Supplementary material

Estimation of chlorophyll-a concentrations in Lanalhue Lake using Sentinel-2 MSI satellite images

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Supplementary Material A

Table A1. Laboratory results.

Sample dates	Station	Chl-a ug L^{-1}
04-08/09/2018	L1	15.3
	L2	7.3
	L3	8.9
	L4	6.1
	L5	9.7
	L6	9.1
	L7	9.1
	L8	8.7
	L9	3.8
	L10	4.4
	L11	4.4
08-11/01/2019	L1	6.7
	L2	12.8
	L3	5.0
	L4	3.7
	L5	7.5
	L6	16.1
	L7	3.9
	L8	14.5
	L9	10.7
	L10	16.4
	L11	12.0
30/07/2019 – 02/08/2019	L1	6.7
	L2	8.1
	L3	5.3
	L4	4.4
	L5	6.9
	L6	7.4

	L7	5.1
	L8	6.4
	L9	5.3
	L10	5.2
	L11	3.8
12-17/03/2020	L1	74.1
	L2	72.1
	L3	12.5
	L4	14.1
	L5	12.6
	L6	6.2
	L7	8.5
	L8	5.8
	L9	5.1
	L10	7.0
	L11	6.6
30/06/2021	L12	13.0
	L13	8.7
	L14	8.7
	L15	8.3
	L16	9.4
	L17	7.4
24/11/2021	L12	7.9
	L13	3.4
	L14	6.4
	L15	3.8
	L16	3.8
	L17	6.1
18/01/2022	L12	8.4
	L13	2.5
	L14	3.0
	L15	2.5
	L16	2.1
	L17	1.9

Supplementary Material B

Table B1. Chl-a and band reflectance ranges used in the MLR. Spring-summer TOA data.

Image date	Station	Chl-a ug L^{-1}	B2	B3	B4	B5	B6	B7	B8A	B11	B12
09/01/2019	L5	7.5	1116.15	815.10	573.85	534.81	531.18	535.80	480.92	323.28	276.93
	L6	16.1	991.12	695.62	439.60	390.77	356.64	347.48	283.10	152.88	119.32
	L8	14.5	1061.60	771.05	514.91	460.29	450.52	432.59	371.33	246.40	162.63
	L9	10.7	1092.73	785.02	509.05	453.65	440.35	448.25	376.55	260.45	210.70
	L10	16.4	937.74	643.75	403.67	361.32	360.28	351.39	311.91	161.96	114.45
14/03/2020	L1	74.1	824.16	688.65	370.23	407.12	274.91	262.34	192.86	31.00	18.32
	L2	72.4	832.22	722.21	381.67	435.74	284.26	273.00	194.40	38.81	21.24
	L3	12.5	819.73	635.19	331.97	303.37	239.32	236.54	192.65	56.63	34.68
	L4	14.1	804.59	589.51	313.23	285.44	231.18	221.97	182.89	41.00	23.10
	L5	12.3	804.02	585.78	310.92	274.00	226.03	213.93	162.02	30.62	17.25
	L6	6.2	798.24	569.87	306.47	269.78	224.39	203.96	159.86	26.15	18.80
	L7	8.5	807.82	578.46	312.99	270.23	216.96	206.51	155.20	24.80	23.32
	L8	5.8	803.26	572.89	303.97	259.80	216.69	210.24	166.54	35.87	19.27
	L9	5.1	802.61	589.50	311.13	273.21	229.00	213.00	164.85	41.00	28.39
	L10	7.0	813.38	592.78	306.37	266.87	227.35	222.68	179.26	48.69	27.47
	L11	6.6	826.32	623.19	318.09	282.31	245.35	218.14	188.30	60.05	35.80
22/11/2021	L16	3.8	846.80	636.61	415.03	368.24	369.41	380.82	343.20	222.10	161.22
	L17	6.1	799.04	578.32	346.47	309.97	315.73	304.37	267.99	153.39	118.19
18/01/2022	L12	8.4	781.97	661.15	353.03	349.87	224.91	212.13	147.97	27.54	15.16
	L13	2.5	762.37	522.55	269.01	232.69	212.89	211.06	161.72	46.63	32.44
	L14	3.0	754.94	518.37	255.40	215.95	182.18	173.15	131.85	25.95	32.51
	L15	2.5	748.24	507.98	255.59	207.96	182.26	161.67	121.50	20.75	13.78
	L16	2.1	759.54	533.33	265.44	215.42	191.29	178.86	133.90	27.14	18.64
	L17	1.9	808.15	566.72	301.65	262.66	242.16	236.35	184.32	76.38	53.25

Table B2. Chl-a and band reflectance ranges used in the MLR. Spring-summer BOA data.

Image date	Station	Chl-a ug L^{-1}	B2	B3	B4	B5	B6	B7	B8A	B11	B12
09/01/2019	L5	7.5	564.36	520.82	390.02	398.49	394.95	403.33	203.66	205.63	281.01
	L6	16.1	413.76	385.26	253.03	246.53	218.77	222.00	194.13	223.79	122.20
	L8	14.5	458.57	427.16	295.77	265.52	232.06	228.83	203.66	205.63	155.20
	L9	10.7	508.25	451.98	298.33	266.85	219.77	231.74	194.13	223.79	199.74
	L10	16.4	302.01	278.71	183.57	164.28	137.12	137.18	133.69	141.50	111.08
14/03/2020	L1	74.1	142.28	351.54	154.69	236.42	87.54	88.70	54.74	2.16	2.10
	L2	72.4	154.48	393.50	165.46	264.16	73.89	77.49	34.91	6.35	3.13
	L3	12.5	131.34	270.78	100.88	96.25	17.97	34.18	32.91	24.98	18.86
	L4	14.1	121.33	223.19	88.19	87.53	15.55	19.48	23.26	12.34	6.98
	L5	12.3	122.47	222.78	91.36	92.61	55.47	66.67	53.04	5.77	2.44
	L6	6.2	115.98	256.25	85.44	84.85	60.54	62.89	57.46	2.70	6.12
	L7	8.5	128.54	213.90	94.43	87.54	52.93	65.32	52.00	1.40	7.84

	L8	5.8	111.50	185.52	70.44	58.85	25.88	37.35	29.11	7.82	3.07
	L9	5.1	112.38	219.86	83.18	73.71	32.22	36.22	28.00	13.02	13.56
	L10	7.0	114.87	211.94	61.50	51.20	13.57	33.87	23.99	12.43	6.01
	L11	6.6	119.78	238.58	63.71	56.16	21.58	15.19	23.08	21.57	17.56
22/11/2021	L16	3.8	310.86	334.67	237.98	220.09	202.05	221.55	210.73	222.01	184.20
	L17	6.1	272.68	275.20	165.65	147.30	133.27	124.71	112.76	141.42	133.93
18/01/2022	L12	8.4	188.68	353.41	161.40	188.41	28.74	30.00	2.63	10.54	11.71
	L13	2.5	162.66	176.07	58.88	46.86	6.30	17.35	4.69	30.54	31.23
	L14	3.0	151.69	171.03	50.45	42.87	14.45	26.16	18.86	12.00	32.88
	L15	2.5	141.94	160.82	52.39	38.02	29.36	30.65	24.13	8.75	10.99
	L16	2.1	149.83	179.72	54.12	27.63	2.66	4.07	1.00	10.14	14.88
	L17	1.9	212.33	219.13	90.04	77.14	49.81	61.57	41.77	60.38	54.25

Table B3. Chl-a and band reflectance ranges used in the MLR. Fall-winter TOA data.

Image date	Station	Chl-a ug L^{-1}	B2	B3	B4	B5	B6	B7	B8A	B11	B12
04/09/2018	L8	8.7	768.48	518.78	264.72	229.03	196.81	176.17	124.72	26.98	12.08
	L9	3.8	778.39	523.58	278.07	241.94	207.87	193.67	146.96	39.96	22.09
	L10	4.4	766.99	518.79	271.32	232.62	214.32	191.30	167.60	36.96	25.69
	L11	4.4	769.16	519.72	268.28	239.32	220.82	208.97	159.88	40.51	22.05
02/08/2019	L1	6.7	984.32	671.84	408.32	354.68	298.76	290.16	243.88	85.57	69.59
	L2	8.1	966.97	665.69	402.44	364.77	301.18	290.74	243.08	78.52	47.59
	L3	5.3	968.36	651.37	392.94	344.39	310.64	302.85	255.49	91.00	67.07
	L4	4.4	953.39	628.94	362.73	329.91	299.92	289.93	242.95	85.44	58.09
	L5	6.9	947.25	635.07	374.06	336.96	306.13	273.66	227.59	83.18	50.12
	L6	7.4	945.30	632.37	363.68	326.87	297.03	284.67	231.32	84.80	60.88
	L7	5.1	965.60	632.99	364.41	329.13	295.66	288.19	217.42	88.32	56.85
	L8	6.4	998.98	663.27	398.84	359.94	335.13	326.45	268.53	120.24	85.89
	L9	5.3	962.28	634.45	367.73	324.51	307.92	281.98	231.00	78.85	56.86
	L10	5.2	1003.70	680.23	408.23	366.60	354.41	347.71	293.85	138.05	93.91
	L11	3.8	991.49	670.89	404.35	378.91	354.23	350.19	309.39	145.62	108.25

Table B4. Chl-a and band reflectance ranges used in the MlR. Fall-winter BOA data.

Image date	Station	Chl-a ug L^{-1}	B2	B3	B4	B5	B6	B7	B8A	B11	B12
04/09/2018	L8	8.7	84.60	143.18	39.26	37.70	12.23	16.98	1.61	1.64	1.12
	L9	3.8	129.02	176.71	66.52	62.38	39.00	49.88	36.58	21.36	10.15
	L10	4.4	85.55	142.40	47.57	34.02	16.53	12.84	28.46	13.11	10.85
	L11	4.4	82.91	132.87	35.85	32.91	7.11	16.98	11.76	13.24	8.18
02/08/2019	L1	6.7	173.38	196.17	100.68	81.08	39.34	60.54	64.87	12.03	5.94
	L2	8.1	142.36	181.56	90.78	82.99	23.58	40.44	44.17	4.25	1.00
	L3	5.3	155.61	165.54	90.27	68.72	40.24	61.10	65.22	26.01	15.23
	L4	4.4	127.17	133.04	45.31	46.20	27.29	41.69	46.95	15.69	1.12

	L5	6.9	127.01	157.56	66.84	73.74	68.19	64.73	61.55	16.62	1.90
	L6	7.4	138.98	154.08	63.96	62.10	57.67	80.13	74.54	24.42	10.09
	L7	5.1	146.81	144.27	49.42	55.61	50.00	74.99	51.24	17.78	1.61
	L8	6.4	159.08	155.53	67.96	64.06	50.64	86.25	62.44	27.98	11.65
	L9	5.3	133.07	134.25	49.49	39.70	48.27	53.86	49.95	5.68	1.00
	L10	5.2	155.76	169.40	66.26	56.44	51.29	75.30	70.78	41.82	8.02
	L11	3.8	145.87	155.21	68.14	73.47	58.67	74.76	90.15	55.78	28.55
30/06/2020	L16	9.4	632.41	610.80	432.67	518.51	602.86	633.07	619.72	481.53	388.83
	L17	7.4	493.71	483.77	398.54	459.35	561.63	594.72	607.96	439.88	335.70

Supplementary Material C

Table C1. Calibration TOA Spring-Summer Data

Station	Chl-a ug L^{-1}	B2	B3	B4	B5	B6	B7	B8A	B11	B12
L5	7.5	1116.15	815.10	573.85	534.81	531.18	535.80	480.92	323.28	276.93
L6	16.1	991.12	695.62	439.60	390.77	356.64	347.48	283.10	152.88	119.32
L8	14.5	1061.60	771.05	514.91	460.29	450.52	432.59	371.33	246.40	162.63
L9	10.7	1092.73	785.02	509.05	453.65	440.35	448.25	376.55	260.45	210.70
L10	16.4	937.74	643.75	403.67	361.32	360.28	351.39	311.91	161.96	114.45
L1	74.1	824.16	688.65	370.23	407.12	274.91	262.34	192.86	31.00	18.32
L2	72.4	832.22	722.21	381.67	435.74	284.26	273.00	194.40	38.81	21.24
L3	12.5	819.73	635.19	331.97	303.37	239.32	236.54	192.65	56.63	34.68
L4	14.1	804.59	589.51	313.23	285.44	231.18	221.97	182.89	41.00	23.10
L8	5.8	803.26	572.89	303.97	259.80	216.69	210.24	166.54	35.87	19.27
L11	6.6	826.32	623.19	318.09	282.31	245.35	218.14	188.30	60.05	35.80
L16	3.8	846.80	636.61	415.03	368.24	369.41	380.82	343.20	222.10	161.22
L12	8.4	781.97	661.15	353.03	349.87	224.91	212.13	147.97	27.54	15.16
L13	2.5	762.37	522.55	269.01	232.69	212.89	211.06	161.72	46.63	32.44
L14	3.0	754.94	518.37	255.40	215.95	182.18	173.15	131.85	25.95	32.51
L15	2.5	748.24	507.98	255.59	207.96	182.26	161.67	121.50	20.75	13.78
L16	2.1	759.54	533.33	265.44	215.42	191.29	178.86	133.90	27.14	18.64
L17	1.9	808.15	566.72	301.65	262.66	242.16	236.35	184.32	76.38	53.25

Table C2. Validation TOA Spring-Summer Data

Station	Chl-a ug L^{-1}	B2	B3	B4	B5	B6	B7	B8A	B11	B12
L5	7.5	1116.15	815.10	573.85	534.81	531.18	535.80	480.92	323.28	276.93
L6	16.1	991.12	695.62	439.60	390.77	356.64	347.48	283.10	152.88	119.32
L7	14.5	1061.60	771.05	514.91	460.29	450.52	432.59	371.33	246.40	162.63
L9	10.7	1092.73	785.02	509.05	453.65	440.35	448.25	376.55	260.45	210.70
L10	16.4	937.74	643.75	403.67	361.32	360.28	351.39	311.91	161.96	114.45
L17	6.1	799.04	578.32	346.47	309.97	315.73	304.37	267.99	153.39	118.19

Table C3. Calibration BOA Spring-Summer Data

Station	Chl-a ug L^{-1}	B2	B3	B4	B5	B6	B7	B8A	B11	B12
L5	7.5	564.36	520.82	390.02	398.49	394.95	403.33	203.66	205.63	281.01
L6	16.1	413.76	385.26	253.03	246.53	218.77	222.00	194.13	223.79	122.20
L8	14.5	458.57	427.16	295.77	265.52	232.06	228.83	203.66	205.63	155.20
L9	10.7	508.25	451.98	298.33	266.85	219.77	231.74	194.13	223.79	199.74
L10	16.4	302.01	278.71	183.57	164.28	137.12	137.18	133.69	141.50	111.08
L1	74.1	142.28	351.54	154.69	236.42	87.54	88.70	54.74	2.16	2.10

L2	72.4	154.48	393.50	165.46	264.16	73.89	77.49	34.91	6.35	3.13
L4	14.1	121.33	223.19	88.19	87.53	15.55	19.48	23.26	12.34	6.98
L5	12.6	122.47	222.78	91.36	92.61	55.47	66.67	53.04	5.77	2.44
L7	8.5	128.54	213.90	94.43	87.54	52.93	65.32	52.00	1.40	7.84
L8	5.8	111.50	185.52	70.44	58.85	25.88	37.35	29.11	7.82	3.07
L16	3.8	310.86	334.67	237.98	220.09	202.05	221.55	210.73	222.01	184.20
L17	6.1	272.68	275.20	165.65	147.30	133.27	124.71	112.76	141.42	133.93
L13	2.5	162.66	176.07	58.88	46.86	6.30	17.35	4.69	30.54	31.23
L14	3.0	151.69	171.03	50.45	42.87	14.45	26.16	18.86	12.00	32.88
L15	2.5	141.94	160.82	52.39	38.02	29.36	30.65	24.13	8.75	10.99
L16	2.1	149.83	179.72	54.12	27.63	2.66	4.07	1.00	10.14	14.88
L17	1.9	212.33	219.13	90.04	77.14	49.81	61.57	41.77	60.38	54.25

Table C4. Validation BOA Spring-Summer Data

Station	Chl-a ug L^{-1}	B2	B3	B4	B5	B6	B7	B8A	B11	B12
L3	12.5	131.34	270.78	100.88	96.25	17.97	34.18	32.91	24.98	18.86
L6	6.2	115.98	256.25	85.44	84.85	60.54	62.89	57.46	2.70	6.12
L9	5.1	112.38	219.86	83.18	73.71	32.22	36.22	28.00	13.02	13.56
10	7.0	114.87	211.94	61.50	51.20	13.57	33.87	23.99	12.43	6.01
L11	6.6	119.78	238.58	63.71	56.16	21.58	15.19	23.08	21.57	17.56
L12	8.4	188.68	353.41	161.40	188.41	28.74	30.00	2.63	10.54	11.71

Table C5. Calibration TOA Fall-Winter Data

Station	Chl-a ug L^{-1}	B2	B3	B4	B5	B6	B7	B8A	B11	B12
L8	8.7	768.48	518.78	264.72	229.03	196.81	176.17	124.72	26.98	12.08
L9	3.8	778.39	523.58	278.07	241.94	207.87	193.67	146.96	39.96	22.09
L10	4.4	766.99	518.79	271.32	232.62	214.32	191.30	167.60	36.96	25.69
L11	4.4	769.16	519.72	268.28	239.32	220.82	208.97	159.88	40.51	22.05
L1	6.7	984.32	671.84	408.32	354.68	298.76	290.16	243.88	85.57	69.59
L2	8.1	966.97	665.69	402.44	364.77	301.18	290.74	243.08	78.52	47.59
L5	6.9	947.25	635.07	374.06	336.96	306.13	273.66	227.59	83.18	50.12
L6	7.4	945.30	632.37	363.68	326.87	297.03	284.67	231.32	84.80	60.88
L9	5.3	962.28	634.45	367.73	324.51	307.92	281.98	231.00	78.85	56.86
L10	5.2	1003.70	680.23	408.23	366.60	354.41	347.71	293.85	138.05	93.91
L11	3.8	991.49	670.89	404.35	378.91	354.23	350.19	309.39	145.62	108.25

Table C6. Validation TOA Fall-Winter Data

Station	Chl-a ug L^{-1}	B2	B3	B4	B5	B6	B7	B8A	B11	B12
L3	5.3	968.36	651.37	392.94	344.39	310.64	302.85	255.49	91.00	67.07
L4	4.4	953.39	628.94	362.73	329.91	299.92	289.93	242.95	85.44	58.09
L7	5.1	965.60	632.99	364.41	329.13	295.66	288.19	217.42	88.32	56.85
L8	6.4	998.98	663.27	398.84	359.94	335.13	326.45	268.53	120.24	85.89

Table C7. Calibration BOA Fall-Winter Data

Station	Chl-a ug L^{-1}	B2	B3	B4	B5	B6	B7	B8A	B11	B12
L9	3.75	129.02	176.71	66.52	62.38	39.00	49.88	36.58	21.36	10.15
L10	4.43	85.55	142.40	47.57	34.02	16.53	12.84	28.46	13.11	10.85
L11	4.44	82.91	132.87	35.85	32.91	7.11	16.98	11.76	13.24	8.18
L1	6.67	173.38	196.17	100.68	81.08	39.34	60.54	64.87	12.03	5.94
L2	8.06	142.36	181.56	90.78	82.99	23.58	40.44	44.17	4.25	1.00
L4	4.38	127.17	133.04	45.31	46.20	27.29	41.69	46.95	15.69	1.12
L5	6.93	127.01	157.56	66.84	73.74	68.19	64.73	61.55	16.62	1.90
L8	6.39	159.08	155.53	67.96	64.06	50.64	86.25	62.44	27.98	11.65
L9	5.31	133.07	134.25	49.49	39.70	48.27	53.86	49.95	5.68	1.00
L11	3.78	145.87	155.21	68.14	73.47	58.67	74.76	90.15	55.78	28.55
L16	9.4	632.41	610.80	432.67	518.51	602.86	633.07	619.72	481.53	388.83
L17	7.4	493.71	483.77	398.54	459.35	561.63	594.72	607.96	439.88	335.70

Table C8. Validation BOA Fall-Winter Data

Station	Chl-a ug L^{-1}	B2	B3	B4	B5	B6	B7	B8A	B11	B12
L3	5.3	155.61	165.54	90.27	68.72	40.24	61.10	65.22	26.01	15.23
L6	7.4	138.98	154.08	63.96	62.10	57.67	80.13	74.54	24.42	10.09
L7	5.1	146.81	144.27	49.42	55.61	50.00	74.99	51.24	17.78	1.61
L10	5.2	155.76	169.40	66.26	56.44	51.29	75.30	70.78	41.82	8.02

Supplementary Material D

Table D1. Table 2. Descriptive statistics values for BOA and TOA images (Reflectance values)

Statistics indicators	BOA Image	TOA Image
Min	-159.58	-63.12
Max	150.08	176.41
Mean	19.59	17.45
S. Desv.	26.02	22.67

Table D2. Covariance matrix for BOA and TOA images

Covariance Matrix	BOA Image	TOA Image
BOA Image	92.82	81.49
TOA Image	81.49	104.29

Table D3. Spatial correlation matrix for BOA and TOA images

Covariance Matrix	BOA Image	TOA Image
BOA Image	1.00	0.83
TOA Image	0.83	1.00

Table D4. Spatial consistency pattern according to range of Chl-a for BOA and TOA images

Value	TOA Number of cells	Percentage for TOA	BOA Number of cells	Percentage for BOA
< 2	8897	12%	9388	19%
2 a 5	8488	11%	3687	7%
5 a 10	19301	26%	10177	20%
10 a 20	25132	34%	16136	32%
20 a 30	3114	4%	2234	4%
30 a 40	536	1%	343	1%
40 a 50	390	1%	288	1%
50 a 60	892	1%	596	1%
60 a 70	2366	3%	2607	5%
>70	5566	7%	5020	10%
Total	74682	100%	50476	100%