# Agricultural Drought Risk Assessment in Lam Ta Kong Watershed, Thailand

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**Abstract**
*This study aimed to analyze the factors that affect agricultural drought in the Lam Ta Kong watershed in northeastern Thailand, in terms of the climate, soil and land utilization factors that cover ten secondary factors, using analysis hierarchy process with geographic information system and remote sensing techniques. The results indicated that the rainfall had a high effect on the agricultural drought risk in the study area, along with the absence of vegetation cover. Most areas showed a very high and high risk of agricultural drought (1,582.93 and 498.2 km$^2$, respectively, or 46.3% and 14.6% of the total area, respectively), with a decreasing area as the drought risk decreased from a moderate to a very low risk (474.7 to 412.4 km$^2$, or 13.9% to 12.0% of the total area).*

## 1. Introduction

Climate change is a global problem that directly affects the environment and human lives. This problem significantly influences the hydrological and ecological systems (Chanchaeng, 2010) that culminate into land degradation, drought and desertification in many parts of the world (Wijitkosum, 2014, Adamo and Crews-Meyer, 2006 and UNCCD, 2007). Due to climate extremes of temperature, droughts occur more often and their impacts are being aggravated by the rise in water demand and the variability in hydro-meteorological variables (Belal et al., 2010). Moreover, the anthropogenic factors have also increased the drought risk (Diffenbaugh et al., 2015, Cox et al., 2008 and Wijitkosum, 2014).

Lam Ta Kong watershed is a sub watershed of Moon basin, Thailand. This includes area of around 64.95 percent as agricultural area. Lam Ta Kong watershed has had a severe water shortage problem for a long time. The tendency of water shortage probably result from the increasing in water demand that greater than the water assets in the watershed which is about 170.76 million cubic meters (Wijitkosum and Sriburi, 2010). In addition, the forecast of water demand in Lam Ta Kong watershed tend to increase from the year 2004 to 2024 around 10 million cubic meters whereas the volume of rainfall tend to decrease (Wijitkosum and Sriburi, 2009).

The characteristic of soil resource in this area is a loam sandy soil that poor in water absorption and low fertility. Moreover, there are evidence of strong changes in the land utilization of upstream area from the forestry areas to resort and golf course resulting in the loss of forest cover while downstream area continuously expand. All of these factors affect the occurrence of drought in the area.

The Analytic Hierarchy Process (AHP) is one of Multi-criteria decision analysis (MCDA) approach that is used for analyzing the characteristics of the complex problem and typically uses a weighted ranking system according to defined situation-specific evaluation criteria (Thungngern et al., 2015 and Simonovic, 2009). The AHP is a decision support tool which can be used to solve complex decision problems (Triantaphyllou and Mann, 1995, Ramanathan et al., 2001 and Wang et al., 2008) for multiple criteria decision-making in many fields such as water resource management, environmental management, economic development and, medicine and healthcare, (Thungngern et al., 2015).

This study aimed to study the drought risk factors and assessment of agricultural drought risk in Lam Ta Kong watershed. The AHP model was applied to investigate the agricultural drought risk assessment. The GIS and RS techniques were employed to evaluate the area of drought risk.

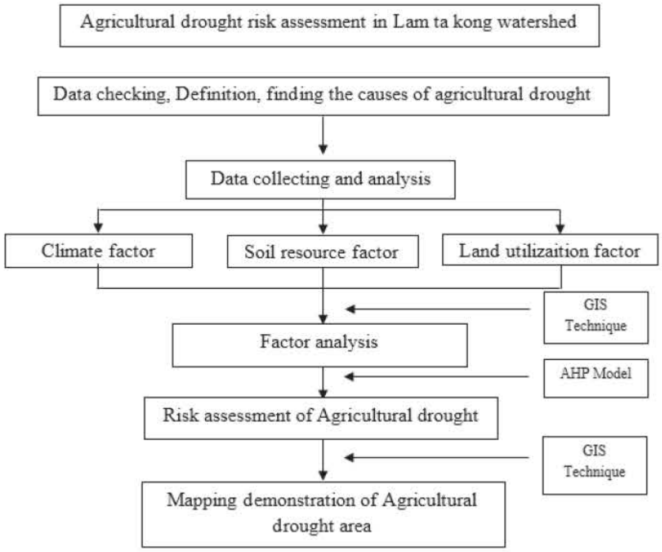


Figure 1: Methodological approach

Therefore, the results of this study will be forwarded to the relevant agencies in the Lam Ta Kong watershed in order to apply as the significant database for laying down the suitable mitigation measures against the agricultural drought based on the spatial data.

## 2. Methodology

The three main factors of climatic, soil and land utilization, which cover ten secondary factors, were used for analyzing the agricultural drought risk level and risk area in the study area using AHP, as outlined in Figure 1.

The climatic factor involved the two indicators of rainfall and number of rain-days, derived from the climate data that had been collected over a 30-y period from 12 agrometeorological stations in the watershed. The soil factor consisted of the five indicators of the soil texture, fertility, drainage, elevation and slope. The land utilization factor, which was investigated based on human activities that affect the Landuse, covered the three indicators of land cover, distance from the nearest irrigation canal and stream density. The RS and GIS technology were integrated to classify and map the land cover data (Wijitkosum, 2016, 2012, Chen et al., 2012, Lillesand et al., 2008 and Wang et al., 2008). The Landsat and Theos satellite images were imported into the ENVI image processing software and the image geo-referencing accuracy was initially checked with a reference map for the area. Both the RS technique and the field survey were applied to interpret the satellite images in order to classify the various types of land cover in the study area. Several image manipulation techniques were employed, including image enhancement, band ratio and spectral classification, in order to optimize the results for multispectral land classification and visual interpretation (Wijitkosum, 2016, Ramadan and Kontny, 2004 and Lillesand and Kiefer, 1994). The drought risk assessment was analyzed by spatial analysis. The drought risk factors were analyzed using mathematical model and applied to the RS and GIS technology. The drought risk assessment and the mapping for drought risk areas were generated by the ArcGIS software to identify the affected areas.

The AHP assessment method employed the matrix calculation. The decision matrix was generated by comparing the index of the same level one by one (Ahmad et al., 2015). The weighted linear combination (WLC) model is the most widely applied model in GIS based decision rules (Hambali et al., 2011, Malczewski, 2000 and Hopkins, 1977), as it takes into consideration multiple criteria and conflicting objectives. A weighted sum analysis provides the ability to weight and combine multiple inputs to create an integrated analysis. In other words, it combines multiple raster inputs, representing multiple factors, of different weights or relative importance. It is a common methodology used for site selection in general. The WLC analysis was applied using Equation 1:

$$\sum_{i=1}^{N} W_i X_i = W_1 X_{1.2} + \cdots + W_N X_N$$

Equation 1

Where $\sum_{i=1}^{N} W_i X_i$ = weighting of factors
$W_i$ = rating from expert
$X_i$ = rating

The data calculated from WLC were then overlaid and integrated. The sum weighting from each layer was computed for classification of the drought risk levels in terms of the five levels of very high, high, moderate, low and very low.

## 3. Results and Conclusion

### *3.1 Effect of Factors on Agricultural Drought in Lam Ta Kong Watershed*

Ten factors including rainfall, the number of raining days, soil texture, soil drainage, soil fertility, slope of the area, the height of the area, soil utility, the density of river and land distance from irrigation sources were weighted and scored for analyzing the risk assessment. This study used the average of rainfall volume in 30 years (1984 - 2013) from 12 meteorological stations which cover all the studying area. The results showed that most areas of Lam Ta Kong watershed ( 42.95% of total area or approximately 1,468.91 km$^2$) have average rainfall of 800-900 mm per year that can be implied that most of areas had an moderate rain volume. For the data of the number of rainy days, it showed that total area (approximately 3,419.85 km$^2$) had more than 90 of rainy days per year. For the soil texture, about 44.89% of total area (approximately 1,535.13 km$^2$) is sandy soil. About 53.97% of total areas showed well drainage of the soil. The soil fertility in most of Lam Ta Kong watershed areas was very low ( 65.29% of total area or approximately 2,232.81 km$^2$) . The slope of most areas in Lam Ta Kong watershed was lower than 5% (79.38% of total area or approximately 2,714.72 km$^2$). The height of the area showed height above sea level of between 200-400 m (65.11% of total area). For the soil utility, the results in year 2013 showed that most of areas were agricultural areas (64.02% of total area or 2,189.38 km$^2$).

Around 18.24% of total area (623.81 km$^2$) was covered with forest. The other areas were construction and human habitat ( 11.26% of total area) and around 4.93% of total area (168.43 km$^2$) was available area. The areas around 1.56% of total area were mainly water resource, water reservoir area, and wetlands. The stream density of Lam Ta Kong watershed was 0.5-1.0 km per km$^2$ (73.72 % of total area or approximately 2 ,521.24 km$^2$) and the most of area has the long distance from irrigation sources (6,000 m) which affects the access to water resources for agriculture.

### *3.2 AHP Analysis*

The values from weight of the criteria and the rating values from expert interviews in each factor were analyzed by Analysis Hierarchy Process (AHP). The results showed that the climate factors had the highest weight (W = 0.74) followed by the factor of land utilization (W = 0.30) and soil resource (W = 0.23). From the values of ten secondary factors, the results indicated that the most significant factor was rainfall volume (W = 0.67), which was followed by land utilization (W = 0.44), soil texture (W = 0.34), number of rainy day (W = 0.33), the distance from irrigation sources (W = 0.31), the density of water (W = 0.25), the water drainage (W = 0.22), the soil fertility (W = 0.16), the height of area (W = 0.15) and the slope of area (W = 0.13) as shown in the Table 1.

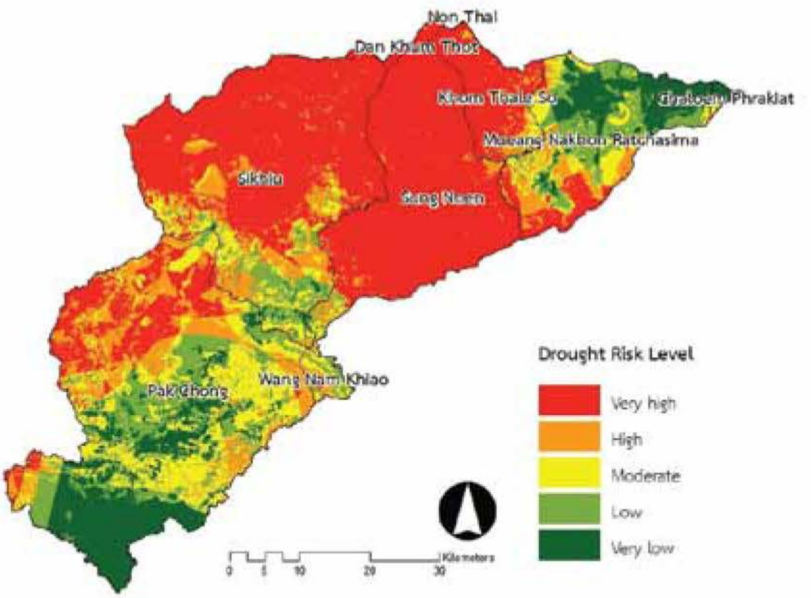


Figure 2: Mapping of risk areas of agricultural drought in Lam Ta Kong watershed

Table 1: Values of weight from factors and rating from expert interview

| Criteria Domain | Criteria | Level of Criteria | Rating | Weighting |
|---|---|---|---|---|
| Weather (W = 0.47) | Rainfall (W = 0.67) | > 1000 mm./year | 1 | 0.20 |
| | | 900 - 1000 mm./ year | 2 | 0.40 |
| | | 800 - 900 mm./ year | 3 | 0.60 |
| | | 700 - 800 mm./ year | 4 | 0.80 |
| | | < 700 mm./ year | 5 | 1.00 |
| | Number of Rainfall (W = 0.33) | > 90 Day/ year | 1 | 0.50 |
| | | < 90 Day/ year | 2 | 1.00 |
| Soil (W = 0.23) | Soil Texture (W = 0.34) | Sediment | 1 | 0.20 |
| | | Soil Slopes Complexes | 2 | 0.40 |
| | | Clay | 3 | 0.60 |
| | | Silt | 4 | 0.80 |
| | | Sand | 5 | 1.00 |
| | Soil Drainage (W = 0.22) | Very Poorly Drained | 1 | 0.25 |
| | | Poorly Drained | 2 | 0.50 |
| | | Moderately Drained | 3 | 0.75 |
| | | Well Drained | 4 | 1.00 |
| | Soil Fertility (W = 0.16) | High | 1 | 0.25 |
| | | Moderately | 2 | 0.50 |
| | | Low | 3 | 0.75 |
| | | Very Low | 4 | 1.00 |
| | Slope (W = 0.13) | < 5% | 1 | 0.13 |
| | | 5 - 10% | 2 | 0.25 |
| | | 10 -15% | 3 | 0.38 |
| | | 15 - 20% | 4 | 0.50 |
| | | 20 - 25% | 5 | 0.63 |
| | | 25 - 30% | 6 | 0.75 |
| | | 30 - 35% | 7 | 0.88 |
| | | > 35% | 8 | 1.00 |
| | Elevation (W = 0.15) | < 200 Meters | 1 | 0.14 |
| | | 200 - 400 Meters | 2 | 0.29 |
| | | 400 - 600 Meters | 3 | 0.43 |
| | | 600 - 800 Meters | 4 | 0.57 |
| | | 800 - 1000 Meters | 5 | 0.71 |
| | | 1000 - 1200 Meters | 6 | 0.86 |
| | | > 1200 Meters | 7 | 1.00 |
| Landuse (W = 0.30) | Land Cover (W = 0.44) | Water Body | 1 | 0.20 |
| | | Forest Land | 2 | 0.40 |
| | | Urban and Built – Up Land | 3 | 0.60 |
| | | Miscellaneous Land | 4 | 0.80 |
| | | Agriculture Land | 5 | 1.00 |
| | Stream Density (W = 0.25) | < 0.5 Km./ Sq.km. | 1 | 0.33 |
| | | 0.5 -1.0 Km./ Sq.km. | 2 | 0.67 |
| | | > 1.0 Km./ Sq.km. | 3 | 1.00 |
| | Distant from Irrigation (W = 0.31) | < 2000 Meters | 1 | 0.25 |
| | | 2000 - 4000 Meters | 2 | 0.50 |
| | | 4000 - 6000 Meters | 3 | 0.75 |
| | | > 6000 Meters | 4 | 1.00 |

Table 2: Risk areas of agricultural drought in Lam Ta Kong watershed

| Risk Level | Area | | |
|---|---|---|---|
| | Sq.km. | Rai | Percent |
| Very High | 1,582.93 | 989,334.01 | 46.29 |
| High | 498.23 | 311,396.47 | 14.57 |
| Moderately | 474.65 | 296,658.63 | 13.88 |
| Low | 451.66 | 282,290.33 | 13.21 |
| Very Low | 412.36 | 257,726.34 | 12.06 |
| Total | 3,419.85 | 2,137,405.79 | 100 |

### *3.3 Risk Assessment Analysis of Agricultural Drought in Lam Ta Kong Watershed*

The results from AHP analysis were analyzed by overlay by GIS software (ArcGIS) for studying the risk assessment of agricultural drought in Lam Ta Kong watershed as showed in Table 2 and Figure 2. The results showed that most areas approximately 1,582.93 km$^2$ (46.29% of the watershed area) showed the risk of the agricultural drought inas very high. The area that showed the high level of the risk of the agricultural drought were approximately 498.23 km$^2$ (14.57% of the watershed area). The moderate risk area were approximately 474.65 km$^2$ (13.88% of the watershed area). The areas with low and very low of risk of agricultural drought were approximately 451.66 (13.21% of the watershed area) and 412.36 km$^2$ (12.06% of the watershed area), respectively.

## 4. Discussion

Wijitkosum (2007) investigated the current water resource management in Lam Ta Kong watershed. The results indicated that this watershed was enhancing the water shortage depending on the demand. The result suggested that the management of water both demand and supply is necessary for preventing the water drought. In this study, the results indicated that the agricultural drought risk in the Lam Ta Kong watershed area was mostly at a very high level, where the largest drought risk category (very high risk) accounted for 46.3% of the total land area. The drought risk depends on many factors, including climatic factors and human activities. However, the major factor causing drought in the Lam Ta Kong area was the climatic factor and specifically the rainfall level, which is considered as the driving factor of drought and desertification risk (Black et al., 2016, Yin et al., 2016 and Brown et al., 2011). The area with a very high drought risk was mainly located in the middle part of the watershed and was a non-irrigated agricultural area (Wijitkosum and Sriburi, 2010). These areas showed a low to moderate rainfall volume, high soil drainage and low soil fertility. In addition, the areas around Kham Thale So district, in the middle part of the watershed, had the highest salinity and mostly alkaline soil in the northeast of Thailand. Alkaline soil normally has a significant impact on drought and reduces the productivity of crops because most crops are sensitive to high concentrations of salts in the soil (Shrivastava and Kumar, 2015). The increasing soil salinity makes the land unusable, deserted and with no landcover, which leads to an increased evaporation rate, a higher soil erosion rate and lower soil fertility, which later contributes to the drought risk in the area.

The areas where a very low risk of agricultural drought were found in upstream of Pak Chong district were covered with forest and were within the range of Khao Yai National Park. This results in high degree of humidity (Cook et al., 2014, Suresh et al., 2010 and Webb et al., 2005). Furthermore, these areas had a high soil fertility due to high organic content and a high volume of rainfall. Although the slope of the area was high, the forested landcover resulted in a decreased soil erosion and high humidity (Wijitkosum, 2012), therefore the risk of drought was very low. The Lam Ta Kong watershed had different drought risk levels, where the critical area (very high risk) was in the middle part of the watershed with a low precipitation, low soil fertility, low land coverage and high drainage. From this study, it can be pointed that each area has the difference in drought risk. Various factors considered were related to the integrated management of natural resources reported by Wijitkosum (2007). The results showed the tendency of water shortage was related to water demand than availability of water resources.

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