Land Suitability Evaluation using GIS-based Multi-Criteria Decision Making

for Bio-Fuel Crops Cultivation in Khon Kaen, Thailand

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Abstract

The effective Multi-criteria Decision Making (MCDM) has been adopted by this study. Several studies agreed that one of the understandable principles of the Analytical Hierarchy Process (AHP) MCDM can be able to work on multiple criteria analysis. It can deal with the data uncertainties among several criteria which is the strength point to be chosen for land suitability evaluation for biofuel crops cultivation in Khon Kaen, Thailand. Due to this study aims to allocate the scarcely land availability for the most suitable crops and turn into the higher beneficial incomes for farmers. Therefore, the sixteen criterion layers that related to the selected crop requirements were analysed using the GIS based approach. These include soil texture, soil reaction, soil drainage, soil depth, soil cat-ion exchange capacity (CEC), ground water, stream water, irrigation zone, slope, elevation, aspect, erosion, soil salinity, drought, rainfall and humidity. The results shown based on the objectives in different degrees. The suitable areas were extracted by matching the potential suitable areas with the existing land use dataset. It shown the total areas of land allocations by MCDM is as 71.86% and by individual crops in the three suitable classes that the rice areas should be preserved around 32.02% while the rest areas of around 24.34%, 10.87% and 4.63% were for sugarcane, oil palm and cassava respectively. While the results of total areas by FAO is 66.76% and provided the total areas by individual crops as around 28.94%, 25.92%, 8.35% and 3.52% for rice, sugarcane, oil palm and cassava respectively. The results can be simulated by multiplying the average cost and benefit values with the suitable areas to visualise the potential budgets and potential incomes for the decision makers.

Key words : Biofuel crops, land suitability evaluation, Analytical Hierarchy Process, Multi-criteria decision making

Rationale

1)The anticipation of the shortage of fossil fuel energy forces the government to create strategy plans for dealing with the anticipated results of increasing fuel demand as the industrial sector expands.

2)The alternative energy policies must take into consideration the effects of increasing population income and aim to harmonise the environmental systems.

3)Biofuel crops were considered to meet both purposes, leading topology guidelines encouraging farmers to cultivate cassava, sugarcane and oil palm as biofuel crops in the most suitable areas.

4)The problem is that oil palm is a newcomer plant for Khon Kaen province and research into its suitability for growing in this area is limited, but some groups of farmers are claiming to grow it on their lands in response to the higher market price than others local cash crops.

5)If the most effective principles on land evaluation and allocation are to be taken into account, then the AHP is one of the most effective evaluators. AHP can provide acceptable results based upon conditions specific to this province, and facilitate the communication of results to planners and farmers, unlike the vectorised analysis of the international FAO framework, which has many inherent limitations.

Aims and Objectives

Aims : The use of AHP MCDM to evaluate land suitability classes and to allocate the land for biofuel crops cultivation under the limited land use availability.

Objectives :

1) To evaluate land suitability using GIS based AHP MCDM analysis for the selected crops.

2) To evaluate and predict the individual expected crops production and their beneficial returning for farmers.

3) To study the different trends of the results between AHP MCDM raster approach and the tabular land evaluation by FAO framework.

Results

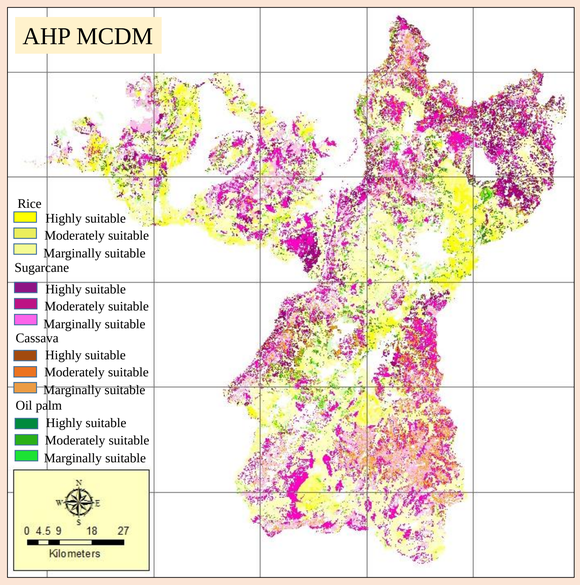


Figure 1. Land suitability evaluation for biofuel crops by AHP MCDM

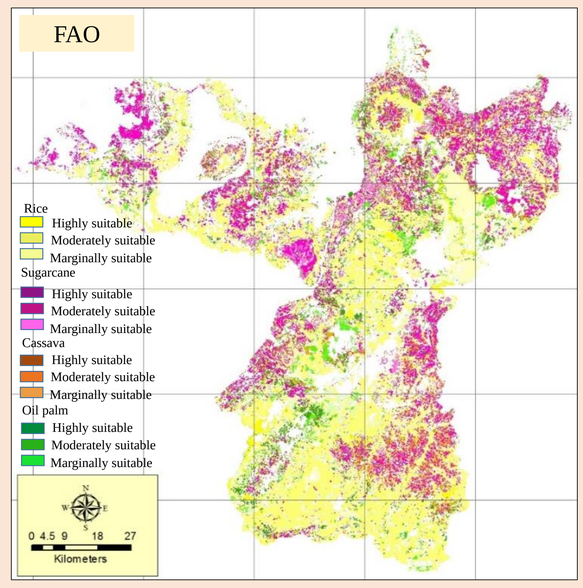
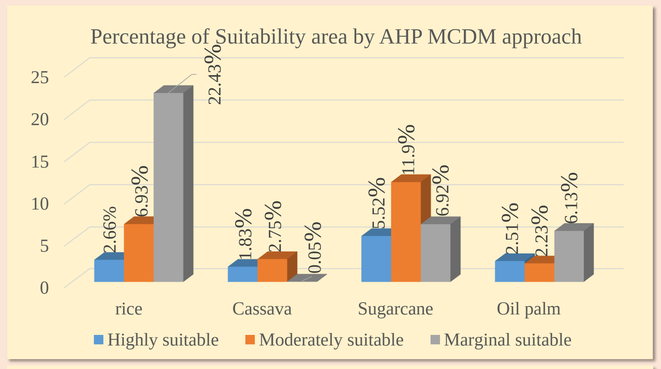
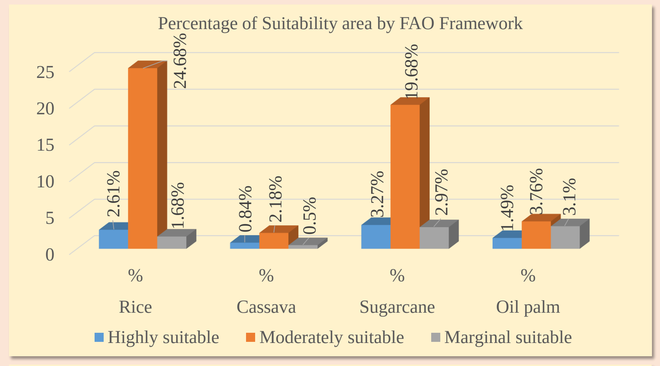
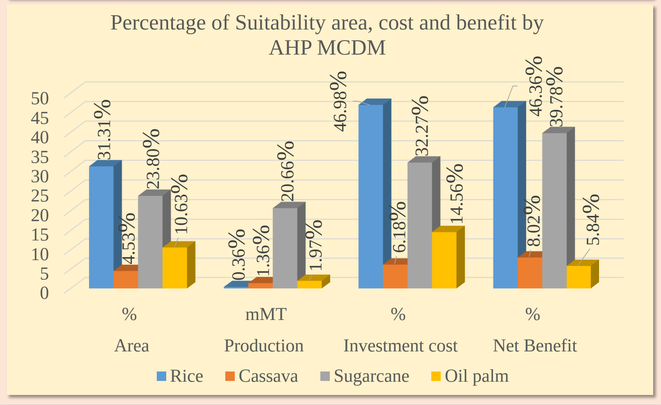
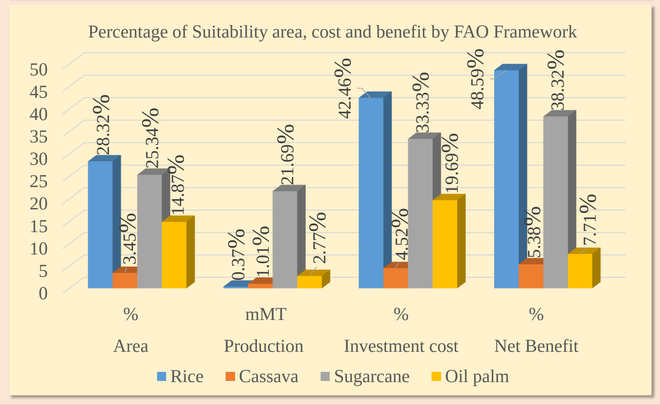


Figure 2. Land suitability evaluation for biofuel crops by FAO









Advantages and Limitations

Advantages

1) Allows to use several related criteria for analysis and can provide the more realistic and more effective results.

2) Cope with several criteria under the uncertainty states.

3) Simple and understandable method but provided the sensible results.

4) Not requires the expert users for performing process, the users can supply the related information from out sources.

5) In the GIS process, allows users to allocate the suitable areas among the several crop types to not overlapping each other

Limitations

1) Several criteria are usually come up with the uncertainty.

2) Consultation process can provide unacceptable results due to the different background knowledge of experts.

3) To prevent the unacceptable results on scoring process the users need to have the sufficiently supporting references.

4) Accuracy assessment cannot be achieved at the time just finished the evaluation.

5) There is no information support for determining break points among the suitable classes, therefore, this study used natural breaks in ArcGIS.

6) The quality of datasets cannot be controlled due to the various sources and scales.

Methodology

Working flowchart

Data Preparation Process

- **Vector datasets** → • Soil properties, ground water, stream water • Drought, irrigation, erosion, saline
- **Data conversion** → • **Raster** dataset of Soil properties, ground water, stream water, drought, irrigation, erosion, saline
- **Reclassify datasets** → • **Raster** dataset of Soil properties, ground water, stream water, drought, irrigation, erosion, saline
- **Points datasets** → • Points of Rainfall and Humidity
- **Interpolation (IDW)** → • **Raster** Rainfall, Humidity
- **Reclassify datasets** → • **Raster** Rainfall, Humidity
- **DEM dataset** → • Deriving elevation, aspect, slope
- **Reclassify datasets** → • Deriving elevation, aspect, slope

Land allocation Process

Crops	Conditional land used types
Rice	Rice, rice and horticulture
Cassava	Cassava, cassava and New Guinea labula, cassava and mangoes.
Sugarcane	Abandoned paddy, Sugarcane, sugarcane and cassava, New Guinea labula, New Guinea labula and mangoes.
Oil palm	Palm, eucalyptus, abandoned area, grassland, shrub, New Guinea labula and eucalyptus.

- **Scoring each data** → • The average scores of each criteria derived from consulting the team experts
- **Weighted sum Analysis** → • The weighted scores derived from pairwise comparison matrix of 16 criteria based on nine-point scale (Saaty, 1980) were multiplied to all sub-scores of all criteria
- **Potential suitability Results** (Con) → • Rice • Sugarcane • Cassava • Oil palm

Rice Class 1 - 3 N Sugarcane Class 1 - 3 N Cassava Class 1 - 3 N Oil palm Class 1 - 3 → **Results**

Land Suitability Evaluation

GIS based Model analysis

Discussions

The greatly different trends of the results were produced due to:

1) Different criteria and different based use between FAO vectorised analysis and MCDM – related criteria were applied .

2) Methodology used for evaluating – physically (MCDM) and ideally (FAO) layers overlaying.

3) Overestimated results can be affected the evaluation of productions, cost and benefit.

4) Both evaluators can not be assessed at the time just finished evaluation process.

Conclusions

AHP MCDM with the sixteen criteria provided the sensible results of suitability classes when comparing the number of cash crop areas to the present land use (lu2010). Moreover, it has advantages for predicting future production scenarios, simulating the total cost and net benefit, and visualising the results. The trends shown by the two approaches are similar, only the magnitudes differing. However, these results must be more reliable after processing the accuracy assessment. Therefore, future research in crop production should be conducted after completing the evaluation process.

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