Title of dissertation			
Integrated Multidimensional UAV Imaging Analysis for Rice Bacterial Leaf Blight Disease Assessment			
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Bacterial Leaf Blight (BLB) poses a significant threat to rice cultivation, capable of causing up to 50% yield loss, particularly in Southeast Asian countries like Indonesia. Rice is a critical staple for millions, making BLB management essential for food security. Integrated Pest Management (IPM) and agricultural insurance programs such as Indonesia's Asuransi Usaha Tani Padi (AUTP) have been implemented to mitigate these risks. However, the current damage assessment method in AUTP, based on pest observer field inspections and simple visual scoring, often introduces subjectivity, overlooks spatial variability, and can result in inaccurate indemnity payouts. Meanwhile, prior remote sensing studies have largely relied on pixel-based methods, which suffer from mixed-pixel effects and low spatial resolution, limiting their effectiveness in capturing the true spatial dynamics of disease.

This research began by developing a rice variety classification model, achieving high accuracy using spectral signatures. This variety classification is important because different rice varieties exhibit distinct disease symptoms, and this model was subsequently validated and applied to the BLB damage assessment models. A textural analysis-based model was then developed, achieving an accuracy of 0.784 using a random forest algorithm. This textural analysis, which quantifies spatial relationships between pixels, is key to capturing disease-related patterns that are often missed in conventional remote sensing approaches, providing a foundation for integrating patch fragmentation metrics. To further enhance accuracy, thermal features were incorporated, resulting in an improved accuracy of 0.813, though the model remained pixel-based. A patch fragmentation-based model then provided spatial insights with an accuracy of 0.7703, mapping how BLB spreads across a field, to complement the textural analysis. The most significant contribution of this study lies in the integration of these multiple data sources using machine learning algorithms to create a comprehensive BLB assessment framework. The idea for this integrated approach arose from the limitations of individual methods. Pixel-based approaches often neglect additional information that can be derived from parameters such as texture, thermal data, and patch analysis, and a need for a comprehensive and accurate method. This integration leverages the strengths of textural analysis, thermal data, and patch fragmentation metrics to overcome their individual limitations, providing a scalable, reliable, and efficient solution for BLB damage assessment. Finally, integrating all models into a multidimensional framework significantly enhanced performance, achieving an overall accuracy of 0.9987.

Beyond accuracy improvements, the study conducted an economic feasibility analysis, comparing the proposed UAV-based method with the current pest observer approach. The findings confirm that the implementation of the proposed method is financially unsustainable when compared to the current method under the BAU scenario, yielding a negative

NPV of USD -11,148. On the other hand, the proposed UAV-based method demonstrates long-term economic viability, achieving a positive NPV of USD 9,793 over a 20-year period, compared to the current method under the accurate scenario. These results suggest that despite its higher initial investment, the proposed method's efficiency and accuracy improvements contribute to cost savings and increased economic returns over time.

To support practical adoption, this study outlines a structured implementation roadmap, covering key phases such as stakeholder engagement, pilot testing, full-scale deployment, and long-term optimization. The roadmap ensures financial sustainability, regulatory compliance, and cost-effectiveness, while also addressing risk mitigation strategies, including policy incentives, cooperative UAV ownership models, and automation of data processing to enhance adoption and scalability.

Unlike previous studies that focus on individual UAV-derived features, this research presents a novel integration of textural, thermal, and patch fragmentation metrics within a machine learning framework. The introduction of NDTI for textural analysis, correlation-based feature selection, and spatial disease quantification through patch fragmentation metrics distinguishes this study as a pioneering approach in UAV-based BLB disease assessment.

Photos

Aerial data collection using a UAV over a rice field as a study area in Indonesia

Final examination at Chiba University, Japan