Fruit Productive Landscapes of Bangkok's Inner Orchard for Urban Greening in Bangkok, Thailand: Identifying Potential Areas for Conservation and Revitalisation

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Abstract: Bangkok's Inner Orchards (BIOs) play a crucial role in offering both food and non-food ecosystem services to the city's residents. As urban development in Bangkok and its neighbouring provinces spreads over these mixed-fruit orchards in the Bangkok Metropolitan Region (BMR), understanding the current extent of orchard areas in these rural-urban zones becomes essential for city and regional planning. Given the city's limited urban green spaces, the existing BIOs represent significant opportunities to incorporate into Bangkok's green infrastructure initiatives. Unfortunately, the data from relevant government sources are often outdated and unreliable. This study harnessed geospatial data and remote sensing technology to identify BIO areas accurately. Analysis of satellite imagery pinpointed the locations of these orchards within the Bangkok Metropolis and the peri-urban regions of Nonthaburi and Samut Prakan Provinces. Spatial evaluation revealed a total of 68.55 km² of BIOs, consisting of 60.49 km² for active orchards and 8.06 km² for abandoned ones. Active orchards require immediate conservation strategies with suitable measures, while revitalising abandoned orchards poses unique challenges, necessitating innovative ideas for developing a variety of urban green spaces to meet future demands.

Keywords: Productive landscape, remote sensing, GIS, NDVI, sustainable development goals

1 Introduction

Productive landscapes are closely related to cities, especially regarding food provisioning services for urban residents. Besides rice paddy fields, vegetable farms, and aquaculture, the fruit orchard is another type of agricultural land surrounding Bangkok, Thailand's capital city. Bangkok's Inner Orchards (BIOs) are mixed-fruit orchards located mainly in Bangkok and peri-urban areas. BIOs are situated on the Chao Phraya River's young silted tidal delta (TAKAYA 1987, MCGRATH & THAITAKOO 2005). Unique land and cultivation methods characterize these types of agricultural landscapes. The low-lying flat land of this young delta area was manipulated into a corduroy-like landform to provide higher land of raised beds for growing fruit trees and lower land of ditches for irrigation (Figure 1). This land modification into ditches and dikes is considered local wisdom that gardeners' ancestors invented to solve geographical limitations for fruit cultivation. Culturing mixed-tropical fruit trees in this area made the BIOs imitate natural forests with complex tree canopy layers and species diversity

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(DAVIVONGS & ARIFWIDODO 2023). The combination of different tree species complement each other by conforming to a suitable environment with shading and moisture. Some trees grow in the orchard to be utilised as a source of natural fertiliser for other fruit trees.

Since the 1980s, Bangkok's urbanised areas have sprawled over other surrounding provinces, and an extended urban region called Bangkok Metropolitan Region (BMR) has been formed (BRYANT et al. 1982, YOKOHARI et al. 2000, JONES 2002, BURCHELL et al. 2005). Consequently, surrounding agricultural lands, especially the BIO areas, have been diminishing due to this rapid urban sprawl (MEKVICHAI et al. 1990, DAVIVONGS 2012, DAVIVONGS et al. 2012, MENAKANIT et al. 2022). Many orchards were intentionally transformed into urban land uses, such as housing estates, condominiums, offices, commercial buildings, etc. Some orchards deteriorated from the irrigation canal system collapsed due to foregoing urbanisation. Therefore, orchards could not continue cultivating fruits without water and became abandoned unintentionally (DAVIVONGS 2012). The former continuous orchard patches have transformed into rural-urban mixed land patches.

BIOs are vital in providing food to Bangkok's residents, mainly tropical fruits, local vegetables, and herbs. Specific to the rural-urban mix, BIOs offer additional benefits as nonfood ecosystem services to the city (SWINTON et al. 2007, MALINGA et al. 2018). Groups of large trees made BIO an urban forest that provides ecological services such as air cleansing, heat reduction, water retention, and biodiversity reserve (WEIRSUM & SANDS 2013, DAVIVONGS & ARIFWIDODO 2023). As a kind of urban green space, BIOs also provide cultural benefits as a recreational space for urban activities and tourism (SWINTON et al. 2007, MALINGA et al. 2018). Notably, Bangkok lacks urban green space, and the Bangkok Metropolitan Administration (BMA) aims to comply with the Sustainable Development Goals (SDGs) by increasing green areas from currently less than 7 m2/person to 10 m2/person in 2030 (C40 CITIES 2020, UNITED NATIONS CLIMATE CHANGE 2021). However, the average of 22 across major Asian cities was 39 m2/person (UNITED NATIONS CLIMATE CHANGE 2021). Therefore, Bangkok's green ratio is still extremely far behind. The existing BIOs are one of the potential greens that can be integrated into Bangkok's urban green infrastructure planning.

The significant impact of these ecosystem services on Bangkok depends on the number of BIO areas that exist, primarily the active orchards. It is crucial to know how much BIO lands have left in the rural-urban mix of the BMR. However, agricultural lands in urbanising areas are considered a data gap between city administration and national agricultural extension agencies. The data from related government agencies are outdated and inaccurate since the BIOs considered minor productive lands with less economic impact on agricultural products at the national level. Therefore, this study aimed to use geospatial data and remote sensing technology to precisely extract the BIOs, the mixed-fruit orchard areas, from the urban-rural mix in the BMR. The BIOs are classified into active and abandoned orchards since they require different appropriate measures. Current active orchards are potential green areas that provide multi-ecosystem services to the city, and they require conservation approaches to ensure the benefit to the city is retained. Although some orchards have been abandoned in the area, they could be potential areas for revitalisation as various kinds of urban green spaces by using different measures to make them active again.

2 Methods

2.1 Study Area

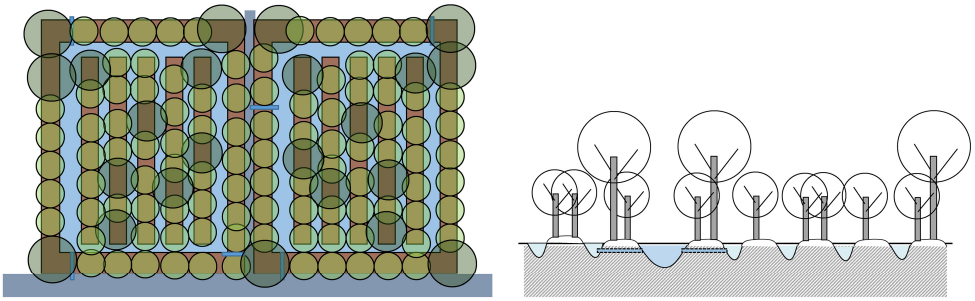

Fig. 1: Typical plan and section of Bangkok's Inner Orchard (BIO) on the landform of ditches and dike system

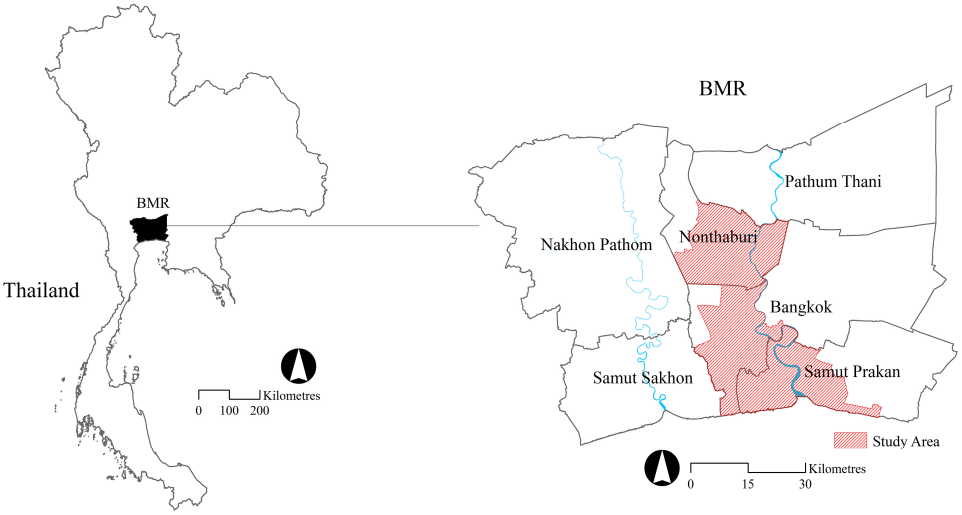

Fig. 2: Map of the study area in Bangkok Metropolitan Region (BMR), Thailand

Bangkok's Inner Orchard was initially established in Bangkok as a small agricultural village at least 330 years ago to provide fruits for the former capital city, Ayutthaya, and continues to survive to this day (DAVIVONGS & ARIFWIDODO 2020). The BIO is defined by mixed-fruit trees growing on the ditches and dikes landform (Figure 1). The study area focused on the BIO areas in the extended urban region of Bangkok, BMR. BMR's area includes the Bangkok metropolis and five surrounding provinces: Nakhon Pathom, Samut Sakhon, Pathum Thani, Nonthaburi, and Samut Prakan (KERMEL-TORRÈS 2004). Based on a land use map in 1959 obtained from the Royal Thai Survey Department, the BIO areas were located mainly along

the west bank of the Chao Phraya River and spread across Bangkok Metropolis, Nonthaburi, and Samut Prakan Provinces. Therefore, the political boundary at the district level covering the BIO areas was selected as the study area. (Figure 2).

2.2 Satellite Imagery and Spatial Analysis

This study employs advanced remote sensing techniques to identify and classify mixed-fruit orchard landscapes within BIO areas. The analysis utilises multispectral imagery from two key satellite datasets: 1) THEOS-1 (Thailand Earth Observation Satellite), which provides a high spatial resolution of 2 meters, and 2) Sentinel-2, an Earth Observation satellite under the Copernicus Program, offering 10-meter spatial resolution. These datasets were selected for their suitability for high-resolution land use and land cover classification. The methodology is structured into several phases.

Image Preprocessing

Preprocessing was conducted on both THEOS-1 and Sentinel-2 datasets to ensure spatial and radiometric accuracy. Geometric corrections were applied using ground control points (GCPs) and the Digital Elevation Model (DEM) to correct terrain distortions. Atmospheric corrections for Sentinel-2 imagery were performed using the Sen2Cor algorithm to generate surface reflectance values. For THEOS-1, radiometric calibration was applied to standardise reflectance values across different acquisition dates, ensuring data consistency.

Analysis of Vegetation Index

The Normalized Difference Vegetation Index (NDVI) was calculated for both datasets to assess vegetation conditions and identify active versus abandoned orchards. NDVI values were computed using the standard formula:

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

NIR represents the near-infrared band, and Red corresponds to the red band. NDVI values were analysed to detect vegetation health trends, providing the foundation for distinguishing between active and abandoned orchard areas. (LI et al. 2015, ARYAL et al. 2022, CHEN et al. 2024).

Image Classification

A hybrid classification approach was implemented, integrating NDVI analysis with supervised classification techniques to improve accuracy. Initially, image segmentation was performed using the Object-Based Image Analysis (OBIA) method to delineate orchard areas based on spectral, textural, and shape characteristics. Subsequently, a supervised classification technique – Random Forest (RF) – was employed due to its high accuracy and robustness in handling complex land cover types. The RF model was trained using manually collected training samples from high-resolution images and validated with field survey data. Texture analysis using the Gray-Level Co-occurrence Matrix (GLCM) was also applied to enhance classification precision by incorporating spatial patterns of vegetation.

Post-Classification

Following the initial classification, a post-classification refinement step was conducted using visual interpretation. Very high-resolution THEOS-1 imagery (2-meter spatial resolution)

was used to correct misclassified areas and increase accuracy. Manual digitisation was performed to refine orchard boundaries, ensuring accurate classification between active and abandoned orchards. This additional step helped to resolve ambiguities caused by spectral similarities and provided a more precise classification output.

Accuracy Assessment

The classification accuracy was evaluated using independent validation points collected from field surveys and high-resolution imagery. A confusion matrix was generated to compare the classified results with ground-truth data. Key accuracy metrics, including overall accuracy, producer's accuracy, user's accuracy, and the Kappa coefficient, were calculated to assess the level of agreement between the classified data and the reference points, ensuring robust validation of the results.

Spatial Analysis

Mixed-fruit orchards identified from the satellite imagery analysis process were spatially analysed using the Geographic Information System (GIS). Our study area was based on district-level political boundaries where the BIO areas were located. Therefore, the Clip function in ArcGIS was used to extract only orchard areas within the study area boundary. Then, the extracted orchard areas were calculated using the Calculate Geometry tool. Each province's active and abandoned orchard areas were quantified in square kilometres for comparison. Maps of BIO classifying into active and abandoned orchards were created in ArcGIS to visualise orchard distribution in the study area.

3 Results

Satellite imagery analysis revealed BIO's locations in the Bangkok Metropolis and the peri-urban areas in Nonthaburi and Samut Prakan Provinces. Spatial analysis to identify and calculate BIO areas revealed 68.55 km2 in total. They were classified into 60.49 km2 active orchards and 8.06 km2 abandoned orchards (Tab. 1) (Figure 3).

Within Bangkok's boundary, the results showed that 16.85 km2 of active orchards and 3.25 km2 of abandoned orchards were found. For neighbouring provinces, 35.96 km2 of active orchards and 3.93 km2 of abandoned orchards were identified in Nonthaburi Province (Tab. 1) (Figure 3). For Samut Prakan Province, 7.68 km2 of active orchards and 0.88 km2 of abandoned orchards were found (Tab. 1) (Figure 3).

Table 1: Amount of active and abandoned orchard areas in the study area

Area (km2)	**Bangkok**	**Nonthaburi**	**Samut Prakan**
Active Orchard	16.85	35.96	7.68
Abandoned Orchard	3.25	3.93	0.88
Total	**20.10**	**39.89**	**8.56**

The classification provided robust results with an overall accuracy of 87% and a Kappa coefficient of 0.81, indicating substantial agreement with the ground truth data.

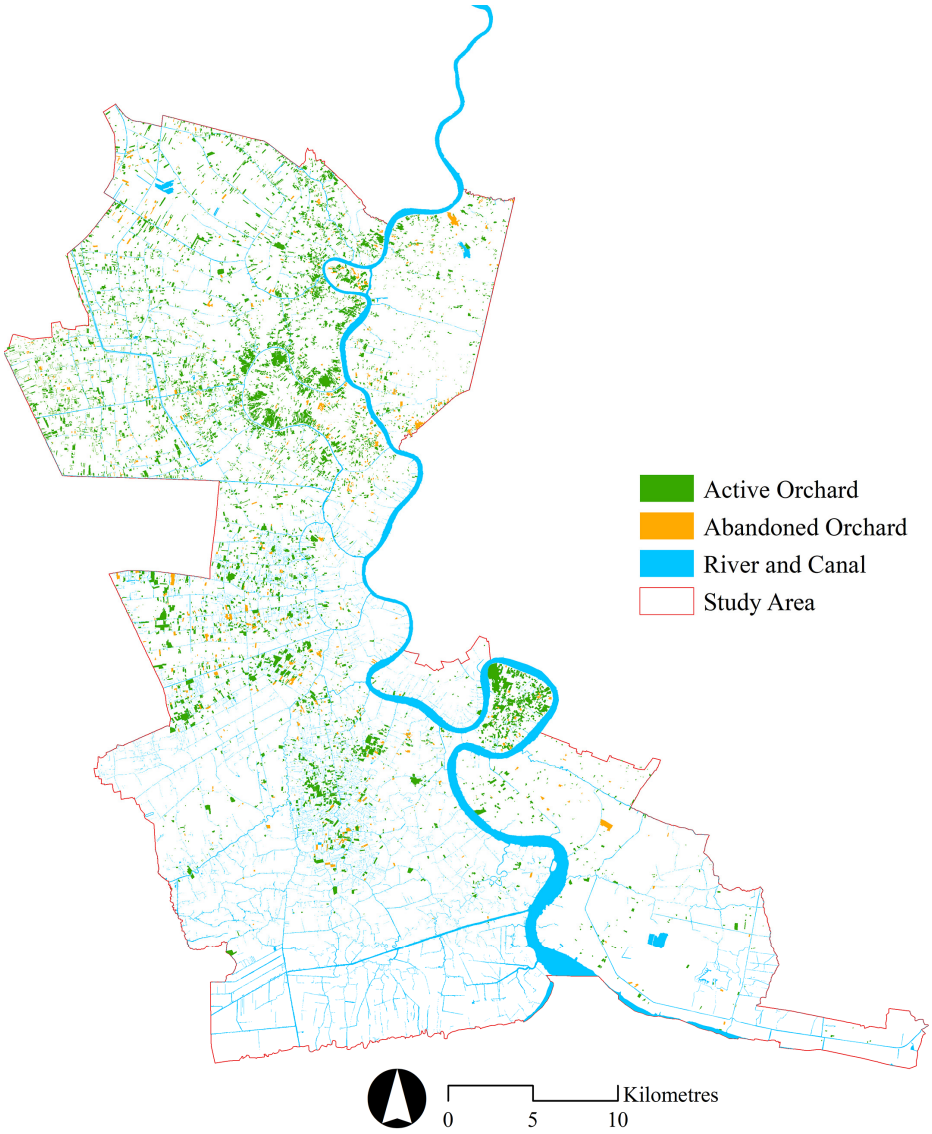

Fig. 3: Map of Bangkok's Inner Orchard areas classified into active and abandoned orchards from satellite imagery analysis

4 Discussions and Conclusions

Satellite imagery analysis made it possible to extract fruit orchards from the rural-urban mix of land uses in the BMR. Advanced remote sensing techniques classified the existing BIOs into active and abandoned orchards. The analysis revealed the number of active orchard areas that should be included as urban green areas with a conservation strategy. Simultaneously,

the study revealed abandoned orchard areas considered potential areas for further revitalisation.

The results revealed that BIO areas exist in Bangkok's boundary. From Bangkok's total area of 1,568.70 km2, approximately 1.28% (20.10 km2) were identified as the BIO areas. These included 16.85 km2 active orchard areas and 3.25 km2 abandoned orchard areas. Based on the estimated Bangkok population of 11.23 million people in 2024, The total BIO areas (20.10 km2) can potentially contribute to increasing Bangkok's green ratio by +1.79 m2/person (WORLD POPULATION REVIEW n. d.).

BIO areas are considered to have the potential to increase Bangkok's urban green areas. Therefore, it is necessary to examine the continuous decline of BIOs due to urban sprawl and devise strategies to protect the existing orchards. On the one hand, active orchard areas need urgent conservation approaches using appropriate measures to support them from both bottom-up and top-down since they have become multi-functionalised urban agriculture and provide multiple ecosystem services. In particular, food provisioning services support local food consumption schemes among urban residents by supplying fresh fruits, vegetables, and herbs to the city's food system. On the other hand, abandoned orchards are more challenging to revitalise and need different approaches. Although some orchards have been abandoned in the area for many reasons, they could be potential areas for revitalisation, allowing for inventive ideas to create various kinds of urban green spaces for future needs. Further in-depth study is necessary to make them active again properly.

Furthermore, many BIOs were also primarily found in neighbouring provinces, such as Nonthaburi and Samut Prakan. Nonthaburi's total active and abandoned orchard areas are 39.89 km2 and 8.56 km2 in Samut Prakan. They are large areas of green (48.45 km2) that can be considered potential areas to support urban greening schemes for Bangkok Metropolis and the BMR. Instead of only focusing on studying the green ratio in Bangkok, BMA should be concerned with integrating urban green infrastructure planning as a whole BMR. Collaborating with other neighbouring provinces is essential to benefit from their available green areas.

In conclusion, this study used geospatial data and applied advanced remote sensing techniques to identify existing BIO areas in Bangkok and neighbouring provinces. Many fruit orchard areas are spread in Bangkok and neighbouring provinces, especially Nonthaburi Province. These areas can be strategically included as potential urban green infrastructure for Bangkok Metropolis and BMR. Active and abandoned orchards were classified to provide appropriate measures for conservation and revitalisation accordingly.

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Data Availability

The datasets generated and/or analysed during the study are available from the corresponding author upon reasonable request.

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