ISSN 2320-2602

International Journal of Advances in Computer Science and Technology (IJACST), Vol.3 , No.1, Pages : 11-15 (2014)
Special Issue of ICACSET 2014 - Held during 13-14 January, 2014 in Royal Orchid Sheraton Hotel & Towers, Bangkok

Using Analytical Hierarchy Process for Selecting Intercrop in Rubber Field – A Case Study in Phitsanulok, THAILAND

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Abstract*:* Selecting the appropriate intercrop for the rubber field offers land usage with high efficiency. It can be great benefit during waiting for the rubber to grow. Analytical Hierarchy Process (AHP) is an effective Multi Criteria Decision Method (MCDM) which provides a rank of suitable intercrop. In this research, the application of AHP was implemented in Phitsanulok, a province in the lower north region of Thailand. Two information domains (geographic criteria and economic criteria) of this province were evaluated. The decision problem was structured into a four-level hierarchy using the AHP. The factors of the decision were arranged in hierarchical structures and the judgments were made by an expert. Moreover, pair-wise comparisons allowed for accurate subjective criteria weighting. The result showed the suitability of each intercrop.

Key words : MCDM, Intercrop, Rubber Field

INTRODUCTION

Rubber is an economic plant in Thailand. It is profitable to both import and export sectors. It takes about 8-10 years of planting the rubber tree before it can be harvested. During the time of rubber-planting, farmers can also grow the intercrop among those rubber trees. This will lead to increase the income from the product of intercrop, greater use of environmental resources, reduction of pest, diseases and weed damage, stability and uniformity yield and improve soil fertility and increase in nitrogen [1] - [3]. Beside from these advantages, the intercrop should be investigated in the nutrient need, size, weather and etc. Otherwise, planting the intercrop may lead some drawback to the rubber tree such as lack of nutrient, lack of water, etc. There are various factors that should be considered before selecting the intercrop. Analytical Hierarchy Process (AHP) is an effective method which can assist the farmer to select the suitable intercrop for their rubber field. In this paper, an overview of Multi Criteria Decision Making is presented. Then processes of AHP are described. Appling AHP to intercrop selection is revealed and, finally, conclusion.

OVERVIEW OF MULTI CRITERIA DECISION MAKING (MCDM)

Multi Criteria Decision Making is an approach which helps the decision maker for identifying and choosing alternatives based on the values and preferences of the decision makers [4]. It provides an effective framework for comparison based on the evaluation of multiple conflicting criteria. The steps of developing an MCDM application differ in the way of information on alternatives, performance, criteria and relative significance that is elicited, specified and analyzed. Step by step of MCDM process are described below:

1. Defining the problem and generate alternatives - clearly defining the problem, discerning the alternatives, identifying the actors, together with the constraints, the degree of uncertainty and the key issues.
2. Assigning criteria weights - weights will show the relative importance of criteria in the multi-criteria problem under consideration. It can be determined by techniques such as Analytical Hierarchy Process and etc.
3. Construction of the evaluation matrix - built up the constitution a process.
4. Selecting the appropriate methods - a multi criteria method must be selected. Then applied it to the problem under consideration in order to rank alternatives. The data and the degree of uncertainty are the key factors for the decision maker when selecting among several multi criteria methods.
5. Ranking the alternatives - the best ranked alternative is proposed as a solution.

There are two general types of MCDM problem: a problem with a finite number of alternatives and a problem with an infinite number of alternatives [5]. Some of MCDM techniques are shown below [4], [6], [7].

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Table 1: Example of MCDM techniques

MCDM techniques	**Type of information required on values of decision makers**
Dominance	No explicit value judgements required
Maximin and minimax	Value judgement concerning the levels of risk particularly toward negative
Maximax	Value judgement concerning the levels of risk particularly toward positive
Conjunctive or disjunctive	Value judgments about the importance of needs to satisfy those needs
Lexicographic or elimination by aspect	Comparative value judgements on importance of attribute of alternatives acceptability. Elimination requires the judgement of only acceptability
Weighting or scaling	Comparative value judgments about the importance of attributes with weights assigned.
Mathematical programming models	Value judgments about the importance of an over-all objective and the development of weights proportional to the relative value of unit changes in the value function.

ANALYTICAL HIERARCHY PROCESS (AHP)

Analytical Hierarchy Process is an effective method which is used weighting and scaling techniques. It derives ratio scale from paired comparisons. Input can be both quantitative (e.g. salary, number of furniture) and quality (e.g. opinion, preferences) [8]. The step of AHP Process is shown as following [8] - [11]:

1. Decompose the decision problem into a hierarchy with a goal on top, factor, sub factor and finally, decision alternative at the bottom.

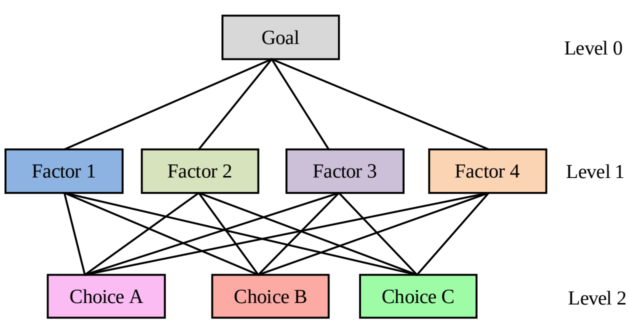

Fig.1 : Decision Hierarchy

Level 0 is the goal of the analysis. Level 1 is multi-criteria that consist of several factors. It can be more level of sub criteria and sub-sub criteria. The last level is the alternative choices.

2. According to the Saaty's nine point scale (Table 2), paired comparisons are operated and write down in a format of a decision matrix. The matrix involves the assessments of each alternative in respect to the decision criteria. If the decision making problem consists of n criteria and m alternatives; the decision matrix takes the form:

$$D = \begin{bmatrix} d_{11} & d_{12} & \Lambda & d_{1n} \\ d_{21} & d_{22} & \Lambda & d_{2n} \\ M & M & M & M \\ d_{m1} & d_{m2} & \Lambda & d_{mn} \end{bmatrix} \quad (1)$$

Table 2: Scale of preference between two parameters in AHP [8]

Scales	**Degree of preferences**	**Explanation**
1	Equally	Two activities contribute equally to the objective.
3	Moderately	Experience and judgment slightly to moderately favor one activity over another.
5	Strongly	Experience and judgment strongly or essentially favor one activity over another.
7	Very strongly	An activity is strongly favored over another and its dominance has shown in practice.
9	Extremely	The evidence of favoring one activity over another is of the highest degree possible of an affirmation.
2, 4, 6, 8	Intermediate values	Used to represent compromises between the preferences in weights 1, 3, 5, 7 and 9.
Reciprocals	Opposites	Used for inverse comparison.

The decision matrix is filled up by following rules:

- The diagonal elements of matrix are always ‘1’.
- Elements in the upper triangle matrix are the judgment value based on Table 2. If the judgment value is on the left side of 1, the value of element is actual judgment. On the other hand, it is the reciprocal value.

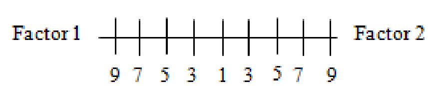

Fig. 2 : Scale of decision matrix [Adapted from 8]

- Elements in the lower uses the reciprocal values of the upper diagonal.

3. Compute Eigen value

The eigen values describes the relative weight of each factor. It can be obtained from following equation:

$$A \times W = \lambda_{\max} \times W \quad (2)$$

where A represents the pairwise comparison matrix (m×n) and λ_{max} is the highest eigen value. If there are elements at the higher levels of the hierarchy, the obtained weight vector is multiplied by the weight coefficients of the elements at the higher levels, until the top of the hierarchy is reached. The alternative with the highest weight coefficient value should be taken as the best alternative.

ISSN 2320-2602

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4. The inconsistency index for both the decision matrix and in pair-wise comparison matrices could be calculated from equations follow:

$$CR = \frac{CI}{RI} \quad (3)$$

$$CI = \frac{\lambda_{\max} - N}{N - 1} \quad (4)$$

The closer the inconsistency index is to zero, the greater the consistency. The consistency of the assessments is ensured if the equality $a_{ij} \cdot a_{jk} = a_{ik}$ holds for all criteria. The relevant index should be lower than 0.10. Then the result is accepted. If this is not the case, the decision-maker should revert to Step No.2 and redo the assessments and comparisons. An acceptable consistency ratio ensures that the priorities of a set of criteria are reliable. The Saaty's average random index based on matrix size is shown in Table 3.

Table 3: Average random index (RI) based on Matrix Size [8]

Size of Matrix (n)	Random Consistency Index (RI)
1	0
2	0
3	0.52
4	0.89
5	1.11
6	1.25
7	1.35
8	1.40
9	1.45
10	1.49

In addition, some of the previous successful researches which contain the similar characteristic of criteria concern the use of weight methods. For example, an advice system for growing the energy crop in Kanchanaburi Province [12] was implemented by using weight method. It provided a list of energy crops which are suitable for the particular area. 1976 FAO framework on crop plantation was applied as the criteria. Another example is zoning the conservative forest in Maha Sarakham Province. Criteria consist of both local ecology issues and public participant indicators. The divided zone has been successful organized without any conflict with the community [13]. Other examples can be found in reference [14] and [15].

In this study, the problem structure includes the number of criteria used and the number of alternatives to be selected in a decision-making problem. AHP uses a hierarchical structure by pairwise comparison this method can solve the selection problem. AHP shows a controlled consistency, unlike SAW and TOPSIS [16], [17]. In terms of the final result, AHP is suitable for small-scale data and reasonably simple like this problem.

APPLYING AHP TO INTERCROP SELECTION – A Case Study in Phitsanulok, THAILAND

The application of AHP for the rubber field is implemented in Phitsanulok, a province of Thailand. All spatial data and attribute data presented forward are based on the area of this province. The process of intercrop selection for the rubber field starts with the following procedure:

1. Information about rubber was gathered such as how to grow, nutrient need, grow up time and etc.
2. Information of the intercrop was collected such as physical information (e.g. nutrient need and water need) and economic information (e.g. selling rate).
3. The discussion of the above information with the experts has been arranged in order to get the most available information. Consequently, there are two main criteria (physical and economic). Each of them consists of several sub-criteria as shown in Fig. 3. Ten intercrops were selected as the alternatives in this study. They ere garlic, sugarcane, cassava, pineapple, coffee, shallot, papaya, maize, sweet corn and banana.
4. Goal was set up. It was the finding the suitable intercrop for the rubber field. The decision hierarchy is drawn (as shown in Fig. 3)

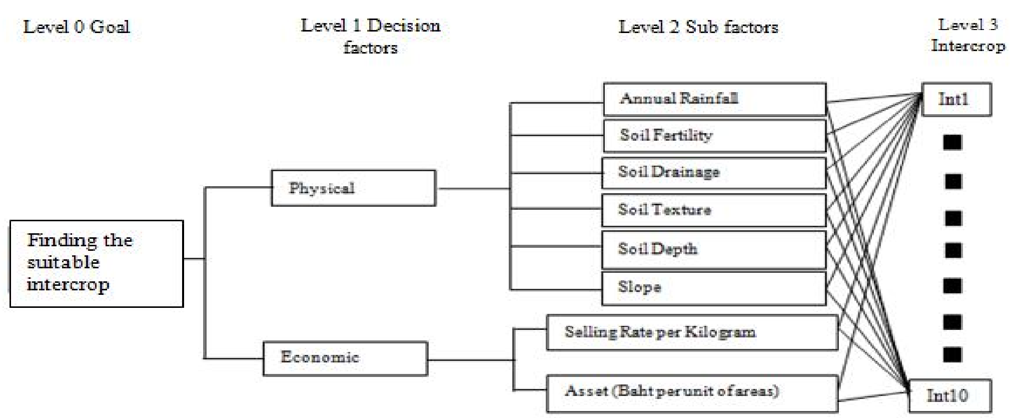

Fig. 3 Intercrop Selection Hierarchy

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5. The Eigen value was calculated by follow the step No. 2 until step No. 4 in the section AHP above. The Eigen values of physical factor are shown as Table 4. Also Table 5 is the Eigen values of economic factor.

Table 4: Eigen Value of Economic Factor

Factors	Selling Rate per Kilogram	Asset (Baht per unit of area)	Eigen Value
Selling Rate per Kilogram	1.0000	3.0000	0.7500
Asset (Baht per unit of area)	0.3333	1.0000	0.2500

6. Consistency values of the decision hierarchy of both physical and economic factors were calculated based on the previous CR formula. CR of physical factor is 0.0125 which mean that the weight is acceptable. In the case of CR of economic factor, it is certainly acceptable due to the decision matrix is 2x2 only. Hence, CR is less than 0.5.

7. Overall composite weight of the alternatives is shown in Table 6.

Table 6: Overall composite weight of the alternatives

Intercrop	Combined Weight
Garlic	0.9750
Sugarcane	0.9750
Cassava	0.9260
Banana	0.9257
Shallot	0.9071
Papaya	0.9071
Pineapple	0.8443
Maize	0.7781
Coffee	0.7568
Sweet corn	0.7531

Therefore, the appropriate intercrop for rubber field in Phitsanulok is listed on the Table 6.

Table 5: Eigen Value of Physical Factor

Factors	Annual Rainfall	Soil Fertility	Soil Drainage	Soil Texture	Soil Depth	Slope	Eigen Value
Annual Rainfall	0.49528	0.51659	0.52553	0.43654	0.48176	0.48176	0.48958
Soil Fertility	0.16509	0.17220	0.17553	0.21390	0.17550	0.16862	0.17847
Soil Drainage	0.09906	0.10311	0.10311	0.13096	0.11356	0.12044	0.11204
Soil Texture	0.09906	0.07028	0.07007	0.08731	0.09153	0.09153	0.08496
Soil Depth	0.07075	0.06753	0.06370	0.06564	0.06882	0.06882	0.06755
Slope	0.07075	0.07028	0.06006	0.06564	0.06882	0.06882	0.06740

CONCLUSION

This paper presents the application of AHP to intercrop selection in the rubber field. AHP processes were illustrated. The result shows the acceptable weight of each factor. Then, a rank of the most appropriate intercrop is revealed. However, the important factors in the rubber plantation that should be concerned is to have the appropriate space for growing intercrop. Further study of this research will be implemented via a web-based Geographic Information System (GIS). It will reveal this application online and more analysis in several approaches for land use. In addition, it can apply to another province by feeding all information required.

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ISSN 2320-2602

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