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Application of Multi-Criteria Decision Analysis (MCDA) to apiculture potential assessment: A case study of Thiruvananthapuram Corporation, Kerala, India

Pratheep Kumar. B* and T. K. Prasad, Kerala

Abstract

Apiculture has now emerged as an important segment of agriculture in rural as well as urban areas. The prompt identification of potential beekeeping suitability areas is vital for maximizing productivity. Analytical Hierarchy Process (AHP) is a tool to support Multi-Criteria Decision Analysis (MCDA) in identifying suitable sites with maximum potential for various agricultural practices. This study tested a GIS-based AHP tool to assess urban beekeeping suitability zones in Thiruvananthapuram Corporation in Kerala State, utilizing multiple public sector repositories. Our analysis indicates that over 67% of the land area of the corporation has a high or very high potential for apiculture, while 27% of the corporation area is not suitable or less suitable for beekeeping. Our inferences can be used by government agencies to implement various apiculture promotional measures and the beekeepers can use it to identify suitable sites for apiary location and relocation to maximize their profit. Using GIS tools, the study also created a model to utilize public data domains for decision-making.

Keywords: *Apiculture, Multi-criteria Decision Analysis (MCDA), GIS, AHP classification*

Introduction

Apiculture is an important allied activity of agriculture in urban, peri-urban and rural areas. It has now emerged as an additional income-generating option for the urban poor (AAFRD., 2000). The Latin word apis is the genus name of the Bee, and 'apiculture' refers to the scientific and systematic practice and management of honey bee rearing for the production of honey and wax. In commercial beekeeping, apiaries are placed conveniently by identifying suitable foraging grounds with enough bee pastures. Honey bees are also important for the biological environment and also to the economy (Patel et al., 2021). However, several studies suggest a substantial decline of honeybee population globally (Neumann and Carreck. 2010; Potts et al., 2010), leading to a severe risk to the stability and productivity of food crops.

Economic benefits generated by apiculture and its various ecological services have immense potential today (Zoccali et al., 2014). Beekeeping is an allied activity of agriculture. It provides pollination services to various crops, thereby increasing crop production, and is mutually beneficial. In economic terms, the global value of pollination services offered by beekeeping stands as high as 153 million dollars (Serda et al., 2014; Mcclavor., 2004). Bees are mainly reared for their honey, and the wax obtained

through processing is also economically beneficial. Bees produce honey from the sugary secretions of plants. It is the main component of the cosmetic industry and also has medicinal values. Bee wax is used as the main constituent for making candles and polishes for wood and leather. Apiculture byproducts such as bee pollen, bee venom, propolis, and royal jelly have a high demand for manufacturing medicines (Mettleson., 2008).

Honey bee behaviors are the same irrespective of their rural or urban location. Similarly, beekeeping practices are also identical in urban and rural environments, but the emphases on certain aspects are critically important. The most crucial aspect to be aware of are: good – tempered bees, swarm control, human settlement, health, and safety of neighboring people. (Claire et al., 2016). Apiculture continues to be a minor cottage industry in India due to 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., 2010).

India is known as the land of honey. But beekeeping is still operating in traditional ways, calling for urgent modernization. Low productivity and poor quality of bee products are the major economic constraints for rural and urban beekeepers. However, they face another primary economic concern i.e., the lack of skill to manage their bees and bee products (Klein et al., 2007). *Apis cerana* and *Apis dorsata* are the two species of honeybees found across the length and breadth of India. Rearing of these species has become a traditional industry in West Bengal and some north-eastern states. The high mountain regions of the Himalayas provide good foraging grounds, where rural beekeepers place log hives in house walls and revetments to produce a sizable amount of good quality honey. The flora nearby the reserved and protected forests in central India and the deltaic regions of Sundarbans have high pollen and nectar potential, and honey yields are substantial from *Apis dorsata* species. In southern India, east and west of the Western Ghats and its foothill zones are most favourable for *Apis dorsata* populations, holding a significant share of the total Indian honey market. The Mahabaleshwar hills of Maharashtra are famous for beekeeping training and experiments. Collecting wild honey from forests and rocky cliffs of Eastern Ghats is a common practice in Andhra Pradesh. *Apis cerana* is the common species found in Karnataka and Tamil Nadu. Areas such as Coorg in Karnataka and Marthandam in Tamil Nadu are famous for their beekeeping culture.

According to estimation by the Khadi and Village Industries commission India, the country's total production is 70000 MT's of honey, which values INR 7700 million, involving 250000 beekeepers (www.kvic.org). The tropical ecosystem of Kerala has a rich biodiversity with abundant scope for natural products. Kerala is one of India's largest honey-producing states, but the inferior quality has reduced the price of Kerala honey in Indian market (Nair., 2010). The major bee species used in Kerala are *Apis Cerana* and *Apis Mellifera*. These species are characterized by gentle temperament and good responds to smoking. A typical bee colony consists of a queen, 20,000 - 30,000 workers, and a few drones. Lack of flora in the foraging area leads to absconding and has

a strong tendency for swarming. Presently the beekeepers in Kerala depend mainly on rubber and coffee monoculture plantations for bee foraging.

Literature review

The present study attempts to identify the apiculture potential of Thiruvananthapuram urban area from a geographical perspective. The assessment of the beekeeping potential of a region involves the assemblage of different physico–cultural parameters with varied weightages. In this regard, many GIS techniques for criteria-specific weighted analysis have been developed and tested by researchers worldwide. Mc Frederick., (2006) has documented the bee communities' response to urbanization in San Francisco city. Multiple regression analysis proved to be a good statistical tool in predicting bee abundance and species richness. Similarly, Matteson et al., (2007) identified bees' richness, abundance, and ecological characteristics in community gardens located in the neighborhoods of the Bronx and East Harlem in New York. The urban community gardens nurture a diverse cluster of bees that may provide pollination services.

Estoque et al., (2011) employed GIS-based Multi-Criteria Evaluation techniques in the suitability analysis of beekeeping sites in La Union, Philippines. Their research developed an empirical conceptual model comprising database creation and management, spatial multi-criteria analysis, and its validation. A GIS-based multi-criteria decision-making land suitability analysis was performed by Feizizadeh et al., (2012) to assess the optimal utilization of land resources for agricultural production in Tabiz country, Iran. The same technique was used in categorizing suitable land parcels for cotton farming in the semi-arid region of central India by Karthikeyan et al., (2019). They used an analytical hierarchy process to rank various suitability factors, and resulting weights were used to construct the suitability map layers. The MCDA-AHP technique's viability in reaching accurate results in land resource management, were utilized by Chowdari et.al., (2013) for prioritization of micro watersheds in the Mayurakshi watershed in India and Kumari et.al., (2020) in extracting fire risk zones in Palamu tiger reserve, Jharkhand state, India.

While assessing the challenges and opportunities of beekeeping in and around Gondar, Ethiopia, Birhan et al., (2015) applied descriptive statistics for interpreting qualitative and quantitative data collected through structured questioners. The study found out the untapped beekeeping potential of the area and the major challenges that hinder its development. Mcclavor et al., (2014) are of the opinion that empirical data based on field observations are inevitable to investigate the influence of different landscapes in the foraging decisions and whether habitat alteration resulting from urbanization influences the activities of bees. A study by Serda et al., (2015) to understand the practices, production potential, and challenges of beekeeping revealed a decreasing colony population over time due to the destruction of forests and excessive use of insecticides, predators, and bee diseases in the Haramaya district of Eastern Ethiopia. Rware., (2005) investigated the need for an integrated approach to beekeeping in Kenya's arid and semi-arid lands and suggested a sustainability model by integrating improved beekeeping technology and natural resource development.

Identifying the potential sites for optimum production seems to be a good management practice. Fernadez et al., (2016) applied the MCDA tool to support decision-making by producing a land suitability map that shows apiaries' location or relocation by avoiding prohibited areas in the Montesinho Natural Park in Portugal. The applications of Fuzzy logic in problem-solving tasks were tested by Zoccali et al., (2017) for assessing the beekeeping suitability of Mediterranean lands.

The MCDA technique, based on weighted thematic layers, can be dependable to the maximum extent and have many potential applications in land resource management at the national, regional, and local scale. Promoting urban agriculture activities becomes a suitable option for maintaining the sustainability of urban livelihood. Thiruvananthapuram urban area provides some favourable physical and cultural factors for apiculture to thrive, and no studies were so far undertaken to identify the potential zones of beekeeping

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″ N latitude and 76°51′50" to 77°1′22" E longitude. The city corporation has an approximately 204.57 km^2 area with a particular NW – SE orientation parallel to the coast. The general elevation of the area is from the mean sea level to 160 m.

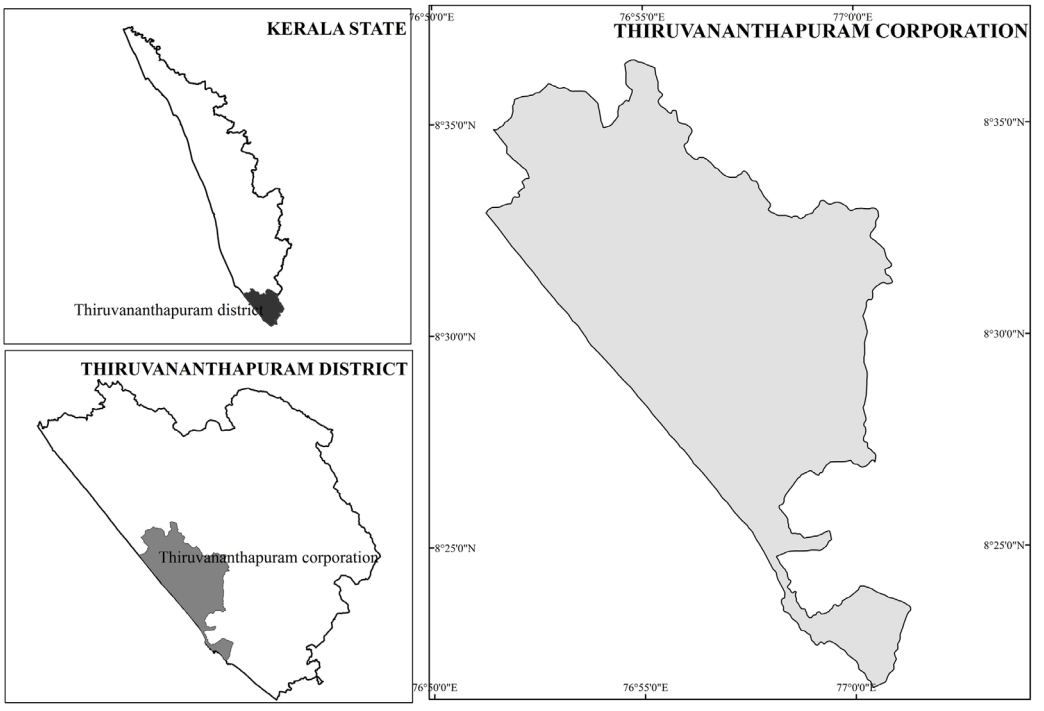

Fig. 1: Location of Thiruvananthapuram Corporation

The region comes under three geomorphic units: the coastal plain, the low rolling terrain, and the moderately undulating terrain with a slope ranging from 1– 15°. The average rise of the land is 27 meters for every kilometer from the coastline towards the east, and relief amplitude increases with the increase in altitude (Chattopadhyay et al., 2013).

The seasonal variations of weather pattern are not well pronounced in this region compared to other parts of the country because of its maritime location. The average annual rainfall varies from 150 to 200 cm. The summer monsoon, locally called *Edavappathy*, from June to September and retreating monsoon called *Thulavarsham* from October to November are the two prominent rainy seasons. The Karamana river originating from the Western Ghats along with its tributaries, forms the major drainage network. The presence of a large number of ponds represents the increased groundwater potential of the area. The coastal plains and river valleys are extensively used to cultivate coconut, tapioca, paddy, tuber crops, plantains, and vegetables. The rise of the mountain range, the 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 (Chattopadhyay et al., 2013).

Objectives

The main objectives of the research are:

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

Data and methods

Table 1 provides the types of data used in this study and its source. The beekeeping activity in a region is closely associated with environmental factors. The preliminary literature review and consultation with entomology expert help us to identify five key factors that are important in beekeeping activity in urban centers: temperature, freshwater sources, transport accessibility, nectar/pollen resource potential, and electromagnetic radiation sources.

Temperature is generally slightly higher in a built-up area than the open countryside, giving the bees an earlier and longer season for foraging (Claire et al., 2016). A temperature map was prepared by spatial

Table 1: Data sources

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

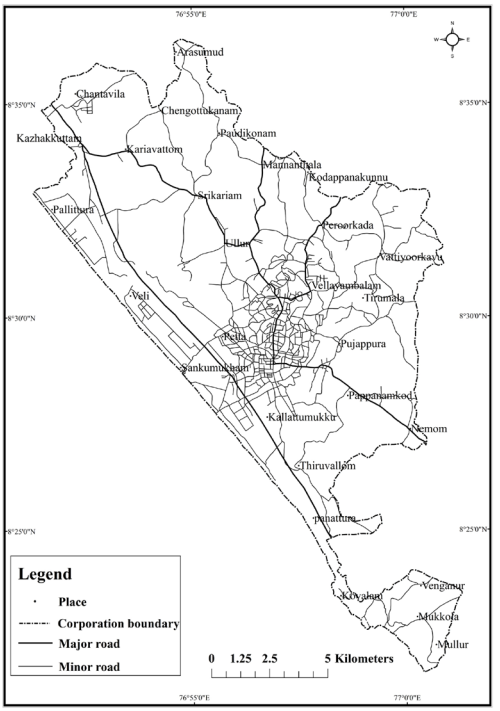

Fig. 2: Major and minor road network in the corporation area

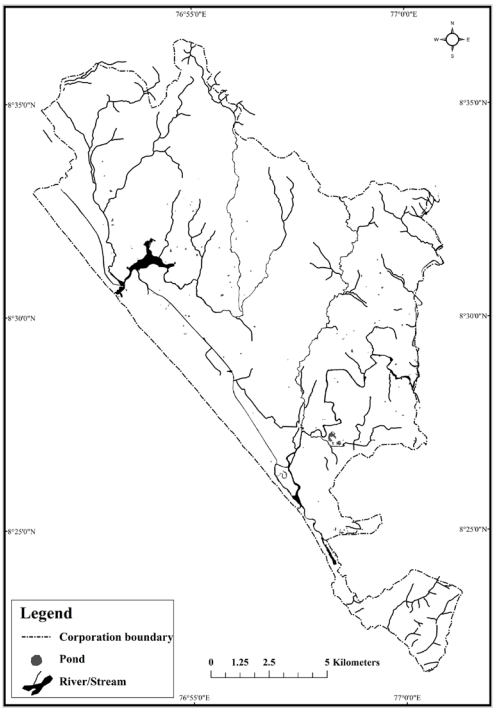

Fig. 3: Drainage Network and other fresh water sources

interpolation of two stations temperature data obtained from India's open government data platform (not shown). As it is a small stretch of land, no significant spatial variation in temperature is noticed. Considering the ubiquitous temperature distribution, we limited the analysis to the other four factors to determine beekeeping suitability. The moderating effect of the sea brings the mean annual maximum temperature to 32°C and mean annual minimum temperature to 24°C with an annual range of 8°C (Natural resource data bank, Thiruvananthapuram. 2013), most suitable for beekeeping activity.

Roads represent a critical factor for beekeeping (Fig. 2). The distance of a particular place from roads directly influences its suitability to hive transportation and implementing emergency safety measures and manipulations such as swarm control (Zoccali et al., 2014). The road network map has been obtained from the Kerala state land use board's web GIS services. 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 freshwater is required near the apiaries. Sites near the ponds, lakes, streams, and rivers are ideal for beekeeping and assigned higher values according to its distance from the water body in the analysis process (table 2). Figures 3 and 4 portray the drainage and land utilization in the study area, respectively.

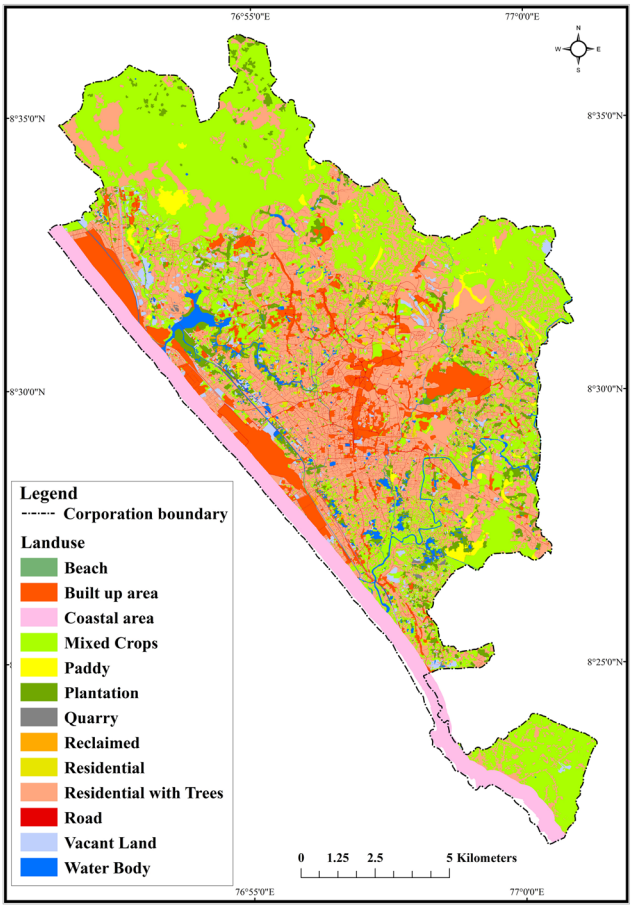

Fig. 4: Land use categories in the corporation Area

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 use has been obtained from the WebGIS services of the Kerala State Land Use Board (Fig. 4). Assigning weightages to land use classes poses a cartographic problem, as it needs to evaluate each land-use class's pollen and nectar potential. Hence, we consulted entomology experts from the Kerala Agricultural University to fix the specific pollination value for each land use class based on pollen and nectar's potential availability (Table 2).

The increased use of electronic communication gadgets leads to electro-pollution of the environment (Sharma et al., 2010). The electromagnetic field is emerging as a potent factor based on widely reported influences on honey bee behavior and

Table 2: Criteria's 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 mts	2	1000 – 2000 mts	2
Low concentration	2	2000 mts and above	1	Mixed agricultural crops/ Urban parks	4	2000 mts above	3	2000 mts above/	1

physiology (Carlo., 2007). Colony Collapse Disorder (CCD) is a new phenomenon of the sudden disappearance of bees with little sign of infection or disease. Such phenomenon is attributed to the memory loss of the bees to return to the hives. The path of CCD in India has followed the rapid increase of cell phone towers, which cause atmospheric electromagnetic radiation pollution. For the present analysis, the location of 60 mobile towers in the Thiruvananthapuram corporation limits have been collected through a GPS survey and interpreted as a thematic map layer (Fig.5).

Multiple criteria decision approaches are a set of formal tools noteworthy for decision-making to complex geographic problems of different levels and types. Statistical techniques like multiple regression analysis, structured questionnaire surveys, and GIS techniques like multi-criteria evaluation methods and fuzzy overlay are widely used for land resource management. The present study adopted a GIS-based Multi-Criteria Analytical Hierarchy (MCAH) process for delineating beekeeping suitability zones, as it is the best to analyze problems that are simultaneously physical, ecological, and cultural. (Fig.6)

The different criteria adopted in this study were measured on different scales and hence followed a standardization to bring their preference value into a 0 - 4 scale before combining them all. Buffer analyses have been performed for road, radiation source, and hydrographic networks and were given preference values according to beekeeping's favoring and constraining aspect (Table 2). All the land parcels thus receive a specific weightage for the selected criteria. The AHP initially calculates each land parcels aggregate preference values and then classifies in to different suitability classes (Schmoldt et al., 2001).

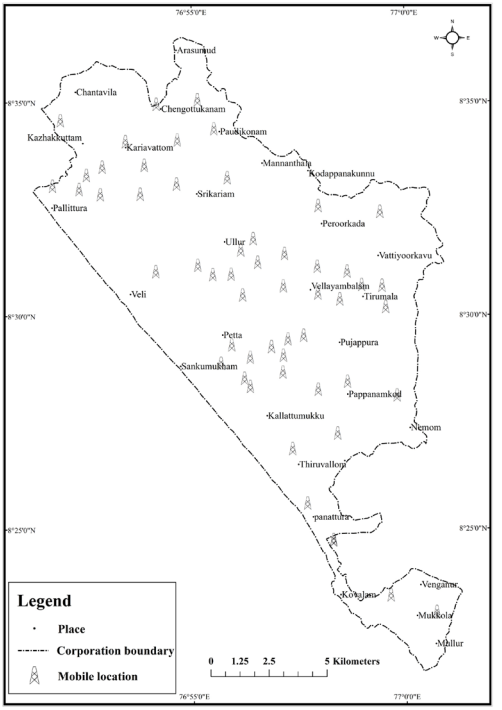

Fig. 5: Location of mobile towers in the corporation area

The aggregate preference value of different land parcels ranges from 0 to 15. The entire corporation area has been categorized in to five equal interval land suitability classes, viz;

1. Not suitable (1 – 3): Class containing the areas where beekeeping is not possible.
2. Less suitable (4 – 6): Class containing the areas where beekeeping is possible but economically not viable.
3. Moderately suitable (7 – 9): Beekeeping activity starts to be economically viable.
4. Suitable (10 – 12): Beekeeping activity economically profitable
5. Highly suitable (13 – 15): Beekeeping activity is economically profitable and the production reaches highest values (Figure 7)

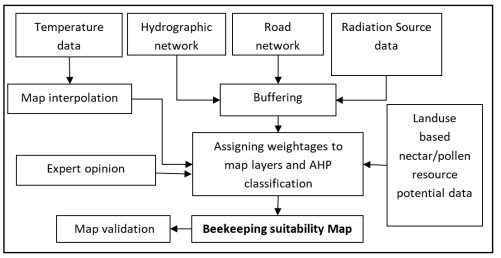

Fig. 6: The methodological structure of the study

Results and discussion

The study revealed that 67.62% of areas in Thiruvananthapuram Corporation have high or very high suitability for beekeeping. Plantation such as rubber and coconut and mixed crop vegetation is the principal land use for high to very high suitability classes. Due to cultivated plants and plantation crops, abundant nectar and pollen resources are available in these areas. Furthermore, these areas have good transportation networks, ample fresh water supply, distant from electromagnetic pollution, and a suitable temperature range of 27-35° C to make room for year-round apiculture practices.

Around 27.02 % of the study area is not suitable or less suitable for beekeeping. The Central Business District and its surrounding high populated zones, long stretch of sandy beach, areas covered by extensive water bodies, wastelands, etc. have minimal nectar/ pollen potential and are not suitable for apiculture. Our study suggests that a significant stretch of land is not suitable for apiculture purely due to its proximity to Radiation sources such as mobile towers (Table 3).

The ward-wise analysis reveals that nearly 25 of the 100 wards (Fig.7) at the city's

Table 3: Thiruvananthapuram Corporation: area wise apiculture suitability zones

Suitability level	Surface area (km^2)	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

fringes adjoining the villages are semi-urban in characteristics and have high apiculture potential. The validation of the beekeeping suitability map also shows the presence of traditional beekeepers in these areas. An inner circle of 26 wards located at the central

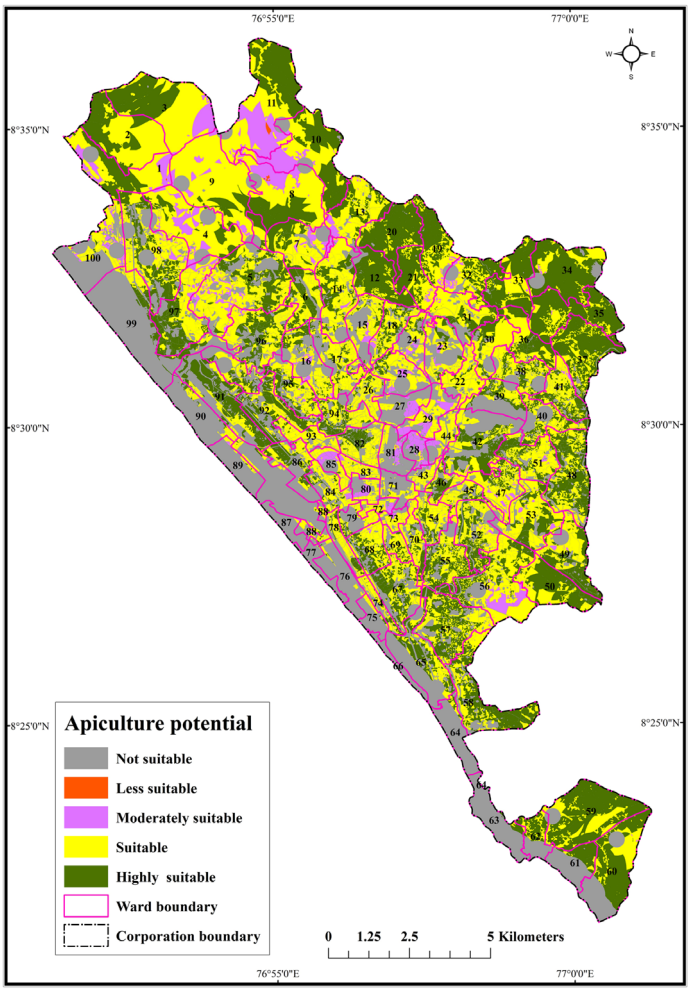

Fig. 7: Apiculture suitability zones in the Thiruvananthapuram Corporation

and northern portions of the corporation satisfies the conditions to come under suitable category. Nearly 30 wards in the corporation have moderate potential, and 19 wards are not suitable for apiculture.

Conclusions

The study formulated a model using public sector data repositories and web services of public bodies for effective decision-making using GIS tools. Moreover, the utilization of public data domains allows this model to apply to various agricultural ecosystems. The apicultural potential of Thiruvananthapuram Corporation is more on its eastern fringes and provides ample scope for development, as our analysis suggests 67% of Thiruvananthapuram corporation area has high potential for beekeeping. 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 to benefit apiculture in the area.

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Pratheep Kumar B.*

Assistant Professor, Dept. of Geography
Government Arts and Science College
Kulathoor, Neyyattinkara,
Thiruvananthapuram, Kerala

T. K. Prasad

Associate professor, Dept. of Geography,
Kannur University, Kerala

*Author for correspondence
E-mail: pratheepgeo@gmail.com