Bumitama Gunajaya Agro

Evaluate Photosynthetic Stress Status using Photochemical Reflectance Index (PRI) and Airborne Multispectral

Project Leader :
Khusniatul Ainiyah

Team Project :
Ahmad Ilmi Hudaya

PROJECT PURPOSE

Oil palm plantations often face various environmental challenges, such as drought, nutrient deficiencies, pest and disease infestations, and climate change, which can disrupt the photosynthesis process and reduce plant productivity. Therefore, a fast, accurate, and technology-based monitoring method is required to assess plant stress levels on a large scale.

The objectives of this project are as follows:

- To evaluate the level of photosynthetic stress in oil palm using the Photochemical Reflectance Index (PRI) on a large scale.
- To develop a multispectral drone-based plant health monitoring system for rapid assessment of the physiological condition of oil palm.
- To enhance the accuracy of early stress detection and the effectiveness of agronomic intervention strategies in improving productivity and plant resilience to environmental changes.

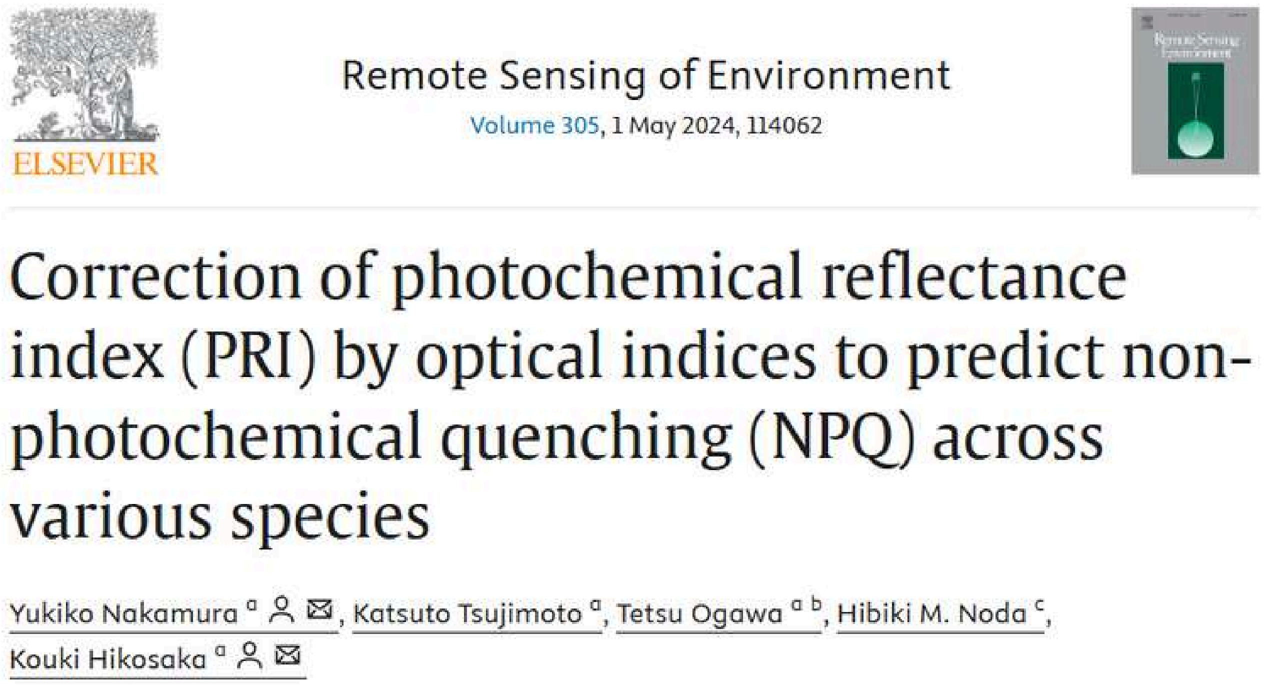
To improve the efficiency of oil palm health monitoring, reduce reliance on time-consuming conventional methods, and support precision plantation practices for optimizing yields and ensuring the sustainability of the oil palm industry.

PROJECT JUSTIFICATION

Research Roadmap

The paper that serves as a reference for this proposal is:
https://doi.org/10.1016/j.rse.2024.114062

This study explores the Photochemical Reflectance Index (PRI)as a potential remote sensing indicator for plant stress with 12 different plants. These findings enhance the potential of PRI for assessing photosynthesis and plant stress in remote sensing, supporting advancements in precision agriculture.


ELSEVIER

Remote Sensing of Environment
Volume 305, 1 May 2024, 114062

Correction of photochemical reflectance index (PRI) by optical indices to predict non-photochemical quenching (NPQ) across various species

Yukiko Nakamura [a], Katsuto Tsujimoto [a], Tetsu Ogawa [a b], Hibiki M. Noda [c], Kouki Hikosaka [a]

Current Research Stage

Oil palm plantations experience environmental stresses that reduce photosynthetic efficiency and yield. Traditional assessments are inefficient, necessitating scalable monitoring solutions. This research integrates PRI-based stress detection using Li-Cor 6800, airborne multispectral sensing, and machine learning to enable large-scale, high-precision stress assessment.

PROJECT JUSTIFICATION

Next Research Step

1. To develop and refine machine learning models to improve the accuracy of detecting oil palm stress levels caused by various stressors that reduce productivity.
2. To implement the proposed approach across different geographical locations to test the generalization and adaptability of the model.

State of The Art

While PRI is a known stress indicator, its large-scale application in oil palm remains underexplored. The key innovations in this research include:

- Combining Li-Cor 6800 ground-truthing with airborne multispectral data to improve accuracy.
- Developing AI-driven stress assessment models for real-time monitoring.
- Scaling up precision agriculture approaches for improved yield management.

GRANT CHART PROJECT

environmental stresses

- Drought
- Flood
- nutrient deficies
- pests
- diseases

impact photosynthesis and reduce productivity

Recent advancements:
Remote sensing and plant physiology to detect early stress symptoms.

Ground Based PRI (Licor 6800)

physiological parameters:
- Fv/Fm of PSII
- NPQ (Non-Photochemical Quenching)
- Chlorophyl content
- CO_2 assimilation

Airborne Multispectral (-)

- capture PRI sensitive wavelengths
- large scale stress detection

Machine Learning

stress classification and predictive analytics

1. automate stress detection across vast plantations
2. improve accuracy by accounting for environmental variability
3. optimize real-time decision making for plantation management

Plant stress category

1. water stress
2. nutrient imbalance
3. heat stress

Instrument

1. Licor 600
2. Spectrometer L-180
3. DJI Mavic 3M

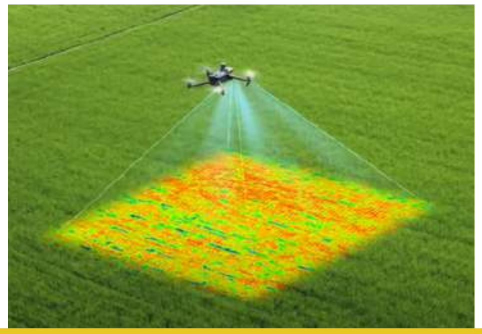
Plant object

Plant age:
1. 3 years (young)
2. 7-20 years (prime)

Plant variety (if possible):
1. Socfin
2. FR
3. Verdant
4. Icalic

METHODOLOGY

$$\text{PRI} = \frac{\rho_{531} - \rho_{570}}{\rho_{531} + \rho_{570}}$$



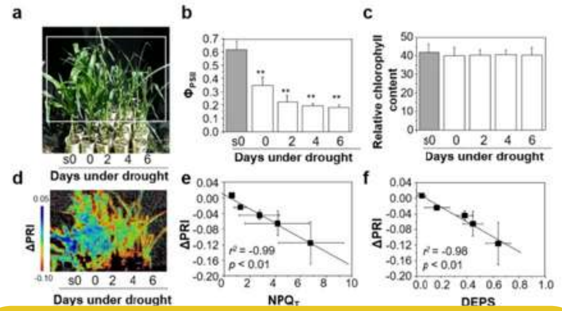
Airborne Data Acquisition

Capture multispectral imagery (including PRI-sensitive bands) using UAVs or aircraft over large plantation areas.

$$\text{NPQ} = \frac{\text{Fm} - \text{Fm}'}{\text{Fm}'}$$

Ground Data Validation

Measure PRI, NPQ, and chlorophyll fluorescence using Li-Cor 600 across different oil palm stress conditions.



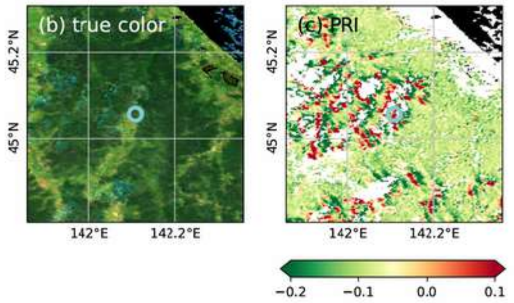
Data Integration

Machine Learning

Train predictive models using supervised learning (Random Forest, CNN, or XGBoost) to classify stress levels based on PRI, NPQ, and multispectral features.

Model Validation

Evaluate model performance using independent field data and apply it across extensive oil palm plantations



Plant Stress Category Map

BIG PICTURE PROJECT

April - Mei 2025

Data Collection & Initial Model Development

Phase 1 - Data Acquisition
- Sentinel-2 Satellite to obtain initial land cover data.
- UAV-Multispectral to capture detailed oil palm canopy structure data.
- Licor 600 for field measurements of oil palm photosynthesis rate.
- Spectrometer L-180 to obtain irradiance values from Photosynthetic Photon Flux Density (PPFD) of oil palm.

Jun - Sep 2025

Model Optimization & Validation

Phase 3 - Model Improvement & Hyperparameter Optimization
- Optimize Deep Neural Network (DNN) to enhance classification accuracy.
- Apply feature selection techniques to filter input parameters from multisensor data.
- Conduct multiple training cycles using different dataset combinations.

Phase 4 - Large-Scale Validation & Risk Mapping
- Deploy the trained model across various oil palm plantation locations.
- Generate high-resolution risk maps showing the spatial distribution of Basal Stem Rot (BSR) infection.

Okt - Nov 2026

Application & Implementation

Phase 7 - Large-Scale Implementation & Model Deployment
- Deploy the final DNN model for real-time Basal Stem Rot (BSR) monitoring.
- Integrate the system with precision agriculture practices.

Phase 8 - Long-Term Monitoring & Adaptive Improvement
- Continuously monitor model performance in real-world applications and refine it as needed.
- Develop an automated system for continuous data collection and risk assessment.

TARGET OUTPUT

Improved Accuracy in Plant Stress Detection

Results:
- Development of a machine learning model based on the Photochemical Reflectance Index (PRI) for more accurate detection of photosynthetic stress in oil palm.
- Integration of Li-Cor 6800 ground truth data with airborne multispectral imagery to enhance precision in stress detection.

Benefits:
- Early stress detection, enabling faster intervention before significant damage occurs.
- Reduced operational costs, as automated monitoring minimizes the need for costly and time-consuming manual inspections.

Optimized Machine Learning Model

Results:
- Development and validation of a Deep Neural Network (DNN) model across multiple plantation locations.
- Improved classification accuracy of plant stress based on multisensor data.

Benefits:
- More precise stress prediction, enhancing the effectiveness of preventive measures.
- Efficient resource allocation, as plantation management can focus interventions on areas with confirmed stress conditions.

High-Resolution Risk Mapping

Results:
- Spatial mapping of plant stress levels and Basal Stem Rot (BSR) risk across large-scale plantations.
- Visual representation of affected areas to facilitate early preventive measures.

Benefits:
- More effective risk mitigation, identifying critical areas before stress spreads.
- Optimized plantation productivity, as management decisions are tailored based on specific risk zones.
- Reduced crop losses, ensuring improved yield stability through proactive intervention.

Drone-Based Monitoring System

Results:
- Implementation of a UAV-multispectral system for real-time assessment of oil palm physiological conditions.
- Reduction in dependence on slow and less accurate conventional monitoring methods.

Benefits:
- Faster and broader plantation monitoring, covering large areas in significantly less time.
- Early detection of stress symptoms, reducing reliance on manual inspections.
- Support for precision agriculture, providing more accurate data for plantation management.

Scalability and Broad Applications

Results:
- The developed model can be applied to various geographical locations and different types of plantations.
- The system can be expanded for monitoring other crops vulnerable to environmental stress.

Benefits:
- Support for climate change mitigation strategies, with adaptive, data-driven approaches to environmental variability.
- Enhanced agricultural sustainability, through more precise and technology-based monitoring solutions.

Bumitama Gunajaya Agro

Terimakasih

Open Innovation BGA Tahun 2025