Supporting Blue Carbon and Circular Economies through AI-Driven Biodiversity Preservation and Risk Mitigation in Southeast Asian Ecosystems

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Background

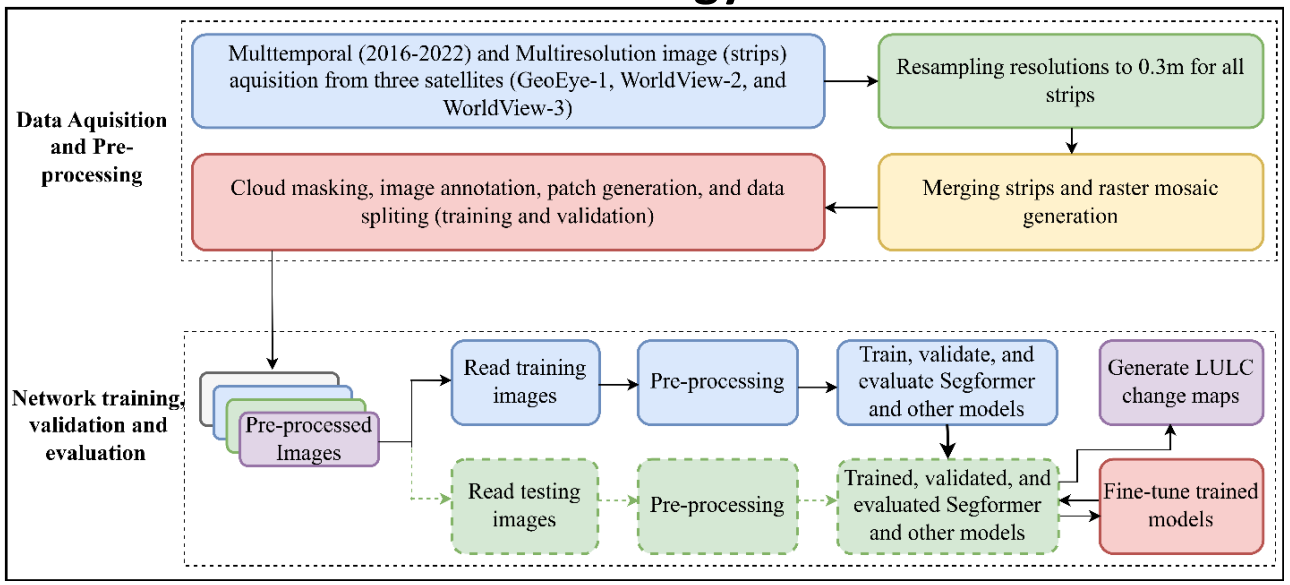
- Southeast Asia contains **over half of the world**'s tropical peatlands and **nearly half** of its mangroves, despite **covering just 3%** of the Earth's land
- Peatlands and mangroves **store up to four times more carbon** than rainforests, playing a vital role in regulating greenhouse gases. Their importance, threats, and global impact are significant
- Peatlands and mangroves offer essential services, from habitat and food to **climate regulation** and **economic support**
- Pristine peat swamps and mangroves enhance carbon storage, water regulation, and biodiversity, **benefiting people indirectly**
- Secondary forests provide **direct benefits**, offering abundant resources like food, fuelwood, and fiber from cultivated land

Project Objectives

- To develop AI models for **accurately estimating carbon stocks** in peatlands and mangroves, supporting **carbon sequestration initiatives** and **carbon credit markets**
- To integrate real-time ecosystem monitoring data into circular economy frameworks, enabling **sustainable use** of forest resources and **enhancing economic value** through carbon credit systems

Existing Project: Mapping Land Use and Land Cover Change (LULC) Patterns

Methodology



- We used our novel transformer architecture on satellite images **to identify and quantify land changes** that occur over time.
- Our improved Segformer network utilizes a custom loss function that amalgamates the **Categorical Cross-Entropy (CCE)** and **Smooth Dice Coefficient (F1-Score)** tailored to the unique characteristics of our LULC datasets.

Results

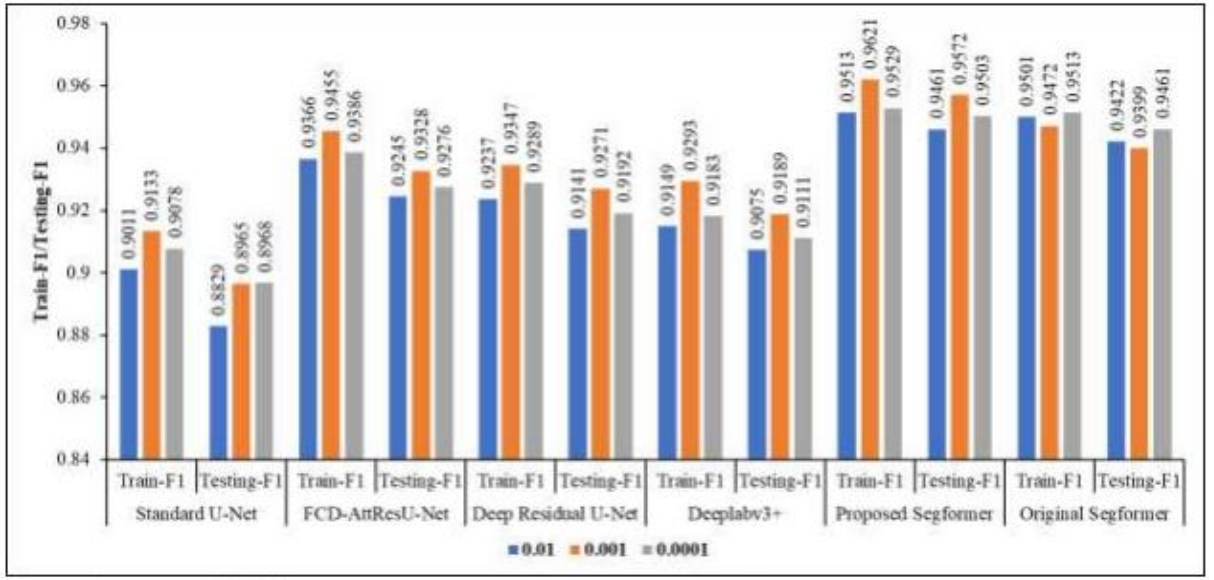


Figure 6 Impact of different LRs on the training and testing F1 scores

- In contrast to the original Segformer architecture that used Cross-Entropy, our custom loss function models complex spatial relationships and long-range contextual information that CNNs struggle to capture.
- Our proposed model **outperformed the state-of-the-art**, with F1 of about 0.96, generating detailed change maps.

K Kalinaki, et. al. "Mapping Land Use and Land Cover Change Patterns in the Tropics Using Deep Learning Techniques and Multisource High-Resolution Satellite Images ", under review

Existing Project: Mapping Land Use and Land Cover Change (LULC) Patterns

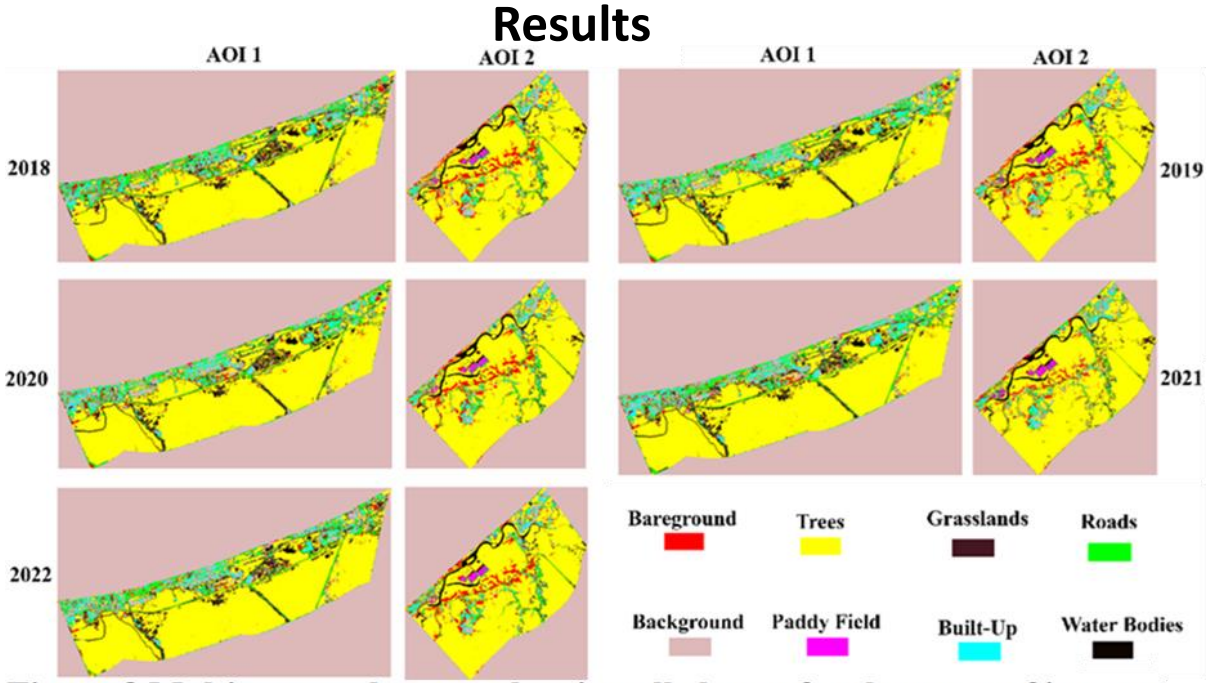


Figure 8 Multitemporal scenes showing all classes for the areas of interest

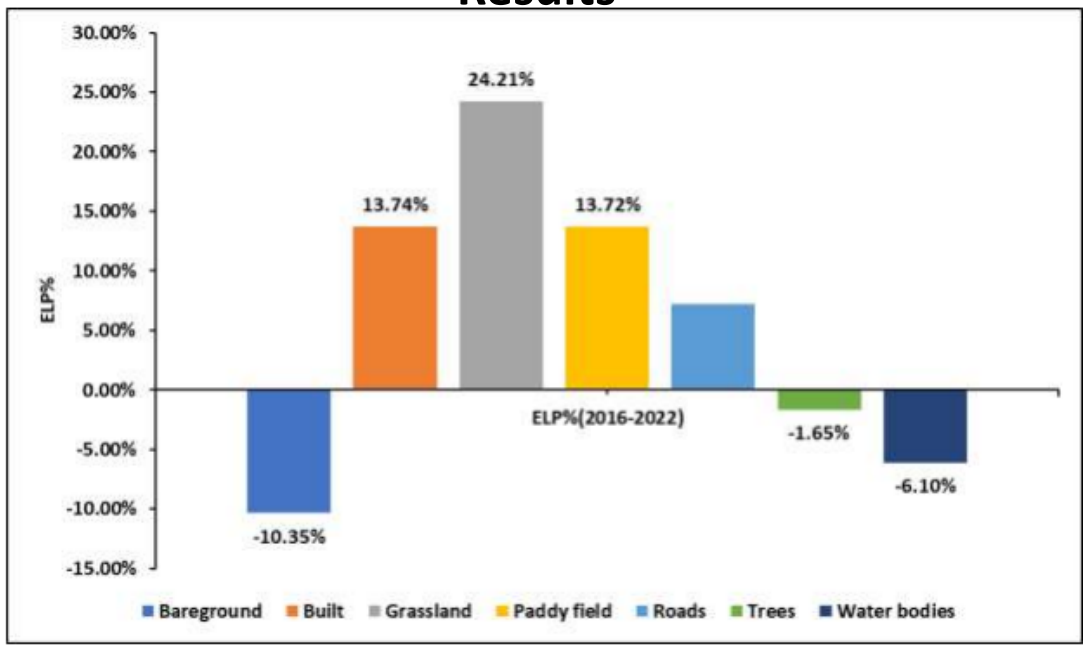


Figure 10 Effective land cover change percentage for seven years (2016-2022) for all classes under investigation

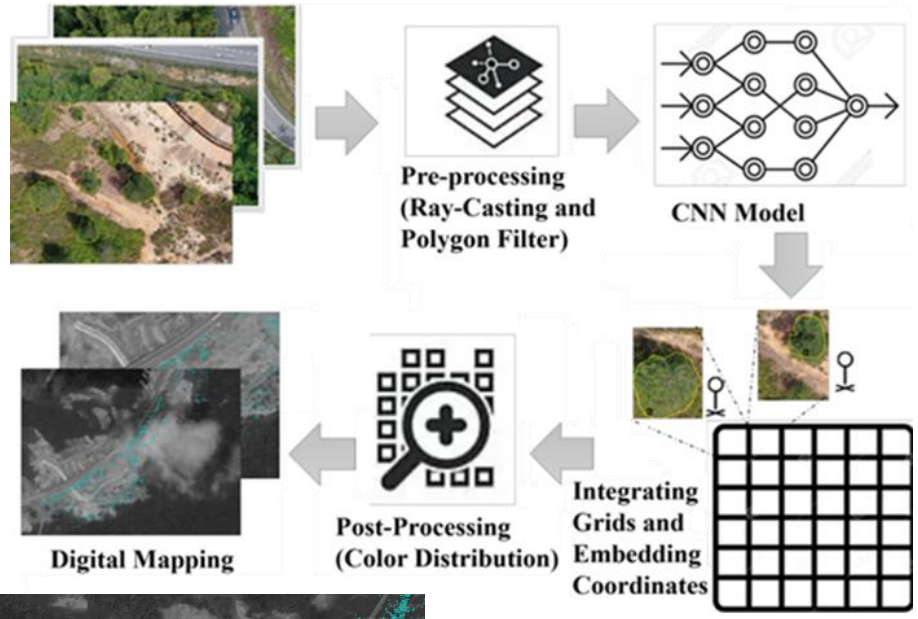
- **Habitat fragmentation** due to road construction exacerbates negative impacts
- There is urgent need for **sustainable practices balancing** economic growth and environmental preservation

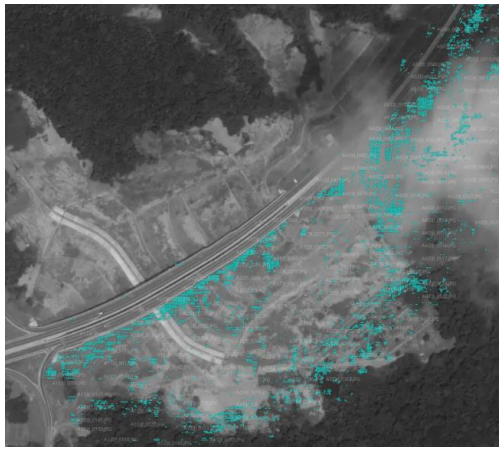
- Increase in the land cover for buildings, grasslands, paddy fields, and roads
- Bare ground, trees, and water bodies decreased

K Kalinaki, et. al. "Mapping Land Use and Land Cover Change Patterns in the Tropics Using Deep Learning Techniques and Multisource High-Resolution Satellite Images ", under review

Existing Project: Digital Mapping of Invasive Species

(1) Digital Mapping



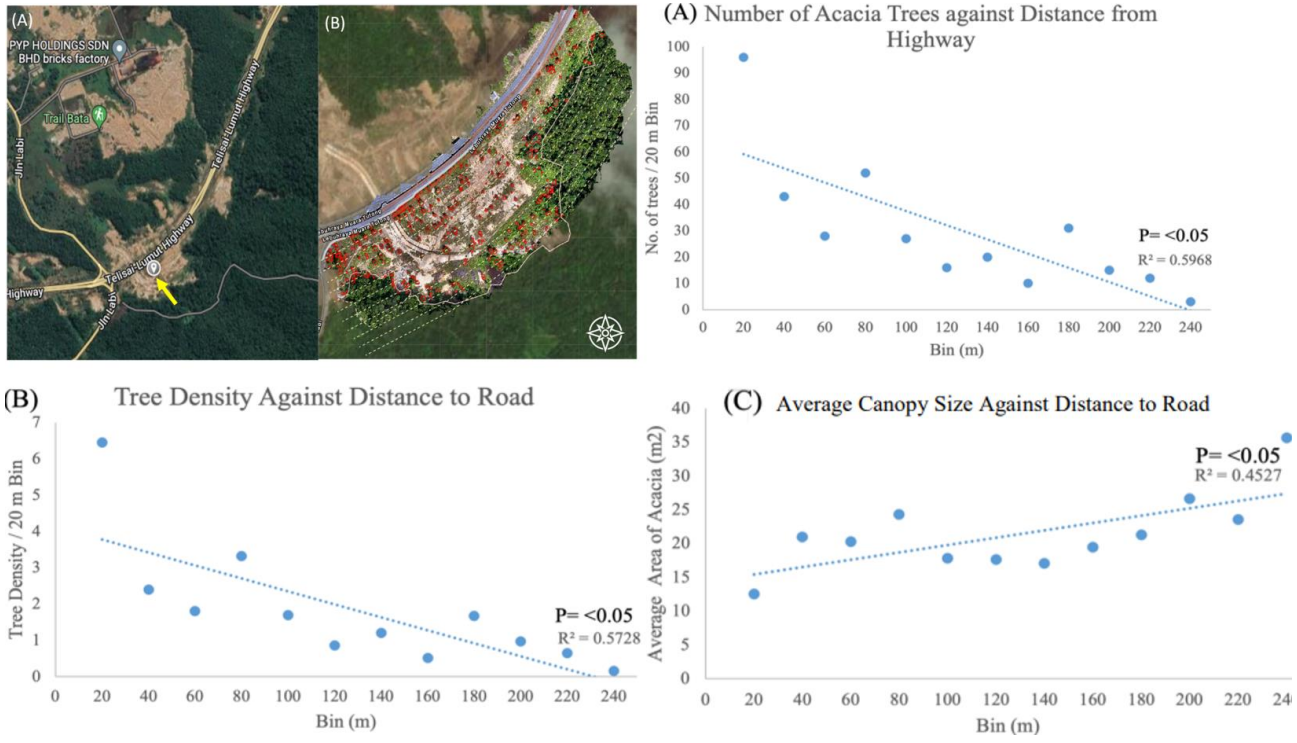


- Automatic geo-identification allows us to identify and extract the GPS locations of the Acacia trees
- First, we **collected images** from drones
- We **manually annotate** and **preprocess** the images
- Next, they are **fed to CNN** to develop the AI model
- Where Acacia is found, its **GPS location** is extracted
- Based on **colour distribution**, misclassifications are removed
- Our AI model has a **mean accuracy of 91%,** demonstrating its effectiveness
- We hope to work with agencies and timber vendor to **regulate Acacia growth** and simulate circular economy

AN Wahab, et. al. "UAV-assisted Acacia mangium Digital Mapping and CNN-based Detection Algorithm with Localisation Embedding Function", under review

Existing Project: Digital Mapping of Invasive Species

(2) Understanding spread and habitat preference



- Using the extracted GPS locations, we can automatically analyse and understand the spread
- GIS tools were used for analysis, dividing the plots into 20m bins
- Higher tree density and numbers were found **closer to the highway**, suggesting it an **important dispersal** agent
- May increase its spread to nearby forest reserve and lead to forest fires and loss given its fire proneness, affecting most ASEAN with haze and poor air quality
- Such work **support forest managers and ecologists** in rapidly evaluating the long-term ramifications of infrastructure initiatives on tropical forests
- We gather large volumes of data **covering large areas without entering deep jungle**
- Our open source codes and models **empower other scientist** to reuse and refine the methods and models, without incurring high computation costs from model training

I Amal, et al. "Digital Mapping Of Invasive Acacia Mangium Willd. Trees Along Telisai-Lumut Highway Along The Andulau Forest Reserve." Proceedings of the 7th International Conference of Recent Trends in Environmental Science and Engineering (RTESE'23). 2023.

Relevance & Significance

Applications

- Automatic identification and quantification of important forest products to **support rural economies and sustainability**
- The models developed can be **applied to other** species, plots and countries
- The underlining technology of semantic segmentation can **solve many computer vision problems**

Economic Value

- In the developing countries, fuelwood accounts for US$70 000 million and forest industry products for US$ 63 000 million.
- Automatic forest monitoring, inventory and assessment system can bring **valuable economic returns** by helping countries generate carbon credits.
- Rural populations also use, protect and create forests as **sources of agricultural inputs**; they depend on tree products to **sustain soil fertility and structure**, to feed livestock and to maintain desired moisture regimes and water flows.

Future Plans

- Using LiDAR data to **precisely estimate carbon stocks** in peatlands and mangroves will support our mission to quantify and protect these ecosystems' carbon sequestration potential
- **Refining current models** using advanced and more sophisticated deep learning techniques such as transformer-based or multimodal architectures
- Deployment of models to achieve realistic ROI and application of developed architectures to **solve other remote sensing and/or computer vision problems**
- **Scaling up** the project to apply to other data types (multimodal), plots and other species
- Starting a **research consortium** with ASEAN partners to share data and resources for application and refinement of models, working towards regional and global research collaboration, social betterment and economic benefits
- Looking into new research paradigm in **bio-inspiration** research