capacity of the data, 41.26% of the total. Positive values were observed in proportions higher than 0.30 of the averages of the months of May, July and August and the deviation of the month of May, variables that reflect a rainy peak in the summer astronomical product of the intertropical convergence in the region of the Venezuelan plains.

This group of stations presents a wet period most of the year, from April-May to November-December with peak in July and August. They are located northeast of the state. It includes the lacustrine and low-lying plains. The stations are Anaco, Cantaura, San Joaquin, Santa Rosa, Santa Ines, Clarines, Santa Clara, Santa Clara II and San Mateo.

The second component explained 17.39% of the total variability. It is related to the averages of the months January, November, December and the deviation of the month of December, variables that reflect a rainy peak at the end of the year. This component is associated with those pluviometric observatories that have high rainfall averages in the months of November and December, the climate in these stations is semi-arid.

It is the driest group of stations of all, tending to a wet period by the end of the year. They are located to the north of the state, includes part of the coastal zone, with landscapes of hills. The stations within this group are: Barcelona, Puerto La Cruz, La Cerca and Boca de Uchire.

For its part, the third component explained 10.02% of the total variance. It has to do with the standard deviation of the month of March, November and December. This group of stations has a not insignificant dispersion for these months and probably important in the opportunity to perform agricultural tasks such as soil preparation, planting, application of fertilizers and / or amendments and harvest, in the study area.

In this group, the difference between the rainy periods of April-October and dry of November-March tends to be more marked. They are located to the northwest of the state, with units of landscapes included between plains, plateaus and hills. The stations belonging to this group are: Aragua de Barcelona, El carito, Guayabal, Querecual, Quiamare, Mundo Nuevo, Campo Mata, Chaparro Caserío, La Viuda, Santo Tomas, Curataquiche, San Bernardino, Guanape, Guaribe-Tenepe and Úrica.

Likewise, 7.09% of the total variance is explained by the fourth component. This is related to the average and standard deviation of April whose absolute values are greater than 30%. This group is humid during the period of May-October, with maximum values of precipitation in the month of August and a dry period very marked the rest of the year. The stations are located in the south of the state, characterized by lacustrine plains-like landscapes. Here are the stations: Bergantin, La Corcovada, Onoto, Chaparro Pueblo, El Manguito, San Diego de Cabrutica and El Tigre.

The fifth component explains 4.22% of the total variability, this has to do with the standard deviation of the months of March and October. This last component is associated with the pluviometric observatory that has high rainfall averages in the dry months with a non-negligible dispersion for the indicated months. This group is humid from October to December. January, February and March tend to be dry. The monthly rainfall amounts exceed the averages of the previous groups. It is located to the southwest of the state, characterized by landscapes of plains. The station belonging to this group is Musinacio.

According to the contributions of Rodríguez et al. (2013), Anzoátegui State showed a temporal variation of significant rainfall in the period between 1970 and 2000. With annual rainfall that increases and locates towards the southern zone of the region. The study establishes a temporal variation in the amounts of precipitation over the three decades, reflected in a significant decrease in annual precipitation (100 to 350 mm) in more than 60% of the area (south-west of the state) and an increase in more than 35% of the state (north-east).

In general, a drier future is evident, clearly distinguishing the areas of the country in which the greatest impact is produced on the areas of agricultural use. In the North-East region the area affected by water deficit would grow from 4,600,000 ha to 9,000,000 ha; Within this area of Anzoategui, there is an area with a greater increase in water deficit ranging from 500,000 ha to 1,300,000 ha (Ovalles et al., 2008).

In the same way, a reduction in the number of wet months is estimated, which limits the use of both annual and perennial crops, depending on the magnitude of the reduction. The distribution of precipitation will be affected, an example of this is the analysis of the distribution derived from the study of Martelo (2004), where the highest incidence is in the month of May, which corresponds to the preparation of the land and planting of the main crops in most agricultural areas; with incidences also in the month of August, month that corresponds to the flowering, fructification and filling of grains mainly of cereals.

CONCLUSIONS

This study represents a characterization of the moisture regime of the region that could be used in long-term agricultural planning and for possible studies of spatial and temporal variability of precipitation in the eastern plains.

The methodology used in this study can be applied in other sites of interest not only for characterization purposes but also for other companies or environmental planning entities that are responsible for the management of water resources in the Venezuelan Llanos. It was determined that there are five groups of climatic stations with homogeneous precipitation patterns in the Anzoátegui state associated with the characteristic landscapes units of the eastern region. Both spatial and temporal distribution can be explained locally by the air mass circulation patterns that are generated between the valley and the more mountainous areas.

Additionally, the study developed by Lobo et al., (2010) indicates that the central zone of the Venezuelan plains, constituted by the south-central region of Guárico state, western Anzoátegui state and eastern Apure and Barinas states, presents some concentrated rainfall with a very high aggressiveness, while the rest of the region presents a combination of moderate seasonality and high to very high aggressiveness, hence the importance of establishing this type of characterizations which would allow applying land management strategies based on the conservation of water and soil resources.

Finally, it is convenient to indicate that the amount of precipitation registered temporally and spatially depends on the density of the network of stations and the location of them, since possibly in other points of the studied territory greater amounts of precipitation can be recorded in scales of time less than a month.