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Apicultural Site Zonation Using GIS and Multi-Criteria Decision Analysis

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ABSTRACT

This paper discusses the application of Geographical Information System (GIS) and Multi-Criteria Decision Analysis (MCDA) technology as a tool to aid decision-making in a case study to locate beekeeping zones in the state of Selangor. The combination of GIS capabilities with MCDM technique provides greater effectiveness and efficiency of decision making while solving spatial decision problems. In this research, land suitability analysis and zoning was carried out with respect to the bee's biotic needs and some other important factors in apiary management. Suitability weighting was determined using the pairwise comparison matrix of the Analytical Hierarchy Process (AHP) and suitability score using Weighted Overlay function in ArcGIS9. The overall consistency ratio value of AHP pairwise comparison was 0.01 which indicates a reasonable level of consistency in the deployment of the pairwise comparisons. The results of the analysis are presented and verified with actual data of the existing apiaries in Selangor. The integration of AHP model with GIS resulted in Non-Suitable, Most Suitable, Moderately Suitable and Suitable beezones. The total Non Suitable Areas (NS) was 34.73%, leaving the remainder as potential areas (65.27%). The remaining are the Most Suitable Areas (S1) 13.72 %, Suitable Areas (S2) of 27.24% and Moderately Suitable Areas of 24.32 %.

Keywords: Geographical Information Systems, Multi-Criteria Decision Analysis (MCDA), Analytical Hierarchy Process (AHP)

INTRODUCTION

Apiculture or beekeeping is a large area of study and application by itself. It is a huge field of agriculture and has been practised by man since the primitive age. The term apiculture as defined by Food and Agriculture Organization of the United Nations (FAO, 2003) is "the science and art of bees and beekeeping", which uses bees as micro-manipulators to harvest plant foods from environmental resources that would otherwise be wasted (FAO, 1986).

Beekeeping is an important component of agriculture and rural development programmes in many Asian countries. Honeybees are natives to the IndoMalaya region where diverse floral sources are available throughout the year. The role of beekeeping in providing nutritional, economic and ecological security to rural communities in Asia cannot be overlooked as it has always been linked with their cultural and natural heritage (Matsuka, 1998).

Bees play a key role in the functioning of agricultural ecosystems as pollinators of crops and flowers. Malaysian Ministry of Agriculture & Agro-Based Industry have started the *'Honeybee Project'* to encourage the honeybee industry in farm families as a main/side income, exploiting the existing resources of plantation. This honeybee industry is expanding and a profitable commercial industry and side income for farmers. The prospect to expand this industry is bright in Malaysia considering that the demand for bee products in Malaysia and worldwide has increased.

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This report demonstrates how GIS can play a role to aid decision-making in locating suitable zones for beekeeping. Land suitability analysis and zonation involve a multiple criteria analysis technique. In this research, land suitability analysis was carried out in respect of the bee's environment and modelled into GIS systems incorporated with Analytical Hierarchy Process (AHP) model for the analysis of the criteria weightage.

Historical Overview

The history of commercial beekeeping in Malaysia started since the establishment of Malaysian Beekeeping and Research and Development Team (MBRDT) in 1981 (IDRC, 1987). The team consists of several institutions namely Universiti Putra Malaysia (UPM), Universiti Malaya (UM), Malaysian Agricultural Research Development Institute (MARDI), Malaysian Industry Small-holders Development Authority (RISDA), Rubber Research Institute Malaysia (RRIM) and Department of Agriculture (DOA).

MBDRT was funded by IDRC (International Dutch Research Council) and the objective of MBRDT is to undertake research and extension activities in promoting modern beekeeping in Malaysia. Although it has been more than 20 years since the establishment of MBDRT, modern beekeeping in movable hives is still not prominent in Malaysia.

Types of bee plants and pollen which are favourable to honeybees have been identified in previous MBDRT research, but the location of the source has not been identified and there is no map for suitable beekeeping locations or zones created using Multi Criteria Decision Analysis (MCDA) and GIS (Geographical Information System) technology. Existing flowering calendars only provides time (month) of blooms but does not contain information such as location and specific time of blooms. Thus, time of the most nectar and pollen production is not known for commercial beekeeping.

The integration of beekeeping with other crop production has been practised in other countries and shown to yield high revenue. According to Akranatul (1987), productive beekeeping depends on good colony management and good beekeeping areas. In order to promote it as a profitable agricultural occupation, areas with a good potential for beekeeping must be located and evaluated.

GIS and MCDA for Land Suitability Analysis

GIS has long been used as a tool for developing alternative uses of agricultural land, precision farming, crop yield or land suitability mapping in determining the best alternatives for agricultural production. It is the capability of GIS for supporting decision making that is of particular importance for the landuse suitability mapping and modelling (Malczewski, 2004). The ability of GIS to integrate, display, and query many types of information at the same time makes it an important tool for decision support in agriculture. Perhaps the most useful tool of all in GIS is its ability to form overlay operations between layers especially in selecting or locating suitable area for agricultural purposes.

The terms Multi-Criteria Decision Making (MCDM) and Multi Criteria Decision Analysis (MCDA) are used interchangeably in referring to the multi-criteria evaluation (MCE) technique, usually carried out for land suitability analysis or in determination of site fitness for any specific application (Malczewski, 2004). The critical aspect of spatial multi-criteria analysis is that it involves evaluation of geographical events based on the criterion values and preferences set with respect to a set of evaluation criteria. The combination of GIS capabilities with the MCDM technique provides greater effectiveness and efficiency of decision making while solving spatial decision problems.

According to FAO (1976), suitability is a measure of how well the qualities of a land unit match the requirements of a particular form of land use. The process of land suitability classification is the evaluation and grouping of specific areas of land in terms of their suitability for a defined use. De la Rosa (2000) stated that land suitability is a component of sustainable evaluation of land use. Suitability together with vulnerability defines the suitability of a land use. The sustainable land use should have maximum suitability and minimum vulnerability, as shown in *Fig. 1*.

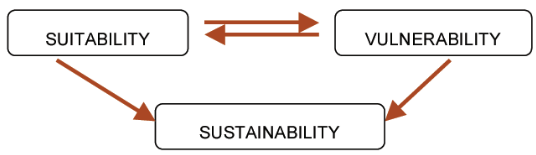

Fig. 1: Land use sustainability (after de la Rosa 2000)

Land suitability analysis deals with information, which is measured in different scales like ordinal, nominal, ratio scale etc. Based on the scope of suitability there are two types of classifications in FAO (1976) framework.

- *Current suitability:* refers to the suitability for a defined use of land in its present condition, without any major improvements in it.
- *Potential suitability:* for a defined use, of land units in their condition at some future date, after specified major improvements have been completed where necessary.

Agricultural land suitability is an interdisciplinary approach thus; determination of optimum land use type for an area involves integration of data from various domains and sources like soil science to social science, meteorology to management science. All these major streams can be considered as separate groups; further each group can have various parameters (criteria) pertaining to that group. However all the criteria are not equally important, every criterion will contribute towards the suitability at different degrees (Prakash, 2003).

There are several decision making approaches for analysing land suitability for land-use or land suitability purposes. Today, the widely used methods for land suitability analysis include ranking and ratings, weighted summation (AHP), Simple Additive Weighting Method (SAW), Boolean overlays, Fuzzy techniques and GAM ratings.

Analytical Hierarchy Process

The Analytical Hierarchy Process (AHP) is a comprehensive, logical and structural framework which enhances the understanding to decompose a complex decision making into a more feasible one to resolve hierarchical structure. AHP was developed by Professor Thomas L. Saaty of the University of Pittsburgh in 1980. AHP is based on three basic principles which are decomposition, comparative judgment and synthesis of priorities as shown in *Fig. 2*.

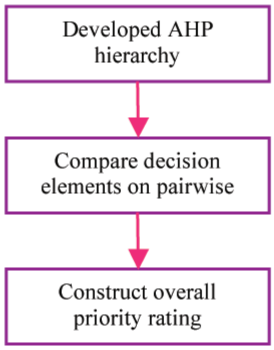

Fig. 2: Three major steps of Saaty's AHP

Comparative judgment by a decision maker requires pairwise comparison assessment between two criteria, including the sub-criteria. The fundamental concept of AHP lies in proceeding from a pairwise comparison of criteria to evaluate the weights that assign relative importance to these criteria. The Pairwise Comparison method was developed in the context of the AHP to create a ratio matrix. The procedure involves input of the pairwise comparison matrix and produces the relative weight as output. Identification of each criterion weightage can be interpreted easily through Pairwise Comparison Matrix; it requires rating scale preferences between two different criteria with values from 1 - 9 as shown in Table 1.

TABLE 1
Scale for AHP comparisons (Saaty, 1980)

Intensity of Importance	Description
1	Equal importance of both elements
3	Weak importance of one element over another
5	Essential or strong importance of one element over another
7	Demonstrated importance of one element over another
9	Absolute importance of one elements over another
2,4,6,8	Intermediate values between two adjacent judgements

The synthesis principle uses the derived ratio scale of the local priorities in the various levels of the hierarchy and constructs a composite set of alternatives (Malczewski, 2004). The procedures involve the utilisation of geographical data, the decision preferences and the manipulation of the data and preferences according to specific decision rules. The critical aspect of spatial multi-criteria analysis involves evaluation of geographical data based on the criteria values and preferences set with respect to a set of evaluation criteria.

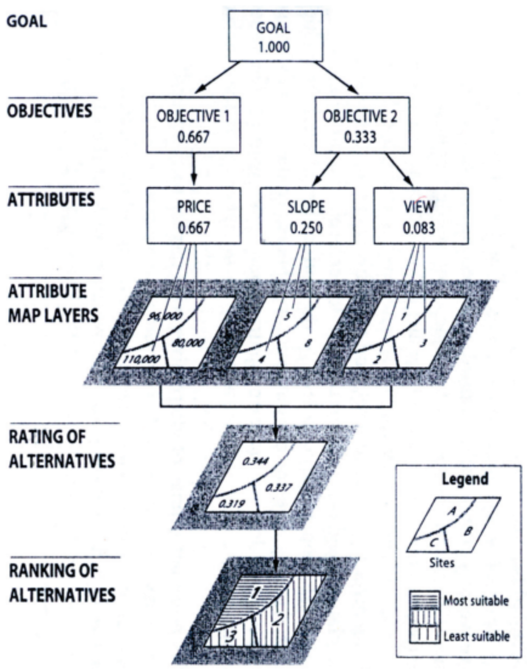

Fig. 3: Analytical Hierarchy Process (modified from Malczewski, 2004)

METHODOLOGY

There are many research methodologies that have been used by various researchers for land suitability analysis, which are all based on the use of GIS and several MCDM techniques as a tool and require certain evaluation criteria.

The methodology framework focuses on decision making as a process which involves a sequence of activities. It starts with problem recognition, criteria and constraints evaluation, data acquisition, AHP weightage analysis, manipulation of the AHP results using GIS and generation of suitability zones, ground truthing and verification, and finally evaluation and recommendations.

Criterion Factor

In multi-criteria analysis using AHP, criteria identification and determination are the most important elements in achieving any set aim or goal. In this research, a suitable bee zone was identified and weighted using AHP mathematical model. Several criterion factors were identified for locating the bee zone. The criterion factor took into account every single factor for locating an apiary for beekeeping as well as other factors such as ensuring migratory beekeeping is successful.

Site assessment of suitable bee settlement areas is important to ensure bees are placed in suitable and favourable areas regardless of abundant sources of nectar and pollen. The criteria used to determine suitable areas for beekeeping was identified based on numerous literature reviews including the FAO (1987b) guidelines on apiculture (beekeeping) and discussions with expert in apiculture. Based on the FAO guidelines, an apiary site should ideally be:

- away from playgrounds and noisy commercial or industrial areas
- near a fresh water supply: the banks of a river, lake or fish-pond, or even a dripping faucet
- near food sources
- fairly dry, away from swampy or flooding valley or any bottom land with stagnant water
- accessible to good roads
- on the leeward side of a hill
- with annual rainfall between 1275 mm and 1875 mm
- away from smoke and fire,
- away from danger of vandalism and unfriendly neighbours

Consequently, information about the relative importance of the criteria is required. This is achieved by assigning a weight to each criterion. After the weightage are derived, these evaluation criteria have to be integrated using multi-criteria decision rules. The decision rules provide the basis for ordering the decision alternatives and for choosing the most preferred alternative.

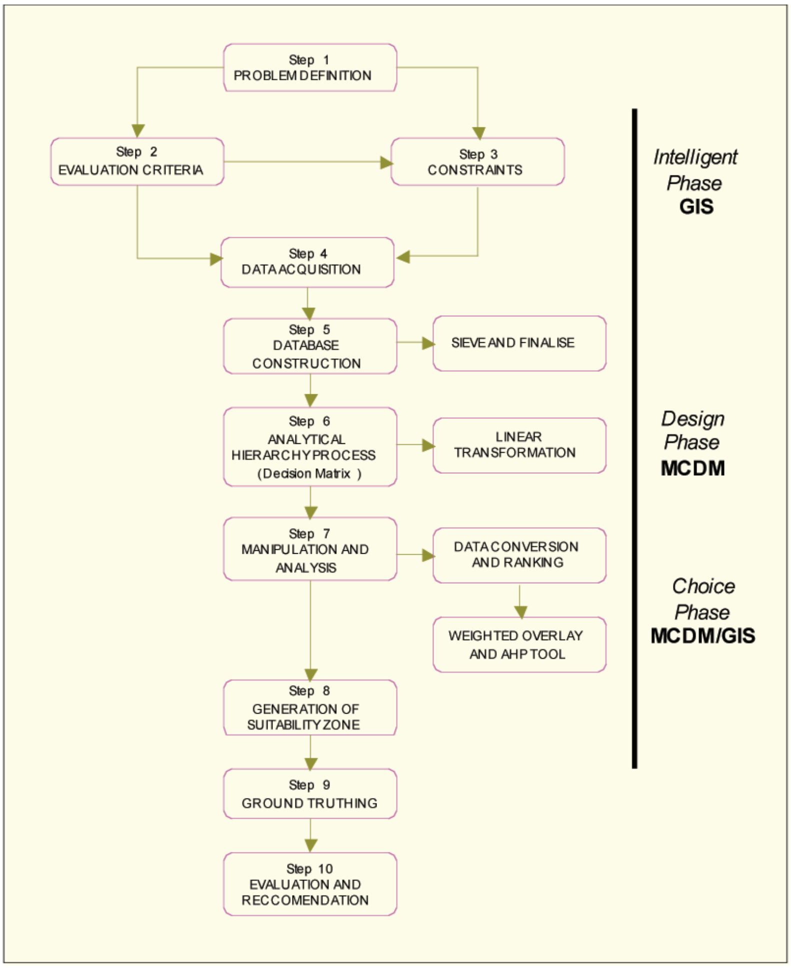

Fig. 4: Research methodology

AHP Weight Analysis Using Expert Choice® Software

Land suitability in this research consisted of generating pairwise comparison matrix for each criterion and sub-criterion of the beekeeping factor using AHP technique. The generation of weight and rank for the suitable area is carried outside the GIS environment or termed as 'loose coupling' using Expert Choice software. Several apiculture experts from the Department of Agriculture Malaysia (DOA) and Universiti Putra Malaysia (UPM) were consulted to determine the preferences and the ratings of AHP. Explanations were given to the experts on the basis of AHP implementation. Several criteria rankings were given as ratios and percentages by the experts and then synthesised to reflect the AHP ratings.

The information on AHP weightage was used to produce a suitability map. Pairwise comparision matrix for each sub-criteria is shown in Table 2 and summary results of pairwise comparison of sub-criteria and criteria are shown in *Fig. 5*.

The estimation of the consistency ratio is one of the important steps in determining the levels of inconsistency in the pairwise comparison. According to Malczewski (2004), the consistency ratio (CR) is designed in such a way that if CR < 0.10, the ratio indicates a reasonable level of consistency in the pairwise comparisons. However, if CR ≥ 0.1, the values of the ratio indicate inconsistent judgement (Saaty, 1980, 1982; Malczewski, 1999), for a complete technical description of AHP technique). The overall weighting values and its consistency of the AHP analysis are shown in *Fig. 6*.

TABLE 2
Pairwise comparison matrix

Comparing the relative importance with respect to : HYDROLOGY FEATURES

	0 - 200m	200 - 500m	500 - 700m	> 700m
0 - 200m from source		2.0	3.0	9.0
200 - 500m from source			2.0	7.0
500 - 700m from source				4.0
>700m from source				
	Incon = 0.01			

Comparing the relative importance with respect to : ROAD NETWORKS

	< 5 km	5 - 10 km	10 - 15 km	>15 km
< 5 km		2.0	4.0	9.0
5 - 10 km			2.0	7.0
10 - 15 km				4.0
>15 km				
	Incon = 0.01			

Comparing the relative importance with respect to : TOPOGRAPHY FEATURES

	< 150m	150 - 300m	> 300m
< 150m		2.0	7.0
150 - 300m			4.0
> 300m			
	Incon = 0.00		

Comparing the relative importance with respect to : NECTAR CLASS

	< 150m	150 - 300m	> 300m
< 150m		2.0	4.0
150 - 300m			2.0
> 300m			
	Incon = 0.00		

Comparing the relative importance with respect to : POLLEN CLASS

	< 150m	150 - 300m	> 300m
< 150m		2.0	4.0
150 - 300m			2.0
> 300m			
	Incon = 0.00		

Comparing the relative importance with respect to : GOAL- SUITABLE ZONE

	NECTAR	POLLEN	HYDROLOGY	ROAD	TERRAIN
NECTAR CLASS		1.0	2.0	5.0	8.0
POLLEN CLASS			2.0	3.0	6.0
HYDROLOGY FEATURES				2.0	3.0
ROAD NETWORKS					2.0
TERRAIN					
	Incon = 0.01				

Linear Transformation

The weight values produced by AHP in Expert Choice software are as pointers. The values need to be transformed as commensurate criterion maps so that they could be further analysed in a GIS environment. Maximum score linear transformation is used to generate the proportional magnitude to the original weight.

Linear scale transformation is a frequently used deterministic method for transforming input data into measurable criterion maps. The linear scale transformation method converts the raw data into standardised criterion scores. The two most often used procedures for linear transformation are maximum score and score range procedures. Linear scale transformation formula for maximum score is

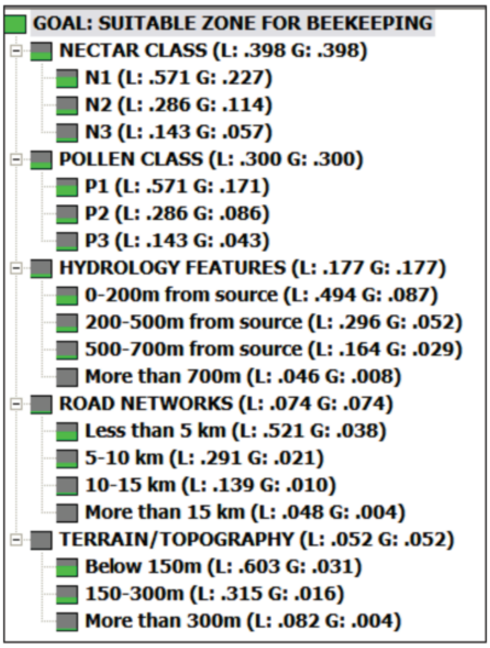

Fig. 5: Pairwise comparison in Expert Choice Software

$$x'_{ij} = \frac{x_{ij}}{x_{ij}^{max}}$$

where, x'_{ij} is the standardised score for the ith object (alternative) and the *j*th attribute, x_{ij} is the raw score and x_{ij}^{max} *is* the maximum score for the jth attribute. The value of the standardized scores would then range from 0 to 1 and according to (Malczewski, 1999) the best standardized score is always equal to 1. The advantage of this method is that it performs proportional (linear) transformation of the raw data. In order to capture the magnitude of the standardised method in a GIS system, it has to be multiplied with an arbitrary multiplier and the formula is

$$x'_{ij} = \frac{x_{ij}}{x_{ij}^{max}} * m$$

The multiplier value in this instance is nine (9) to reflect the maximum values as applied in Saaty's (1980, 1982) AHP. The final value generated was then rounded to the nearest integer value to allow the weight to be input into a GIS environment. Linear transformation results of the final value corresponding to the criterion are shown in Table 3.

Data Preparation for Available Area

In order to determine available areas for beekeeping zoning several steps have to be accomplished, which include sieving of unsuitable areas according to the guidelines provided by FAO (1987b), expert's opinion and availability of bee plants listed by Atim (1981). Only areas that have major bee plants as listed by Atim

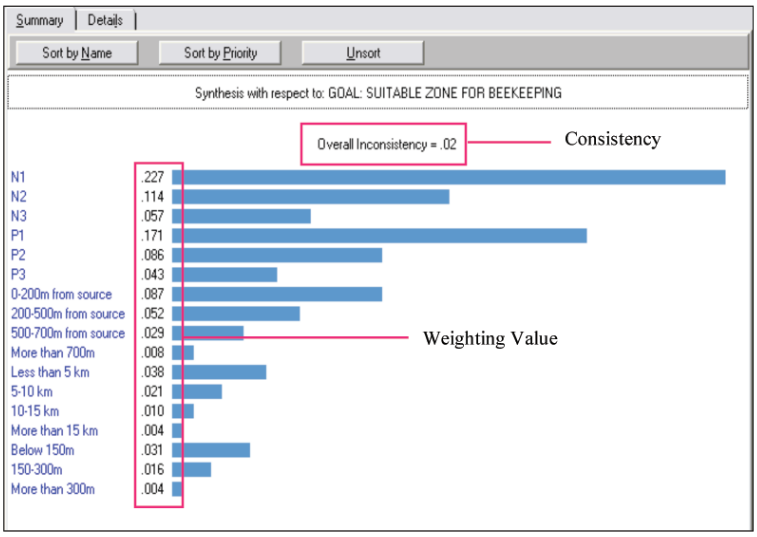

Fig. 6: Overall consistency ratio of AHP

TABLE 3
Criteria and commensurate weight

CRITERION	SUB-CRITERIA	DESCRIPTION	WEIGHT
CLIMATIC	Rainfall	Dry Season	9
		Wet Season	3
PHYSICAL	Topography/ Elevation	Low Land : Below 150m	9
		Hill Land : 150 -300m	5
		High Land: Above 300m	1
	Hydrology Bodies (Water Network)	Best Suited: Below 200m	9
		Moderately Suited : 200-500m	5
		Slightly Suitable : 500-700m	2
		Modifiable : More than 700m	1
EXISTING INFRA-STRUCTURE	Road Networ	Best Suited: Below 5 km	9
		Moderately Suited : 5-10 km	5
		Suitable : 10- 15 km	2
		Unsuitable : More than 15 km	1
FOOD SOURCE/ BEE PLANT	Nectar	High nectar source : N1	9
		Medium nectar source : N2	5
		Low nectar source : N3	3
	Pollen	High nectar source : N1	9
		Medium nectar source : N2	5
		Low nectar source : N3	3
OVERALL CRITERION WEIGHT		Terrain/Topography	1
		Road Networks	2
		Hydrology Networks	4
		Pollen Class	7
		Nectar Class	9

(1981) are selected as available areas. All other landuse occupancies such as built-up areas, mining areas, urban, towns and associated areas and other agricultural areas that are not classified as having bee plants are sieved. The selected agricultural areas which consist of several major bee plants are grouped into classes to determining the volume of nectar or pollen. N1/P1 indicates High Nectar/Pollen Source, N2/P2 indicates Medium Nectar/Pollen Source while N3/P3 indicates Low Nectar/Pollen Source as shown in Table 4.

Data Conversion and Ranking

Data conversion consists of converting map layers, which are in vector format to raster layer. The layers are then ranked accordingly as previously identified through AHP analysis. This is important because the AHP extension tool in ArcGIS9 only allows raster datasets for analysis.

TABLE 4
Classification of bee plants according to nectar and pollen class

CATEGORY	LANDUSE	Nectar Class	Pollen Class
Agriculture	Grassland	N2	P2
Agriculture	Coconut	N1	P1
Agriculture	Coconut/Cocoa	N1	P1
Agriculture	Coffee	N1	P2
Forest	Forest	N1	P1
Agriculture	Orchards	N1	P1
Agriculture	Rubber	N1	P3
Agriculture	Mixed Horticulture	N2	P2
Agriculture	Oil Palm	N3	P2

Spatial analysis for land evaluation comprises of overlaying several thematic layers to find locations that encompass all desired criteria. The relative weights of factors for beekeeping suitability were used as multi-factors to rank and classify the GIS database map layers of the study area in order to generate the suitability map of beekeeping zones.

Criterion 1: Topography

Naturally, bees inhabit lowlands or highlands. In this analysis, topography is divided into three classes; the highest rank is for lowlands which are easier for apiary management in comparison to highlands. The elevation map of the study area is divided into three regions. The topographic features are divided into three classes' lowland (0-150 m above sea level), hilly land (150 - 300 m above sea level) and highland (more than 300 m above sea level) (refer to *Fig. 7*).

Criterion 2: Hydrology

A suitable beekeeping zone must be located near to water resources. Therefore, 200 m, 500 m and 700 m buffers were input into the GIS software to generate surrounding water surfaces. In this research, the main contributing factor was the hydrologic features because in tropical climate bees need water to cool their hives and the water resources must be at least 500 m from their hives. Areas nearest to water resources are of the highest rank. Values for 700 m or more are still acceptable if a proper apiary management could be established by placing dripping faucets near hives in the apiary (refer to *Fig. 8*).

Criterion 3: Road Network

In terms of logistics, a good road network is very important to the location of an apiary or beezone. The highest ranked placed areas are nearest to road networks. Buffering of road networks is executed using Spatial Analyst Tool in which the processes include reclassification of required buffer zone followed by another reclassification according to the AHP weight. (refer to *Fig. 9*).

Criterion 4: Nectar Class

The nectar class map of the study area is divided into three ranks. Each bee plant is classified accordingly to its corresponding nectar class; the highest rank has the most nectar production. The ranking for High Nectar Source (N1) is 9, Medium Nectar Source (N2) is 5 and for Low Nectar Source (N3) is 3 (refer to *Fig. 10*).

Criterion 5: Pollen Class

The pollen class map of the study area is divided into three ranks. Each bee plant is classified accordingly to its corresponding pollen class; the highest rank has the most pollen production.

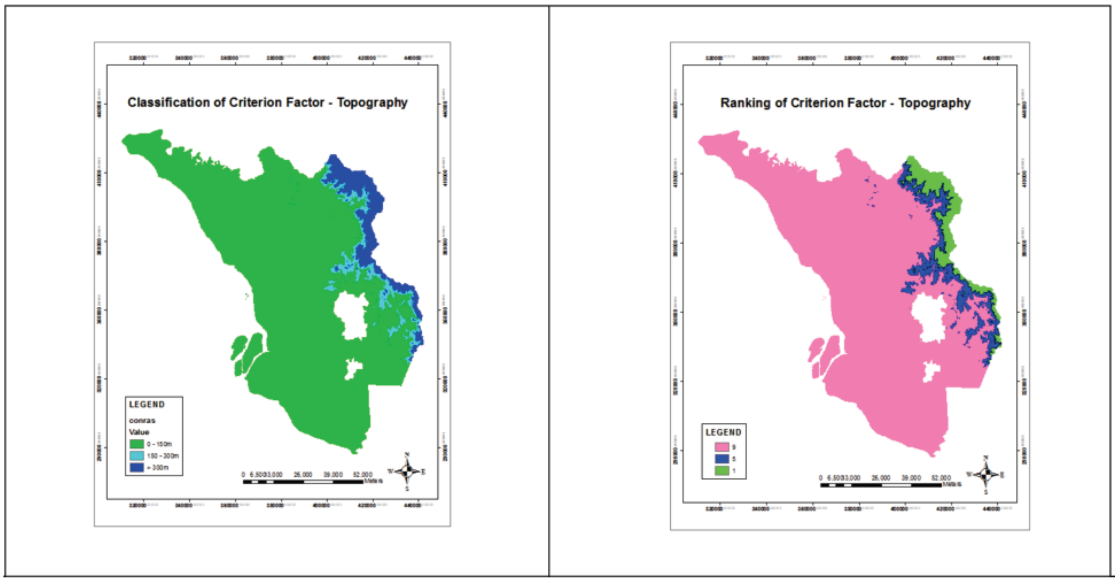

Fig. 7: Topography - Classification and ranking

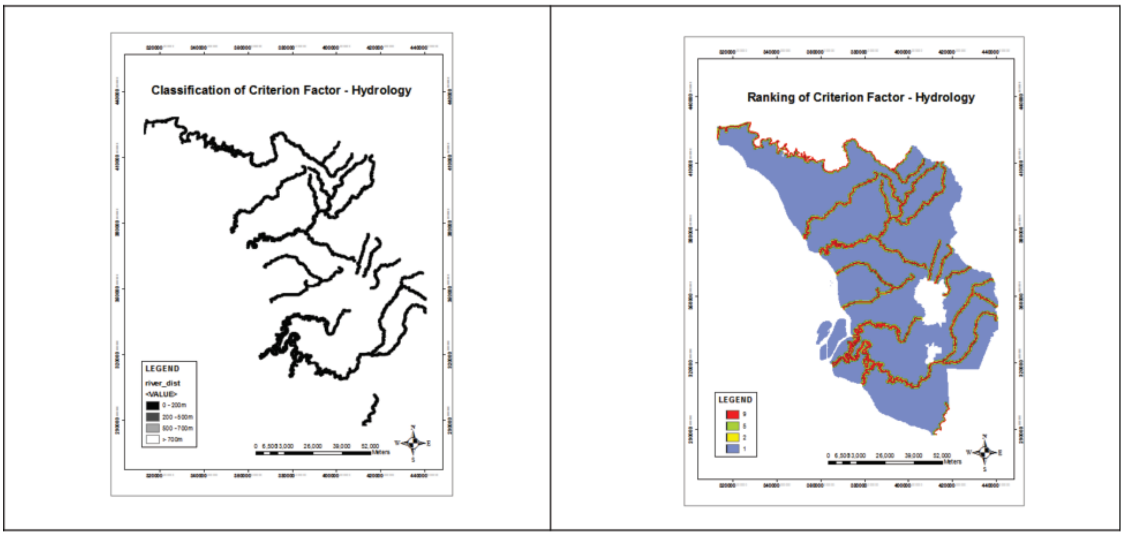

Fig. 8: Hydrology - Classification and ranking

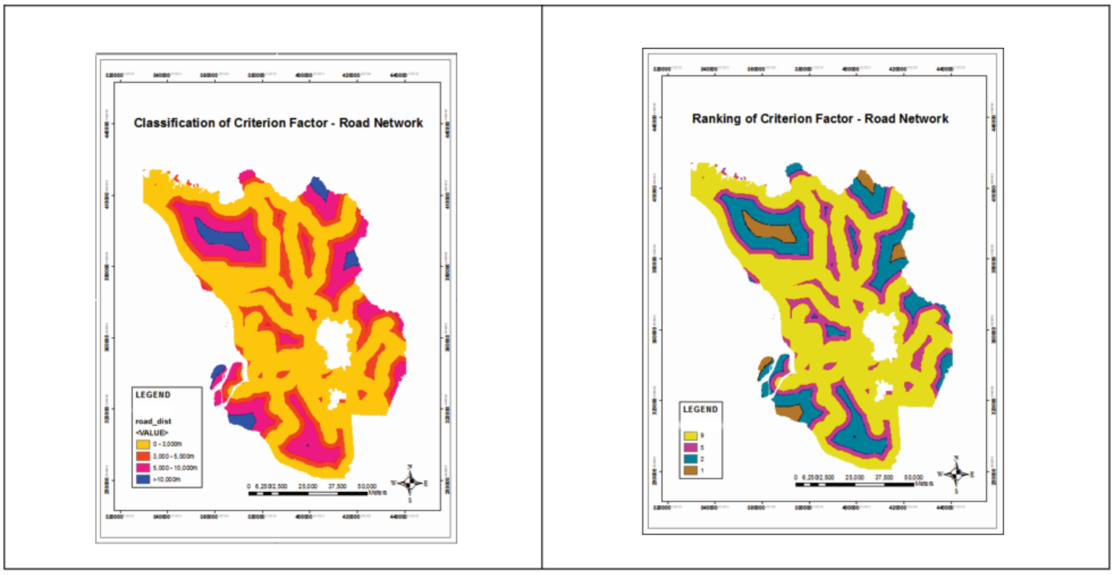

Fig. 9: Road network - Classification and ranking

The ranking for High Pollen Source (N1) is 9, Medium Pollen Source (N2) is 5 and for Low Pollen Source (N3) is 3 (refer to *Fig. 11*).

RESULTS

The ranks for each criterion maps were produced using Linear Transformation according to AHP value; and used for further suitability analysis. The are several methods in performing suitability analysis in ArcGIS9, for instance using map calculator, Weighted Overlay function or using tools that have been developed for AHP analysis.

Suitability Analysis - Weighted Overlay

Weighted Overlay is a technique for applying a common measurement scale of values to diverse and dissimilar inputs in order to create an integrated analysis. Geographic problems often

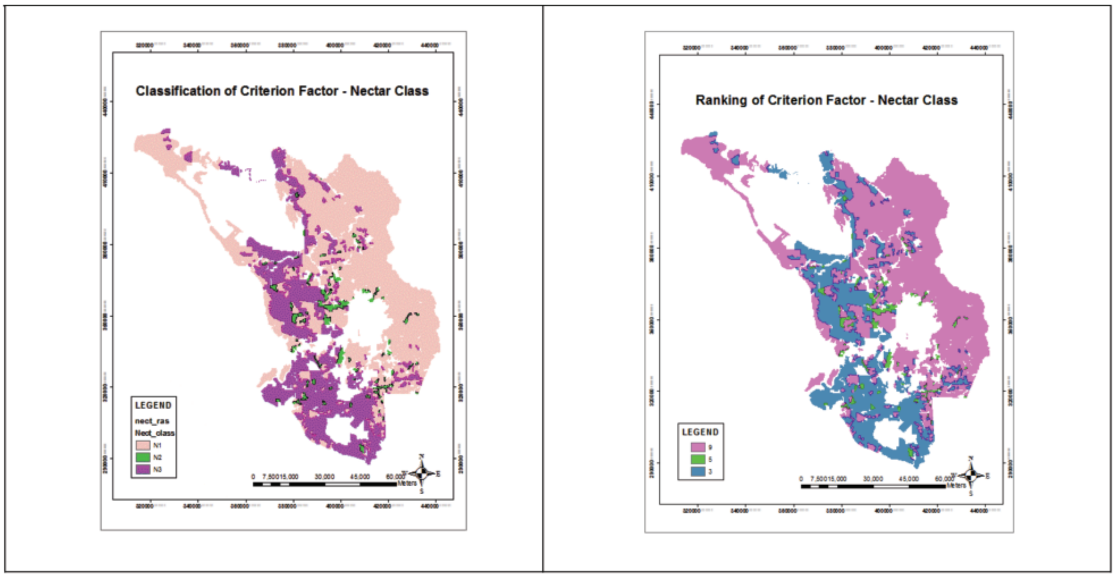

Fig. 10: Nectar class - Classification and ranking

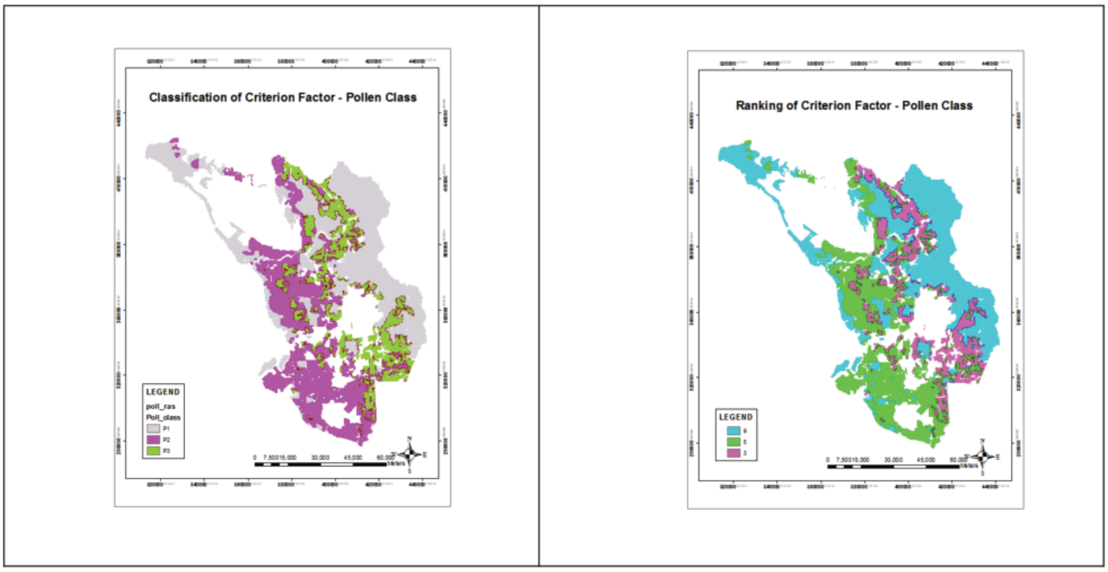

Fig. 11: Pollen class - Classification and ranking

require the analysis of many different factors, for instance, choosing the sites in the beekeeping zones. Every single layer of data must be prioritized accordingly.

Continuous (floating-point) rasters must be reclassified to integer before they can be utilised in ArcGIS9 which has been done during the linear transformation process. Each range must be assigned a single value before it can be used in the Weighted Overlay tool. The assigned weight need to be inserted in each input raster. The weight of each criterion is stated in Table 5.

For suitability analysis, five factors were considered: nectar class, pollen class, hydrology, road network and topography. The goal was to find suitable zones for beekeeping activity. The

TABLE 5
Percentage of weight

Criteria Factor	Weight % (Expert Choice)	Weight (%) Weighted Overlay
Nectar Class	37.4	37
Pollen Class	31.8	32
Hydrology Feature	16.8	17
Road Network	9	9
Topography	5	5

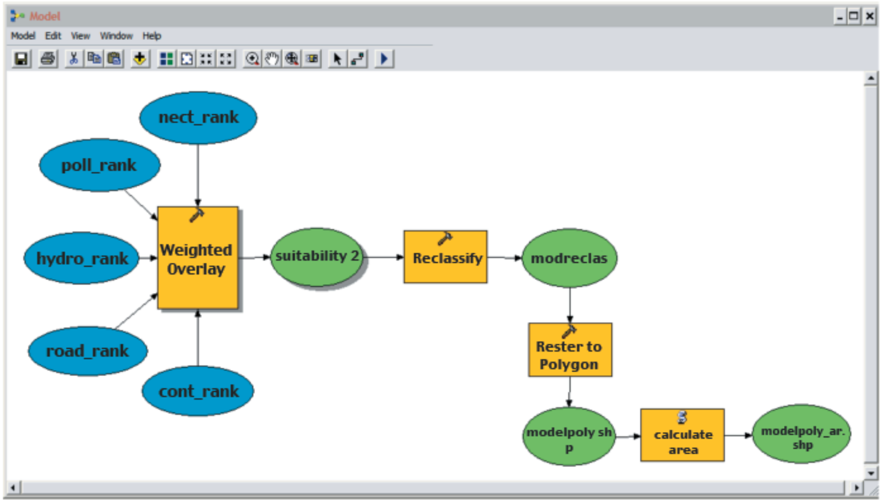

Fig. 12: Model for Generating Beekeeping Suitability Zone

weighted overlay model is displayed in *Fig. 12* as a process generated using Model Builder.

The weighted overlay function dialogue box is shown in *Fig. 13*, the integer values of each criterion was inserted in the percentage of influence column, while the rank was automatically inserted according to existing rank of each layer.

The results of weighted overlay analysis are the creation of a suitability map as shown in *Fig. 14*.

The most suitable areas are ranked as 9 followed by rank 3 for the least suitable area. The classification is accomplished using a Reclassification tool, Equal Interval and determines 3 classes. This analysis produces results in raster format and the suitability map was reclassified to S1 - Most Suitable, S2 - Suitable, S3 - Moderately Suitable as shown in *Fig. 15*.

A calculation of the total area was done to determine the effective suitable area for apiculture in Selangor as shown in Table 6.

DISCUSSION

The site verification was carried out at apiaries in Kuala Selangor and Mardi, Serdang to verify the results of the model. Several areas were visited and visually captured. The coordinate of each beekeeping site was recorded using a Silva Multi-Navigator GPS System. Information about the sites are shown in Table 7. The coordinates were then transferred into GIS system and evaluation of the area assessed in terms of its suitability according to the model developed.

The result is comparatively acceptable whereby the site verification data of the apiaries corresponded to S1 which is the Most Suitable area, as verified with the existing apiaries location as shown in *Fig. 16*.

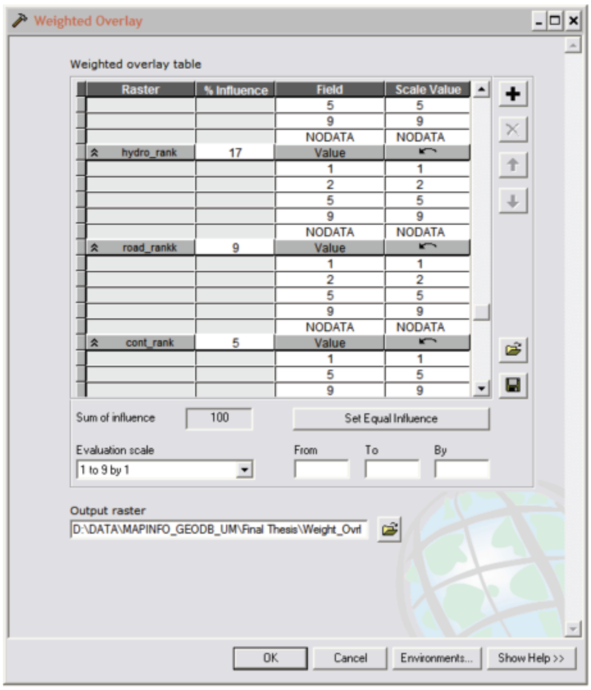

Fig. 13: Weighted overlay function

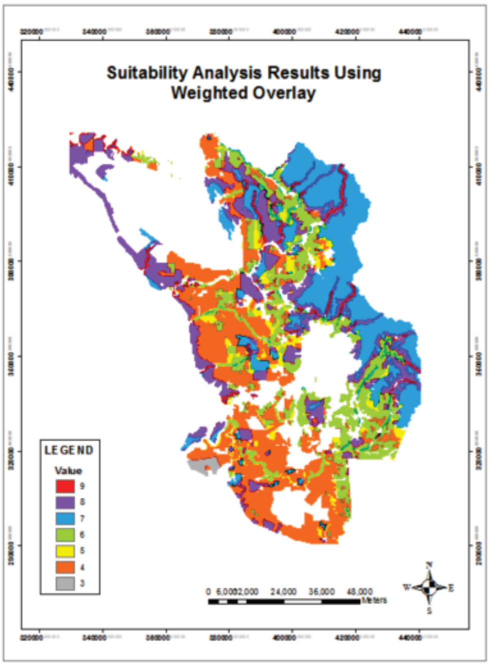

Fig. 14: Suitability map using weighted overlay

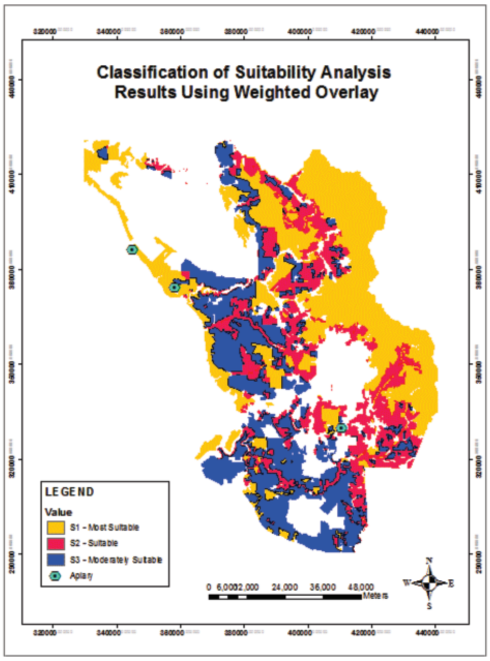

Fig. 15: Beekeeping uitability zone classification using weighted overlay

TABLE 6
Suitability hectarage

Suitability Analysis	Weighted Overlay	
	Hectares	Percentage
S1 - Most Suitable	109, 166.67	13.72%
S2 - Suitable	216, 757.24	27.24%
S3 - Moderately Suitable	193, 498.15	24.32%
Total Suitable area	519, 422.0589	65.27%
Not Suitable	276, 358.66	34.73%

TABLE 7
Information on Apiaries

GPS ID	X	Y	Owner	Address/Area	# Hives	Species
1.	3.38	101.20	Misbah b. Yusof	Kampung Sungai Gulang-Gulang, Kuala Selangor	9	Cerana, Trigona
2.	3.48	101.08	Lee Man Fay	Kampung Sekinchan, Kuala Selangor	100	Cerana
3.	2.98	101.68	Haji Hamzah	Mardi, Serdang	20	Cerana, Trigona, Florea

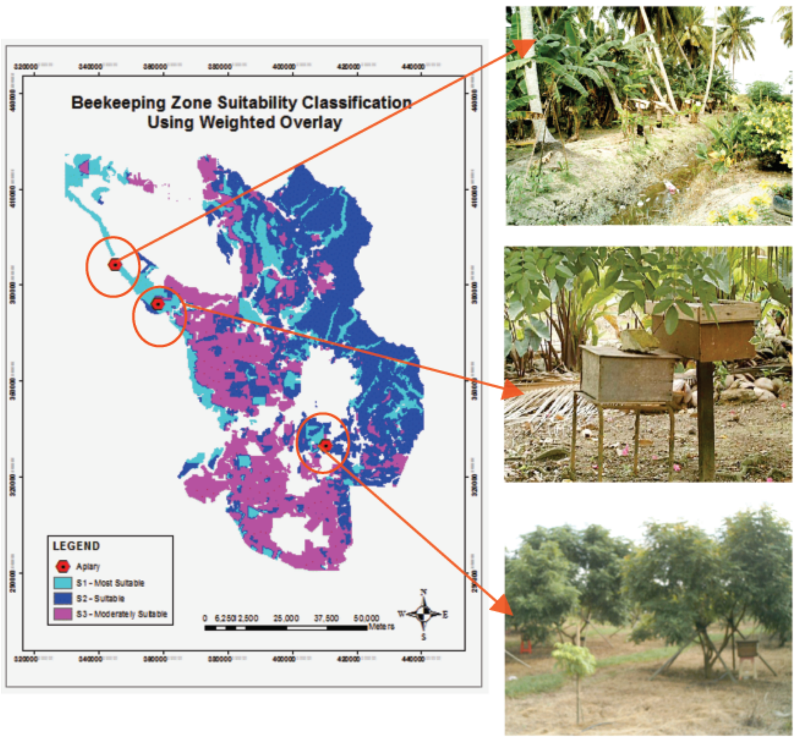

Fig. 16: Verification of suitability maps with existing apiaries

CONCLUSIONS

Integrating multi-criteria decision-making and GIS technology in locating beekeeping areas is one of the ways to determine or evaluate potential zones for beekeeping, since there are several factors that contribute to potential zones and each factor has a different weight. This research achieved its objective of using GIS and MCDA as tools to locate suitable zones for beekeeping. Verification of existing apiaries with the model using AHP techniques provides satisfactory results of weightage of each criterion for beekeeping zones suitability. By using AHP, a mathematical model of criteria that contributes to suitability of beekeeping zones could be established. The analysis is a guideline of suitable factors of beekeeping and the model could be modified to suit certain needs depending on the area of interest. The research outcome could be expanded in further research to forecast the flowering time for migratory beekeeping. Evaluation and zoning of suitable beekeeping areas can contribute to the implementation of beekeeping activity on a large or small scale.

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