

Supplementary

Changing Land Use and Population Density Are Degrading Water Quality in the Lower Mekong Basin

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Supplementary Material 1. Watershed-station names and mean (2000-2017) water quality parameters \pm standard deviation in the dry season. “n” refers to number of observations.

Station name	Country	Location of Dam	TSS mg/L	NO ₃ mg/L	NH ₄ ⁺ mg/L	TN mg/L	PO ₄ ³⁻ mg/L	TP mg/L	DO mg/L
1) Backprea	Cambodia	No dam	86.42 ± 29.48 n=15	0.19 ± 0.10 n=15	0.15 ± 0.05 n=15	0.58 ± 0.26 n=11	0.01 ± NA n=1	0.14 ± 0.05 n=15	5.43 ± 1.56 n=15
2) Kampong Thom	Cambodia	Upstream	77.83 ± 38.99 n=6	0.16 ± 0.13 n=6	0.05 ± 0.03 n=6	0.27 ± 0.07 n=2	0.00 ± NA n=1	0.09 ± 0.04 n=6	6.62 ± 1.83 n=6
3) Kampong Toul	Cambodia	Upstream	78.51 ± 46.70 n=4	0.11 ± 0.06 n=4	0.03 ± 0.01 n=4	NA n=4	0.02 ± 0.02 n=4	0.03 ± 0.02 n=4	6.61 ± 0.55 n=4
4) Kampong Thmar	Cambodia	Upstream	58.37 ± 16.22 n=6	0.14 ± 0.06 n=6	0.05 ± 0.02 n=6	0.23 ± 0.08 n=2	0.00 ± NA n=1	0.06 ± 0.03 n=6	6.90 ± 0.50 n=6
5) Mekong	Cambodia	No dam	18.82 ± 10.35 n=18	0.07 ± 0.03 n=18	0.05 ± 0.02 n=18	0.26 ± 0.11 n=11	0.01 ± 0.00 n=5	0.05 ± 0.03 n=18	7.64 ± 0.52 n=18
6) Neak Luong	Cambodia	No dam	20.67 ± 9.32 n=18	0.08 ± 0.03 n=18	0.04 ± 0.02 n=18	0.27 ± 0.11 n=11	0.01 ± 0.00 n=5	0.05 ± 0.02 n=18	7.10 ± 0.39 n=18
7) Phnom Krom	Cambodia	No dam	222.19 ± 152.11 n=15	0.17 ± 0.08 n=15	0.12 ± 0.07 n=15	0.57 ± 0.27 n=11	0.01 ± NA n=1	0.26 ± 0.15 n=15	6.15 ± 0.73 n=15
8) Tonle Sap	Cambodia	No dam	40.15 ± 13.87 n=18	0.24 ± 0.11 n=18	0.07 ± 0.03 n=18	0.50 ± 0.27 n=11	0.02 ± 0.01 n=5	0.10 ± 0.06 n=18	6.07 ± 0.87 n=18
9) Ban Hat Kham	Laos	Upstream	22.90 ± 14.80 n=18	0.14 ± 0.10 n=18	0.04 ± 0.03 n=18	0.40 ± 0.21 n=12	0.01 ± 0.00 n=6	0.05 ± 0.04 n=18	7.02 ± 0.72 n=18
10) Ban Keng Done	Laos	No dam	32.33 ± 19.76 n=18	0.11 ± 0.07 n=18	0.04 ± 0.02 n=18	0.37 ± 0.16 n=12	0.01 ± 0.01 n=6	0.05 ± 0.04 n=18	7.10 ± 0.63 n=18
11) Houay Mak Hiao	Laos	No dam	39.94 ± 52.30 n=15	0.92 ± 0.55 n=15	0.48 ± 0.45 n=15	2.54 ± 1.15 n=12	0.05 ± 0.04 n=3	0.10 ± 0.05 n=15	4.20 ± 0.72 n=15
12) Nam Houm Dam	Laos	Upstream	9.03 ± 2.55 n=9	0.04 ± 0.03 n=9	0.07 ± 0.03 n=9	1.51 ± 1.73 n=3	0.01 ± 0.01 n=6	0.02 ± 0.00 n=9	7.38 ± 0.50 n=9
13) Nam Ngum	Laos	Downstream	5.09 ± 2.47 n=9	0.05 ± 0.03 n=9	0.04 ± 0.02 n=9	0.30 ± 0.15 n=3	0.00 ± 0.00 n=6	0.08 ± 0.20 n=9	5.02 ± 0.37 n=9
14) Nam Souang	Laos	Upstream	21.14 ± 36.14 n=9	0.15 ± 0.29 n=9	0.05 ± 0.01 n=9	0.39 ± 0.12 n=3	0.12 ± 0.27 n=6	0.02 ± 0.00 n=9	7.06 ± 0.37 n=9
15) Se Bang Fai	Laos	No dam	25.36 ± 19.53 n=18	0.12 ± 0.08 n=18	0.04 ± 0.02 n=18	0.89 ± 1.48 n=12	0.01 ± 0.00 n=6	0.04 ± 0.04 n=18	7.29 ± 0.70 n=18
16) Sedone Bridge	Laos	Upstream	32.91 ± 21.74 n=15	0.15 ± 0.09 n=15	0.08 ± 0.07 n=15	0.47 ± 0.21 n=12	0.01 ± 0.01 n=3	0.07 ± 0.04 n=15	6.48 ± 0.60 n=14
17) Thaleth Keokou	Laos	Upstream	19.51 ± 11.62 n=9	0.06 ± 0.05 n=9	0.04 ± 0.03 n=9	0.32 ± 0.12 n=3	0.01 ± 0.00 n=6	0.02 ± 0.00 n=9	7.71 ± 0.82 n=9
18) Ban Chai Buri	Thailand	Upstream	6.75 ± 5.79 n=15	0.22 ± 0.10 n=15	0.06 ± 0.03 n=15	0.69 ± 0.60 n=15	0.00 ± 0.00 n=2	0.04 ± 0.02 n=15	7.70 ± 0.67 n=15
19) Ban Ku Phra Kona	Thailand	Upstream	34.67 ± 15.97 n=5	0.47 ± 0.66 n=5	0.17 ± 0.11 n=5	0.77 ± 0.31 n=4	0.02 ± 0.01 n=5	0.06 ± 0.03 n=5	6.75 ± 1.04 n=5

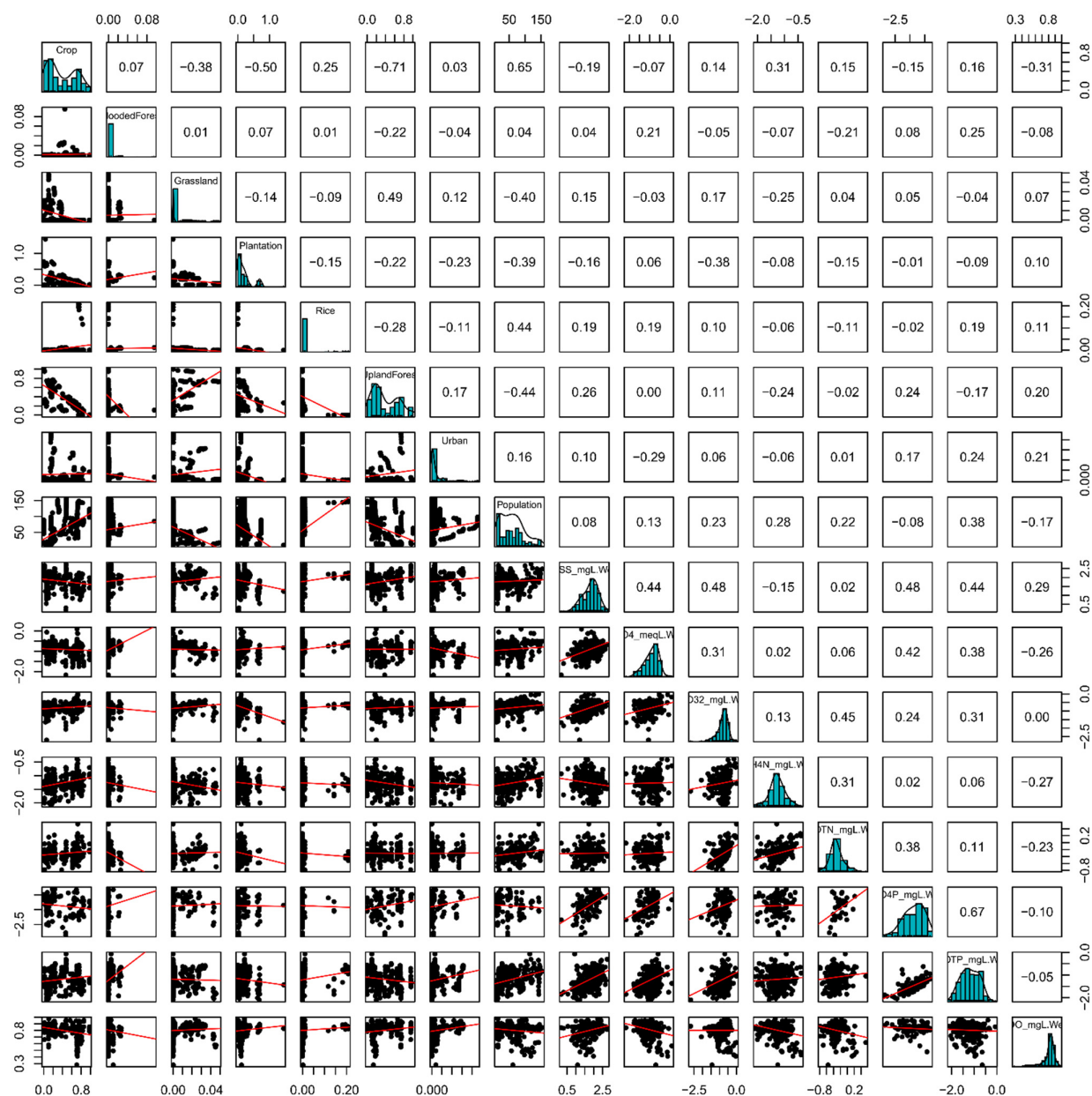
20) Ban Som	Thailand	No dam	39.71 ± 24.09 n=5	0.60 ± 0.21 n=5	0.14 ± 0.06 n=5	1.08 ± 0.33 n=4	0.08 ± 0.06 n=5	0.16 ± 0.08 n=5	6.17 ± 1.10 n=5
21) Ban Tad Ton	Thailand	Upstream	29.84 ± 22.45 n=5	0.38 ± 0.26 n=5	0.09 ± 0.07 n=5	0.43 ± 0.03 n=4	0.01 ± 0.00 n=5	0.03 ± 0.02 n=5	8.24 ± 0.78 n=5
22) Chiang Rai	Thailand	Downstream	61.47 ± 48.63 n=18	0.27 ± 0.14 n=18	0.05 ± 0.02 n=18	0.54 ± 0.32 n=18	0.03 ± 0.01 n=6	0.11 ± 0.04 n=18	7.88 ± 0.52 n=18
23) Lam Dom Noi	Thailand	Downstream	24.42 ± 24.85 n=6	0.07 ± 0.03 n=6	0.06 ± 0.04 n=6	0.50 ± 0.38 n=6	0.00 ± 0.00 n=6	0.02 ± 0.01 n=6	7.86 ± 0.74 n=6
24) Lam Pao Dam Site	Thailand	Upstream	30.03 ± 21.36 n=5	0.19 ± 0.15 n=5	0.06 ± 0.03 n=5	0.43 ± 0.12 n=4	0.01 ± 0.00 n=5	0.02 ± 0.01 n=5	8.17 ± 0.56 n=5
25) Nam Kae	Thailand	Upstream	14.54 ± 22.01 n=18	0.09 ± 0.11 n=18	0.05 ± 0.03 n=18	0.46 ± 0.27 n=18	0.01 ± 0.00 n=6	0.03 ± 0.02 n=18	7.33 ± 0.67 n=18

Supplementary Material 2. Watershed-station names and mean (2000-2017) water quality parameters ± standard deviation in the wet season. “n” refers to number of observations.

Station name	Country	Location of Dam	TSS mg/L	NO ₃ ⁻ mg/L	NH ₄ ⁺ mg/L	TN mg/L	PO ₄ ³⁻ mg/L	TP mg/L	DO mg/L
1) Backprea	Cambodia	No dam	58.70 ± 32.55 n=14	0.12 ± 0.05 n=14	0.09 ± 0.05 n=14	0.40 ± 0.11 n=10	0.05 ± NA n=1	0.14 ± 0.05 n=14	5.24 ± 1.59 n=14
2) Kampong Thom	Cambodia	Upstream	87.06 ± 22.68 n=5	0.11 ± 0.03 n=5	0.05 ± 0.03 n=5	0.29 ± NA n=1	0.01 ± NA n=1	0.10 ± 0.05 n=5	6.61 ± 0.26 n=5
3) Kampong Toul	Cambodia	Upstream	124.33 ± 25.15 n=4	0.11 ± 0.04 n=4	0.04 ± 0.02 n=4	NA ± NA	0.02 ± 0.01 n=4	0.05 ± 0.04 n=4	6.59 ± 0.23 n=4
4) Kampong Thmar	Cambodia	Upstream	49.86 ± 18.31 n=5	0.10 ± 0.04 n=5	0.05 ± 0.02 n=5	0.26 ± NA n=1	0.00 ± NA n=1	0.09 ± 0.06 n=5	6.98 ± 0.57 n=5
5) Mekong	Cambodia	No dam	134.15 ± 39.09 n=18	0.23 ± 0.04 n=18	0.05 ± 0.03 n=18	0.43 ± 0.07 n=10	0.02 ± 0.01 n=5	0.13 ± 0.07 n=18	7.09 ± 0.32 n=18
6) Neak Luong	Cambodia	No dam	131.85 ± 28.75 n=18	0.22 ± 0.04 n=18	0.05 ± 0.02 n=18	0.41 ± 0.07 n=10	0.01 ± 0.01 n=5	0.14 ± 0.08 n=18	6.98 ± 0.36 n=18
7) Phnom Krom	Cambodia	No dam	233.19 ± 156.78 n=14	0.16 ± 0.07 n=14	0.09 ± 0.05 n=14	0.57 ± 0.23 n=10	0.01 ± NA n=1	0.30 ± 0.20 n=14	6.88 ± 0.85 n=14
8) Tonle Sap	Cambodia	No dam	68.82 ± 25.93 n=18	0.17 ± 0.07 n=18	0.04 ± 0.02 n=18	0.37 ± 0.11 n=10	0.02 ± 0.01 n=5	0.11 ± 0.06 n=18	6.28 ± 0.46 n=18
9) Ban Hat Kham	Laos	Upstream	198.49 ± 148.53 n=18	0.20 ± 0.06 n=18	0.04 ± 0.02 n=18	0.47 ± 0.20 n=11	0.03 ± 0.00 n=6	0.07 ± 0.04 n=18	6.83 ± 0.79 n=17
10) Ban Keng Done	Laos	No dam	140.84 ± 74.35 n=18	0.19 ± 0.08 n=18	0.06 ± 0.03 n=18	0.47 ± 0.18 n=11	0.03 ± 0.01 n=6	0.09 ± 0.08 n=18	6.82 ± 0.81 n=17
11) Houay Mak Hiao	Laos	No dam	50.08 ± 22.91 n=14	0.52 ± 0.26 n=14	0.21 ± 0.11 n=14	1.39 ± 0.79 n=11	0.03 ± 0.01 n=2	0.10 ± 0.05 n=14	3.34 ± 0.51 n=14
12) Nam Houm Dam	Laos	Upstream	19.96 ± 12.69 n=9	0.04 ± 0.02 n=9	0.09 ± 0.05 n=9	0.59 ± 0.02 n=2	0.02 ± 0.01 n=6	0.03 ± 0.01 n=9	6.93 ± 0.42 n=9

13) Nam Ngum	Laos	Downstrea	13.56 ± 6.40	0.09 ± 0.05	0.05 ± 0.04	0.31 ± 0.15	0.01 ± 0.01	0.02 ± 0.01	4.68 ± 0.76
		m	n=9	n=9	n=9	n=2	n=6	n=9	n=9
14) Nam Souang	Laos	Upstream	15.23 ± 7.68	0.07 ± 0.04	0.05 ± 0.02	0.42 ± 0.22	0.01 ± 0.01	0.02 ± 0.01	6.89 ± 0.43
			n=8	n=8	n=8	n=2	n=5	n=8	n=8
15) Se Bang Fai	Laos	No dam	91.32 ± 50.75	0.25 ± 0.06	0.05 ± 0.03	0.60 ± 0.32	0.01 ± 0.00	0.05 ± 0.06	7.06 ± 0.84
			n=18	n=18	n=18	n=11	n=6	n=18	n=17
16) Sedone Bridge	Laos	Upstream	96.90 ± 28.69	0.18 ± 0.07	0.07 ± 0.04	0.47 ± 0.14	0.04 ± 0.02	0.08 ± 0.04	6.62 ± 0.83
			n=14	n=14	n=14	n=11	n=2	n=13	n=13
17) Thaleth Keokou	Laos	Upstream	74.26 ± 22.94	0.13 ± 0.03	0.04 ± 0.02	0.36 ± 0.16	0.02 ± 0.01	0.03 ± 0.01	7.10 ± 0.33
			n=9	n=9	n=9	n=2	n=6	n=9	n=9
8) Ban Chai Buri	Thailand	Upstrea	19.10 ± 10.27	0.13 ± 0.03	0.07 ± 0.02	0.55 ±	0.01 ± NA	0.06 ± 0.02	4.92 ± 0.52
		m	n=14	n=14	n=14	0.33 ±	n=1	n=14	n=14
19) Ban Ku Phra Kona	Thailand	Upstrea	52.50 ± 33.60	0.25 ± 0.02	0.13 ± 0.05	0.67 ±	0.02 ± 0.00	0.06 ± 0.01	6.70 ± 0.44
		m	n=4	n=4	n=4	0.17 ±	n=4	n=4	n=4
20) Ban Som	Thailand	No dam	51.54 ± 9.43	0.42 ± 0.08	0.06 ± 0.02	0.73 ±	0.03 ± 0.01	0.06 ± 0.02	6.74 ± 0.46
			n=4	n=4	n=4	0.17 ±	n=4	n=4	n=4
21) Ban Tad Ton	Thailand	Upstrea	35.67 ± 15.68	0.31 ± 0.07	0.08 ± 0.05	0.54 ±	0.01 ± 0.00	0.02 ± 0.00	8.43 ± 0.46
		m	n=4	n=4	n=4	0.13 ±	n=4	n=4	n=4
22) Chiang Rai	Thailand	Downstr	193.10 ± 61.22	0.29 ± 0.07	0.06 ± 0.04	0.68 ±	0.03 ± 0.01	0.20 ± 0.06	7.52 ± 0.50
			n=18	n=18	n=18	0.29 ±	n=5	n=18	n=18
23) Lam Dom Noi	Thailand	Downstr	14.42 ± 12.05	0.13 ± 0.12	0.09 ± 0.06	0.50 ±	0.00 ± 0.00	0.01 ± 0.00	7.65 ± 0.72
		eam	n=6	n=6	n=6	0.25 ±	n=5	n=6	n=6
24) Lam Pao Dam Site	Thailand	Upstrea	31.54 ± 13.39	0.29 ± 0.05	0.08 ± 0.03	0.62 ±0.21	0.01 ± 0.01	0.03 ± 0.02	8.34 ± 0.81
		m	n=4	n=4	n=4	n=4	n=4	n=4	n=4
25) Nam Kae	Thailand	Upstrea	29.32 ± 14.00	0.11 ± 0.10	0.06 ± 0.03	0.45 ±	0.01 ± 0.00	0.04 ± 0.02	6.72 ± 0.91
		m	n=18	n=18	n=18	0.22 ±	n=5	n=18	n=18

Supplementary Material 3. Correlation analysis between land use categories and water quality parameters in the dry season for the watersheds of our study in the Lower Mekong Basin.



Supplementary Material 4. Correlation analysis between land use categories and water quality parameters in the wet season for the watersheds of our study in the Lower Mekong Basin.

