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Monitoring Coastal Infrastructures in the Maldives using Remote Sensing and Machine Learning

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September 2024

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Outline

Background

Vulnerability of the Maldives

- Low-lying islands, average elevation: 1 meter
- Highly vulnerable to sea level rise

Economic Importance of Tourism

- Tourism contributes 25%-30% of GDP
- Main source of foreign exchange and employment

Role of Coastal Infrastructure

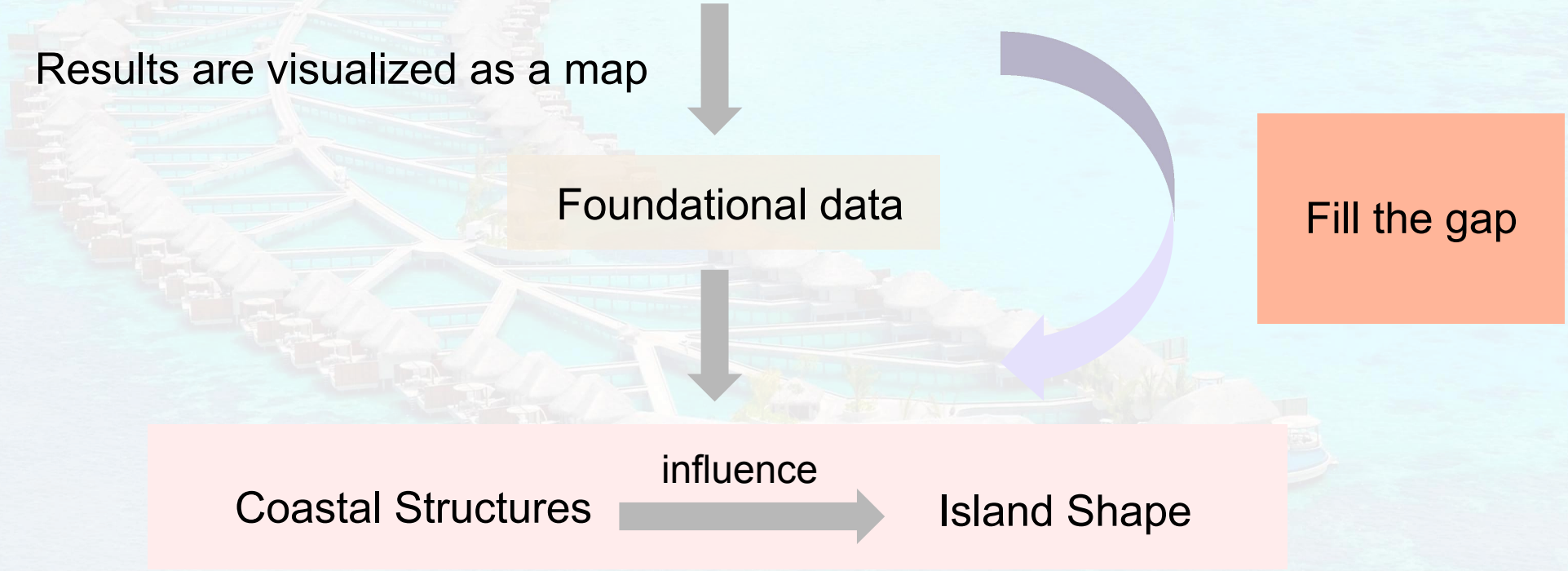
- Vital for tourism support
- Key infrastructures: harbours, jetties, resorts

Environmental Impact of Man-made Structures

- Influence on sediment transport, salinity, hydrodynamic processes
- Cause erosion and sedimentation
- **Change the shape of the island**

Objectives

This project aims to develop a tool that can detect the **spatial and temporal evolution** of coastal infrastructures in the Maldives such as **harbours**, **jetties** and **resorts**.



Methodology

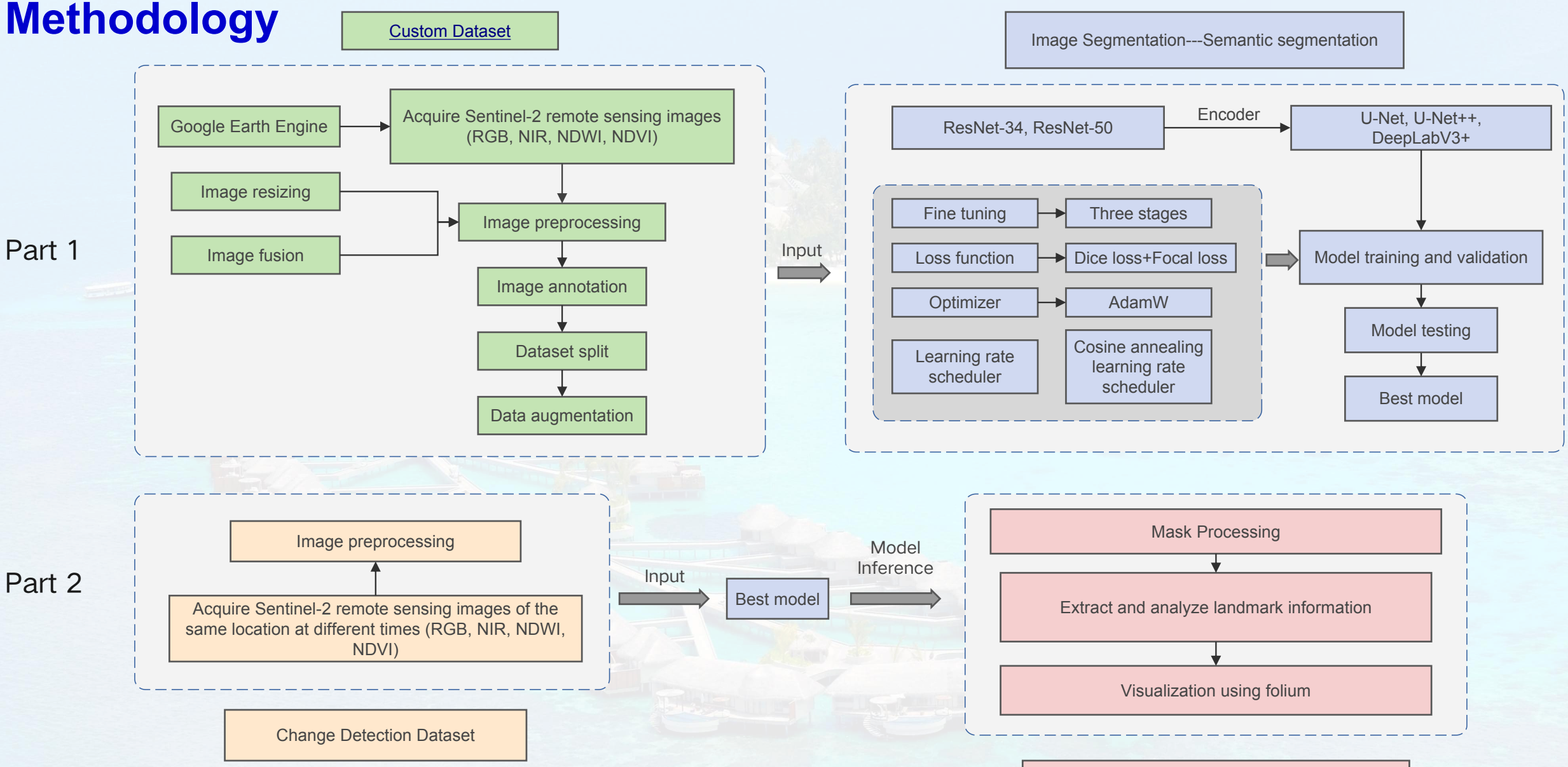


Figure 1: Flow Diagram of the Methodology

Methodology

Very unbalanced!

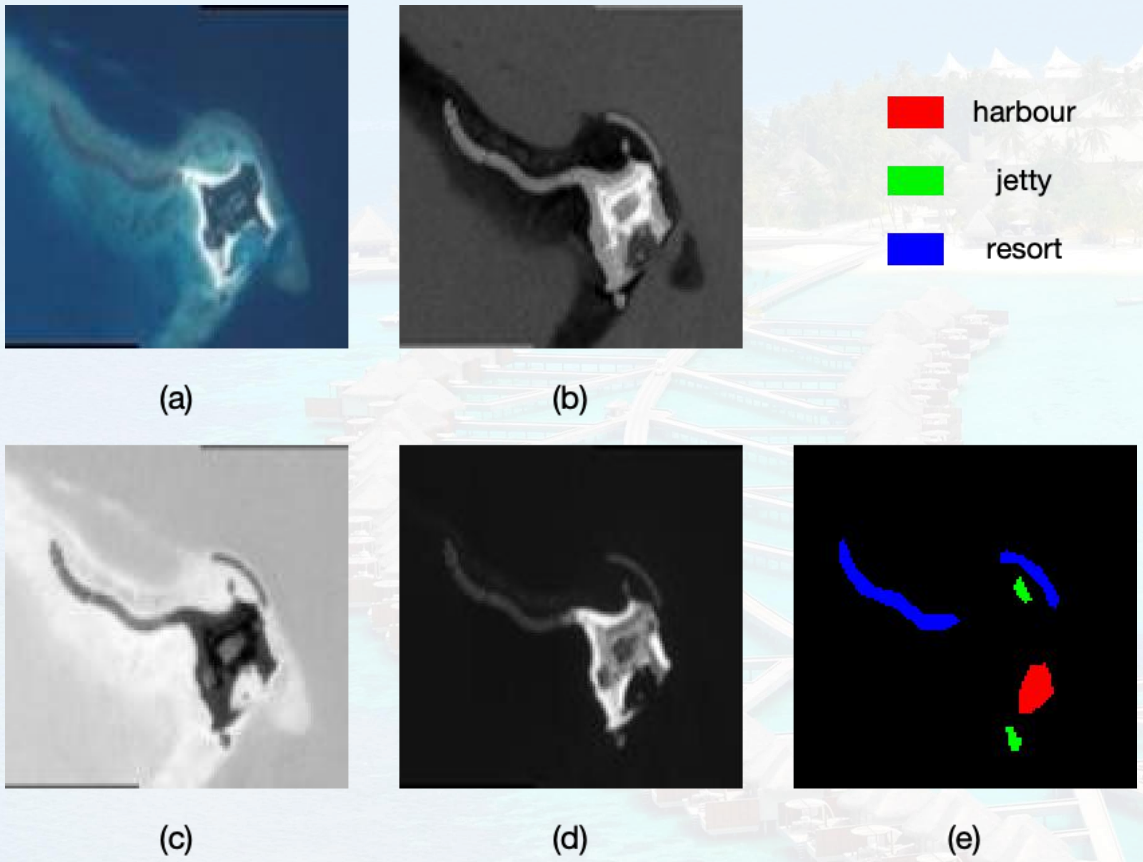


Figure 2: (a) RGB band, (b) NIR band, (c) NDWI, (d) NDVI, and (e) the mask image generated from annotations

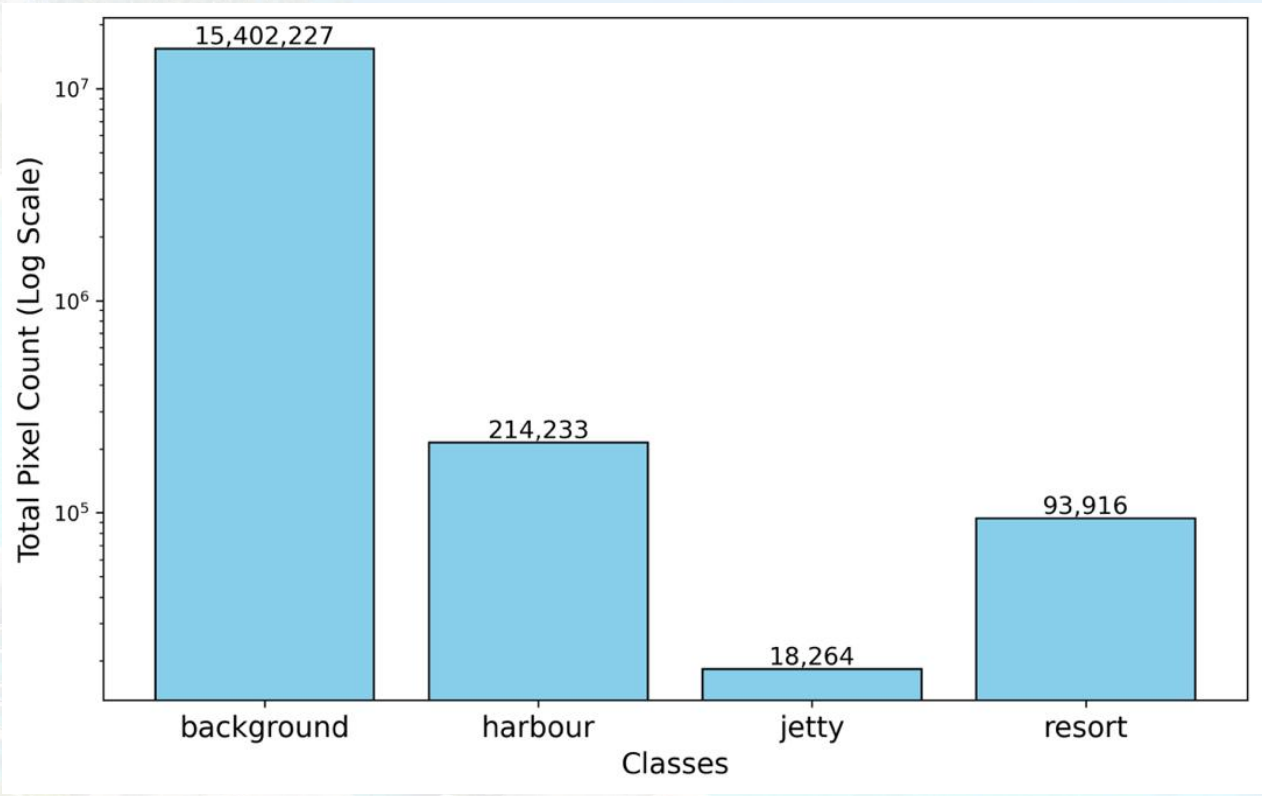
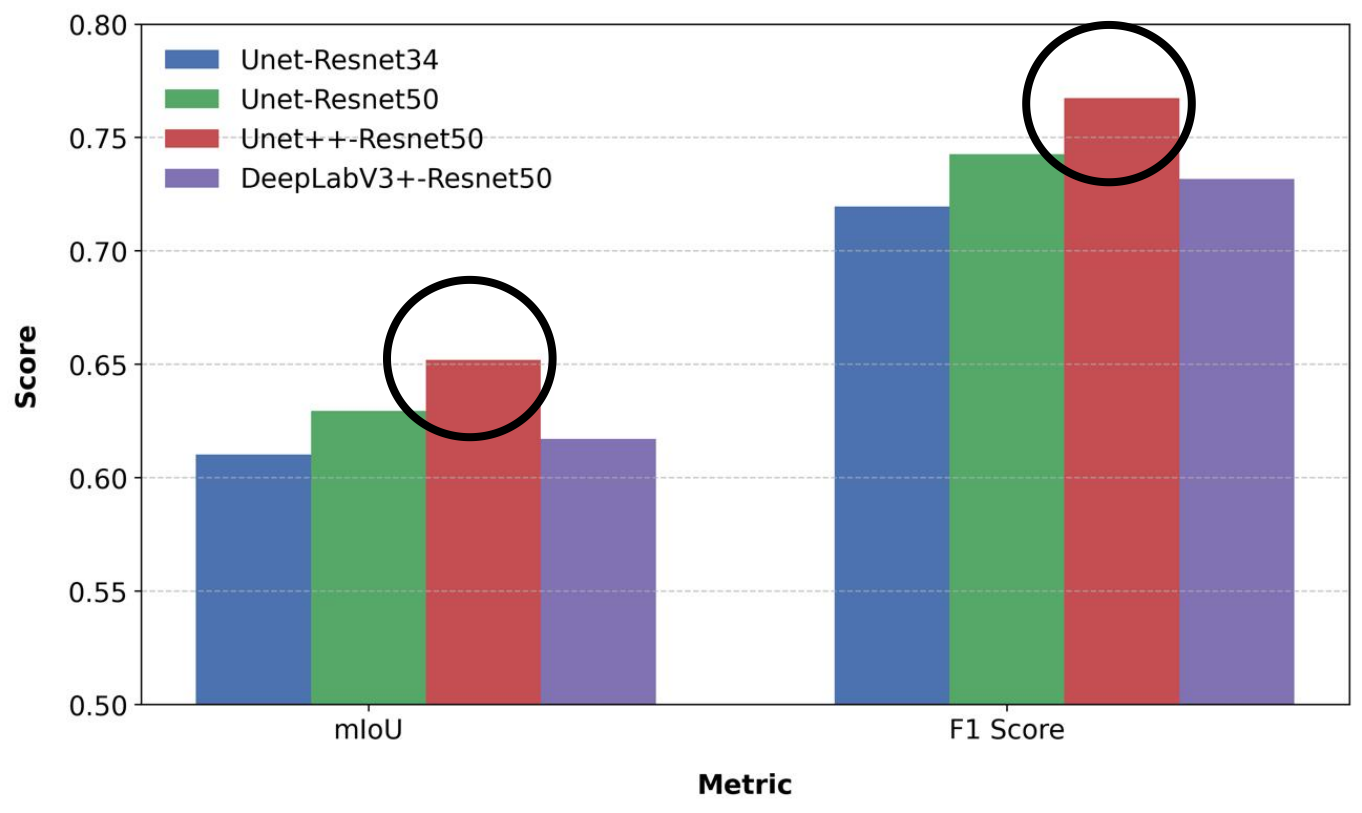


Figure 3: Pixel counts for different classes in the log scale

Result



U-net++-ResNet-50 had the best overall performance

Figure 4: Comparison of mIoU and mean F1 Score across different models

Result

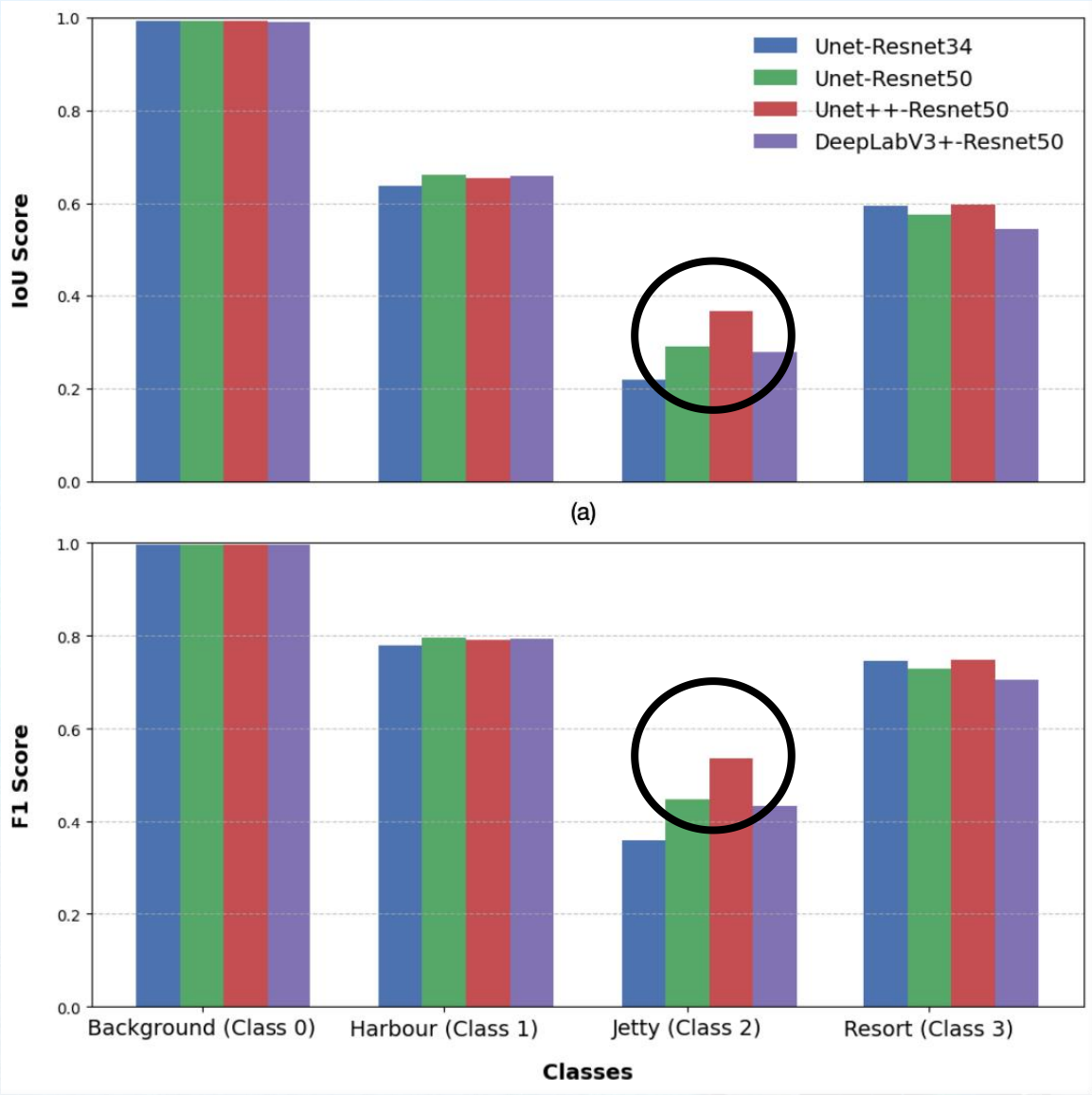


Figure 5: Comparison of IoU and F1 Scores across Different Models for Each Class

U-Net++-ResNet-50 had the best performance on the jetty class

Result

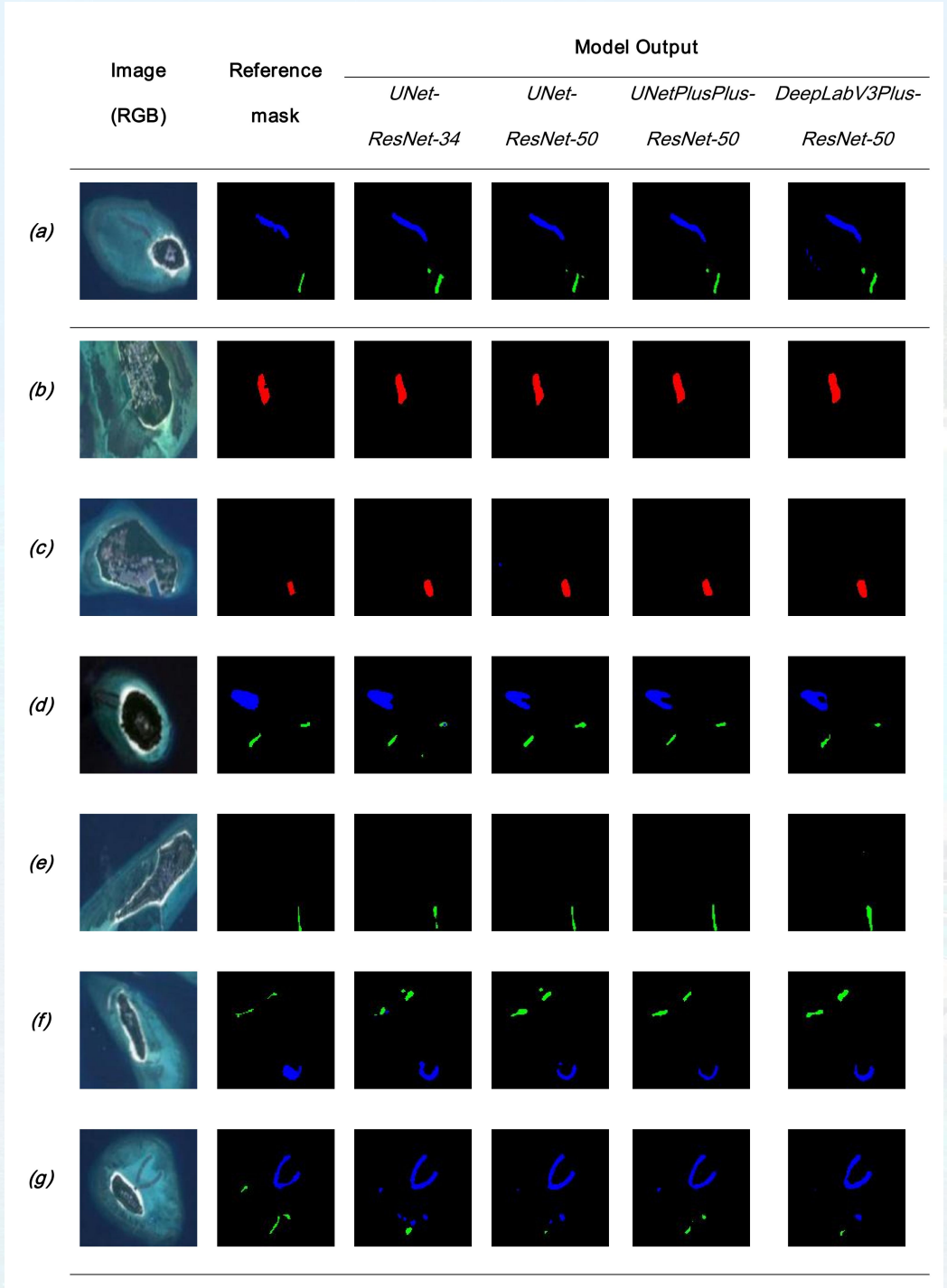


Figure 6: A selection of input images, their corresponding reference masks, and the output masks predicted by various segmentation models (a-g).

The segmentation results of U-Net++-ResNet-50 are more refined, with fewer misclassified masks

Result

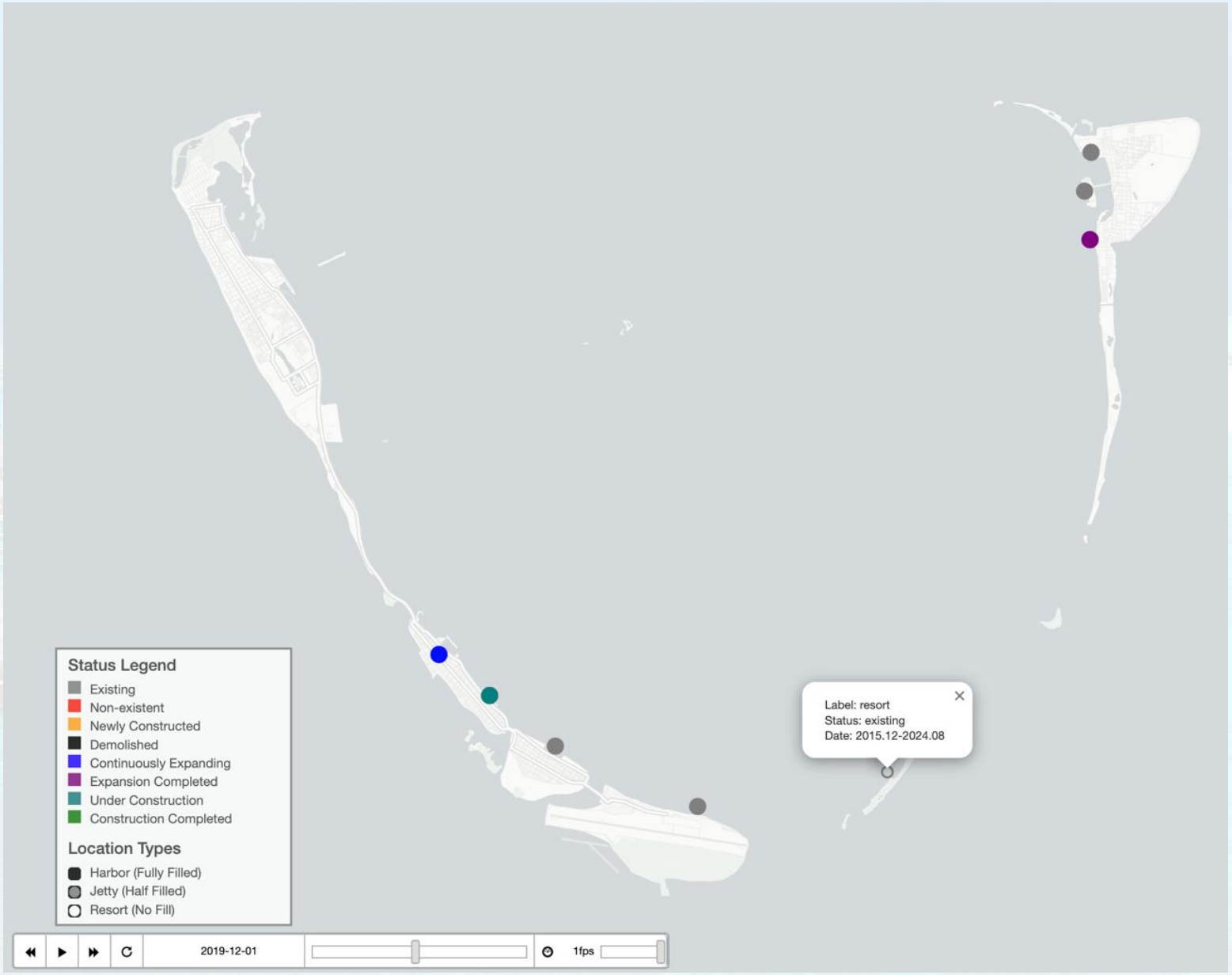


Figure 7: Interactive Folium map of the Addu Atoll, illustrating changes in coastal infrastructure and providing detailed status information for each location.

Discussion

1. Model Performance

- U-Net++-ResNet-50 is the best model: mIoU = 0.6520, Macro F1 = 0.7674
- Multi-level skip connections & deep feature extraction
- Captures fine details in small targets like jetty and resort
- DeepLabV3+ focuses more on global context, less effective for small objects

2. Class Imbalance

- Background class dominates dataset; jetties, resorts, harbours are **underrepresented**
- Dice loss + Focal loss, center cropping
- Jetty is small, hard to identify
- Result: Improved, but jetty identification still challenging (mIoU = 0.3661)

Discussion

3. Image Resolution

- Medium resolution of Sentinel-2 limits model's ability to detect small objects (jetties)
- Difficult to distinguish between jetties and noisy objects in the background
- Fine details missed in medium resolution
- Solution: Multispectral data fusion (RGB, NIR, NDWI, NDVI)

4. Application of Coastal Infrastructure Monitoring

- Monitoring example: Harbour in Maradhoo Island
- Multiple phases of construction, demolition, reconstruction (2015-2024)
- Visualizes spatial and temporal changes in infrastructure
- Helps analyze correlations between man-made infrastructure and changes of island shape

Conclusion

TO SUM UP…

- **Objectives Met:** The tool was successfully developed for monitoring coastal infrastructure changes in the Maldives
- **Model Performance:** The segmentation accuracy of the jetty needs to be further improved
- **Study Impact:** Helps identify potential links between man-made structures and island shape changes

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Thank you!