Supplementary data

Hydrodynamic Simulation of Suspended Solids Concentration in Isahaya Regulating Reservoir

Table S1. Technical specifications of UAV (i.e., Phantom 4)

Parameter	Description
Weight	1,380 g
Diagonal size	350 mm
Image size	3,000 × 4,000
Sensor	1/2.3” CMOS Effective pixels:12.4 m
Satellite positioning system	0-40 ^{o}C
Operating temperature range	GPS/GLONASS
Max speed	20 m/s
Max flight time	~28 minutes

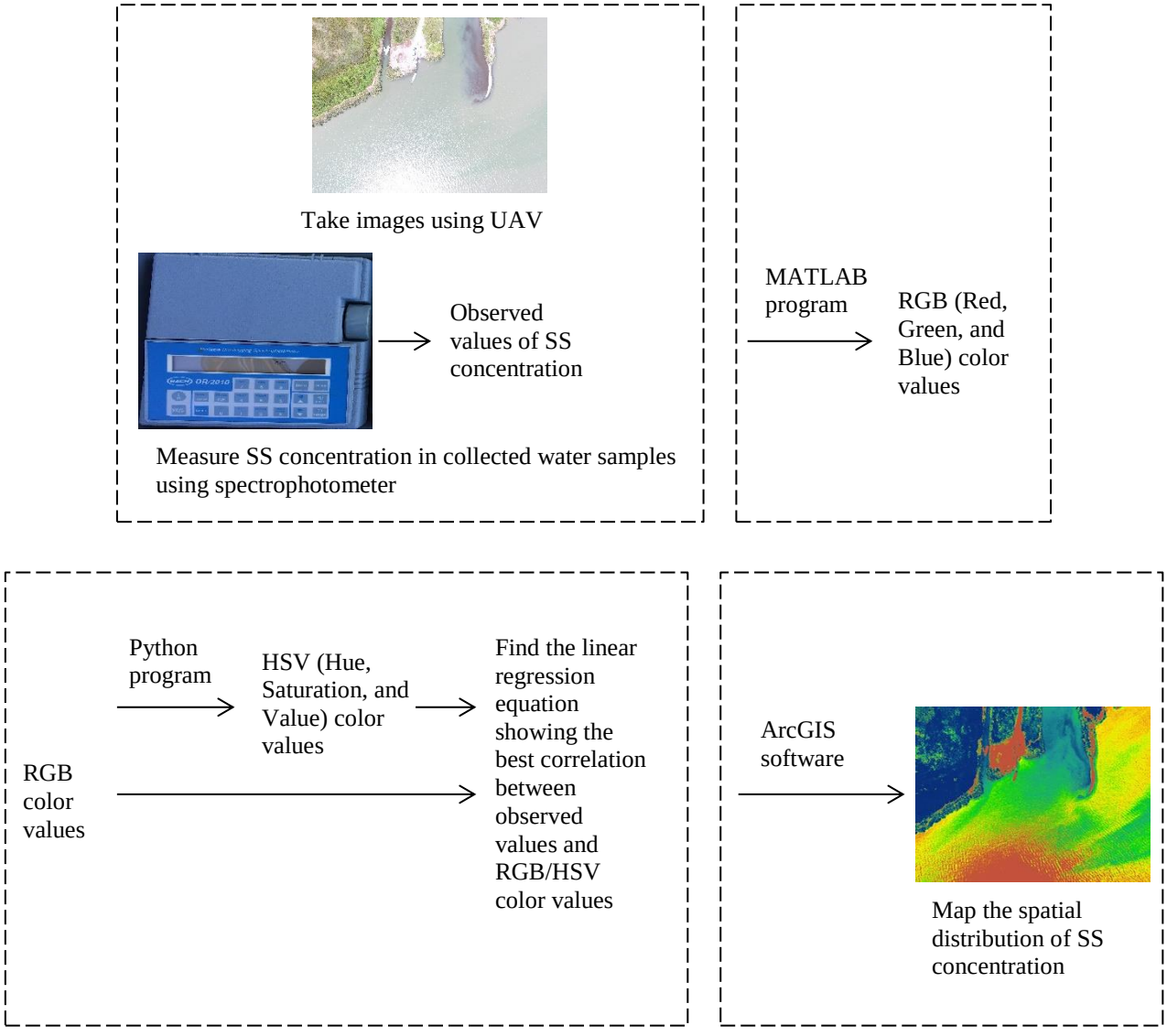

Figure S1. Procedure for measuring and estimating SS concentration using UAV

Table S2. Technical specifications of DR/2010 portable datalogging spectrophotometer

Parameter	Description
Weight	2 kg
Dimension	22 × 24 × 11 cm
Detector	Silicon Photodiode, UV enhanced
Source lamp	Halogen Tungsten
Wavelength range	400-900 nm
Wavelength accuracy	±2 nm from 400 to 700 nm, ±3 nm from 700 to 900 nm
Standard solution of SS	847.4 mg/L
Standard deviation of SS	±18.2 mg/L
Operating temperature range	0-40 ^{o}C
Storage temperature range	-40-60 ^{o}C
Battery weight	1.1 kg

Procedure 1. Procedure for analysis of SS using spectrophotometer and estimation of SS using images taken by UAV.

Sampling, measurement, and analysis of samples were conducted every h from 9:00 to 15:00. The following are step-by-step analyzing procedure of SS using DR/2010 spectrophotometer:

- Rinse a 1-cm square cuvette with demineralized water
- Dry the outer surface of the cuvette using tissue
- Choose an appropriate stored program number for SS
- Adjust wavelength to 810 nm
- Press **ENTER**
- Pour demineralized water into the cuvette to the limit mark
- Insert the cuvette into the cell holder and close the light shield cap
- Press **ZERO**
- Shake the capped plastic bottle containing sample thoroughly and pour the sample immediately into the cuvette to the limit mark
- Place the sample cuvette into the cell holder and close the light shield cap
- Press **ENTER**

In parallel with that, SS concentration simulated by ODEM model was compared with that estimated form digital images taken by UAV. Therefore, the observing procedure with UAV can be briefly presented as follows: Digital images of the study area were taken continuously at each point (9:00, 10:00, 11: 00,12: 00, 13:00, 14:00, and 15:00) by UAV at a maintained height of 70 m (see Figure S1 for more details). Subsequently, the SS concentration from these digital images was estimated based on the steps shown in Figure S1. To be more precise, the R (red), G (green), and B (blue) (RGB) color bands were extracted from the image using the MATLAB program. In addition, the H (hue), S (saturation), and V (value) (HSV) color bands were also converted from RGB using the Python program and compared simultaneously with RGB. Then, the correlation relationships between RGB and HSV variables on a specific image and observed SS were deduced to select the best fit linear regression equation with the highest R^2 coefficient. This equation was then used to calculate the SS concentration value of the remaining images. In general, SS concentration estimated from images taken by UAV is also based on the above principle. This view is supported by the findings of a recent study, which showed a clear link between near infrared (NIR), green (G), and blue (B) with observed SS in a lake through linear and non-linear regression analysis and artificial neural network (ANN) (Guimarães et al., 2019). Three variables, containing NIR, G, and B, were extracted from images taken by UAV and then were shown in relationship to observed SS and used as input parameters of ANN, which could convert NIR, G, and B bands into SS concentration. By this way, SS concentration could be inferred from either regression analysis or ANN. Another example is that Larson et al. (2018) used green, red, red edge (RE) and near infrared (NIR) extracted from images taken by UAV to find best fit linear regression equation between them and observed suspended sediment. This equation was then used to calculate suspended sediment concentration in Maumee River.

Table S3. Analysis results of water quality parameters

Time	Point	SS (mg/L)	Turbidity (FTU)	pH	DO (mg/L)	Temperature (°C)	Chlorophyll	Salinity (‰)
09:00	A	9.00	7.38		9.19	20.41	2.25	0.08
	B	83.00	55.68	8.62	9.60	20.99	8.56	0.42
	C	93.00	50.89	8.50	10.36	20.88	11.56	0.42
	D	98.00	39.21	8.81	9.80	20.61	9.66	0.44
	E	92.00	49.70	8.15	10.28	21.31	9.90	0.48
	F	3.00	25.00	9.00	9.90	20.14	7.50	
	G	26.00	15.91	8.45	9.08	23.08	5.32	0.23
	H	69.00	38.10	8.27	8.71	20.16	8.03	0.39
	I	123.00	56.61	8.19	8.79	20.53	11.25	0.50
10:00	A	12.00	7.50	8.72	9.10	21.18	1.17	0.10
	B	64.00	33.00	7.96	9.80	20.98	5.90	0.34
	C	68.00	50.36	8.21	10.80	21.63	9.99	0.30
	D	98.00	53.00	8.90	10.03	21.85	12.95	2.85
	E	104.00	45.60	8.22	10.43	21.94	8.71	0.51
	F	3.00	12.75	8.90	10.13	21.79	6.37	
	G	36.00	19.37	8.26	9.39	20.81	5.21	0.19
	H	70.00	32.23	8.31	9.30	20.50	7.80	0.35
	I	131.00	57.03	8.14	9.16	20.83	11.80	0.49
11:00	A	11.00	8.03	9.31	10.31	22.21	1.99	0.10
	B	61.00	21.03	8.40	10.81	21.86	5.13	0.20
	C	56.00	42.50	8.46	10.88	22.26	6.13	0.28
	D	96.00	50.23	8.56	10.28	21.50	8.65	0.14
	E	112.00	56.20	8.23	10.60	23.10	9.70	0.52
	F	17.00	23.53	8.89	12.03	23.46	6.60	
	G	45.00	32.25	8.46	10.38	21.03	8.31	0.27
	H	69.00	32.18	8.50	9.84	21.03	8.00	0.34
	I	135.00	76.72	8.41	10.36	21.14	12.23	0.49
12:00	A	10.00	4.46	9.89	10.31	23.59	1.15	0.09
	B	49.00	25.32	8.90	10.29	22.33	4.90	0.26
	C	62.00	38.95	8.65	10.96	22.81	5.67	0.26
	D	91.00	63.55	8.76	10.21	22.90	8.56	0.19
	E	124.00	49.00	8.89	10.74	22.36	10.91	0.52
	F	24.00	20.78	8.77	12.90	24.74	4.55	
	G	58.00	40.00	8.63	11.20	21.69	10.54	0.31
	H	74.00	31.63	8.65	10.51	21.81	7.56	0.33
	I	155.00	75.73	8.54	11.76	21.56	12.08	0.51
13:00	A	10.00	4.10	9.29	10.35	23.98	1.15	0.08
	B	53.00	26.99	8.60	10.55	23.12	5.50	0.24
	C	51.00	36.55	8.60	10.91	23.36	5.55	0.24
	D	49.00	32.53	8.72	10.86	23.46	6.32	0.21
	E	40.00	43.60	8.45	11.45	23.45	9.81	0.51

Table S3. Analysis results of water quality parameters (cont.)

Time	Point	SS (mg/L)	Turbidity (FTU)	pH	DO (mg/L)	Temperature (°C)	Chlorophyll	Salinity (‰)
	F	32.00	28.16	8.90	12.00	24.57	4.86	
	G	62.00	45.81	8.66	11.39	23.30	13.56	0.26
	H	76.00	36.30	8.85	10.92	22.33	7.03	0.30
	I	114.00	78.24	8.70	11.96	22.15	32.24	0.45
14:00	A	10.00	4.15	9.39	10.55	24.30	1.20	0.08
	B	49.00	33.32	8.68	11.10	23.29	6.12	0.26
	C	54.00	30.81	8.98	12.26	23.69	5.35	0.26
	D	49.00	40.20	9.01	11.04	23.83	6.65	0.25
	E	107.00	47.55	8.84	11.90	23.51	10.22	0.51
	F	29.00	17.44	9.09	12.52	24.98	4.17	
	G	35.00	19.10	8.95	11.16	23.63	4.12	0.19
	H	71.00	43.87	9.04	11.56	22.75	8.02	0.32
	I	148.00	74.11	8.94	12.52	22.61	12.03	0.45
15:00	A	10.00	12.45	8.90	10.90	24.15	3.24	0.08
	B	60.00	32.14	8.93	11.55	23.64	8.16	0.30
	C	70.00	40.23	8.89	12.90	23.58	8.65	0.34
	D	56.00	49.38	9.21	12.16	23.25	9.52	0.36
	E	90.00	58.60	9.00	12.67	24.50	10.84	0.54
	F	26.00	24.44	9.22	18.83	25.44	7.03	
	G	27.00	13.02	9.12	11.07	23.90	3.09	0.16
	H	79.00	51.10	9.10	12.24	22.92	11.03	0.39
	I	78.00	50.76	9.11	12.19	23.01	8.63	0.35

Table S4. SS concentration simulated by ODEM and estimated by image analysis from UAV

Time	A	B	C	D	E	F	G	H	I
	SS concentration simulated by ODEM (mg/L)								
09:00	12.07	45.46	59.13	74.60	132.14	14.79	25.91	59.65	99.51
10:00	13.59	47.94	60.56	74.34	131.09	17.49	28.78	61.61	95.28
11:00	15.62	55.79	69.09	81.67	130.90	24.60	35.15	71.02	113.13
12:00	19.31	54.51	66.47	80.43	133.25	29.62	41.34	93.89	136.00
13:00	20.22	60.30	72.89	84.91	134.54	28.35	40.37	83.05	137.59
14:00	23.49	66.61	80.48	93.05	134.82	33.20	44.88	85.01	135.00
15:00	27.44	67.37	81.29	94.74	134.90	32.71	45.78	81.71	126.96
Time	SS concentration estimated by image analysis from UAV (mg/L)								
09:00	13.70	92.69	52.57	43.03	88.93	3.44	40.33	55.41	109.01
10:00	11.28	67.27	60.01	64.89	119.04	14.70	31.36	59.58	165.31
11:00	13.73	60.51	49.51	40.39	119.19	8.70	38.68	62.01	82.16
12:00	12.47	53.03	50.47	41.02	171.24	13.60	39.14	59.58	148.51
13:00	9.83	67.17	69.37	87.78	100.46	23.61	47.76	62.01	140.39
14:00	11.97	102.77	53.17	97.41	160.66	53.17	35.45	74.71	103.19
15:00	12.44	96.11	57.64	106.68	123.63	30.65	35.45	57.36	85.24

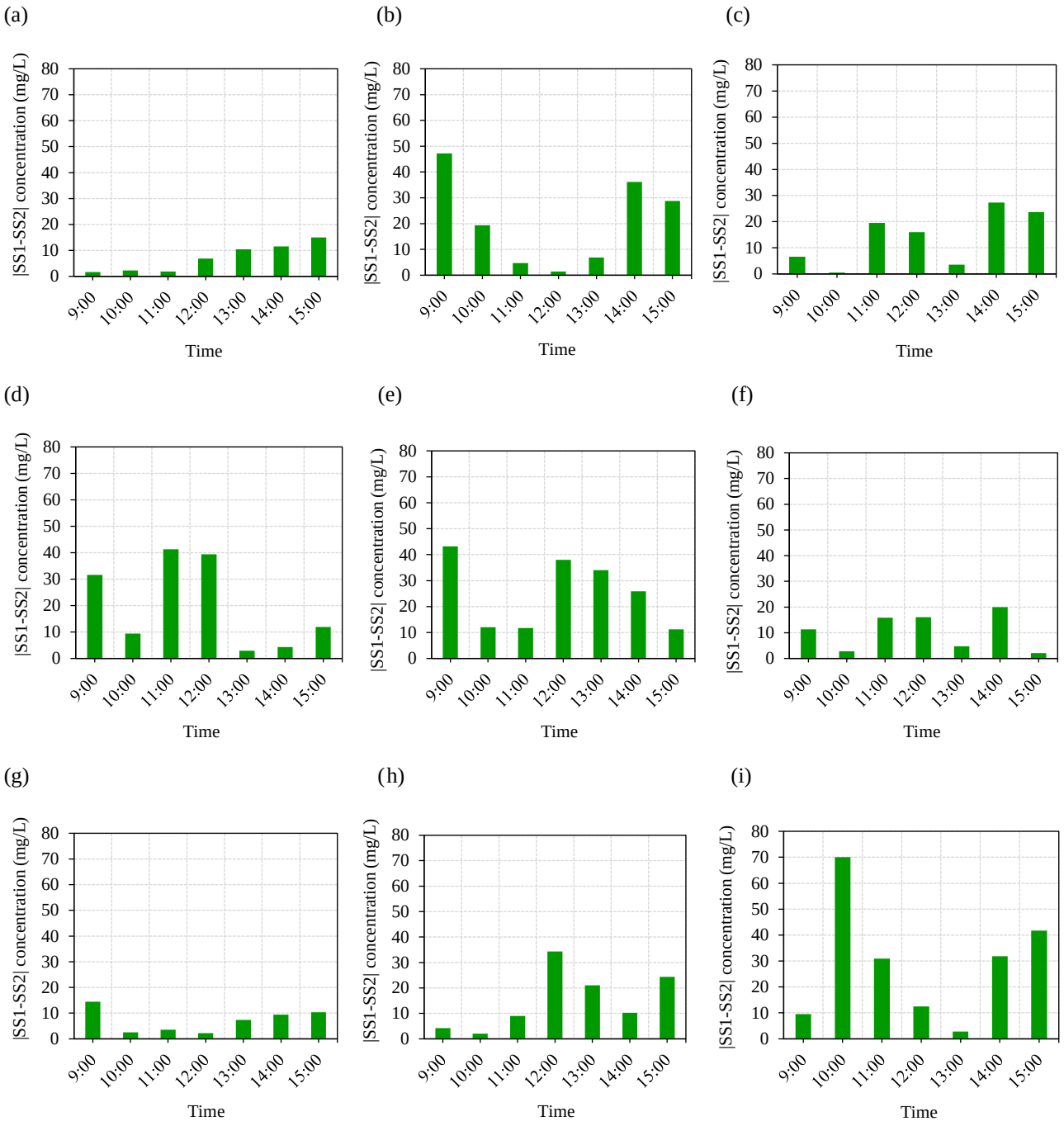

Figure S2. Difference in SS Concentration between Simulated Values (SS1) and Estimated Values (SS2) of point: a) A, b) B, c) C, d) D, e) E, and f) F g) G, h) H, and i) I

REFERENCES

Guimarães TT, Veronez MR, Koste EC, Souza EM, Brum D, Gonzaga L, Mauad FF. Evaluation of regression analysis and neural networks to predict total suspended solids in water bodies from unmanned aerial vehicle images. Sustainability 2019;11(9):2580.

Larson MD, Simic Milas A, Vincent RK, Evans JE. Multi-depth suspended sediment estimation using high-resolution remote-sensing UAV in Maumee River, Ohio. International Journal of Remote Sensing 2018;39(15-16):5472-89.