Automated Detection of Shrimp Aquaculture Zones in Puttalam District, Sri Lanka: A Deep Learning Segmentation and Machine Learning Classification

R.M.D.M. Karunarathna[1*], K.L.P.I. Liyanage[2], K.H.N. Kulapathi[3]
[1]*School of Ecology and Applied Meteorology, Nanjing University of Information Science and Technology, Nanjing, China*
[2]*School of Atmospheric Physics, Nanjing University of Information Science and Technology, Nanjing, China*
[3]*Sri Lanka Navy, Colombo, Sri Lanka*
*r.m.d.karunarathna@gmail.com

Accurate spatial mapping of shrimp farms is crucial for sustainable aquaculture management, environmental monitoring, and regulatory compliance in tropical coastal regions. The present study conducted a comparative analysis of two machine-learning paradigms for the automated detection of shrimp farms using high-resolution satellite imagery in the Puttalam District, Northwestern Province, Sri Lanka. The study area encompasses an 85 km coastal belt, divided into five operational zones containing 939 digitized farms and 4,651 ponds covering 2,883 hectares, systematically surveyed from May to October 2025. An enhanced U-Net convolutional neural network, incorporating residual blocks, Squeeze-and-Excitation (SE) attention, and atrous spatial pyramid pooling, was employed for pixel-level semantic segmentation. A Random Forest classifier was used for tile-level binary classification based on 256×256 pixel tiles derived from Bing Maps satellite imagery. The enhanced U-Net, trained with Focal Tversky Loss to optimize recall, achieved an Intersection over Union (IoU) of 0.62, a Dice coefficient of 0.77, and a recall of 0.81. The Random Forest classifier, trained on 18 engineered features comprising spectral statistics, Grey-Level Co-Occurrence Matrix (GLCM) texture descriptors, and vegetation indices, attained a tile-level accuracy of 0.96 and a Receiver Operating Characteristic Area Under the Curve (ROC AUC) of 0.98. Feature-expansion experiments confirmed that the original 18-feature set captured essential discriminative information. The results demonstrate that the Random Forest model excels at rapid large-scale screening, whereas the enhanced U-Net provides spatially explicit pond-boundary delineation essential for area estimation. An integrated two-stage framework combining Random Forest pre-screening with U-Net segmentation is proposed as an operationally efficient solution, warranting further empirical validation for national-scale aquaculture monitoring.

Keywords: *Shrimp aquaculture, Remote sensing, U-Net semantic segmentation, Random Forest classification, Satellite imagery, Puttalam District*