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RESEARCH ARTICLE

Application of multicriteria decision analysis (MCDA) to apiculture potential assessment: A case study of Thiruvananthapuram Corporation, Kerala, India

B Pratheep Kumar[1], T K Prasad[2]

1 *Asst. Prof. of Geography, Govt. Arts and Science College Kulathoor Neyyattinkara, Thiruvananthapuram*
2 *Associate professor, Dept: of Geography Kannur University, Kerala*

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Abstract

Apiculture now emerged as an important segment of agriculture in rural as well as urban areas. The prompt identification of beekeeping suitability areas is strategic for maximizing productivity. The Analytical Hierarchy Process is a tool to support decision-making in the identification of suitable sites with utmost potential for various agricultural practices. This study tested a GIS based AHP tool to assess urban beekeeping suitability zones in Thiruvananthapuram Corporation, Kerala state. Furthermore, the study utilized data, which were completely retrieved from various public sector repositories. The resulting map indicates, over 65% of the land area of the corporation have a high or very high potential of apiculture. The map can also be utilized by Government agencies to implement various promotional measures and also the beekeepers to identify suitable sites for apiary location and relocation for maximizing their profit. The study also created a model for utilization of public data domains for decision making, using GIS.

Keywords: Apiculture; multi-criteria decision analysis; GIS; AHP classification

Introduction

Apiculture is an important allied activity of agriculture in rural as well as urban and peri- urban areas. It now emerged as an additional income generating option for the urban poor. The word 'apiculture' comes from the Latin word 'apis' meaning bee. So, apiculture or beekeeping is the care and management of honey bees for the production of honey and the wax. In this method of apiculture, bees are bred commercially in apiaries, an area where a lot of beehives can be placed. Apiaries can be set up in areas where there are sufficient bee pastures – usually areas that have flowering plants. Honey bees are significantly important for the biological environment and to the economy. However, studies suggest that, there are substantial decline globally, leading to serious risk to the stability and productivity of food crops. Considering the ecological services provided by honeybees and the wide economical aspect of

honey production, Beekeeping has enormous potential today(Paolo Zoccali et.al 2014). Beekeeping provides key ecological roles pollinating a wide range of crops, with a global value of 153million dollars (Biressaw Serda et.al 2014, J.S Mcclavor 2004). Bees are mainly reared for their honey. Besides that, we also obtain bees wax through beekeeping. Bees produce honey from the sugary secretions of plants. Although honey is an important ingredient in many food dishes, beeswax holds a lot of commercial significance too. It is used in the cosmetic and medical industry, as well as a coating for cheese, and as a food additive. It is also used as the main component for making candles, preparing polishes for the shoe, furniture, etc. Furthermore, honeybees also provide honey and other apiculture products such as bee pollen, bee wax, bee venom, propolis and royal jelly (Kevin S Mettleson, 2008).

Honey bee behaviors are the same whether they belong to a rural or an urban location. Beekeeping practices are identical in the urban environment as in the rural one, but the emphases on certain aspects are critically important. The most important thing is to be aware of are good – tempered bees, swarm control, neighboring people and health and safety. Apiculture continue to be a minor cottage industry in India, because of the poor scientific support and infrastructure extended to this industry. The potential for gainful employment and income generation from beekeeping in urban areas is yet to be tapped to its capacity (Nair Maya C, 2010).

India is known as the land of honey. Beekeeping is still operating in the old traditional ways in India, indicating the need for modernization. Low productivity and poor quality of bee products are the major economic constraints for rural as well as urban bee keepers, however they face another primary economic concern i.e., lack of skill to manage their bees and bee products (Klein A.M et.al, 2007). Apis cerana are found across the breadth and range of the country. There are rural beekeepers in the high mountains of the Himalayas who keep log hives in house walls and revetments. Beekeeping with this species is a traditional industry in West Bengal and some North-Eastern states like Arunachal Pradesh and Sikkim. In the central parts of the country honey yields are substantial from Apis dorsata, primarily due to good forest patches in and around sanctuaries and protected areas. The mangrove forests of the Sunderbans are an excellent habitat for *Apis dorsata*. The entire southern region is rich in *Apis dorsata* populations—contributing to a large share of the total Indian honey market. The hills of Mahabaleshwar located in Maharashtra were the pioneering areas for beekeeping training and experiments. In Andhra Pradesh, farmers and honey hunters in the hills of the Eastern Ghats collect honey. In Karnataka and Tamil Nadu there is a strong tradition of beekeeping with *Apis cerana*. Areas such as Coorg in Karnataka and Marthandam in Tamil Nadu are famous for their beekeeping culture.

According to the estimation of KVIC, India, the total production of the country is 70000MT's honey which values 770 crores, involving 2.5lakh beekeepers (www.kvic.org). The tropical ecosystem of kerala has rich biodiversity with abundant scope for natural products. Kerala is one of the largest honey producing state in India, but the inferior quality has reduced price of Kerala honey in Indian market (Nair Maya C, 2010). The major bee species used in Kerala are Apis Cerana and *Apis Mellifera*. A colony consists of a queen, 20,000 to 30,000 workers and a few drones. This species is with gentle temperament and responds to smoking. Lack of flora leads to absconding and also has a strong tendency for swarming. Presently the bee keepers in Kerala depend mainly on rubber, coffee like monoculture plantations for bee foraging. Present study is an attempt to identifying Apiculture potentials of Thiruvananthapuram from a geographical perspective. The study highlights the model for utilization of public data domains for decision making using GIS.

Literature Review

Quinn S. Mc Frederic et al. documented how the bee community in San Francisco has responded to urbanization. They sampled bees in fifteen urban parks and two nearby wild parks, and used multiple regression analysis tool to determine which characteristics predicted bee abundance and species richness. Kevin C Mattleson et.al (2007) identified the richness, abundance and ecological characteristics of bees in community gardens located in heavily developed neighborhoods of Bronx and East Harlem in Newyork. According to the study, despite their small size and location within highly urbanized areas, urban community gardens harbor a diverse assemblage of bees that may provide pollination services.

Ronald C. Estoque et.al (2011) employed GIS and MCE techniques in the suitability analysis of beekeeping sites in La Union, Philippines. An empirical conceptual model has been developed comprising database creation and management, spatial multi – criteria analysis and validation process. Final suitability map was validated through correlation analysis of existing honey yield and calculated suitability values. A GIS based multi criteria decision making land suitability analysis were performed by Bakhtiar feizizadeh et.al (2012) for assessing the optimal utilization of land resources for agricultural production in Tabiz country, Iran. An AHP was used to rank various suitability factors and resulting weights were used to construct the suitability map layers.

Malede Birhan et al. (2015) assessed the challenges and opportunities of beekeeping in and around Gondar, Ethiopia. Primary data were collected through structured questionnaires. Both qualitative and quantitative data were interpreted by descriptive statistics. The study found out

the untapped beekeeping potential of the area, and the major challenges that hinder its development. J.S Maclavor et.al (2014) investigated how different landscapes influence foraging decision, and whether habitat alteration such as that resulting from urbanization, influences large scale foraging activities of bees. Sampling tests were conducted in urban parks and gardens. A cross sectional study by collecting data using questionnaire survey to understand the practices, production potential and the challenges of beekeeping in Haramaya district Eastern Ethiopia were done by Biressaw Serda et.al 2015. The study revealed decreasing colony population from time to time due to destruction of forests and excessive use of insecticides, predators and bee diseases. Rware H.I investigated the need for an integrated approach to beekeeping in the arid and semi-arid lands of Kenya. The study suggests a sustainability model by integrating improved beekeeping technology and natural resource development.

Paulo Fernadez et.al (2016) applied multi criteria decision analysis tool to support decision making in the identification of beekeeping potential of different regions of Montesinho Natural Park in Portugal. The MCDA analysis produced land suitability map showing apiaries location or relocation by avoiding prohibited areas. The applications of Fuzzy logic in problem solving tasks were tested by Paolo Zoccali et.al (2017) for assessing beekeeping suitability of Mediterranean lands. As part of the analysis five criteria's were selected and weightages were given. Along with environmental data, the Fuzzy overlay produced beekeeping suitability map. All the data required for the analysis were collected from public repositories.

Study area

The study area is in the administrative limits of Thiruvananthapuram city corporation (Fig.1), which is located in southern Kerala between 8°21′38" to 8°36'33" North latitude and 76°51′50" to 77°1′22" East longitude. The total area is approximately 204. 57 sq.km. The average annual rainfall varies from 150 to 200 cms. The region is characterized by four seasons, southwest monsoon (June to September), North East monsoon (October to November), winter (December to February) and pre monsoon (March to May). The elevation ranging from 0 to 160 metres above mean sea level. The average rise of land is 27 meters for every kilometer from the coastline towards east and relief amplitude increases with rise in altitude. Abrupt rise of the mountain range Western ghats from 100m upward with precipitous slope is a characteristic feature of Kerala's topography that controls hydrology, climate, land use, infrastructural development and settlement (Srikumar Chattopadhyay et.al, 2013).

Objectives

To identify economically viable sites for practicing beekeeping in Thiruvananthapuram Corporation. To identify the various favoring and constraining factors of apiculture in the study area. Creating a model for utilization of public data domains for decision-making using GIS.

Fig. 1. Study area

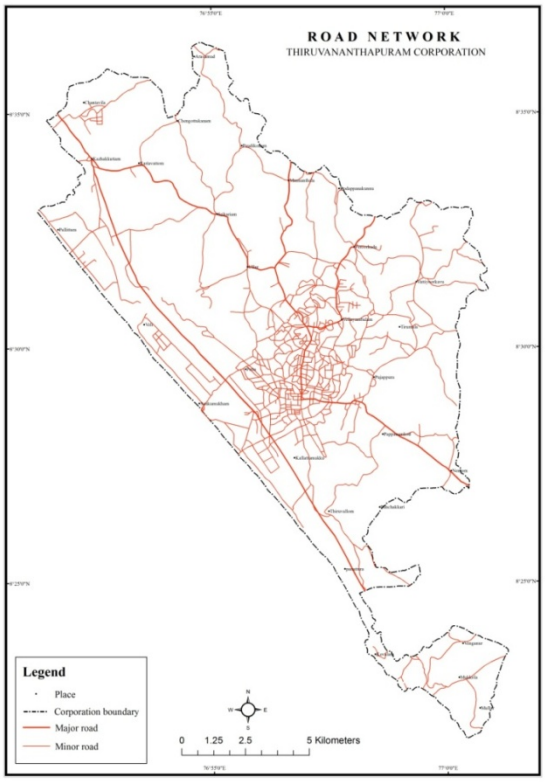


Fig. 2. Road network

Data and Methods

The beekeeping activity in a region is closely subjected to environmental factors. The preliminary literature search and consultation with experts helps to identify five key factors namely Temperature, Fresh water sources, Transport accessibility, Nectar/pollen resource potential of the area and Electromagnetic radiation sources are positively or negatively influencing beekeeping activity in urban centers. Temperature is generally slightly higher in a built – up area compared with the open country side giving the bees an earlier and longer season for foraging (Claire et.al, 2016). A temperature map was constructed by spatial interpolation of temperature data obtained from the open government data platform-India. As it is a small stretch of land no significant variation in temperature noticed spatially. The moderating effect of sea brings the mean annual temperature of the area at 27°c with an annual range of 2°c, most ideal and a positive relationship between temperature and beekeeping suitability is observed.

Roads represent a critical factor for beekeeping (Fig.2). Indeed, the distance of a certain area from roads influences directly its suitability to hive transportation and implementing emergency safety measures and manipulations such as swarm control (Paolo Zoccali et al. 2014). The road network map had been obtained from the web GIS services of Kerala state land use Board. Land parcels close to the road except major highways are considered as most appropriate for beekeeping.

Bees are living creatures and, as such, need water. A constant source of fresh water is needed near the apiaries. Sites near the ponds, lakes, streams and rivers are ideal for beekeeping and assigned higher values in the analysis process. Fig. 3 and 4 portray the drainage and land utilization in the study area respectively.

Bees are very adaptable and can live equally successfully in urban and rural situations. However, to do so, they need suitable and sufficient forage within flying distance of their hives (Claire et al., 2016). Along with various agricultural land uses, urban recreational parks are excellent foraging grounds. The data regarding land uses had also been obtained from the WebGIS services of KSLUB (Fig.4). Based on the potential availability of pollen and nectar each land use classes were given a specific pollination value by relying on expert's knowledge.

Increase in the use of electronic gadgets has led to electro pollution of the environment (Ved Parkash Sharma et.al 2010). On the basis of widely reported influences on honey bee behavior and physiology electromagnetic field is emerging as a potent factor (Carlo.G, 2007). Colony Collapse Disorder (C.C.D) is a new phenomenon of sudden disappearance of bees with little sign of disease or infection is attributed by the memory loss of the bees to return to the hives. The path of CCD in India has followed the rapid

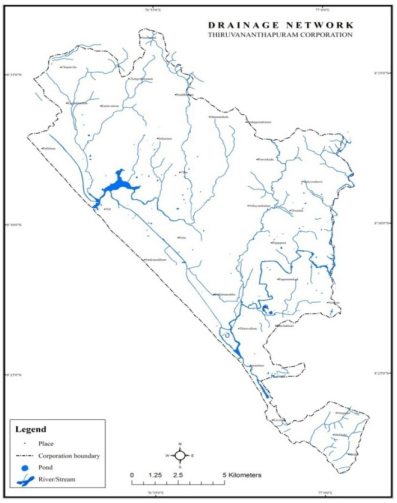


Fig. 3. Drainage network

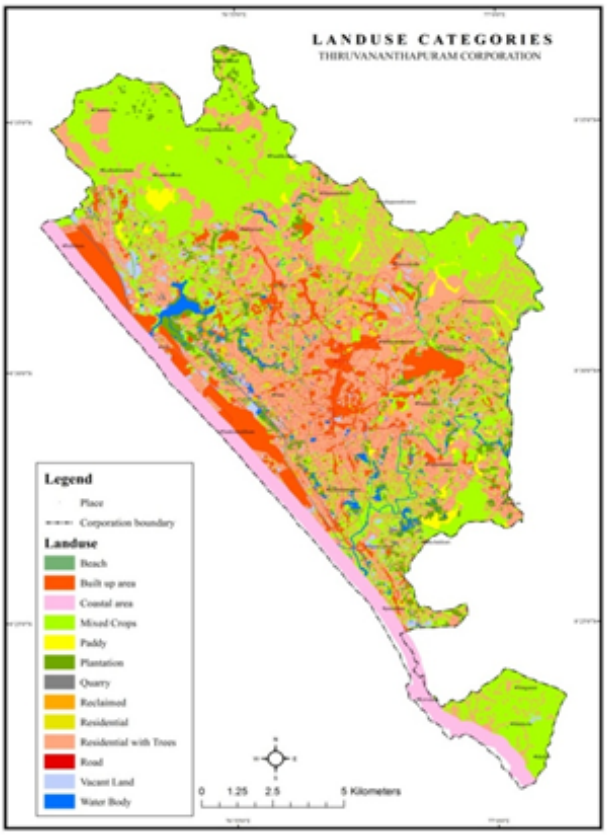


Fig. 4. Landuse categories

Table 1. Data sources

Data	Source
Climatic data	Open government data platform - India https://data.gov.in/node/394701/download
Land use data	LRIS, kerala state
Hydrographic data	www.kslublris.com/lris/kerala/district:php
Road network data	
Radiation source data	Primary GPS survey

development of cell phone towers, which cause atmospheric electromagnetic radiation pollution. For the analysis the location of 60 mobile towers in the study area have been collected through GPS surveys and interpolated as a thematic map layer (Fig.5).

The present study adopted a GIS based Analytic Hierarchy Process classification technique for delineating beekeeping suitability zones. The AHP multi criteria decision-making combines various spatial sets according to the value judgments in to a final decision (Paulo Fernandez et.al).

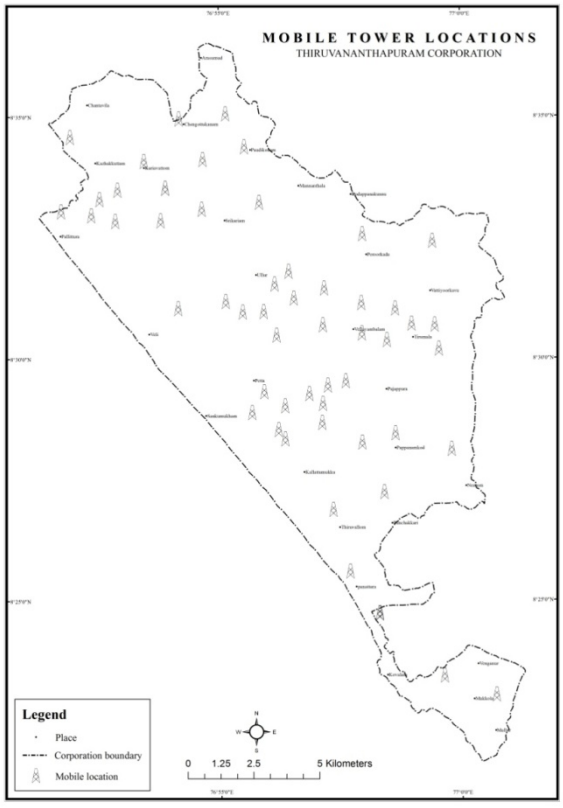
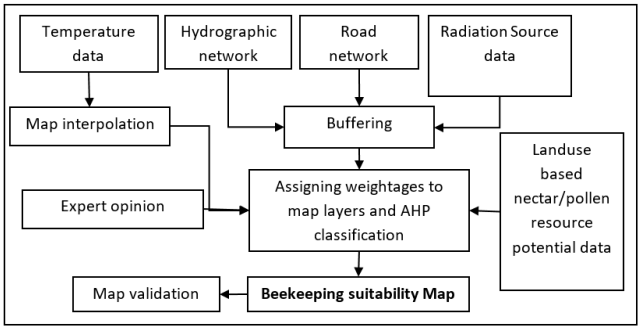


Fig. 5. Mobile network towers

Results and Discussion

Urban beekeeping is gaining importance all over the world due to the increasing demand for honey and other beehive products. It has immense potential in supporting urban agriculture production by providing pollination services. Apiculture now emerged as an important segment of agriculture in rural as well as urban areas. The prompt identification of beekeeping suitability areas is strategic for maximizing productivity. The Analytical Hierarchy Process is a tool to support decision-making in the identification of suitable sites with utmost potential for various agricultural practices. This study tested a GIS based AHP tool to assess urban beekeeping suitability zones in Thiruvananthapuram Corporation, Kerala state. Furthermore, the study utilized data, which were completely retrieved from various public sector repositories.

The different criteria's selected for the study were measured on different scale and a standardization bringing their preference value in to a 0 - 4 scale performed before combination. Buffer analyses have been performed for road, radiation source and hydrographic networks and were given weightages according to its favoring and constraining aspect to beekeeping. All the land parcels thus receives a specific weightage with respect to selected criteria. The AHP compares criteria pair wise and then computes overall relative weights based on aggregate calculations of all pair wise ratios (D.Schmoldt et al. 2001).



This study adopted a GIS based AHP classification technique for delineating beekeeping suitability zones (Fig 6). The aggregate AHP values range from 0 to 15. The land suitability was grouped in to five classes.

Not suitable (0 – 3): Representing the areas where beekeeping is not possible.

Less suitable (4 – 6): Representing the areas where beekeeping possible but economically not viable.

Moderately suitable (7 – 9): Beekeeping activity starts to be economically viable. Suitable (10 – 12): Beekeeping activity

Table 2. Different criteria and their preference values for the AHP classification

Urban built up land	Water bodies	Nectar/pollen potential	Radiation source	Road network
CBD/ built up within 2000 mts of major high ways 0	Within 500 mts buffer 4	CBD/wasteland/ Quarry/Beach/ Coastal area 0	Within 500 mts buffer 0	Metalled / unmetalled roads within 500 mts buffer 4
High concentration 0	500 -1000 mts 3	Paddy/ reclaimed paddy land /residential/ residential with trees 2	500 – 1000 mts 1	500 -1000 mts 3
Medium concentration 1	1000 -2000 mts 2	Plantation crops 3	1000 – 2000 mts2	1000 – 2000 mts2
Low concentration2	2000 mts and above 1	Mixed agricultural crops/ Urban parks 4	2000 mts above 3	2000 mts above/ 1

economically viable.

Highly suitable (13 – 15): Bee keeping activity is economically viable and the production reaches the highest values.

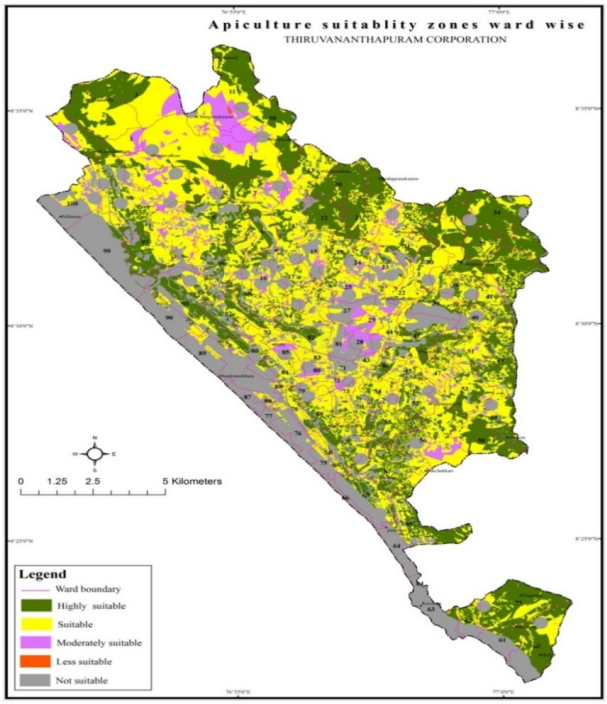


Fig. 6. Apiculture suitability zones

The study revealed the potential areas of beekeeping in Trivandrum Corporation, given that 67.72% of the surface area has high or very high suitability for beekeeping. Plantation such as rubber and coconut and mixed crop vegetation represent the principal land use for high and very high classes. Due to the presence of cultivated plants and plantation crops, abundant nectar and pollen resources are available in these areas. Furthermore, these areas are well-connected with roads; abundant supply of fresh water, distant from electromagnetic pollution, and a suitable temperature range of

Table 3. Thiruvananthapuram corporation: Suitable zones of Apiculture

Suitability level	Surface area (sq.km)	Surface area (%)
Highly suitable	62.03	30.32
Suitable	77.04	37.75
Moderately suitable	8.80	4.30
Less suitable	0.05	0.02
Not suitable	56.65	27.0

27° to 35°c make it ideal for year round apiculture practices.

Around 27.02% of the study area is not suitable or less suitable for beekeeping. The CBD and its surrounding high populated zones, long stretch of sandy beach, areas covered by extensive water bodies, wastelands, etc have very limited nectar/ pollen potential as such it is unsuitable for apiculture. The study also revealed that a significant stretch of land become not suitable for apiculture purely due to its proximity to Radiation sources such as mobile towers.

The ward wise analysis reveals that, of the 100 administrative wards, nearly 25 wards, located at the fringes of the city adjoining the villages have high potential in apiculture. The validation of the map also shows the presence of traditional beekeepers in these areas. An inner circle of wards nearly 26 satisfies the suitability conditions of beekeeping. Nearly 30 wards in the corporation have moderate potential and 19 wards are not suitable for apiculture.

Conclusion

The study formulated a model of utilization of public sector data repositories and web services of public bodies for effective decision-making using GIS. Moreover, the utilization of public data domains allows this model to apply on a wide variety of agricultural ecosystems. The apiculture potential of Thiruvananthapuram Corporation is more on its eastern fringes and provides ample scope for development. Training on improved beekeeping technologies, conservation of traditional bee species, disease control, community participation,

export based processing and marketing are some of the measures that can be implemented for the benefit of apiculture in the area.

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