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SPATIALIZED SEQUENTIAL WATER CLIMATOLOGICAL BALANCE FOR DROUGHT MONITORING OF RIO DO PEIXE BASIN/SC

Espacialização do Balanço Hídrico Climatológico Sequencial para o Monitoramento das Secas na Bacia do Rio do Peixe/SC

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ABSTRACT

This research investigates the relation between registered damages due to drought and monthly value occurrences of hydric deficit, calculated by the Climatological Water Balance Sequential. The study area is Rio do Peixe Basin located at western of Santa Catarina State (South of Brazil). It was made the Climatological Water Balance Sequential for 2001-2010 period, considering three stations located inside and nearby Rio do Peixe Basin. From this Climatological Water Balance it was noticed that the highest hydrous deficits occurred in these short periods: February and March of 2005, April and May of 2006 and March and April of 2009. Afterwards, it was related the hydrous deficit values with official damage registers by drought called "AVADAN". In fact the results characterized the correlations between registered damages due to drought and monthly value occurrences of hydric deficit. Besides, in the three drought periods, the year 2009 was defined as a special sample to spatialized the damage occurrences by (AVADAN) documents and hydric deficit registered in the meteorological stations. The year 2009 was selected due the fact that 92% of the municipalities within the Rio do Peixe Basin registered of damage by drought. For generate the surface in the Rio do Peixe Basin area it was interpolate data by mathematic model called Exponential Kriging. The result guided to confirm the correlation between negative values of Climatological Water Balance Sequential and AVADANs in effective way. It is recommended apply this methodology in others basins as procedure to validate it.

Keywords: Drought, Climatological Water Balance Sequential, Damage Registers (AVADAN), Rio do Peixe Basin.

RESUMO

Esta pesquisa investiga a relação entre os registros oficiais de danos e situações de emergência com os valores de deficit hídrico calculados por meio do Balanço Hídrico Climatológico Sequencial.. A área de estudo escolhida foi a Bacia do Rio do Peixe, localizada na porção Oeste do território de Santa Catarina, Sul do Brasil,. Foi realizado o Balanço Hídrico Climatológico Sequencial para o período compreendido entre 2001 – 2010, considerando dados de três estações localizadas na bacia ou em suas adjacências. A elaboração do Balanço Hídrico evidenciou a ocorrência de três curtos períodos com deficit hídrico: Fevereiro e Março de 2005, Abril e Maio de 2006 e Março e Abril de 2009. Posteriormente, realizou-se o cruzamento entre os valores de deficit hídrico calculados com as decretações de situação de emergência publicadas no Diário Oficial da União, bem como os formulários de avaliação de danos (AVADAN) da Defesa Civil. Os resultados obtidos caracterizaram as correlações entre os danos registrados devido à seca e valor ocorrências mensais de déficit hídrico. Além disso, dos três períodos de seca evidenciados, o ano de 2009 foi definido como uma amostra especial para espacialização das ocorrências de danos (AVADAN) e do déficit hídrico registrado nas estações meteorológicas . O episódio de 2009 foi escolhido devido ao fato de que 92% dos municípios da Bacia do Rio do Peixe foram afetados. Para gerar a espacialização foi utilizado o modelo matermático de interpoção de dados denominado Krigagem Exponencial. Os resultados apontam a confirmação da correlação entre os valores de deficit hídrico do Balanço Hídrico Climatológico Sequencial e os AVADANs. Recomenda-se aplicar essa metodologia em outras bacias como procedimento para validação do método.

Keywords: Secas, Balanço Hídrico Climatológico Sequencial, Registros de danos (AVADAN), Bacia do Rio do Peixe.

1. INTRODUCTION

Water is one of the Earth's main components; it has a role in many processes that act on the planet, with emphasis in its fundamental importance for the maintenance of life. To the human societies, water has an even greater importance, because it is directly related to social and economic development.

An evaluation performed by the United Nations Program for the Environment led to the conclusion that there are about 80 countries with serious problems in maintaining the availability of water, representing 40% of the world's population. The evaluation also reveals that over 1/3 of the world's population live in countries where the lack of water ranges from moderate to highly impactful. The shortage of water is normally associated to the population increase, degradation of water resources and the occurrence of drought episodes. The lack of water availability leads to difficulties in the development, social and economic distress, elevates inequality among regions and even endangers the survival of human species in the planet (TUNDISI and TUNDISI, 2011).

Data from "The International Disaster Database – EM-DAT" shows that, between the years of 2000 and 2014, the shortage of water caused by drought episodes affected approximately 820 million of people throughout the planet, causing damage of about 67 billion dollars.

Only in Brazil, in the same period, droughts affected 20 million people, causing damages of about 8 billion dollars. Because they do not cause structural damage nor generate dramatic cases of destruction, like earthquakes or hurricanes, the impact of droughts tend to be underestimated and many times even neglected by public power.

In Brazil, despite the good water supply - when compared in worldwide scenario, the country is not immune to droughts. Figure 1 expresses the distribution of drought occurrence records between 1991 and 2010 in the regions of Brazil. It appears that the Northeast is the most affected by drought, with 59.30% of cases, although there are a significant number of records in the South, with 25.06%.

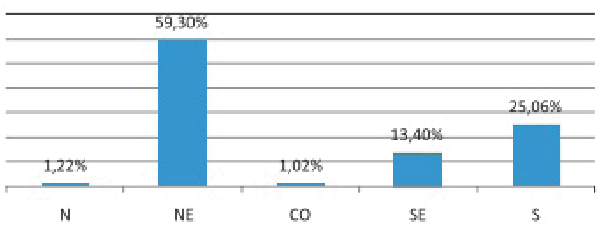

Fig. 1 - Graphic of Distribution of drought records in Brazil between 1991-2010. Source: Brazilian Atlas of Natural Disasters 2012.

Among the drought occurrences recorded in the Brazilian's south states, the Western region of Santa Catarina, where the area of interest of this study is situated, stands out as the region with the largest number of dry records between the years 1991 and 2010 (Figure 2).

Data compiled by Lindner (2007) on the drought records in the Rio do Peixe Basin between 1972 and 2006 indicate the occurrence of 200 episodes. According to a survey conducted by the National Water Agency on the relationship between demand and availability in normal

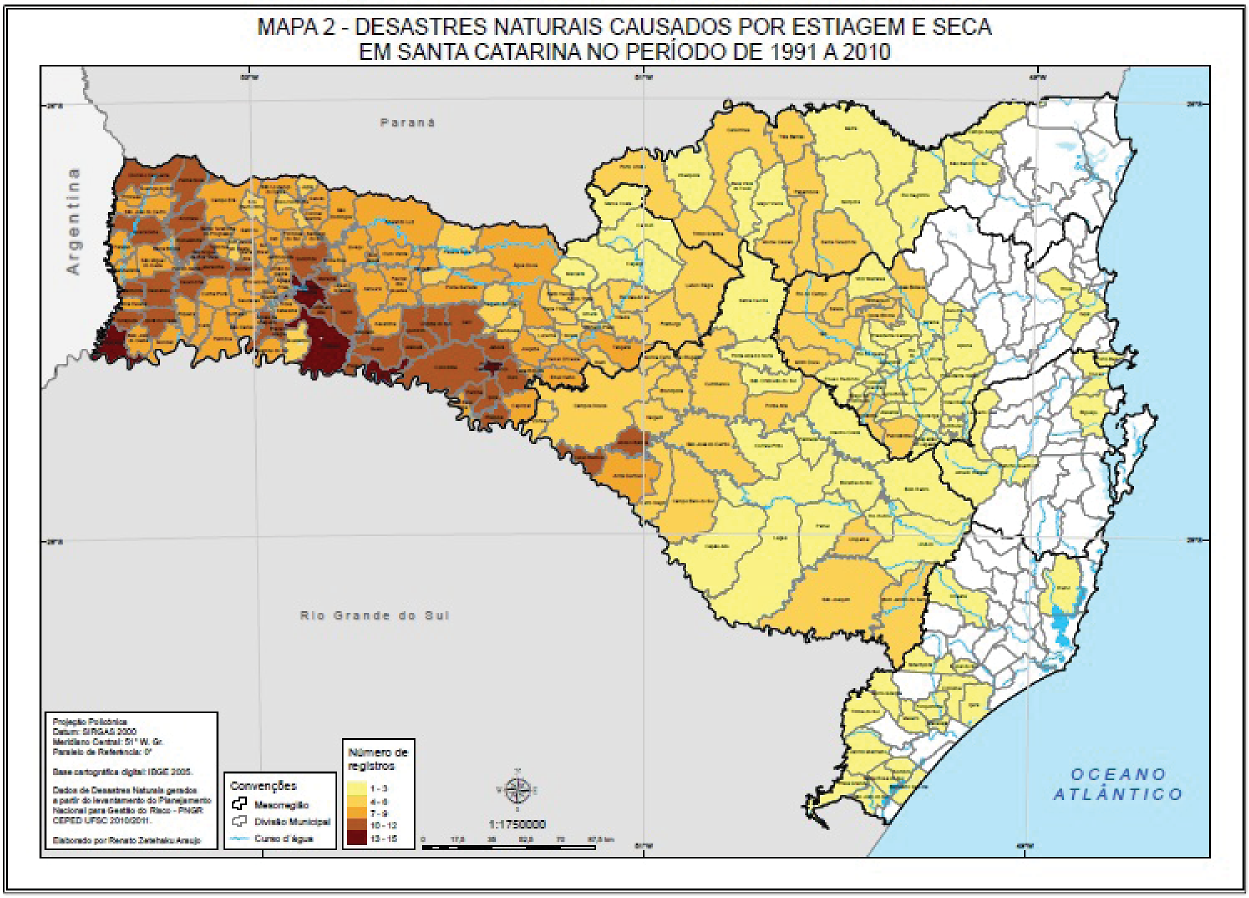

Fig. 2 - Quantity of drought records in Santa Catarina between 1991 and 2010. Source: Brazilian Atlas of Natural Disasters 2012.

times, Rio do Peixe Basin presents a classification ranging from very critical to worrying. It is evident, therefore, that the basin has a high degree of vulnerability to droughts, because even under normal conditions there are problems regarding the use of water (ANA, 2005).

The study area of this work is Rio do Peixe Basin, with a total area of 5,476 km², component of the so-called *Mesorregião Oeste Catarinense*, in the state of Santa Catarina, Southern region of Brazil (Figure 03). The basin comprises 28 municipalities, some of which are only partially inserted in the basin (SANTA CATARINA, 2006). The municipalities in this basin have agriculture as an important economic activity, thus the water availability is extremely important.

The main purpose of this research is to verify the correlation between periods of year (2001-2010) that shows negative values of sequential climatic water balance and records of damage (Damage Evaluation Forms – AVADAN), as well as adjudication - when it happens in the study area.

2. DROUGHTS

Droughts are a natural phenomenon of climatological nature, represented by the temporary decrease in rainfall considered normal for a certain region. It should be noted that droughts differ from the aridity phenomenon, which is a "permanent" condition of no or little rain. For being part of climate dynamics, droughts should always be taken into account in planning actions and management of water resources (WORLD METEOROLOGICAL ORGANIZATION, 2011).

From the point of view of the so-called natural disasters, perspective of this study, droughts are consistent with *natural hazard*. Natural Hazards are defined by Mishra and Singh (2010) as "a threat of a naturally occurring event that will have negative effect on people." It is important to say that the negative effect on the population also depends on their vulnerability to natural hazard. In the case of droughts, considering the fundamental role of water in several economic production processes, there is

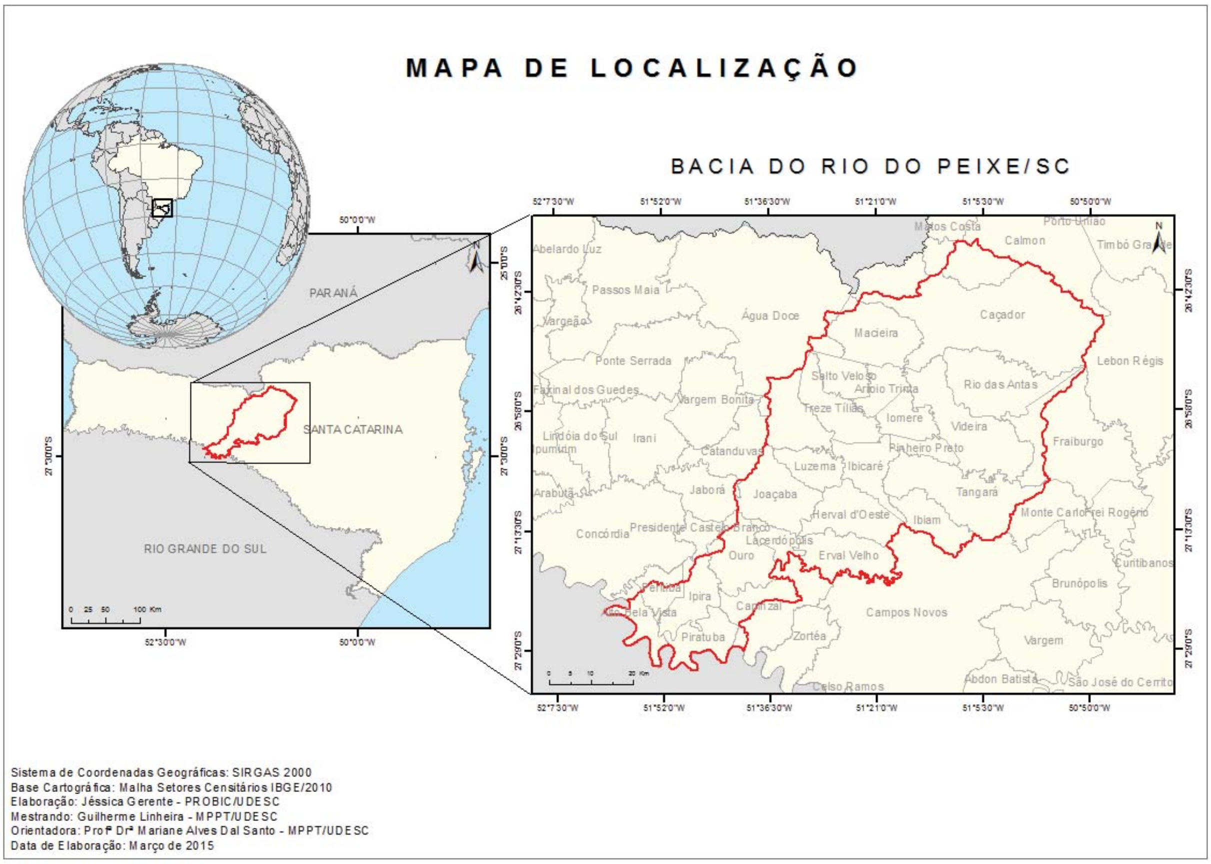

Fig. 3 - Localization map of Rio do Peixe Basin, State of Santa Catarina.

a high vulnerability of society as a whole when compared to other hazards such as earthquakes or hurricanes, for example.

Other specific characteristics of droughts are the large territorial extent that can be affected, the time of occurrence that they can reach long seasons and the difficulty in identifying the beginning and end of their occurrence. It is precisely because of these characteristics that droughts are often referred to as the cause of natural disasters that most affect people around the world.

Among the possible classifications of Droughts, it is the noted the proposal of Wilhite y Valiente (1985) apud Glantz (2001), which was adopted by the American Meteorological Society, which classify droughts in four types: meteorological or climatological drought, agricultural drought, hydrological drought and socioeconomic drought.

Meteorological drought is represented by the occurrence of rainfall below normal values for a given period, and in a certain region. Thus, the determination of occurrence of dry weather will vary according to the climate regime of that region. This type of drought directly impact to the moisture of the soil and river rails, the occurrence of dry weather on a certain time period will generate other types of drought, such as agricultural and hydrological

Agricultural drought is represented by the decrease in the moisture of the soil, caused by the lack of rainfall. This type of drought is not only connected to the loss of agricultural crops but also to impacts in areas of natural vegetation, negatively affecting the strength of plants, and possibly causing their death. As the soil has no moisture, superficial water outflow phenomenon, which occurs only after the soil is saturated with water, ceases. Thus, the persistent agricultural drought ends up influencing the nourishment of the flow of river runners, generating another type of drought: hydrological drought.

Hydrological droughts are related not only to the decrease in rivers' volume but also with the volume of dams and other types of artificial reservoirs. This type of drought is the cause of impact in urban water supply and in several industrial activities that demand usage of water for the production process. One of the activities widely impacted by hydrological drought is the generation of hydroelectric power that depends on water impoundment as São Paulo happens on 2015.

Finally, the drought type denominated as socioeconomic drought triggers a situation of widespread water shortage for at least one kind of human activity. The socio-economic impacts of this type of drought are enormous and may even cause migration of large populations. It is important to highlight that the impacts to society are registered already in the occurrence of meteorological drought and that, as droughts persist, they cause even greater impacts (VALIENTE, 2001; MISHRA AND SINGH, 2010).

Historically, many countries, such as Brazil, have been struggling when facing droughts due to the fragmentation of responsibilities of the people involved in this issue. The mitigation actions towards the droughts issues were usually executed under damage repair perspectives, thus, acting after the occurrence of droughts. This type of action is recognized nowadays as being expensive, difficult, disarticulated and with results of minor importance, being able of even increase the vulnerability of societies once it faces the consequences, but not the causes of the damages. In order to face the droughts, it is necessary to act also in the moments before their occurrence. Thus, interinstitucional efforts with great circulation are necessary, as well as the participation of all involved in the drought issue and whose objectives must walk towards the implantation of drought management programs, which must include the creation of monitoring and alert systems for possible adverse conditions, actions for decrease society vulnerability and construction of efficient action plans to respond to the occurrences (WORLD METEOROLOGICAL ORGANIZATION, 2011).

A fundamental point for facing drought is the participation of Science and scientists, who are responsible for collect and analyze evidence about the phenomenon and its manifestations in different scales of possible analysis. In the case of drought, considering that its occurrence has an impact mainly on global food production, responsible for the maintenance and development of human societies on the planet, the responsibility of the scientific field becomes even greater.

3. CLIMATOLOGICAL WATER BALANCE

The water balance is an accounting system of inputs and outputs of water in a certain system, based on the mass conservation principle. Among the existing water balance models, the most known was proposed by Thornthwaite in 1948, subsequently modified by Mather in 1955, which became known as "water balance of Thornthwaite and Mather, 1955" (PEREIRA *et al*., 2002).

In this model of Climatological water balance, the natural supply of water to the soil is notated by the difference between values of precipitation and values of atmospheric water demand, symbolized by the potential evapotranspiration. Also the water capacity available in the soil is an input parameter in this model. Thus, water balance is capable of providing estimates of quantities of water stored in soil, real evapotranspiration, water deficiency and water surplus in several time scales.

There are two ways to elaborate the Climatological Water Balance (BHC): normal and sequential. The Normal way is elaborated with average precipitation and evapotranspiration data in a certain region, used as a climatic indicator of water availability, by varying of water deficiency and water surplus over an average year, and is mainly used in agricultural planning. Climatological Water Balance Sequential is elaborated based on rainfall or evapotranspiration data of a period or a sequence of periods (months, weeks, days) of a specific year. This type of balance provides us with the characterization and seasonal variation of the conditions of shortage or surpluses over the analyzed period (PEREIRA *et al*., 2002)

Among the climatic water balance applications, it is highlighted the characterization and regional climatic comparison regarding the average water availability in the soil, characterization of drought periods, agroclimatic zoning and the determination of the best periods for sowing (PEREIRA *et al*., 2002)

Among the output values generated by the Climatological Water Balance is the volume (in mm) of water surplus, water shortage and water storing in soil. Whereas water surplus is represented by positive values of water balance, evidencing the input of water in the system in greater volume than its output, the water shortage is represented by negative values of water balance, indicating a greater volume of water output than input in the soil.

The advance of geostatistical tools made possible the spatial representation of several phenomena, including the ones of agrometeorological nature, by the quantification and modeling of continuous phenomena and interpolation techniques. Among the interpolators used to generate the maps, Castro et. al (2010) defines how the exponential kriging method as the most suitable for the representation of surpluses and water deficits.

4. METHODS AND MATERIALS

This research follows the methodologic presupposition of Medeiros and Câmara (2012) for studies of environmental character involving geoprocessing techniques, which consist in the process of selecting and combining the geographic variables of interest, considering the spatial limits stablished by them. Moura (2007) highlights as one of the qualities of Geoprocessing the application of spatial analysis models destined to the characterization of spatial occurrences, and that are able to generate scenarios and simulations of phenomena based on observed tendencies. In the case of this research, the geographic variable to be combined are the climatologic water balance and the records of drought occurrence in the study area, within the timeframe of 2001 and 2010.

The research therefore presents quantitative character applied in the form of case study. Moresi (2003) reasons that quantitative research is projected to generate precise and trustworthy measures that allow statistical analysis, where the collection of data is done in a way so that the set of processes and instruments elaborated can guarantee the record of information, control and data analysis.

For the development of this research, the following tools were used: Software ArcGIS 10.1, Microsoft Excel 2010 and Hidro, forms of damage evaluation – AVADANS, adjudications of Emergency situation published in official newspaper, air temperature data and rainfall in stations EPAGRI-CIRAM, besides of shapefiles and other necessary files to the elaboration of maps.

The data referring to AVADANS and the adjudications of emergency situations were obtained in the data bank managed by National Civil Defense. The data of interest for this variable is the quantity of Damage Evaluation Forms records – AVADAN, and adjudications of emergency situation and the record date. For its achievement, a documental analysis for each municipality individually was made, summarized in a data spread sheet. Thus, a spread sheet in monthly scale with all the municipalities within the study area was generated, with annotations referring to the existence of AVADAN's or adjudications of emergency situation for the whole period of study.

The achievement of air temperature and rainfall data was made along with the Center of Information of Environmental Resources and hydrometeorology of Santa Catarina (*Centro de Informações de Recursos Ambientais e de Hidrometeorologia de Santa Catarina* – CIRAM). Data referring to the three meteorological stations were obtained in between 2001 and 2010: Station 60 – Caçador, Station 442 – Videira and Station 469 – Campos Novos.

The first step of the research was the extraction of data of interest in the meteorological stations records: temperature and rainfall. From the compilation of these data the Sequential Climatological Water Balance was accomplished for each station. In order to elaborate the Climatological Water Balance a value of water capacity available in the soil (CAD) of 60 mm was utilized a value that corresponds to the type of soil existent in Rio do Peixe Basin. The balance was elaborated through Hidro Software, which performs the climatological water balance for the stablished period and calculates the water surplus and deficit values in a monthly scale.

Once the water balance was performed, three periods with the highest values of water deficit recorded were selected. After, it was performed the crossing between the months in which the highest deficit and the number of register of AVADAN's or adjudication of emergency situation were observed in order to verify the existence of correlation among these variables. When comparing such data, the period with the most number of adjudications and damage records was chosen for elaboration of spatial representation. After, it was performed the spatial representation of the water deficit by using the Software ArcGIS 10.1, using the tool Spatial Analyst, and the method of interpolation called Exponential Kriging. uses tabular data and its geographic position to calculate interpolation through mathematical functions. Besides this interpolation add higher weight in positions closer to the sampling points and lower weights in more distant locations, thus creating new points interpolated based on those linear combinations of data.

5. RESULTS AND DISCUSSION

The first results presented refer to the Sequential Climatological Water Balance of the three meteorological stations used. As the balance generates a considerable number of tabular data, it was chosen to present the results summarized in chart form (figures 4, 5 e 6).

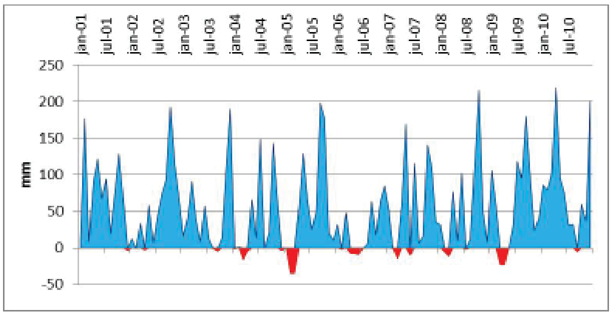

Fig. 4 - Sequential Water Balance for the period between 2001 e 2010 – Station Caçador, SC

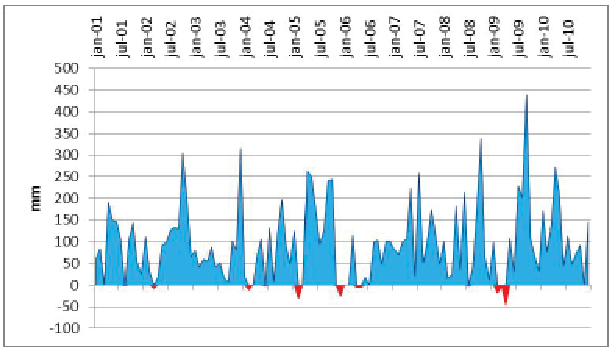

Fig. 5 - Sequential Water Balance for the period between 2001 e 2010 – Station Videira, SC.

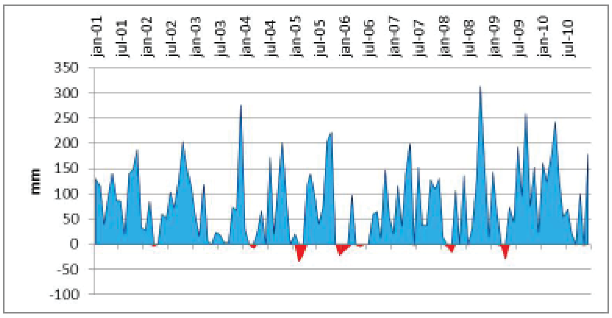

Fig. 6 – Sequential Water Balance for the period between 2001 e 2010 – Station Campos Novos, SC.

When observing the charts it is possible to note the occurrence of different times of water deficit in the analyzed time frame. Considering that Santa Catarina has no "clear" dry season, that is, there is no period of the year when there is naturally water deficit, graphic data that indicate negative values in red, can be understood as indicators of drought. Thus, from the water balance calculations, three periods in which there is greater accumulated water deficit were extracted, listed in the Table 1.

Table 1: Absolute water Deficit accumulated at Caçador, Videira and Campos Novos stations, between the years (2001 and 2010).

Date		**Weather Station – hydric deficit (mm)**		
Month	**Year**	**Caçador**	**Videira**	**Campos Novos**
2	2005	-34,5668	- 34,1525	- 31,6782
3	2005	- 34,5774	- 21,1794	0
4	2006	- 7,682	- 1,0163	- 5,6178
5	2006	-7,8398	- 4,772	- 5,0526
3	2009	- 22,6667	- 4,2392	- 3,6837
4	2009	- 22,7315	- 29,3472	- 46,5053

As observed in the spreadsheet, in the months of February and March of 2005 the highest accumulated water deficit values at stations in the municipalities Caçador and Videira were recorded, while in Campos Novos station, the highest accumulated deficit occurred during March and April of 2004.

When performing the crossing of these data with the record of damage and adjudications of emergency, the following chart (Table 2) is obtained.

When observing the chart it is possible to verify the direct correlation (proportional) between the occurrence of water deficit and the record of damage or emergency situation adjudications. It is noteworthy that the occurrence of damage and emergency situations arises not only due to the occurrence of water deficit, but also because of the vulnerability degree of the municipalities in Rio do Peixe Basin regarding water availability. Thus, the different numbers of AVADAN's and adjudications may have suffered variations not only by the intensity of water deficit, but also by the vulnerability degree of the municipalities at that time.

Another key point to be noted is the manifestation of these losses up until one month after the water deficit record, which is because there is a certain "delay" between the rainfall decrease and the reduction of soil moisture, compromising agricultural crops and leading

Table 2: Numbers of water deficit accumulation, adjudications, AVADANS and percentage of affected municipalities (2005-2009).

Event	Meteorological Stations – Water deficit accumulated in mm (-)			Adjudications and AVADAN's*	% Municipalities affected – Rio do Peixe Basin
Date (months and year)	E1	E2	E3		
Feb - Mar 2005	69,1	55,3	31,7	19	67%
Apr - May 2006	15,5	5,78	10,6	14	50%
Mar - Apr 2009	45,3	33,6	50,2	26	92%

***Adjudications and AVADAN's records were notated up until the month following the occurrence of water deficit.**

to such loses. Yet another important point that deserves attention is the fact that emergency situations adjudications are published in Official State Newspaper, which requires a certain times until they are legally established and recorded.

Given the results summarized in the table 01, the year of 2009 was elected for spatial representation of AVADAN's records and adjudications by the municipalities within the study area (Figure 7).

Another spatial representation performed corresponds to the water deficit recorded at the three stations used in this study for the months of March and April, 2009. Because data from three meteorological stations only were obtained, it was not possible to perform the spatialization of the interest variable for the whole hydrographic basin area. This spatialization covered only part of the Basin, including the municipalities of Ibiam, Tangará, Videira, Rio das Antas, Pinheiro Preto and Caçador. The thematic map clearly shows the spatial distribution of drought and also indicates the magnitude of water scarcity in the interpolated area.

When observing the map (Figure 8), one can see that Videira/SC had the lowest water deficit for the period and there were no reports of damage or emergency adjudications. As for the municipalities of Ibiam and Caçador/SC, located in areas with higher water deficit, there were emergency adjudications.

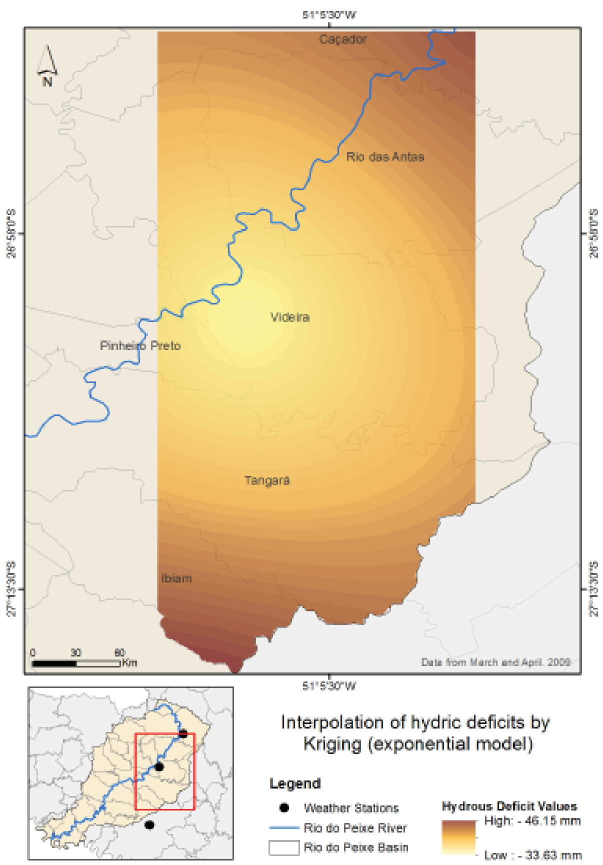

Fig. 7 - Occurrences related to the drought and hydric deficit at Rio do Peixe Basin. March and April of 2009.

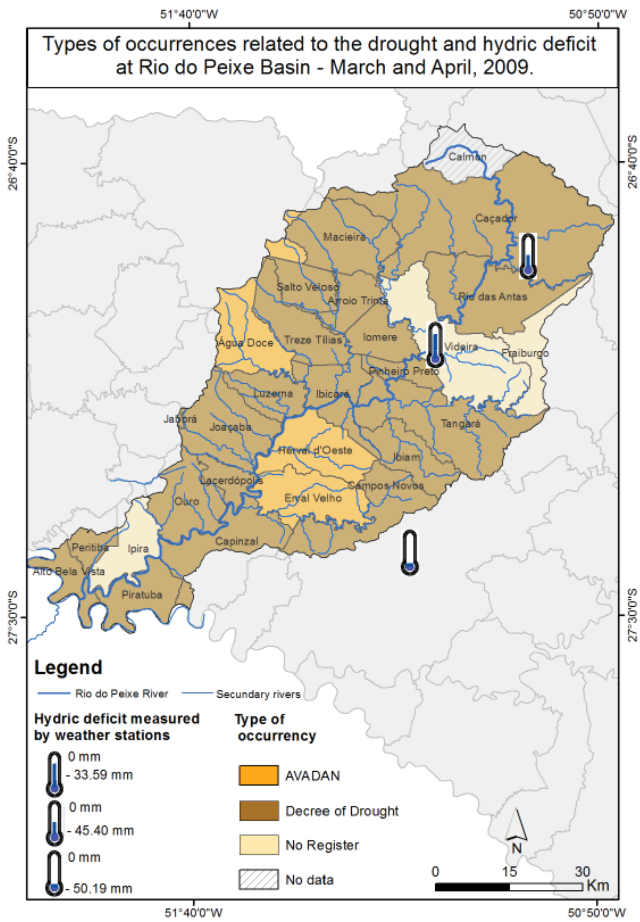

Fig. 8 - Interpolation of hydric deficits. Data from March and April of 2009.

6. CONCLUSIONS

Despite the database used in this research needs to be enhanced (i.e. better detailed), the proposed methodology showed satisfactory results. For the studied area the data related with temperature and precipitation it was disposable a “better” detailed temporal scale (daily scale), but for this research application it was used the monthly data.

Representing hydric deficit database by thematic mapping is an efficient way to complement pre-existent meteorological data. Thus, the thematic maps allows to decision maker evaluate the drought effects in each municipality, as well as to generate maps representing different occurrences in different levels of details.

By the results, it was noticed the direct correlation and effectiveness between negative values from the Climatological Water Balance Sequential and AVADANs. This means that when it was declared by State Civil Defense a register of damage in fact there was a hydric deficit.

The Civil Defense of Santa Catarina State nowadays is working in order to improve their technological way of monitoring droughts as well as to implement the efficiency related with bureaucratic procedures for System of Monitoring and Alert. Thus, the results gotten from this research will be reference to Santa Catarina Civil Defense in order to promote and validate a new resilience behavior as response from the society- based on public policies.

Furthermore, the results obtained from the thematic maps become guiding references to Santa Catarina Civil Defense for making better decisions and supporting the decision makers related with others State Department, such as manage land use, water supply consuming, territorial planning, etc.

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REFERENCES

ANA. Agência Nacional de águas. Ministério do Meio Ambiente. **Cadernos de Recursos Hídricos: Disponibilidade e demanda de Recursos Hídricos no Brasil.** Brasília: Spr, 2005. 134 p. Available in: <http://arquivos.ana.gov.br/planejamento/planos/pnrh/VF DisponibilidadeDemanda.pdf> . Access: 11 abr. 2014.

CASTRO, F. da S.; PEZZOPANE, J. E. M.; CECÍLIO, R. A.; PEZZOPANE, J. R. M.; XAVIER, A. C. Avaliação do desempenho dos diferentes métodos de interpoladores para parâmetros do balanço hídrico climatológico. **Revista Brasileira de Engenharia Agrícola e Ambiental**, Campina Grande, v. 14, n. 8, p.872-880, 09 mar. 2010.

CEPED. Centro Universitário de Estudos e Pesquisa Sobre Desastres. Universidade Federal de Santa Catarina. **Atlas de Desastres Naturais 1991 - 2010: Volume Brasil.** Florianópolis: Ceped, 2012. 94 p. Available in: <http://150.162.127.14:8080/atlas/atlas.html>. Access: 18 abr. 2014

CEPED. Centro Universitário de Estudos e Pesquisa Sobre Desastres. Universidade Federal de Santa Catarina. **Atlas de Desastres Naturais 1991 - 2010: Volume Santa Catarina.** Florianópolis: Ceped, 2012. 94 p. Available in: <http://150.162.127.14:8080/atlas/atlas.html>. Access: 18 abr. 2014

HERMANN, M. L. de P. **Atlas de Desastres Naturais de Santa Catarina**. Florianópolis: Copy Laser, 2006. 148 p. Available in: <http://www.cfh.ufsc.br/~gedn/atlas/Atlas_Ceped.pdf>. Access: 22 mar. 2014.

LINDNER E.A; MASSIGNAM, A. M.; KOBIYAMA, M.; ANTONELLO, K.; CANALE, D. P. Análise dos desastres naturais de excesso e de escassez hídrica decretados na bacia rio do Peixe, SC. **Jornadas Internazionales sobre Gestión del riesgo de inundaciones y deslizamentos de laderas**, Brasil, 2007.

MORESI, E. **Metodologia da pesquisa.** Programa de Pós-Graduação Strictu Sensu em Gestão do Conhecimento e Tecnologia da Informação. Universidade Católica de Brasília, p. 64, 2003.

MOURA, A. C. M.. Reflexões metodológicas como subsídio para estudos ambientais baseado em análises multicritérios. In: Simpósio Brasileiro de Sensoriamento Remoto, 13., 2007, Florianópolis. **Anais**. . Florianópolis: Inpe, 2007. p. 2899 - 2906.

MEDEIROS, J. S. de; CÂMARA, G. GIS para estudos ambientais. In: CÂMARA, G.; DAVIS, C.; MONTEIRO, M. V. **Introdução à Ciência da Geoinformação.** Brasília: Inpe, 2007. p. 01-36. Disponível em: <http://www.dpi.inpe.br/gilberto/livro/introd/cap10-aplicacoesambientais.pdf>. Acesso em: 10 fev. 2015..

MISHRA, Ashok K.; SINGH, Vijay P.. **A review of drought concepts.** Journal Of Hydrology. Austin, p. 202-216. 02 fev. 2010.

SANTA CATARINA. Secretaria de Estado de Desenvolvimento Sustentável. **Panorama dos Recursos Hídricos de Santa Catarina**. [s.i.]: Sds, 2006. 134 p.

VALIENTE, Ó. M. Sequía: Definiciones, tipologías y métodos de cuantificación. **Investigaciones Geográficas**, Barcelona, v. 2001, n. 26, p.59-80, mar. 2001.

WORLD METEOROLOGICAL ORGANIZATION - WMO. United Nations (Org.). **Integrated Drought Management Programme: Concept Note**. 2011. Available in: <http://www.droughtmanagement.info/literature/WMO_IDMP_concept_note_2011.pdf>. Access: 01 fev. 2015

WILHITE, D. A.; GLANTZ, M.H. Understanding the drought phenomenon: the role of definitions. **Water Internacional**, vol. 10: 111-120, 1985.

PEREIRA, A. R., ANGELOCCI, L. R.,

SENTELHAS, P. C., 2002: **Agrometeorologia: fundamentos e aplicações práticas**. Livraria e Editora Agropecuária, Guaíba – RS, 478p.

TUNDISI, J. G.; TUNDISI, T. M. **Recursos Hídricos no século XXI**. São Paulo: Oficina de Textos, 2011. 237p.

THORNTHWAITE, C.W.; MATHER, J.R. **The water balance**. Publications in Climatology. New Jersey: Drexel Institute of Technology, 104p. 1955

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