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Research Paper

Comparative Study Between Object-Based Image Analysis Using Mean Shift and Multiresolution Segmentation Algorithms for Green Open Space Identification: Case Study in Sleman Regency

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Abstract

We elaborate on the critical importance of green open spaces in the context of urban sustainability. Public health is inextricably linked to the green open spaces in urban regions, as green spaces contribute to the ecological balance. In Indonesia, Green Open Space (GOS) is guided by Law No. 26 of 2007, which designates at least 30% of urban areas as GOS. However, tracking GOS is challenging due to urbanization and a lack of ground surveys. Remote sensing techniques and Object-Based Image Analysis (OBIA) may help solve this problem. We used high-resolution SPOT-7 imagery to determine GOS in Sleman Regency, Indonesia. The study also compares two OBIA segmentation algorithms, Mean Shift and Multiresolution Segmentation. The classification included city parks, rice fields, gardens, buildings, water bodies, and areas labeled as unclassified. Mean Shift segmentation, combined with SVM, achieved an accuracy of 81.25% and a Kappa index of 0.739. On the other hand, Multiresolution Segmentation with Nearest Neighbour attained 91.25% accuracy and a Kappa index of 0.878. Although these results indicate the superiority of Multiresolution Segmentation over Mean Shift in heterogeneous urban settings, there is a potential for the latter in fine-scale feature detection.

Keywords *Green Open Space, OBIA, Mean Shift, Multiresolution Segmentation, Remote Sensing*

INTRODUCTION

The processes of urbanization and land conversion in Indonesia have had an intense impact on the provision of Green Open Spaces (GOS). Based on Law No. 26 of 2007, urban areas must allocate 30 percent of their total area for GOS, consisting of 20 percent for public use and 10 percent for private use. Many urban areas struggle to meet this requirement due to population surges, expanding infrastructure, and unregulated land-use shifts. The lack of up-to-date GOS spatial data further complicates policy enforcement and monitoring.

Remote sensing technology has emerged as a low-cost and scalable methodology for urban green space mapping and monitoring. Traditional pixel-based classification methods are often unsuccessful in heterogeneous urban environments because they rely solely on spectral values without considering spatial or contextual relationships. Object-Based Image Analysis (OBIA) addresses this limitation by incorporating additional features such as spatial and topological attributes, which makes it more effective. OBIA has been successfully applied in urban land-cover mapping, vegetation monitoring, and GOS assessment (Danoedoro, 2012; Hapsari & Murti, 2015).

Earlier studies have yielded differing outcomes. For instance, Putri et al. (2023) reported high accuracy (>91%) when using OBIA with Pleiades imagery for land-cover classification in Kulon

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Progo. In contrast, Devi and Santosa (2022), using SPOT-6 imagery with OBIA in Purwokerto, reported a lower accuracy (77%) due to over-segmentation. These discrepancies indicate that the accuracy and outcomes of OBIA are influenced by the selection of the algorithm, parameter configurations, and regional characteristics.

Located in Yogyakarta Province, Sleman Regency is a region with diverse land cover, including dense settlements, active agricultural fields, rivers, and urban parks. This heterogeneity, while posing challenges, also makes the area a representative test site for OBIA segmentation algorithms. The primary aim of this research is to evaluate the effectiveness of the Mean Shift and Multiresolution Segmentation algorithms in extracting GOS from SPOT-7 imagery. The findings are expected to clarify the advantages and limitations of each algorithm, thereby enhancing the accuracy of urban green space assessments and providing support for evidence-based policymaking in sustainable urban development.

LITERATURE REVIEW

The research on Object-Based Image Analysis (OBIA) has been particularly focused on the advantages it offers compared to older methods based on pixels. Rather than a single pixel classification, which only looks at the spectral values of the pixels, OBIA looks at the spectral, spatial, and contextual elements, making it more ideal in diverse and complex urban settings (Danoedoro, 2012; Hapsari & Murti, 2015). It has also been used for mapping land cover in the cities, tracking vegetation, and identifying Green Open Spaces (GOS).

A. Uses of OBIA for Land Cover and GOS Mapping

In Indonesia, an increasing number of research papers have proven the use of OBIA in mapping Green Open Spaces (GOS) areas. Putri et al. (2023) explained the use of OBIA and Pleiades images in Kulon Progo, achieving over 91% accuracy, which is impressive. On the other hand, Devi and Santosa (2022) applied SPOT-6 images to Purwokerto, but only achieved 77% accuracy due to over-segmentation issues. From these studies, we can conclude that OBIA accuracy depends on the segmentation algorithm, the parameters set, and also the research area. Using SOP-7 and the Multiresolution Segmentation algorithm (Yafi et al., 2022), continued to examine GOS availability in East Jakarta within the Multiresolution Segmentation framework. The authors achieved an overall accuracy of approximately 83.3% and were able to assess the still low GOS proportion in the city (18.18%), which, even for the year 2022, remained below the required 30%. This level of GOS proportion highlights the importance of accurate GOS measurement in city planning.

B. Mean Shift Algorithm in Remote Sensing.

Mean Shift has, for the most part, been avoided in the application of OBIA in remote sensing, as it is more commonly used in computer vision for tasks such as object tracking (Wijayana et al., 2015). Segmentation using the Mean Shift algorithm, as proposed by Comaniciu and Meer (2002), enables efficient delineation of discrete objects, as it operates in feature space without making assumptions about the data's form. Wicaksono and Farda (2015) used the Mean Shift algorithm to map the benthic habitats of Karimunjawa and reported that, although the map contained plenty of details, it was more accurate than the pixel-based classification. The Mean Shift algorithm is effective in isolating shapes, as demonstrated by Wicaksono and Farda (2015). However, they also found that its classification accuracy decreases when the data becomes more discrete. Another study by Farhan et al. (2018) also employed Mean Shift segmentation to estimate the extent of built-up areas in Bogor, and in comparison to ground-truth digitized data, provided acceptable results ($R^2 \geq 0.8$). These works, overall, indicate that whilst Mean Shift can detect and unify a high number of features, it often garners over-segmentation.

C. Multiresolution Segmentation Algorithm

The flexibility and ability to balance scale, shape, and compactness parameters of Multiresolution Segmentation (MRS) make it one of the most popular algorithms used in OBIA research. According to Putri et al. (2023) and Setiani (2016), MRS yielded consistent segmentation results for various land-cover classes, particularly in urban areas where land use is mixed. A study by Koman et al. (2022) analyzed the results of different segmentation parameters and concluded that optimal results are object-type dependent; water bodies and settlements require different scale and compactness parameters.

D. Research Gap

In GOS studies based on OBIA, MRS has been the dominant approach according to the reviewed literature, while the Mean Shift algorithm has been overlooked. The applications of the Mean Shift algorithm were primarily limited to benthic habitat mapping (Wicaksono & Farda, 2015) and estimating built-up areas (Farhan et al., 2018). Therefore, analyzing the two algorithms in high-resolution images to identify GOS in a complex urban and rural area, such as Sleman Regency, is unique.

RESEARCH METHOD

A. Study Area

The region of study is Sleman Regency, located in Yogyakarta Province, Indonesia. Sleman is a peri-urban area where undulating, dense settlements, farmlands, urban parks, rivers, and other infrastructural facilities coexist. Sleman is suitable for testing OBIA segmentation algorithms because of its heterogeneous land cover. It is also marked by rapid urban expansion, which impacts the supply of Green Open Space (GOS).

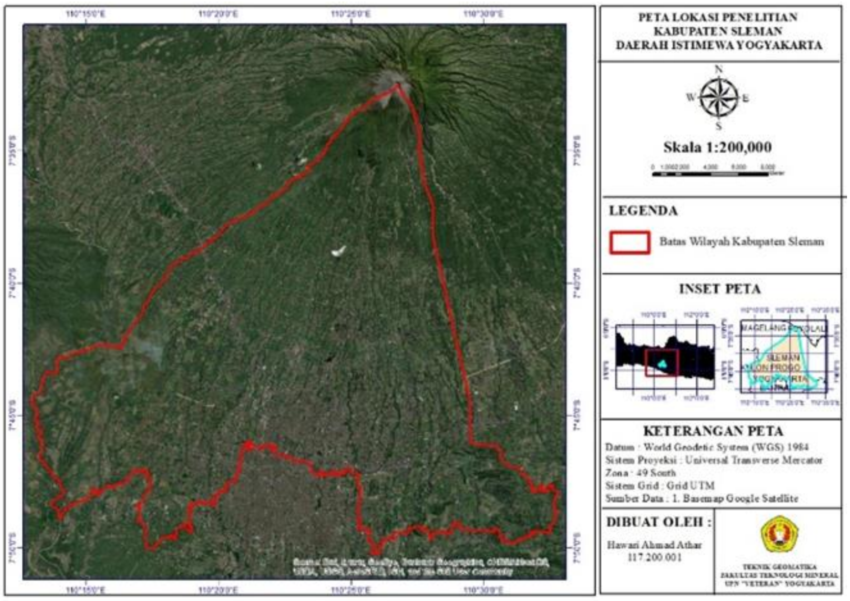

Figure 1. Study Area

B. Data Source

The primary dataset for this research was SPOT-7 imagery (2019), and it was described as follows:

- Panchromatic band: 1.5 m spatial resolution
- Multispectral bands (Blue, Green, Red, NIR): 6 m spatial resolution
- Scene size: 60 × 60 km

The imagery, orthorectified and geometrically corrected to eliminate distortions, was provided by BRIN (the National Research and Innovation Agency of Indonesia). Ancillary data consisted of Google Earth 2019 imagery, which was used for validation as a substitute for aerial surveys.

C. Pre-Processing

To prepare the satellite images for further analysis, a series of preprocessing steps was undertaken. Radiometric corrections were made for the still persistent effects of the atmosphere, and to calibrate the pixel values geometrically, and orthorectification corrections were made for the still persistent effects of spatial positioning distortions. The SPOT-7 image was further digitally processed to focus on the administrative boundaries of Sleman Regency, reducing data volume and concentrating on the study area. Techniques of image enhancement, like contrast stretching, were used for person-made classification to simplify the more complex image data to enable easier and more efficient interpretation and segmentation.

D. Object-Based Image Analysis Framework

The OBIA framework was followed in the analysis. This framework includes two primary aspects: segmentation and classification. This paper compared two segmentation strategies. The first method involved implementing the Mean Shift algorithm in ArcMap 3.8. This method employs a non-parametric clustering approach, which shifts a search window in the feature space to areas of high spectral density in the image and then produces detailed image objects. These objects are subsequently used to cluster the image. After the segmentation is completed, the SVM classifier is used to perform classification, which is noted for its proficiency in high-dimensional feature spaces and accurate boundary definition. The second method was the Multiresolution Segmentation in eCognition Developer 9.0. This method employs a hierarchical, region-growing approach to optimize the defined scale, shape, and compactness parameters, thereby minimizing object heterogeneity. After segmentation, classification used the Nearest Neighbour algorithm, which assigns class labels based on the training reference samples closest to the input image.

E. Training Sample Development

Three main types were created to serve as training samples for public Green Open Spaces (such as city parks and city and field parks), private Green Open Spaces (including agricultural land and gardens), and GOS lesser land (built land, water, barren land, and other unclassified areas). For each segmentation method, the selection of training samples was customized to their strengths; for Mean Shift, small and fragmented objects were the primary focus, whereas for Multiresolution Segmentation, the focus shifted to larger homogeneous objects.

F. Accuracy

The accuracy of the achieved classification results was determined using stratified random sampling, guaranteeing class representation for all classes. Validation data were obtained from Google Earth images, and the verification process, using a confusion matrix, yielded overall accuracy as well as the Kappa index, which assesses the level of agreement in the classification results for each method. Classification reliability for each used method was determined from these measures. Google Earth Imagery was used for validation, as the images were high-resolution and provided land cover details that could not be obtained through fieldwork for the year of study.

As a result, the entire process for completing the project incorporated the architecture of 'My Work', including classifying the works, supervised classification using SVM, as well as compiling the training samples and assessing accuracy via confusion matrices. In this study, the comparison of algorithms that were more reliable and consistent in their reliability was used to identify Green Open Spaces throughout the entire Sleman Regency.

FINDINGS AND DISCUSSION

A. Outcomes of Segmentation

Though critical in OBIA, segmentation defines spatial units for later classification. Mean Shift segmentation, for instance, creates multiple tiny segments in heterogeneous areas such as mixed settlements and the suburban periphery. This is useful for identifying narrow and intricate features, such as small gardens, scattered vegetation, and road medians. It was, however, over-segmentation, in which homogeneous areas were divided into multiple unnecessary objects, which increased the complexity of classification.

On the other hand, Multiresolution Segmentation produced larger, more coherent objects by optimizing the parameters of homogeneity, shape, scale, and compactness. This produced smoother boundary segmentation, especially in agricultural fields and urban parks, which enhanced classification consistency. It resulted in slight under-segmentation, where small objects, such as narrow vegetation strips and scattered trees, were merged with surrounding classes. Results should be clear and concise. Discussion should explore and elaborate on the significance of the results of the work, not repeat them. Avoid extensive citations and discussion of published literature.

Figure 1. Before Segmentation

Figure 2. After Segmentation

The results of segmentation using the Mean Shift algorithm were applied to heterogeneous areas, including rice fields, gardens, city parks, and buildings, at a scale of 1:5,000.

B. Classification Accuracy

Classification accuracy results have been summarized. Mean Shift with SVM: Overall accuracy 81.25%; Kappa index 0.739. Inaccuracies in classification primarily occurred between constructed regions and small patches of vegetation, highlighting the susceptibility of Mean Shift to mixed pixels in complex environments. Multiresolution Segmentation with Nearest Neighbour: Overall accuracy 91.25%; Kappa index 0.878. Most of the classes were accurately classified, although some confusion still existed between farmland and flower gardens. The additional 10% accuracy enhancement illustrates the effectiveness of MRS in integrating the homogeneity and heterogeneity of urban land-cover mapping.

C. Visual Comparison with Ancillary Data Overlay comparisons using Google Earth 2019 revealed the dominant visual effectiveness of Multiresolution Segmentation. In contrast, Mean Shift frequently dissevered these zones into numerous polygons, modifying these complex shapes. On the other hand, in cases of precise features, such as roadside vegetation and riverbank greenery, Mean Shift was more precise in capturing spatial details that were neglected in MRS.

Figure 3. Multiresolution Segmentation Algorithm Classification Results

Figure 4. Google Earth Image Results 2019

Information: Black ellipses indicate buildings and gardens. The orange ellipses indicate city parks, gardens, and buildings. Location: AOI Lembah UGM, scale 1:5,000

D. Comparison with Previous Research

The accuracy levels obtained are consistent with findings from other OBIA-based studies. (Putri et al., 2023) applied Multiresolution Segmentation (MRS) with Pleiades imagery in Kulon Progo and achieved an accuracy of 91.07%, which is comparable to the results of this study. In contrast, Devi and Santosa (2022) reported an accuracy of 77.1% in Purwokerto, highlighting the importance of parameter optimization and image quality for OBIA outcomes. In the present study, the accuracy of Mean Shift is relatively high (81.25%), suggesting that although the algorithm is rarely used in remote sensing applications, it remains useful for fine-scale analysis in complex urban environments.

E. Implications for Urban Planning

Accurate identification of Green Open Spaces (GOS) is essential for urban planning, environmental sustainability, and public health. MRS should be prioritized for GOS monitoring at the municipal level due to its higher accuracy, while the Mean Shift algorithm may serve as a complementary method for micro-scale analyses such as detecting street trees, small parks, and informal green spaces that are often overlooked in large-scale planning (Comaniciu & Meer, 2002; Wicaksono & Farda, 2015) A hybrid approach that integrates both methods could therefore provide a balanced solution, combining the accuracy of MRS with the fine-detail sensitivity of Mean Shift.

CONCLUSIONS

This research showed that, in terms of identifying Green Open Space in Sleman Regency, Multiresolution Segmentation performed better than Mean Shift in terms of lower accuracy and reliability. The results suggest that Mean Shift can be used for more coarse-grained analyses, whereas Multiresolution Segmentation is more appropriate for policy and planning purposes. Further studies should focus on integrating the two methods while broadening the validation through empirical field studies and UAV data.

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