Mangrove Mini Model: Attention-based U-Net for Detecting Mangrove Loss in Satellite Images

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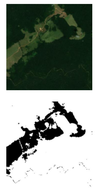
Original Paper: An attention-based U-Net for detecting deforestation within satellite sensor imagery

- Implements an Attention U-Net model to detect deforestation by constructing segmentation masks from Sentinel 2 satellite images
- Compares Attention U-Net (2M) with U-Net (31M), Residual U-Net (31M), ResNet50-SegNet (72M) and FCN32-VGG16 (134M) on RGB and 4-band datasets
- Attention U-Net has fewest parameters, is fastest to train, and performs the best of all of the models



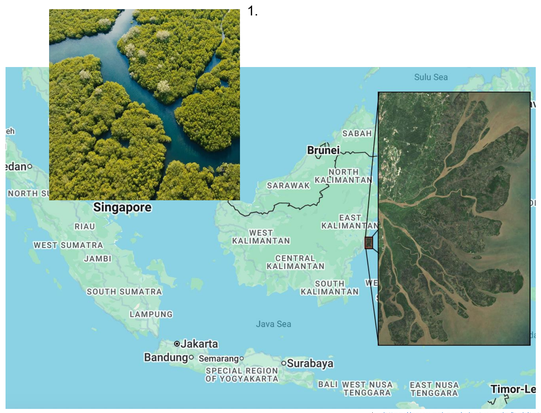
Classifier	Dataset							
	Validation				Test			
	IoU	Precision	Recall	F1-score	IoU	Precision	Recall	F1-score
Attention U-Net	**0.9581**	**0.9790**	**0.9779**	**0.9785**	**0.9516**	**0.9758**	**0.9748**	**0.9753**
U-Net	0.9530	0.9766	0.9752	0.9759	0.9473	0.9738	0.9724	0.9731
Residual U-Net	0.9432	0.9723	0.9696	0.9720	0.9429	0.9715	0.9703	0.9709
ResNet50-SegNet	0.9467	0.9733	0.9717	0.9725	0.9416	0.9707	0.9694	0.9701
FCN32-VGG16	0.8592	0.9210	0.9214	0.9212	0.8557	0.9212	0.9205	0.9208

D. John, C. Zhang, An attention-based U-Net for detecting deforestation within satellite sensor imagery

New Context: Kalimantan Mangroves

- Coastal mangroves provide coastal protection from erosion & natural disaster, act as carbon sinks, and support biodiversity
- Mangroves are at risk of destruction from pollution, coastal development, logging, and conversion to aquaculture
- Over 2/3 of global mangrove habitat has already been lost or degraded
- From 1994 to 2015, over half of the mangrove forest in the Mahakam Delta in Indonesia has been converted to commercial aquaculture
- Compared to the original paper's task: segmenting mangroves presents new challenges of narrow & fragmented coastal belts, mixed pixels at water-land edges, and noisy labels

1.



1. https://www.zsl.org/what-we-do/habitats-and-regions/habitats/marine-and-freshwater/mangroves

Adaptation of the Model Architecture

- Separable depthwise convolution layers drastically decrease parameter count

Model	Parameters
U-Net (Unmodified)	31M+
Attention U-Net (Unmodified)	2M+
Modified Attention U-Net (Batch Norm + Dropout + Leaky ReLU)	2M+
'Mini' Model (Mod. Att. U-Net + Separable Conv)	454K

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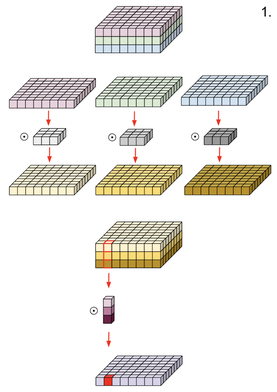
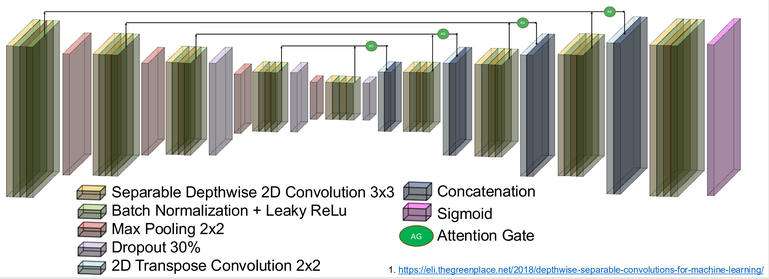


- To boost performance with fewer parameters, Batch Normalization, Leaky ReLU, and Dropout Layers were added



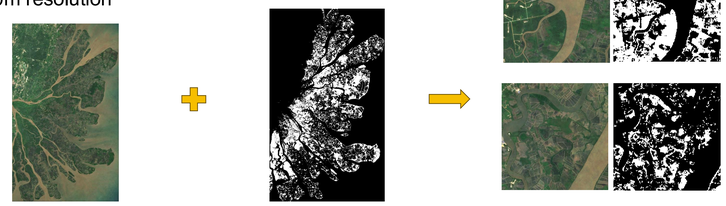
1. https://eli.thegreenplace.net/2018/depthwise-separable-convolutions-for-machine-learning/

Datasets

Inputs:
- Sentinel-2 Level-2A (2019-2021)
- Cloud-filtered & median composite from Google Earth Engine
- 4 bands: B4 (R), B3 (G), B2 (B), B88 (NIR)
- 10m resolution

Labels:
- Global Mangrove Watch 2020 Sentinel-2 10m baseline
- Cropped to Kalimantan Mangrove Deltas
- Aligned to Sentinel-2

Preprocessing:
- Radiometric scaling & conversion to uint8
- 512×512 tiling, masking tiles where labels incomplete



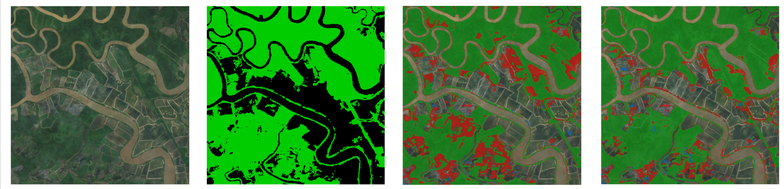
Model Performance

Model	Accuracy	Precision	Recall	F1-Score
U-Net (Unmodified)	0.9488	0.9499	0.9489	0.9494
Attention U-Net (Unmodified)	0.9483	0.9497	0.9483	0.9490
Modified Attention U-Net (Batch Norm + Dropout + Leaky ReLU)	0.9443	0.9885	0.9442	0.9463
'Mini' Model (Mod. Att. U-Net + Separable Conv)	**0.9499**	**0.9507**	**0.9499**	**0.9503**

- Separable attention U-Net 'Mini Model' achieves F1 = 0.9503 with ~4.5x fewer parameters than Attention U-Net

Evaluation of the Performance

- None of the models were able to reach the 98% f1-score of the original paper
- The adjusted model performs well on small channel boundaries, but has trouble classifying thin bands of mangrove, as well as the distinguishing the noisy boundaries between mangrove and aquaculture ponds
- The Global Mangrove Watch 10m dataset only reports 95% accuracy, so there are instances in which the model produces correct classifications that diverge from GMW and are marked as error



Sentinel 2 | GMW Mask | Attention U-Net Prediction | 'Mini' U-Net Prediction

Discussion and Critical Reflections on SDGs

- Mangrove protection directly impacts biodiversity (SDG 15), marine life (SDG 14) and coastal protection, and blue carbon store (SDG 13)
- Scaling down models while maintaining performance is also integral to developing sustainable, energy-friendly AI
- Improved 10m mapping allows monitoring of small-scale clearing and erosion & enables conservation and restoration projects
- Limitations & Ethics: reliance on global-scale datasets, risk of being misinterpreted by policymakers without proper context
- Future work: incorporate higher resolution, larger datasets, multi-year training, include biomass estimation for mangrove stability prediction

Project Github:
https://github.com/zachmothner/MangroveMiniModel