DROUGHT ZONING FOR BINH THUAN PROVINCE, IN VIETNAM BASE ON ETo CALCULATOR AND GIS.

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ABSTRACT

Binh Thuan, located at the South Central, is one of two driest provinces in Vietnam. Drought, desertification has been more widespread and hash, risked to agriculture, the main economy of this province. The drought zoning will be fundamentals of building drought scenarios and propose suitable adaptive solutions.

In the article, we used arid index (AI) to assess drought in Binh Thuan province. According to meteorological data (temperature, humidity, wind speed, Solar radiation) from 1980 – 2009 of 6 stations in the area, the authors have used ETo calculator software to calculate ETo (potential evapotranspiration) based on Penman-Monteith equation. AI (classified following UNEP standards with 6 levels), the average annual precipitation and ETo of the period were interpolated and extrapolated in GIS to build drought zoning map. However, drought in Binh Thuan is mainly in dry season, so drought zoning should do for the dry season in relationship with the annual zoning.

Keywords: *drought zoning, Binh Thuan province, ETo calculator and GIS*

1. INTRODUCTION

Binh Thuan is the poor province located the Southern Central of Vietnam (figure 1), its area is 7997 km^2 and population is 1,2 million people (2010). Binh Thuan, the one of two driest provinces in Vietnam, has the lowest annual rainfall (600 – 1200 millimetres per year) but mainly in rain season (from May to October). And, precipitation in dry season (from November to April) is usually less than 50 millimetres per month, even that precipitation in 3-4 months is lower 1 millimetre per month.

The less is surface current, in the dry season. Almost river and stream basin is short and slope. That is disadvantages for reserving water for dry season and supplying to ground water. Therefore, in dry season, the province was characterized by arid and semi arid. Typically, the phenomenon has been harsher in the recent 10 years. For instance, in 1998, there were 203000 people having to put up with lacking of household water seriously, arid is danger of 20% - 25% cultivation area directly, many places became desert in each year.

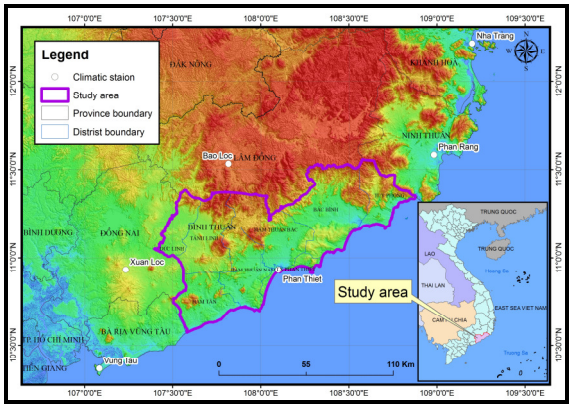

Figure 1: Study area

In difference to other Southern provinces in Vietnam, dry season in Binh Thuan is clearer and harsher because the position of Binh Thuan is parallel to the winter wind. Also, the mountain ranges, near the beach, prevent main sea winds; integrate to upwelling of the cold current near the seashore preventing the rain – cloud building process. Drought in Binh Thuan has been spreading because of erosion enlargement (caused by deforestation, unsustainable cultivation) and unreasonable management of irrigation. That has been contributing to increase degradation, drought and desertification in the study area. According

to Nguyen Van Cu and other researchers, Binh Thuan province has 4 desert types: sandy desert (56740 hectares), stone desert (9355 hectares), bare land desert (12490 hectares); salt desert (11410 hectares).

However, Binh Thuan is not arid province but drought in dry season. In the context, drought zoning for managing arid has been becoming strong urgent problem in the province, particularly with agriculture. In the past, there were some projects assessing drought in the South Central Vietnam and Binh Thuan, but their results have still been qualitative. Therefore, using ETo and GIS permitted assessing quantitatively drought status in the case study. Drought zoning for dry season in the relationship with annual zoning is scientific fundamentals to propose mitigating and adaptive solutions of disasters for human life.

In the article, we used the data: temperature, moisture, precipitation in 30 years (1980 – 2009) of 6 meteorological stations (Bao Loc, Vung Tau, Xuan Loc, Phan Thiet, Phan Rang, (figure 1). The stations distribute around Binh Thuan province, in that, Phan Thiet station is within the study area. It shows dry - hot features of Binh Thuan climate completely.

2. METHODOLOGY

2.1. ETo Calculator

The ETo calculator (FAO, 2009) is software developed by the Land and Water Division of FAO. ETo (potential evapotranspiration) represents the evapotranspiration rate from a reference surface that is not short of water. A large uniform grass field is considered worldwide as the reference surface. The reference crop completely covers the soil, is kept short, well watered and is actively growing under optimal agronomic conditions. The Eto calculator assesses ETo from meteorological data by means of the FAO Penman–Monteith equation (Allen et al., 1998) as follow: [Sam Geerts and Dirk Raes, 2010]

$$ET_o = \frac{0.408\,\Delta(R_n - G) + \gamma \frac{900}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34\,u_2)} \qquad (1)$$

ET_o : reference evapotranspiration [mm day^{-1}], e_s : saturation vapour pressure [kPa],
R_n : net radiation at the crop surface [MJ m^{-2} day^{-1}], e_a : actual vapour pressure [kPa],
G : soil heat flux density [MJ m^{-2} day^{-1}], $e_s - e_a$: saturation vapour pressure deficit [kPa],
T : mean daily air temperature at 2 m height [^{0}C], Δ : slope vapour pressure curve [kPa $^oC^{-1}$],
u_2 :wind speed at 2 m height [m s^{-1}], γ : psychrometric constant [kPa $^oC^{-1}$].

The program can use either daily, ten-day or monthly climatic data. When data for certain weather variables are missing, procedures are incorporated to estimate missing climatic data from temperature data or from specific climatic conditions according to methodologies outlined by Allen et al (1998). Maximum and minimum air temperature data are considered as the minimum dataset because a reasonable estimate of ETo can already be made based on these data alone. ETo estimations become more precise if data on air humidity, radiation and wind speed are available. [Sam Geerts and Dirk Raes, 2010]

2.2. Aridity index (AI)

An aridity index (AI) is a numerical indicator of the degree of dryness of the climate at a given location. These indicators serve to identify, locate or delimit regions that suffer from a deficit of available water, a condition that can severely affect the effective use of the land for such activities as agriculture or stock-farming [Wikipedia]

The index was considered in the first time, at the turn of the 20th century by Wladimir Koppen and Rodolf Geiger. They defined arid areas where the annual rainfall accumulation

(in centimeters) is less double than evotranspiration. This was one of the first attempts at defining an aridity index, one that reflects the effects of the thermal regime and the amount and distribution of precipitation in determining the native vegetation possible in an area.

More recently, in 1992, UNEP has adopted another index of aridity, defined as ratio between P (the average annual precipitation) and ETo (potential evapotranspiration) both of them must be expressed in the same units, e.g., in millimeters.

$$AI = \frac{P}{ETo} \qquad (2)$$

AI : Aridity index
P : the annual rainfall average [mm per day]
ETo : Reference evapotranspiration (potential evapotranspiration) [mm per day],

Table 1: Arid regions classification base on UNEP arid index.

Desertification alarm class	UNEP arid index	Arid Regions
Real desert	AI < 0.05	Ultra arid
Very high	0.05 < AI < 0.20	Arid
High	0.20 < AI < 0.50	Semi-arid
Mid	0.50 < AI < 0.65	Dry sub-humid
Low	0.65 < Ai < 1	Sub-humid
Lack of desertification danger	AI > 1	Humid and very humid

Source: UNEP classification

2.3. Zoning AI by GIS and ETo Calculator

Base on data calculated by ETo calculator and AI, we used the UNEP classification (table 1) for zoning drought in Binh Thuan province in Arc/GIS software.

3. RESULTS

3.1. Calculating and zoning ETo, AI

We used meteorological data (temperature, humidity, wind speed, Solar radiation) from 1980 – 2009 of above 6 stations, the authors have used ETo calculator software to calculate ETo (potential evapotranspiration) based on equation (1) and AI base on equation (2). The results are listed at the following figures (from figure 2 to figure 7)

ETo zoning is presented in figure 2 and figure 3. Annual ETo average is divided into 5 levels from around 1300 to around 1400 mm per year. In that, Tuy Phong and Bac Binh district have maximum ETo (higher 1400 mm per year), Duc Linh and Tanh Linh district have minimum ETo (lower 1300 mm per year). In the dry season, ETo is much lower than annual ETo average, limitted from 660 to 840 mm per year. In that, Phan Thiet city, Ham Thuan Nam, Ham Thuan Bac district are places having highest ETo (upper 840 mm per year). The reasons explain why ETo in the dry season is lower than annual one is that, the number of sunlight hours and average temperature and rainfall in dry season are lower than whole year.

Precipitation zoning is presented in figure 4 and figure 5. Annual rainfall average fluctuates from 1400 – 2900 mm per year. In that, Duc Linh and Tanh Linh are 2 districts having the highest rainfall (upper 2900 mm per year). Rainfall is lower than 1400 mm per year, quite popular in the province, distributing in Tuy Phong, Bac Binh, Ham Thuan Bac, Ham Thuan Nam district and Phan Thiet city. In contradiction, in the dry season, rainfall is so little, fluctuates from 180 – 210 mm per dry 6 months. Phan Thiet city and Ham Thuan Nam, Ham Tan district are the least rainfall region (lower 180mm per 6 dry months). And the highest rainfall regions (upper 210 mm per dry 6 months) are around Central Highland belonging districts like Duc Linh, Tanh Linh, Tuy Phong, Bac Binh. By survey, research the

study area, although annual rainfall and coming watter of rivers were not lack of, but Binh Thuan's rivers are also short and slope, integrating the long dry season (lasting 6,7 months, sometimes 9 months). Therefore, lacking of water in the dry season has been becoming serious problem for agriculture and human life.

AI zoning is presented in figure 6 and figure 7. Annual aridity index fluctuates from 0,654221 to 2,43618. The low AI belongs to the North areas of this province, mainly distributing in Tuy Phong district. The highest AI area distributed in the West regions, in Duc Linh and Tanh Linh district. In the dry season, AI is much less than annual one, fluctuating from 0,133469 to 0,678403. The lowest AI region distributed in Phan Thiet city and communes of Ham Thuan Bac, Ham Thuan Nam around Phan Thiet city. Besides, three communes: Vinh Hao, Phuoc The, Lien Huong (Tuy Phong district) also have the lowest AI (around 0,13)

3.2. Zoning drought area

According to the AI zoning results, we classified drought region base on UNEP classification and the facts of the case study and Vietnam. The specific classification is in the following table:

Table 2: Drought zoning base on AI for Binh Thuan province

AI	Arid alarm	Annual area (km^2)	Dry season area (km^2)
0,05 – 0,2	Arid	0	224
0,2 – 0,5	Semi arid	0	3823
0,5 – 0,65	Dry sub – humid	755	1390
0,65 – 1	Sub – humid	3141	2560
>1	Humid and hyper humid	4101	0
	Total	**7997**	**7997**

Typically, in the small province, Binh Thuan still appeared 2 contradict landscapes: very humid landscape in the West and arid landscape in the East and Northeast. Generally, in whole year, drought phenomenon is not urgent problems. The minimum water need of this province was still enough because annual average rainfall (600 – 1200 mm per year) integrated to quite good irrigation system. AI still was high level (from 0,65 to 2,43). Therefore, in whole year, the province has not arid, semi arid phenomena. The dry and sub humid region was the small region of 9 communes (Tuy Phong district) and 4 communes (Bac Binh district). The humid and very humid regions distributed mainly in the entire province.

Difference to whole year, in the dry season, drought phenomenon happened popularly with 4 levels: arid, semi arid, sub humid, humid. In that, the arid area distributed in Phan Thiet city (at the communes: Mui Ne, Phu Hai, Phong Nam, Duc Long, La Gi), Ham Thuan Nam (Ham Tien), Ham Thuan Bac (Ham Du, Ham Nhon, Ham Thang). That explains why in these areas exist many sandy deserts. The semi arid region covered the large part area of the province from Tuy Phong district to Ham Thuan Nam district. That was the condition establishing bare land deserts. The dry sub humid and sub humid distributed in the West and North – West of Binh Thuan, including districts (Bac Binh, Ham Thuan Bac, Ham Tan, Duc Linh, Tanh Linh)

To date, by many suitable adaptive solutions, Binh Thuan resolved the drought in the dry season quite effectively. Firstly, the province invested to build many artificial reservoirs for water using need in the dry season, for instance, some communes in Bac Binh district can cultivate 2 or 3 paddy rice crop. However, the most difficulty is that, building the adjusting water channels for the dry season because of landform. Secondly, non – construction solutions were carried out such as: plantation in bare land, protecting forest in sandy land (preventing flying sand and flowing sand), changing seasonal crop structure (planting many trees

adapting to drought like dragon fruit, grape, watermelon, cashew) applying the methods saving water irrigation and decreasing evotranspiration like: spray, drip, covering ground by straw.

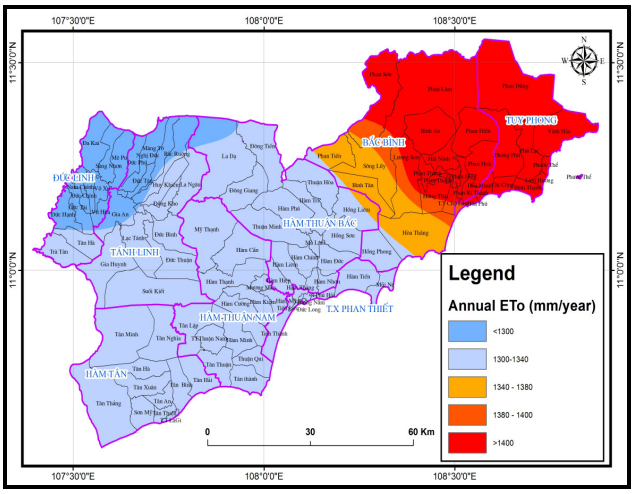

Figure 2: Annual ETo average (1980 - 2009) in Binh Thuan province

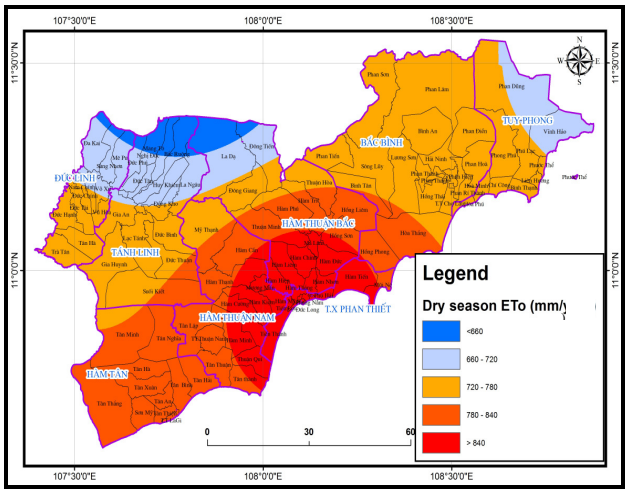

Figure 3: ETo in dry season (1980 - 2009) in Binh Thuan province

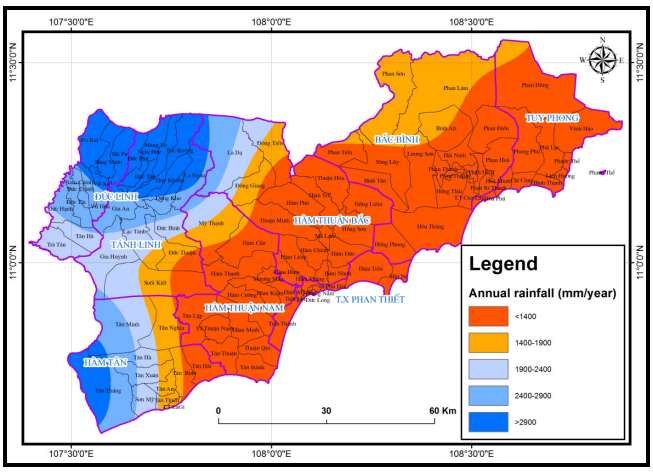

Figure 4: Annual rainfall average (1980 - 2009) in Binh Thuan province.

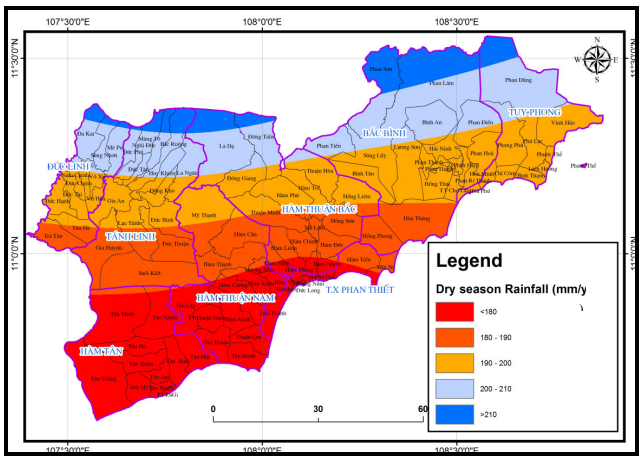

Figure 5: Rainfall in the dry season (1980 - 2009) in Binh Thuan province.

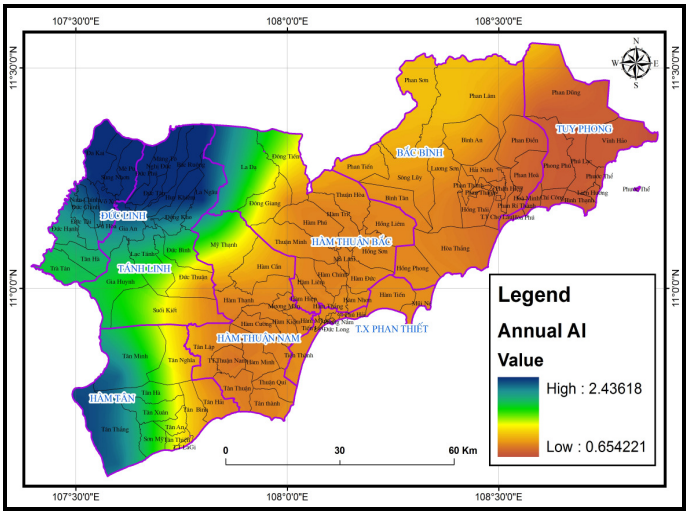

Figure 6: Annual AI average (1980 - 2009) in Binh Thuan province

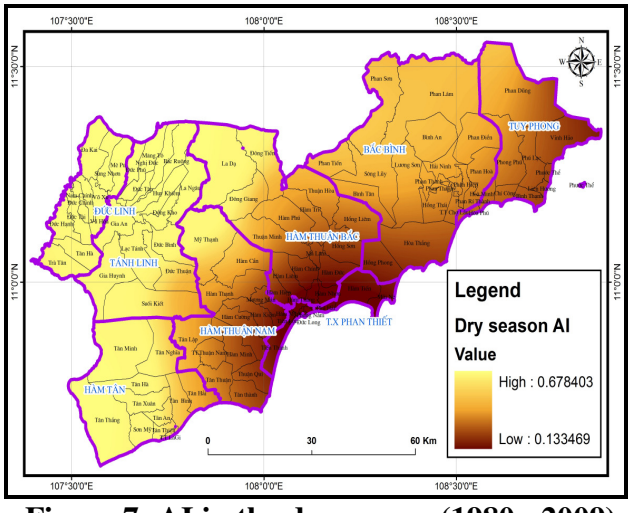

Figure 7: AI in the dry season (1980 - 2009) in Binh Thuan province

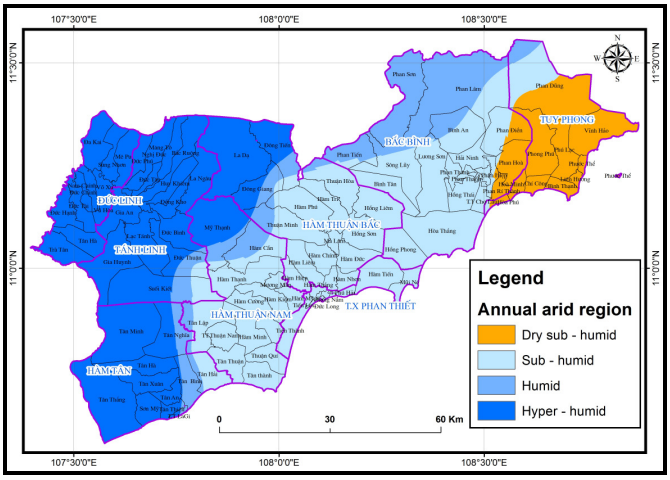

Figure 8: Drought zoning (1980 – 2009) for Binh Thuan province

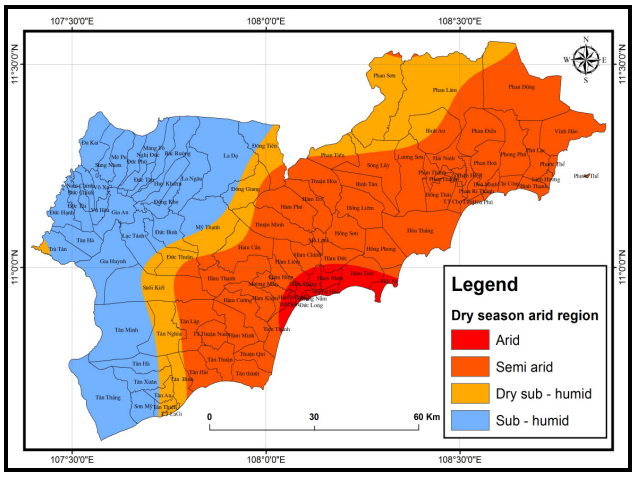

Figure 9: Drought zoning (1980 – 2009) in the dry season for Binh Thuan province

4. CONCLUSION

ETo in dry season was less double than annual ETo, rainfall was 1/10 annual rainfall, AI was 1/5 annual AI, therefore, the arid and semi regions enlarged by ¾ total area of this province in the dry season. But the phenomena did not happen, in the whole year. According to UNEP classification, Binh Thuan is not the arid province but arid and semi arid phenomena happened in all over districts in the province, in the dry season. Confirming that, the drought in Binh Thuan is drought in dry season. Arid was danger of some districts in the dry season like Tuy Phong, Bac Binh and Phan Thiet city. Semi arid was danger of districts, in the dry season like: Ham Thuan Bac, Ham Thuan Nam and Ham Tan.

Drought zoning for the dry season in the relationship with annual zoning has much meaningful to socioeconomic planning for Binh Thuan province, especially, agriculture. Irrigation system development, exchanging cultivation structure, distributing trees will be more effectively when having the helps of the above drought zoning results, the believable scientific fundamentals.

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