

Three Digital Beekeeping Tools in Taiwan: Varroa Mite Monitoring System, Nectar Source Geographic Information System and Apicultural Traceability System

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Abstract

Beekeeping is labor intensive. This study has developed the following three applications to support the advancement of apiculture in Taiwan.

(1) **Varroa mite monitoring system:** Monitoring *Varroa* mite population is essential for integrated pest management, but the small body size makes visual identification difficult. This system is able to calculate the infestation level of the *Varroa* mite in a beehive by using mobile device to take photos of live honeybees on frames. The algorithm based on deep learning analysis of the photos counted the number of honeybees and mites. Trained on a dataset of 3,987 images, the algorithm reaches a precision of 84% for honeybee counting and 91% for mite counting. This non-destructive method provides a fast and effective alternative to traditional approaches.

(2) **Nectar source geographic information system:** In the past, there was a lack of comprehensive information on nectar and pollen sources for beekeepers, and no system existed to connect farmers in need of pollination with beekeepers. Traditionally, beekeepers search for apiaries independently with limited exchange of experiences. Making it difficult for newcomers to identify suitable locations. To address this, we developed a cloud-based platform using ArcGIS to manage geographical data on nectar and pollen crops. The system includes orthophotos, electronic maps, and 13 major crop distribution layers. Users can select crop layers to identify suitable locations, enhancing pollination services and apiculture development.

(3) **Apicultural traceability system:** Beekeepers typically used branches, stones, bricks, or markings to track hive status, with most records kept on paper. This made data difficult to utilize or analyze effectively. To improve apiary management, this study designed a database format tailored to Taiwanese apiculture. The user interface adopts a calendar format, recording key parameters such as personnel, tasks, time, location, and equipment involved in beekeeping. Data is uploaded to a public cloud-based platform, only providing necessary information to certification companies and consumers to comply with Taiwan Good Agricultural Practice standards. Additionally, the system includes predefined expert guidelines for pest control and queen rearing, along with a report export function for assessment and analysis.

Keywords: artificial intelligence, *Varroa*, monitoring, geographic information system, traceability

(1) Varroa mite monitoring system

This study developed an automated *Varroa* mite monitoring system using deep learning algorithms combined with mobile devices and cloud computing. The dataset consisted of images captured using cameras or smartphones with a resolution of 12 megapixels, taken at fixed distances toward the frame (Figure 1). The dataset includes 3,987 labeled images, with a total of 416 mite annotations and 46,110 honey bee annotations. We employed the YOLOv4 architecture for object detection, training the model to distinguish between large objects (honey bees) and small objects (mites). After evaluating various image cropping dimensions (192×192, 416×416, 608×608, 960×960, and 1280×1280 pixels), the 608×608 size yielded the best performance. Data augmentation and image enhancement techniques, such as brightness and saturation adjustment, were applied during training. The trained model achieved a precision reached 84% for honey bees and 91% for mites (Figure 2). Each image is analyzed in less than 15 seconds, enabling real-time estimation of mite infestation rate (Figure 3).



Figure 1. Beekeepers can simply upload smartphone photos for cloud analysis.

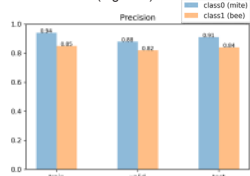


Figure 2. The model precision for honey bees and *Varroa* mite.



Figure 3. Output of image recognition.

(2) Nectar source geographic information system

There are many plant species in Taiwan that can be used as nectar and pollen sources. However, plant species that can produce honey or bee pollen with commercial value are mainly fruit trees cultivated in large areas, with longan (*Dimocarpus longan*) honey, lychee (*Litchi chinensis*) honey and tea (*Camellia sinensis*) pollen comprising the majority in the domestic market. Additionally, nectar source fruit trees also include citrus fruit (*Citrus* spp.), Indian jujube (*Ziziphus mauritiana*), persimmon (*Diospyros* spp.), coconut (*Cocos nucifera*), avocado (*Persea americana*), loquat (*Eriobotrya japonica*), and carambola (*Averrhoa carambola*). Pollen source fruit trees also include plum (*Prunus mume*), pear (*Pyrus pyrifolia*), and pitaya (*Hylocereus* spp.) (Figure 4). The Taiwan Agricultural Research Institute, Ministry of Agriculture has conducted surveys and released the maps of a variety of perennial crops, including the crops above. This system framework adopts ArcGIS software to draw maps and manage geographical information data and release produced map platform service on the Internet (Figure 5). The system map platform base maps are provided by the National Land Surveying and Mapping Center in Taiwan, including orthophotos with clear landscape and universal electronic maps with administrative boundaries and road markings.

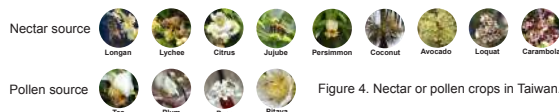


Figure 4. Nectar or pollen crops in Taiwan.



Figure 5. One dimension of the system main screen. Demonstrating 8 crop layers overlaying on landscape orthophotos.

(3) Apicultural traceability system

To enhance data management and streamline certification in apiculture, we developed this system capable of recording a wide range of operational events and producer data (Figure 6). The records are divided into 4 functional modules: **Apiary**, **Material**, **Feed**, and **Harvest**, according to the nature of the task. Among them, the **Apiary Management** module is the most complex, with hierarchical structures that allow for detailed recording of hive conditions, queen characteristics, and colony status—including data such as colony strength, number of frames, occurrence of pests and diseases, and queen loss. The **Harvest Management** module supports traceability from collection through packaging to shipment, and enables users to upload relevant documents to designated authorities for swift application for Taiwan Good Agricultural Practice (TGAP) or Taiwan Beekeeping Association certification.

To simplify the data input process, we designed a **Calendar-based user interface**, allowing users to assign and track tasks via clickable event scheduling (Figure 7). This includes not only single tasks, but also task kits (e.g., weekly pest control routines). Furthermore, we integrated an expert-driven schedule (e.g., queen rearing) as a reference template, which users can customize to fit their individual beekeeping practices. This system aims to reduce manual labor, support certification processes, and enhance digital transformation in modern beekeeping management.



Figure 7. User interface of beekeeping calendar.

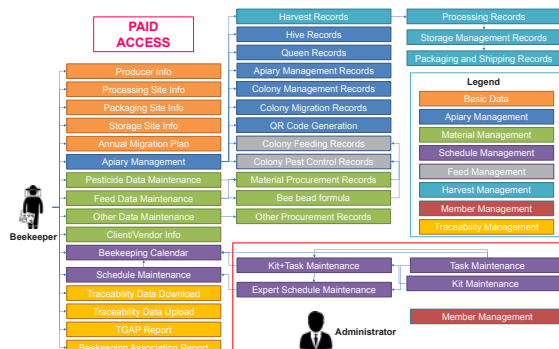


Figure 6. Apicultural traceability system function flowchart.

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(1) Varroa mite monitoring system: Monitoring Varroa mite population is essential for integrated pest management, but the small body size makes visual identification difficult. This system is able to monitor the infestation level of the Varroa mite in a beehive by using mobile device to take several photos of live honeybees on frames. A computer vision algorithm based on deep learning analysis of the photos counted the number of honeybees and mites. Trained on a dataset of 3,987 images, the algorithm reaches a precision of 83% for honeybee counting and 78% for mite counting. This non-destructive method provides a fast and effective alternative to traditional approaches, completing the analysis in less than one minute.

(2) Nectar source geographic information system: In the past, there was a lack of comprehensive information on nectar and pollen sources for beekeepers, and no system existed to connect farmers in need of pollination with beekeepers. Traditionally, beekeepers search for apiaries independently with limited exchange of experiences. Making it difficult for newcomers to identify suitable locations. To address this, our institution developed a cloud-based platform using ArcGIS to manage geographical data on nectar and pollen crops. The system includes orthophotos, electronic maps, and thirteen major crop distribution layers. Users can select crop layers to identify suitable locations, enhancing pollination services and apiculture development.

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