

Supplementary Materials for

Long-time Interval Satellite Image Analysis on Forest Cover Changes and Disturbances around Protected Area, Zeya State Nature Reserve, in the Russian Far East

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Table S1 Major Forest Types of Zeya State Nature Reserve

Major Forest Types	Description (Elevation)
Mountain tundra vegetation with fragments of dwarf pine woodland	Shrub, sedge, lichen, moss (1200-1442.8 m asl)
Dwarf pine woodland	The communities of <i>Pinus pumila</i> (Pall.) Regel are wild rosemary, green moss, dead cover (1100-1400 m asl)
Mountain spruce forests	The communities of <i>Picea ajanensis</i> (Lindl. et Gord.) Fisch. Ex Carrière and <i>Betula lanata</i> (Regel) V.N. Vassil. reed grass and grass-green moss. Forbs reed meadows (1100-1300 m asl)
Spruce forests in a river valley	<i>Picea ajanensis</i> (Lindl. et Gord.) Fisch. ex Carr. (900-1300 m asl)
Larch and Birch forests	<i>Larix gmelinii</i> (Rupr.) Kuzen, <i>Betula platyphylla</i> Sukacz. (315-1000 m asl)
Mixed forests in a river valley	<i>Larix gmelinii</i> (Rupr.) Kuzen, <i>Vaccinium uliginosum</i> L., <i>Salix myrtilloides</i> L., <i>Chamaedaphne calyculata</i> (L.) Moench; muddy, wetland, willow, floodplain (below 700 m asl)
Oak - Daurian birch forests	<i>Larix gmelinii</i> (Rupr.) Kuzen, <i>Picea ajanensis</i> (Lindl. et Gord.) Fisch. ex Carr., <i>Chosenia arbutifolia</i> (Pall.) DC., <i>Populus suaveolens</i> Fisch., <i>Swida alba</i> (L.) Opiz, grass (below 700 m asl)

Table S2 Data from survey plots at Zeya State Nature Reserve

Plot name	Date (mm/dd/yyyy)	Latitude	Longitude	Elevation (m)	Slope direction	Slope angle (Degree)	Dominant species (#of trees)	Average DBH of dominant species (cm)	Average height of dominant species (m)	Forest Fire Disturbance Intensity
NR1	8/6/2016	54.1218440	126.932333	1,305.40	195	12	<i>Picea ajanensis</i> (18)	21.1	11.2	N/A
NR2	8/7/2016	54.1083570	126.932428	853.04	192	5.5	<i>Larix gmelinii</i> (13)	17.5	14.8	N/A
NR3	8/8/2016	54.0913000	126.882125	626.02	335	1	<i>Larix gmelini</i> (29), <i>Picea ajanensis</i> (22)	8.7, 6.3	9.4, 5.7	N/A
NR4	8/8/2016	54.0831370	126.874603	600.15	245	2	<i>Larix gmelinii</i> (11)	19.3	18.5	N/A
NR5	8/2/2017	54.1418611	126.758556	716.00	10.5	9.7	<i>Picea ajanensis</i> (8)	25.94	16.14	N/A
NR6	8/3/2017	54.1479444	126.779139	1065.00	53	9.4	<i>Picea ajanensis</i> (26)	14.18	11.67	N/A
NR7	8/3/2017	54.1473333	126.781278	1073.00	136	11.0	<i>Pinus pumila</i> (10), <i>Picea ajanensis</i> (4), <i>Larix gmelinii</i> (5)	3.71, 4.00, 6.39	2.68, 2.78, 4.83	N/A
NR8	8/4/2017	54.1315000	126.739833	622.00	112	4.1	<i>Betula platyphylla</i> (13)	14.59	16.54	N/A
NR9	8/5/2017	54.0135833	127.039083	594.00	26	7.7	<i>Betula platyphylla</i> (5), <i>Larix gmelinii</i> (13)	15.36, 11.71	17.41, 14.34	N/A
NR10	8/7/2017	54.0135833	127.039083	569.00	78	8.4	<i>Betula platyphylla</i> (15)	3.41	4.43	High
NR11	8/8/2017	54.0080555	127.047361	509.00	116	3.2	<i>Betula platyphylla</i> (13), <i>Pajanensis</i> (38)	13.93, 2.18	12.38, 4.38	High
BZ1	8/10/2016	54.0119300	127.037063	555.61	198	34	<i>Betula platyphylla</i> (36)	2.5	3.6	High
BZ2	8/7/2017	53.8724722	127.109806	491.00	38	4.9	<i>Betula platyphylla</i> (23)	4.57	6.74	Medium
BZ3	8/1/2018	54.0578056	126.920083	545.91	135	1	<i>Larix gmelinii</i> (12)	10	9.4	Low
BZ4	8/2/2018	54.1035556	126.796111	561.05	207	2	<i>Betula platyphylla</i> (4)	8.2	3.8	Medium
BZ5	8/3/2018	54.1273056	126.704778	559.85	180	4	<i>Larix gmelinii</i> (7)	12.5	11.6	N/A
BZ6	8/5/2018	53.8680556	127.121556	458.19	165.5	4.4	<i>Larix gmelinii</i> (14)	8.5	11.1	N/A
ONR1	8/10/2016	53.8178850	127.150909	508.97	265	10.1	<i>Larix gmelinii</i> (4)	17.3	16.1	High
ONR2	8/5/2017	53.9668333	127.056333	455.00	0	0.0	<i>Larix gmelinii</i> (4)	26.36	16.67	High
ONR3	8/7/2017	53.9180556	127.073889	498.00	0	0.0	<i>Betula platyphylla</i> (6), <i>Larix gmelinii</i> (16)	10.39, 10.24	12.67, 11.07	High
ONR4	8/8/2017	53.8365556	127.146806	451.00	1	8.0	<i>Betula platyphylla</i> (16)	3.72	5.80	High
ONR5	8/1/2018	53.9619722	127.045139	409.40	135	1	<i>Larix gmelinii</i> (6)	22.5	16.5	Medium
ONR6	8/5/2018	54.1512778	126.661583	503.61	304	3	<i>Larix gmelini</i> (7), <i>Picea ajanensis</i> (15)	15.6, 5.4	18.7, 6.2	Low

Table S3 Class cover area (km²) inside, buffer zone, and outside of the Reserve in 1988-1999, 1999-2010 and 2010-2016

Class Name	1988-1999			1999-2010			2010-2016		
	Inside	Buffer	Outside	Inside	Buffer	Outside	Inside	Buffer	Outside
BURN	4.5468	0.2565	10.6101	53.9343	5.5899	77.3883	2.5308	0.8019	64.2762
CCTA	0	0.3438	19.6704	0	0.8631	7.2702	0	0.0063	6.5871
CCE	0.0405	1.062	3.1842	0.0081	0.7677	2.8305	0	1.341	8.1378
MD	0	0.1188	2.997	0	0	10.1043	0	0.7884	48.9456
VGR	12.6243	9.0414	84.2985	10.0431	7.9245	79.9902	6.8292	0.8667	37.7973
GRASS	25.5249	6.4998	216.5724	6.4692	9.8541	299.871	3.6405	12.3417	324.9864
MF	27.6849	13.536	183.4983	36.1269	29.8836	251.9901	21.0087	18.6777	169.5321
OBF	6.6636	10.2654	53.5068	8.6436	7.0272	36.5031	14.031	8.4276	23.9886
BLF	766.1223	190.4535	1710.271	729.8622	168.2964	1570.734	765.0216	189.0576	1644.802
SFRV	17.9739	5.9688	48.1482	14.6304	2.7171	14.3802	40.0995	3.1482	22.3695
MSF	88.6113	9.1035	33.4161	84.4155	7.2963	23.7906	95.0013	6.8472	24.4206
DPW	20.4147	0.6993	0.0054	24.165	0.6903	0.0171	23.2344	0.3159	0.0297
MTV	6.9417	0.1773	0.0063	6.7068	0.0297	0	8.1981	0	0
TOWN	0	0.0702	5.1813	0	0.0135	2.9754	0.0081	0	4.581
ROAD	2.2095	1.512	1.9152	0.9702	1.5588	1.6965	1.3338	1.8639	4.0815
ROCK	3.0096	1.4625	37.0782	4.563	2.6334	22.5963	1.7559	1.0107	20.9691
WATER	6.6753	51.156	56.781	8.505	56.3742	63.8595	6.3504	56.232	61.3656

Table S4 Area changes in different vegetation classes during 1999-2010 compared to 1988-1999. Green color gradient indicates upgrading process of vegetation succession. Red color gradient indicates degrading process of vegetation succession.

	1999-2010 Total Area (km ²)																	
	CLASS	BURN	CCTA	CCE	MD	VGR	GRASS	MF	OBF	BLF	SFRV	MSF	DPW	MTV	TOWN	ROAD	ROCK	WATER
1988-1999 Total Area (km ²)	BURN	0.1062	0	0.018	0.2511	2.3697	1.287	2.2455	0.0099	6.5349	0.0855	0.108	0	0	0	0.0009	0.117	0.2637
	CCTA	0.8541	0.0243	0.0585	0.549	4.9005	2.4156	2.7657	0.1035	8.1018	0.0009	0	0	0	0.0207	0.0171	0.0621	0.1404
	CCE	0.2529	0.0576	0.4545	0	0.369	1.7667	0.3483	0	0.8874	0	0	0	0	0	0	0.1098	0
	MD	0.1224	0	0	0.3429	0.9891	0.2286	0.2754	0	1.0674	0.0216	0	0	0	0.0135	0.0549	0	0
	VGR	1.3518	0.2097	0.1332	0.7785	15.9309	28.6947	22.3056	1.3779	27.0648	0.0018	0.0684	0	0	0.0018	0.1773	0.828	1.2411
	GRASS	5.4918	0.6957	0.5247	0.1719	7.4547	165.535	15.6564	1.7838	27.4311	0	0.1035	0.0117	0.0162	0.009	0.0585	1.5723	0.0594
	MF	9.9081	0.9963	0.3105	0.8379	12.8349	42.399	41.4657	2.3688	100.433	0.1701	3.1077	0.1791	0	0.0477	0.0504	1.5795	1.0134
	OBF	2.2635	0.1098	0.1422	0	2.2104	1.9692	8.244	22.7376	36.2295	0.072	0	0	0	0	0	0.4185	3.4065
	BLF	108.887	5.9805	1.3239	6.9669	41.8617	69.345	212.485	23.6709	2134.61	15.0183	25.884	1.2267	0.0234	0.1179	0.7434	8.9937	7.8048
	SFRV	5.3388	0.0063	0	0.0054	0.3789	0.1611	1.1736	0.036	68.5566	14.877	1.0179	0	0	0	0.0054	0.5553	2.0421
	MSF	1.6326	0	0.0009	0.1962	0.0378	0.0072	0.0216	0	49.8411	0.8802	81.4131	3.1941	0.2457	0	0	0	0.0504
	DPW	0.0063	0	0	0	0	0	0	0	1.6884	0	3.0789	17.8938	1.2717	0	0	0	0
	MTV	0.0513	0	0	0	0	0	0	0	0.0666	0	0.7173	2.367	5.1795	0	0	0	0
	TOWN	0.045	0.0045	0.0009	0	1.5696	0.6417	0.6381	0.0027	0.1953	0	0	0	0	2.025	0.1017	0.0333	0.0018
	ROAD	0.207	0	0.0756	0.0009	0.2043	0.0297	0.4527	0.0009	1.4382	0	0	0	0	0.0099	1.9512	0.2718	0.1188
	ROCK	0.387	0.0486	0.5634	0.0036	6.831	1.7064	9.8712	0.0693	2.8935	0.0072	0.0027	0	0	0.7434	1.0593	14.9274	1.1826
	WATER	0.0072	0	0	0	0.0153	0.0072	0.0522	0.0126	1.8558	0.5931	0.0009	0	0	0	0.0054	0.324	111.414

Table S5 Area changes in different vegetation classes during 2010-2016 compared to 1999-2010. Green color gradient indicates upgrading process of vegetation succession. Red color gradient indicates degrading process of vegetation succession.

	2010-2016 Total Area (km ²)																	
	CLASS	BURN	CCTA	CCE	MD	VGR	GRASS	MF	OBF	BLF	SFRV	MSF	DPW	MTV	TOWN	ROAD	ROCK	WATER
1999-2010 Total Area (km ²)	BURN	1.5741	3.1644	0.7056	3.1167	13.8816	40.9257	18.5418	0.2961	50.6457	0.2178	0.8946	0.0072	0.0144	0.9306	0.4734	1.3941	0.1287
	CCTA	0.4293	0.0423	0.1998	0.7407	0.6291	1.6587	1.0746	0.0261	3.2418	0	0	0	0	0	0.0549	0.0351	0.0009
	CCE	0.0855	0	0.6102	0.0225	0.0063	0.495	0.5301	0.0324	1.6236	0	0.0216	0	0	0	0.1611	0.018	0
	MD	0.0171	0	0.063	0	5.769	1.4517	0.7101	0	1.6353	0.0063	0.4266	0	0	0.0045	0.0162	0.0045	0
	VGR	1.2447	0.027	0.72	3.2652	3.6819	18.7506	17.991	1.422	49.1004	0.009	0.036	0	0	0.279	0.2727	1.0341	0.1134
	GRASS	0.5427	3.0384	1.6668	2.3949	10.9485	216.296	36.4806	0.5967	41.7294	0.0027	0.0414	0	0	0.2637	0.4329	1.4157	0.2925
	MF	7.8813	0.0342	1.2555	8.7705	2.5983	24.3063	37.7244	5.8869	225.44	0.1746	0.2871	0	0	0.1512	0.8577	2.3004	0.3213
	OBF	3.2958	0	0.0801	0.3537	0.0027	0.6687	2.3517	15.6384	29.5704	0.0207	0	0	0	0	0.0405	0.0135	0.1377
	BLF	52.7517	0.1881	3.9762	30.969	12.6198	51.0975	98.775	14.769	2130.01	27.0972	34.6779	1.1691	0.0009	0.2952	3.1635	4.5486	2.6685
	SFRV	1.1511	0	0	0.0045	0.0162	0.0684	0.0072	0.0054	15.7005	13.3038	1.0008	0	0	0	0.0153	0.018	0.4365
	MSF	0.486	0	0	0	0.7344	0.423	0	0	33.0786	0.8559	76.9401	2.5776	0.3474	0	0.0009	0.0585	0
	DPW	0	0	0	0	0.0009	0.0288	0	0	2.3616	0	5.1831	15.7635	1.5048	0	0	0.0297	0
	MTV	0	0	0	0	0.0189	0.0342	0	0	0.0027	0	0.3474	1.2429	5.0742	0	0	0.0162	0
	TOWN	0	0.0153	0	0.0036	0.0882	0.4734	0.0099	0	0.2826	0	0	0	0	1.773	0.0873	0.2556	0
	ROAD	0	0.0126	0.0405	0.0117	0	0.3717	0.4122	0.0036	1.287	0	0	0	0	0.0135	1.8405	0.144	0.0882
	ROCK	0.0378	0.0657	0.1647	0.0306	0.2601	4.1427	1.0809	0.144	8.0064	0.045	0	0	0	0.8262	0.4779	12.8556	1.6398
	WATER	0.1278	0.0045	0.0369	0.0504	0.0324	1.5831	0.1755	0.2511	5.7564	1.7397	0.0225	0	0	0.0441	0.2484	0.1728	118.429

Table S6 The change matrix of successional stages of class cover area (km²) in different periods and different zones of the Reserve.

1988-1999 Inside	1999-2010 Inside								2010-2016 Inside								
		BURN	VGR	GRASS	MF	OBF	BLF	Total	1999-2010 Inside		BURN	VGR	GRASS	MF	OBF	BLF	Total
	BURN	0	0.6147	0.0144	0.0981	0	1.5354	2.2626		BURN	0.0153	6.8742	12.6018	7.5231	0.1062	25.4916	52.6122
	VGR	0.1521	0.8955	0.6687	1.3356	0.1341	3.3102	6.4962		VGR	0.0189	0.1836	1.1826	1.3401	0.009	7.164	9.8982
	GRASS	0.4275	0.3186	0.639	0.6264	0.1305	1.3401	3.4821		GRASS	0.0054	0.0081	2.8089	1.098	0.0639	2.106	6.0903
	MF	0.9063	1.1862	0.7506	3.2112	0.2934	11.6217	17.9694		MF	0	0.0909	1.3518	2.8458	0.6372	30.9636	35.8893
	OBF	0.9171	0.2763	0.1485	1.1376	3.9978	6.9138	13.3911		OBF	0	0	0.0396	0.3249	3.2994	4.9284	8.5923
	BLF	47.2599	6.2649	4.2039	29.3067	4.0581	648.4518	739.5453		BLF	3.9078	4.6998	6.0525	14.3442	2.4588	665.5131	696.9762

1988-1999 Buffer	1999-2010 Buffer								1999-2010 Buffer	2010-2016 Buffer							
		BURN	VGR	GRASS	MF	OBF	BLF	Total			BURN	VGR	GRASS	MF	OBF	BLF	Total
	BURN	0	0.0828	0	0.0027	0	0.1422	0.2277		BURN	0.0009	0.2925	1.5273	0.9981	0.0531	2.4048	5.2767
	VGR	0.1386	1.9062	1.2942	2.3553	0.0405	2.376	8.1108		VGR	0	0.0054	1.2735	1.7973	0.1692	4.4163	7.6617
	GRASS	0.1539	0.2889	3.0375	1.2042	0.0126	1.5048	6.2019		GRASS	0.0216	0.4185	4.7646	1.8234	0.0972	2.1429	9.2682
	MF	0.0882	0.9531	1.4481	3.2409	0.2961	6.5565	12.5829		MF	0.0999	0.0234	0.7029	3.852	1.5759	23.0715	29.3256
	OBF	0.2763	0.5598	0.0378	0.9828	3.1032	3.2805	8.2404		OBF	0.0216	0	0.0828	0.3942	3.4254	3.0042	6.9282
	BLF	4.6467	3.7332	3.6207	21.8178	3.5451	144.639	182.0025		BLF	0.5688	0.1251	2.5506	9.351	2.8863	146.0259	161.5077

1988-1999 Outside	1999-2010 Outside								1999-2010 Outside	2010-2016 Outside							
		BURN	VGR	GRASS	MF	OBF	BLF	Total			BURN	VGR	GRASS	MF	OBF	BLF	Total
	BURN	0.1062	1.6722	1.2726	2.1447	0.0099	4.8573	10.0629		BURN	1.5579	6.7149	26.7966	10.0206	0.1368	22.7493	67.9761
	VGR	1.0611	13.1292	26.7318	18.6147	1.2033	21.3786	82.1187		VGR	1.2258	3.4929	16.2945	14.8536	1.2438	37.5201	74.6307
	GRASS	4.9104	6.8472	161.8587	13.8258	1.6407	24.5862	213.669		GRASS	0.5157	10.5219	208.7226	33.5592	0.4356	37.4805	291.2355
	MF	8.9136	10.6956	40.2003	35.0136	1.7793	82.2546	178.857		MF	7.7814	2.484	22.2516	31.0266	3.6738	171.405	238.6224
	OBF	1.0701	1.3743	1.7829	6.1236	15.6366	26.0352	52.0227		OBF	3.2742	0.0027	0.5463	1.6326	8.9136	21.6378	36.0072
	BLF	56.9799	31.8636	61.5204	161.3601	16.0677	1341.517	1669.308		BLF	48.2751	7.7949	42.4944	75.0798	9.4239	1318.469	1501.537

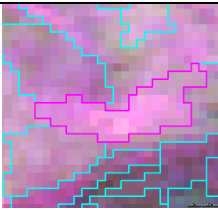
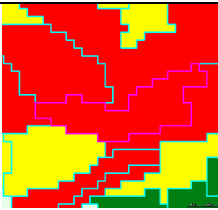
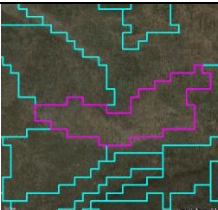

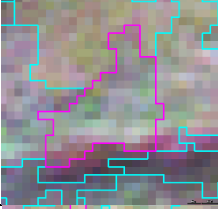
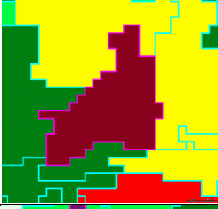
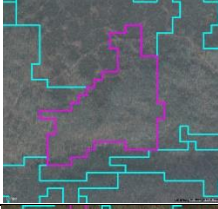

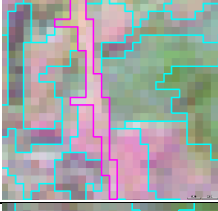
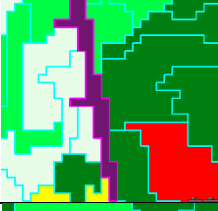
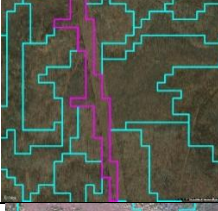

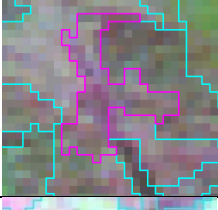
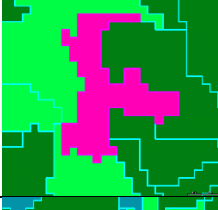


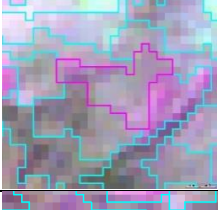
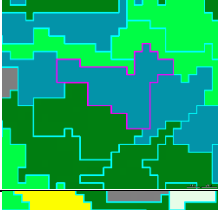
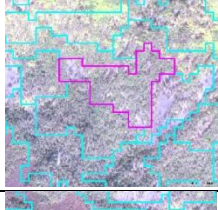

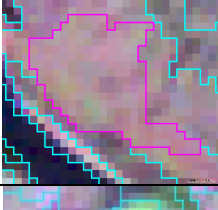
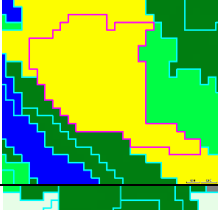
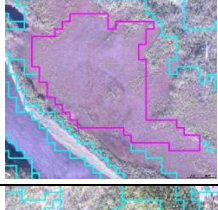

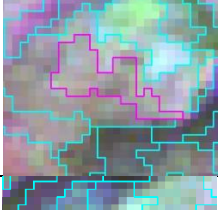
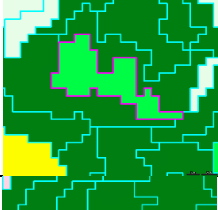
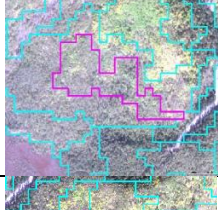

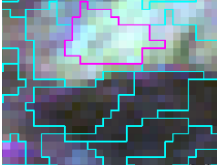
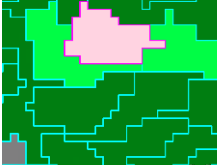


CLASS	Landsat Image	Classification Layer	High-resolution Image	Field Photograph
BURN				
CCTA				
CCE				
MD				
VGR				
GRASS				
MF				
OBF				

Figure S1 continued

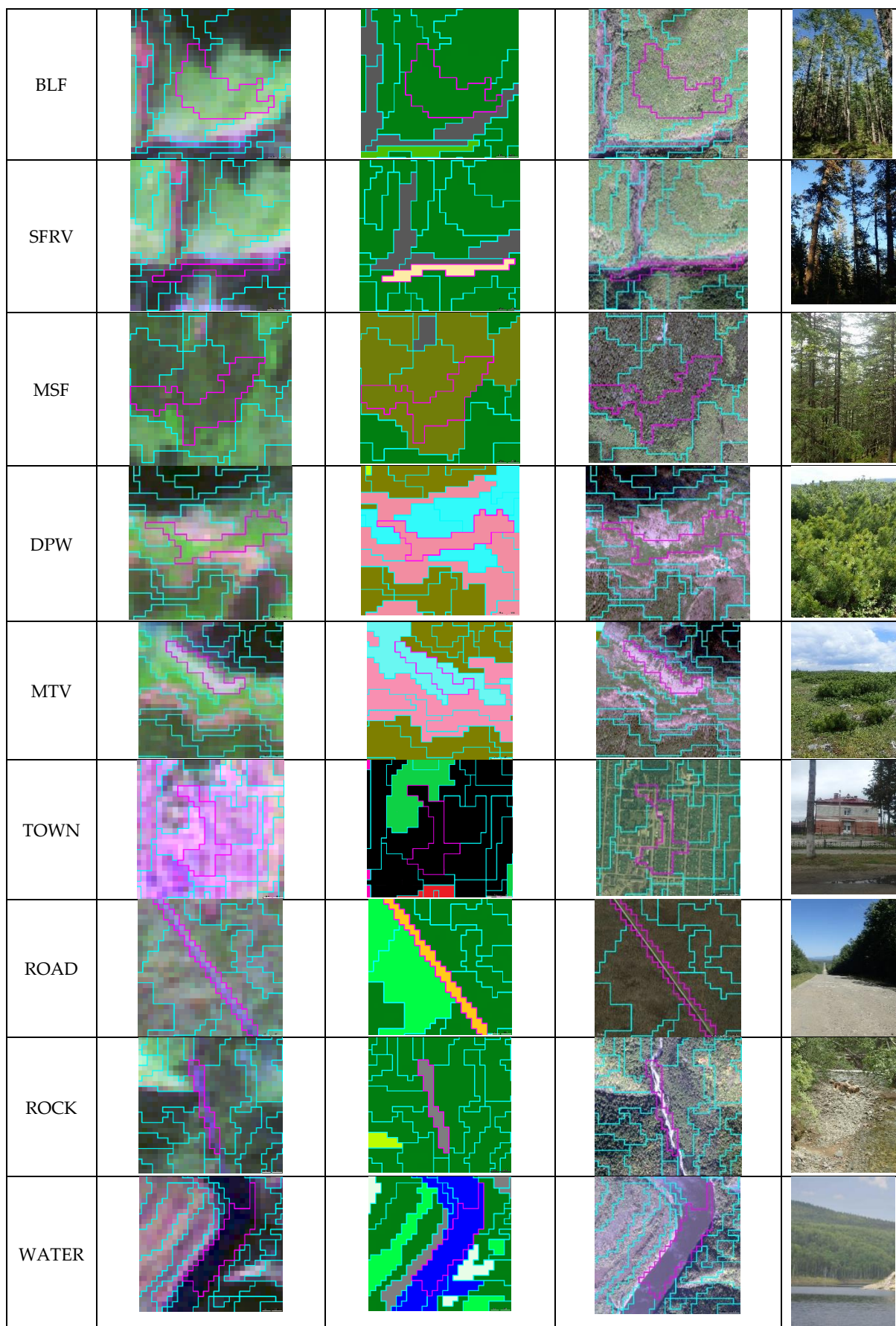


Figure S1 Examples of comparison of Landsat image data, classification result, and reference data (high-resolution image and field photographs) for 17 classes.

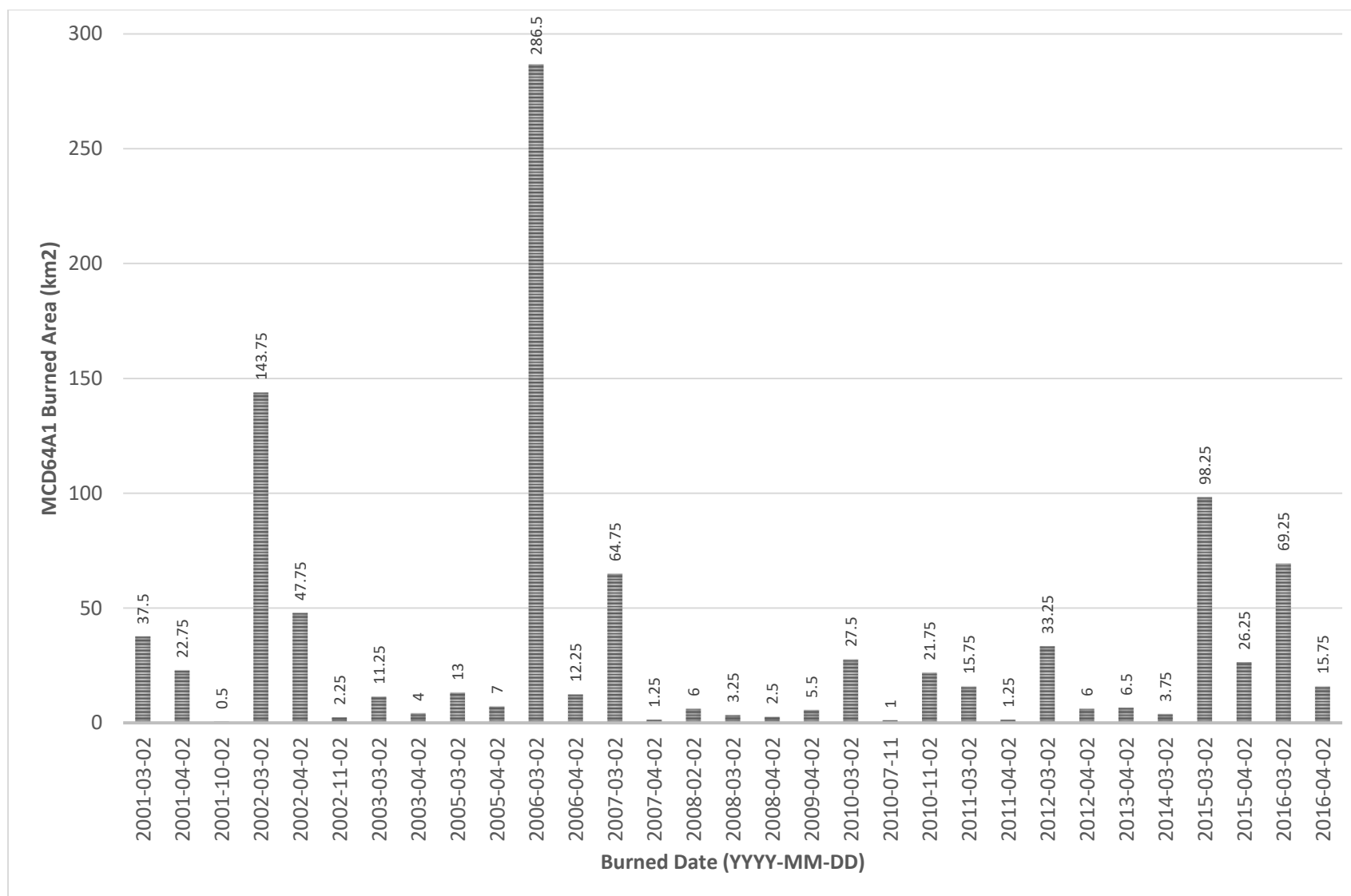


Figure S2 The Reserve burned area in each date registered by the MCD64A1 product.

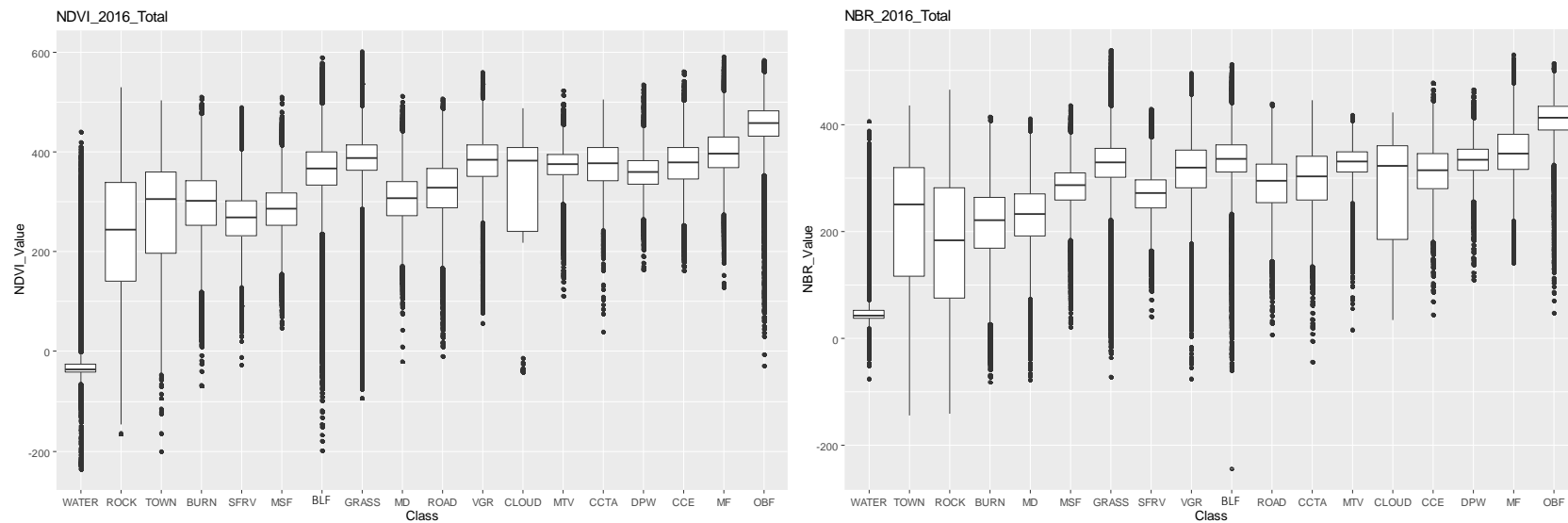


Figure S3 Box plot of (a) normalized difference vegetation index (NDVI) and (b) normalized burn ratio index (NBR) values in total area of the Reserve for each class in 2016. Middle line in box represents the median; lower box bounds the first quartile; upper box bounds the 3rd quartile. Whiskers represent the 95% confidence interval of the mean.

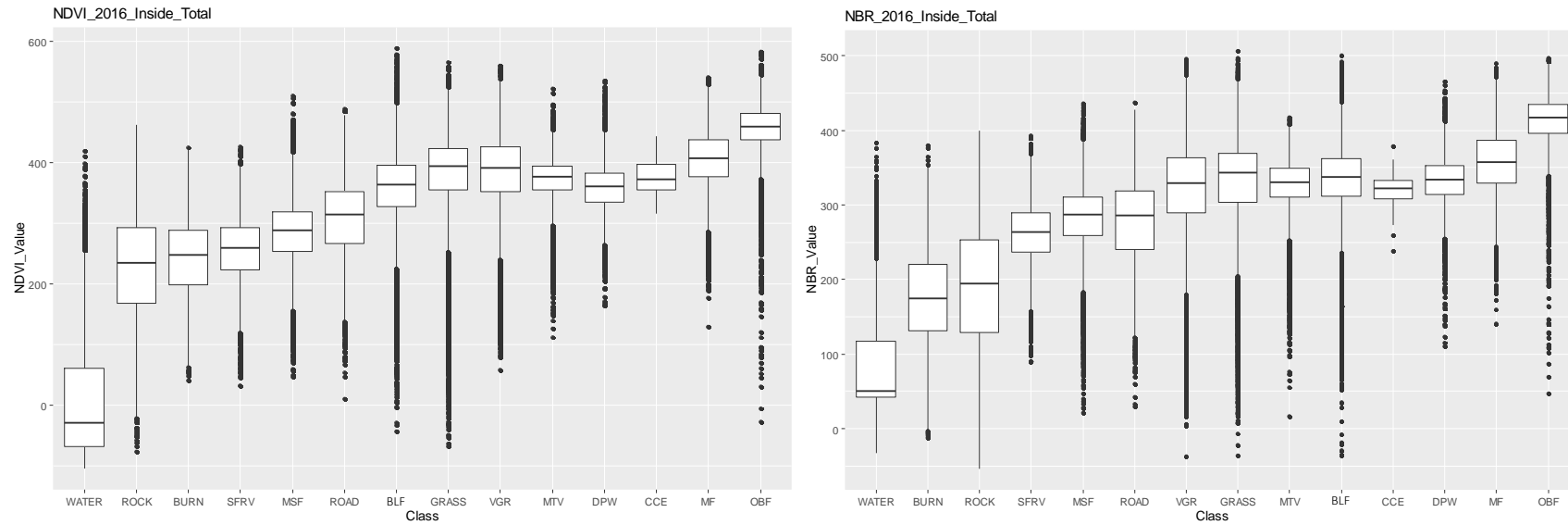


Figure S4 Box plot of (a) normalized difference vegetation index (NDVI) and (b) normalized burn ratio index (NBR) values in inside area of the Reserve for each class in 2016. Middle line in box represents the median; lower box bounds the first quartile; upper box bounds the 3rd quartile. Whiskers represent the 95% confidence interval of the mean.

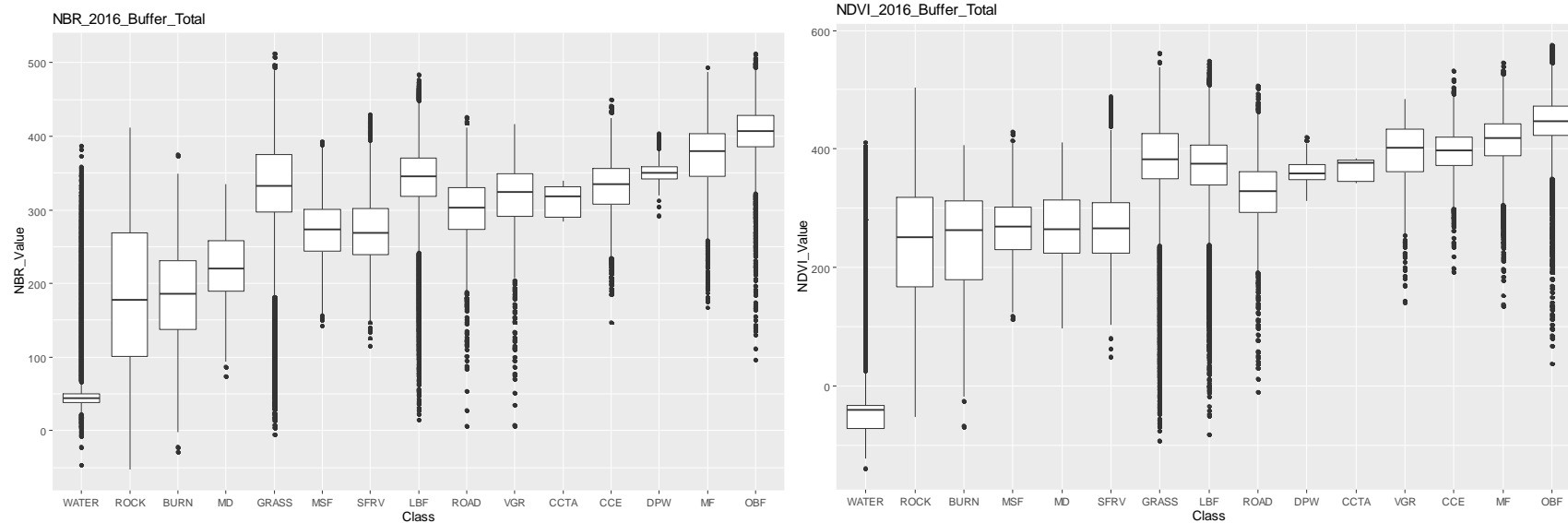


Figure S5 Box plot of (a) normalized difference vegetation index (NDVI) and (b) normalized burn ratio index (NBR) values in buffer zone area of the Reserve for each class in 20_{BLF}15. Middle line in box represents the median; lower box bounds the first quartile; upper box bounds the 3rd quartile. Whiskers represent the 95% confidence interval of the mean.

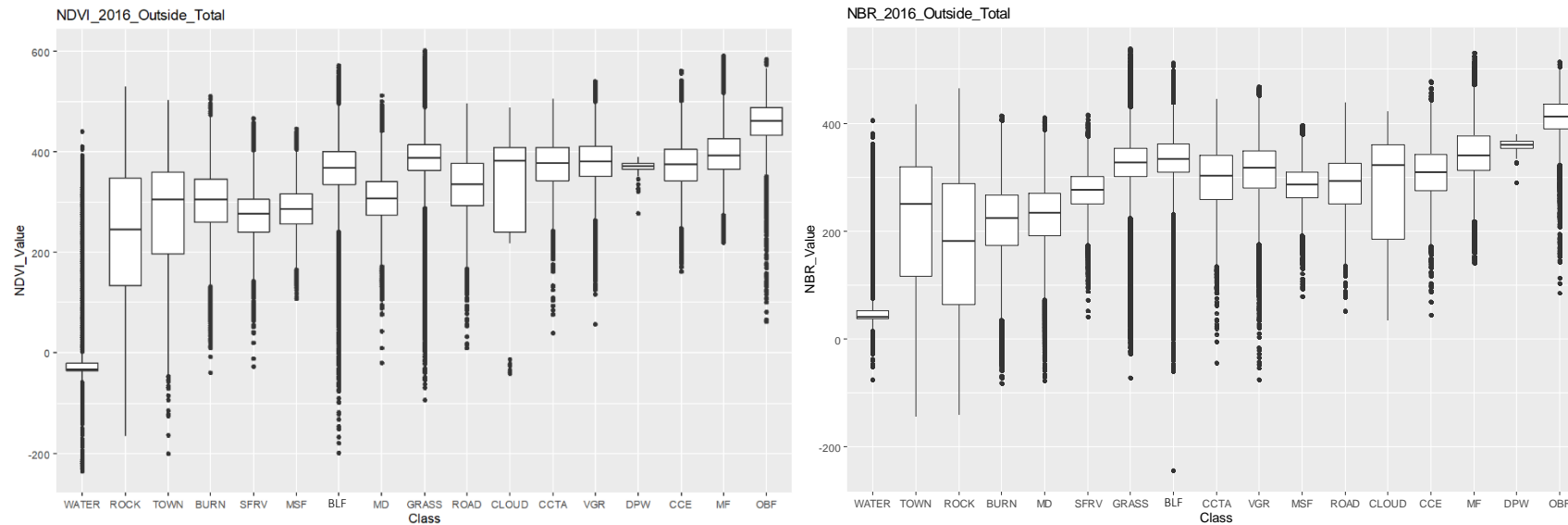


Figure S6 Box plot of (a) normalized difference vegetation index (NDVI) and (b) normalized burn ratio index (NBR) in outside area of the Reserve for each class in 2016. Middle line in box represents the median; lower box bounds the first quartile; upper box bounds the 3rd quartile. Whiskers represent the 95% confidence interval of the mean.