# Assessment of the suitability of land use for agriculture by analytical hierarchy process: AHP in lower Prachinburi watershed, eastern Thailand

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**Abstract**: The low Prachinburi watershed is a gateway to other regions of the country. Due to a rapid increase in population there, there is also an increase in agricultural production area. This study aims to assess the appropriateness of land use by using an analytical hierarchy process (AHP) for land use planning. The results of the study revealed that there is a moderate level of the appropriateness in land use development. The most appropriate area (S1) accounts for 22.07%; the moderately appropriate area (S2) accounts for 54.15%; the lowly appropriate area (S3) accounts for 10.25%; and the inappropriate area accounts 13.52% of the area. Regarding a guideline for agricultural area management, it is found to be most appropriate, particularly on field crop growing such as cassava, sugar cane, and maize growing and followed by rice growing and or charding (58.51%, 25.17%, and 6.04%, respectively). Only 10.25% of the total area is inappropriate for farming.

**Keywords**: land suitability, analytical hierarchy process, watershed, assessment, GIS

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## 1 Introduction

A rapid increase in population has an effect or increase land use. It is a true that Thailand need increased land use to be responsive to increased need for food an agricultural yield. However, this agricultural yields must be safe and meet standards increase to be consistent with the 12th economic development plan. Thus, it is essential to prepare a plan for appropriate land use, an assessment of appropriateness of land use aims to predict capability in land use. Also, area selection is important to an increase in safe agricultural yields. This will result in effective resound utilization in accordance with the 12th economic development plan of the country.

An assessment of land utilization can be made based on the quality of the locale of the study and indicators of the characteristics of the land (the Socio-economic and environmental aspects). This is on the basis of an integrated analysis, which multi-group decision-making and analytic hierarchy process (AHP) are employed (Akinci et al., 2013; Chavez et al., 2012). MCA is one method used in the decision-making to make a plan on land utilization (Elsheikh et al., 2013) for producing safe agricultural products.

The lower Prachinburi basin is located in Sakaeo province, Eastern Thailand. It covers an area of 719,513.92 hectares which is close to Cambodia. The geographic condition of Sakaeo is appropriate to be the gateway to northeastern Thailand and Indo-china. The lower Prachinburi basin covers 332,512.80 hectares of

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agricultural area or 88.80% of the total area and there is an amount of surface run off for 2,532,660 cubic meter. In fact, Sakaeo province has a capacity to store water for about 1,154.305 cubic meter but there is only 376.705 cubic meter of water stored there at present (15% of an average amount of surface runoff). Besides, the irrigation area there covers 39,174.08 hectares 10.4% of the agricultural area. In addition, an increase in population has an effect on decrease in agricultural areas. This is risky to the security of agricultural yield production due to the expansion of infrastructure, industry, housing, etc.

Therefore, this study aims to assess a level of appropriateness in land use for developing safe agricultural area in the lower Prachinburi watershed, which will lead to the economic development plan on sustainable farming.

## 2 Materials and methods

### 2.1 Study area

The study was conducted in the lower Prachinburi watershed covers an area of about 719,513.92 hectares in Sakhae province eastern Thailand. Its location is between latitude 13º45'0"N and latitude 102º19'60"E (Figure 1). The area is close to Cambodia and appropriate to be the gateway to northeastern Thailand and Indo-china. The study area has a wet tropical climate with an average annual rainfall of 2,200 mm per year. The monthly average temperature range is 25ºC to 30ºC. The elevation of the study area ranges between 0 meter and 750 meter above sea level.

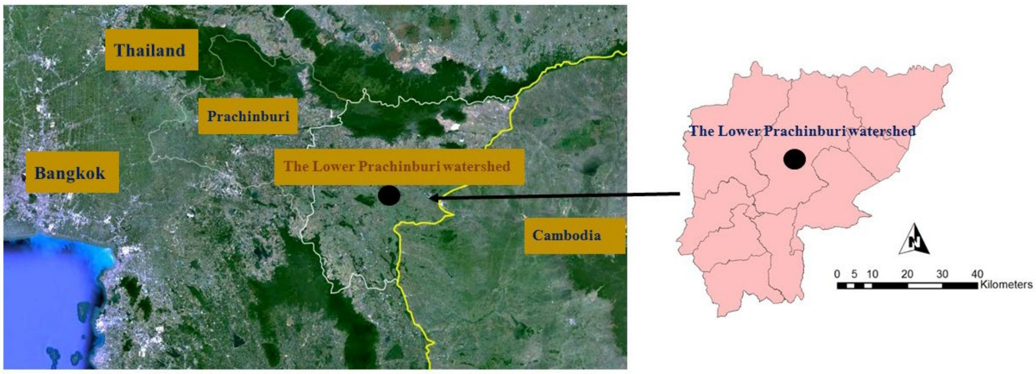



Figure 1 The study area of the lower Prachinburi watershed, Eastern Thailand

### 2.2 General analysis

The AHP is a multi-criteria decision-making approach introduced by Saaty (2008). The AHP has attracted the interest of many researchers mainly because of the effective mathematical properties of the method. Land suitability valuation was conducted using AHP or MCA procedure (Figure 2). Four parameters were used, consisting of five criteria; each criterion consisted of several sub-criteria. The results of land suitability were then analyses to obtain suitable land which is available for agriculture.

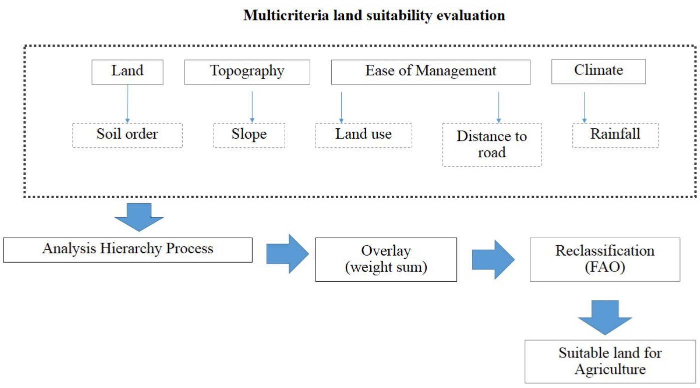



Figure 2 Procedure followed in generating suitable land for agriculture in the lower Prachinburi watershed, Eastern Thailand

### 2.3 Land suitability evaluation

2.3.1 Criteria used and data sources

**Land parameter:** The land parameter used in this research consist of soil class and capability class as criteria (FAO, 1976). Soil class data were derived from a soil survey in 2017, resulting soil map at a scale of 1:250,000. The map presents four soil orders: Oxisols, Spodosols, Vertisols, and Entisols. Oxisols occupy the largest area 42.56% of the region. Spodosols are also quite widely spread 36.25%. The other soil, such as Vertisols and Entisols, is less than 15% of the study area shown in Figure 3(a) and Table 1.

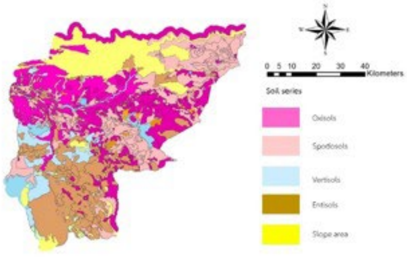
**Topographic parameters:** The topographic parameter included slope and slope distance from the stream as criteria. All two criteria were taken from the Thailand Topographic map at a scale of 1:250,000. Slope and slope distance from stream map were made from this topographic map using the modules available in the ArcMAP 10.1 (Figure 3(b) and Table 1). According to slope, the dominant land form varies from undulating 0%-5%, gently sloping 5%-10%, and hilly 15%-25%, respectively. This slope distance from stream, slopes facing north and south are dominant, followed by slopes facing east and west (Sys et al., 1991).

**Ease of management:** The land use and land cover was two criteria were obtained from analysis using the ArcMAP 10.1 software (Figure 3(c) and Table 1). The main land use/land covers in lower Prachinburi watershed, Eastern Thailand. It's area coverage is agricultural of 337,917.92 hectares or 88.80% of the total area. It comprises cash crops such as cassava, sugar cane, and maize (184,720.48 hectare). The rest are rice field (153,006.56 hectare) and fruit trees such as rose apple, santol, and cantalube (192.48 hectare). In addition, there are residential areas covering an area of 34,369.44 hectares. The accessibility was represented by distance to a main road, Obtained from the Thailand Topographic map of 1:250,000 (Figure 3(d) and Table 1).

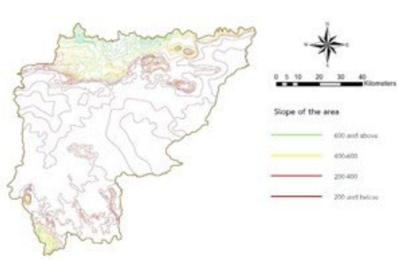
**Climatic parameter:** The climatic parameter considered in this study was the amount of rainfall. The monsoon influence (2 seasons): south western monsoon (humid air with rainfall) and north-eastern monsoon (dry air). This climate influence has an effect on livelihoods and earning a living of people there. The distribution of rainfall is shown in Figure 3(e) and Table 1 (an amount of rainfall range is 1,225.40 -1,599.00 mm. or 133.25 mm. on average).

**Table 1 The criteria and subcriteria in lower Prachinburi watershed, Eastern Thailand.**

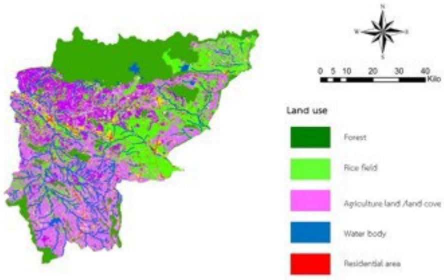
| Parameter | Criteria | Sub-criteria | Percent |
|---|---|---|---|
| **Land** | Soil order | Oxisols | 42.56 |
| | | Vertisols | 13.72 |
| | | Spodosols | 36.25 |
| | | Entisols | 7.47 |
| **Topography** | Slope | 0-200 | 50 |
| | | 200-400 | 30 |
| | | 400-600 | 15 |
| | | >600 | 5 |
| **Ease of management** | Land use/Land cover | Agricultural land /paddy field | 28.27 |
| | | Dry land | 54.66 |
| | | Forest | 11.20 |
| | | Water body/residential area | 5.87 |
| | Distance from stream (km) | Less than 1-2 | 62.73 |
| | | 2-3 | 19.84 |
| | | 3-4 | 9.72 |
| | | 4-more than 5 | 7.71 |
| **Climate** | Rainfall (mm.year$^{-1}$) | 1800-more than 2000 | 11.25 |
| | | 1500-1800 | 15.84 |
| | | 1200-1500 | 48.28 |
| | | Less than 1000-1200 | 24.63 |
| | **Total** | | 100 |



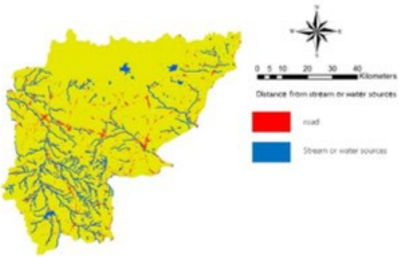
**(a) Soil order**



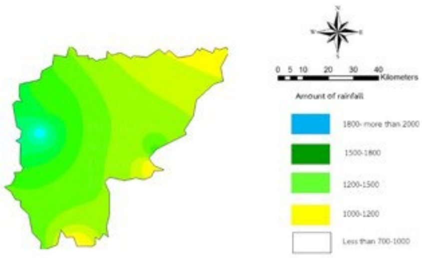
**(b) Slope**



**(c) Land Use**



**(d) Distance from stream**



**(e) Rainfall**

Figure 3 Criteria used for land suitability analysis in lower Prachinburi watershed, Eastern Thailand.

2.3.2 Weighting of criteria and scoring of sub-criteria

**Weighting of criteria:** All of the spatial data were classified and weighted to contribute to the suitability agriculture map. For weighting, expert consultation was conducted, in which 5 experts were involved. The weighting was performed using AHP (Akinci et al., 2013; Widiatmaka et al., 2016). In this method, a pairwise comparison was done to obtain the relative importance of criteria considered. The ratings were derived from a nine interest scale, with a value from 1 to 9 (Table 2).

**Scoring:** The scores were given according to the contribution of each sub-criteria to agriculture; the score range from 0 to 10. High scores were given to the sub-criteria that are considered the most important for agriculture, while low scores were given to the least influential sub-criteria. A score of 0 was given as a constraint, indicating that it is not suitable for agriculture.

**Table 2 Pairwise comparison scale (Widiatmaka et al., 2016)**

| 1/9 | 1/7 | 1/5 | 1/3 | 1 | 3 | 5 | 7 | 9 |
|---|---|---|---|---|---|---|---|---|
| **Extreme** | Very strong | Strong | Moderate | Equal | Moderate | Strong | Very strong | Extreme |
| | **Less important** | | | | | More important | | |

2.3.3 Land suitability map

The criteria weights and sub-criteria score were appointed to the related layers in ArcMAP 10.1, using the weighted to analysis agricultural land suitability map was generated (FAO, 2012). The weights of the criteria were multiplied with the score of the sub-criteria; this multiplication was performed in raster format on the map. The result was then reclassified using equal distance as four classes of suitability (Zhang et al., 2015; Ghafari et al., 2000; Nasrollahi et al., 2017). Highly suitable (S1), moderately suitable (S2), marginally suitable (S3), and not suitable (N), according to the following Equation (1) below :

$$LS = \sum_{i=1}^{n} WiSi \qquad (1)$$

Where: $LS$ =land suitability (%);

$Wi$=weight of land suitability criteria

$Si$=score of sub -criteria

$n$=number of land suitability classes

## 3 Results and discussion

### 3.1 Results

3.1.1 Weights of criteria and scores of sub-criteria

The pairwise comparisons are shown so that the value of 9 indicates (Cengiz and Akbulak, 2009). That the line is relatively more important than the column, (Malczewski, 2004; Saaty, 1977, 1980) while the value of 1-9 shows that the line has significantly less importance than the column Table 3. The results indicated that the consistency ratio (CR) was 0.085. The ratio of consistency ratio being equal to or less than 0.10, this value was good.

**Table 3 Comparison of the importance of the criteria used for lower Prachinburi watershed development**

| Criteria | SO | SLP | LU | DR | RF | Level of weight score |
|---|---|---|---|---|---|---|
| **SO** | 1 | 3 | 6 | 4 | 3 | 0.480 |
| **SLP** | 1/3 | 1 | 1 | 1 | 2 | 0.129 |
| **LU** | 1/6 | 1/1 | 1 | 5 | 3 | 0.207 |
| **DR** | 1/4 | 1 | 1/5 | 1 | 4 | 0.117 |
| **RF** | 1/3 | 1/2 | 1/3 | 1/4 | 1 | 0.067 |

Note: SO: soil order; SLP: slope; LU: land use; DR: distance from stream; RF: rainfall. Max eigenvalue ($\varphi$max)=5.38; n = 5; consistency index (Ci) = ($\varphi$max-n)(n-1) = 0.095; consistency ratio (CR) =0.085

The scoring of each sub-criteria is shown in Table 4. When evaluating soil order, a score of 10 was given to Oxcisoil, which most soils are clay, have good soil texture, physical properties and fertility. A score of 8 was given to Vertisoil which have high pH so that they have sufficiently high nutrient availability. A score of 6 was given to Spodosoil which most soils are sand, poor water holding capacity and fertility. While a score of 4 was given to Entisoils which are original soil, and no development of soil layers (Soil Conservation Service [SCS], 2004).

The lower Prachinburi watershed, the more desirable are lowlands for agriculture and most suitable for the cultivation of various crops such rice field; thus, given to a high score. The heightland are less suitability for many crops; so, low score was given. Slopes are very effective for agriculture. The flat land has low erosion processing was given to score of 10. The slope direction is associated with several properties, including exposure to sunlight, drying winds, and rainfall, which determine the different levels of suitability for agriculture.

The land use/land cover, the actual agriculture land and rice field was given to highest score. The prohibited for land use/land cover such as the Water body and residential area was given to score of 0. The higher scores to lands that were imminent to the road, as agricultural production transport.

In terms of rainfall, a higher score was given to high intensity rainfall due to its implication for water sufficiency for agriculture. In this lower Prachinburi watershed, the whole climate range remained suitable for agriculture; therefore, no extreme scores were given, because of either too high or too low rainfall intensity.

**Table 4 Score of the subcriteria in lower Prachinburi watershed, Eastern Thailand.**

| Parameter | Criteria | Sub-criteria | Score | Weight |
|---|---|---|---|---|
| **Land** | Soil order | Oxisols | 10 | 0.480 |
| | | Vertisols | 8 | |
| | | Spodosols | 6 | |
| | | Entisols | 4 | |
| **Topography** | Slope | 0-200 | 10 | 0.129 |
| | | 200-400 | 8 | |
| | | 400-600 | 6 | |
| | | >600 | 4 | |
| **Ease of management** | Land use/Land cover | Agricultural land /rice field | 10 | 0.207 |
| | | Dry land | 8 | |
| | | Forest | 6 | |
| | | Water body/residential area | 4 | |
| | Distance from stream (km) | Less than 1-2 | 10 | 0.117 |
| | | 2-3 | 8 | |
| | | 3-4 | 6 | |
| | | 4–more than 5 | 4 | |
| **Climate** | Rainfall ($mm.year^{-1}$) | 1800-more than 2000 | 10 | 0.067 |
| | | 1500-1800 | 8 | |
| | | 1200-1500 | 6 | |
| | | Less than 1000-1200 | 4 | |
| | | Total | | 1.000 |

3.1.2 Land suitability in lower Prachinburi watershed area

Regarding the five criterias: land use, soil type, area slope, stream distance, and an amount of rainfall, it is found that the land use development area has a moderate level of the development.

( Liu et al., 2007) However, the most appropriate area for the development (S1) covers an area of 122,092.33 hectares or 22.07 percent of the total area. A moderately appropriate area (S2) covers an area of 299,612.63 hectares (54.15%); a lowly appropriate area (S3) covers an area of 56,755.69 hectares (10.25%); and an appropriate area covers an area of 74,805.25 hectares (13.52%) as shown in Table 5 and Figure 4.

**Table 5 Land suitability for agricultural in lower Prachinburi watershed.**

| Level of appropriateness | Area | |
|---|---|---|
| | Hectare | Percent |
| **Highly appropriate (S1)** | 122,092.33 | 22.07 |
| **Moderately appropriate (S2)** | 299,612.63 | 54.15 |
| **Lowly appropriate (S3)** | 56,755.69 | 10.25 |
| **Inappropriate (N)** | 74,805.24 | 13.52 |

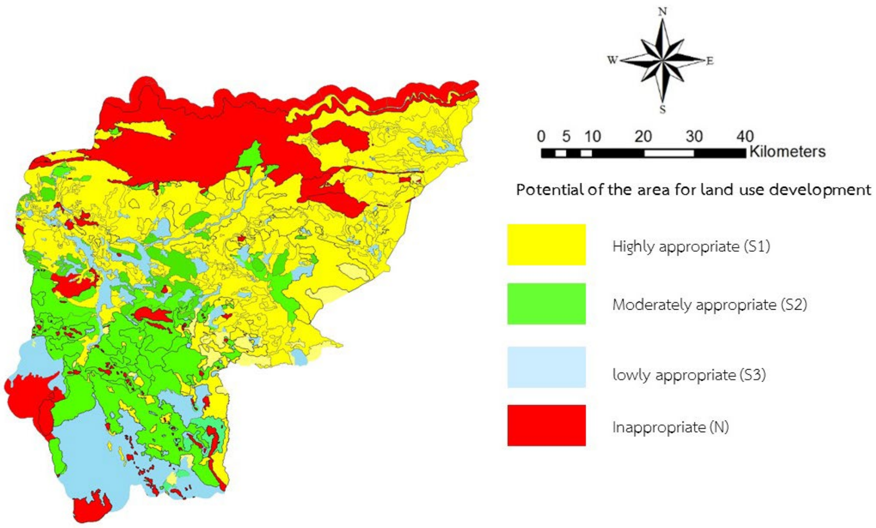



Figure 4 Land suitability for agricultural in lower Prachinburi watershed

Regarding a guideline for land use development Table 6. It is found that most of the area is suitable for growing field crops such as cassava 334,380.75 hectares, followed by growing rice 143,880.56 hectares, growing vegetables and tobacco 33,562.11 hectares, and the rest in not suitable for farming 57,634.50 hectares or 58.51%, 25.17%, 6.04%, and 10.25%, respectively.

**Table 6 The area suitable for farming**

| Level of appropriateness | Area | |
|---|---|---|
| | Hectare | Percent |
| **Highly appropriate (S1)** | 334,380.75 | 58.51 |
| **Moderately appropriate (S2)** | 143,880.56 | 25.17 |
| **Lowly appropriate (S3)** | 33,562.11 | 6.04 |
| **Inappropriate (N)** | 57,634.50 | 10.25 |

## 3.2 Discussion

The results of the assay show that the unsuitable are corresponding with high slopes falling under land suitability for agriculture. Results which indicate the high percentage of suitable land for agriculture in the lower Prachinburi watershed confirm the known fact that the study area has fertile soil (Mohr et al., 1972). The results of the analysis showed that the area which is suitable and available for agriculture remains 28.4%. Regarding the analysis results in this study, it can be stated that the suitable lands which are available for agriculture are moderately appropriate.

There are some limitations to the plausibility of this assay, which should be noted. Firstly, from the methodology, the suitability analysis depended on the AHP result, which is highly dependent on experts' opinions. The second limitation to the validity of this suitability analysis lies on how the parameter and criteria are viewed upon.

However, there were many other aspects which should also be considered, such as land availability and social aspects. One of the obstacles to integrate more social aspects of this type of study is the difficulty in which to integrate social aspects into spatial representation. Consequently, other aspects that are not explored during this study should be considered in further.

## 4 Conclusions

The assay in this study shows the land suitability for agriculture in lower Prachinburi watershed, east Thailand. Using GIS and AHP method, for comparing criterion importance and development factor in the watershed area, a pairwise comparison matrix. This was in accordance with the fixed criteria based on hierarchy. Because of this, it was easy to analyze for finding an appropriate alternative with efficiency. Hence, it was suitable to be used for selecting for the area. Land suitability analysis was proceeded by means of integration the main important parameters for agriculture, which include soil order, slope, land use and land cover, distance to the road and amount of rainfall. The most important parameter was the soil order having 48% of weight value, followed by land use in the area having 20.7% weight value, slope having 12.9% of weight value, the distance between the river having 11.7% of weight value, and amount of rainfall having 6.7% of weight value, respectively. Besides, it was found that y max value was 5.98 and CR value was 0.18. According to the AHP, it was found to be reliable at a high level. The results of this analysis show the importance for the appropriation of land to anticipate the suitability land for agriculture in the area with a population increase, as well as the development of political policy in support of agricultural development.

## Acknowledgement

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