# AGRICULTURAL LAND USE PLANNING IN KHON KAEN PROVINCE: GIS APPLICATION

PAIBOONSAK S.
Fac. of Agriculture
Khon Kaen University
Khon Kaen Province
Thailand
Email: sathaprn@kku.ac.th

MONGKOLSAWAT C.
Computer Centre
Khon Kaen University
Khon Kaen Province
Thailand
Email: charat@kku.ac.th

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## ABSTRACT

The objectives of this study were to create spatial information on the suitability of land for economic crops and for agricultural land use planning. The study area, Khon Kaen Province, covers an area of about 10,886 sq km. Three groups of economic crops in the area are paddy rice, field crops (sugarcane and cassava) and tree crops (mango and rubber). The suitability assessment of land for each crop was conducted, based on the climatic, soil and topographic qualities. For each crop, land unit is created from an overlay process of the defined quality layers on which the suitability is based. As a result, suitability map layers with their associated class attributes for rice, sugarcane, cassava, mango and rubber trees were obtained. Furthermore, the overlay process was then performed on these suitability map layers with selection criteria of only highly and moderately suitable class. The resultant map is a unit of combination of the defined suitability class of combining crops and plants within the provincial areas. Finally the planning unit could be formulated and based on the combination of the suitability land for a number of economic crops. Economically the planning alternative that best matches land use to land suitability should therefore be the most valuable and efficient.

## 1. RATIONALE

Land requirement for country development tends to increase since land is a basic factor necessary for production process both in and outside of the agricultural sector. Land is a limited factor. Consequently, the area expansion of an activity often affects another and has a relatively serious competition in terms of needs to acquire a land without any considerations or evaluations of land potentials whether it is suitable for the needed activity or not. As a result, land miuse to scatter everywhere. The Department of Land Development (LDD) whose responsibility is taking care of land use for agricultural purposes, always realize the problems arisen. Therefore, land use plans in the national, regional, provincial, and village levels are conducted (LDD, 1993). However, land use plan that has been made before is not applicable in some situations since it is not updated, especially information concerning land requirement for agricultural purpose due to the fact that most farmers tend to grow crops in response to market price. Conducting an achievable land use plan requires updated information much enough to support the plan making. Therefore, land use planning is mainly a process of analysis or evaluation to find the area most suitable to or potential for a defined activity. To do this, it is necessary to examine the relationship between land information, land use, and economic aspects to match the land requirement (LDD, 1993). The mentioned information is processed from sets of information in the area and such information is complex or varied according to the area. It takes quite a long time to make a plan. Thus, land use plan creation can hardly respond to the changing situations. Nowadays, computer technology either hardware or software is more efficient. Many systems have been developed, including Geographic Information System or

GIS. It is capable of systemically storing and analyzing either spatial data or non-spatial data of a great amount. Furthermore, GIS is flexible and lets the operators create models of a situation they need. Therefore, applying GIS in land evaluation to provide fundamental information supporting in decision making on land use plan seems to be able to reduce problems caused by improper land use mentioned above. The objective of this study was to create spatial information on the suitability of land for economic crops and for agricultural land use planning

## 2. STUDY AREA

The study area is Khon Kaen, a province in the Northeast, and locate between latitude 15° 40′ to 17° 5′ N and longitude 101° 45′ to 103° 10′ E (Fig. 1). It covers a total area of 10,886 sq km. (Office of National Statistic, 2000). Average rainfall varies from 1,000 - 1,500 m.m. The rainfall is unevenly distributed during the rainy season (May to October) with over 80% occuring during August and September. Physiographically, the gently undulating areas were found in the northern and western part of study area, central and soutern part were low land to floodplain belong to main river. Main economic crops include rice, sugarcane, and cassava.

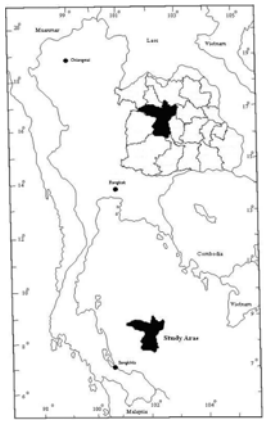


**Figure 1.** Study area

## 3. LITERATURE REVIEW

Land evaluation is a process of potential evaluation between land quality and land requirement. Typically, result of the evaluation is in form of Land Suitability Map. Land evaluation is a process of great importance for land use planning (FAO, 1993). Mongkolsawat et al. (1997) applies GIS in the assessment of the suitability of land for rice growing in the lower area of Pong River by creating spatial database, storing factors needed for the evaluation, and applying the overlay method for an analysis. Both Kuppatawuttinan (1998) and Charuppat (2002) create spatial models in place of suitability assessment. Duc (2002) suggests that land evaluation and land use planning should make use of GIS as an analysis tool due to the fact that GIS can store information in a form of databases ready to be used to make a decision on planning. The outcomes are reliable and reduce time and cost comparing to the manual method (Bera et al., 2003).

## 4. METHODOLOGY

The methodology comprised 4 main stages as shown in Figure 2 which include:

4.1 Stratification of study area, this stage was to devide area into 2 parts which were (1) agricultural land and (2) non-agricultural land.

4.2 Land Suitability, agricultural land was to evaluate for each economic crop (rice, sugarcane, cassava, mango, rubber). The FAO Land Evaluation (FAO, 1983) was employed in this study. For each crop, land units resulting from the overlay process of the selected factor layers were established. Factors used in land suitability were collected based on affecting growth and yield of each crop as Table 1. Each factor is a thematic layer in the GIS. The evaluation process comprised 6 steps which include:

1) Suitability based on climate, the factor used to evaluate was only the average annual rainfall.

2) Suitability base on soil, the factor used to evaluated comprised of 7 factors which include (1)Drainage capacity (DRN, it is a layer name) (2)Soil depth (DPT) (3)Soil texture (TXT) (4)Cation exchange capacity(CEC) (5)Base saturation(BS) (6)Available

Phosphorus(P) (7) Organic matter(OM). If land evaluation for paddy rice will add soil reaction(pH) factor.

3) Evaluation of land suitability based on topography, two factors were used which included: (1)Landform (LF) and (2)Slope(SP).

4) Evaluation of land suitability based on area, this process used resulting layers of suitability based on climate, soil and topography to overlay together.

5) Land suitability for sugarcane production, three factors were used which include: (1) Resulting layer of evaluation of land suitability based on area (2)Irrigation information layer and (3)Soil salinity information layer.

4.3 Establishment of spatial database base on land suitability for each crop production, this process is creating spatial database to support land use planning. All land suitability layers were overlaid together and kept in new layer.

4.4 Creating land use plan, the spatial database was supported to create two provincial land use plan which based on land potential by selecting high and moderate suitability for economic crops and crops' prices.

## 5. RESULTS

### 5.1 An evaluation of land suitability for economic crops

The study area is divided into two portions: 1) non-agricultural land and 2) agricultural land, which cover 24.02 per cent and 75.98 per cent of the study area respectively (Table 7). The agricultural area is classified into levels of crop-growing suitability. The details of each crop are as follow:

**5.1.1 Rice:** agricultural area can be classified into various levels according to its suitability to grow rice. It is found that marginal suitable area is most found among the suitable group (Table 7). In the central part of the country, there is a large area of highly suitable area due to the fact that it is within Nongwai Irrigation area (Fig. 3a).

**5.1.2 Sugarcane:** moderately suitable areas are found the most among the suitable group (Table 7). Highly suitable areas are generally found over the study area, but can be found more in the northern part of the study area than other parts (Fig. 3b).

**5.1.3 Cassava:** among the suitable group, it is found that the marginal suitable areas are found the most (Table 7). Considering the whole agricultural area, unsuitable areas are found the most. The highly suitable areas are mostly found within Nongwai irrigation area (Fig. 3c).

**5.1.4 Mango:** highly suitable areas are found most in the study area (Table 7). Moderately suitable areas are found in small land of long ranges scattering over the study area as shown in Figure 3d.

**5.1.5 Rubber:** regarding agricultural area, unsuitable areas are the most found. Then, there are marginal suitable areas, moderately suitable areas, and highly suitable areas (Table 7). Most of the marginal suitable areas are found in large area over the southern and southeastern parts of the study area as shown in Figure 3e.

### 5.2 Land use planning

**5.2.1 Land use planning based on land suitability:** only highly suitable areas (S1) and moderately suitable areas (S2) for crop growing are selected and arranged newly map unit as in Table 8 and shown in Figure 4. Five land use plan were created from this map which include 1)Land use plan for irrigation area, 2)Land use plan for rainfed area, 3)Land use plan for forest, 4)Land use plan for urban or build-up area and 5)Land use plan for freshwater animals culture and water source. It is found that the plan of land use for rainfed area is the highest total approximately about 60.60 per cent of the study area.

**5.2.2 Land use planning based on product-price of crops:** Table 8 shows the land suitability in the high and moderate levels of each crop made up into map unit. When replacing with value or amount of money from selling crop products, it is found that mango growing offers highest value. Besides, this crop can be grown in an approximate area of 38.20 per cent of the provincial area. The second highest to lowest values of crops are rice, sugarcane, and rubber. They can be grown in approximate areas of 16.73, 8.16, and 0.56 per cent of the provincial area respectively.

## 7. CONCLUSIONS

The overlay technics makes it possible to find the answer conveniently and quickly for the wide area with many related factors. However, spatial model has to be made in place of the study, especially in the evaluation of land suitability, in order that various factors have a clear consequence of analysis and can easily be checked for results. The evaluation process is very important due to the fact that it is a continuous process in conducting information that supports provincial land use planning. Land use plan construction using supportive information from the prepared databases is quick and convenient since the planner can easily define or selected the target area. Besides, various layers can conveniently be used in support of plan making.

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**Table 1** Illustration of the rating of land-use requirements: Rice, Sugarcane, Cassava, Mango, Rubber

| Factors used in land suitability clssification | Unit | Rice | | | | | Sugarcane | | | | | Cassava | | | | | Mango | | | | | Rubber | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Factor Rating [1] | | | | Source [5] | Factor Rating [1] | | | | Source [5] | Factor Rating [1] | | | | Source [5] | Factor Rating [1] | | | | Source [5] | Factor Rating [1] | | | | Source [5] |
| | | S1=10 | S2=8 | S3=4 | N=1 | | S1=10 | S2=8 | S3=4 | N=1 | | S1=10 | S2=8 | S3=4 | N=1 | | S1=10 | S2=8 | S3=4 | N=1 | | S1=10 | S2=8 | S3=4 | N=1 | |
| Rainfall of the growing period | mm. | >1,500 | 1100-1500 | 800-1100 | <800 | 1 | 1600-2500 | 1200-1600 | 900-1200 | <900 | 3,4 | 1200-2500 | 1500-2500<br>900-1200 | 2500-4000<br>500-900 | >4000<br><500 | 2,3,4 | 1200-1800 | 1800-2000<br>1000-1200 | >2000<br>800-1000 | <800 | 3,4 | 1500-2500 | 1200-1500 | 110-1200 | <1100 | 3,4 |
| Irrigation area | | In | Out | | | 1 | In | Out | | | 3 | In | Out | | | 3 | In | Out | | | 3 | In | Out | | | 3 |
| Soil drainage [2] | class | 1,2 | 3 | 4 | 5,6 | 2,3,4 | 5,6 | 4 | 3 | 1, 2 | 3,4 | 5,6 | 4 | 3 | 1, 2 | 3,4 | 5,6 | 4 | 3 | 1, 2 | 3,4,6 | 5,6 | 4 | 3 | 1, 2 | 3,4 |
| Effective soil depth | cm. | >50 | 25-50 | 15-25 | <15 | 2, 3, 5 | >100 | 50-100 | 25-50 | <25 | 3,4,6 | >100 | 50-100 | 25-50 | <25 | 3,4,6 | >150 | 100-150 | 50-100 | <50 | 3,4,6 | >150 | 100-150 | 50-100 | <50 | 3,4,6 |
| Soil texture [3] | - | K,J,B,O | G,D,A,C | F,H | L,M,N | 6 | G,A,D,C,E | B,F | J,H | K-O | 2,3,6 | A-G | H | J | K-O | 2,3,6 | A-J | H | L | K,M-O | 3,6 | A-E,J | F | H | G,K-O | 2,3,6 |
| Cation exchange capacity (C.E.C) | meq/ 100g | >15 | 5-15 | <5 | | 1,2,3,4 | >15 | 5-15 | <5 | | 3,4 | >10 | <10 | | | 3,4 | >15 | 5-15 | <15 | | 3,4 | >10 | 3-10 | <3 | | 3,4 |
| Base saturation (B.S.) | % | >50 | 35-50 | <35 | | 1,2,3,4 | >75 | 35-75 | <35 | | 4 | >35 | <35 | | | 3,4 | >35 | <35 | | | 3,4 | >35 | <35 | | | 3,4 |
| Available phosporus | ppm | > 25 | 10-25 | <10 | | 1,2 | >25 | 6-25 | <6 | - | 2 | >25 | 6-25 | <6 | - | 2 | >3 | <3 | - | - | 3 | >15 | 10-15 | 3-10 | <3 | 3,4 |
| Organic matter (O.M) | % | >3 | 1-3 | < 1 | | 4 | | | | | | | | | | | | | | | | | | | | |
| Salinity potential [4] | class | 5,6,7 | 4,3 | 2 | 1 | 3,4 | 5,6,7 | 4,3 | 2 | 1 | 3,4 | 5,6,7 | 4,3 | 2 | 1 | 3,4 | 5,6,7 | 4,3 | 2 | 1 | 3,4 | 5,6,7 | 4,3 | 2 | 1 | 3,4 |
| Landform | class | See Table 2 | | | | 2,3 | See Table 3 | | | | | See Table 3 | | | | | See Table 4 | | | | 2,3 | See Table 5 | | | | 3 |
| Slope | % | | | | | | | | | | | | | | | | | | | | | | | | | |

Remark (1) Factor Rating: S1= Highly suitable, S2 = Moderately suitable, S3 = Marginally suitable, N = Not suitable
(2) Soil drainage class: 1 = Very poorly drained, 2 = Poorly drained, 3 = Somewhate poorly drained, 4 = Moderately well drained, 5 = Well drained, 6 = Somewhat excessively drained, 7 = Excessively drained.
(3) Soil texture: A = Loam, B = Silty clay loam, C = Silty loam, D = Sandy clay loam, E = Clay loam, F = Sandy loam, G = Clay (%clay <60), H = Loamy sand, I = Sandy clay, J = Silty clay, K = Clay(%clay>60), L = Sand, M = Gravel soil, N = Slope complex, O = Alluvial complex
(4) Salinity potential: 1 = Very Highly affected by salt, 2 = Highly affected by salt, 3 = Moderately affected by salt, 4 = Slightly affected by salt, 6 = Not affected by salt, 7 = Hill area
(5) Source 1 = Mongkolsawat(1997), 2 = Kuppatawuttinan(1998), 3 = Charuppat(2002), 4 = LDD(1992), 5 = Thavone(1999) 6 = Sys et al(1993)

**Table 2** Relationship between landform and slope for rice growing

| | | Landform* | | | | | |
|---|---|---|---|---|---|---|---|
| | | FP | LT | MT | HT | FS&ES | M |
| Slope (%) | 0-2 | S1 | S1 | S3 | N | S2 | N |
| | 2-5 | S2 | S2 | N | N | N | N |
| | >5 | N | N | N | N | N | N |

**Remark** * FP = Flood Plain, LT = Low Terrace, MT = Middle Terrace, HT = High Terrace FS&ES = Foot Slope&Erosion Surface, M = Mountain
**Source** Modified from Charuppat(2004) and Kuppatawuttinan(1998)

**Table 3** Relationship between landform and slope for sugarcane and cassava growing

| | | Landform* | | | | | |
|---|---|---|---|---|---|---|---|
| | | FP | LT | MT | HT | FS&ES | M |
| Slope (%) | 0-2 | N | S2 | S1 | S2 | S1 | N |
| | 2-5 | N | S1 | S2 | S3 | S2 | N |
| | 5-12 | N | S3 | S3 | N | N | N |
| | 12-20 | N | N | N | N | N | N |
| | >20 | N | N | N | N | N | N |

**Source** Modified from Charuppat(2004) and Kuppatawuttinan(1998)

**Table 4** Relationship between landform and slope for mango growing

| | | Landform* | | | | | |
|---|---|---|---|---|---|---|---|
| | | FP | LT | MT | HT | FS&ES | M |
| Slope (%) | 0-2 | N | N | S1 | S1 | S1 | N |
| | 2-5 | N | S2 | S2 | S2 | S2 | N |
| | 5-12 | N | S2 | S2 | S2 | S2 | N |
| | 12-20 | N | S3 | S3 | S3 | S3 | N |
| | 20-35 | N | S3 | S3 | S3 | S3 | N |
| | >35 | N | N | N | N | N | N |

**Source** Modified from Charuppat(2004) and Kuppatawuttinan(1998)

**Table 5** Relationship between landform and slope for rubber growing

| | | Landform* | | | | | |
|---|---|---|---|---|---|---|---|
| | | FP | LT | MT | HT | FS&ES | M |
| Slope (%) | 0-2 | N | N | S1 | S1 | S1 | N |
| | 2-5 | N | S3 | S2 | S2 | S2 | N |
| | 5-12 | N | S2 | S2 | S2 | S2 | N |
| | 12-20 | N | S3 | S3 | S3 | S3 | N |
| | 20-35 | N | S3 | S3 | S3 | S3 | N |
| | >35 | N | N | N | N | N | N |

**Table 6** Suitability class considering the relationship between data in SOLCHM and SOLPHY layer

| | | SOLCHM | | | |
|---|---|---|---|---|---|
| | | *S1* | *S2* | *S3* | *N* |
| SOLPHY | *S1* | **S1** | **S1** | **S2** | **N** |
| | *S2* | **S2** | **S2** | **S3** | **N** |
| | *S3* | **S2** | **S3** | **S3** | **N** |
| | *N* | **N** | **N** | **N** | **N** |

**Table 7** The total areas in each suitability class of each crop

| Suitability class | Area(%)* | | | | |
|---|---|---|---|---|---|
| | Rice | Sugarcane | Cassava | Mango | Rubber |
| Agricultural land | 75.98 | 75.98 | 75.98 | 75.98 | 75.98 |
| *Highly suitable* | *5.79* | *9.43* | *0.42* | *26.35* | *0.50* |
| *Moderately suitable* | *16.01* | *24.91* | *5.04* | *14.01* | *7.73* |
| *Marginal suitable* | *17.93* | *6.55* | *33.78* | *0.71* | *13.75* |
| *Not suitable* | *36.27* | *35.10* | *36.74* | *34.91* | *54.01* |
| Non-agricultural land | 24.02 | 24.02 | 24.02 | 24.02 | 24.02 |
| Total area | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

**Remark** * Total area about 10,886 sq. km.

Table 8: the area of map unit in each land use plan

| Map unit | Land suitability | Area (%) |
|---|---|---|
| Irrigation area land use plan | | |
| 1 | Highly suitable area (S1) for rice farming | 2.40 |
| 2 | Highly suitable area (S1) for field crops (sugarcane and cassava) | 0.26 |
| 3 | Highly suitable area (S1) for fruit crop (mango) | 0.01 |
| 4 | Highly suitable area (S1) for field and fruit crops | 0.38 |
| 5 | Highly suitable area (S1) for field, fruit, and tree crops (rubber) | 0.01 |
| Non-irrigation area land use plan | | |
| 6 | Highly suitable area (S1) for rice farming | 3.12 |
| 7 | Highly suitable area (S1) for field crops | 0.27 |
| 8 | Highly suitable area (S1) for fruit crops | 17.25 |
| 9 | Highly suitable area (S1) for field and fruit crop | 7.96 |
| 10 | Highly suitable area (S1) for fruit and tree crops | 0.11 |
| 11 | Highly suitable area (S1) for field, fruit, and tree crops | 0.13 |
| 12 | Moderately suitable area (S2) for rice farming | 11.21 |
| 13 | Moderately suitable area (S2) for field crops | 4.92 |
| 14 | Moderately suitable area (S2) for fruit crops | 7.75 |
| 15 | Moderately suitable area (S2) for rice and field crops | 2.71 |
| 16 | Moderately suitable area (S2) for rice and fruit crops | 0.20 |
| 17 | Moderately suitable area (S2) for field and fruit crops | 4.40 |
| 18 | Moderately suitable area (S2) for fruit and tree crops | 0.06 |
| 19 | Moderately suitable area (S2) for field, fruit, and tree crops | 0.50 |
| 20 | Other areas | 12.81 |
| Land use plan for forest | | |
| 21 | Reserved forest, watershed class 1, and slope complex land | 12.65 |
| Land use plan for residence, building, and community | | |
| 22 | Residential and town and city municipal areas | 5.95 |
| Land use plan for freshwater animals and water sources | | |
| 23 | Surface water sources (data recorded in 2002 from LANSAT) | 4.94 |
| **Total area** | | **100.00** |

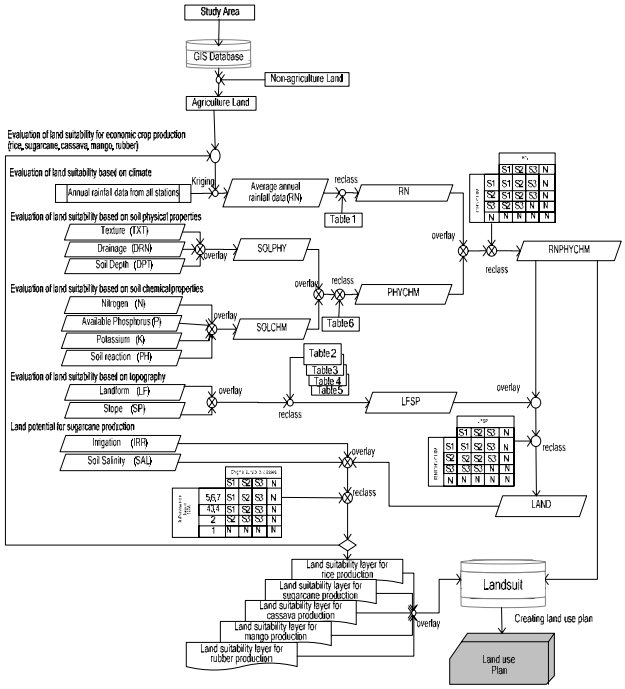


**Figure 2.** Step of the operation

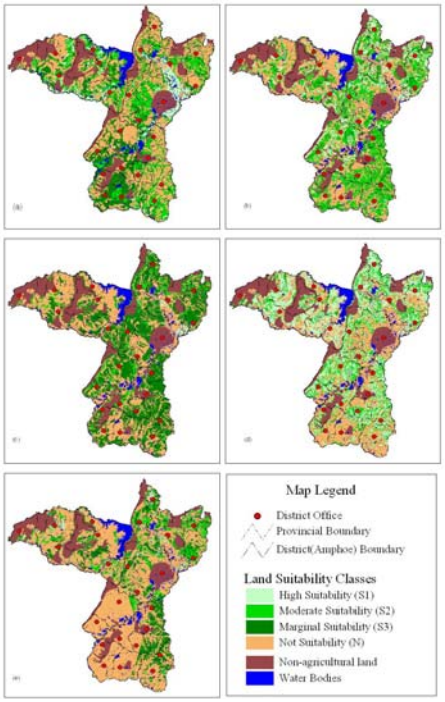


**Figure 3**. Land suitability map for rice(a), sugarcane(b), cassava(c), mango(d) and rubber(e)

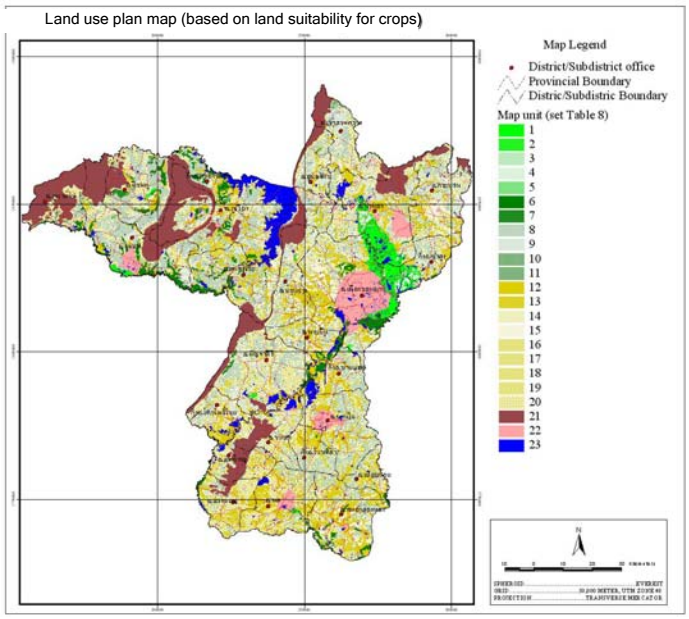


**Figure 4**. Land use plan map based on land suitability for crops