

COASTAL POND AQUACULTURE EXPANSION IN ASIA: A MULTI-DECADAL SATELLITE TIME SERIES ANALYSIS

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Global Aquaculture and the Role of Asia

Aquaculture in Asia has rapidly expanded, driven by rising fish demand and overfishing [1]. Coastal pond systems are crucial protein sources and support regional economies. This study uses Earth observation time series data to map and monitor the spatio-temporal changes of pond aquaculture systems (Fig.1) across 22 Asian countries along a 300,000 km coastal zone from the 1980s to 2019.



Fig. 1: Shrimp pond system in Vietnam.

Continental-Scale Pond Monitoring

We developed a comprehensive method to map pond aquaculture across the entire Asian coastal zone using all available Sentinel-1 and Sentinel-2 data from 2019 [2]. Over 25,000 Sentinel-1 IW GRDH images were processed into temporal median composites, followed by automated pond detection with histogram-based segmentation at the single-pond level. Extracted pond units were enriched with multispectral time series (S2-L2A), topographic and geometric information, and global water data to accurately identify aquaculture ponds. This multi-sensor fusion approach achieved 91.9% accuracy, resulting in a reference dataset of 3.4 million pond objects (see Fig.2).

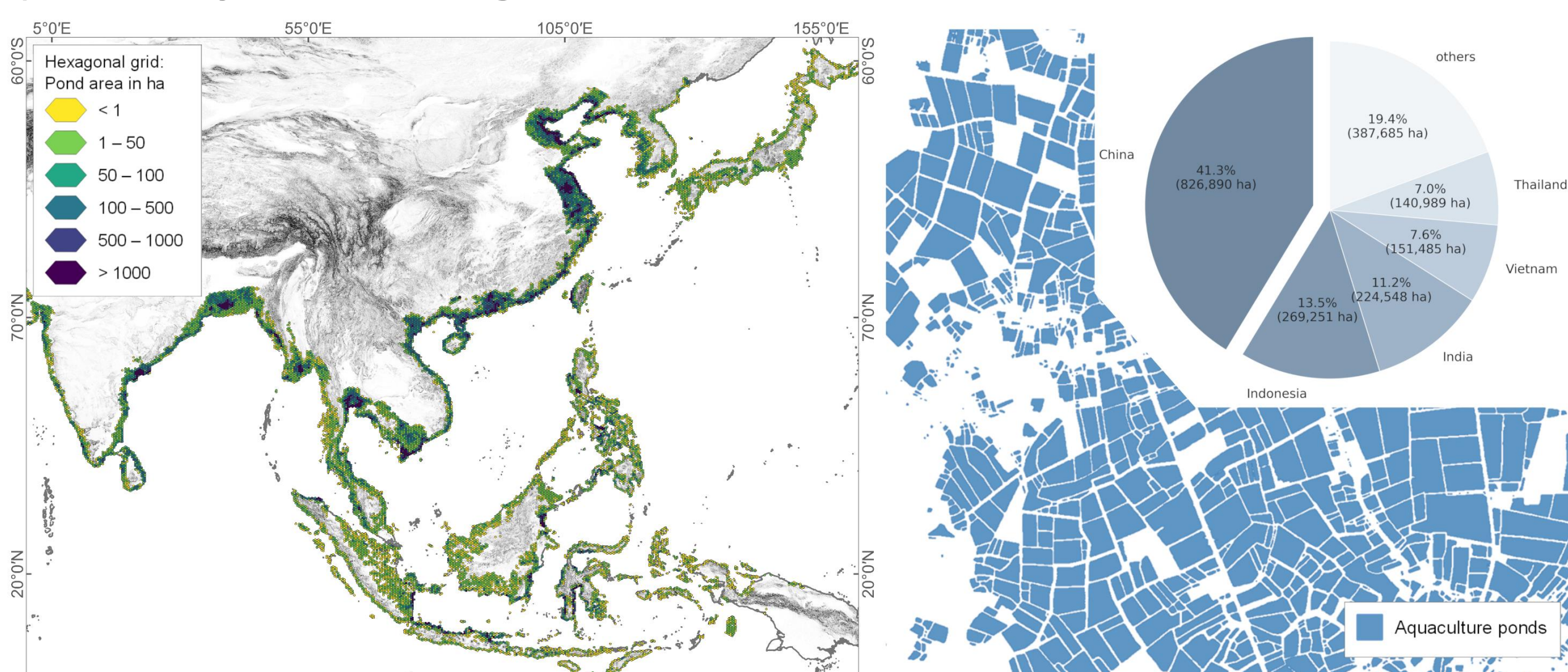


Fig. 2: Left: Detected ponds summarized into a hexagon grid (hexagon cells with a side length of 10 km). Right: Mapped aquaculture ponds (blue, right) [2]

Time Series Monitoring of Pond Water Status

Using the full Landsat archive (1984 – 2019), we created annual water masks to track pond activity over time, optimizing water detection with indices like NDWI, MNDWI, AWEI, and WIFI, the latter giving the best results (Fig.3). These water masks enabled long-term monitoring of the reference pond objects to determine the yearly aquaculture status (active/inactive) for each reference pond identified in 2019. We monitored all reference ponds (>2 million ha) within a 200 km coastal buffer; 45% lie within 5 km of the coast (Fig. 4).

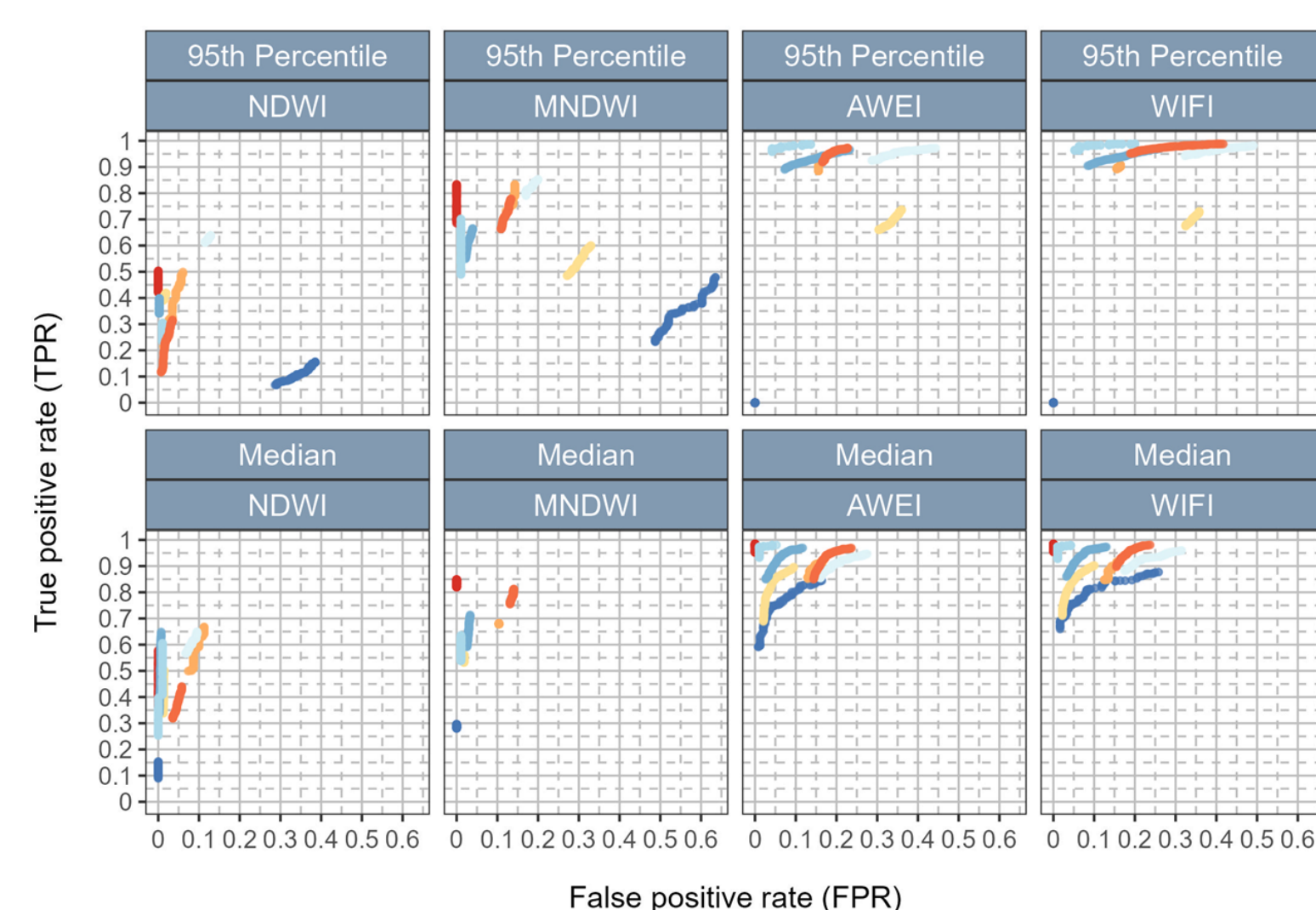


Fig. 3: ROC curves of parameter variations at test sites [3].

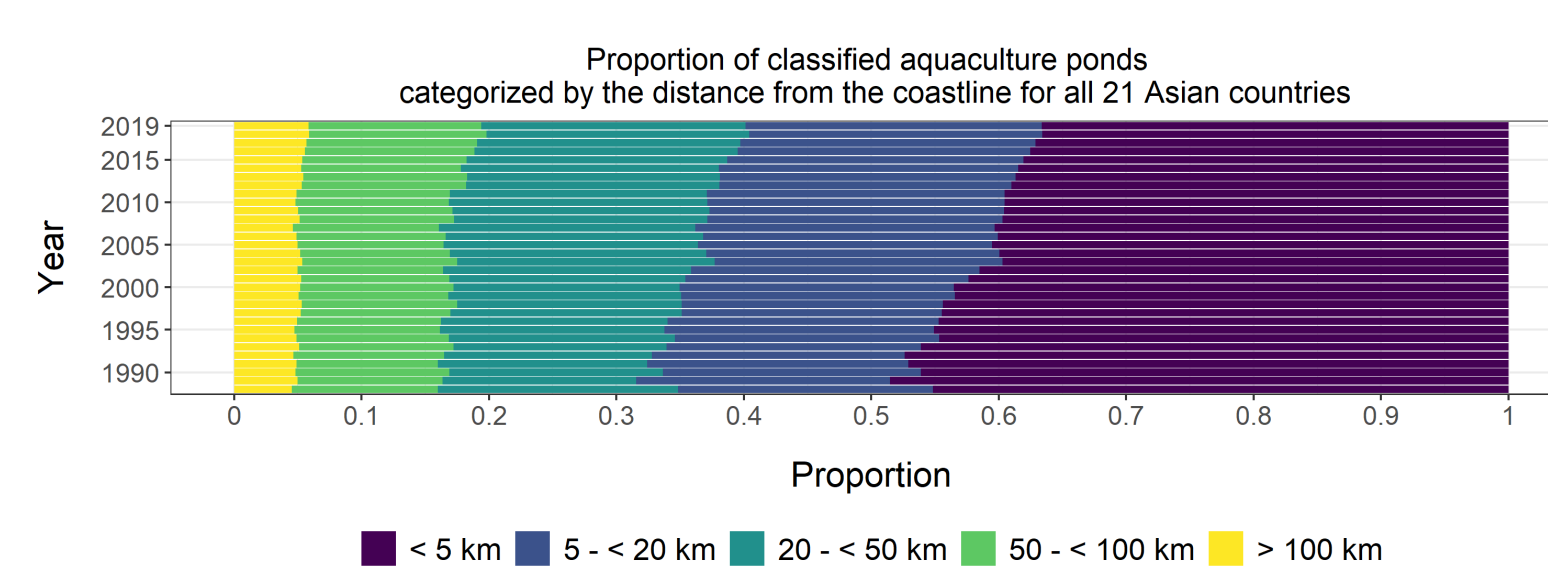


Fig. 4: Proportion of reference ponds by distance from the coastline, for each year and all countries combined [3].

Growth Analysis of Asian Coastal Aquaculture

Using the continental-scale dataset on annual pond aquaculture status, this research quantified growth rates and spatial expansion patterns across Asia's coastal regions. A five-year interval map (Fig. 5) reveals that pond aquaculture is expanding inland, highlighting a dynamic shift in coastal aquaculture development. Between 1988 and 2019, active pond areas expanded from 6,500 km² to over 19,000 km² - representing a more than threefold increase. China dominated pond aquaculture, holding 40% of total active pond area in 2019, followed by Indonesia (13%), India (11%), Vietnam (7.7%), and Thailand (7.2%).

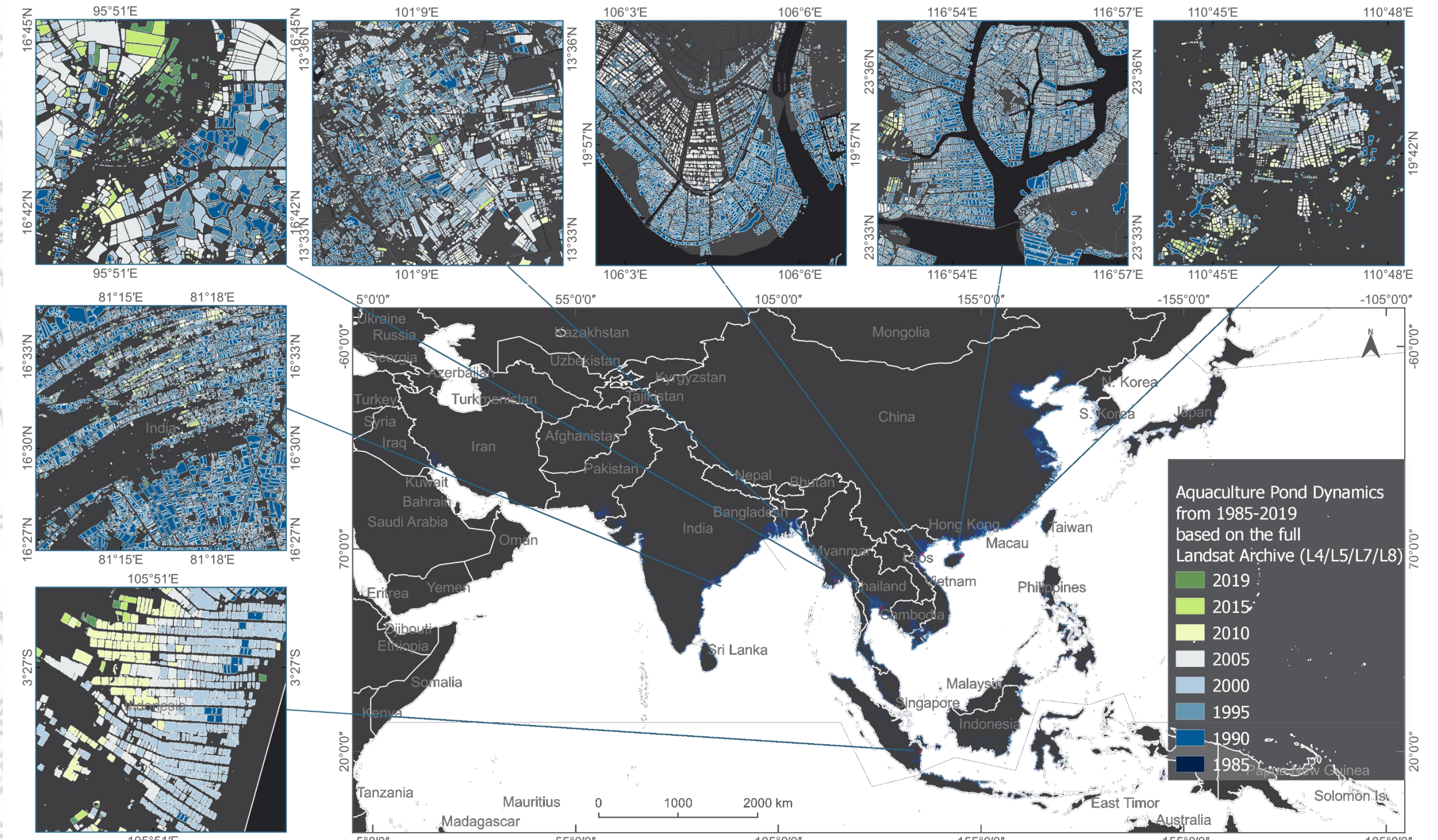


Fig. 5: Hotspot aquaculture regions showing the Landsat-derived active aquaculture status at pond polygon level from 1985-2019 for the mapped reference ponds [3].

Spatial expansion dynamics correlated with FAO production data, though deviations indicate environmental factors, market shifts, policy changes, and diseases also shaped trends (Fig.6). Highest rates of pond expansion occurred in rapidly industrializing districts. These findings underscore the strong growth of coastal Asian pond aquaculture and importance of integrated analyses considering both spatial and non-spatial

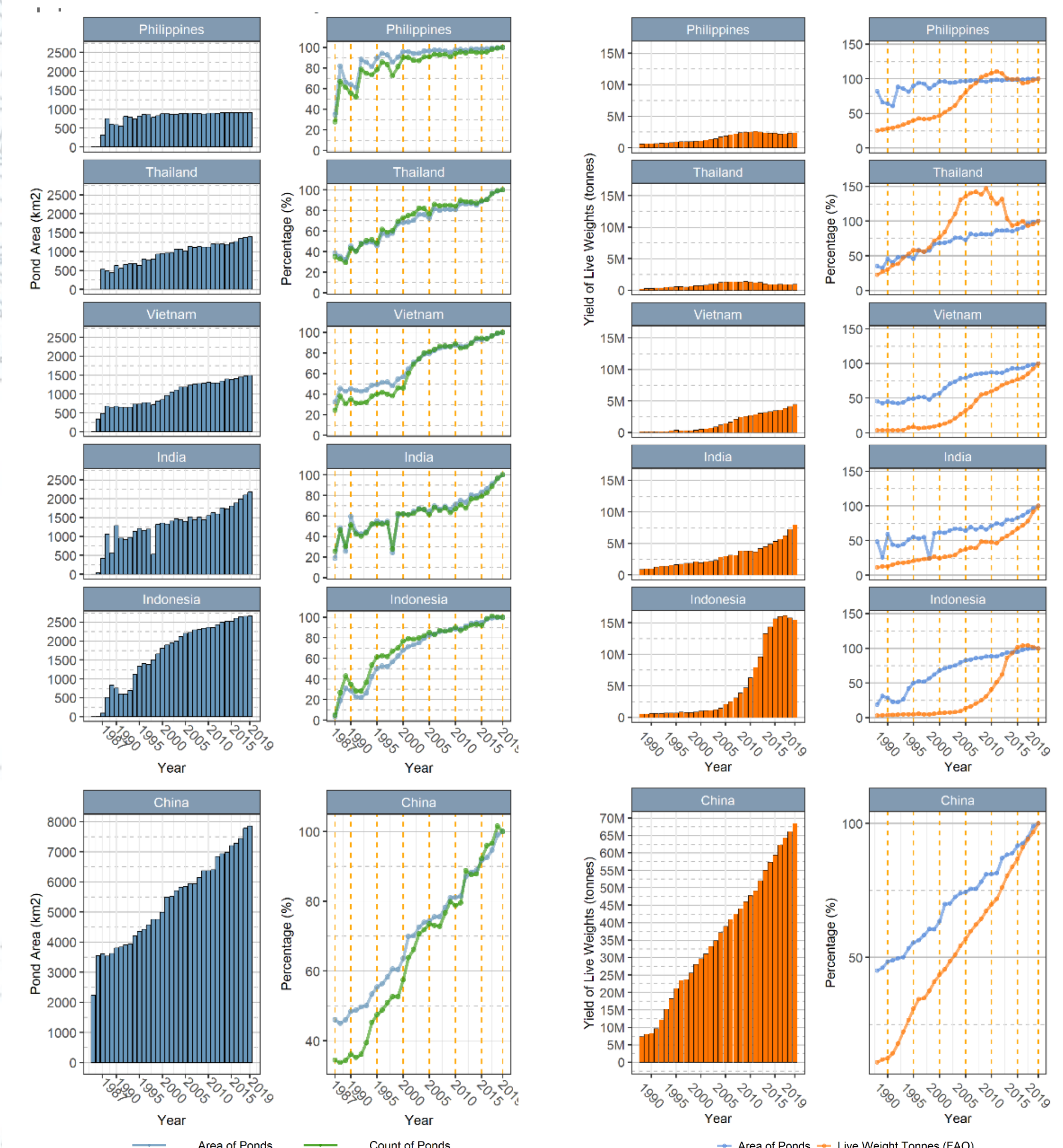


Fig. 6: Earth Observation derived pond dynamics (area – blue, count - green) vs official FAO statistics on aquaculture production (orange) [3].

[1] Ottinger, M., Clauss, C., Kuenzer, C., 2016: Relevance, distribution, impacts and spatial assessments—A review. *Ocean & Coastal Management*, 119, 244-266. <https://doi.org/10.1016/j.ocecoaman.2015.10.015>.

[2] Ottinger, M., Bachofer, F., Huth, J., Kuenzer, C., 2022: Mapping Aquaculture Ponds for the Coastal Zone of Asia with Sentinel-1 and Sentinel-2 Time Series. *Remote Sensing*, 14, 153. <https://doi.org/10.3390/rs14010153>.

[3] Ottinger, M., Liu, K., Ullmann, T., Huth, J., Kuenzer, C., Bachofer, F.: Pond Aquaculture Dynamics in Asia: Satellite Time Series for Analyzing the Spatio-temporal Development of Coastal Aquaculture. Under review.