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Suitability Analysis for Beekeeping Sites in La Union, Philippines, Using GIS and Multi-Criteria Evaluation Techniques

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Abstract: Geographic Information System (GIS) has been proven in many studies and experiences to aid in the decision-making process based on Multi-Criteria Evaluation (MCE) techniques. This study aims to evaluate the suitability of the Province of La Union, Philippines for beekeeping using GIS and MCE techniques. This study presents an empirical method for suitability analysis involving GIS and the participation of stakeholders and experts in the decision-making process. The empirical conceptual model used in this study contains three main components: database creation and management; spatial and multi-criteria analysis and validation process. As an integral part of the model, the final suitability map was validated through a correlation analysis method involving the existing beekeeping projects honey yield data and the calculated suitability values. Results showed relatively high correlation between the suitability index and honey yield. This indicates some degree of reliability of the model used and the output produced. The results of this study may be used as a basis in evaluating the suitability of other areas for beekeeping. It may also serve as a take-off board for more complex studies in the future.

Key words: Suitability analysis, GIS, MCE, beekeeping, La Union, Philippines

INTRODUCTION

In many developing countries, beekeeping plays an important role in helping the rural poor through the products derived from it that give them additional income. It is the management of honeybees for the production of honey and other by-products and for the pollination of crops. Technically, the science and art of beekeeping is called apiculture (FAO, 2003). In a case study conducted in the northern part of the Philippines involving *Apis mellifera* colonies, De Padua (2009) found out that the average annual return on investment for 4 years of beekeeping operation was 182.20% equivalent to 62,596 Philippine Peso or about US$ 1,391 annual net income. In a case study conducted in Uganda in 2001 as reported by FAO (2003) each of the 150 families engaged in beekeeping was able to gain an annual net profit of US$1,400. In addition to this economic incentive, honeybees are very important because they are the key pollinators of about 33% of crop species (Oldroyd and Nanork, 2009). Although the degree of pollination dependency of plants varies significantly, the yield of highly pollinator-dependent crops would decrease by 100% with the absence of pollinators (Garibaldi *et al*., 2009). Given the economic benefits it offers, beekeeping can help lift people's economic status especially the marginalized. However, productive beekeeping depends on good colony management and richness of the foraging areas and in order to promote it as a profitable agricultural occupation, areas with a good potential for beekeeping must be located and evaluated (FAO, 1987). In this regard to systematize and facilitate the mapping of suitable areas for beekeeping with careful consideration of the factors, the use of Geographic Information System (GIS) and Multi-Criteria Evaluation (MCE) techniques may be explored. MCE techniques have been recognized as decision-support tools in dealing with complex scenarios where technological, economical, ecological and social aspects have to be considered for proper land use planning (Marinoni, 2006).

Likewise, computer-based system decision support tools strongly help decision makers in evaluating criteria and alternatives for a specific objective (Ghribi, 2005). The recent developments in computer-based tools like GIS and MCE techniques can assist the analysts and decision makers deal with this complexity (Joerin *et al*., 2001). Furthermore, the integration of MCE with GIS is a powerful tool in environmental monitoring and decision-

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making (Hubina and Ghribi, 2008) and land suitability assessments (Joerin *et al*., 2001). There had been several studies that were able to demonstrate the application of GIS along with MCE techniques on a wide range of area of interests from the technical aspect of integrating GIS with MCE techniques (Jankowski, 1995; Laaribi *et al*., 1996) land suitability mapping for industry using raster-based GIS (Eastman *et al*., 1993) and Analytical Hierarchy Process (AHP) (Saaty, 1980, 1994, 2008) to combining MCE and GIS in evaluating habitat for endangered species (Pereira and Duckstein, 1993).

More specifically, Boonyanuphap *et al*. (2004) concluded that the integration of GIS with a multifactor spatial analysis made them effectively assess the environmental suitability of an area for banana plantation in Lower Northern Thailand. Roy and Grealish (2004) were able to demonstrate the capability of GIS in mapping arable soils using detailed soil characteristics. Likewise, Thapa and Murayama (2008) had successfully applied AHP and GIS in evaluating suitable lands for peri-urban agriculture in the Hanoi Province, Vietnam. In land suitability assessments like these rather than isolating the best alternatives, it is helpful to map the suitability index of the whole area being studied (Joerin *et al*., 2001).

Recognizing that the data needed in any multi-criteria assessment usually come from various fields of disciplines, careful evaluation and prioritization based on the actual characteristics and potential use of the land must be done. The determination of priorities and the importance of factors for the efficient use of land may be done using MCE techniques combined with GIS (Tudes and Yigiter, 2009). In this aspect, weighting methods for the different factors and alternatives like the AHP (Saaty, 1980) may be used. In a study conducted by Farajzadeh *et al*. (2007) they found that a pairwise comparisons method of the AHP showed better results when compared to the other weighting methods like Boolean, ranking and rating.

The main purpose of this study is to evaluate the suitability of the Province of La Union, Philippines for beekeeping using GIS and MCE techniques. The study presents an empirical method for suitability analysis involving GIS and the participation of stakeholders and experts in the decision-making process. The final suitability map was validated through a correlation analysis method involving the existing beekeeping projects honey yield data and the calculated suitability values.

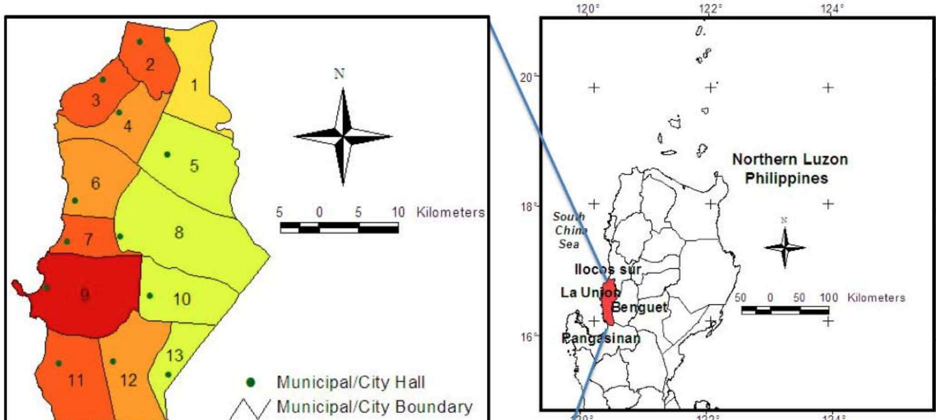
MATERIALS AND METHODS

The study site: In the Province of La Union, the science and art of beekeeping called apiculture was first implemented and showcased officially to the public when the former Apiculture Training Development Center (ATDC) of the Don Mariano Marcos Memorial State University (DMMMSU) in the municipality of Bacnotan was established in 1997. DMMMSU itself has been offering an undergraduate program in agriculture with a major in apiculture. Prior to this, though, local people became familiar with honey and bees through the wild honeybees present in the locality and also through honey hunting.

On August 10, 2001 considering the economic importance of beekeeping, the Philippine Congress enacted the Republic Act 9151 establishing the National Apiculture Research, Training and Development Institute (NARTDI) based at DMMMSU replacing the former ATDC. NARTDI being the national institute has been involved in many extension activities throughout the entire country promoting beekeeping as a profitable venture. In La Union alone as of 2008, NARTDI has been supporting at least 43 successful beekeepers (NARTDI, 2008). There are also other private individuals trained by NARTDI who have initiated their beekeeping activities. Being the host province and one of the primary collaborators of NARTDI and DMMMSU in the promotion of beekeeping, the Provincial Government of La Union has officially adopted honey in 2005 as its banner agricultural product in response to the One-Town-One Product (OTOP) Program of the Philippine national government.

As far as its location and extent are concerned, La Union is situated in the southwestern part of the Ilocos Region between latitudes 16°12'N and 16°55'N and longitudes 120°17'E and 120°35'E (Fig. 1). The capital city, San Fernando is 273 km north of Manila and 57 km from Baguio City. The climate of La Union is classified based on rainfall and belongs to the Type 1 of the Philippine Atmospheric Geophysical Astronomical Services Administration (PAGASA). Climatic Type 1 is characterized with one distinct wet and one dry season. The dry period is generally lasting from November to April. The temperature is high (above 27°C) or intermediate (26-27°C), seldom or never mild (below 26°C) except during night.

The population of the Province had increased from 657,945 in 2002-720,972 in 2007. The primary sources of livelihoods in the province are agriculture (53%), services (37%) and industry (10%) according to the La Union Provincial Government. The continuous growth of population along with its inherent increasing resources requirement poses a great pressure to the province's land resources particularly to its arable land. Apparently, additional sources of livelihood are needed to meet people's increasing needs while rationalizing the escalating pressure to the natural resources. Cognizant to the foregoing and to provide more scientific basis in the promotion of beekeeping not



Population Data (NSO, 2007)

No.	Municipality	Population	No.	Municipality	Population
1	Sudipen	15,949	11	Bauang	69,837
2	Bangar	33,335	12	Naguilian	45,232
3	Luna	35,372	13	Burgos	8,261
4	Balaoan	36,829	14	Caba	20,927
5	Santol	11,712	15	Aringay	43,438
6	Bacnotan	38,743	16	Agoo	57,952
7	San Juan	32,952	17	Tubao	26,402
8	San Gabriel	15,803	18	Pugo	18,265
9	City of San Fernando	114,813	19	Sto. Tomas	33,604
10	Bagulin	12,521	20	Rosario	49,025

Note: *Numbers on the map correspond to the assigned number of the municipalities in the table (right).*

Fig. 1: Location map of La Union

Fig. 2: Photos during the field survey and monitoring of the NARTDI team. (a) Landscape of Bacnotan, La Union; (b) NARTDI demonstration bee colonies; (c) From left: Elisio pera (cooperator-Balaoan, La Union), Reynaldo Laquidan (NARTDI Estension and Development Services Division Head); (d) From left: Anicet Derotchers (Canadian Excutive Services Organization Volunteer); Divid Atolba (Cooperator-San Juan La Union) and (e) From left: Anicet Derotchers (Canadian Excutive Services Organization Volunteer); Joseph Panas (NARTDI Staff) and Reynaldo Mostrales (Cooperator-Oya-oy, Bacnotan, La Unoin). Source: a and b (by the authors); c-e (NARTDI)

only in the Province of La Union but also in other places, this study was framed and carried out. Figure 2 shows some photos taken from the study area.

Determination and preparation of the criteria: In this study, criteria are of two types. These are factors and constraints. Generally, according to FAO (1990), the ideal apiary site should be away from playgrounds and busy commercial or industrial areas; near to 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; away from danger of vandalism and unfriendly neighbors and with annual rainfall between 1275 and 1875 mm. In consideration of the above-mentioned criteria and in consultation with experts, the following factors were believed to be the most important features to consider in selecting beekeeping sites in the province of La Union: land use/cover (nectar and pollen sources), distance to river, distance to road, elevation and rainfall.

On the other hand, the following were considered constraints because they do not contain any nectar and pollen source plants and it is not advisable to place the beehives exactly in these locations: built up areas, water body, sand, river wash and areas within 25 m from the road. In the case of rainfall factor, although the

Table 1: Data used and their sources

Data sources	Descriptions
Landsat TM image (Source: USGS)	Acquired on 6th December 2004; resolution = 30 m; used to derive the land use/cover of La Union
Topographic map of La Union (Source: NAMRIA, Philippines)	Scale = 1:50,000; used to derive DEM, river and road networks
Ground survey data	1st-June 2005-used in image classification and accuracy assessment; 2nd-Nov. 2008-visited the beekeeping projects
12 beekeeping projects	2005 data on honey yield in kg/colony were collected; geographic locations were recorded
Experts	Sources of expert's opinion used in the Analytical Hierarchy Process (AHP)

average annual rainfall in the province of La Union from 1997-2003 (2810.50 mm) is beyond the limit set by FAO (1990) beekeeping can still be done in the area since about 70% of the total rainfall usually occurs during the months of July-September only. The significance of these factors is further discussed. The data used and their sources are shown in Table 1.

DEM, river and road networks: The Digital Elevation Model (DEM) was developed from the digitized contour lines based on the topographic map of the province with a scale of 1:50000 using Vertical Mapper-MapInfo software. Likewise, the river and road networks were also extracted from the same topographic map.

Land use/cover development: A detailed vegetation map of the bee plants is ideal to represent the source of nectar and pollen. However, mapping individual plant species over a relatively wide area has been a major challenge in beekeeping industry due to the complexity and limitations. While recognizing the fact that a land use/cover map will never be the same as a detailed map of bee plants, For purposes of identifying sites with high potential as a source of nectar and pollen, the former can still be used to represent the latter.

Cognizant to the foregoing, this study attempts to contribute potential approach towards addressing this issue by using Remote Sensing (RS) image in mapping land use/cover of the area under investigation. In this regard, a two-scene Landsat TM image acquired on the 6th of December 2004 with a resolution of 30 m was used in mapping the land use/cover of the study area.

The derived land use/cover map of La Union (Fig. 3) from this RS image, supported by the floral calendar of northern Luzon (ATDC and FAO, 1997) and field observation was then used to represent the sources of nectar and pollen.

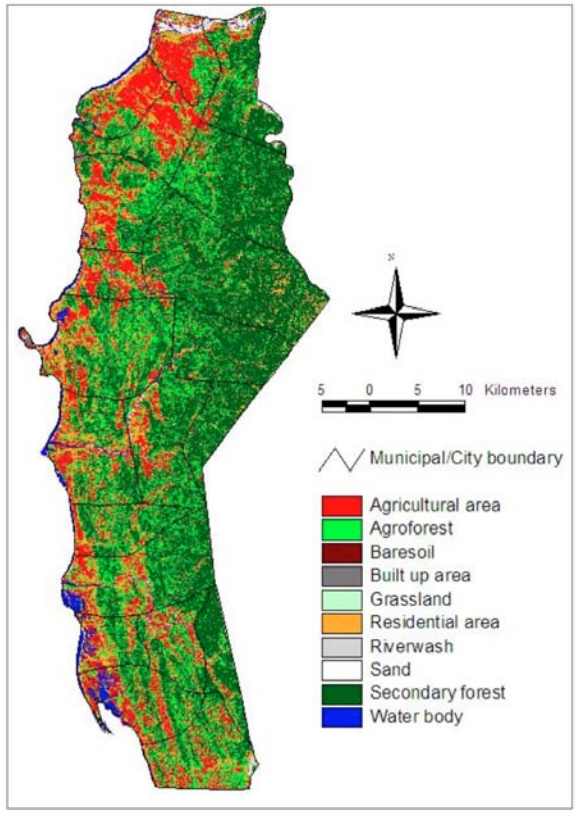


Fig. 3: Land use/cover map of La Union as of December 2004

Supervised classification: During the field survey on June 2005, ground truth points were collected on the different land uses/covers with the aid of a Global Positioning System (GPS) receiver. The vegetation was described and coordinates were recorded. The different cropping systems were known through interview with the local farmers. These points and attribute information were used as a basis in the conduct of a supervised classification on the Landsat image. Generally, the process of supervised classification is divided into two parts: training and classifying.

The process of defining the criteria by which patterns are recognized and by which the computer is trained to recognize these pattern is called training (Leica Geosystems, 2005). The training sites were created using the ERDAS Imagine Signature Editor. Then a maximum likelihood supervised classification was done to identify pixels in the Landsat TM image with similar characteristics. In the final land use/cover map, the different cropping systems were merged into one land use category called agricultural area, narrowing down the classification classes to 10 (Table 2 and Fig. 3). The different land use/cover categories were selected with

Table 2: La Union land use/cover types and their extent

	Area		
Land use/cover	Hectare	Percent	Description
Agricultural area (AG)	25,678.71	17.20	Includes areas cultivated for annual crops such as rice, corn, tobacco, vegetables
Agro Forest (AF)	30,358.98	20.33	Includes areas with trees and agricultural crops
Secondary Forest (SF)	58,886.91	39.44	Includes second growth forests
Residential Area (RA)	22,018.31	14.75	Includes housing areas with gardens
Grassland (GL)	2,691.17	1.80	Includes grasses and bushes
Water Body (WB)	3,410.72	2.28	Includes sea, ponds and rivers
Built up area (BU)	2,444.63	1.64	Includes industrial and commercial areas
Bare soil (BS)	2,001.63	1.34	Includes areas without any vegetative cover
Sand (SD)	1,077.21	0.72	Includes sand along seashore
Riverwash (RW)	740.93	0.50	Includes soils, sand and rocks/stones deposited along river banks
Total	149309.19	100.00	

guidance from the Department of Environment and Natural Resources (DENR), Department of Agriculture (DA) and National Economic and Development Authority (NEDA) in Region 1, Philippines.

Accuracy assessment: Accuracy assessment is a methodical way of evaluating the result of the classification with reference data like but not limited to ground truth data, previously tested map and aerial photos (Leica Geosystems, 2005). Furthermore, accuracy assessment is a process of comparing the classified results to any geographical data as reference that are assumed to be true (Richards, 1999). In this study, since there was no updated and validated and/or digital land use/cover map of the study area that would be used as reference data during the accuracy assessment, ground truth points were collected. A total of 300 points (30 points per land use/cover category) were collected through random and purposive sampling techniques. Random sampling technique was necessary to give every location or pixel the chance to become part of the sample while the latter was necessary to ensure that equal samples are collected for each land use/cover category. It was also ensured that the recorded land use/cover in a particular sampling location is the actual land use/cover when the Landsat TM image was acquired.

The collected points were encoded in MS excel format and saved as Windows formatted txt file. Using the import user-defined points option in the Classifier-Accuracy Assessment modules in Erdas Imagine software, this file was imported as ASCII point file. The reference values assigned to each corresponding geographic coordinates were referred to the ground survey data. These values were then compared to the class values of the corresponding locations in the classified image. The error matrix of the classification is shown in Table 3. The results showed that there were areas classified incorrectly for example, RW classified as SD; BS classified as AG; BU classified as RA; SF classified as AF and soon. The training sites developed for each category were believed to have contributed to this error when these training sites failed to completely delineate the spectral patterns for each land use/cover category being classified. Furthermore, it was observed that when using band combinations 4, 3, 2 and 3, 2, 1, several land use/cover categories had comparable color patterns for example, RW and SD; SF and AF and BU and RW.

The conceptual model: The conceptual model (Fig. 4) integrates GIS and MCE techniques in the suitability analysis for beekeeping sites in the province of La Union, Philippines using information ranging from ground truth to digital data. Basically, the model has three main steps such as database creation and management, spatial and multi-criteria analysis and validation process. More specifically, database and management include the collection of both primary and secondary data and preparation of thematic layers for analysis. Spatial and multi-criteria analyses involve assessment, prioritization and weighing of criteria, both factors and sub-factors and constraints. Likewise, it includes the determination of the consistency ratio based on experts knowledge and perceptions using AHP. Lastly, the model integrates a validation component that provides opportunity to determine the reliability of the suitability map based on assessments. Assessments may be done through but not limited to either one or combination of the following: project implementation; ground verification and using the existing projects honey yield data in validating the suitability map.

The standardization of factors to a continuous scale: The fuzzy concept was used to standardize the factors to a continuous scale. Standardization was needed to transform the disparate measurement units of the factor images into comparable suitability values (Eastman, 2006). The factors were standardized to a byte-level range of 0-255 in order to use fuzzy factors with the multi-criteria evaluation with 255 indicating the highest suitability. The experts knowledge of how suitability changes for each factor was used as a basis in the selection of parameter for this standardization. Specifically, since most of the bee plants currently grown in the Province do not grow well in higher elevation (for example >100 m asl) where temperature can drop below the minimum temperature for active honeybee foraging which is approximately 55°F (13°C), the elevation factor was standardized showing an inverse relationship with the suitability

Table 3: Error matrix of the land use/cover supervised classification

Classified data	Reference data BS	GL	RW	SD	SF	WB	AG	RA	AF	BU	Total	User's accuracy (%)
BS	23	1	1	0	0	0	1	0	0	0	26	88
GL	1	26	0	0	0	0	1	0	0	0	28	93
RW	1	1	25	2	0	0	1	0	0	1	31	81
SD	2	1	2	26	0	0	0	0	0	0	31	84
SF	0	0	0	0	27	0	0	1	2	0	30	90
WB	0	0	0	0	0	28	1	0	1	0	30	93
AG	1	1	1	1	0	1	26	0	0	0	31	84
RA	1	0	0	0	1	0	0	26	1	2	31	84
AF	0	0	0	0	2	1	0	1	26	0	30	87
BU	1		1	1	0	0	0	2	0	27	32	84
Total	30	30	30	30	30	30	30	30	30	30	300	
Producer's accuracy (%)	77	87	83	87	90	93	87	87	87	90		

Overall classification accuracy = 86.67%; Overall kappa statistics = 0.8519

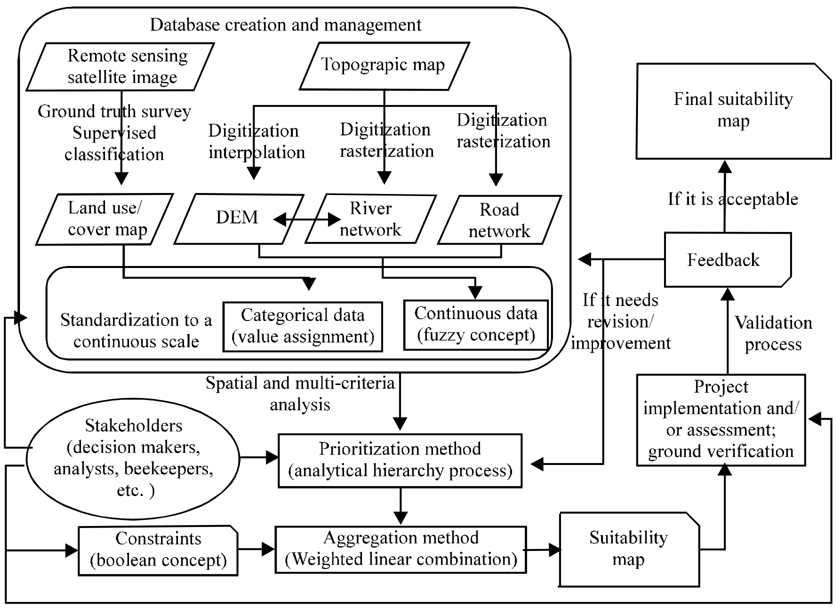


Fig. 4: The conceptual model

values. Good accessibility to water source is important because bees use water to cool their hives during hot weather and to dilute the honey for their own consumption during extreme conditions (BBKA, 2006). Likewise, access to a road is essential for better monitoring and evaluation of the beehives as part of the management routine. Thus, areas closer to these features were considered more suitable.

On the other hand, land use/cover factor was standardized using a different approach. Since it is a categorical set of data, the relative suitability of the different land uses/covers was scaled in the range of 0-255 by assigning suitability values based on experts knowledge and careful and fair judgment. Agroforest was given a value of 255 while agricultural area, secondary forest, residential area with gardens and grassland were given a value of 200, 150, 100 and 50, respectively. Other land uses/covers considered constraints were masked out. The main reason why agroforest was given the highest value is that it is the only land use that sustains the availability of nectar and pollen almost all year around. Agroforestry is a cropping system of growing agricultural crops and trees, be it forest or fruit trees, simultaneously or sequentially in a given piece of land. Trees during their blooming seasons augment the fallow periods in agriculture and vice versa.

Based on the floral calendar of Northern Luzon, Philippines (ATDC and FAO, 1997) not a single bee plant flowers continuously except for coconut with a relatively short flowering period gap and usually a main component in an agroforestry farm. On the other hand, there are more bee plants in the agricultural area than the rest of the land uses. Some produce flowers in different period stretching the period of availability of nectar and pollen, thus giving

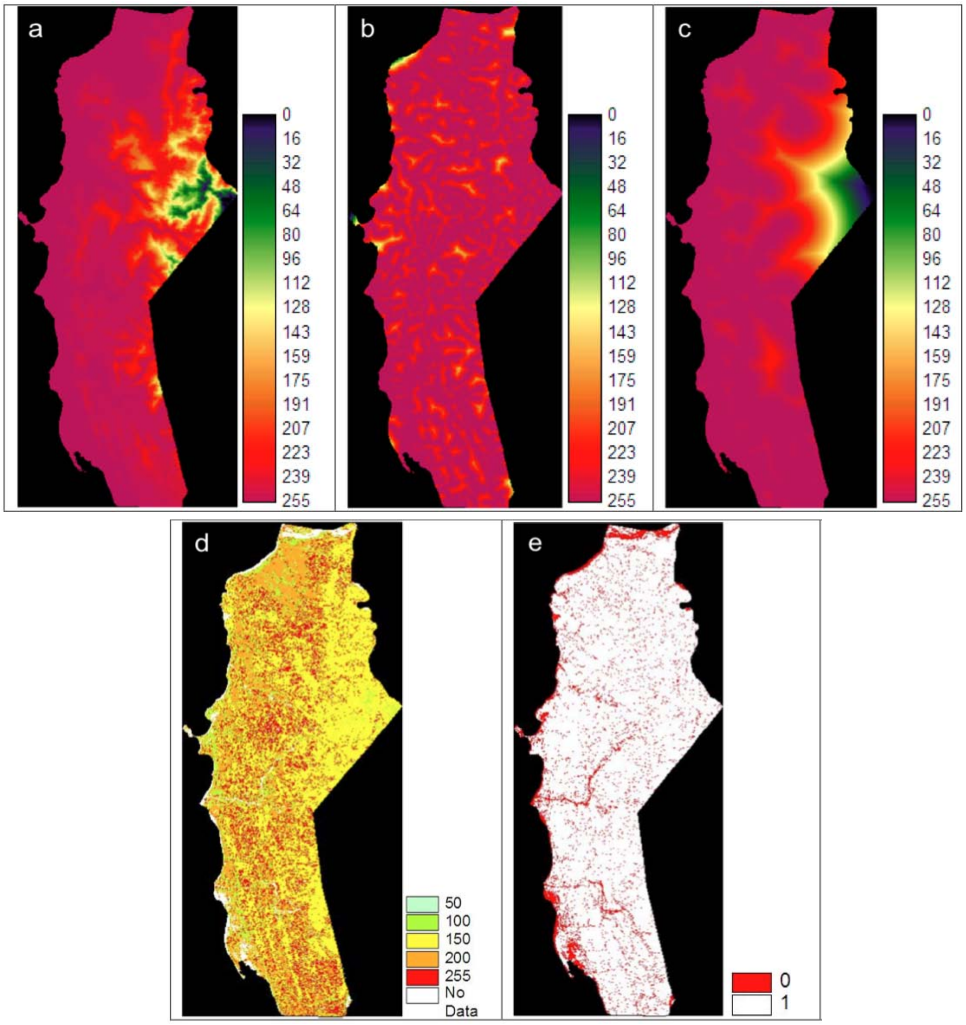


Fig. 5: The standardized factors (a) Elevation; (b) Distance to river; (c) Distance to road; (d) Land use/cover and (e) Constraints (Value = 0)

agricultural area the second highest value. The values of the rest of the land uses were also based upon the experts knowledge, the floral calendar and ground observation. The standardized factors are shown in Fig. 5.

The Analytical Hierarchy Process (AHP): Saaty (2008) described AHP as a theory of measurement through pairwise comparisons and relies on the judgments of experts to derive priority scales. Furthermore, AHP is a decision-making technique which is developed based on the inherent ability of people to make excellent decisions (Saaty, 1994). It allows the analysts and decision makers to explore all possible options to understand more deeply the underlying problems before a choice is made.

In this study, the development of a suitability map for beekeeping involves the consideration of a set of criteria that includes factors, sub-factors and constraints as shown in Fig. 6. AHP was used to determine the respective weight of each factor based on existing knowledge and information, deep understanding on the requirements and consistency of judgment based on preference.

Numerical values expressing the judgment of the relative importance (or preference) of one factor against another had to be assigned to each factor according to a comparison scale consisting of values ranging from 1-9 which describe the intensity of importance (preference/dominance) as suggested by Saaty and Vargas (1991) and Saaty (2008) as follows: 1-Equal importance; 3-Moderate importance of one factor over another; 5-Strong or essential importance; 7-Very strong importance; 9-Extreme importance; and 2, 4, 6, 8 are intermediate values. The experts opinions were necessary in assigning the weights of each criterion as well as the

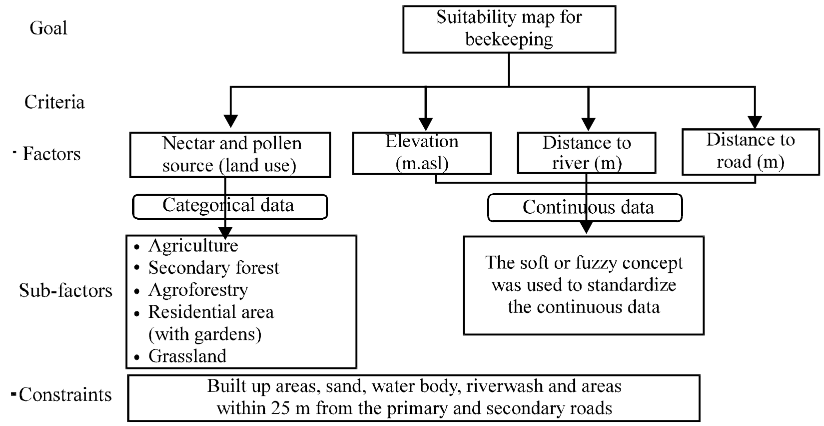


Fig. 6: Suitability analysis hierarchy for beekeeping

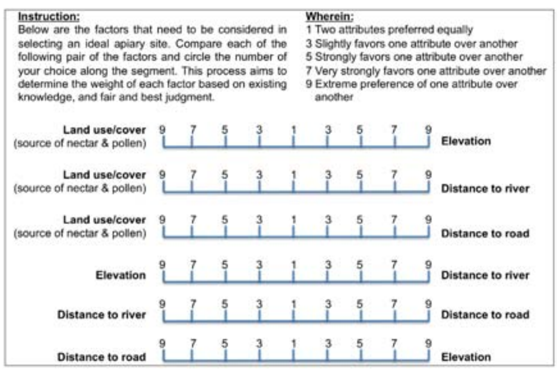


Fig. 7: The AHP format questionnaire

suitability values of each of the sub-criteria. Thus, a core group of decision makers composed of a beekeeping specialist, agriculturist, forester and analyst was consulted for this purpose to minimize bias. Figure 7 shows the questionnaire in AHP format used in the interview process. After a thorough deliberation, it was decided to come up with a consensus evaluation among the group.

The paired comparison matrix including the final weight of each of the criteria is shown in Table 4. The suitability map was produced using the standardized criteria and AHP weight following the WLC method as shown in Eq. 1. For better visual interpretation purposes, the map was further scaled into qualitative information using equal interval method as very high suitability, high suitability, medium suitability, low suitability and very low suitability (Fig. 8).

$$WLC = \left(\sum_{i=1}^{n} X_i \times W_i \right) \times C \quad (1)$$

Where:

WLC = Weighted Linear Combination

X_i = Decision parameters (factors and sab-factors)

Table 4: Paired comparison matrix

Factors	Land use	Elevation	Distance to river	Distance to road	Priority vector or weight
Land use	1	7	3	5	0.5650
Elevation	1/7	1	1/5	1/3	0.0553
Distance to river	1/3	5	1	3	0.2622
Distance to road	1/5	3	1/3	1	0.1175

Consistency ratio = 0.04<0.10 (acceptable)

W_i = AHP weight

n = Numbers of parameters (factors)

C = Constraints

The validation process: The objective of this part of the conceptual model is to determine how valid and convincing the suitability map really is? The suitability map can be validated in several ways. In this study, it was decided that the final suitability map be validated through a correlation analysis method involving the existing beekeeping projects honey yield data and the calculated suitability values.

In validating the suitability map, evaluating the honey yield production performance of the more established commercial scale projects is preferred to obtain a more scientific and reliable assessment. However, since beekeeping industry in the Province has just started several years ago such projects are not yet available especially during the conduct of this study. Recognizing this limitation, it was decided that the 12 available 3-5 years old, small-scale projects with an average number of colonies of 7 would be used. All of these projects raise *Apis mellifera* honeybee species. A ground survey was conducted in November 2008 to gather information about these projects. The main set of information gathered includes geographic locations, physical characteristics of the projects immediate surroundings, number of colonies per project, honey yield in kilogram and problems encountered. The survey was aided with GPS receiver. In order to assess the validity of the suitability map, geographic coordinates of every project were loaded into the GIS platform. This made it possible to do some spatial analyses like respective locations of the projects in the suitability map, proximity analysis (their distances to roads and rivers, elevations and land use/cover where the projects are established) and correlation analysis between honey yield and suitability index. Since the status of the land use/cover map is as of December 2004, the 2005 set of honey yield data was used in the analysis.

RESULTS AND DISCUSSION

The analytical hierarchy process result: The common evaluation derived from the AHP questionnaire was translated into a paired comparison matrix that is shown in Table 4. Factors in the left vertical column were compared with the criteria in the top row and the comparisons scored with the 1-9 system. A comparison was assigned a reciprocal score if the item in the left vertical column was preferred less than that in the top row. Each factor compared with itself results in a diagonal of 1s which means equal preference. The vector of normalized weights, summing to 1 was calculated to determine the final weight or influence of each factor.

The La Union suitability map for beekeeping: By using the above-mentioned AHP weights and WLC aggregation method on the thematic layers representing the factors and constraints, the suitability values for beekeeping in the province of La Union, Philippines were calculated and a map showing the spatial distribution of these values was produced (Fig. 8). The map also contains the geographic locations of the existing beekeeping projects used in the validation process (Table 5).

Both GIS and MCE showed their usefulness in dealing with the complexity of suitability mapping for beekeeping where a multifaceted set of guidelines had to be considered. By using the empirical conceptual model, the development and validation of the suitability map for beekeeping in the province of La Union, Philippines was successful. The inherent opportunities to invoke experts participation and the cyclical characteristic of the model have demonstrated its strengths towards achieving agreeable and acceptable results without compromising scientific standards.

The standardization of data to a common 0-255 continuous scale helped in the determination of suitability values of the areas where existing knowledge and information cannot justify any appropriate value or specific weight to be assigned. This was experienced particularly when the thematic layers of the continuous data like the DEM, distance to river and road were being

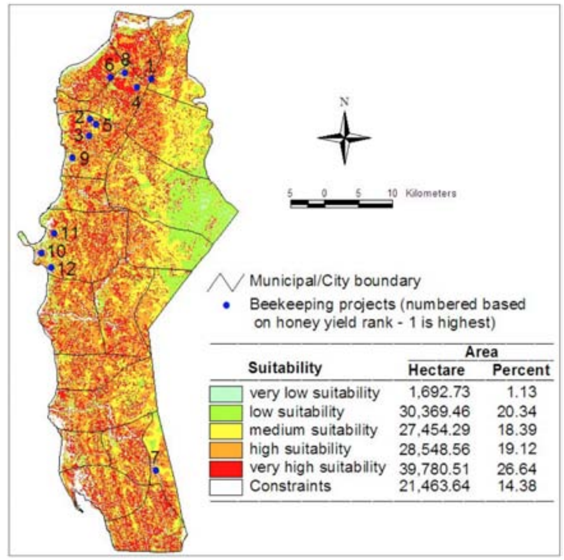


Fig. 8: The La Union suitabilty map for beekeeping

Table 5: The result of the validation using the 12 existing beekeeping projects

Rank based production rate[a]	Geographic coordinates UTM 51N) x	y	2005 Production rate (kg/colony)	(Suitability value where the project is located
1	229019	1862524	37.50	252.0000
2	220036	1856655	33.33	240.0000
3	219872	1854181	21.05	222.0000
4	226969	1861279	20.00	214.0000
5	220892	1855846	19.17	211.0000
6	223035	1862736	14.00	204.0000
7	229723	1804923	13.50	194.0000
8	225145	1863452	12.67	204.0000
9	217464	1850916	11.00	123.0000
10	212872	1836852	10.00	146.0000
11	214720	1839716	8.00	151.0000
12	214298	1834668	5.00	49.0000
Pearson product moment correlation coefficient, r between the production rate and suitability value				0.8010

[a]As shown in Fig. 8

prepared. The aggregation method used in this study, WLC, allowed retention of the variability from the continuous factors and made it possible to trade off with each other. For example, a low suitability value in distance to river factor for a particular area was balanced or counterweighed by a high suitability value in the distance to road and in the DEM factors. Furthermore, detailed examination of the suitability map and the land use/cover map revealed that although agroforestry was given the highest suitability value, this did not guarantee that all agroforestry areas had to have the same high suitability values. Likewise, this did not preclude other land uses like agriculture to be included and become part of the most suitable areas in the final suitability map. It was really a dynamic process since all factors came into play. The extent or degree of trade off however depends on the relative importance of each factor as defined by their AHP weights.

Although, areas under very high suitability class are the most ideal in the final suitability map, the acceptable limit of suitability still depends on the stakeholders decision. Nevertheless, the result of the validation process strengthened the suitability map. It must be pointed out however that the projects yield performance was used directly in the analysis without bringing into the analysis whatever management factors may have influenced each project. On the other hand, it was noticed that although the correlation is still far from perfect, the resulting suitability map is not that bad at all. Despite of this however, this does not necessarily mean that honeybees foraged only where the beehives were placed and where suitability values used in the correlation analysis were recorded. Honeybees might have flown to other places too. The distance of flight depends on the spatial variability and availability of nectar and pollen in the foraging landscape. According to Steffan-Dewenter and Kuhn (2003), foraging flight distance depends on the plant and floral density that generally provides the needed nectar and pollen for the honeybees. Thus, flight distance is shorter if there is high plant and floral density in a given area. BBKA (2006) mentioned, honeybees mostly forage for both nectar and pollen within a kilometer of their hive and up to about 5 km for exceptionally rewarding sources. Moreover, if within the foraging area nectar and pollen are scarce, bees are going to find suitable foraging patches (Naug, 2009). In the simulation study conducted by Ricketts *et al*. (2008) concerning the visitation rate of *Apis mellifera*, they determined that the rate decreased to 50% of its maximum between 2-4 km distances depending on the characteristic of the foraging area. In tropical areas where the landscapes are generally more diverse, visitation rates to farther distances are expected to drop more drastically than in temperate areas (Sande *et al*., 2009).

However, despite the fact that honeybees may fly to other places to forage, other advantage of knowing the location of the most suitable areas aside from good harvest is the inherent possibility and opportunity of minimizing the potential risk of absconding. Absconding usually happens when the foraging landscape is fragmented and there is a scarce source of nectar and pollen near the beehives that forces honeybees to increase their flight distance. Efficiency is another advantage. The shorter the distance honeybees fly in collecting nectar and pollen, the more efficient they are. The life expectancy of foraging bees may also be affected by foraging at extreme distances wearing out their wings and eventually affecting the efficiency of the colony. Thus, in order to really achieve these advantages, spatial contiguity of suitable areas is important in the final decision making process as to where beehives shall be placed. In this instance, the suitability map will be of great importance.

Looking at the suitability map, beekeeping can be recommended in the municipalities that have relatively good spatial contiguity of areas with very high suitability values like Rosario and Sto. Tomas in the southern most part of the province. These are in addition to the municipalities of Luna, Balaoan and Bangar in the northern part. However, having all these outputs is not adequate to guarantee immediate success of beekeeping promotion. The interest of the people to engage into this venture especially the poor farmers to whom this source of livelihood hopes to help more, remains a key factor toward a successful wide dissemination of beekeeping.

CONCLUSION

It is undeniable that when people try to make critical decisions, they are often caught in hard situations especially when there are various aspects that are inevitable to consider and when decision choices and alternatives are of equal importance. The advent of computer-based planning and decision-making tools like GIS coupled with MCE techniques not only provide relatively easier, faster and more scientific methods but also make decision makers, planners and end-users more confident in their decisions.

Despite of some limitations encountered in this study particularly on the unavailability of a detailed map of bee plants, this study successfully evaluated the suitability of the province of La Union for beekeeping. This made it possible through the empirical conceptual model used which integrates RS with GIS and MCE techniques. The empirical conceptual model not only invoked experts knowledge and participation and enhanced the decision-making capabilities but it also made the decision-making process dynamic while preparing the suitability map for beekeeping in the province of La Union. The relatively high correlation between the existing beekeeping projects honey yield data and the calculated suitability values has indicated some degree of reliability of the model used and the output produced. It believed that this study can provide significant and valuable experience that can be used as a basis in designing more complex conceptual model to be used in assessing the suitability of other areas for beekeeping in the future taking into consideration those limitations encountered in this study. In general, this study should be useful to those who are interested in GIS-based MCE techniques, suitability analysis and mapping and beekeeping.

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