

# THE LANDSCAPE CONTEXT FOR REMAP IV: PLANT COMMUNITY DISTRIBUTION AND COVER DERIVED FROM VEGETATION MAPPED WITH WORLDVIEW-2 SATELLITE DATA

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# Everglades is the “River of Grass”

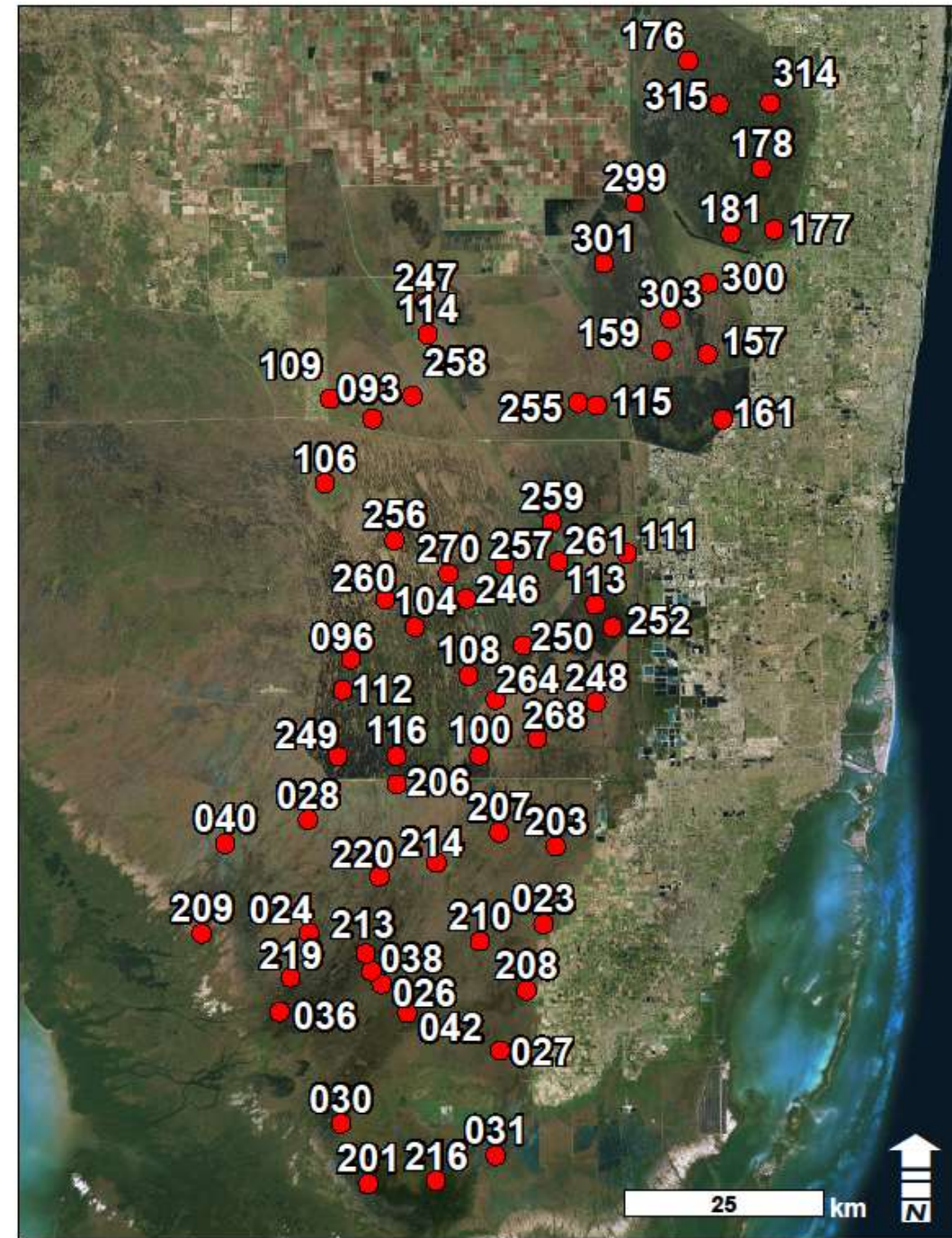
Amount of sawgrass variously estimated to be 50-75% of the vegetation; estimates have been qualitative or based on localized samples

Using high-resolution remotely sensed data within the REMAP sampling protocol allows us to make a quantitative estimate of community composition and of sawgrass cover across the landscape

Quantitative estimates of cover can be used to estimate sawgrass biomass

# Landscape Context

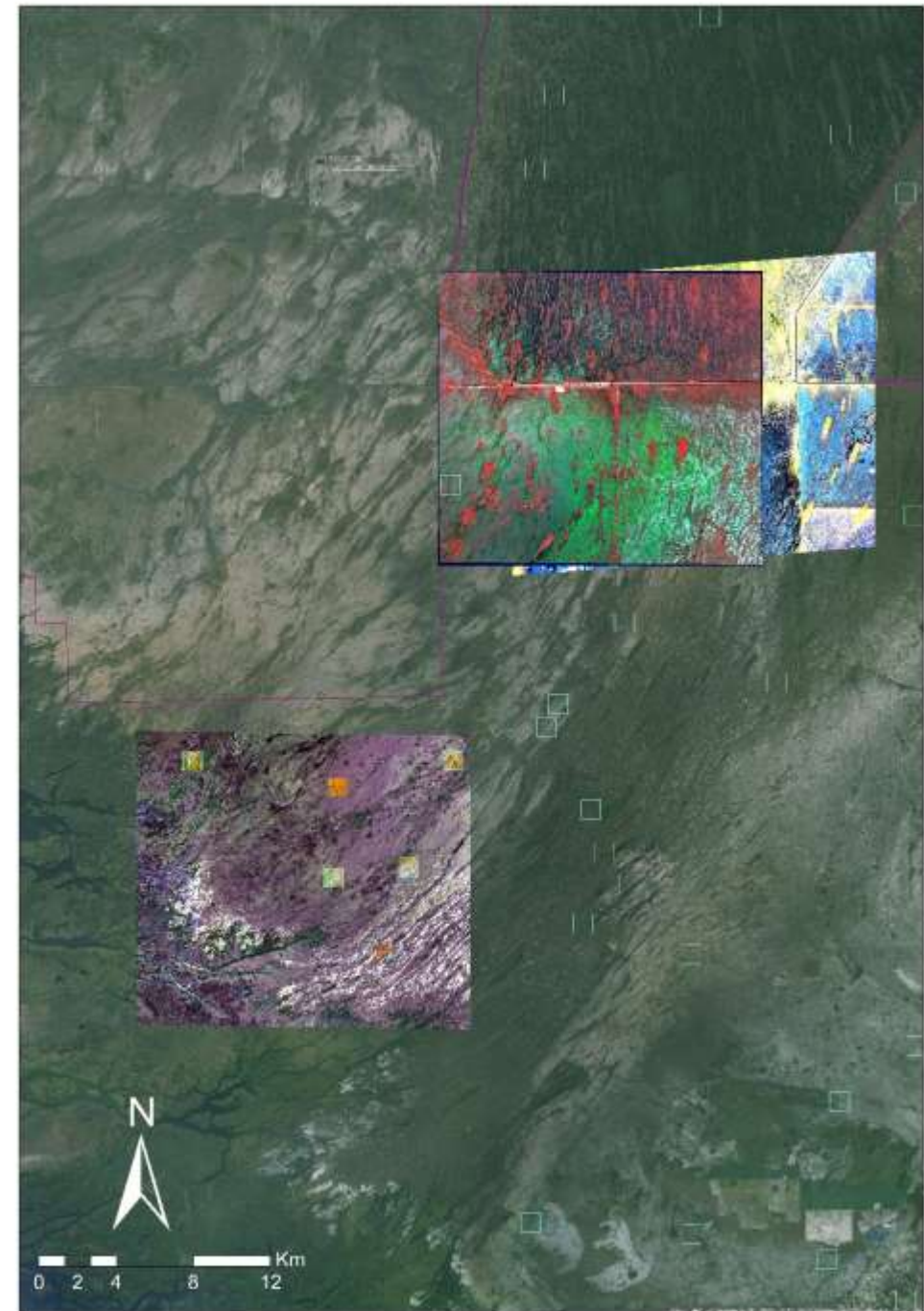
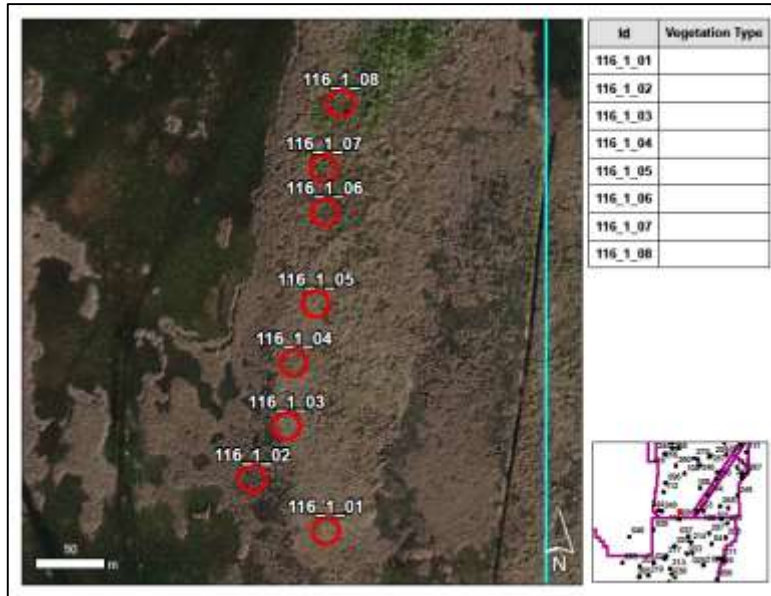
- REMAP sampling at a ‘point’
- Point occurs within a landscape that provides the context for environment at that point
  - “Landscape” exists at a variety of scales: local to regional to ecosystem
  - Environmental drivers act at different scales
- Mapped 1 km<sup>2</sup> sites around a subset of 65 of the REMAP points.
  - 22 in Everglades National Park,
  - 1 in Big Cypress National Park,
  - 29 in Water Conservation Area 3,
  - 7 in WCA 2,
  - 6 in WCA 1





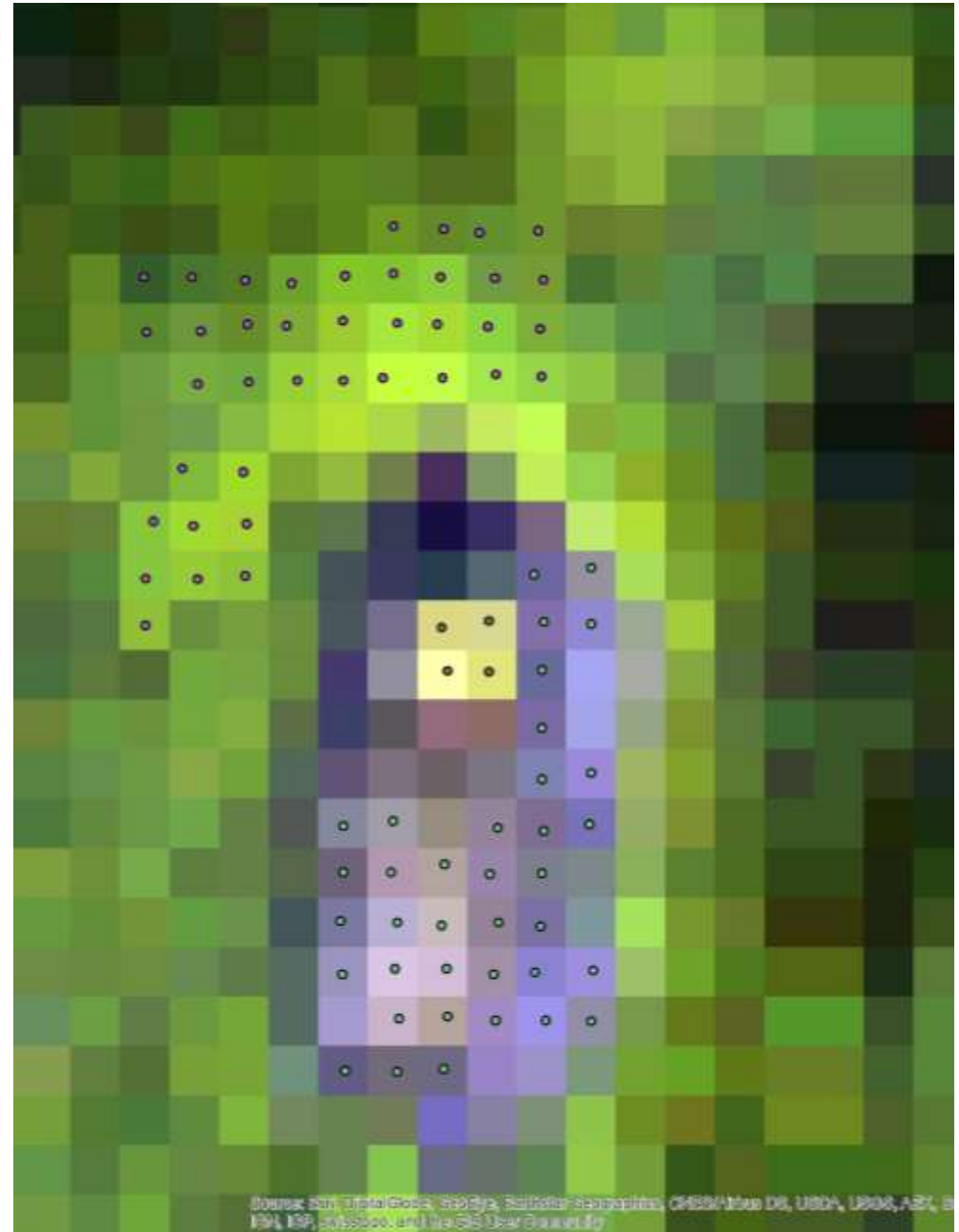
# Data

- 33 of Digital Globe's WorldView-2 satellite images (2x2 m pixels, 8 spectral bands)
- Images between 11/6/2010 and 9/22/2013
- Interpretation relied on visits to sites by helicopter, use of 2004, 2009, 2012 aerial photography, data from South Florida and Caribbean Inventory and Monitoring Network



# Methods

- In ArcGIS, digitized app. 3000 to 6000 training points in each 1 km<sup>2</sup>
- A random forest classifier was generated from the training points to classify each pixel within the 1 km<sup>2</sup> area
- Iterative process: from 3 to 18 maps made for each 1 km<sup>2</sup>
- Accuracy assessment done for 95% confidence using stratified random sample across all sites (Olofsson et al. 2013, 2014); samples evaluated from aerial photography
- Cover of sawgrass classes was used to estimate sawgrass biomass by site



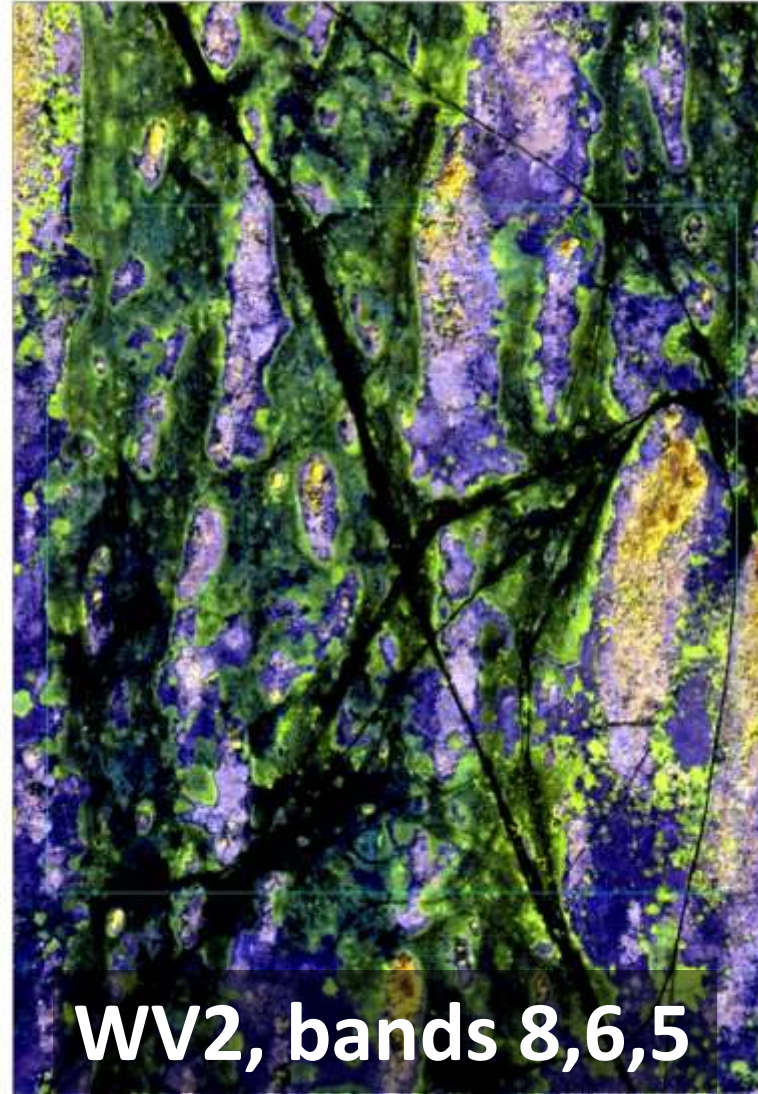
# Classes and Class Descriptions (10 of 48 total)

Class Code	Class Name	Abbreviated Name	Full Name	Description
1	aS	Aqua.Sbmr.	Aquatic submerged	Open water with submerged aquatic vegetation, usually <i>Utricularia</i> species, and substrate beneath
2	bIE	Brdlv.Emrg.	Broad-leaved emergent	Broad-leaved emergent vegetation, including <i>Sagittaria lancifolia</i> , <i>Pontederia cordata</i> , <i>Peltandra virginica</i> , <i>Crinum americanum</i> and <i>Thalia geniculata</i> , and a variety of ferns, as single or mixed species
3	bIE_s	Brdlv.Emrg_Shrb	Broad-leaved emergent and shrubs	Broad-leaved emergent vegetation, as in 'bIE' above, mixed in with shrubs, such as <i>Salix caroliniana</i> and <i>Cephalanthus occidentalis</i> .
4	bIFNu	Brdlv.Flt.Nuph.	Broad-leaved floating <i>Nupha advena</i>	Dominated by floating-leaved <i>Nuphar advena</i>
5	bIFNy	Brdlv.Flt.Nymp.	Broad-leaved floating <i>Nymphaea odorata</i>	Dominated by floating-leaved <i>Nymphaea odorata</i>
6	bIFNy_aS	Brdlv.Flt.Nymp_Aqua.Sbmr.	Broad-leaved floating <i>Nymphaea odorata</i> with aquatic submerged	Open marsh with floating-leaved <i>Nymphaea odorata</i> intermixed with submersed aquatics
7	bIFNy_gM	Brdlv.Flt.Nymp_Grm.Mrsh.	Broad-leaved floating <i>Nymphaea odorata</i> and graminoid marsh	A mixture of <i>Nymphaea odorata</i> interspersed with open water with graminoid marsh, including species as described in 'gM', below
8	bIFNy_peF	Brdlv.Flt.Nymp_Peri.	Broad-leaved floating <i>Nymphaea odorata</i> and floating periphyton	<i>Nymphaea odorata</i> at medium to low density in water covered by floating periphyton
9	gM	Grm.Mrsh.	Graminoid marsh	A graminoid marsh, including one or more species such as <i>Eleocharis cellulosa</i> , <i>E. elongata</i> , <i>Rhynchospora tracyi</i> , and <i>Panicum hemitomon</i> ; may have <i>Cladium jamaicense</i> and/or <i>Typha domingensis</i> at low densities in the mixture.
10	gM-D	Grm.Mrsh-Dns.	Graminoid marsh dense	A dense graminoid marsh of such species as <i>Eleocharis cellulosa</i> , <i>Rhynchospora tracyi</i> , and/or <i>Panicum hemitomon</i> ; usually a single species present



# Results

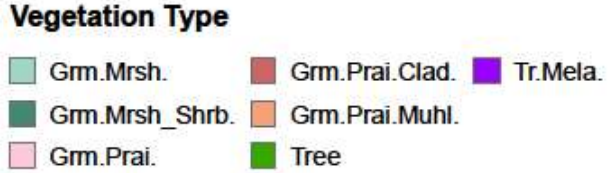
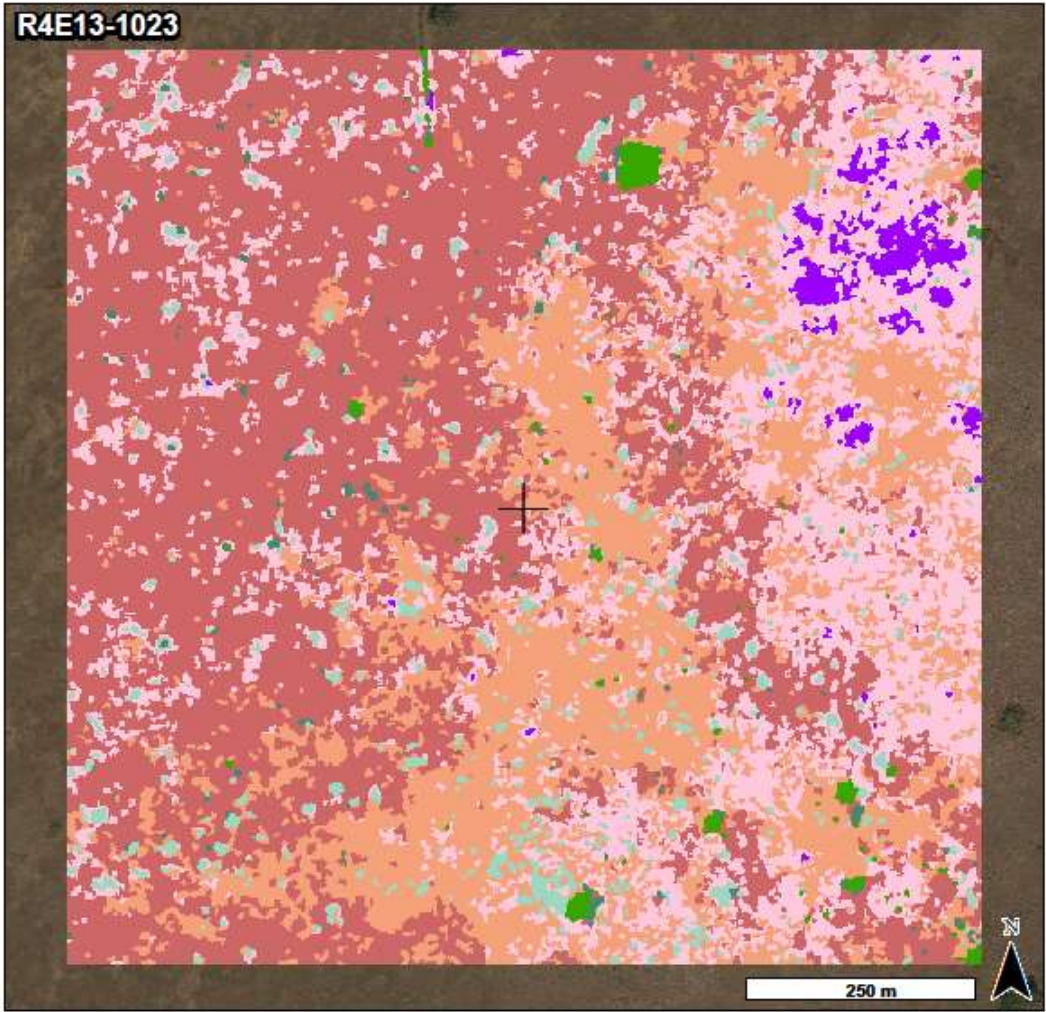
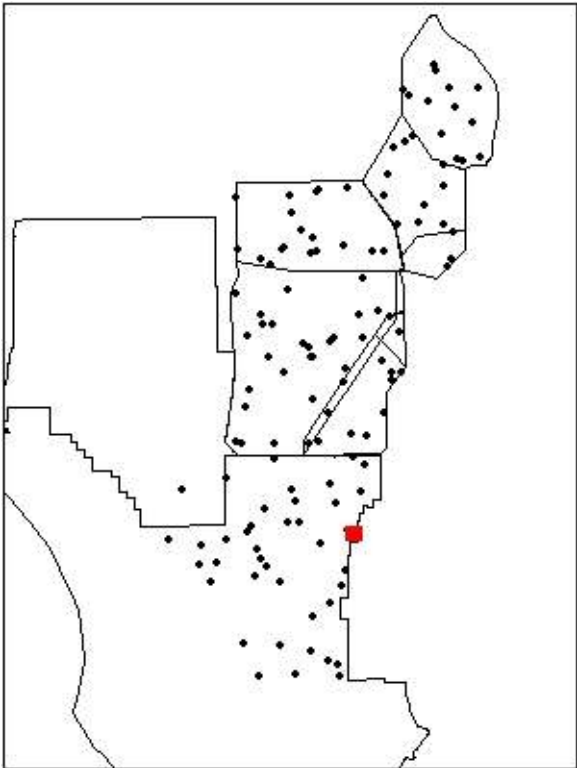
adjusted overall accuracy of 94%





# Everglades National Park, marl prairie

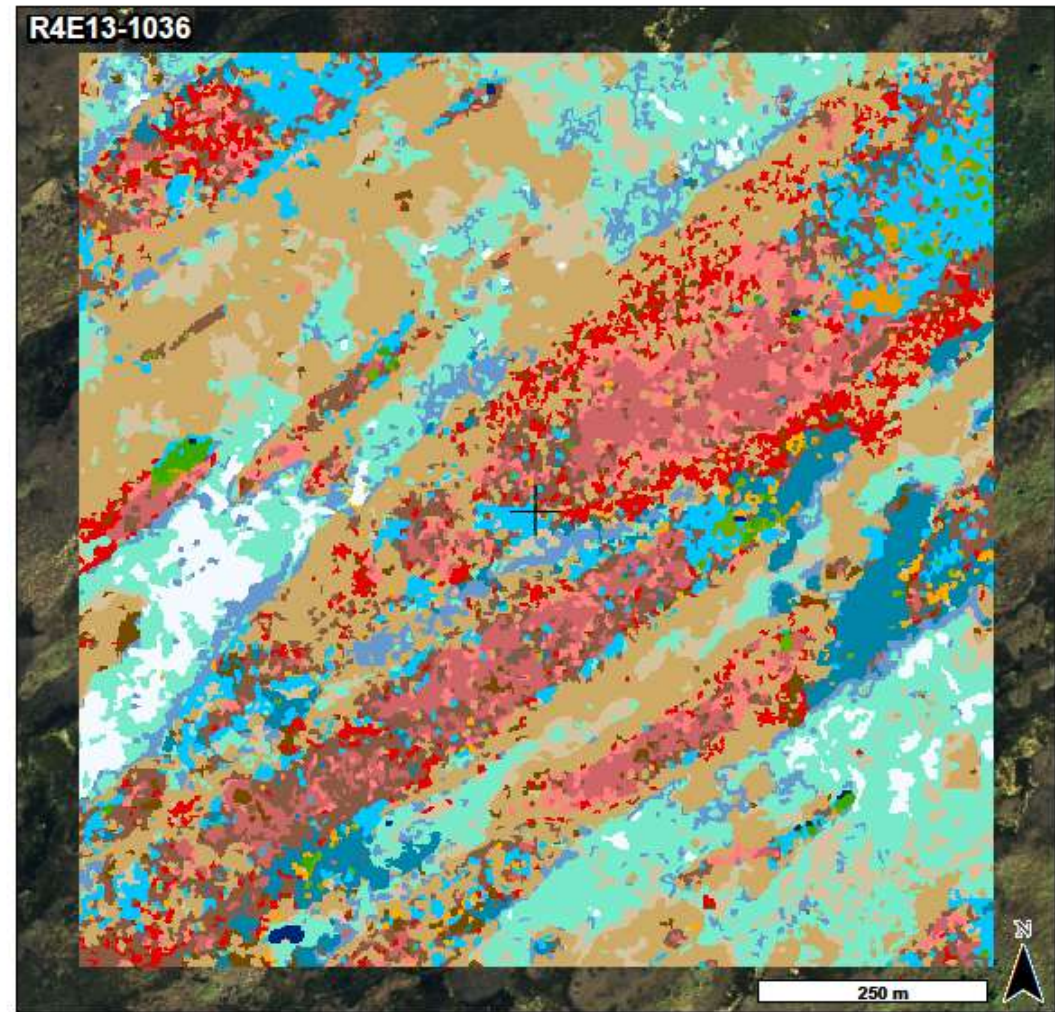
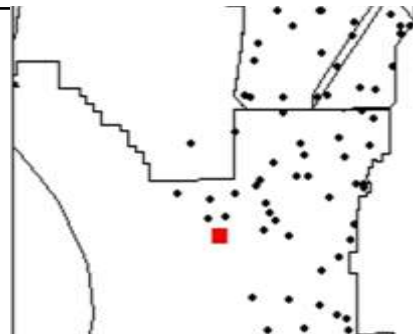
value	count	name	site	version	prpArea	areaHa
9	8269	gM	R4E13-1023	106	0.03308	3.3076
16	1459	gM_s	R4E13-1023	106	0.00584	0.5836
32	59312	gP	R4E13-1023	106	0.23725	23.7248
34	111739	gPCl	R4E13-1023	106	0.44696	44.6956
35	63912	gPMu	R4E13-1023	106	0.25565	25.5648
43	1748	t	R4E13-1023	106	0.00699	0.6992
44	3561	tMe	R4E13-1023	106	0.01424	1.4244





# Everglades National Park, southern Shark River Slough

value	count	name	site	version	prpArea	areaHa
1	281	aS	R4E13-1036	104	0.00112	0.1124
2	1631	blE	R4E13-1036	104	0.00652	0.6524
3	818	blE_s	R4E13-1036	104	0.00327	0.3272
7	12424	blFNy_gM	R4E13-1036	104	0.0497	4.9696
13	16661	gM_blE	R4E13-1036	104	0.06664	6.6644
17	74902	gMCl	R4E13-1036	104	0.29961	29.9608
23	24861	gMCl_s	R4E13-1036	104	0.09944	9.9444
24	14861	gMCl_Ty	R4E13-1036	104	0.05944	5.9444
18	4055	gMCl-D	R4E13-1036	104	0.01622	1.622
19	17522	gMCl-Sp	R4E13-1036	104	0.07009	7.0088
25	10033	gMEI-D	R4E13-1036	104	0.04013	4.0132
11	41144	gM-Sp	R4E13-1036	104	0.16458	16.4576
29	11457	gMTy	R4E13-1036	104	0.04583	4.5828
31	9669	gMTy_s	R4E13-1036	104	0.03868	3.8676
38	7560	peF	R4E13-1036	104	0.03024	3.024
39	1328	s	R4E13-1036	104	0.00531	0.5312
43	793	t	R4E13-1036	104	0.00317	0.3172



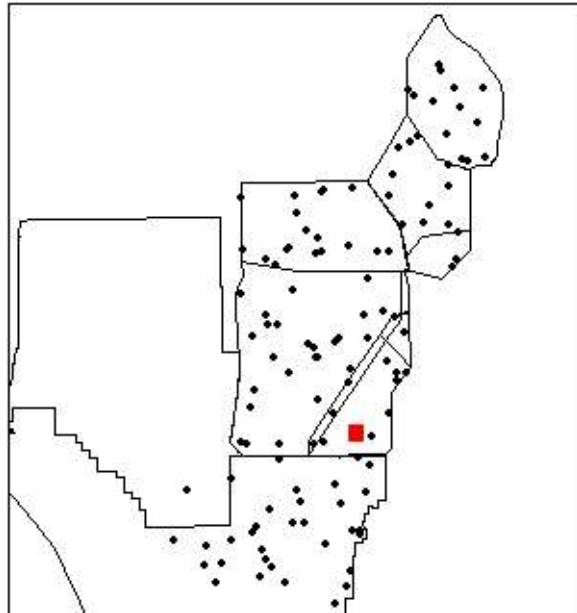
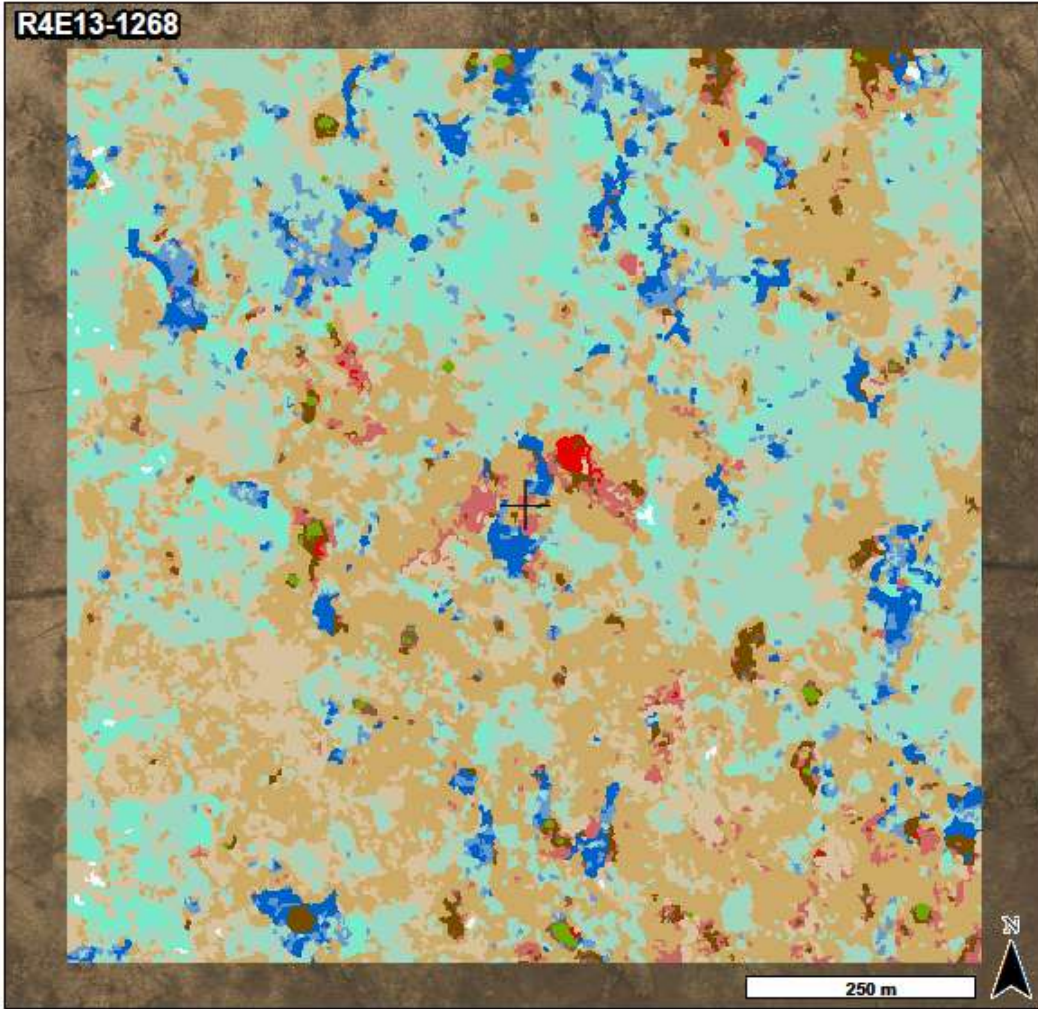
## Vegetation Type





# Water Conservation Area 3B

value	count	name	site	version	prpArea	areaHa
5	8947	bIFNy	R4E13-1268	117	0.03579	3.5788
7	7929	bIFNy_gM	R4E13-1268	117	0.03172	3.1716
9	77481	gM	R4E13-1268	117	0.30992	30.9924
17	82498	gMCl	R4E13-1268	117	0.32999	32.9992
23	940	gMCl_s	R4E13-1268	117	0.00376	0.376
24	5608	gMCl_Ty	R4E13-1268	117	0.02243	2.2432
18	4248	gMCl-D	R4E13-1268	117	0.01699	1.6992
19	44265	gMCl-Sp	R4E13-1268	117	0.17706	17.706
11	16531	gM-Sp	R4E13-1268	117	0.06612	6.6124
29	445	gMTy	R4E13-1268	117	0.00178	0.178
38	379	peF	R4E13-1268	117	0.00152	0.1516
39	729	s	R4E13-1268	117	0.00292	0.2916

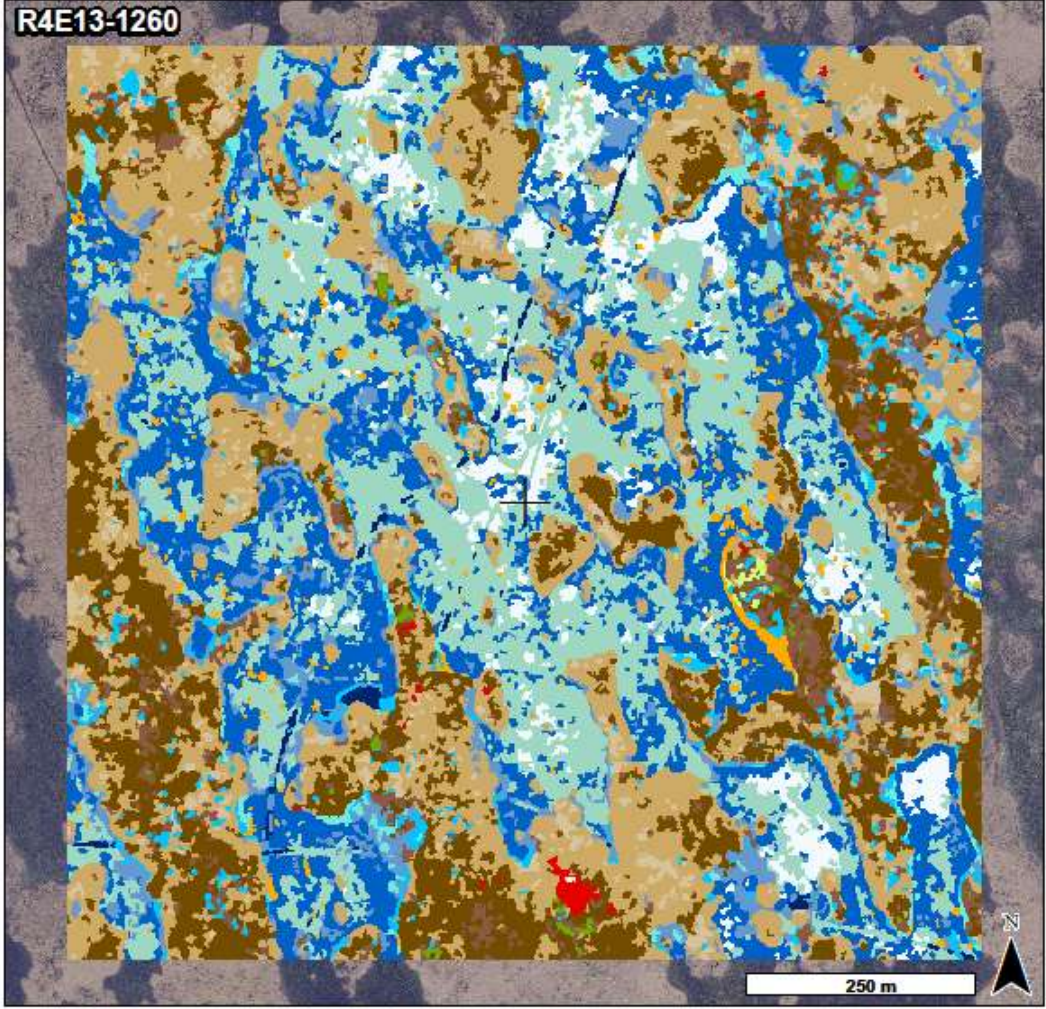
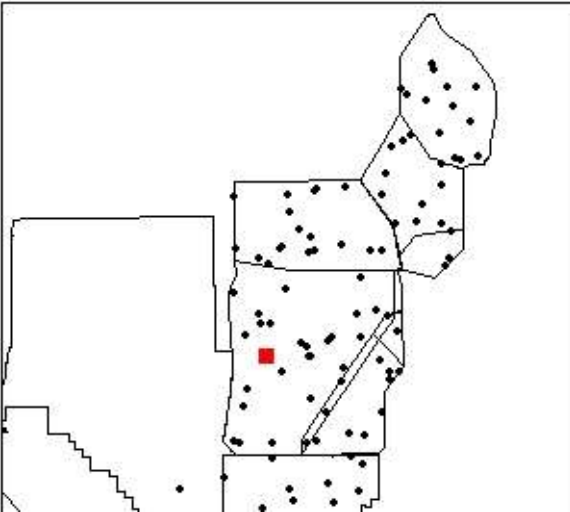


- Vegetation Type**
- Brdlv.Fit.Nymp.
  - Grm.Mrsh.Clad.
  - Grm.Mrsh.Clad\_Typh.
  - Brdlv.Fit.Nymp\_Grm.Mrsh.
  - Grm.Mrsh.Clad-Dns.
  - Peri.
  - Grm.Mrsh.
  - Grm.Mrsh.Clad-Spr.
  - Shrb.
  - Grm.Mrsh-Spr.
  - Grm.Mrsh.Clad\_Shrb.



# Water Conservation Area 3A

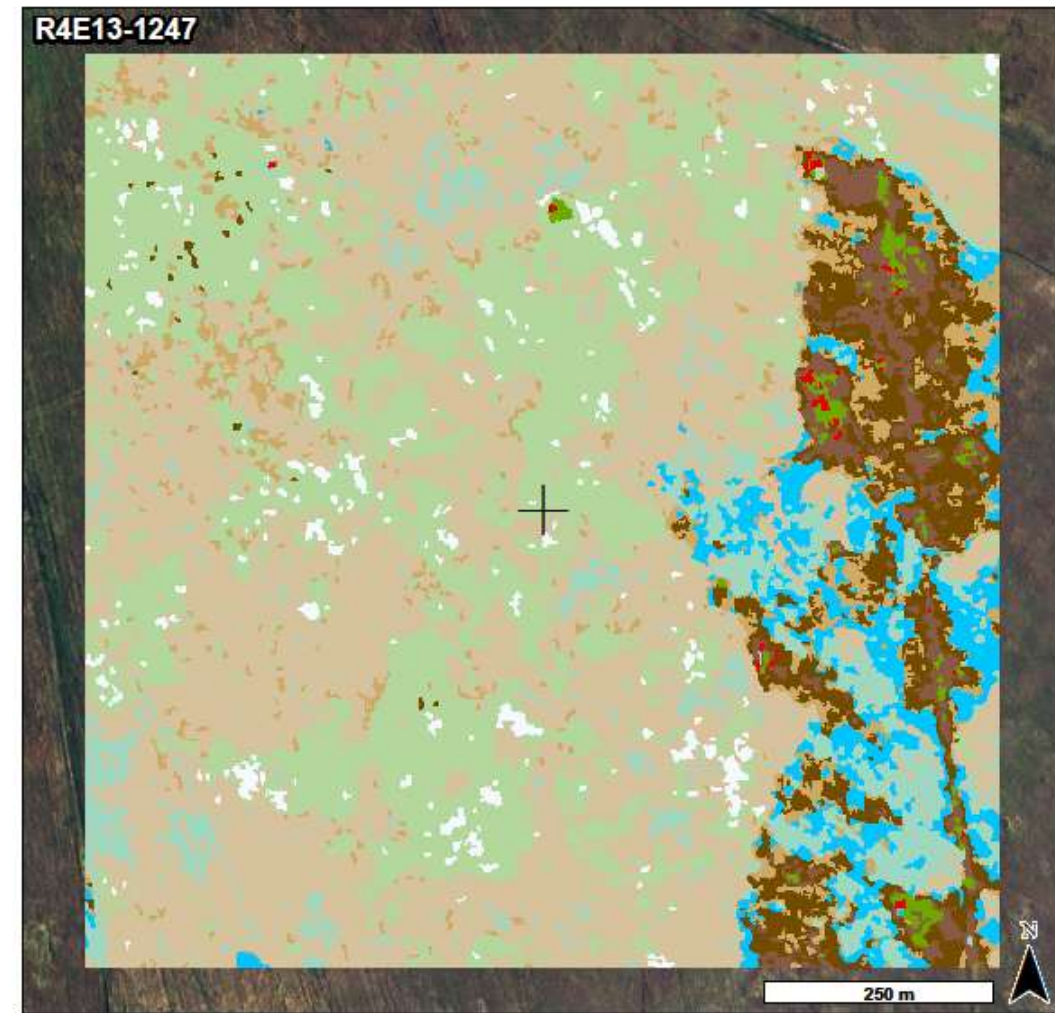
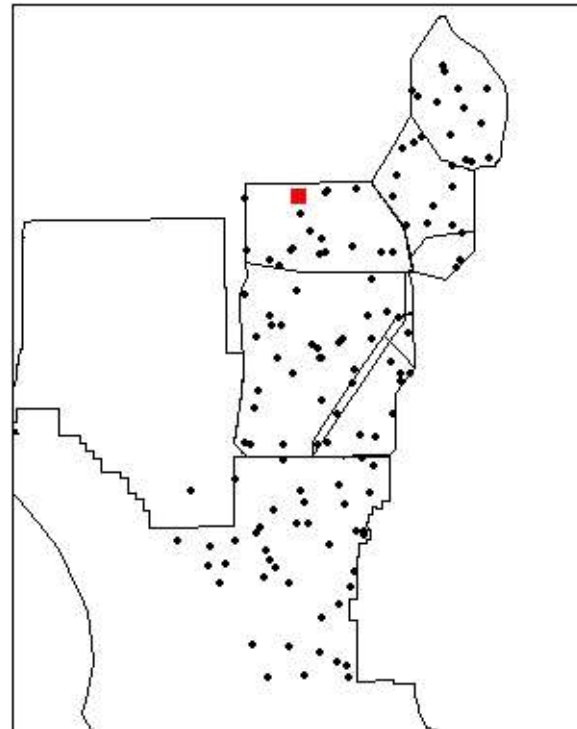
value	count	name	site	version	prpArea	areaHa
1	1097	aS	R4E13-1260	108	0.00439	0.4388
2	2698	bIE	R4E13-1260	108	0.01079	1.0792
5	44857	bIFNy	R4E13-1260	108	0.17943	17.9428
7	15719	bIFNy_gM	R4E13-1260	108	0.06288	6.2876
9	48540	gM	R4E13-1260	108	0.19416	19.416
13	6510	gM_bIE	R4E13-1260	108	0.02604	2.604
17	61887	gMCI	R4E13-1260	108	0.24755	24.7548
23	10711	gMCI_s	R4E13-1260	108	0.04284	4.2844
18	35916	gMCI-D	R4E13-1260	108	0.14366	14.3664
19	6990	gMCI-Sp	R4E13-1260	108	0.02796	2.796
28	3253	gMsg	R4E13-1260	108	0.01301	1.3012
29	558	gMTy	R4E13-1260	108	0.00223	0.2232
38	10531	peF	R4E13-1260	108	0.04212	4.2124
39	550	s	R4E13-1260	108	0.0022	0.22
42	183	sSa	R4E13-1260	108	0.00073	0.0732





# Water Conservation Area 3A, north

value	count	name	site	version	prpArea	areaHa
9	18249	gM	R4E13-1247	114	0.073	7.2996
13	11147	gM_bIE	R4E13-1247	114	0.04459	4.4588
17	13990	gMCl	R4E13-1247	114	0.05596	5.596
22	69034	gMCl_h	R4E13-1247	114	0.27614	27.6136
23	7128	gMCl_s	R4E13-1247	114	0.02851	2.8512
18	15028	gMCl-D	R4E13-1247	114	0.06011	6.0112
19	108189	gMCl-Sp	R4E13-1247	114	0.43276	43.2756
29	372	gMTy	R4E13-1247	114	0.00149	0.1488
38	5193	peF	R4E13-1247	114	0.02077	2.0772
39	1670	s	R4E13-1247	114	0.00668	0.668



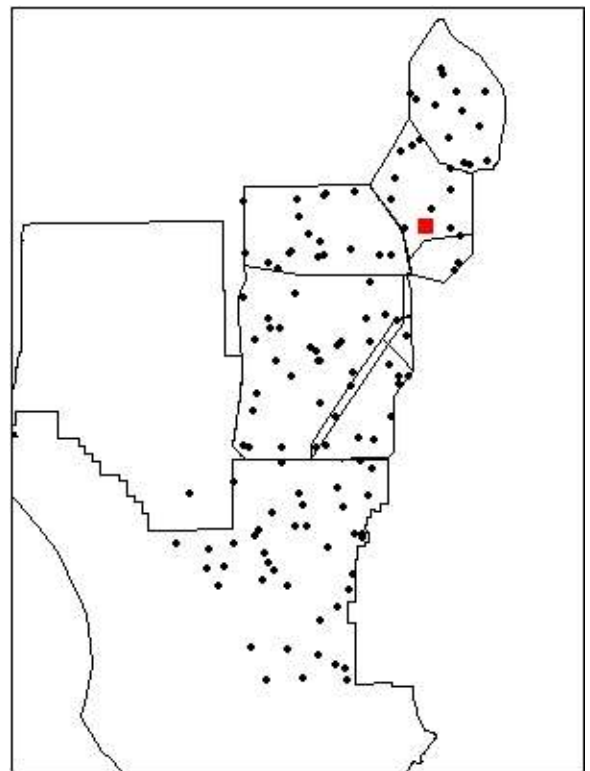
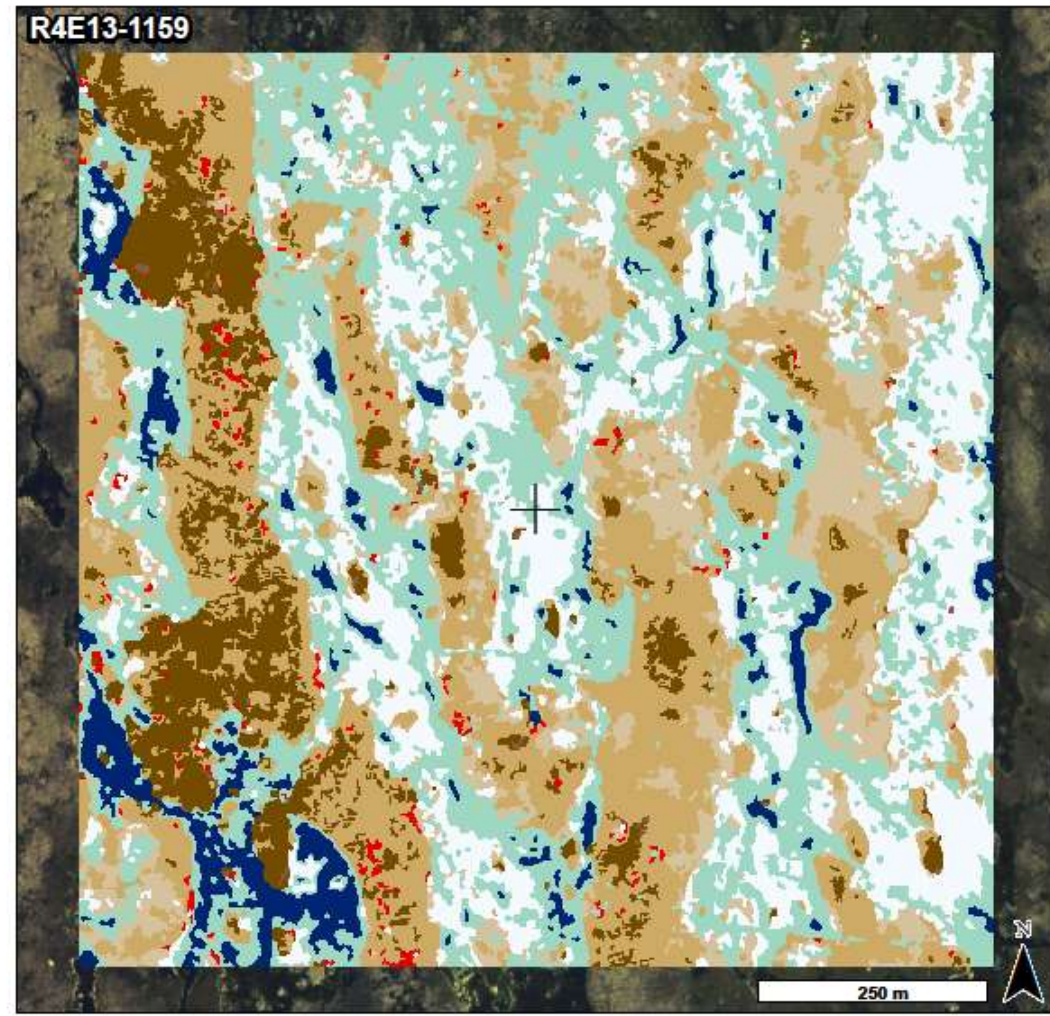
## Vegetation Type





# Water Conservation Area 2A

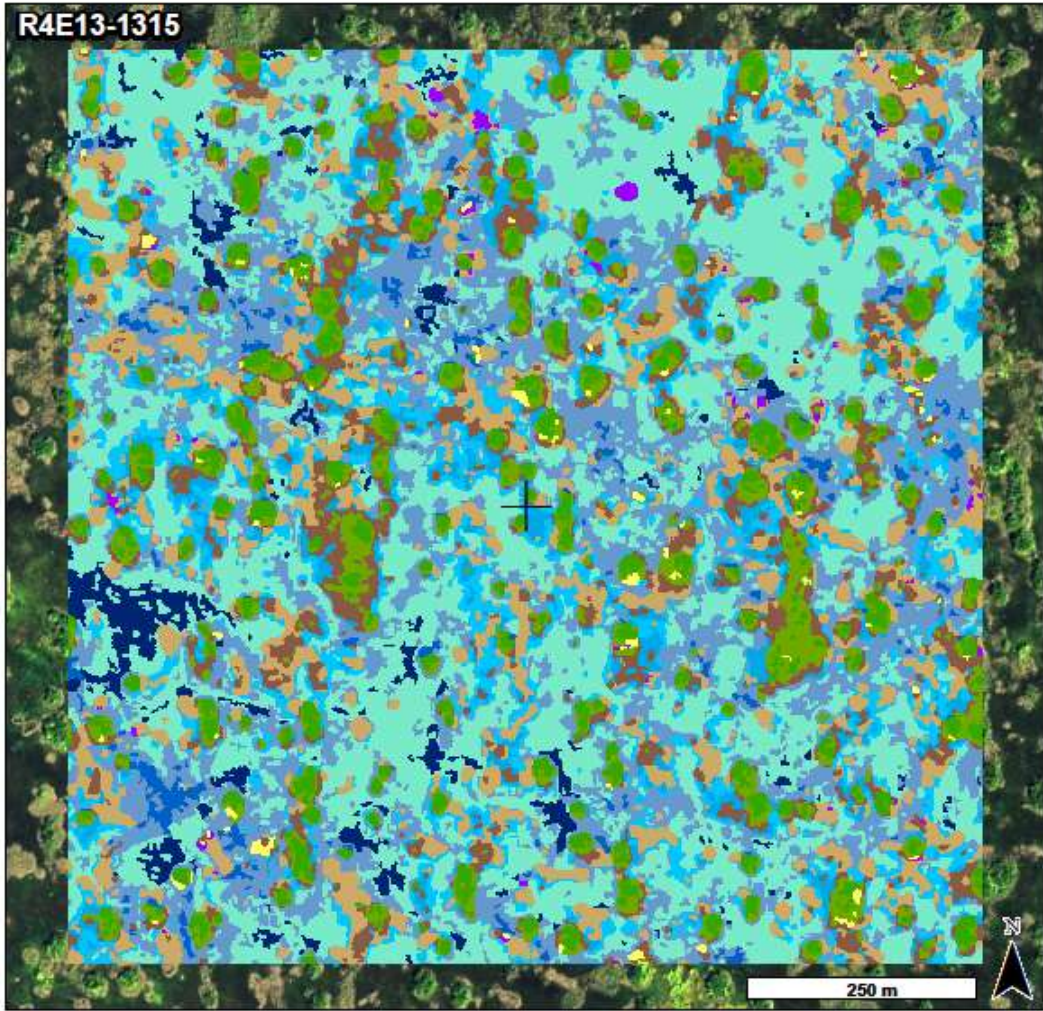
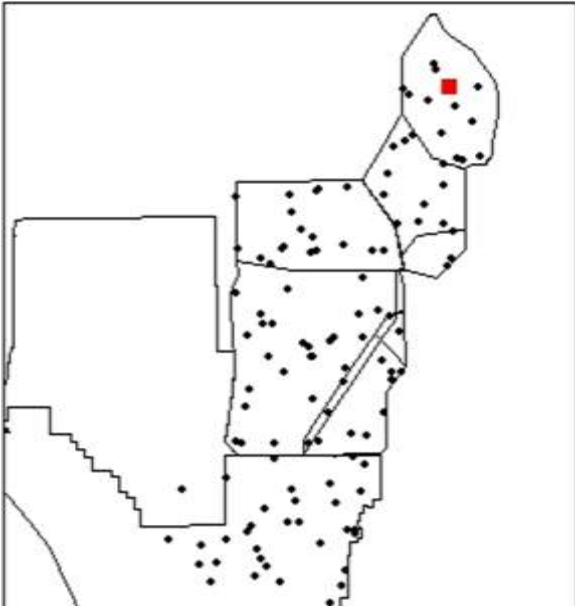
value	count	name	site	version	prpArea	areaHa
1	10810	aS	R4E13-1159	105	0.04324	4.324
9	69316	gM	R4E13-1159	105	0.27726	27.7264
17	63505	gMCl	R4E13-1159	105	0.25402	25.402
23	513	gMCl_s	R4E13-1159	105	0.00205	0.2052
18	21334	gMCl-D	R4E13-1159	105	0.08534	8.5336
19	33192	gMCl-Sp	R4E13-1159	105 <td 0.13277	13.2768	
29	1930	gMTy	R4E13-1159	105	0.00772	0.772
38	49400	peF	R4E13-1159	105	0.1976	19.76





# Loxahatchee National Wildlife Refuge

value	count	name	site	version	prpArea	areaHa
1	6632	aS	R4E13-1315	109	0.02653	2.6528
5	3292	bIFNy	R4E13-1315	109	0.01317	1.3168
7	51748	bIFNy_gM	R4E13-1315	109	0.20699	20.6992
13	21219	gM_bIE	R4E13-1315	109	0.08488	8.4876
14	10914	gM_bIE_s	R4E13-1315	109	0.04366	4.3656
17	32074	gMCl	R4E13-1315	109	0.1283	12.8296
23	19276	gMCl_s	R4E13-1315	109	0.0771	7.7104
11	76437	gM-Sp	R4E13-1315	109	0.30575	30.5748
39	13606	s	R4E13-1315	109	0.05442	5.4424
43	12990	t	R4E13-1315	109	0.05196	5.196
44	780	tMe	R4E13-1315	109	0.00312	0.312
47	1032	vLy	R4E13-1315	109	0.00413	0.4128

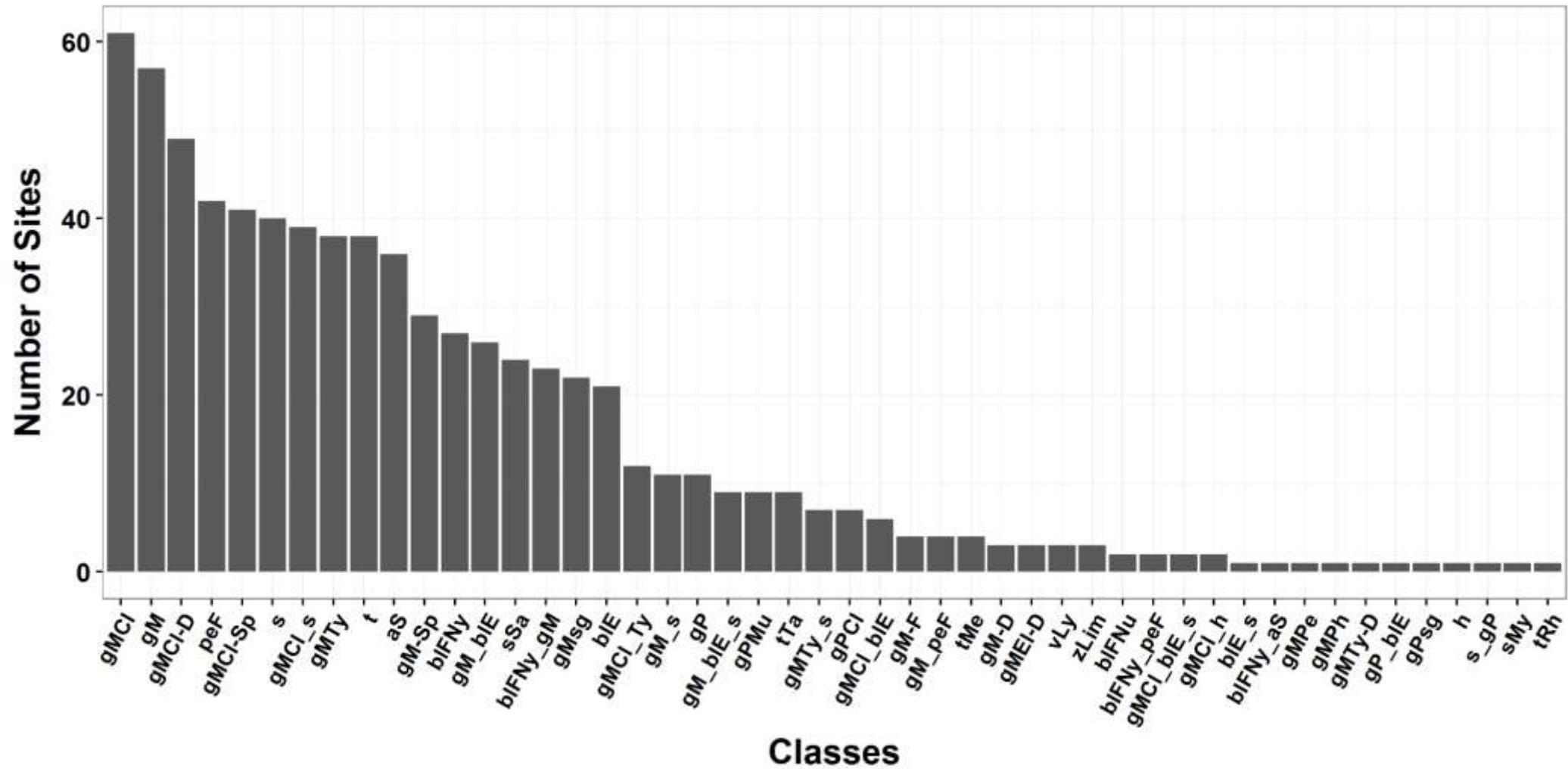


### Vegetation Type

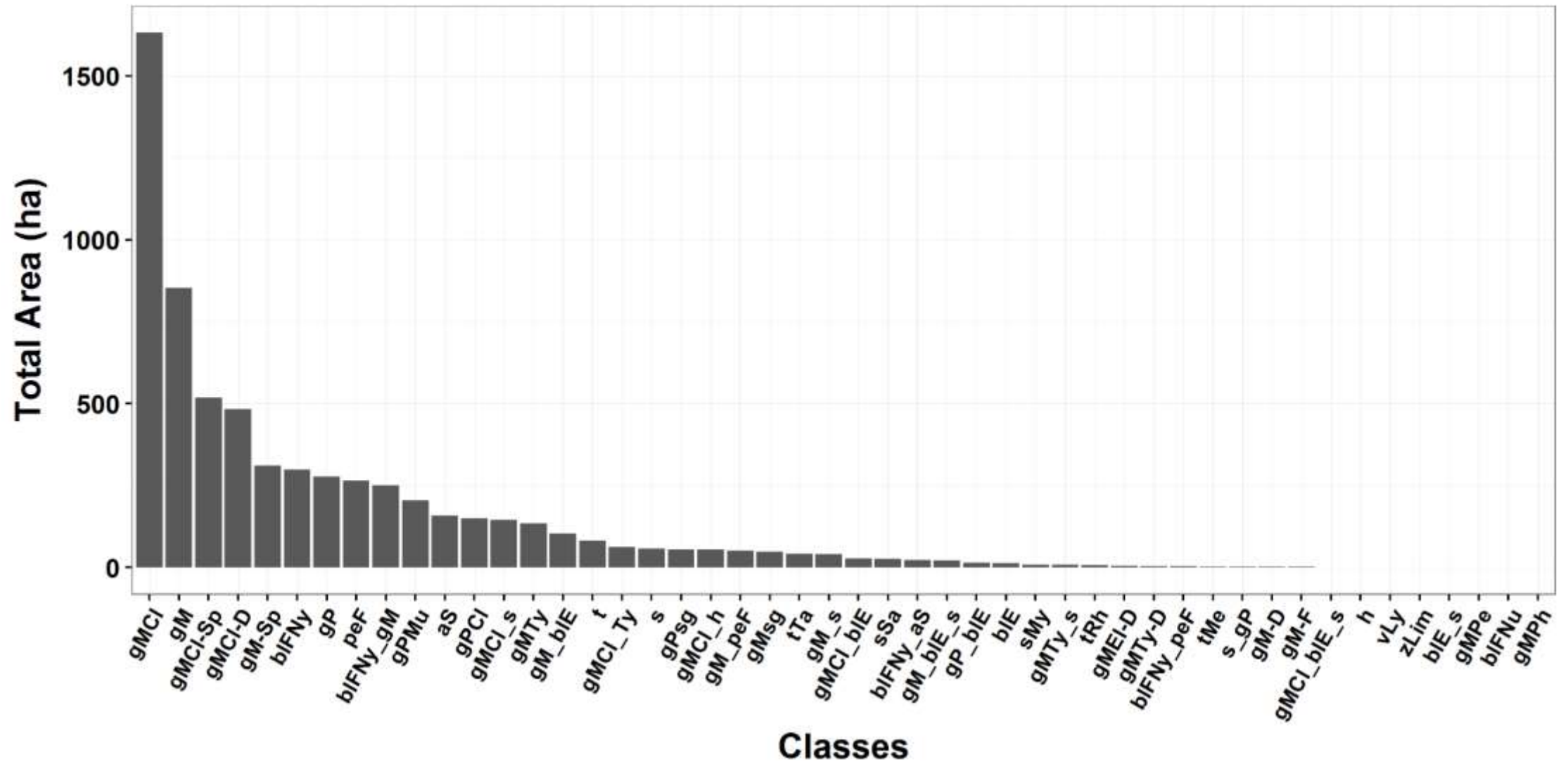
- Aqua.Sbmr.
- Grm.Mrsh\_Brdlv.Emrg.
- Shrb.
- Brdlv.Fit.Nymp.
- Grm.Mrsh\_Brdlv.Emrg\_Shrb.
- Tree
- Brdlv.Fit.Nymp\_Grm.Mrsh.
- Grm.Mrsh.Clad.
- Tr.Mela.
- Grm.Mrsh-Sprs.
- Grm.Mrsh.Clad\_Shrb.
- Vn.Lygo.



# Vegetation class frequency across 65 1-km<sup>2</sup> sites



# Vegetation class abundances across 65 1-km<sup>2</sup> sites

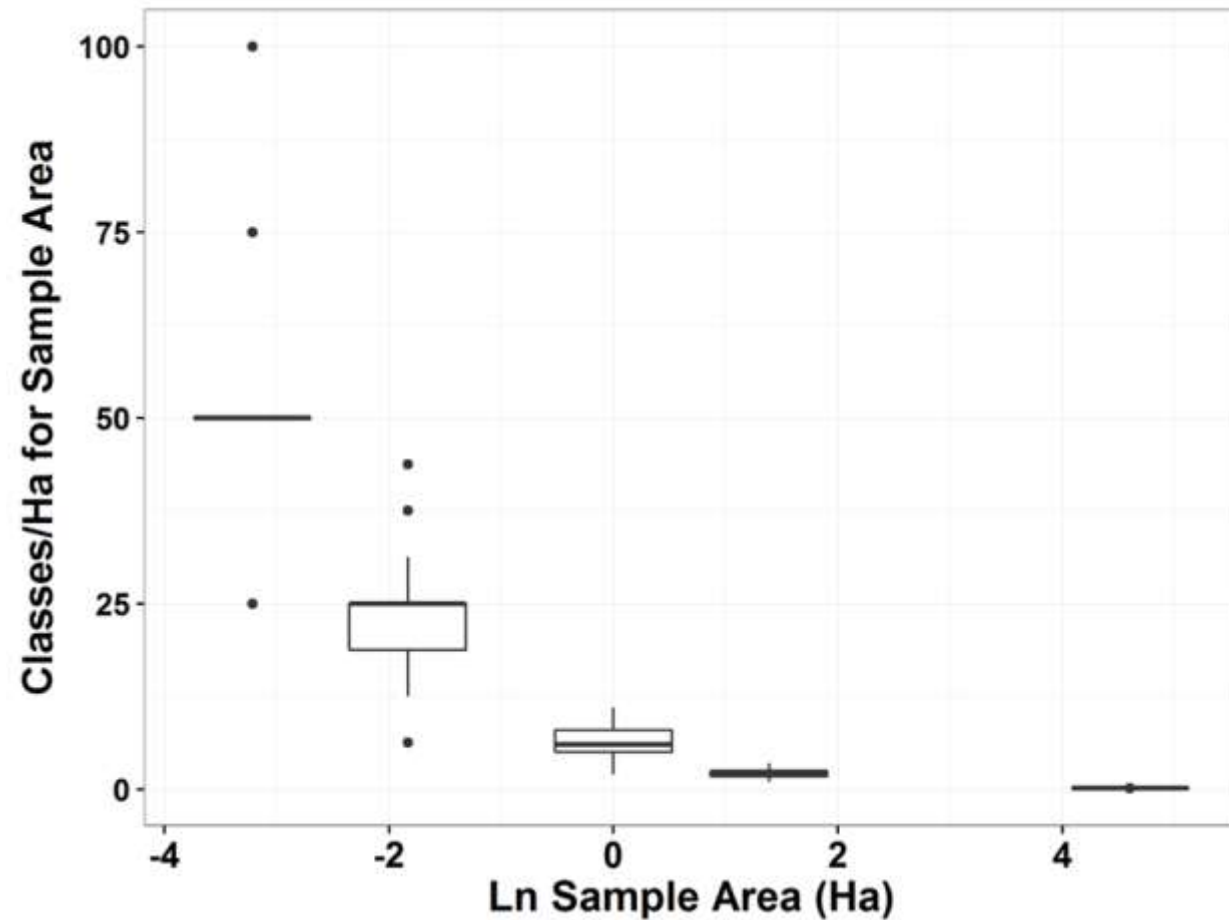
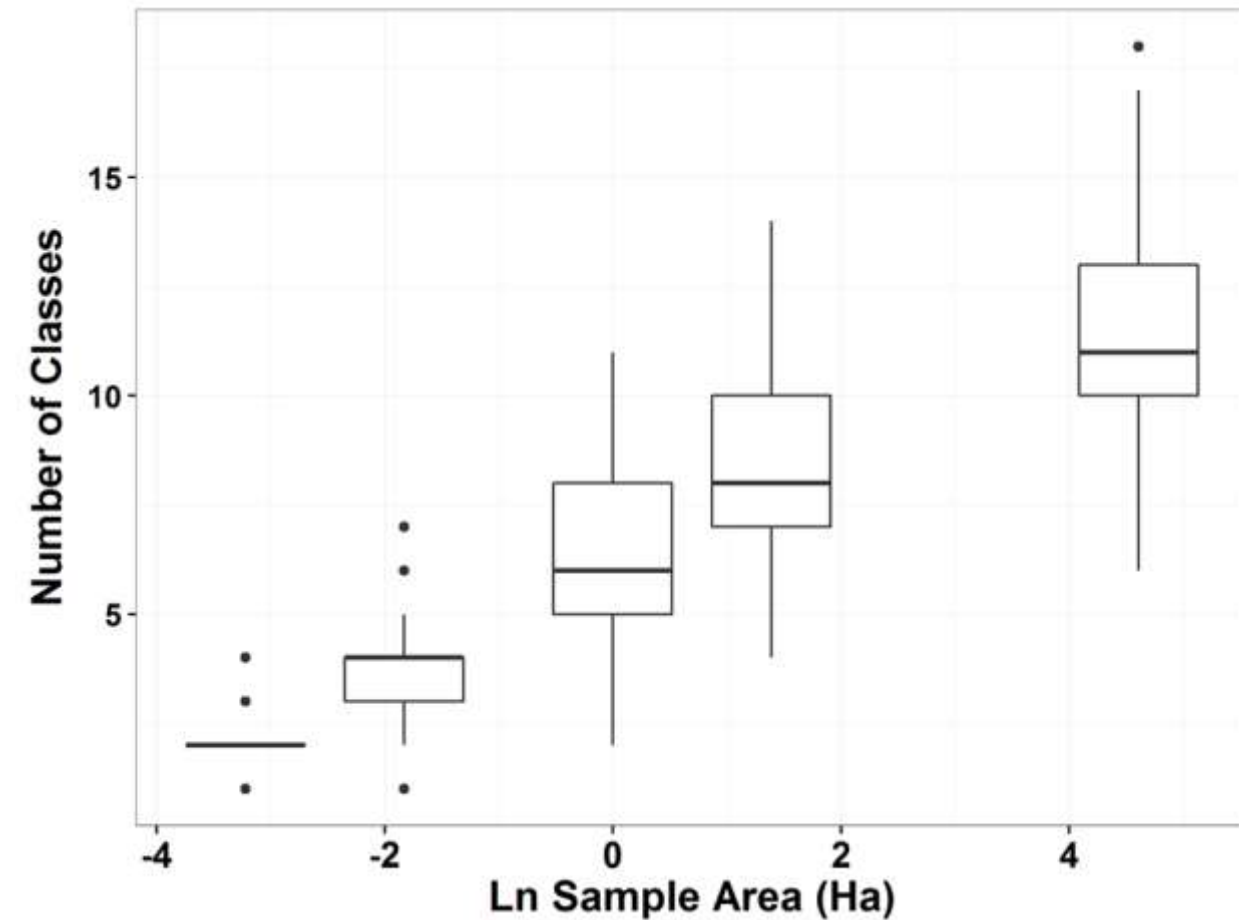




# Sawgrass classes as a percent of total (pure and mixed classes)

classAbb	Class	area (ha)	area (%)
gMCl	sawgrass marsh	1633.2240	25.26
gMCl-D	dense sawgrass marsh	484.3612	7.49
gMCl-Sp	sparse sawgrass marsh	518.5200	8.02
gMCl_blE	sawgrass-broadleaved emergent mix	28.5684	0.44
gMCl_blE_s	sawgrass-broadleaved emergent-shrub mix	2.4104	0.04
gMCl_h	sawgrass-herbaceous plants mix	56.2208	0.87
gMCl_s	sawgrass-shrub mix	146.0452	2.26
gMCl_Ty	sawgrass-cattail mix	64.4960	1.00
gPCl	sawgrass marl prairie	151.2512	2.34
		<b>Total:</b>	<b>47.72</b>

# Number of classes as a function of area mapped around each site



samples = 20x20m (400 m<sup>2</sup>, 0.04 ha), 40x40m (1600 m<sup>2</sup>, 0.16 ha), 100x100m (10,000 m<sup>2</sup>, 1.00 ha), 200x200m (40,000m<sup>2</sup>, 4 ha) and 1000x1000m (1 km<sup>2</sup>, 100 ha).



# Literature-derived estimates for sawgrass biomass by sawgrass class\*

(pure sawgrass classes only)

Class	Aboveground Live Biomass (g/m <sup>2</sup> )	Ratio of Live to Dead Aboveground Biomass	Ratio of Aboveground Live to Belowground Biomass	Estimated Total Biomass (g/m <sup>2</sup> )
gMCI-D	2000	1	0.5	5000
gMCI	500	2	1	1250
gMCI-Sp	150	3	0.25	237.5
gPCI	250	2.5	0.4	450

\* Twenty-four sources including published literature, reports, databases, and unpublished data covering different parts of the whole plant

# Estimates of average sawgrass cover and biomass per site (for the pure sawgrass classes combined)

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	<b>mean</b>	<b>SD</b>	<b>min</b>	<b>max</b>
<b>Total area per site (ha)</b>	42.82	22.14	0.71	90.43
<b>Total biomass per site (kg)</b>	715,017	510,504	12,426	1,954,096
<b>Total live aboveground biomass per site (kg)</b>	292,004	203,235	7,848	786,608

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# Estimates of average sawgrass cover and biomass per site by region (for the pure sawgrass classes combined)

	ENP		WCA3		WCA2		LNWR		<i>p</i>
	mean	SD	mean	SD	mean	SD	mean	SD	
<b>Total area (ha)</b>	41.23 <sup>ab</sup>	21.29	45.92 <sup>a</sup>	21.58	54.01 <sup>a</sup>	24.55	20.9 <sup>b</sup>	11.46	0.0351
<b>Total biomass (kg)</b>	570,516 <sup>ab</sup>	474,827	867,538 <sup>ab</sup>	503,689	939,684 <sup>a</sup>	549,195	269,640 <sup>b</sup>	146,618	0.0126
<b>Tot. live abg. biomass (kg)</b>	236,934 <sup>ab</sup>	188,649	352,031 <sup>a</sup>	200,009	382,106 <sup>a</sup>	219,360	107,856 <sup>b</sup>	58,647	0.0115