Researching impact of drought on agricultural production and proposing adaptation measures in Quang Nam province

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● **Abstract:** This paper used record of observed rainfall data and rainfall data measured by applying the Tropical Rainfall Measuring Mission (TRMM) to assess the situation of drought and proposes drought adaptation measures under the climate change condition in Quang Nam province. We found that: (i) During 1980-2017, drought in Quang Nam province was quite serious and there was a difference between mountains, midlands and

plains; (ii) Droughts in Winter-Spring crop often occurred in Eastern, Southern and Southeast regions of the province. In Summer-Autumn crop, drought appearred very erratic throughout province and there was no specific spatial trend; (iii) According to climate change scenario of the Ministry of Natural Resources and Environment, it is forecasted that by 2035, drought in Winter-Spring crop will be serious in Southern region. In Summer-Autumn crop of 2035, drought will expand throughout midland and delta areas of Quang Nam province; (iv) In order to adapt to drought in the use of agricultural land in Quang Nam province, it is necessary to synchronize construction and non-construction method.

● **Key words:** climate change, drought, agricultural land, SPI, Quang Nam province.

1. Introduction

Nowadays, there are many researches on drought in the world. However, due to complexity of this phenomenon, there has not been a common method for drought researches. In identifying, monitoring and warning of drought, scientists often use drought indicators as main tool. Tracking fluctuations of drought indicator values will help determine starting point, length of time and intensity of drought. In the trend of global warming, change of drought is also very complicated. Therefore, use of remote sensing technology in rain monitoring is playing an increasingly important role in natural disaster research, monitoring, forecasting and warning. With not too much independence on field monitoring data and fast processing results, this is an advanced method that needs to be further applied and researched in the future.

Quang Nam province has an area of 10,406 km2, located on the central coast of Vietnam. In recent years, the risk of drought is ranked as a serious impact, especially on agricultural production in the whole province [1]. According to a report by the Department of Agriculture and Rural Development of Quang Nam province, the midland and mountainous districts of Quang Nam province have more than 3,000 hectares of rice that cannot be sown due to aridity, along with 5,000 hectares of crops that lack irrigation water and are nearly 5,000 people lack running water [8]. According to statistics of Quang Nam Department of Irrigation, from 2010 up to now, the weather has been complicated, prolonged hot weather, common rainfall in the whole province have been 20-30% lower than the average of many years, Therefore, amount of water on the lakes is low and the water must be regularly opened to serve agricultural production. Water level in the rivers fluctuates at a low level, affecting supply of water for pumping stations. Provinces frequently affected by drought are Dien Ban town and Duy Xuyen, Que Son, Bac Tra My, Dong Giang and Tay Giang districts [3]. Stemming from that practice, studying the situation, forecasting drought risks and proposing adaptation solutions in Quang Nam province to guide long-term agricultural development strategies as well as specific plans in prevention and mitigation of impacts caused by natural disasters are very necessary and very important for development of Quang Nam province.

2. Research method

2.1. Method for collecting data and documents

- Data on land use, statistics, inventory, irrigation systems, climate change and sea level rise scenarios, maps such as current land use status map, land use planning map, hydrological maps, and river basin maps ... were collected at specialized agencies of Quang Nam province.

- Rainfall data was collected during 1980-2017, temperature monitoring data was collected in 1986-2017 and hydrological data was collected during 2000-2017. Monitoring data was collected at hydro-meteorological stations in Quang Nam province. Using monitoring data from 10 rain measurement stations located in different terrain areas (6 stations in delta, midland areas and 4 stations in mountainous areas). In addition, this research strengthened 27 rain measurement stations by remote sensing TRMM technology to make the calculation and interpolation of SPI drought indicator more accurate. Rainfall data source is available from website: http://waterdata.dhigroup.com/octopus/home.

2.2. Method of data processing

The rainfall data from the TRMM satel-lite were acquired with Mike Zero software:

(https://www.mikepoweredbydhi.com/).

The SPI value was calculated with the downloaded SPI_SL_6 tool (http://drought.unl.edu/MonitoringTools/ DownloadableSPIProgram.aspx). Drought status was assessed using the SPI value.

Microsoft Excel, SPSS, Minitab and R softwares were used for statistical processing of the collected data.

2.3. Caculation of SPI

SPI is a meteorological index used to evaluate drought conditions, calculated by:

$$SPI = \frac{R-\bar{R}}{\sigma}.$$

where

R: Rainfall during a calculated period;

$\bar{R}$: Average annual rainfall over the period of calculation;

σ: Standard deviation of rainfall in the rel-evant period.

SPI is calculated based on the ob-served rainfall for different periods such as 1 month, 3 months, 6 months, and 12 months. The main impacts of drought on agriculture are declining soil moisture and increasing evapotranspiration, resulting in rapid depletion of water during prolonged droughts. Soil moisture and water in soils are significantly affected by drought over a period of three months, which is why the three-month SPI value was used in this study [5].

The drought level was assessed accord-ing to SPI indicators as shown in Table 1.

Tab.1: Drought level classification based on SPI

SPI level	Value
Extremely wet	SPI ≥ 2.00
Very wet	1.50 < SPI ≤ 2.00
Relatively wet	1.00 < SPI ≤ 1.50
Approximately Neutral	-1.00<SPI ≤ 1.00
Relatively dry	-1.50< SPI ≤ − 1.00
Severely dry	-2.00< SPI ≤ − 1.50
Extremely dry	SPI ≤ − 2.00

2.4. Method of simulating rainfall from climate change scenarios

Percentiles algorithm (also called Centile) is applied to preliminary simulate rainfall based on climate change scenarios to simulate future drought risks [4].

$$\text{Percentile} = \frac{(B+0,5E)}{n} \text{ x } 100$$

Percentile = x 100

Of which: B is number of values below threshold of the value needs to be calculated; E is number of values equal to threshold of the value needs to be calculated; n is total number of observed values.

2.5. Interpolation method of spatial analysis

According to Hossein et al (2013) and Mozafari (2011), IDW is the most optimal method of spatial analysis interpolation for drought indicators such as SPI, DI, MCZI. Kriging, meanwhile, is the more appropriate method of spatial interpolation analysis for other drought indicators such as EDI [2,7]. Therefore, this research uses IDW interpolation method to analyze spatial distribution of SPI drought indicator in research area.

2.6. Mapping method

Research using specialized software such as ArcGIS 10.3, Mapinfo, Microstation, FME to process, analyze and present results such as map and diagrams. Coordinate system used in research is VN 2000, ellipsoid WGS 84 and 107o45' axis meridians.

3. Research results

3.1. Movement of climate factors and drought characteristics in Quang Nam province

3.1.1. Movement of climate factors related to drought

Rainfall and temperature data in research area were collected from monitoring stations including 10 rainfall measurement (Tra My, Thanh My, Nong Son, Ai Nghia, Hoi An, Hoi An, Cau Lau, Giao Thuy, Hiep Duc, Tam Ky) and 2 temperature

measurement stations (Tra My, Tam Ky). Data of monitoring water levels of main rivers in Quang Nam province were collected from 9 stations including Nong Son, Giao Thuy, Cau Lau, Hoi An, Hiep Duc, Thanh My, Hoi Khach, Ai Nghia and Cam Le.

a. Rain movement

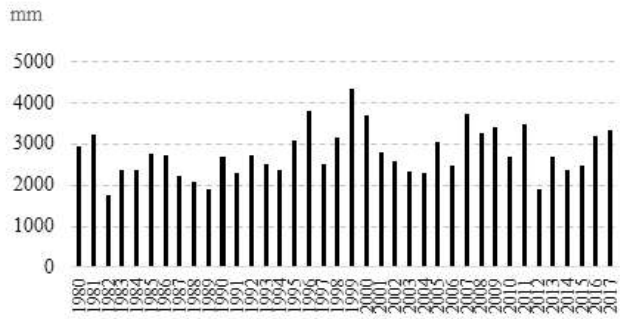


Fig.1: Total annual rainfall in Quang Nam province

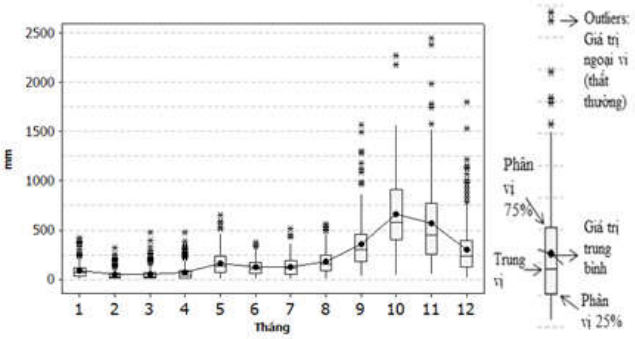


Fig. 2: Average monthly rainfall in Quang Nam province in the period 1980-2017

(Source: Processing data from sources provided by Central Hydro- Meteorological Station)

During 1980-2017, total annual rainfall in Quang Nam province ranged from 1,700 mm to 4,400 mm (Figure 1). Rainfall was not evenly distributed throughout the year, but concentrated mainly from September to December, from January to April with the lowest rainfall in months (Figure 2).

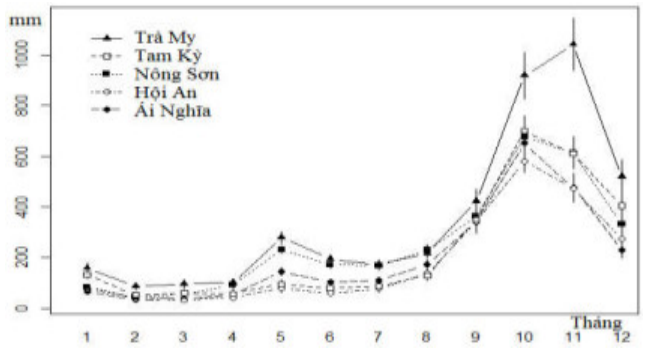


Fig.3: Average monthly rainfall at some measurement stations in Quang Nam province in the period 1980-2017

(Source: Processing data from sources provided by Central Hydro- Meteorological Station)

Figure.3 Showed that rainfall also has a difference between high mountains and midlands and plains. Specifically, monitored rainfall at Tra My station (in mountainous areas) is higher than measurement stations in the midlands (Ai Nghia station, Nong Son station) and the plain (Hoi An station, Tam Ky station).

b. Temperature movement

Temperature base in Quang Nam province was markedly different by season and by region. High mountainous areas had lower average temperatures than plain areas (Figure 4).

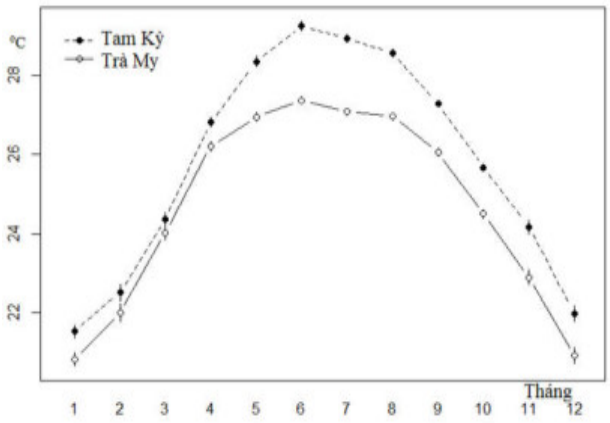


Fig.4: Average temperature in the period 1986-2017

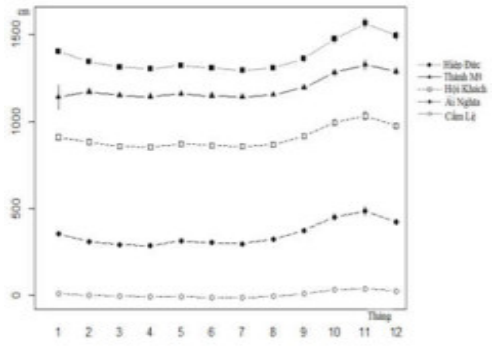


Fig.5: Average temperature (highest) in the period 1986-2017

(Source: Processing data from sources provided by Central Hydro- Meteorological Station)

However, during period from January to April and from October to December, the highest temperature in high mountains was usually higher than in plains. Remaining months had lower temperatures than the delta (Figure 5). The highest temperature usually occurred in April in mountainous areas (37.50C) and from May to August in the delta (~ 380C). It can be seen that temperature of Summer-Autumn months was often much higher than the months in the Winter-Spring season. Therefore, drought usually occurred more in Summer-Autumn crop.

c. Water level and flow of major rivers

Data in Figure 6 showed that water levels in rivers of Quang Nam tended to decrease gradually from January to August and increased from September to December of the year. This made it more difficult to get water from rivers at pumping stations during Summer-Autumn months.

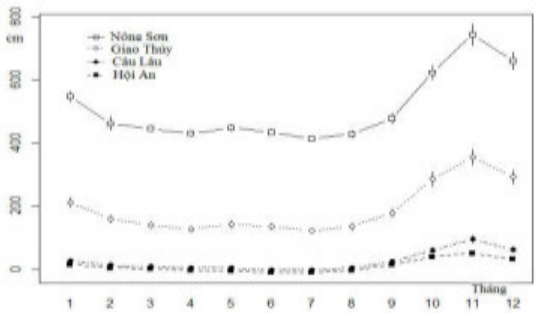


Fig.6: Monthly average water levels in stations on Thu Bon river (a) and in other rivers (b) in Quang Nam province in the period of 2000-2017

(Source: Processing data from sources provided by Central Hydro- Meteorological Station)

3.1.2. Drought characteristics

Based on topography and climate, Quang Nam province is divided into 3 ecological regions which are mountainous areas including 6 districts (Dong Giang, Nam Giang, Tay Giang, Phuoc Son, Bac Tra My and Nam Tra My), the midland consists of 4 districts (Dai Loc, Nong Son, Hiep Duc and Tien Phuoc) and the delta region consists of 8 districts (Dien Ban, Hoi An, Duy Xuyen, Que Son, Thang Binh, Tam Ky, Nui Thanh and Phu Ninh). Therefore, conduct an analysis of drought level in research area according to the three ecological regions mentioned above.

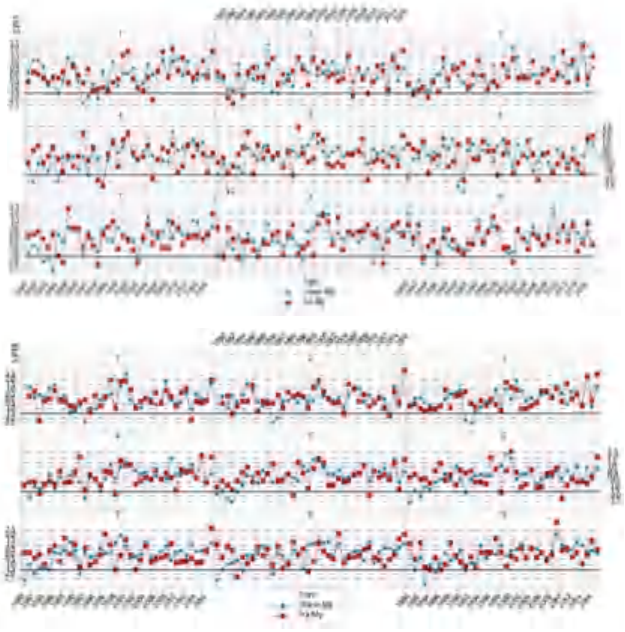


Fig.7: Movement of SPI indicator in mountainous months

Data in Figure 7 showed that SPI-1month and SPI-3month indicators at ≤ -1.5 almost appeared from January to September but with not much frequency, especially very rare in March and September. From 2000 to the present, the frequency of occurrence of drought tends to be less than that of the previous 2000

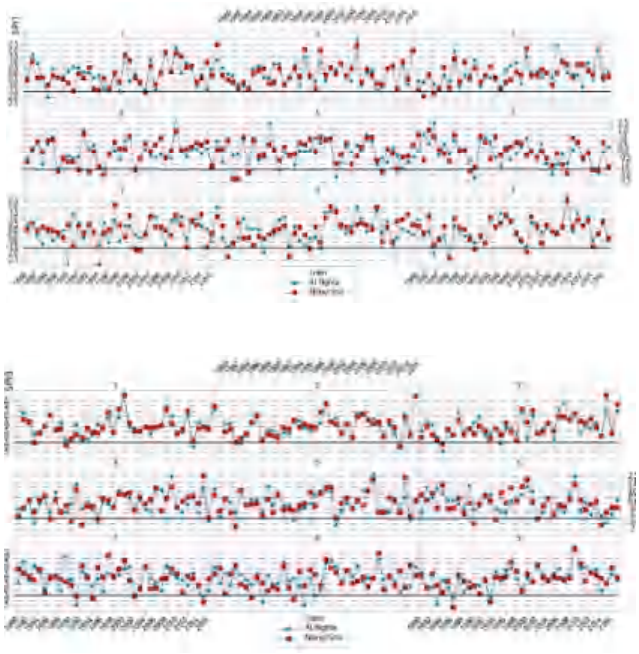
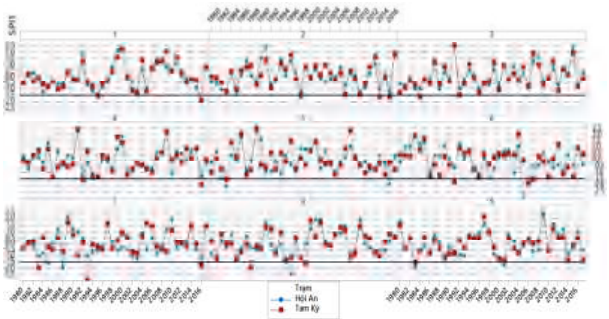


Fig.8: Movement of SPI indicator in midland months

Results in Figure 8 showed that SPI-1month and SPI-3month at ≤ -1.5 level rarely appeared in January, February and March but appeared from April to August. About trend, SPI indicator increased slightly from January to March and August, September. May, June and July were tending to decrease, especially in June. In recent years, the frequency appeared in May and June with increasing trend compared to 1990 and earlier period.



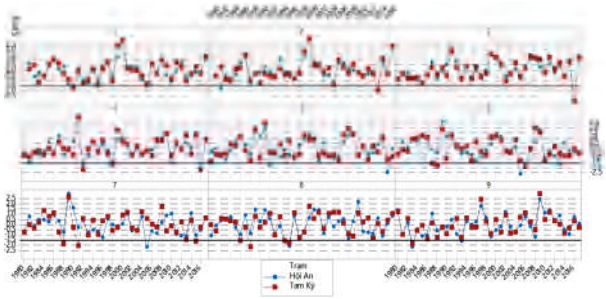


Fig.9: Movement of SPI indicator in delta months

Figure 9 showed that movement of SPI-1month and SPI-3month at ≤ -1.5 threshold rarely appeared in January, February and March but appeared from April to August; more appeared in June since 2005, while remaining months have not shown a clear change trend. Frequency of occurrence in June has been on an upward trend in recent years.

In general, during the period 1980-2017, drought level in the delta tended to be more serious than in the midland and mountainous areas of Quang Nam province.

3.2. Developing a current status map and assessing impact of drought on agricultural production land use in Quang Nam province

3.3.1. Developing a current drought status map

To analyze spatial distribution characteristics of drought in Quang Nam province, research conducted years with low SPI drought indicator and appeared in many areas for interpolation. Specifically, in Winter-Spring crop, the research conducted interpolation for 1998, 2001, 2007, 2010, 2014, 2016 and in Summer-Autumn crop including 1998, 2002, 2005, 2006, 2009, 2010, 2015, 2016.

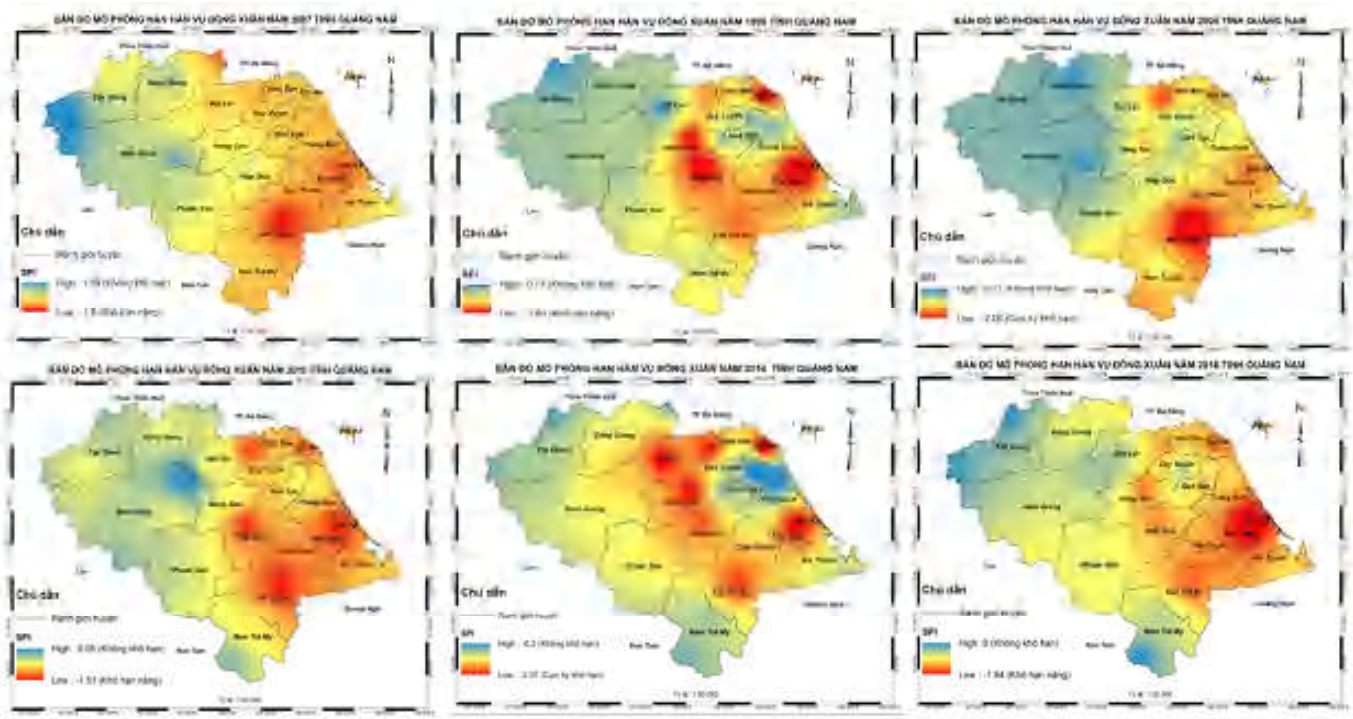


Fig.10: Simulation map of Winter-Spring drought in recent years

Results in Figure 10 showed that droughts in Winter-Spring crop often occurred in Eastern, Southern and Southeast regions of the province. Meanwhile, the Northern, Western, and Northwest regions rarely appearred drought in Winter-Spring crop. The most severe drought level in Winter-Spring crop occurred in 2001 and 2016 (SPI indicator appeared below -2).

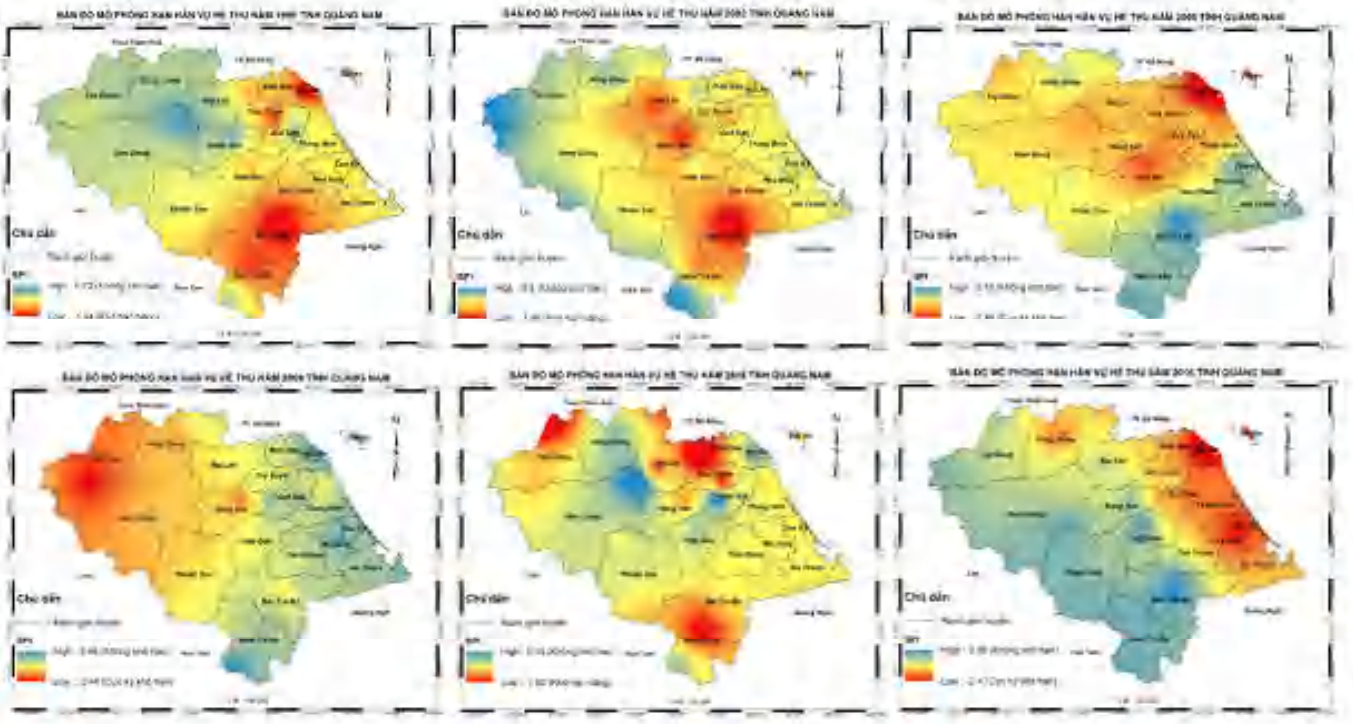


Fig.11: Simulation map of Summer-Autumn drought in recent years

Results in Figure 11 showed that drought in Summer-Autumn crop appeared erraticcally throughout Quang Nam province and there was no specific spatial trend. Extremely severe drought levels occurred in most years (SPI index <-2), except for 1998, 2002 and 2015.

3.2.2. Impact of drought on agricultural land use

2016 was one of the most severe drought years in Vietnam in general and Central region in particular. Therefore, 2016 drought map will be overlapped with rice and other annual crop land maps to assess annual cropland area affected by drought in Quang Nam province.

Results in Figure 12 showed that, in Winter-Spring crop in 2016, about 58% of the province's rice area (about 35,000 ha) was in drought. For other annual crop land, the area was limited by 51% (22,000 ha). The area of annual crop land in drought was concentrated mainly in delta districts from Dai Loc to Nui Thanh district, especially Thang Binh district and Dien Ban town.

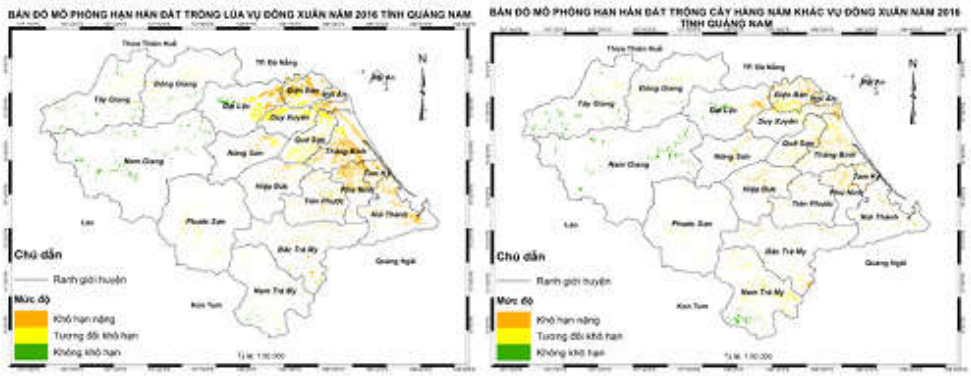


Fig.12: Drought situation of annual crop land in Winter-Spring crop in 2016

In Summer-Autumn crop in 2016, about 76% of the province's rice area (about 47,000 ha) was drought, of which about 25,000 ha was severed drought. For other annual crop land, nearly all of the area was drought (about 43,000 ha).

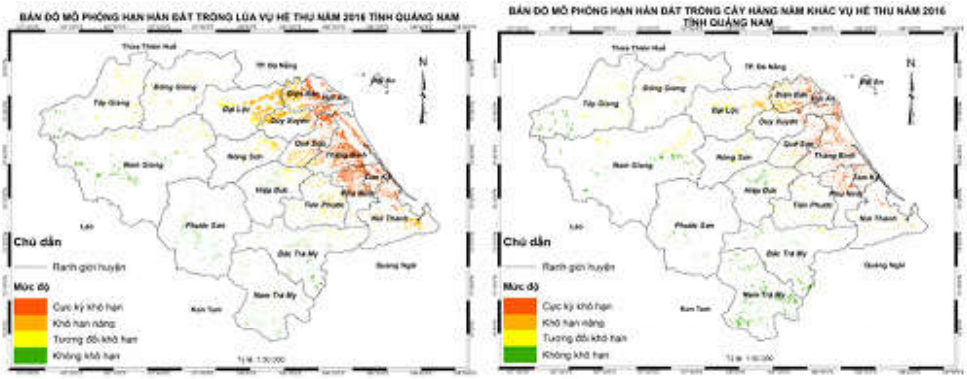


Fig.13: Drought situation of annual crop land in Summer-Autumn crop in 2016

3.3. Develop a forecast map of drought in Quang Nam province until 2035

Percentile algorithm was used to create a rain scenario so that rainfall change of seasons is within range of climate change scenario of rainfall in Quang Nam province issued by the Ministry of Natural Resources and Environment in 2016 [6].

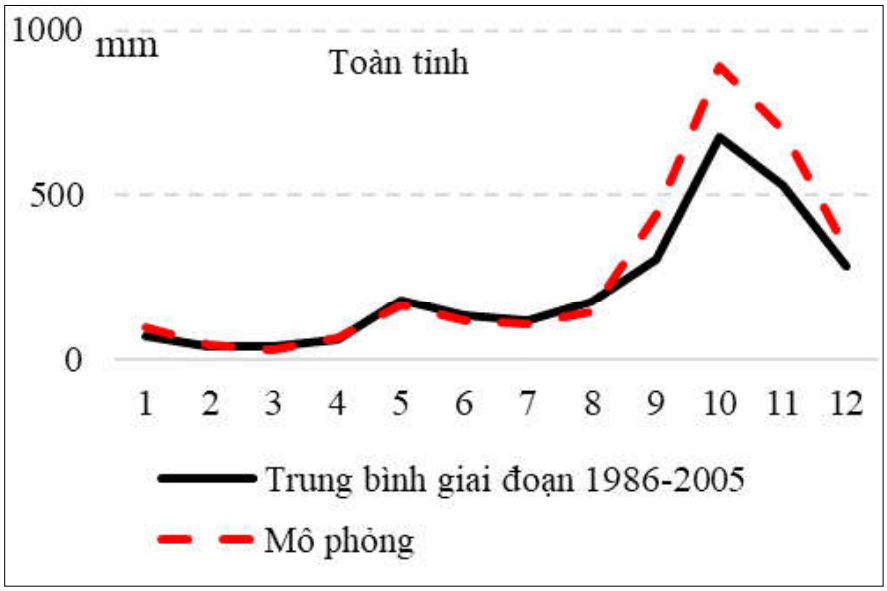


Fig.14: Rainfall simulation under climate change scenario for Quang Nam province

Simulation result in Figure 14 showed that, by 2035, rainfall will be expected to decrease in Spring and Summer months, and increase in Autumn and Winter months. Besides, sharp increase in temperature in Summer-Autumn months makes drought situation in Summer-Autumn crop become more and more intense.

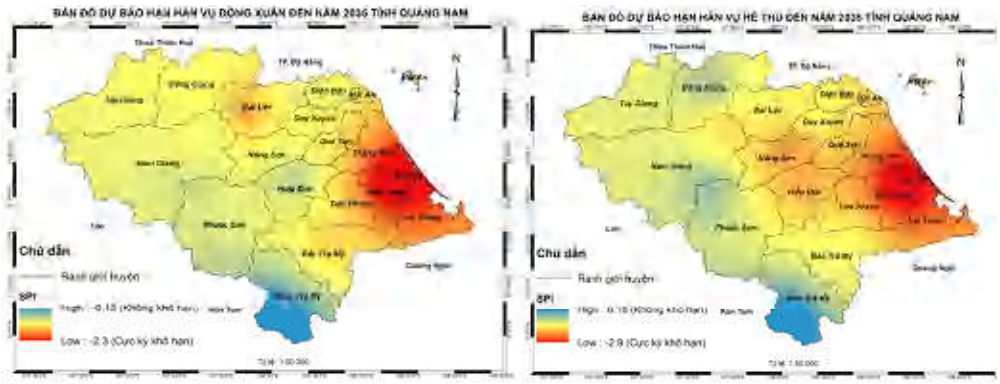


Fig.15: Drought risk map of Winter-Spring crop (a) and Summer-Autumn crop (b) of Quang Nam province till 2035

Simulation results in Figure 15 showed that, predicting Winter-Spring crop in 2035, drought will appear seriously in Southern region from Thang Binh district to Nui Thanh district; In midland, drought will negligible and only appear in some districts such as Dai Loc and Tien Phuoc; In high mountains, drought will not occur. In Summer-Autumn crop of 2035, drought will expand throughout midland and delta areas of Quang Nam province; Severe drought will occur in Nui Thanh, Phu

Ninh, Tien Phuoc, Thang Binh districts and Tam Ky city; Drought in midland districts will milder and decreases gradually to the western mountainous districts of the province.

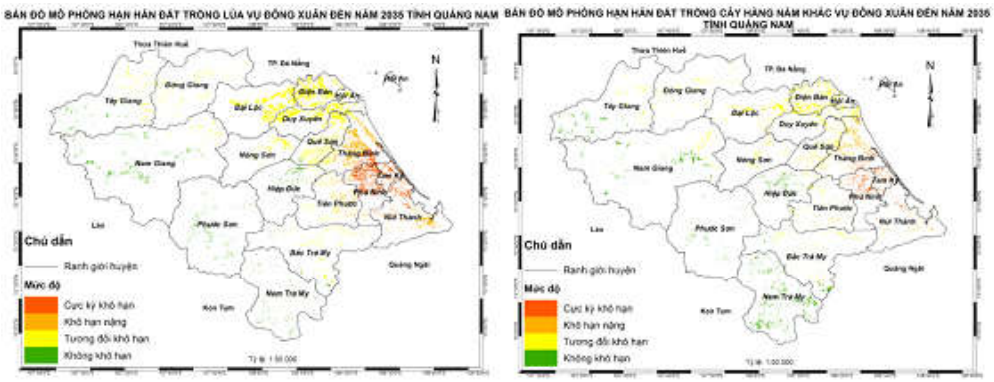


Fig.16: Drought forecast map for annual crop land in Winter-Spring crop in Quang Nam province until 2035

Figure 16 showed that it is forecast that in Winter-Spring crop in 2035, 23% of rice area (about 14,000 ha) will be severely drought and 19% of the area (about 12,000 ha) will be severely drought; About 18% of other annual crop land (about 7,700 ha) will severely drought and 15% of the area (about 6,500 ha) will extremely dry. Areas affected by drought will concentrate in Southeast region of the province, plain districts from Thang Binh to Nui Thanh and Tien Phuoc district.

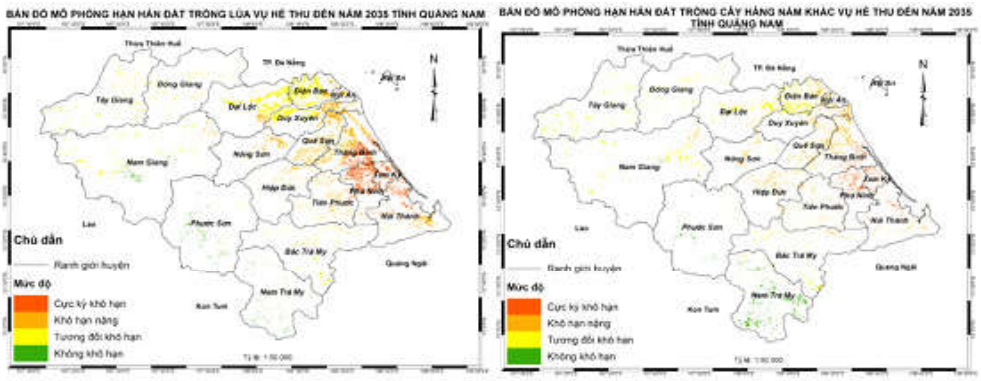


Fig.17: Drought forecast map for annual crop land of Summer-Autumn crop in Quang Nam province until 2035

It is forecast that by 2035, 35% of Summer-Autumn rice crop area (about 21,500 ha) will be severely drought and 22% of the area (about 13,500 ha) will be severely drought; About 43% of other annual crop land (about 18,600 ha) will severely drought and 16% of the area (about 7,000 ha) will extremely dry. Area of annual crop land which is drought-dried during Summer-Autumn crop of 2035 will be distributed throughout most of Quang Nam province, except for highland districts (Figure 17).

3.4. Solutions to adapt to drought in Quang Nam province

a. Non-construction solution

- Reasonable land use arrangement to reduce the total amount of water demand. Based on characteristics of soil, topography and climate to arrange a more suitable crop structure, specifically:

+ Reducing area of wet rice, however, it is necessary to ensure food security, area of wet rice in areas often lacking water or giving low productivity can be converted through such purposes as changing to planting crops and other short-day crops.

+ Limit use of long-term rice varieties, instead of medium and short-term varieties with high tolerance to drought, pests and high yields.

+ Arrangement of concentrated sowing to facilitate irrigation operation. Area, time of sowing must be suitable with water condition to reduce irrigation pressure in drought time.

- In mountainous districts such as Bac Tra My, Nam Tra My, Phuoc Son, Nam Giang, Tay Giang and Dong Giang, it is necessary to conduct afforestation and protection of headwater protection forests to hold water in service of agricultural production activities in midland and downstream tributaries.

- Actively change crop structure; economically and effectively use local water sources. Propagating and guiding ethods to save water for rice plants from beginning of Winter-Spring crop to area of reservoirs so that water sources can be ensured for irrigation till the end of Summer-Autumn crop. In addition, it is possible to adjust seasonal schedule to suit situation of drought in each district.

b. Construction method

- For midland and mountainous areas, it is necessary to consolidate existing dams, to supplement temporary dams on rivers and streams; Dredging canals, repairing damaged solid dams and losing water. In areas where conditions for installation and operation of electric pumping stations and field oil pumps are recommended, make use of water sources in rivers, streams, ponds and lakes to combat drought. In addition, new reservoirs should be built in the future to ensure water resources for midland and mountainous areas of Quang Nam province.

- For delta and coastal districts and cities, it is necessary to install and operate electric pumping stations, field oil pumps, mobile pumps and take advantage of water sources in rivers, streams and ponds to combat drought, which concentrates crop areas that lack of water, drought at the end of canals and dredging system of canals to guide water to clear the flow.

- Downstream area of Vu Gia - Thu Bon river concentrates on a large area of agricultural land, while flow of two rivers is very complicated, with many horizontal flows and near the sea. Therefore, Quang Nam province needs to calculate to upgrade Ai Nghia pumping station (Dai Loc district), Cam Van, Ben Huc (Dien Ban town); To build saline prevention dams on Vinh Dien river so that pump stations upstream of Vinh Dien river will get water that is not affected by salinity.

4. Conclusion

In recent years, drought situation in Quang Nam province is quite complicated and seriously affects agricultural land use, especially agricultural land. Rainfall, temperature, water levels in rivers and SPI are signs that drought in Summer-Autumn crop is much more intense than Winter-Spring crop and causes many challenges to agricultural production land use.

During 1980-2017, drought in Quang Nam province was quite serious and there was a difference between mountains, midlands and plains. Droughts in Winter-Spring crop often occurred in Eastern, Southern and Southeast regions of the province. In Summer-Autumn crop, drought appearred very erratic throughout province and there was no specific spatial trend. In Winter-Spring crop in 2016, about 35,000 hectares of rice land and 22,000 hectares of other annual crops were drought. In Summer-Autumn crop of 2016, drought area for rice and other annual crops was 47,000 ha and 43,000 ha, respectively. In general, drought in Summer-Autumn crop in 2016 was more serious and occurred on a wider scale than Winter-Spring crop.

According to climate change scenario of the Ministry of Natural Resources and Environment, it is forecasted that by 2035, drought in Winter-Spring crop will be serious in Southern region; In midland, drought will negligible and only appear in some districts such as Dai Loc and Tien Phuoc; In high mountains, drought will not occur. In Summer-Autumn crop of 2035, drought will expand throughout midland and delta areas of Quang Nam province; Severe drought will occur in Nui Thanh, Phu Ninh, Tien Phuoc, Thang Binh and Tam Ky cities; Drought in the midland districts will milder and decreases gradually to Western mountainous districts of the province.

In order to adapt to drought in the use of agricultural land in Quang Nam province, it is necessary to synchronize construction and non-construction method, focusing on conversion of crop structure based on special characteristics about land, topography and climate.

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