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APPLICATION OF STANDARDIZED PRECIPITATION INDEX (SPI) AND GIS FOR DROUGHT ASSESSMENT IN DAK NONG PROVINCE

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ABSTRACT

In recent years, climate change, El Nino phenomenon caused global warming, the lack of rainfall, making the drought more serious. In Dak Nong, the distribution of rainfall in the year between rainy season and dry season is different. This is one of the major causes of the drought in the province during the dry season. To study drought, many different indices have been used, and the Standardized Precipitation Index (SPI) is the most commonly used tool today. It is a powerful, flexible index that is simple to calculate. The SPI is based on precipitation within a long-term period. The objective of this research is to assess meteorological drought in Dak Nong province. In this study, SPI was calculated to determine the 1, 3, 6 and 12 - month droughts over the period of 1980-2009 for 9 monitoring stations. The SPI results showed that the SPI 3-month and SPI 12-month are suitable to monitor seasonal and annual drought. In addition, to analyze the spatial distributions of drought and its characteristics, IDW (Inverse Distance Weighting) interpolation method is appropriate for this study area. The results of the study show that, during the period from 1980 to 2009, the most serious drought occurred in 2004 -2005, in which, Dak Mil, Cu Jut, Krong No, Tuy Duc and Dak Song districts had severe and extreme drought.

***Keywords**: drought, precipitation, SPI index, GIS, Dak Nong*

1. INTRODUCTION

In recent years, in the context of global climate change, especially, global warming, extreme event likes drought is likely to become more frequent. The impacts from drought tend to cause a lot of environmental, economic, social damage and directly affecting the lives of human. The crop failures, the lack of clean water, loss of ecosystems and biodiversity and eventual related health problems, famine, energy shortages, mass migrations, and political unrest are typical examples of the impact of drought.

Drought can be defined as a recurring climate phenomenon over land characterized by water deficit over a period of months to years. According to (Wilhite and Glantz, 1985), the droughts are divided in four types as Meteorological drought, Hydrological drought, Agricultural drought and Socio-economic drought. In which, meteorological drought has been defined as a period of more than a particular number of days with precipitation less than some specified small amount. Definitions of hydrologic drought are concerned with the effects of dry spells on surface or subsurface hydrology. Agricultural drought definitions link various characteristics of meteorological drought to agricultural impacts, focusing, for example, on precipitation shortages, or numerous meteorological factors. Definitions which express features of the socioeconomic effects of drought can also incorporate features of meteorological, agricultural, and hydrological drought.

In general, the rainfall shortage is the main element which causes the drought phenomenon. Thus, using data such as precipitation is suitable way to monitor and access the drought risk. In this direction, many specialized indices have devised, for example,

Standardized Precipitation Index – SPI (McKee, 1993), Ped (Ped, 1975), Rainfall Anomaly Index – RAI (Van Rooy, 1965)... Each index has different advantages and disadvantages. Inside, Standardized Precipitation Index (SPI) is the most commonly used tool today. It is a powerful, flexible index that is simple to calculate. Globally, many studies have been conducted for assessment of drought intensity by application this index. (Hedayati, 2005) analyzed drought over Kohkyloye - Boyerahmad province (west part of country) for a 20 - year period, using five time scales of SPI - (3, 6, 12, 24 and 48 months). The result of this research have shown that severe drought has been occurred in 80% of region in 1993 and 1999. (Bagheri, 2016) established the hazard maps of drought vulnerability in 2011 and 1999 in Fars Province which located in the southern Iran, using meteorological data consisting of annual precipitation measurements for 10 station between 1994-2011 and 7 station between 2007-2011. This index has been applied to Hambantota area of Sri Lankan, (Manesha et al., 2015) calculated SPI values with cumulative time scales (1,3,6 months) in 1976 and 2001 and identify the spatial distribution based on 26 rainfall measuring stations. Application of SPI to determine drought conditions has been interested by many researchers (Karavitis et al., 2011; Sohaila Javanmard, 2017) . In Vietnam, (Thang and Khiem, 2017), (Chau et al., 2017) have assessed the status of droughts using monthly precipitation data from many stations and mapped the drought distribution.

Base on that idea, the study carried out the assessment of drought conditions in Dak Nong province following standard precipitation index (SPI) at varying time scales such as SPI 1, 3, 6, 12 months. In addition, to analyze the spatial distributions of drought and its characteristics, IDW (Inverse Distance Weighting) interpolation method of GIS is appropriate for this study area. The results of the research may provide the useful information about drought hazard for authorities and regional planners.

2. MATERIALS AND METHODOLOGY

2.1 Study area

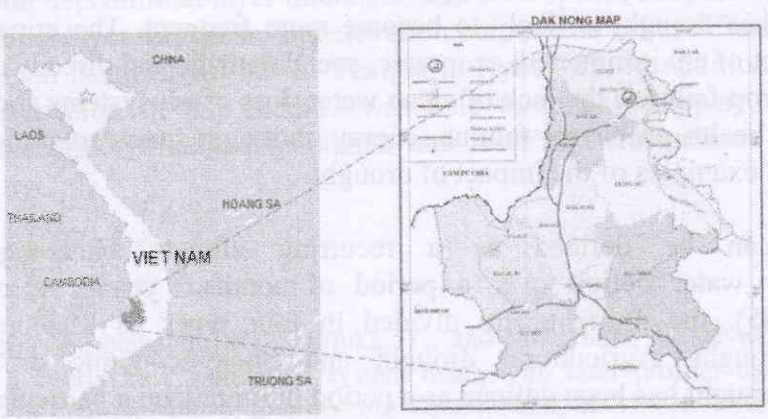

Figure 1. The location of Dak Nong province

Study area is Dak Nong, a province in Southwest gate of Tay Nguyen. This province has complex terrain surface and is strongly separated. Terrain surface is an alternation of high mountains, large plateaus and low plains. Weather in Dak Nong is divided into two seasons including rainy and dry season, causes disadvantages and unbalance of annual precipitation. Seasonally, rainy season in Dak Nong ranges from May to the end of October of next year and last in six months and dry season ranges from November to April of next year. Rainfall in total in dry season accounts for 13% to 16% of annual precipitation. By contrast, precipitation in six months of rainy season is recorded from 84% to 87% of annual precipitation.

Distribution of precipitation in a year between rainy and dry season is completely distinctive. This is a main cause of lack of water in dry season (Hang, 2012). Therefore, thousands of hectares of crops are in drought or loss in Dak Nong and coffee, pepper account for the largest proportion. Drought and extreme hot weather situation drained the irrigation water.

2.2 Methodology

As mentioned earlier, to monitor drought, the study used SPI *(Standardized Precipitation Index)* that is calculated based on rainfall data of 09 monitoring stations in Dak Nong during a period of 30 years from 1980 to 2009 and Inverse Distance Weighting – IDW in ArcGIS software version 10.5.

2.2.1 *Standardized Precipitation Index*

This index is developed by (McKee, 1993) and aimed to monitor drought situation at different period of time at certain area that has precipitation report. It can be calculated monthly or in several months. To calculate index, accumulative rainfall in a period of time is used for estimating proper probable density function.

SPI is written by following equation:

$$SPI = \frac{R - \bar{R}}{\sigma} \quad (1)$$

where:

R: Precipitation in a period of time *i*

$\bar{R}$: Average precipitation in a period of time through many years

σ: Standard deviation of precipitation in a period of time (i.e. 1, 3, 6, 12 months)

To assess drought level, criteria of drought level are in Table 1.

Table 1. Drought level distribution following SPI (McKee, 1993)

SPI	Drought level
SPI ≤ -2.0	Extreme drought
-1.5 < SPI ≤ -2.0	Severe drought
-1.0 < SPI ≤ -1.5	Moderate drought
0 < SPI ≤ -1.0	Slight drought

SPI is calculated for different scale of time including 1,3, 6, 9, 12, 24 and 48 months. SPI can be used as an indicator, and drought level forecast is set for each time scale. A drought phenomenon in a period of time *i* can be defined is a period of time which SPI is continuously negative and smaller than -1.0. Drought event ends when SPI value is positive. From above table, it can be seen that the more negative SPI is the more severe drought level is.

2.2.2 *Inverse Distance Weighting interpolation*

This is the simplest interpolation and is the most popular used in analysis functions of GIS. IDW method determines cell value by calculate average value of sample points in around area of each cell. The closer distance from point to determining point the more influence it will has. IDW method is used to interpolate SPI values of meteorological monitoring stations around study area.

3. PROCESS AND RESULTS

From the analysis of precipitation in a period from 1980 to 2009 at monitoring stations in Dak Nong area, the lowest average precipitation was in 1991, 1994 and 2004 (Figure 2).

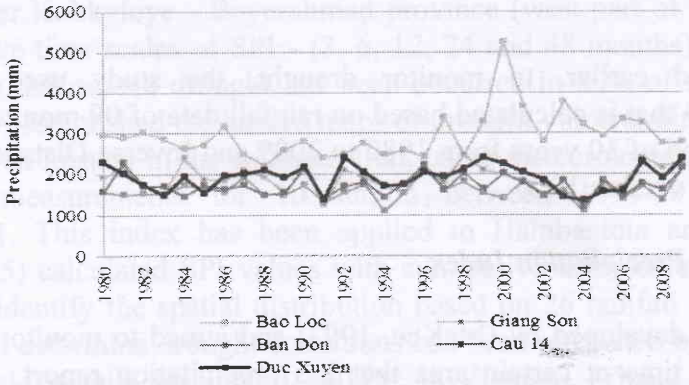

Figure 2. Annual average precipitation at monitoring stations

SPI was calculated for 1 month, 3 months, 6 months, 12 months cumulative time scales from rainfall values from 1980 to 2009 (namely SPI_1, SPI_3, SPI_6, SPI_12 respectively) to find out the suitable period for Dak Nong climatology. Analysis of 1 month cumulative time scale shows that there was not any severe drought event throughout the years. One month deficiency of rainfall is not indicate continuation of drought.

To clarify the situation, analysis extended to find out the three months cumulative SPI values. Figure 3 is an example which is to illustrate three month drought index (SPI_3) of two monitoring stations including Duc Xuyen and Cau 14.

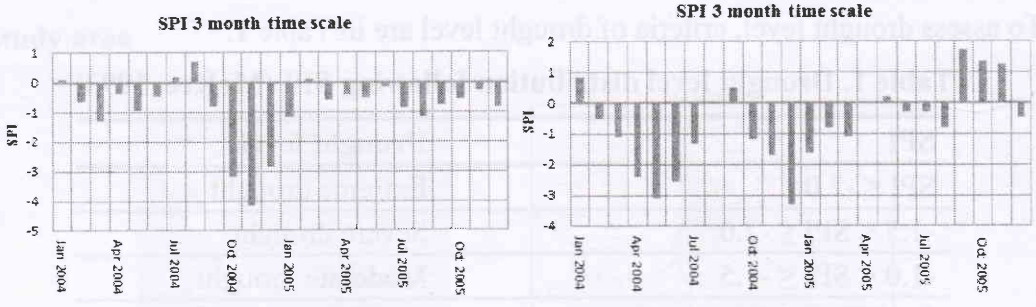

Figure 3. SPI_3 at Duc Xuyen (left) and Cau 14 (right)

From Figure 3, it is indicated that SPI of Duc Xuyen monitoring station is less than -2 in October, November and December. This means that it is extreme drought (Figure 3-left). At Cau 14 monitoring station, SPI is less than -2 from April to June and less than -1.5 from October to December. They are all severe drought (Figure 3-right). SPI analysis results of the rest of monitoring stations in a period of 30 years showed that Dak Nong had to deal with drought situation the most in months 10, 11, 12 in the year 2004. Apparently, accumulative rainfall analysis in several months is a good approach. Thus, SPI for 3 months (SPI-3) was was considered as a best time scale to monitor onset of drought in Dak Nong. Besides, to identify the strength and the length of drought condition, time scale should be longer, and 12 months time scale is suitable in this study. Analysis of SPI for 12 months clearly indicated the drought phenomenon and it occurred from October 2004 and continued up to September 2005 even though the rain has still occurred within that period.

On the other hand, a drought map of Dak Nong will be built using IDW interpolation tool in ArcGIS. It aims to show the spatial change of SPI index give the conclusion of drought area and drought level (Figure 4, Figure 5).

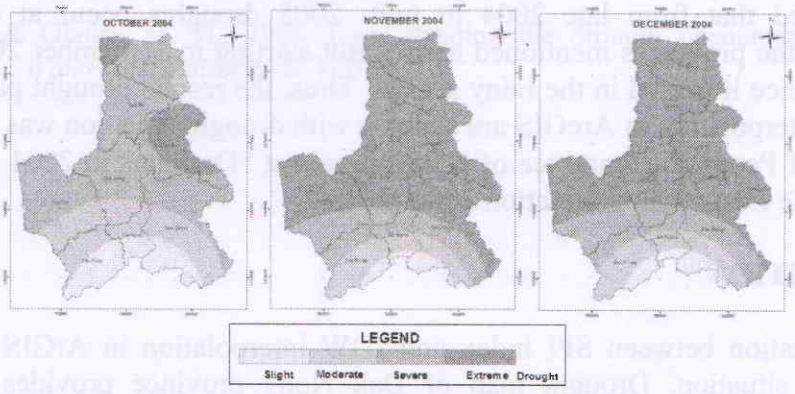

Figure 4. Drought map of Dak Nong in three month of dry season in 2004

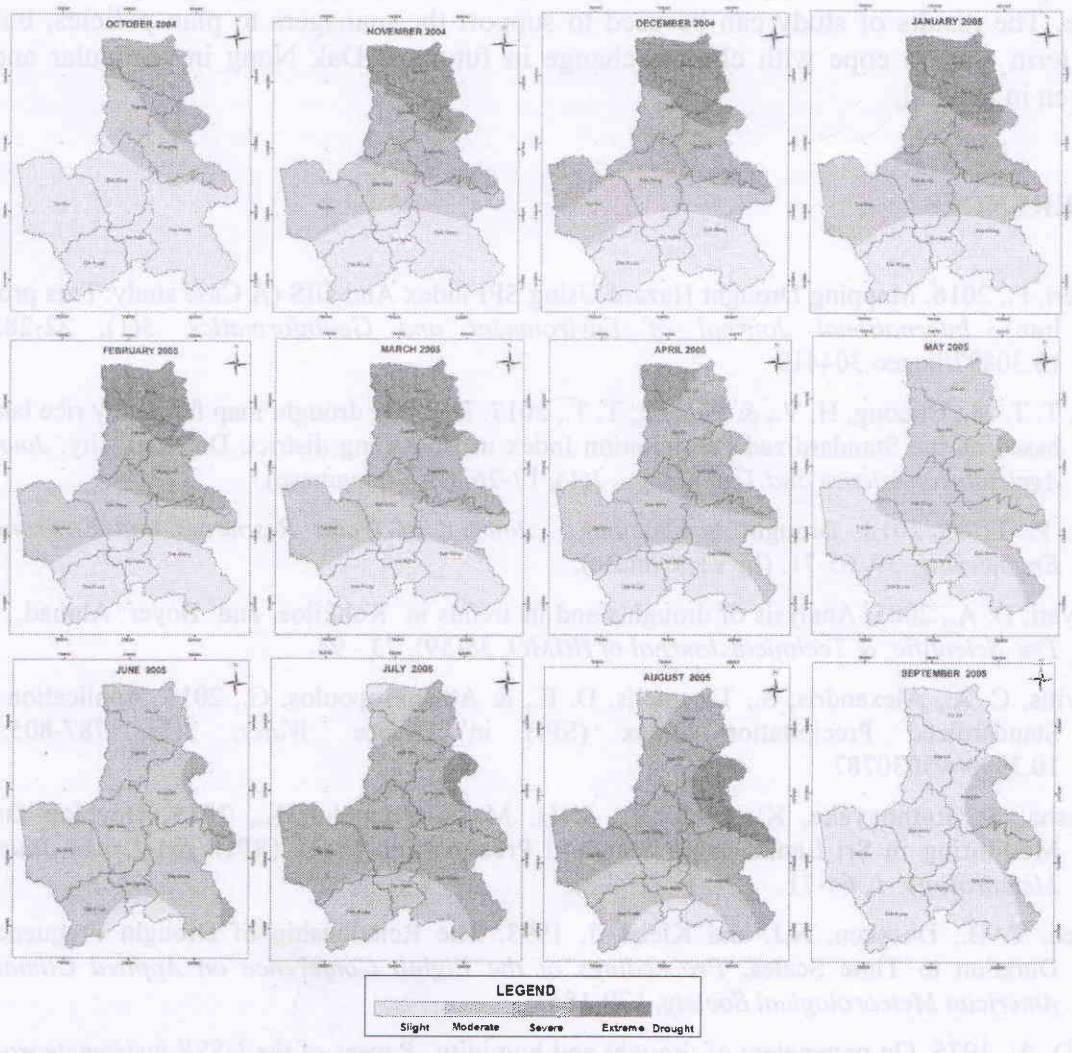

Figure 5. Drought map of Dak Nong from 2004 to 2005

The results of study showed that in the period from 1980 to 2009, the extreme drought occurred in 2004 and 2005. Base on drought map analysis, it shows that drought situation occurred on the entire of territory of Dak Nong province in 2004 and severe and extreme drought occurred in Cu Jut, Dak Mil, Krong No, Tuy Duc, Dak Song district (Figure 4). Figure 5 showed that from late 2004 to mid- 2005 droughts occur at different levels, concentrated in the provinces mentioned above. But starting in September 2005, the drought has decreased since it started in the rainy season. Thus, the results drought partition based on SPI and IDW interpolation in ArcGIS are suitable with drought situation was recorded in Dak Nong in 2004 of People's Committee of DakNong about "Droughts in 2004 and measures to limit losses in the East-Xuan production 2004 -2005".

4. CONCLUTION

A combination between SPI index and IDW interpolation in ArGIS can be used to assess drought situation. Drought map of Dak Nong province provides information of drought in term of spatial and level of drought.

Quick and accurate results are the prerequisite for study and drought prediction in the future. The results of study can be used to support the managers to plan policies, building long term plan to cope with climate change in future at Dak Nong in particular and Tay Nguyen in general.

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