A Preliminary Study on Remote Sensing-Based Detection of Vacant Houses in Urban Areas

Shota Tsujino[1]*, Kiichiro Kumagai[2], Kazuki Hatao [3]

[1]*Graduate student, Graduate School of Science and Engineering, Setsunan University, 17-8 Ikeda-Nakamachi, Neyagawa, Osaka, Japan. 2552M113ts@edu.setsunan.ac.jp*
[2]*Professor, Faculty of Science and Engineering, Setsunan University, 17-8 Ikeda-Nakamachi, Neyagawa, Osaka, Japan. kumagai@civ.setsunan.ac.jp*
[3]*HawksMap Co., Ltd., 27-5 Kusunokidani-cho, Hyogo Ward, Kobe, Hyogo, Japan.*

Abstract: In Japan, population decline has heightened the need for long-term monitoring of urban structures and living environments. The identification of vacant houses represents a practical approach to capture underutilized urban spaces. However, the execution of field surveys for the identification is constrained by access, safety, and privacy issues. This study evaluates the applicability of high-resolution satellite imagery for the support of the field surveys. We apply three band combinations, RGB, NIR-R-G, and Red Edge-R-G, to image recognition using deep learning for the assessment of degraded site conditions as vacancy indicators. The feasibility of implementing large-scale, continuous vacant property monitoring using satellite imagery is examined by analysing building-level results in the study area.

Keywords: Vacant houses, UAV imagery, Deep learning, Spatial resolution

1. Introduction

In Japan, the increase of underutilized or unused spaces, including vacant houses, has become a growing concern as the population continues to decline. As part of urban structure monitoring, the need to understand the spatial distribution of vacant houses is increasing. However, it is often difficult to visually identify the subjects in on-site surveys, which are mainly adapted in vacant housing investigations and focus on the exterior appearance of residences. To address this issue, we have previously attempted to identify the management condition of residential gardens, one of the indicators of vacancy, using UAV aerial images and deep learning techniques. On the other hand, UAV flights over densely populated districts require prior permissions and approvals, posing restrictions on their application to large-scale surveys. Therefore, from the viewpoint of future utilization of satellite imagery, this study clarified the impact of differences in band combinations of satellite images on the identification performance. Through this examination, the applicability of satellite imagery for supporting on-site vacant house surveys was assessed. It also provided insights as to support wide-area survey applications.

2. Methodology

The study area is Neyagawa City in Osaka Prefecture, located in the northeastern part of the Osaka Plain. After World War II, residential expansion and urbanization have rapidly progressed in this region. The authors have collaborated with the city since 2014, conducting surveys in 16 neighbourhood blocks across five typical urban types: a densely built-up area, a central urban area, a suburban residential area, a roadside area, and a historical district (Kumagai et al. 2018). These areas are suitable for examining vacant houses and changes in residential environments. The city also revised its “Vacant and Dilapidated Buildings Countermeasure Plan” in 2022.

For the analysis, we used satellite images acquired by Pléiades Neo (Airbus Defence and Space) in April 2025. The satellite provides a panchromatic image at 0.30 m/pixel and six-band multispectral images at 1.2 m/pixel (Deep Blue, Blue, Green, Red, Red Edge, NIR). The images have undergone atmospheric correction and pan-sharpening and were generated as 16-bit Geo TIFF reflectance images. Polygons created from the 2015 Zmap-TOWN II dataset were buffered to automatically extract image patches containing buildings and their surrounding environments. This enabled the analysis of management conditions, including the state of gardens.

For image recognition, we employed deep learning with transfer learning, using the pre-trained VGG19 model as the base architecture. VGG19, trained on the ImageNet dataset, is widely known for its strong performance in image recognition. In this study, selected layers were fine-tuned to adapt the model to the target task. Three band-combinations were examined for training: a) RGB natural colour, b) false colour composite (NIR-R-G), and c) false colour composite (Red Edge-R-G) (see Table 1). These band combinations were selected considering representative applications in remote sensing: RGB serves as a standard for natural colour imagery, NIR-R-G enhances vegetation vigour and stress detection, and Red Edge-R-G is sensitive to subtle changes in vegetation canopy (EUMeTrain, n.d.). These combinations were selected to clarify the impact of spectral band selection on the image recognition accuracy. Sample images for each band combination are shown in Figure 1.

The recognition labels were defined in two categories: “Deteriorated surrounding environment”: overgrown vegetation obscuring pathways around residences, while “Non-deteriorated surrounding

Table 1: Band combinations used for image classification.

Case	R Channel	G Channel	B Channel
a)Natural Color	Red	Green	Blue
b) False Color (NIR-Red-Green)	NIR	Red	Green
c) False Color (Red Edge-Red-Green)	Red Edge	Red	Green

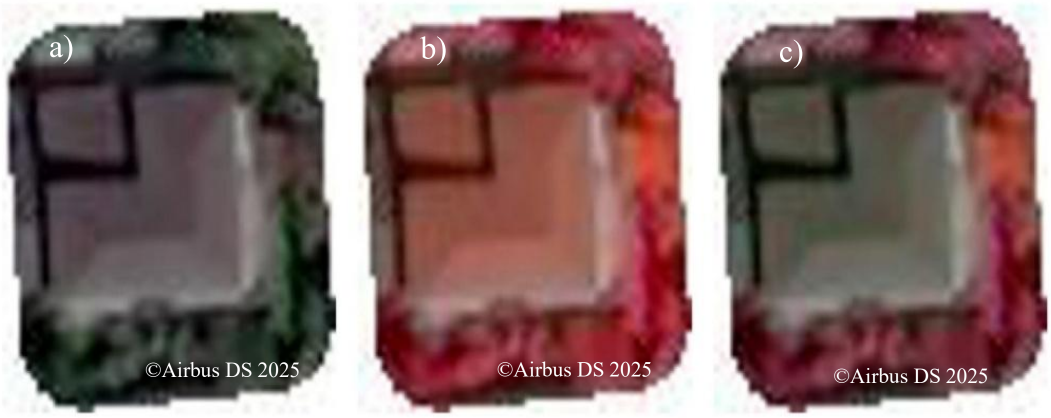

Figure 1: Examples for each band combination used in image recognition: a) Natural colour, b) False colour (NIR-R-G), c) False colour (Red Edge-R-G).

environment": indicates properly managed vegetation, paved courtyards, or adjacent buildings eliminating open space. Labelling was performed through visual interpretation of UAV images by our research team. A dataset of 480 training images and 140 validation images was consequently generated. The datasets obtained respectively from cases a) to b) were then used to train and evaluate the recognition model, thereby assessing the potential of satellite images for distinguishing residential environmental conditions related to vacant houses.

3. Results

The validation results reveal clear performance differences. UAV imagery achieves the best performance due to its finer spatial resolution (validation loss: 5.91%, validation accuracy: 96.88%). Among satellite data, NIR-R-G shows the highest accuracy (validation loss: 16.23%, validation accuracy: 95.31%), RGB yields stable performance (validation loss: 20.81%, validation accuracy: 93.75%), and Red Edge-R-G results in the lowest accuracy (validation loss: 32.95%, validation accuracy: 92.97%).

In addition to validation accuracy, recognition performance is assessed by Producer's and User's accuracy (see Figure 2). In Case b), the highest Producer's accuracy of 0.94 is achieved for the

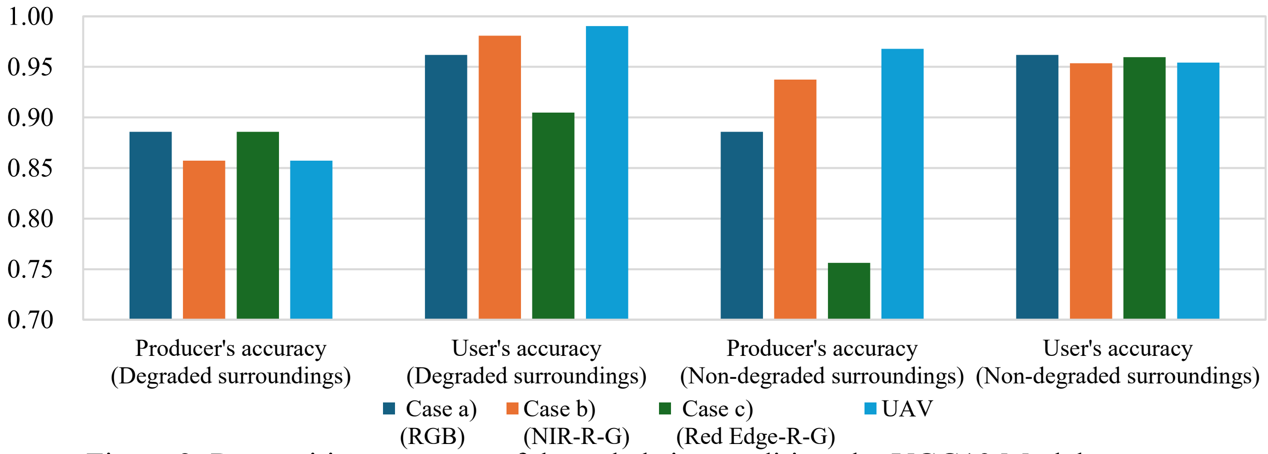

Figure 2: Recognition accuracy of degraded site conditions by VGG19 Model.

recognition of "Non-deteriorated surrounding environment", though the accuracy for recognition of "Deteriorated surrounding environment" indicates slightly lower. Case c) shows the lowest accuracy: Producer's accuracy of 0.76 for the "Non-deteriorated surrounding environment", while User's accuracy was relatively high (0.96).

UAV imagery previously yielded the highest Producer's accuracy of 0.97 for the "Deteriorated surrounding environment" and very high User's accuracy of 0.99 for the "Non-deteriorated surrounding environment", highlighting the advantage of higher spatial resolution.
Overall, RGB images provides the most balanced performance. NIR-R-G improves accuracy in "Non-deteriorated surrounding environment". Red Edge-R-G, on the other hand, is prone to misrecognition. While UAV imagery excels in degraded environment detection, high-resolution satellite imagery seems to provide practically useful accuracy with the advantage of wide-area and continuous monitoring.

4. Conclusions

This study evaluated the applicability of high-resolution satellite imagery to identify vacant or underutilized houses. RGB images provided the most stable recognition, while NIR improved detection of non-degraded areas. Red Edge alone tended to misclassify them. It was indicated that the possibility of the application of high-resolution satellite imagery to on-site vacant house surveys, i.e. complementing UAV-based investigations and enabling large-scale continuous monitoring.

Future work will contain the exploration of additional band combinations with the objective of enhancing accuracy, the comparison of results across the entire study area, and the integration of deep learning-based recognition methods into existing vacant house estimation models to assess their impact.

Acknowledgments
The authors would like to express their sincere gratitude to the Housing Policy Division of Neyagawa City for their generous support regarding the use of public parks during this study. We also thank Satellite Image Marketing Co., Ltd. for providing Pléiades Neo data for technical evaluation purposes.

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