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The influence of El Nino on water shortage area in Sa Kaeo province, Thailand by using GIS

Noichaisin, L.[1,2 *], Buranapratheprat, A.[3], Manthachitra, V.[3] and Intarawichian, N.[4]

[1]Environmental Science Program, Faculty of Science, Burapha University, Chonburi Campus, Saen Sook, Mueang, Chonburi, 20231, Thailand; [2]Faculty of Science and Social Science, Burapha University, Sakaeo Campus Watthana Nakhon, Sa Kaeo 27160, Thailand; [3]Department of Aquatic Science, Faculty of Science, Burapha University Saen Sook, Mueang, Chonburi, 20231, Thailand; [4]Faculty of Geoinformatics, Burapha University Chonburi, Campus, Saen Sook, Mueang, Chonburi, 20231, Thailand.

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Abstract The influence of El Nino on the area of land impacted by water shortage in Sa Kaeo Province, Thailand was recorded by using Geographic Information System (GIS). As results, the normal conditions revealed that water shortage based on many criteria, average annual rainfall from 30 years, volume of groundwater, distance of water and irrigation sources, soil drainage, slope, and land use. In the year with El Nino phenomenon, the studied criteria were resulted as the same as normal years, except rainfall data from 2015, because it is strated to faced this phenomenon in Thailand. The results indicated that El Nino influenced the degree of water shortage in area of Sa Kaeo Province. The total area with moderate and low water shortage decreased, while the area with high and very high water shortage increased as compared to normal years. The high water shortage area increased from 3,406.19 km^2 to 4,489.80 km^2 (15.06%). The very high water shortage area increased from 203.17 km^2 to 762.22 km^2 (7.77%). Preparation of mitigate, the effects of drough from El Nino can ~~should~~ be separated into three phases; before, during, and after. Before an El Nino year, relevant government agencies should determine agricultural production targets in drought condition and plan irrigation management. During the El Nino year, activities should include the monitoring of weather condition and water suppy, Royal rain-making operations, water allocation planning, support for agricultural production, and damage survey for assistance and subsidy. After the phenomenon, mitigation and careers revitalization should be appropriately offered to people in area affected by water shortage.

Keywords: El Nino, water shortage area, geographic information system, Sa Kaeo province

Introduction

Climate change is a serious problem of concern worldwide because it deeply affects human health, food security, economic activity, natural resources

[*] **Coressponding Author**: Noichaisin, L.;**Email:** likhit@buu.ac.th

and the environment (Ueangsawat *et al.*, 2015; Mary and Majule, 2009) The El Nino phenomenon is a change of weather patterns over the Pacific Ocean. Generally, this phenomenon occurs every 2-5 years causing drought in nearby areas. Further, it results in water shortage in the household and agricultural sectors (Setimela. *et al.*, 2018). Every year, Thailand faces drought, especially in the northeastern, central, and eastern regions. Drought causes damage to agricultural fields by water shortage, preventing farmers from growing cash crops. From drought reports in 2010, there were 36 provinces, 277 districts, 1,874 sub-districts, and 13,975 villages facing drought. It accounted for 38.15% of villages in the province experiencing drought (36,634 villages) or 18.65% of villages throughout the country.

Sa Kaeo Province has suffered drought continuously for several decades. According to the report of the Department of Disaster Prevention and Mitigation in 2016, Sa Kaeo was the only province that declares as drought disaster zone (Sa Kaeo Disaster Prevention and Mitigation Office, 2017). The major causes of drought were insufficient rainfall and low rain distribution, fewer water reservoirs and low water holding capacity (Meteorological Department, 2017). Moreover, climate change, was a significant factor, especially the occurrence of El Nino phenomenon, affects the irregularities of rainfall in Thailand (Kripalani and Kulkarni, 1997; Tangtham et al. 1999; Otarig, 2000; Shrestha and Kostaschuk, 2005; Nounmusig *et al.*, 2006).During the rainy season, the rainfall in Southeast Asia, including most of Thailand, has been decreasing which affects the well-being of humans and other organisms use in agriculture and animal husbandry. Therefore, the study of the influence of El Nino as it affects water shortage in Sa Kaeo Province can indicate areas exposed to the risk of water shortage. In this research, a geographic information system(GIS) was used to assess areas experiencing water shortage when the El Nino phenomenon occurs, because GIS is a powerful tool and is widely used (Pijanowski *et al.*, 2009; Solaimani *et al.*, 2005; Mahiny and Gholamalifard, 2007; Alam *et al.*, 2008; Faryadi and Taheri, 2009). It can be applied to analyze spatial and time data to calculate area. Moreover, it can easily improve and change information used as inputs. The results can be shown in map form, making them easy to communicate. The results can be further applied to plan and manage water resourcess Sa Kaeo Province in the future. The objective of this research was to study the influence of the El Nino phenomenon on the area of land experiencing water shortage in Sa Kaeo Province using GIS.

Materials and Methods

Study area

Sa Kaeo Province is located along the eastern border of Thailand, adjacent to Poi Pet in Cambodia at Aranyaprathet District. The province is 245 kilometers east of Bangkok, with an area of 7,195.44 square kilometers. It is located at latitude 13̇49' 0'' N and longitude 102̇4' 0'' E (Figure 1).

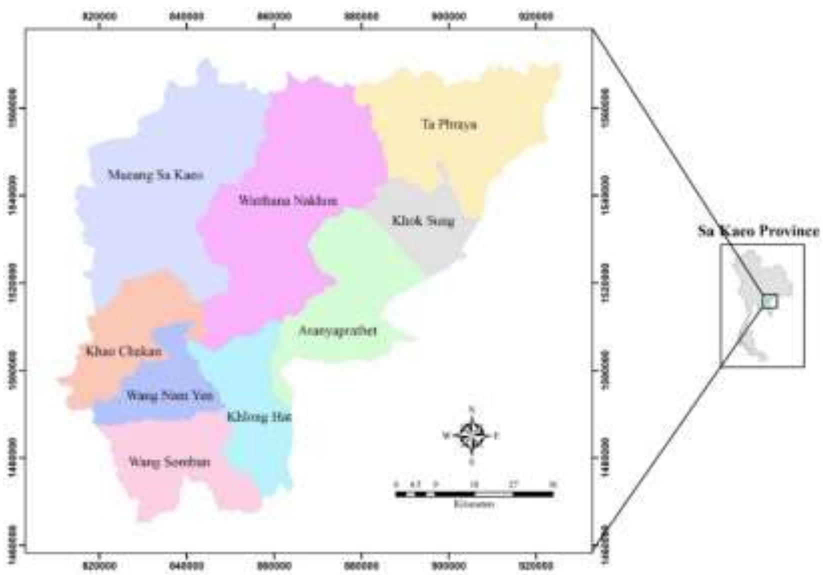


Figure 1. Study area of Sa Kaeo Province, Thailand

Tools

Data were collected from various relevant agencies and then prepared as a database. The data used were 1) a spatial database consisting of topographic maps (1: 50,000) covering the area of Sa Kaeo Province, a map of district level administrative divisions according to the announcement of the Ministry of Interior, a map showing soil series, a map showing surface water sources, a map showing slope and a map showing irrigation sources; and 2) an attribute Database which includes secondary data from agencies responsible for data collection, such as rainfall data, soil series data and irrigation area.The processing program consisted of GIS and database management.

Water shortage area in normal years was analyzed by GIS. The factors in the study were averaged annual rainfall over 30 years (1988-2017), volume of groundwater, distance from water sources, distance from irrigation source, soil drainage, slope, and land use. In this step, the data were analyzed using expert systems, a method determined the variables that causing water shortage and provided the weight values via the GIS weighting and related factors. It was divided into two levels: 1) the score of the variable or variable -weighted values and 2) weight values, or factor levels used to classify the chance of water shortage for each variable. In this study, ten experts from relevant environmental and water resource management agencies were questioned.

Data values were collected throughout the study area which used to calculate the chance of occurrence of water shortage in following equation (1).

$$S = W1\,R1 + W2\,R2 + W3\,R3 + ... + Wn\,Rn \qquad (1)$$

where S is the score of the risk level of water shortage, $W1 ... n$ is the score of the importance of factors $1 - n$, $R\,1 ... n$ is the sub-score of each factor $1 - n$

When receiving data, the occurrence of water shortage was derived from each of the spatial factors by calculating the sum of the data using the Geographic Information System, as shown in equation (1). It was classified as chance of occurrence of water shortage area based on the mean of data and standard deviation of the point. Then, the results was shown on a map expressing risk area of water shortage in Sa Kaeo Province. The degree of water shortage risk was classified into four levels, as shown in Table 1.

Table 1. Level of water shortage used for classifying area of Sa Kaeo Province, Thailand

Level	**Meaning**
Higher than $\bar{x}$+ 1 S.D	Very high water shortage area
Between $\bar{x}$ - $\bar{x}$ + 1 S.D	High water shortage area
Between $\bar{x}$ - $\bar{x}$ - 1 S.D	Moderate water shortage area
Lower than $\bar{x}$ - 1 S.D	Low water shortage area

The sea surface temperature index at NINO 3.4 position (SST Index NINO 3.4) was used to classify the occurrence of the El Nino phenomenon, as shown in Table 2. The table showed that year 2015 was a year in which the El Nino phenomenon occurred throughout the year and therefore it represented the year of the El Nino phenomenon where chosen for this study.

The analysis of the influence of El Nino phenomena affecting water shortage area in Sa Kaeo Province was performed by using eq. 1, using the same set of analyzed factors for water shortage areas in normal years, with the substitution of the amount of rainfall in 2015 (30-year data), which was the year in which the El Nino phenomenon occurred.

Table 2. Sea surface temperature index at NINO 3.4 position during the years 2002-2016 (NASA Official, 2019)

Year	Jan	Fab	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2002	-0.07	0.23	0.10	0.16	0.30	0.78	0.76	0.97	1.11	1.36	1.62	1.52
2003	1.19	0.77	0.59	0.03	-0.48	-0.17	0.21	0.03	0.24	0.50	0.40	0.32
2004	0.17	0.14	-0.12	0.06	0.21	0.11	0.47	0.72	0.75	0.69	0.66	0.74
2005	0.53	0.24	0.33	0.29	0.35	0.40	0.25	0.06	-0.09	0.06	-0.31	-0.68
2006	-0.93	-0.64	-0.65	-0.19	0.06	0.20	0.13	0.40	0.62	0.78	1.08	1.19
2007	0.69	0.09	-0.04	0.00	-0.28	-0.10	-0.43	-0.62	-0.95	-1.47	-1.59	-1.60
2008	-1.86	-1.89	-1.15	-0.95	-0.67	-0.48	-0.03	0.03	-0.28	-0.36	-0.35	0.83
2009	-1.03	-0.68	-0.55	-0.27	0.18	0.47	0.72	0.71	0.75	0.94	1.54	1.72
2010	1.50	1.22	1.08	0.59	-0.17	-0.65	-1.13	-1.32	-1.65	-1.68	-1.58	-1.62
2011	-1.64	-1.27	-0.98	-0.76	-0.43	-0.18	-0.26	-0.64	-0.74	-0.97	-1.05	-1.04
2012	-1.08	-0.69	-0.58	-0.39	-0.05	0.31	0.53	0.73	0.51	0.29	0.36	-0.11
2013	-0.41	-0.40	-0.22	-0.10	-0.27	-0.21	-0.31	-0.28	-0.07	-0.33	0.01	-0.04
2014	-0.51	-0.55	-0.22	0.24	0.46	0.46	0.18	0.20	0.45	0.49	0.85	0.78
2015	**0.53**	**0.56**	**0.58**	**0.78**	**1.03**	**1.32**	**1.60**	**2.07**	**2.28**	**2.46**	**2.95**	**2.82**
2016	2.60	2.40	1.68	1.09	0.30	-0.12	-0.47	-0.54	-0.16	-0.73	-0.55	-0.41

*Normal conditions (-0.4 ≤ SST Index NINO 3.4 ≤ 0.4) during El Nino phenomenon (SST Index NINO 3.4> 0.4); and La NiNa phenomenon (SST Index NINO 3.4 <-0.4)

Results

Factors used in the study were averaged the annual rainfall over 30 years (1988-2017), volume of groundwater, distance of water and irrigation sources, soil drainage, slope, and land use. The results of the data analysis are shown by GIS layers in Figure 2a and 2b.

Figures 2a and 2b showed the factors of this study related to water shortage in Sa Kaeo Province. It was found that most of upper and centralSa Kaeo had average rainfall between 1,332.64-1,623.44 mm/year. In the southern part, an average annual rainfall was more than 1,623.44 mm/year. Volume of groundwater indicated the potential use of groundwater. If it is possible to be used, there would be less chance of water shortage. Based on results, it was found that volume of groundwater could provide a water supply of less than 5 m^3/hr in most areas of Sa Kaeo Province. Distance of water sources played an important role in determining the potential for water shortage. Areas that far from natural water sources would be faced at higher risk of drought.

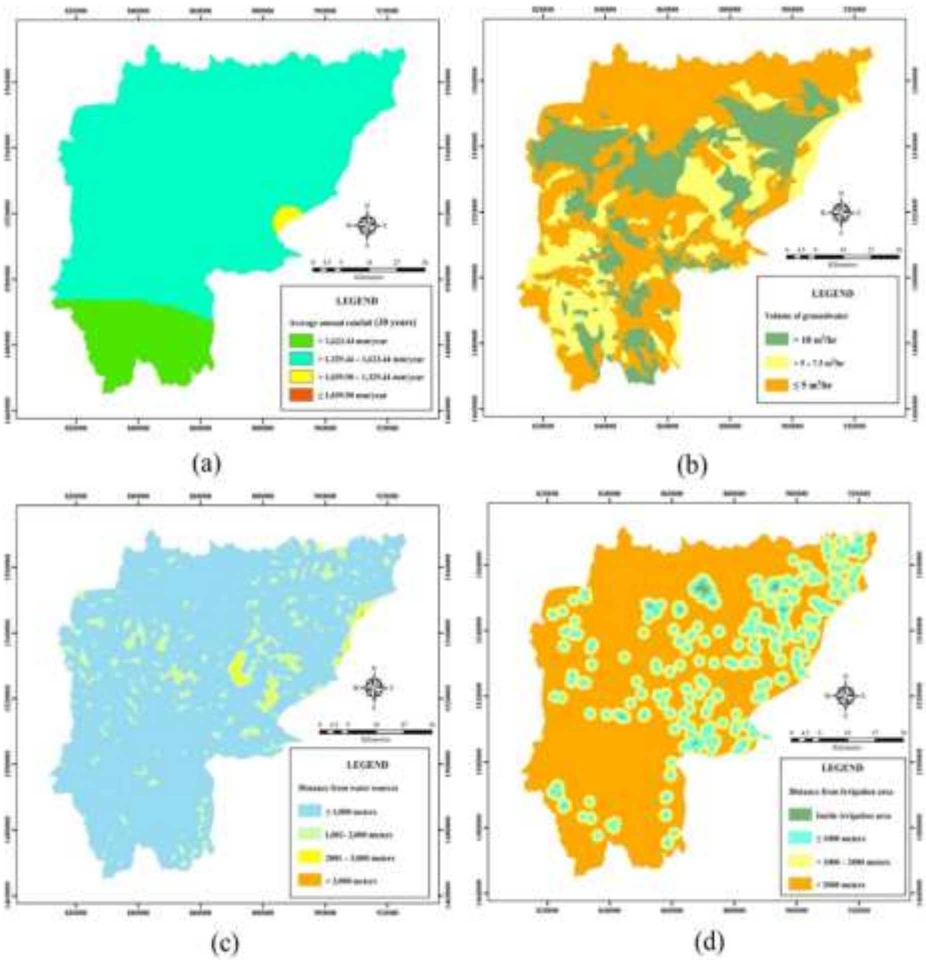


Figure 2a. Spatial maps of (a) average annual rainfall (b) volume of groundwater (c) distance from water sources (d) distance from irrigation sources

In this study, it was found that most areas of Sa Kaeo Province had a distance from water sources of less than or equal to 1,000 meters. Irrigation sources were man-made water reservoirs, such as water reservoirs, which can irrigate to appropriate areas. Therefore, there was a lower chance of water shortage in area with reach of irrigation sources. It was not the case for most of Sa Kaeo Province area. The most affected locations were more than 2,000 meters away from an irrigation sources. Soil drainage, depends on physical characteristics of soil texture, and greflected by the drainage properties of the soil series. Land areas with rough or coarse soil texture would greater risk of drought because good drainage capacity. Then, the most areas of Sa Kaeo province faced bad drainage. Slope affects both the speed of water run-off on the surface and under the ground. In upland area with steep slopes, water will flow out of the area faster than in areas with low slope or lowland areas. Faster runoff offers less chance for water to seep into the ground and store in aquifer, resulting in higher drought risk. Based on our data analysis, slopes in most areas were less than 6%. Land use factors were related to the risk of drought. Land use that decreased infiltration, such as buildings, increased the risk of water shortage. In this study, land use was divided into four types: forest area, community areas and buildings, farm area and miscellaneous space. It was found that most areas of Sa Kaeo Province were used for agriculture, which was the primary occupation of people living in the province.

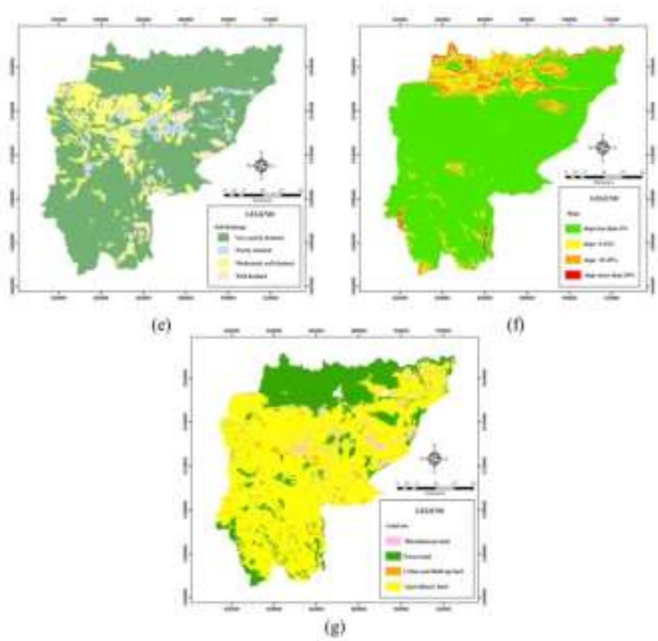


Figure 2b. Spatial maps of (e) soil drainage (f) slope and (g) land use

Water shortage area in Sa Kaeo Province

Water shortage area in normal conditions

The different drought risk factors were overlaid for the entire province, and the degree of water shortage was divided into four levels; low, moderate, high, and very high water shortage areas (Figure 3 and Table 3). It was found that Sa Kaeo Province had a low water shortage area of 103.39 km^2, equivalent to 1.44 % of the total area. These areas were in the southern part of the province, including parts of Nong Waeng, Nong Muang, Wang Sombun, Wang Mai and Wang Thong sub-districts, and in the northeastern part of the province, Thap Rat and Kho Khlan sub-districts. The total moderate shortage area was 3,482.67 km^2 (48.40% of the total area). It included some areas of Wang Mai, Wang Thong, and Non Mak Kheng sub-districts. High water shortage areas covered 3,406.19 km^2, or 47.34 % of the total area. Most of these areas were in the north and northeast of the province, such as Sae-o, Nong Mak Fai, Thap Rat sub-districts. The very high water shortage area covered 203.17 km^2, which was 2.82 % of the total provincial area. It included some parts of Pa Rai, Huai Chot, Han Sai and Tha Yaek sub-districts. Most areas of Sa Kaeo Province were rated as moderate or– high water shortage areas covering 95.74 % of the total area.

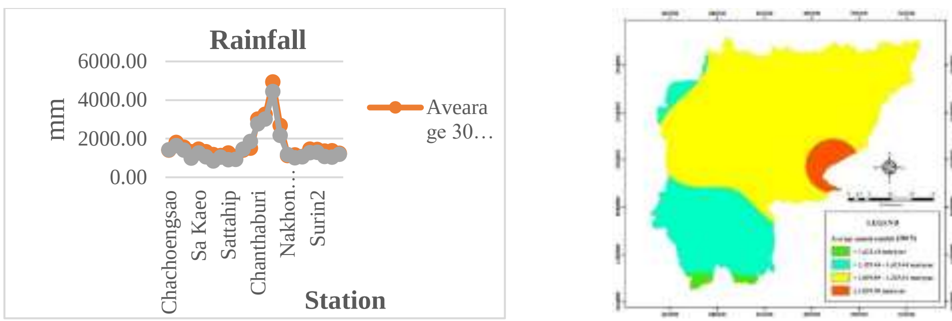
Water shortage area in El Nino year

In the analysis of water shortage data in the El Nino year, the additional factors of annual rainfall in 2015 was considered (Figure 4h.). It was found that the average annual rainfall in the El Nino years decreased from normal years at almost all measurement stations. After analyzing by GIS program (Figure 4i), it was found that most of the province had an average rainfall of 1,039.90-1,329.44 mm/year, but there were some areas on the east side of the province with less than 1,039.90 mm / year. In the El Nino year, water shortage area was increased (Figure 5.); for example, the total high water shortage area increased from 3,406.19 km^2 to 4,489.80 km^2 (15.06% higher than normal years). The very high water shortage area increased 7.77%, from 203.17 km^2 to 762.22 km^2 (Table 3).

Figure 3. Water shortage in normal rainfall years in Sa Kaeo Province, Thailand

Table 3. Percentage of increase - decrease in water shortage area from normal rainfall years to the year of the El Nino phenomenon

Level	Water Shortage area (km²) Normal year	Percentage	Water Shortage area (km²) El Nino year	Percentage	Percentage increase - decrease
Low	103.39	1.44	5.25	0.07	-1.37
Moderate	3,482.67	48.40	1,938.14	26.94	-21.46
High	3,406.19	47.34	4,489.80	62.40	+15.06
Very High	203.17	2.82	762.22	10.59	+7.77



(h) (i)

Figure 4. Rainfall in normal years and in an El Nino year (2015) (h) and map of rainfall in the El Nino Year (i).

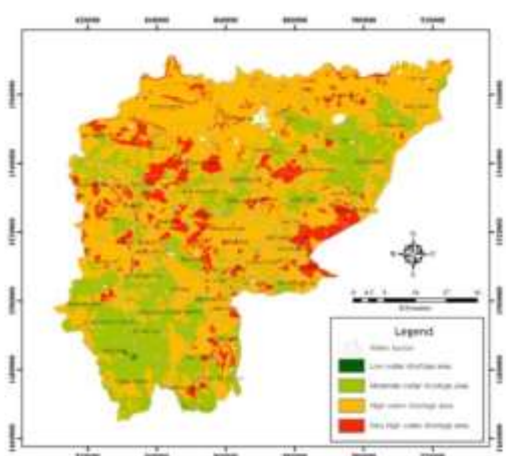


Figure 5. Water shortage areas in an El Nino year in Sa Kaeo Province, Thailand.

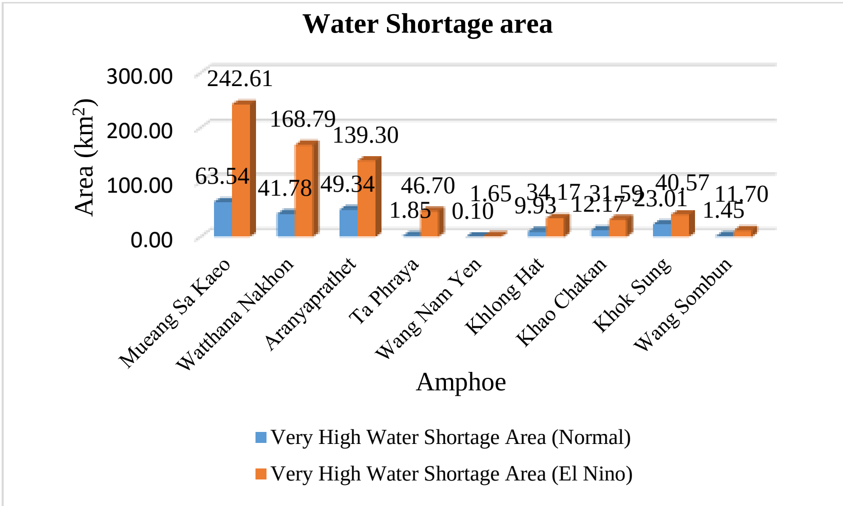


Figure 6. Area of very high water shortage for districts of Sa Kaeo Province, Thailand in normal years compared to an El Nino year

Discussion

When considering the change in water shortage between normal years compared to the El Nino year, it was found that when the El Nino phenomenon occurred, Sa Kaeo Province experienced increased in total area with very high water shortage in every district, and especially in Mueang, Watthana Nakhon, Aranyaprathet and Ta Phraya Districts (increases of 178.07, 127.01, 89.96 and 44.85 km^2, respectively). This is in agreement with report of The Thai Meteorological Department (2017) indicated that the El Nino phenomenon affected the amount of rainfall in Thailand. The amount of rain was lower than normal, especially in the summer and early rainy season, resulting in a shortage of water in Sa Kaeo Province. Therefore, the preparation for an El Nino year would be made in order to help the areas where water shortage. Lohpittayakorn (2017) studied the influence of El Nino, and similarly that it affected the distribution of rainfall during the rainy season and dry season in the eastern region of Thailand, and the amount of rain during the rainy season decreased as compared to normal rainfall years in the eastern part of Thailand ($p < 0.05$).

The guidelines to prepare for an El Nino situation in Sa Kaeo Province should be divided into three phases:

1. Before the El Nino event, relevant government agencies should target crop cultivation during the dry season, and methods to manage farm space in the form of the "Khok Nong Na" model (Nectec, 2019), which uses a pond to store water to reserve for plants, even during the dry season. It also maintains fertility of the area even though it is surrounded by monoculture plants. Plan

should be made to allocate water appropriately, in line with the Royal Rainfall Action Plan. Pumps and water trucks should be readied.

2. During the El Nino event, weather conditions and water supply must be monitored for proper planning of Royal rain-making (cloud seeding) operations and water allocation, for support of agricultural production, and for evaluating and assessing damage for mitigation.

3. After the El Nino, mitigation and careers revitalization should be appropriately offered to people in drought- stricken areas.

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