Revista Agro@mbiente On-line, v. 10, n. 2, p. 88 - 95, abril - junho, 2016
Centro de Ciências Agrárias - Universidade Federal de Roraima, Boa Vista, RR
www.agroambiente.ufrr.br
DOI:10.18227/1982-8470ragro.v10i2.3500

Artigo Original

ISSN 1982-8470

Uncertainties of the rainfall regime in a tropical semi-arid region: the case of the State of Ceará[1]

Incertezas do regime pluviométrico no semiárido tropical: o caso do estado do Ceará

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Abstract: The rural population of a tropical semi-arid region such as the northeast of Brazil is directly dependent on rainfall for agricultural production, pasture for livestock, and the storage of drinking water for human consumption. The region is characterised by the frequent occurrence of dry years and consecutive dry days (CDD) during the rainy season, demonstrating the vulnerability of rainfed agriculture. The aim of this study therefore, was to identify homogeneous regions of the State of Ceará where there is greater or lesser uncertainty of the rainfall regime. Accordingly, the occurrence of dry and very dry years were investigated as uncertainties between years, together with the occurrence of two classes of CDD (10-20 and 21-30 days) during the rainy season. To define similar regions as to the uncertainty of the rainfall regime, the technique of Hierarchical Cluster Analysis (HCA) was used. The study considered time series of least 30 years, from 77 rain gauge stations around the state of Ceará. The use of HCA resulted in the formation of seven homogenous groups in both of the phenomena being investigated. Municipalities in the Central Backlands, the Inhamuns Backlands and the Jaguaribana Region displayed a higher frequency of both inter-annual (dry years) and intra-annual (CDD) uncertainty, demonstrating the greater vulnerability of rainfed agriculture. The occurrence of a CDD event is not dependent on the total annual rainfall, as several stations with an average rainfall higher than that of the state showed potential for the occurrence of CDD. The number of CDD events recorded in the 11-20 day class was higher than in the 21-30 day class.

Key words: Dry semi-arid regions. Precipitation. Consecutive Dry Days. Rainfed agriculture.

Resumo: A população rural das regiões semiáridas tropicais como o Nordeste brasileiro é diretamente dependente das chuvas para a produção agrícola, pasto para os animais domésticos e armazenamento de água potável para consumo humano. A região se caracteriza pela frequente ocorrência de anos secos e de dias secos consecutivos (DSC) durante a estação chuvosa, caracterizando a vulnerabilidade da agricultura de sequeiro. Assim, objetivou-se com esse estudo identificar as regiões homogêneas do estado do Ceará com maior ou menor incertezas do regime pluviométrico. Para tanto, investigou-se a ocorrência de anos secos e muitos secos como incertezas interanuais e a ocorrência de duas classes de DSC (10-20 e 21-30 dias) durante a estação das chuvas. Para definir as regiões similares quanto a incerteza do regime pluviométrico, empregou-se a técnica de Análise de Agrupamento Hierárquico (AAH). Foram consideradas neste estudo séries históricas com no mínimo 30 anos de 77 postos pluviométricos distribuídos no estado do Ceará. O emprego da AAH resultou na formação de 7 grupos homogêneos em ambos os fenômenos investigados. Os municípios localizados no Sertão Central, Sertão do Inhamuns e Zona Jaguaribana apresentaram uma maior frequência das incertezas interanuais (anos de seca) e intra-anuais (DSC), caracterizando a maior vulnerabilidade da agricultura de sequeira. A ocorrência do evento DSC independe da precipitação total anual, pois vários postos com precipitações médias superiores à do estado apresentaram potencial à ocorrência de DSC. O número de eventos de DSC registrados na classe de 11 a 20 dias foi superior ao da classe de 21 e 30 dias.

Palavras-chave: Semiárido-secas. Precipitação. Dias Secos Consecutivos. Agricultura de sequeiro.

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Enviado para publicação em 20/05/2016 e aprovado em 23/05/2016
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INTRODUCTION

In the semi-arid regions of the world, water is the limiting factor in the development of agricultural production and of pasture for livestock. This limitation becomes more obvious in semi-arid areas located in the tropical zone where high rates of evapotranspiration are recorded as a result of the total amount of solar energy available (ANDRADE *et al*., 2010), with a consequent reduction in agricultural production (BARRON *et al.,* 2003; GOENSTER *et al*., 2015). The semi-arid area of northeastern Brazil, inserted in the tropical region, has an agricultural production which is intrinsically dependent on the rainfall of the region, but this regime is fairly irregular, both on an inter-annual and intra-annual scale. Such uncertainty exposes both the rural population and agricultural production in particular to a high level of vulnerability to the climate conditions of the region (NELSON; FINAN, 2009). As an integral part of the Brazilian semi-arid region, the State of Ceará is also characterised by a high spatial and temporal variability of the rainfall regime (GUERREIRO *et al*., 2013); despite this, agricultural production in the state is based on rainfed agriculture (ALVES *et al*., 2009).

The rainy season in the Brazilian semi-arid region is limited to a period of 4 to 5 months, with 60% of the total annual rainfall occurring between February and May. It is a regime characterised by a high degree of both inter-annual and intra-annual uncertainty in the occurrence of rainfall events. It is possible in a single month for the rainfall depth to exceed 70% of the regional average (ANDRADE *et al*., 2010). Despite water being the limiting factor in agricultural production, the distribution of rainfall events over time is what most affects crop development and agricultural production (BARRON *et al*. 2003; GOENSTER *et al.,* 2015).

This variability, whether on an annual or monthly scale, is defined by the different weather systems which are related to sea surface temperatures (SST) in the Pacific or tropical Atlantic (HASTENRATH, 2012; ALVES *et al.,* 2006; SUN *et al*., 2006). The source inducing rainfall from February to May is related to the advancement of the Intertropical Convergence Zone (ITCZ) over the southern hemisphere (SANTOS; BRITO, 2007, MENEZES *et al.,* 2008; SANTOS; MANZI, 2011). When the SST in the Atlantic favour formation of more-intense southeasterly trade winds, and northeasterly trade winds of low intensity, there is a reduction or absence of rainfall between March and April over the Brazilian Northeast (HASTENRATH, 2012).

Another characteristic of the dry regions of the globe is the occurrence of consecutive dry days (CDD) during the rainy season; this process increases the vulnerability of agricultural production (GOENSTER *et al.,* 2015; DIXIT; TELLERIA, 2015). Such a phenomenon can result in the total or partial loss of a harvest (MENEZES *et al.,* 2010; ALVES *et al*., 2009).

There are various proposals for a precipitation threshold to define a "break" in the number of CDD (Chatfield 1966). This work considers the 2 mm threshold proposed by Fernandes (2014) as breaking the number of CDD. That author found that rainfall of around 2 mm was able to maintain and increase the rates of transpiration and photosynthesis in the cowpea (*Vigna unguiculata* (L.) Walp.).

The aim of this study therefore, was to define homogeneous regions of the State of Ceará with a greater potential for a number of years of extreme water shortage, as well as the occurrence of CDD occurring over intervals of 11-20 and 21-30 days.

MATERIAL AND METHODS

This study considered 77 rain gauge stations around the State of Ceará (Figure 1), of which 93% of the territory is inserted in the semi-arid region of northeastern Brazil. The historical series comprised at least 30 years (1974-2012) of continuous 24-hour events, provided by the Ceará Foundation for Meteorology and Water Resources - FUNCEME.

The rainfall regime in the region is characterised by high temporal and spatial variability (ALVES *et al*., 2009), with over 60% of the total rainfall distributed from February to May (ANDRADE *et al*., 2010). The source inducing rainfall during this period is the Intertropical Convergence Zone (ITCZ), the end of the rainy season occurring with the return of the ITCZ to the northern hemisphere.

To map agricultural vulnerability to the availability of water during the rainy season in the State of Ceará, only rainfall events were considered that occurred between January and May, the period of the rainy season and rainfed agricultural production. Rain gauge stations representative of the eight climatically homogeneous regions proposed by Xavier (2001) were analysed: Coastal 1 (9 stations), Coastal 2 (6 stations), Coastal 3 (5 Stations), Central and Inhamuns Backlands (23 stations) Jaguaribana (10), Ibiapaba (12), Baturité (9) and Cariri (3).

To define and investigate the homogeneous regions for greater or lesser vulnerability to the rainfall regime, two types of analysis were developed: the first considering inter-annual variability (the occurrence of droughts) and the second considering intra-annual variability (the existence of consecutive dry days during the rainy season). To identify the presence or absence of drought in the 77 municipalities being investigated, classification of the Humidity Index (HI) proposed by Hevia (2002) was used. The HI is determined from the following equation:

$$I_U = \frac{P}{\overline{P}} \qquad \text{E1}$$

Where,

I_U – Humidity Index

P – Annual precipitation (mm) and

$\overline{P}$ - Average precipitation for the series under study (mm).

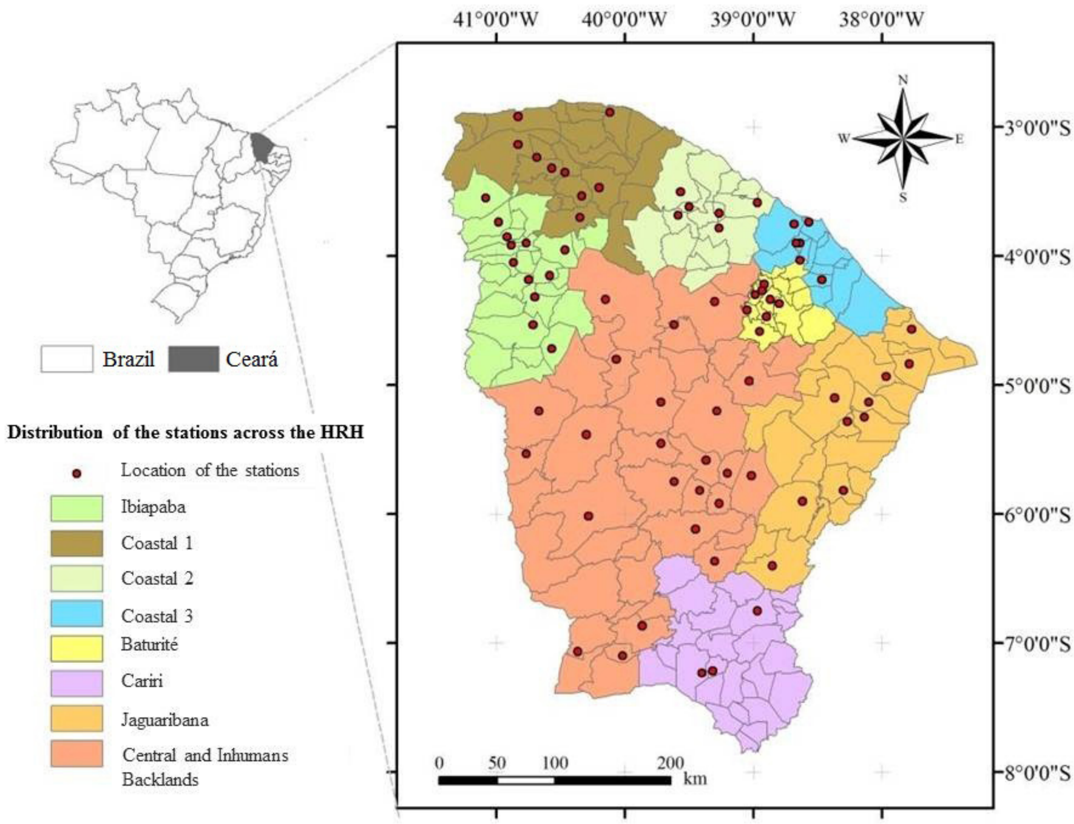

Figure 1 - Location of the stations and regions of homogeneous rainfall (HRH) in Ceará.

The classes of HI considered in this study were defined according to the limiting rainfall indices (SALGADO *et al*., 2015) found in the new delimitation of the Brazilian semi-arid region. After a probabilistic determination for a year considered as normal for moisture content, the other classes were standardised (Table 1).

Table 1 - Yearly classification by humidity index (IU)

Class	IU
Very wet	IU > 1.3
Wet	1.1< IU ≤ 1.3
Normal wet	1 < IU ≤ 1.1
Normal	IU = 1.0
Normal dry	0.9 ≤ IU < 1
Dry	0.7 ≤ IU < 0.9
Very dry	IU < 0.7

Hierarchical Cluster Analysis (HCA), a technique of multivariate analysis, was used to define regions which were similar in vulnerability to the greater or lesser occurrence of dry years, as well as to the presence of Consecutive Dry Days (CDD). When investigating dry years, the classes of dry and very dry years were considered (Table 1). To quantify the existence of CDD, two classes were considered (11-20 days and 21-30 days). These two intervals were chosen as they express a high degree of vulnerability of agricultural production to water stress (FERNANDES *et al*., 2015). To define the number of groups, a technique employing the first large jump in the rescaled distance was used (FONTENELE *et al*., 2011), i.e. the increase in dissimilarity of the agglomeration coefficient establishes the cut-off point of the dendrogram for defining the number of groups.

RESULTS AND DISCUSSION

HCA was used in two analyses. The first was when investigating similarity as to the occurrence of dry/very dry years (inter-annual uncertainty). In the second analysis, homogeneous regions were identified for the occurrence of CDD (intra-annual uncertainty).

Inter-annual uncertainty

Cluster analysis defined seven similar groups for a greater or lesser occurrence of dry and/or very dry years. Of the seven groups formed, the first three displayed a greater vulnerability to, or the uncertainty of success in, the availability of water (ALVES *et al*., 2009) for human consumption and agricultural production (Table 2). This increase in vulnerability is defined by the greater occurrence of very dry years during the period under study, and by the rainfall events of less than 584 mm recorded during the rainy season. Such a framework defines the severe vulnerability of 30 of the 77 municipalities investigated; all located in Inhamuns, West Cariri, Central Backlands and the Jaguaribana Region (Figure 2).

Table 2 - Grouping of rain gauge stations for the occurrence of dry and very dry years

Group	Number of stations	Mean rainfall (mm)	Occurrence of dry years			Occurrence of very dry years		
			Max	Mín	Mean	Max	Min	Mean
1	3	417.8	9	4	6.3	20	16	17.7
2	10	509.8	11	6	7.9	13	7	9.8
3	17	584.9	6	4	5.2	9	4	6.3
4	8	617.5	9	5	6.9	5	2	3.1
5	14	715.5	4	1	2.5	6	2	4.3
6	18	826.1	4	1	2.6	3	0	0.8
7	7	1078.2	0	0	0	1	0	0.1

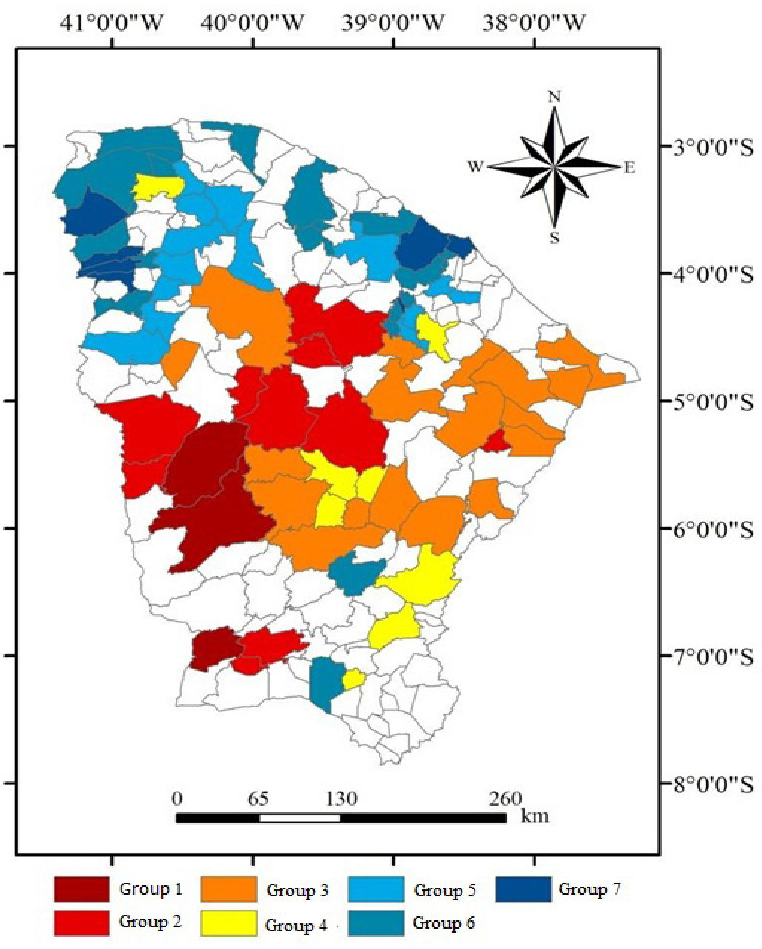

Figure 2 - Spatial distribution of the groups for the number of dry and very dry years.

Groups 4, 5 and 6 comprised municipalities with the second largest vulnerability to the rainfall regime, since a smaller number of years were classified as dry or very dry and greater rainfall depths were recorded. With the vast majority of the rural population of Ceará depending directly on rainfall (NELSON; FINAN, 2009), whether for the production of food, pasture for cattle, or supplying water tanks and reservoirs, there is great vulnerability due to the concurrent use of water for food production and other demands, in an environment completely dependent on the rainfall regime.

Group 1 has the lowest average rainfall for the rainy season (417.8 mm), and comprises the municipalities of Campos Sales, Tauá and Independência (Figure 2). The town most vulnerable to rainfall was Campos Sales, since besides recording the lower rainfall depth during the rainy season (Table 3) it also saw the highest occurrence of very dry years, a total of 20 in a series of 30 years. These characteristics express the complete vulnerability of agricultural production in the region due to low soil moisture (ALVES *et al*., 2009).

It is understood that Groups 1, 2 and 3 present severe limitations to the development of rainfed agriculture, whether due to the total rainfall or the occurrence of dry and very dry years. For this condition of very dry years, the town of Campos Sales displays the greatest vulnerability, either because of the average annual rainfall or the high number of very dry years.

One fact worth noting is that of Group 4, since the eight municipalities that make up that group are distributed over five of the eight HRHs. Such a fact demonstrates that the similarity of the water regime between stations is independent of geographical continuity, as discussed by Andrade (2000). The years classified as dry for this group account for approximately 32.45% of the total for the years in the series being studied, while very dry years account for 13.44%; that is, 46% of the years were classified as dry or very dry.

Group 6, made up of 18 rain gauge stations with an annual average rainfall >800 mm, showed only 3.9% of the years of the series as very dry, while 10.4% were shown as dry. Of the 77 stations being investigated, only seven municipalities (Group 7) showed no record of dry years, and only one year was classified as very dry. It should be noted that average rainfall for this group was 1078.2 mm (Table 2). With these characteristics, Group 7 expresses a region of sub-humid climate, since for five months there is on average more than 1000 mm of rain. These seven municipalities are located in the Ibiapaba and Baturit mountains or on the coast (Figure 2), and are therefore areas that are influenced by orographic rainfall and the coastal region (HASTENRATH, 2012). This shows that to better characterise homogeneous regions, other factors that influence total annual rainfall should be considered, such as the topography of the state (REIS; SILVA; OLIVEIRA SILVA, 2011).

Table 3 - Maximum occurrence of dry and very dry years

Variable	Station	Number of years	Mean Precipitation (mm)
Very dry years	Campos Sales	20	392.8
	Tauá	17	404.3
	Independência	16	456.3
	Itatira	13	466.6
	Potengi	12	501.8
Dry years	Canindé	11	485.9
	Quixeramobim	10	514.7
	Milhã	9	559.9
	Itatira	9	466.6
	Tauá	9	404.3

Intra-annual uncertainty

In the investigation into homogeneity between the rain gauge stations for the occurrence of CDD, seven similar groups were also identified (Table 4). It can be seen that the

Table 4 - Homogeneous groups for the two classes of CDD

Group	Number of stations	Mean rainfall (mm)	Occurrence of CDD 11 - 20 days			Occurrence of CDD 21 - 30 day			Mean CDD
			Max	Mín	Mean	Max	Min	Mean	
1	5	529.9	57	50	53	24	18	21	74
2	15	546.4	70	55	63	20	11	15	78
3	8	575.0	54	44	56	10	3	7	63
4	13	607.6	54	45	49	14	8	12	61
5	7	718.1	39	32	37	10	7	9	46
6	20	827.6	44	26	34	6	1	4	38
7	9	988.1	24	13	19	7	0	3	22

first four groups had an average rainfall of less than 610 mm and that they contain more than 50% of the stations being investigated; they also recorded the greatest occurrences of CDD for the two classes under study (11-20 and 21-30 days). Group 2, consisting of 15 municipalities, displayed the highest frequency of CDD in the 11-20 day class, followed by Groups 1 and 3.

Analysing average precipitation together with the two classes of CDD, it is found that Group 2 is the region with the greatest occurrence of CDD, with an average of 78 events. This fact expresses the high vulnerability of these 15 municipalities for rainfed agriculture, the production of pasture, and the availability of water for human consumption (DIXIT; TELLERIA, 2015). In this group are found municipalities from the macro-region of the Inhamuns and Central Backlands. Municipalities such as Tauá and Independência, included in the group, are part of the nucleus of desertification of the Inhamuns (REIS *et al*., 2011), where the periods of CDD are frequent and long, occurring every year and lasting more than a month.

Among the groups with the most vulnerability to climate, Group 3 displayed the smallest occurrence of CDD in the 21-30 day class (on average seven events). This class generates the greatest losses to agriculture, as few crops can withstand a sequence of 20 days or more without rain (GOENSTER *et al*., 2015). Fernandes (2015) found that ten days without rain in an Argisol of the semi-arid region significantly reduced development in the cowpea (*Vigna unguiculata* (L.) Walp.), a crop which is generally produced under rainfed systems in the state of Ceará. Researchers like Nelson and Finan (2009) found that a dry period of 10 days during the rainy season is capable of destroying the complete crop, even in a year of high annual rainfall. This observation confirms the hypothesis that agricultural planning and water management for rural communities should not be based solely on total rainfall, but on how the events are distributed.

It can further be seen from Table 4 that in groups with an average rainfall greater than the limit for a semi-arid climate (800 mm yr^{-1}), there are CDD events present. This illustrates the fact that an analysis based solely on total annual rainfall may lead to misinterpretation of water availability or to bad management of the water resources. Guerreiro *et al*. (2013) showed that the rainfall regime in the State of Ceará has a tendency for the number of consecutive dry days to increase, with extreme events concentrated at the start of the rainy season.

It can be seen in Figures 2 and 3 that Group 4 has the greatest geographic diversity, with municipalities in most of the homogeneous rainfall regions defined by Xavier (2001), (Figure 1). This diversity of geographic location demonstrates that any similarity in the occurrence of dry spells has no geographic continuity.

Group 7 consisted of municipalities with a greater rainfall depth (average of 988.1 mm yr^{-1}) and less occurrence of CDD, an average of 19 occurrences for the 11-20 day class, and only 3 for the 21-30 day class (Table 4). This behaviour can be explained by the location of the stations in regions on the windward side of the mountains and the coast; privileged areas with a higher rainfall index due to the orographic effect (CORDEIRO *et al*., 2007) of humid air masses coming from the ocean. However the

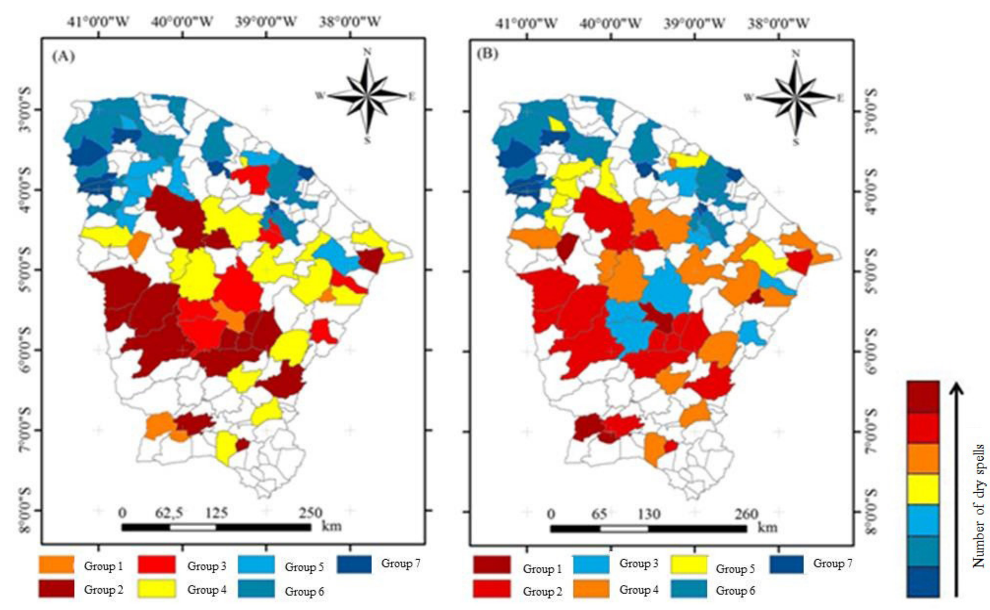

Figure 3 - (A) Groups with the occurrence of dry spells of from 11 to 20 days. (B) Groups with the occurrence of dry spells of from 21 to 30 days.

results make it clear that even in regions where there is greater annual rainfall, uncertainty over the distribution of events is found. This observation confirms the argument of Finan and Nelson (2009); even in regions with high annual rainfall the intra-annual irregularity continues.

CONCLUSIONS

The municipalities located in the Central Backlands, the Inhamuns Backlands and Jaguaribana Region showed greater susceptibility, both in relation to inter-annual uncertainty (drought years), as to the occurrence of intra-annual uncertainty (CDD). Of the 77 municipalities investigated, 30 displayed severe vulnerability to inter-annual and intra-annual uncertainty;

The occurrence of a CDD event is independent of the total annual rainfall, as several stations with an average rainfall greater than that of the state showed potential for the occurrence of a CDD. Throughout the State of Ceará, the occurrence of a CDD with a duration of between 11 and 20 days was more frequent than for a CDD of 21 to 30 days.;

Hierarchical Cluster Analysis demonstrated that uncertainty of the rainfall regime shows no geographical continuity, which limits the definition of homogeneous regions within a continuous area;

The municipalities that make up Group 7, located in the coastal region and in areas under the orographic effect of the mountains, although displaying low vulnerability to the occurrence of dry years, recorded occurrences of CDD, expressing a vulnerability to intra-annual uncertainty.

ACKNOWLEDGEMENT

Thanks are due to the National Council for Scientific and Technological Development (CNPq) for the research grant and Scientific Initiation Grant awarded to the authors.

SCIENTIFIC LITERATURE CITED

ALVES, J. M. B.; SERVAIN, J.; CAMPOS, J. N. B. Relationship between ocean climatic variability and rain-fed agriculture in northeast Brazil. **Climate Research**, v. 38, p. 225 - 236, 2009.

ANDRADE, E. M. Regionalization of Small Watersheds in Arid and Semiarid Regions: Cluster and Andrews' Curve Approaches. **Engenharia Agrícola**, v. 18, n. 04, p. 39 - 52, 2000.

ANDRADE, E. M.; PEREIRA, O. J. ; DANTAS, F. E. R. O SEMIÁRIDO e o manejo dos recursos naturais. Fortaleza: Imprensa Universitária, 2010. cap. 3, p. 71 - 94.

BARRON, J.; ROCKSTRÖM, J.; GICHUKI, F; HATIBU, N. Dry spell analysis and maize yields for two semi-arid locations in east Africa, **Agricultural and Forest Meteorology**, v. 117, p. 23 -37, 2003

CHATFIELD, C. Wet and dry spells. **Monthly Weather Review**, Boston, v. 21, n. 3, p. 308-310, 1966.

CORDEIRO, A. M. N.; GARCEZ, D. S. A influência dos componentes geoambientais e das intervenções antropogênicas nos movimentos de massa na APA da serra de Maranguape, Ceará. 2012. In: **Congresso Brasileiro Sobre Desastres Naturais**. p. 01 - 10. Rio Claro, São Paulo.

DIXIT, P. N.; TELLERIA, R. Advancing the climate data driven crop-modeling studies in the dry areas of Northern Syria and Lebanon: An important first step for assessing impact of future climate. **Science of the Total Environment**, v. 511, p. 562 - 575, 2015

FERNANDES, F. B. P.; LACERDA, C. F.; ANDRADE, E. M.; NEVES, A. L. R.; SOUSA, C. H. C. Efeito de manejos do solo no déficit hídrico, trocas gasosas e rendimento do feijão-de-corda no semiárido. **Revista Ciência Agronômica**, v. 46, n. 03, p. 506 - 515, 2015.

FONTENELE, S. B.; ANDRADE, E. M.; SALGADO, E. V.; MEIRELES, A. C. M.; SABIÁ, R. J. Análise espaço-temporal da qualidade da água na parte alta da bacia do rio Salgado, Ceará. **Revista Caatinga**, v. 24, n. 03, p. 102-109, 2011.

GRAEF, F.; HAIGIS, J. Spatial and temporal rainfall variability in the sahel and it'Graef, F s effects on formen management strategies. **Journal of Arid Environments**, v. 48, p. 221-231, 2001.

GOENSTER, S.; WIEHLE, M.; GEBAUER, J.; ABDALLA MOHAMED, A. A.; STERN, R. D.; BUERKERT, A. Daily rainfall data to identify trends in rainfall amount and rainfall-induced agricultural events in the Nuba Mountains of Sudan. **Journal of Arid Environments**, v. 122, p. 16- 26, 2015.

GUERREIRO, M. J. S.; ANDRADE, E. M.; ABREU, I.; LAJINHA, T. Long-term variation of precipitation indices in Ceará State, Northeast Brazil. **International Journal of Climatology**, v. 33, p. 2929 - 2939, 2013.

HASTENRATH, S. Exploring the climate problems of Brazil's Nordeste: a review. **Climatic Change**, v. 112, p. 243 - 51, 2012.

MENEZES, H. E.; BRITO, J. I. B.; LIMA, R. A. F. A. Veranico e a produção agrícola no Estado da Paraíba, Brasil. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 14, n. 02, p. 181-186, 2010.

MENEZES, H. E.; BRITO, J. I. B.; SANTOS, C. A. C.; SILVA, L. L. a relação entre a temperatura da superfície dos oceanos tropicais e a duração dos veranicos no estado da paraíba. **Revista Brasileira de Meteorologia**, v. 23, n. 02, p. 152 - 161, 2008.

MONCUNILL, D. F. The rainfall trend over Ceara and its implications. In **8ª** CONFERÊNCIA INTERNACIONAL DE METEOROLOGIA E OCEANOGRAFIA DO HEMISFÉRIO SUL, Foz do Iguaçu, p. 315 - 323, 2006.

HEVIA, J. N. **Control de la erosión em desmontes originados por obras de infraestructura viária: aplicación al entorno de Palencia capital**. 316 f. Tesis (Doctorado en Ingenieria de Montes). Universidad Politécnica de Madrid, 2002.

NELSON, D. R.; WEST, C. T.; FINAN, T. J. Introduction to "In focus: Global change and adaptation in local places". **American Anthropologist**, v. 111, n. 03, p. 271-274, 2009.

REIS, G. P.; BRITO, D. S.; SILVA, F. M. A.; OLIVEIRA, S. G.; RIBEIRO, S. C. Propensões dos veranicos no núcleo de desertificação dos inhamuns no ceará (1979 - 2011). In: **III Simpósio de Mudanças Climáticas e Desertificação no Semiárido Brasileiro**, 2011, Juazeiro - BA. Cenários Futuros, 2011.

SALGADO, E. V.; HEVIA J. N.; NUNES, E. P.; RODRIGUES, M. M. D. A. Rainfall patterns and the contribution of litter in the Caatinga dry tropical forest1. **Revista Ciência Agronômica**, v. 46, n. 02, p. 299-309, 2015.

SANTOS, C. A.; BRITO, J. I. Análise dos Índices de Extremos para o Semiárido do Brasil e suas Relações com TSM E IVDN. **Revista Brasileira de Meteorologia**, v. 22, n. 03, p. 303–312, 2007.

SANTOS, C.A.; MANZI, A.O. Eventos extremos de precipitação no estado do Ceará e suas relações com a temperatura dos oceanos tropicais. **Revista Brasileira de Meteorologia**, v. 26, n. 01, p. 157–165, 2011.

SUN, L.; LI, H.; WARD, M.N. 2006. Climate variability and corn yields in semiarid Ceara, Brazil. **Journal of Applied Meteorology and Climatology**, v. 46, p. 226–239, 2006.

XAVIER, T. M. B. S. **Tempo de chuva: Estudos climáticos e de previsão para o Ceará e Nordeste Setentrional**. Fortaleza: ABC Editora, 478p, 2001.