Aquaculture and Coastal Habitats Report No. 5

A Mapping of Pond Aquaculture, Mangroves and Coastal Wetlands in Vietnam, Cambodia, Thailand and Myanmar in 1999 and Comparison to 2014

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Introduction

On behalf of the Gordon and Betty Moore Foundation, Clark Labs has been engaged in a series of projects to map aquaculture and coastal habitats. This report summarizes the procedures used for a rapid mapping of pond aquaculture, mangroves and coastal wetlands in Vietnam, Cambodia, Thailand and Myanmar for 1999. For information on the broader objectives of the program, please refer to Eastman et al., (2015). For this product, however, the goal was to try to record the state of the land with respect to these categories as close as possible to the beginning of May 1999 to support the regulations of the Aquaculture Stewardship Council.

Procedure

Although the baseline mapping for 2014 (Eastman et al., 2015) was done with Landsat 8 data processed to 15 m, for 1999 Landsat 5 data needed to be used. Since Landsat 5 had no high resolution panchromatic band, the data needed to be mapped at 30 m resolution.

For the geographic reference system, the same datum (WGS84) and projection (Albers Equal Area Conic with standard parallels at 19.33 and 8.66 degrees north) and origin (104 E and 14 N) were used. However, the false origin was changed such that the true origin had coordinates of 1,716,000 m E and 880,020 m N. This reference system was named Albers_SEAsia2.

In total, 7 classes were mapped: Mangrove, Forested Wetland, Marsh, Pond Aquaculture, Water, Other land cover and Missing. Images were acquired as close to the end of April 1999 using the protocol indicated in the sidebar on the next page.

For all but the pond aquaculture class a Mahalanobis classifier (Foody et al., 1992) was used. However, the image bands used were as follows:

- SRTM 30 m elevation data
- Tasseled Cap Greenness (derived from the Landsat TM imagery)
- Tasseled Cap Wetness (derived from the Landsat TM imagery)

Within each image, the analyst delineates polygons around some examples of specific classes. The Mahalanobis classifier then computes a probability image known as a *typicality* that indicates for each pixel how typical it is of the class it was trained on. This would then be thresholded to yield a hardened class. This is the only classifier that is capable of mapping a single class at a time.

For pond aquaculture, a very different procedure was used. Inspired by the characteristics of a Convolutional Neural Network (CNN) a procedure was developed in which the Landsat 5 TM bands are augmented by derivative indices and convolutional filters of these inputs. Specifically, the following were used:

- Landsat Bands 1-5 and 7
- Tasseled Cap Greenness, Wetness and Brightness Indices
- 3x3 and 5x5 mean filters and 3x3 slope images of the above
- SRTM elevation

Within each image, the analyst delineates polygons around examples of ponds and examples of a broad class called “not pond”. A Multi-Layer Perceptron (MLP) neural network (Eastman, 2014) was then used for the classification. This procedure has proven to yield excellent results with minimal post-classification clean-up.

Protocol for 1999 Image Acquisition

The target date for image acquisition is April 1999. If a clear image is not available, classify and superimpose the results from several images, but keep to the 1999 dry season (Dec 1998-Apr 1999 inclusive) as close to April 30 as possible.

If a pixel cannot be classified within this time frame you can use a newer image (up to May 2001) if you are classifying mangrove and an older image (back to Dec 1997) if you are classifying pond.

For ANY other class, if there is no cloud-free imagery for the 1999 dry season, mark it as Obscured by Clouds and record the date (see below) as 999.

Here is the logic behind using earlier and later images:

Imagery is Post-1999 (forward to 2001)

- If mangrove in image then mangrove in 1999=true
- Assumes the mangrove could not grow to maturity this fast

Imagery is Pre-1999 (back to 1997)

- If pond in image then pond in 1999=true
- Assumes that ponds could not transition back to mangrove in such a short period of time

In a separate image, record the year and Julian date of each pixel classified.

Accuracy Assessment

After all scenes were classified and the results mosaicked, an accuracy assessment was undertaken. However, the procedure used was altered slightly from that used in Eastman et al. (2015). The sampling design is a two stage scheme that combines a *critical sampling* for selection of the primary sampling units (PSU) and a stratified probability sampling for selection of the secondary sampling units (SSU). The primary sampling units were Landsat scene WRS-2 footprints. These footprints were chosen by a non-random judgement of the project team. Scenes with high quantities of pond aquaculture and mangroves were chosen, while those with few instances were not sampled. Figure 1 shows the scenes samples. Within these primary units, 300 points were randomly selected within 2 strata. 200 were selected in the near-shore zone up to 2.6 km and 100 were selected in the back zone. Table 1 presents the results in the form of an error matrix.

In the 2014 baseline mapping a standard was set of 85% for critical categories and 70% for non-critical categories. In this mapping, pond aquaculture and mangroves were the critical categories. Accuracy exceeded 90% for both the user's accuracy and producer's accuracy for these categories.

Table 1 Accuracy Assessment of the 1999 Land Cover Classification (cell entries are the number of validation points)

		Actual								
Mapped		Mangrove	Forested Wetland	Marsh	Pond	Water	Other	Total		User's Accuracy
	Mangrove	468					9	477		98.11%
	Forested Wetland		3				1	4		75.00%
	Marsh			3				3		100.00%
	Pond	2			297	1	3	303		98.02%
	Water	4			3	189	8	204		92.65%
	Other Land Cover	29	1	1	24	15	2219	2289		96.94%
	Total	503	4	4	324	205	2240	3280		
	Producer's Accuracy	93.04%	75.00%	75.00%	91.67%	92.20%	99.06%			96.92%

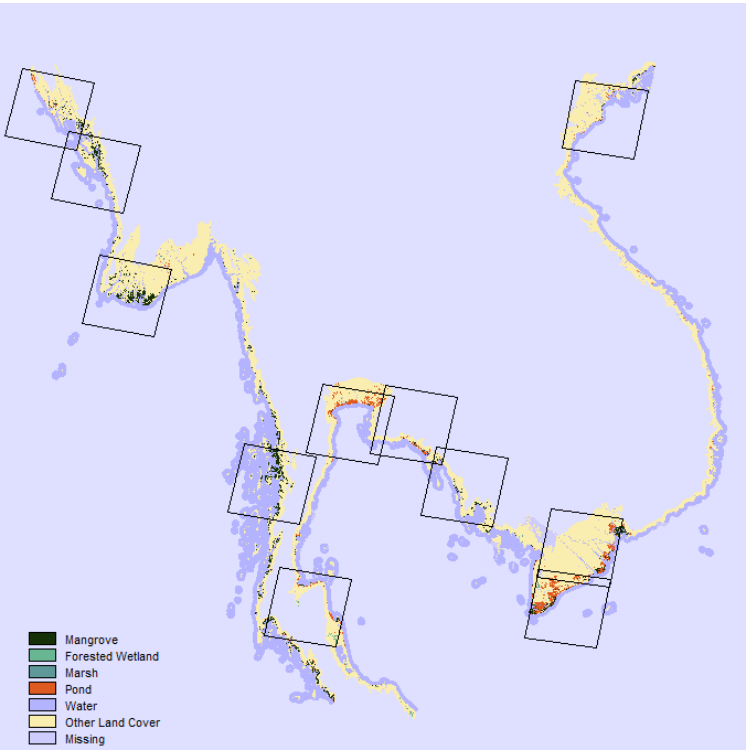

Figure 1 : The classified map of 1999 and scenes sampled for accuracy assessment

Area Statistics

Table 2 summarizes the area of mangrove and pond aquaculture by region/state for Thailand in 1999 and 2014, along with the percent change in each. Over this 15 year period, the area of pond aquaculture declined by 22% while mangroves had a net expansion of 14%.

Table 2 Area Statistics for Thailand

Subdivision	Pond 1999	Pond 2014	%Change		Mangrove 1999	Mangrove 2014	%Change
Chanthaburi	222.21	164.79	-25.84%		84.79	125.14	47.59%
Chon Buri	71.33	61.11	-14.32%		3.35	11.68	249.27%
Chumphon	57.55	51.84	-9.93%		48.04	60.72	26.40%
Krabi	40.90	37.82	-7.53%		346.64	370.70	6.94%
Bangkok Metropolis	97.51	54.44	-44.16%		2.67	1.39	-48.17%
Chachoengsao	357.94	208.65	-41.71%		7.55	18.49	144.78%
Nakhon Nayok	5.65	6.85	21.34%		0.00	0.00	0.00%
Nakhon Pathom	104.00	59.54	-42.75%		0.20	0.00	-100.00%
Nakhon Si Thammarat	223.04	222.81	-0.10%		106.56	130.40	22.37%
Narathiwat	1.37	0.59	-57.07%		1.70	0.64	-62.25%
Pathum Thani	3.49	9.64	175.92%		0.00	0.00	0.00%
Pattani	15.02	18.39	22.41%		24.56	27.27	11.06%
Phangnga	28.99	24.91	-14.08%		439.23	448.24	2.05%
Phatthalung	6.52	3.90	-40.16%		9.38	4.54	-51.58%
Phatthalung (Songkhla Lake)	0.13	0.08	-38.13%		0.77	2.55	229.80%
Phetchaburi	89.78	63.63	-29.13%		12.04	52.52	336.33%
Phra Nakhon Si Ayutthaya	0.23	0.34	48.06%		0.00	0.00	0.00%
Phuket	10.68	5.51	-48.46%		19.49	19.16	-1.72%
Prachin Buri	56.38	51.77	-8.17%		0.00	0.00	0.00%
Prachuap Khiri Khan	41.83	116.69	178.97%		3.30	1.41	-57.21%
Ranong	18.95	11.29	-40.45%		164.54	149.14	-9.36%
Ratchaburi	52.00	43.06	-17.20%		0.00	0.00	0.00%
Rayong	36.97	38.32	3.64%		11.18	17.25	54.30%
Samut Prakan	346.90	183.36	-47.14%		9.97	18.09	81.40%
Samut Sakhon	261.24	148.02	-43.34%		25.49	19.57	-23.21%
Samut Songkhram	120.76	95.28	-21.10%		14.09	40.75	189.29%
Satun	39.72	36.65	-7.73%		338.82	348.53	2.87%
Songkhla	53.70	89.72	67.07%		11.59	8.82	-23.89%
Surat Thani	163.17	162.78	-0.24%		48.03	130.10	170.88%
Trang	42.20	39.66	-6.02%		337.98	341.99	1.19%
Trat	60.66	49.79	-17.91%		91.58	119.05	29.99%
Songkhla (Songkhla Lake)	0.07	0.06	-4.67%		0.16	2.88	1649.25%
Nonthaburi	0.55	0.87	58.37%		0.00	0.00	0.00%
Mae Hong Son	0.00	0.00	0.00%		0.00	0.00	0.00%
THAILAND TOTAL	2631.44	2062.16	-21.63%		2163.69	2471.00	14.20%

For Cambodia (Table 3), the amount of pond aquaculture is very small and the net increase of 35% is not large. In contrast, there has been a substantial loss of mangroves (45%), most notably in Koh Kong.

Table 3 Area Statistics for Cambodia

Subdivision	Pond 1999	Pond 2014	%Change		Mangrove 1999	Mangrove 2014	%Change
Kampot	0.79	7.21	807.73%		8.77	8.92	1.67%
Koh Kong	4.70	1.80	-61.64%		435.10	206.96	-52.43%
Kep	1.20	0.00	-100.00%		3.14	5.08	61.99%
Preah Sihanouk	0.00	0.05	0.00%		81.58	67.28	-17.53%
Pusrsat	0.00	0.00	0.00%		0.00	0.00	0.00%
Svay Rieng	0.00	0.00	0.00%		0.00	0.00	0.00%
Takeo	0.00	0.00	0.00%		0.00	0.00	0.00%
CAMBODIA TOTAL	6.70	9.07	35.36%		528.59	288.25	-45.47%

Table 4 presents the area statistics for Vietnam. Vietnam has a significant amount of pond aquaculture, and experienced a 103% increase over the 15 years from 1999 to 2014. Meanwhile, the net area of mangroves actually increased slightly by 7%.

Table 4 Area Statistics for Vietnam

Subdivision	Pond 1999	Pond 2014	%Change		Mangrove 1999	Mangrove 2014	%Change
Can Tho	0.00	0.01			0.00	0.00	0.00%
Dong Thap	0.00	4.27			0.00	0.10	
Hau Giang	0.00	0.04	1466.67%		0.00	0.02	
Kien Giang	77.94	1091.10	1299.88%		26.49	85.15	221.43%
Long An	97.67	110.35	12.97%		0.00	52.43	
Soc Trang	264.34	501.46	89.70%		84.20	64.98	-22.82%
Ha Tinh	7.47	41.61	456.79%		2.06	6.74	227.55%
Nghe An	12.14	28.11	131.46%		2.34	7.58	223.44%
Quang Binh	19.09	25.09	31.42%		0.00	0.98	
Quang Tri	17.12	17.23	0.63%		0.06	0.17	167.03%
Thanh Hoa	41.08	56.03	36.39%		0.99	5.64	471.90%
Thua Thien-Hue	35.78	58.27	62.85%		0.00	0.00	0.00%
Bac Giang	0.00	0.00	0.00%		0.00	0.00	0.00%
Quang Ninh	71.69	134.41	87.48%		168.79	122.38	-27.49%
An Giang	0.00	0.14			0.00	0.02	
Bac Lieu	596.72	1366.51	129.00%		37.54	38.84	3.45%
Ben Tre	382.78	384.77	0.52%		93.04	115.38	24.01%
Ca Mau	1274.56	2612.79	105.00%		582.06	545.66	-6.25%
Tien Giang	29.01	55.53	91.42%		9.85	53.66	445.03%

Tra Vinh	211.86	366.07	72.79%		198.67	132.85	-33.13%
Vinh Long	0.00	0.94			0.03	0.03	23.28%
Bac Ninh	6.72	0.00	-100.00%		0.00	0.00	0.00%
Ha Nam	1.80	0.00	-100.00%		0.00	0.93	0.00%
Ha Tay	0.00	0.00	0.00%		0.00	0.00	0.00%
Hai Duong	8.42	1.05	-87.59%		0.00	0.01	0.00%
Hai Phong	65.20	128.75	97.46%		13.29	26.18	96.97%
Hung Yen	3.10	0.00	-100.00%		0.00	0.00	0.00%
Nam Dinh	31.74	70.16	121.02%		9.26	18.20	96.43%
Ninh Binh	25.27	31.49	24.65%		0.63	4.84	668.96%
Thai Binh	23.91	55.97	134.07%		13.75	22.03	60.20%
Ba Ria-Vung Tau	62.38	116.36	86.51%		54.71	9.01	-83.53%
Binh Duong	0.00	0.00	0.00%		0.00	0.00	0.00%
Binh Thuan	7.22	18.58	157.28%		0.00	0.00	0.00%
Dong Nai	15.99	24.22	51.50%		49.37	62.28	26.16%
Ho Chi Minh	156.23	76.21	-51.22%		318.15	414.05	30.14%
Ninh Thuan	9.65	17.19	78.18%		0.00	0.06	
Tay Ninh	0.00	0.00	0.00%		0.00	0.00	0.00%
Binh Dinh	30.21	27.90	-7.65%		2.69	0.16	-94.12%
Da Nang	2.03	2.56	25.61%		3.55	0.00	-100.00%
Khanh Hoa	77.35	70.79	-8.49%		0.57	0.22	-61.46%
Phu Yen	21.83	28.87	32.24%		0.00	0.03	
Quang Nam	30.94	37.91	22.52%		7.08	1.27	-82.11%
Quang Ngai	8.26	12.51	51.42%		3.57	0.80	-77.59%
Hoa Binh	0.00	0.00	0.00%		0.00	0.00	0.00%
VIETNAM TOTAL	3727.54	7575.23	103.22%		1682.73	1792.68	6.53%

For Myanmar (Table 5), there has been a sharp decline in pond aquaculture (34%), primarily in Rakhine State and a 9% decline in mangrove, primarily in the Ayeyarwadi Region.

Table 5 Area Statistics for Myanmar

Subdivision	Pond 1999	Pond 2014	%Change		Mangrove 1999	Mangrove 2014	%Change
Ayeyarwady Region	1.22	4.02	228.80%		1962.60	1533.88	-21.84%
Bago Region	0.00	0.00	0.00%		0.04	11.23	26452.66%
Kayin State	0.00	0.00	0.00%		4.43	0.00	-100.00%
Mon State	6.71	0.96	-85.75%		146.96	164.40	11.87%
Rakhine State	186.21	83.16	-55.34%		1668.03	1577.03	-5.46%
Tanintharyi Region	6.51	8.09	24.28%		2854.43	2780.58	-2.59%
Yangon Region	2.27	37.27	1540.75%		28.65	28.24	-1.43%
MYANMAR TOTAL	202.92	133.50	-34.21%		6665.14	6095.35	-8.55%

Table 6 provides a summary by country and statistics for the region as a whole. Interestingly, although there was a 49% regional increase in pond aquaculture, there was only a 4% net loss of mangrove. However, this 4% loss was largely because of new mangrove balancing loss. Regionally, 69.96% of mangroves in 1999 persisted, but 30.04% were lost. New mangrove growth then reduced this net loss to 3.56%. That said, only 5.14% of mangroves in 1999 were lost to pond aquaculture. The remaining 24.9% of loss went to other covers – primarily cropland and land in transition to cropland.

Table 6 Summary of Areas Statistics by Country and for the Region

Area (km^2)	Pond 1999	Pond 2014	% Change		Mangrove 1999	Mangrove 2014	% Change
Thailand	2631.44	2062.16	-21.63%		2163.69	2471.00	14.20%
Cambodia	6.70	9.07	35.36%		528.59	288.25	-45.47%
Vietnam	3727.54	7575.23	103.22%		1682.73	1792.68	6.53%
Myanmar	202.92	133.50	-34.21%		6665.14	6095.35	-8.55%
Regional Total	6568.61	9779.96	48.89%		11040.15	10647.28	-3.56%

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