Quantifying the Impact of 20-Year Flood Frequency on Land Cover Change Type

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Association of State Floodplain Managers

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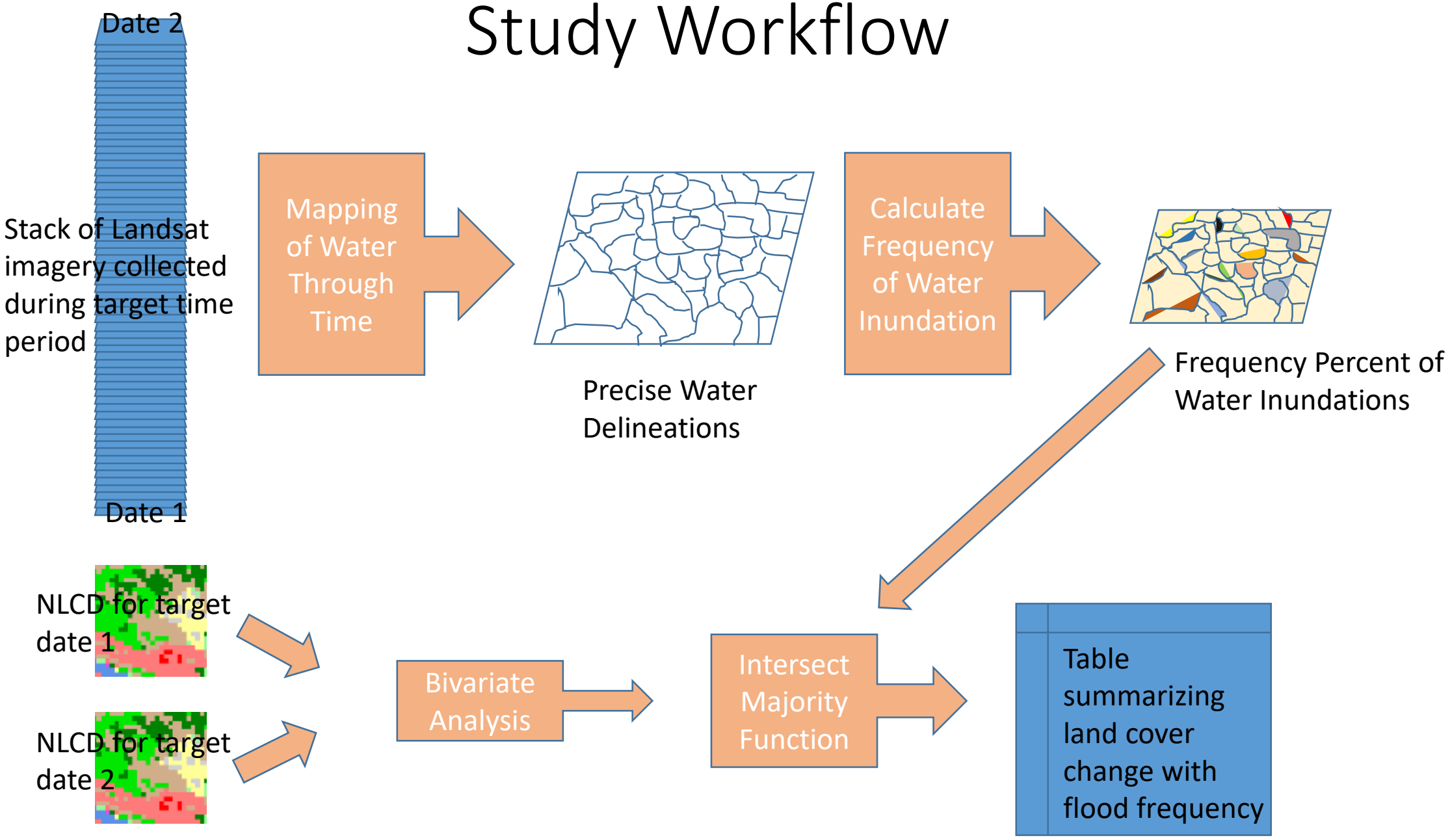
Study Objectives

- Objective:
  - Utilize advances in satellite remote sensing and geospatial science to quantify the effect of frequent flooding on land cover
- This study asks:
  - Is there a relationship between flood frequency and land cover change?
  - What is the impact of frequent flooding on land cover/land use?
- Why are these questions important?
  - To help understand the impact of frequent flooding on the landscape
  - To logically predict what will happen to the landscape and how land is used in areas that flood multiple times
  - As climate change causes changes in weather patterns, flooding will occur in different frequencies and in new areas, so it is useful to understand how land cover will change over time as a response
  - To provide empirical (quantifiable) data that can be used to inform community mitigation and planning efforts and improve our understanding of flood risk, flood prone areas, and as aid for prioritizing flood studies.

Study Design

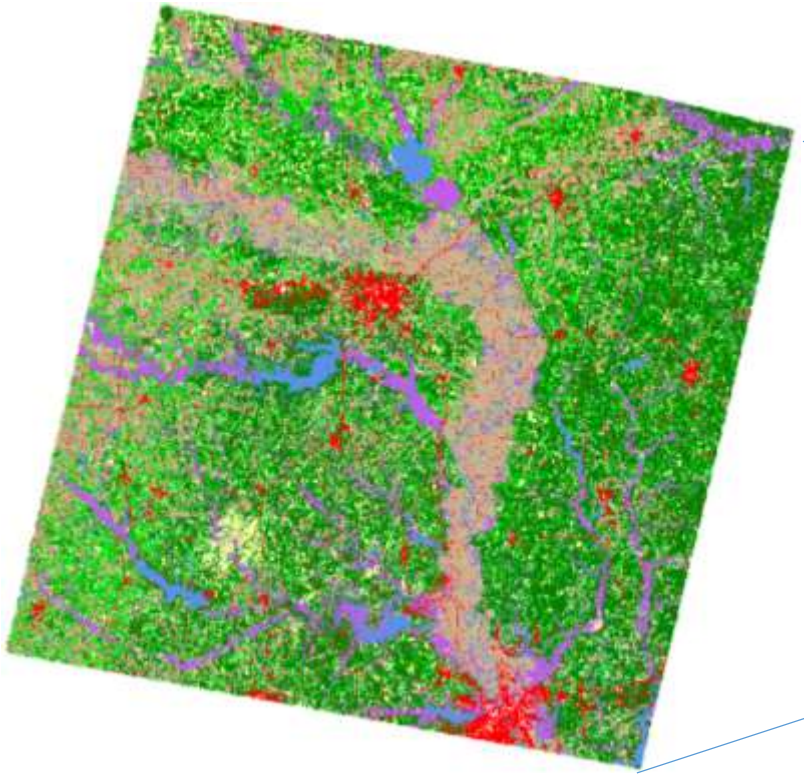
- Collected over 300 Landsat images over the same footprint between the years of 1984 and 2011
- Collected NLCD land cover for 4 years: 1992, 2001, 2006, 2011
  - National Land Cover Dataset, US Government standard LC, accuracy generally 80-90% overall and per class per pixel
- Created 5 Bivariate Matrixes (from-to class change statistics) using NLCD for selected date pairs
  - 2011 – 1992
  - 2011 – 2001
  - 2011 – 2006
  - 2006 – 2001
  - 2001 – 1992
- Calculated flood frequency using satellite imagery for each of those date pairs, 5 sets
- For each time interval, intersected flood frequency data with bivariate change results using a zonal majority function
- Analyzed the resulting tabular datasets

Study Workflow



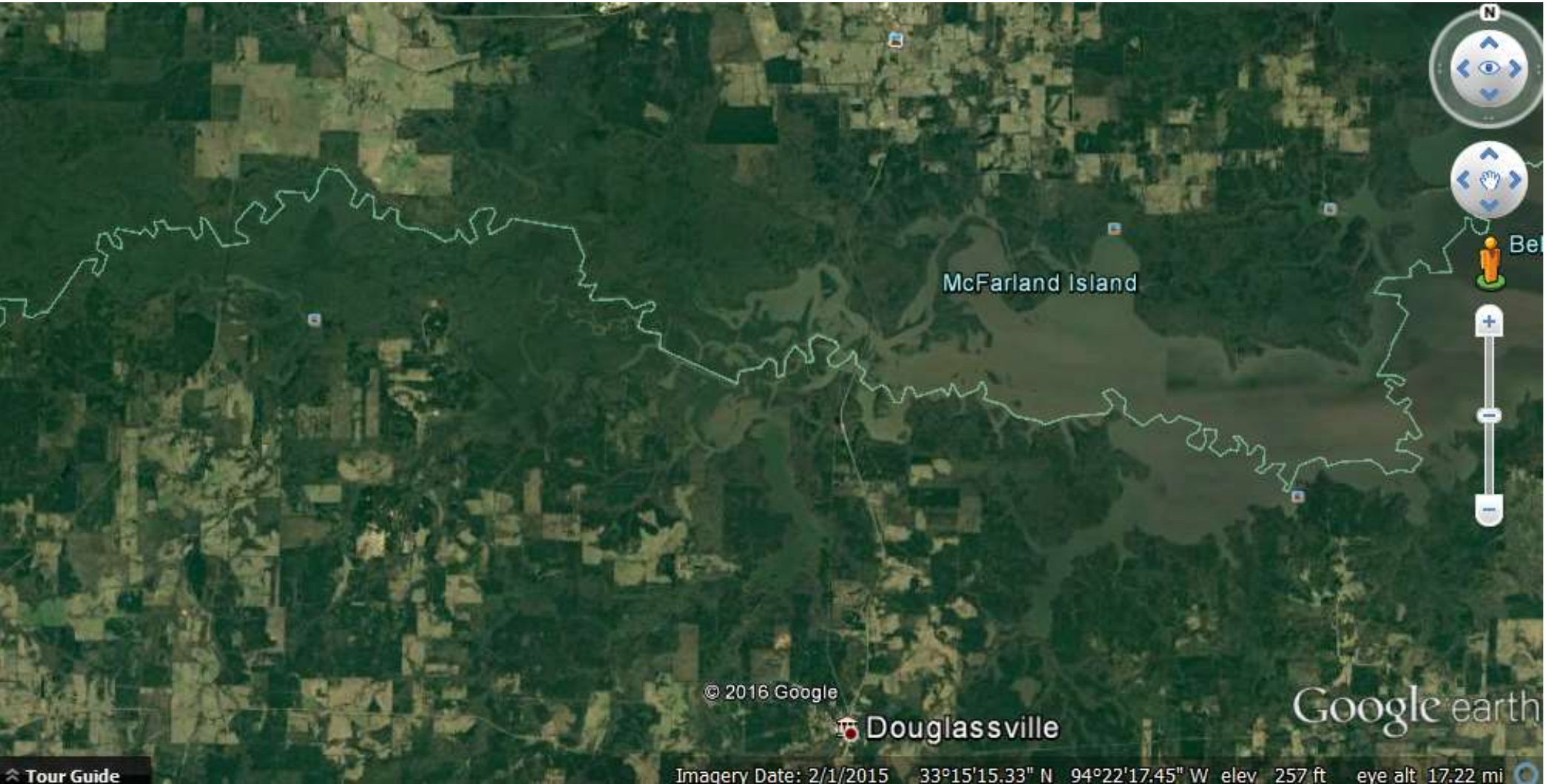
Study Area: Red River Near Shreveport LA

Area: ~2,600,000 Hectares

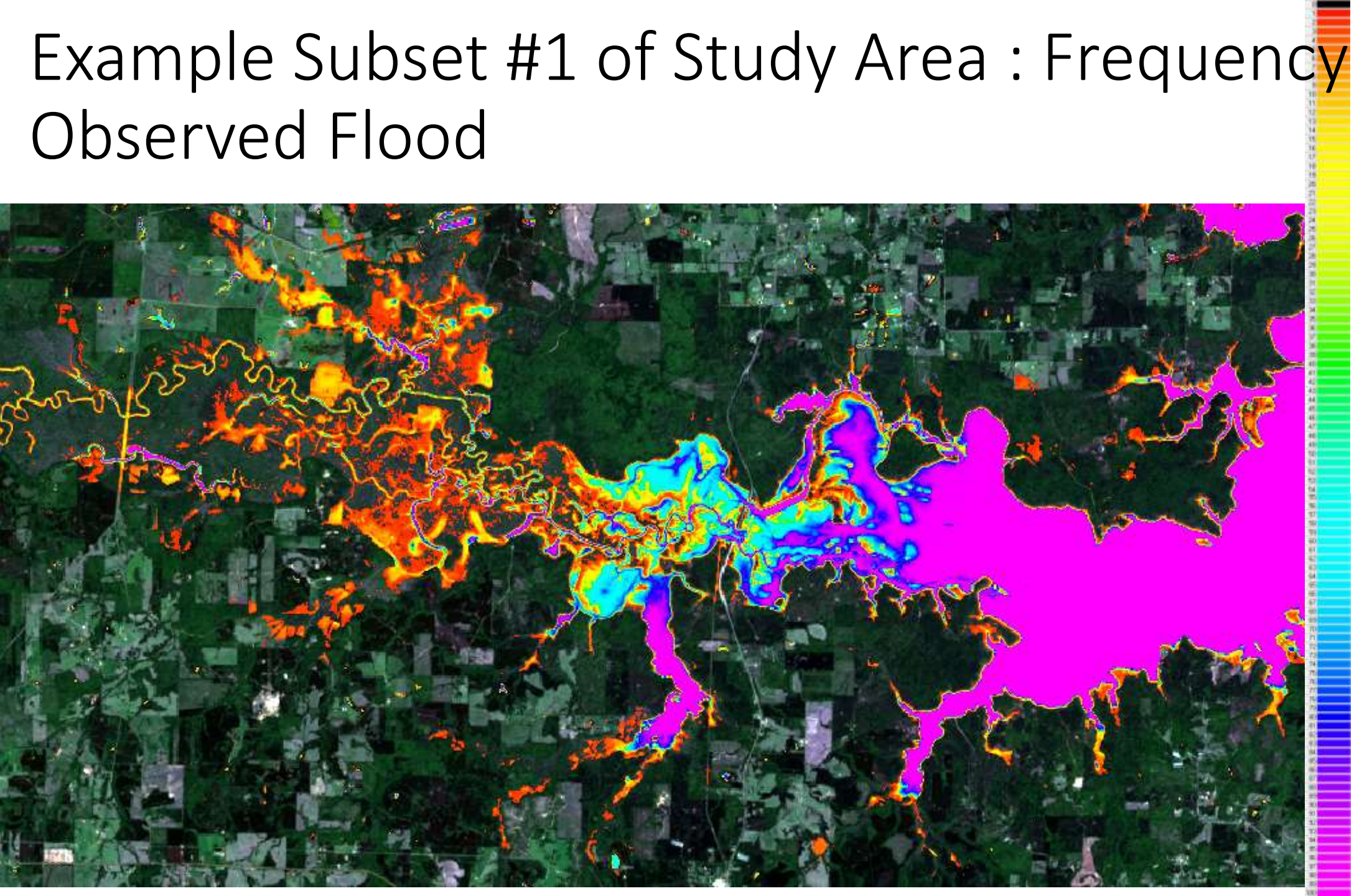


This area is known to have flooded on multiple occasions during the study period.

Example Subset #1 of Study Area : Google earth



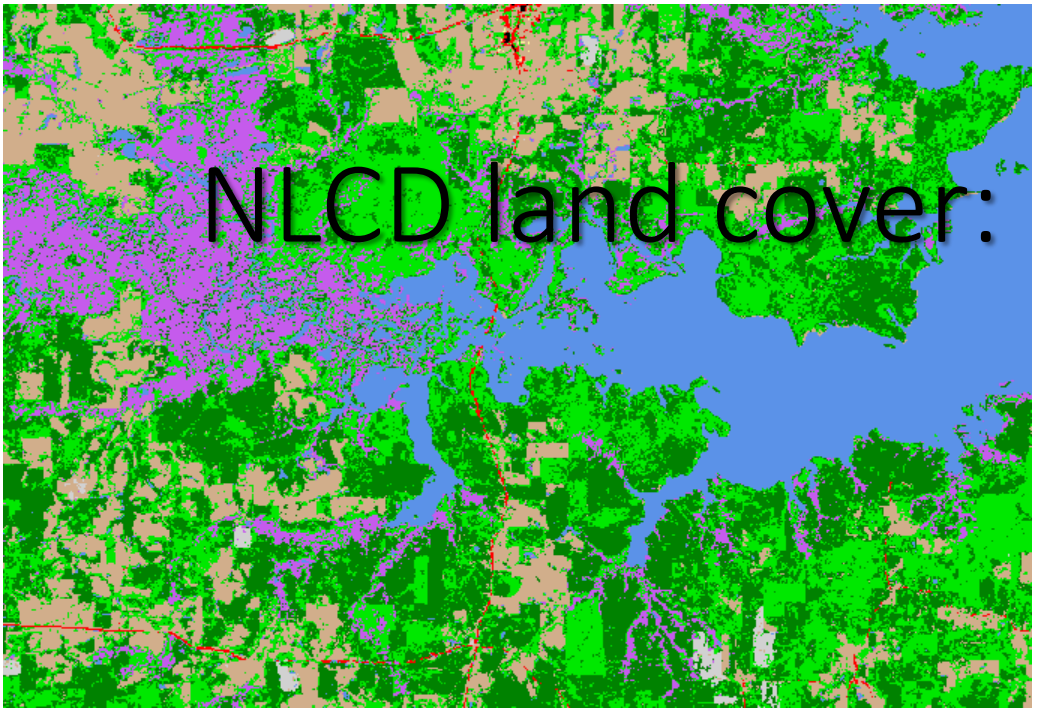
Example Subset #1 of Study Area : Frequency of Observed Flood



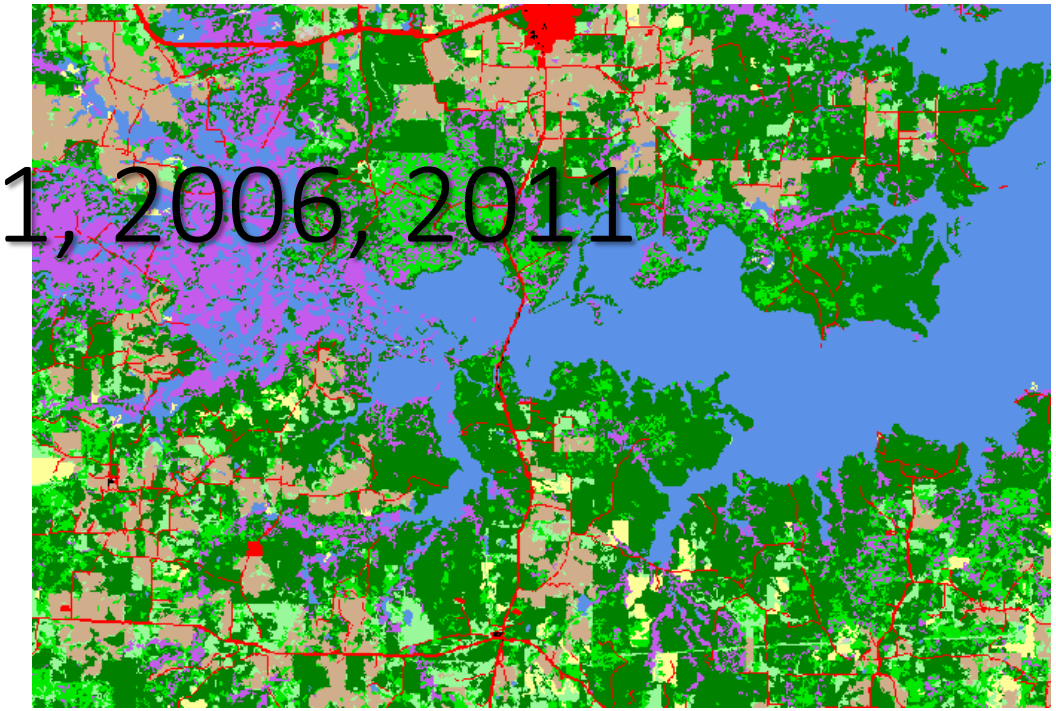
- Percent of the number of observations in which inundation occurred (0 – 100%)
- Inundations occurring > 50% considered “permanent”
- Inundations occurring > 1 time but <= 50 considered “intermittent” or flood water
- Based on a dataset of hundreds of images stacked together and analyzed using water detection algorithms
- Dates of imagery ranged from mid-1980’s to present
- No erection of any infrastructure should happen within a pixel that was flooded

NLCD land cover: 1992, 2001, 2006, 2011

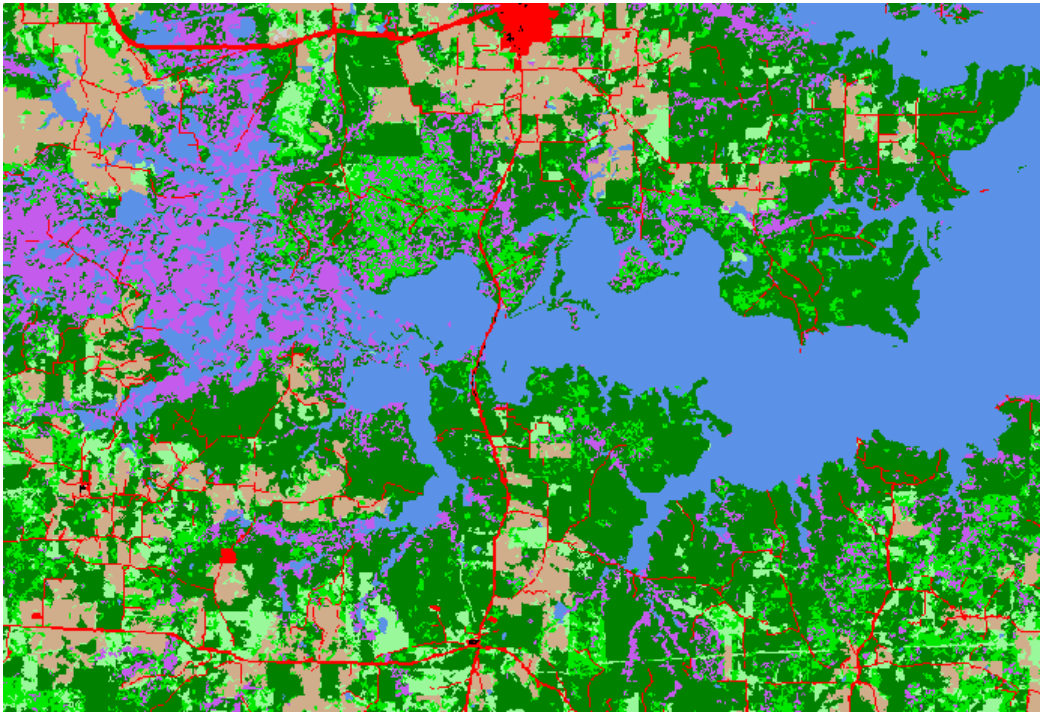
Subset #1



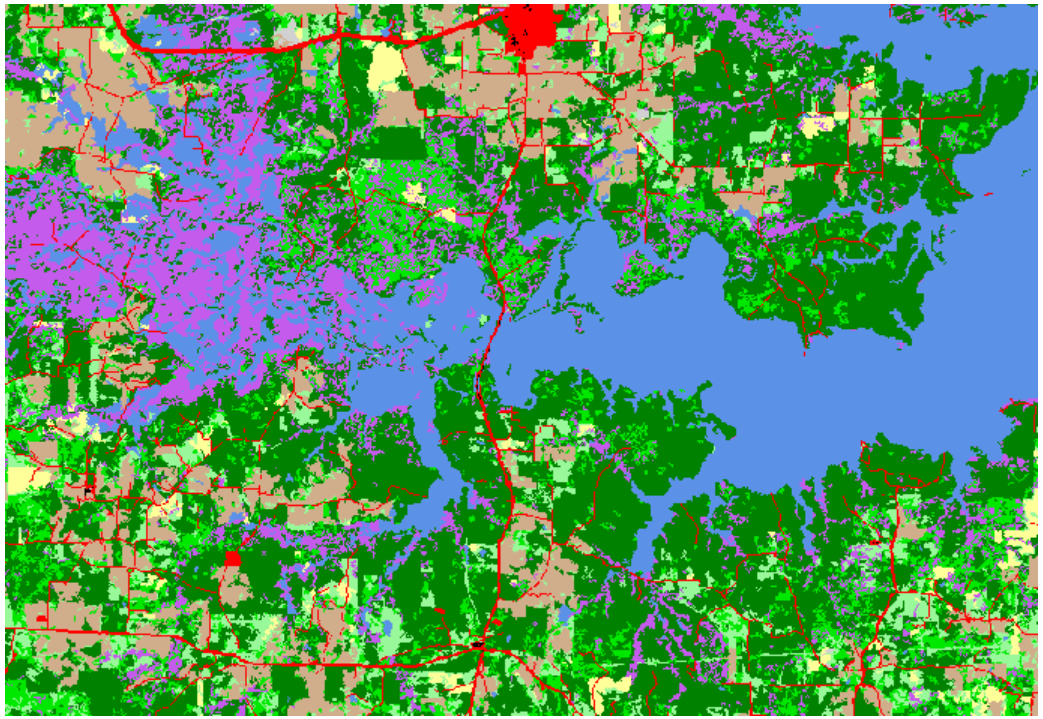
1992



2006



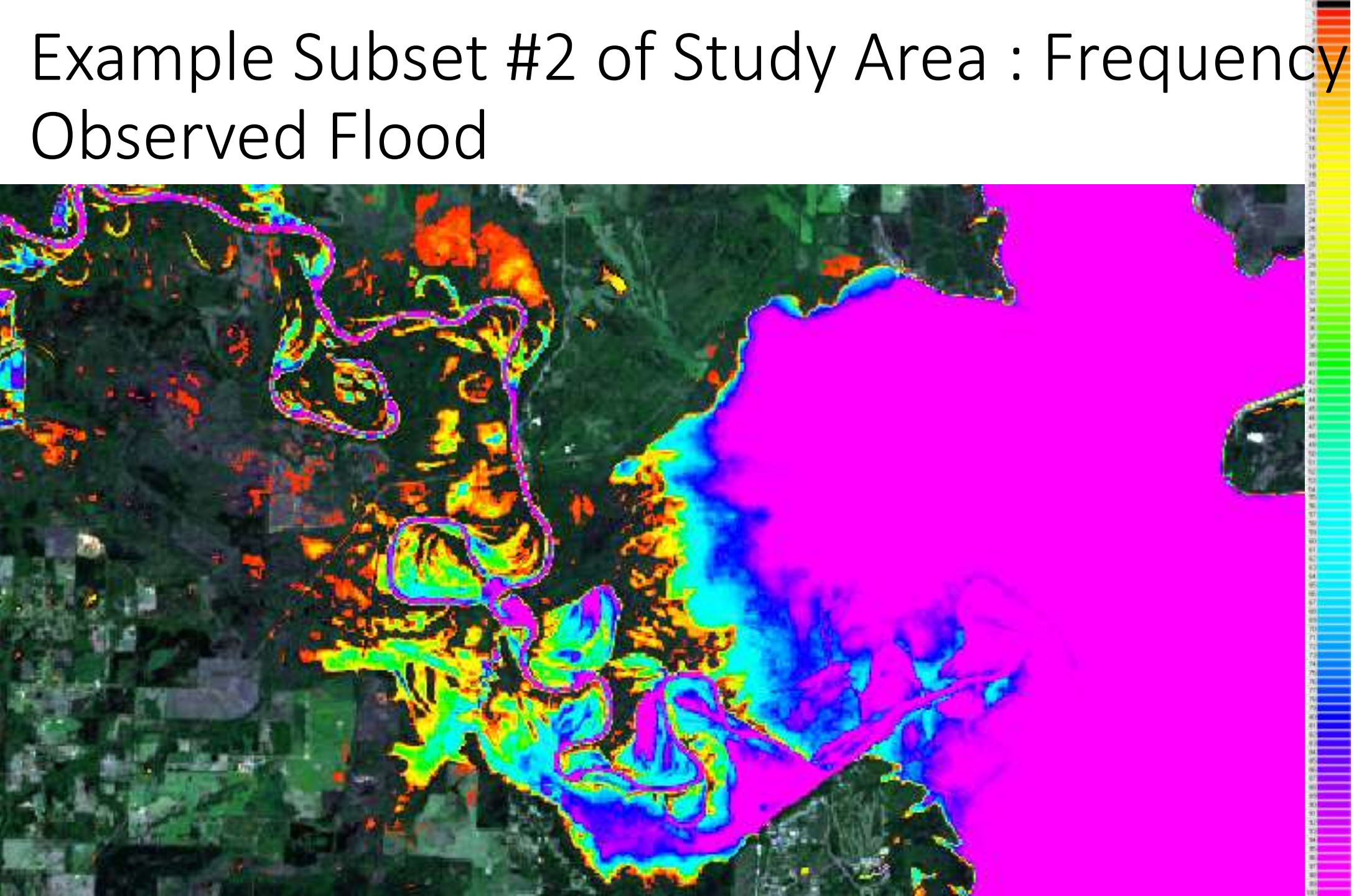
2001



2011

Example Subset #2 of Study Area : Google earth

Example Subset #2 of Study Area : Frequency of Observed Flood



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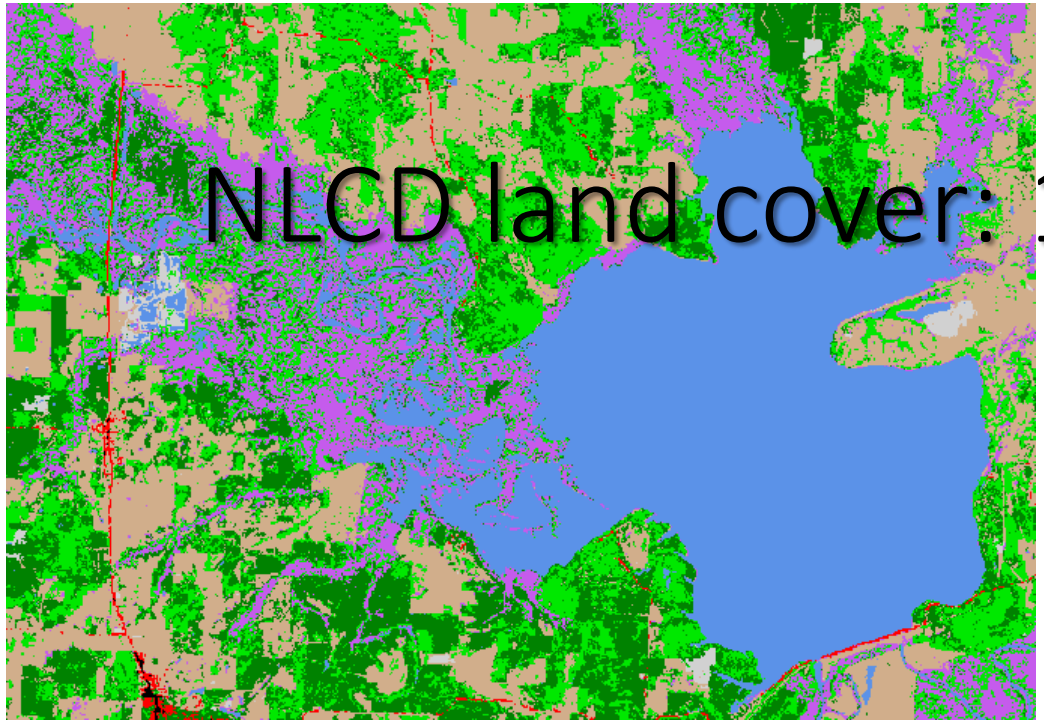
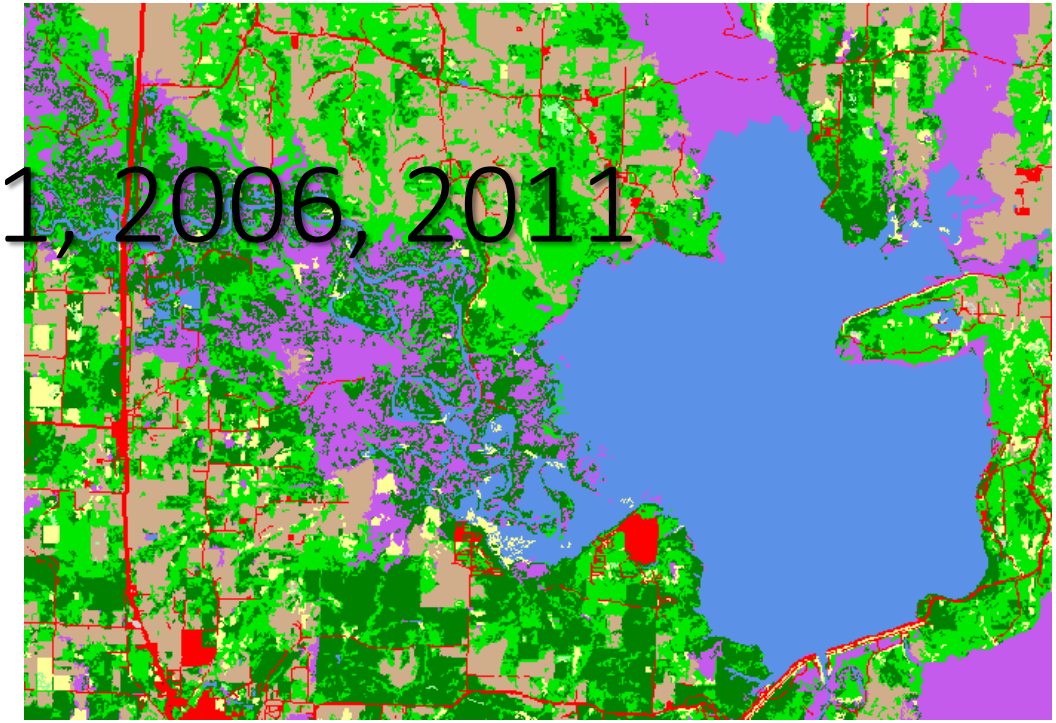
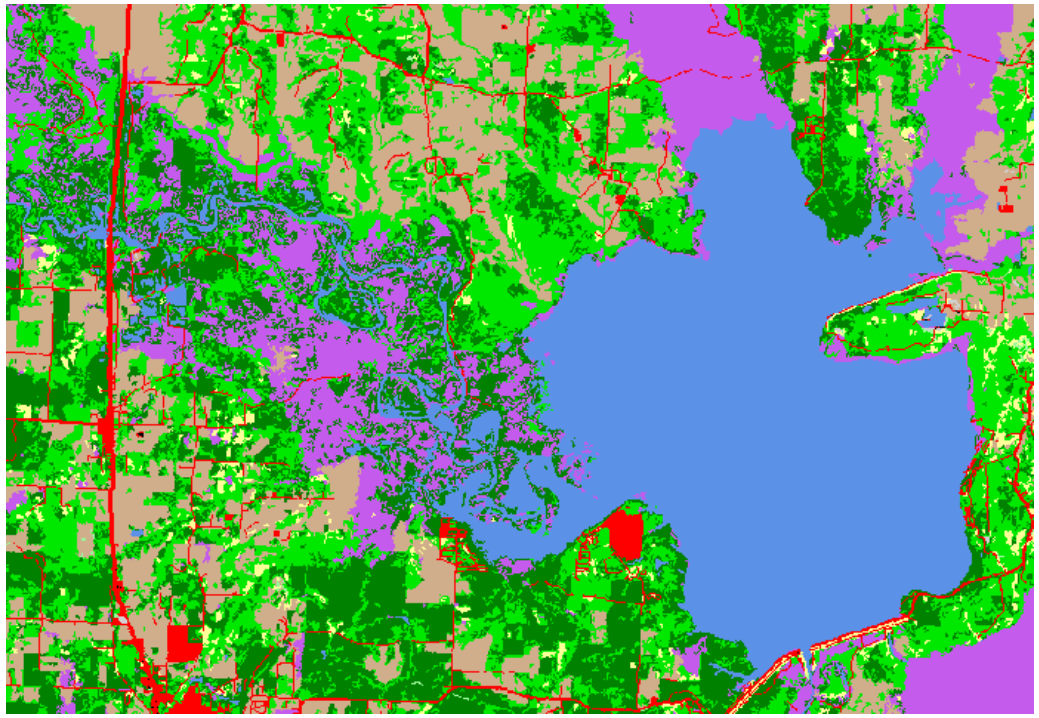


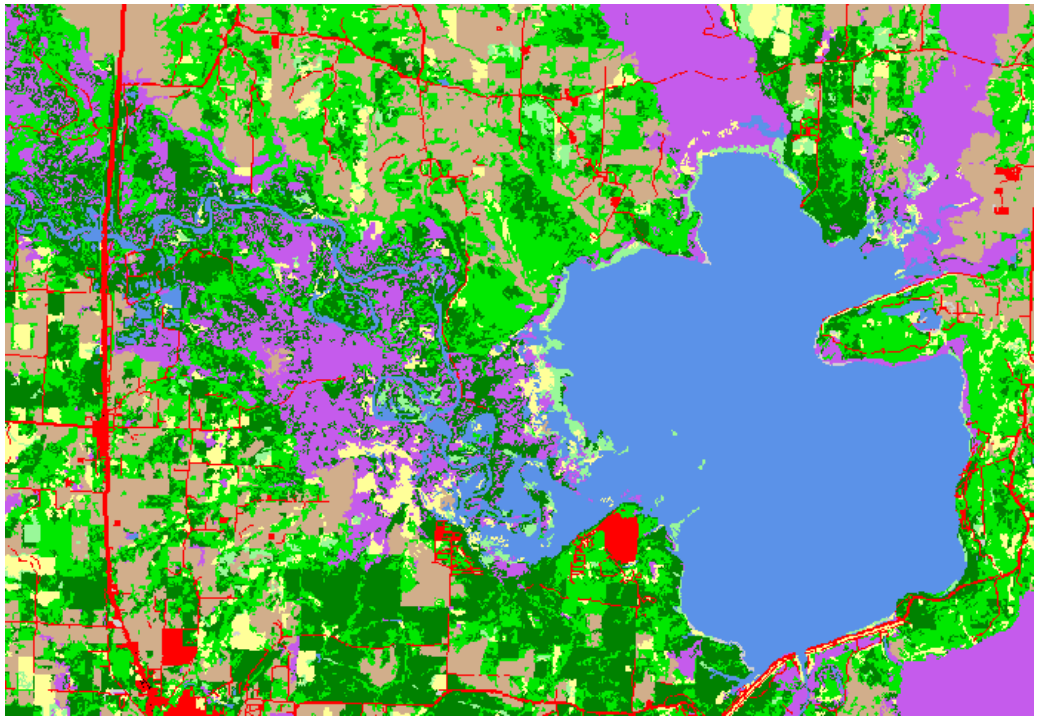
1992



2006

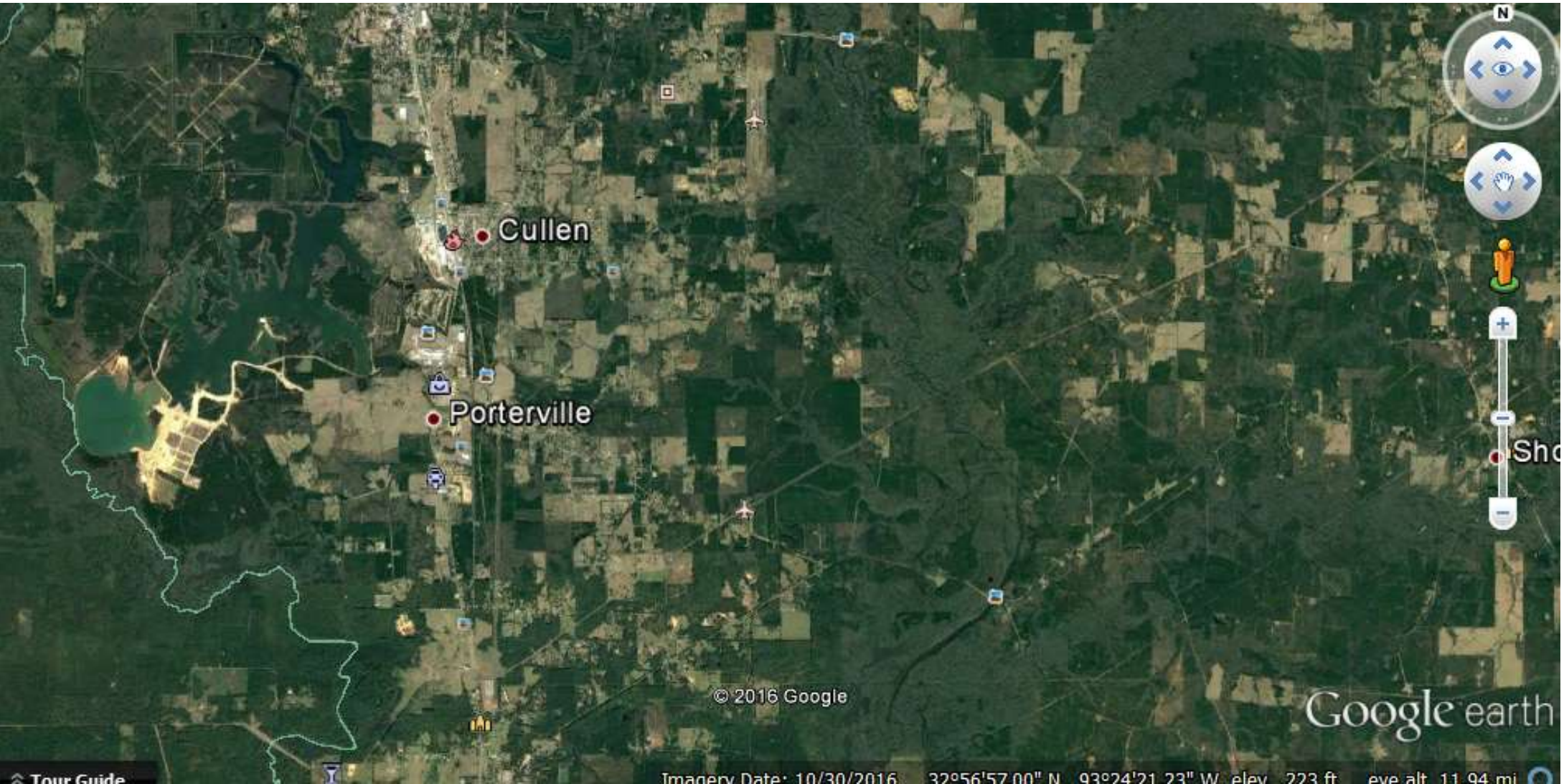


2001

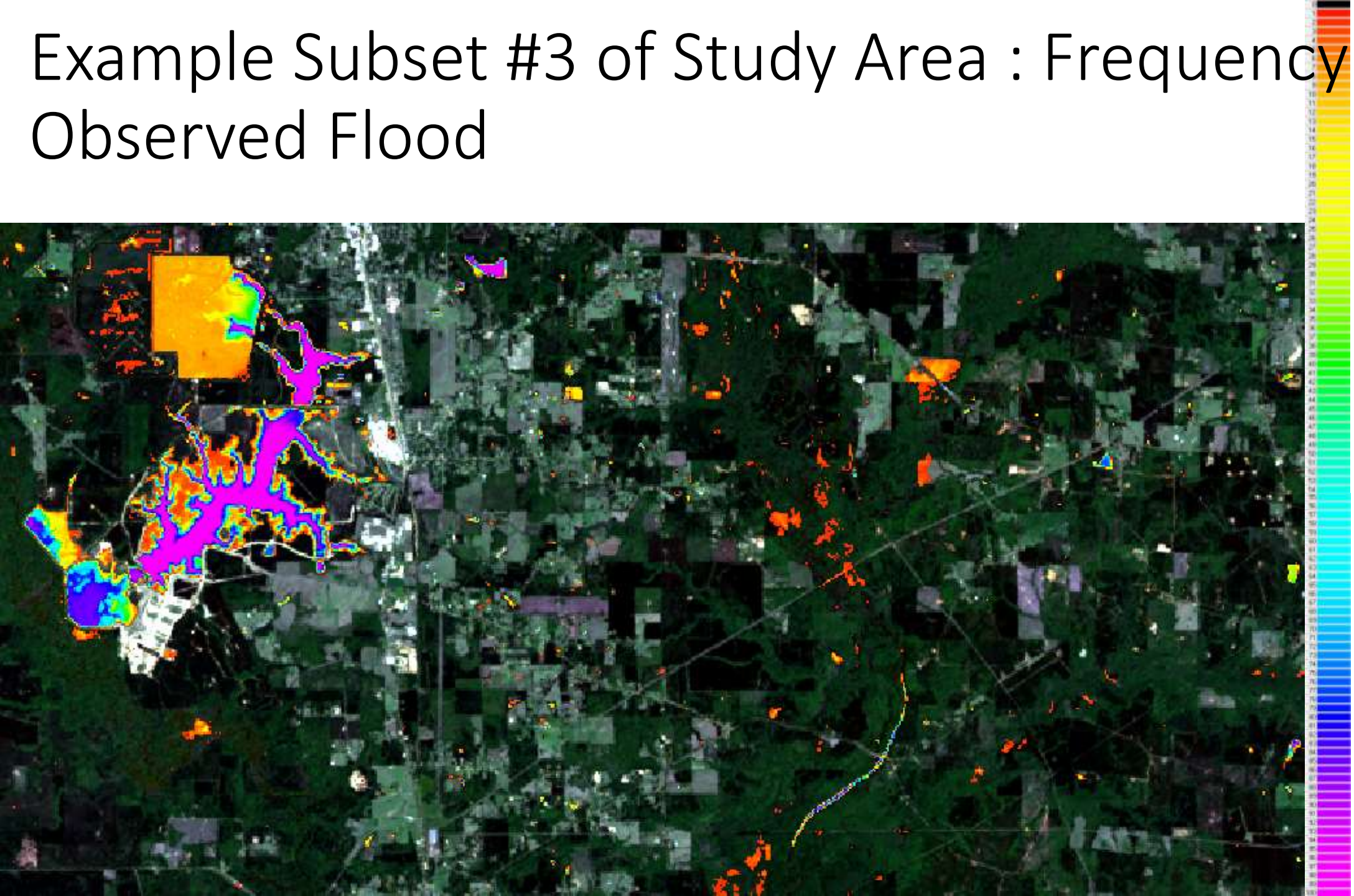


2011

Example Subset #3 of Study Area : Google earth



Example Subset #3 of Study Area : Frequency of Observed Flood



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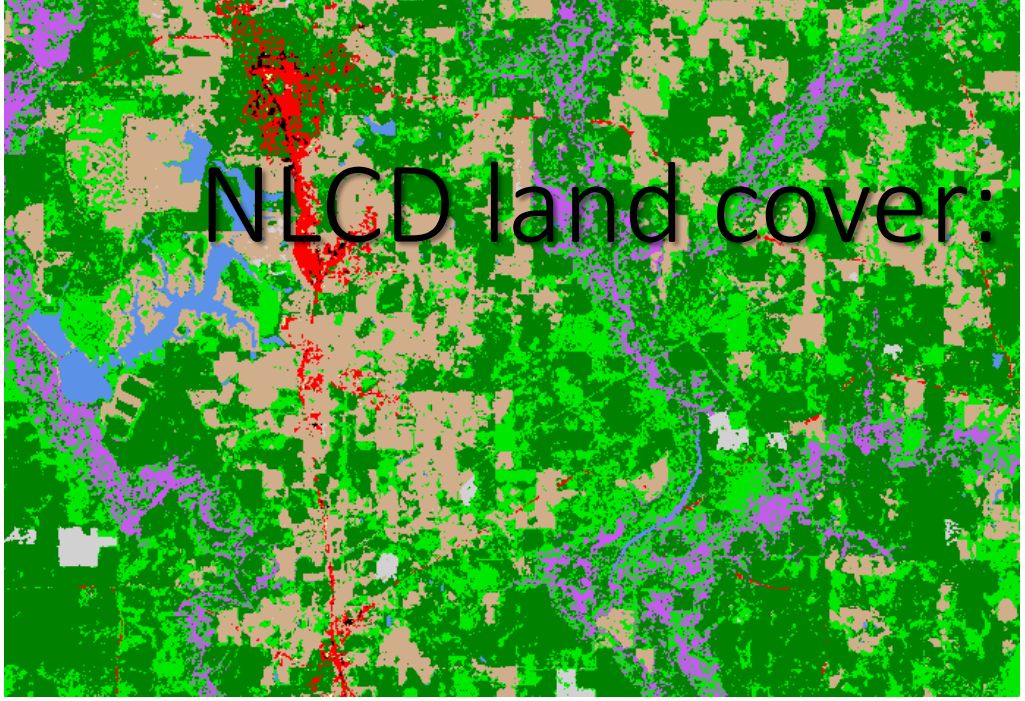
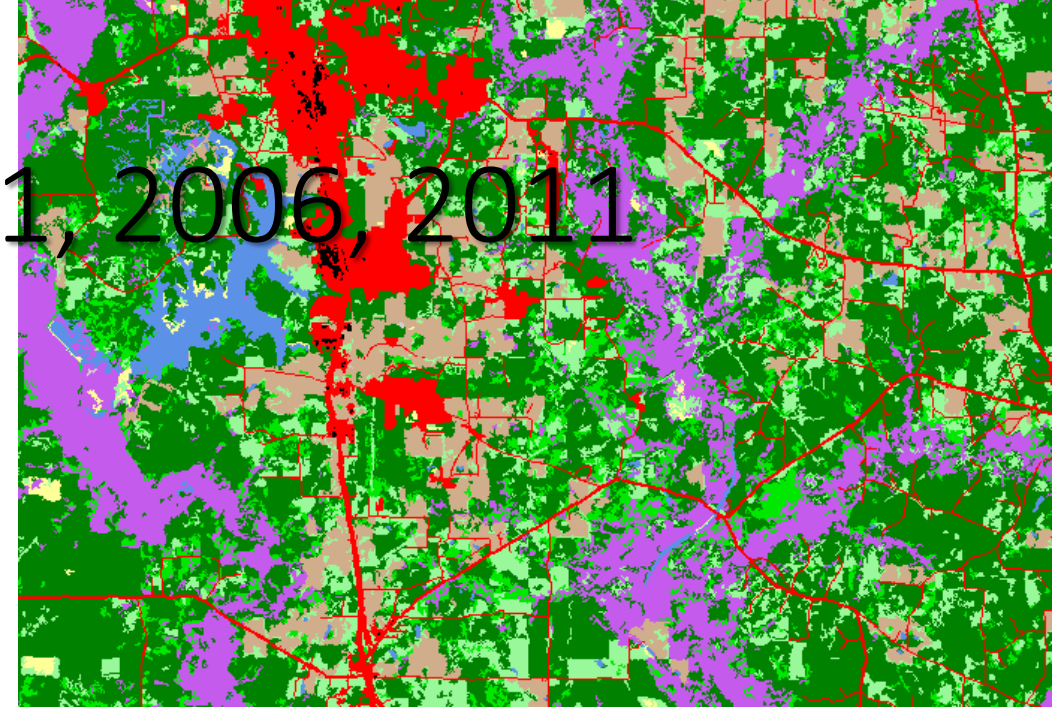
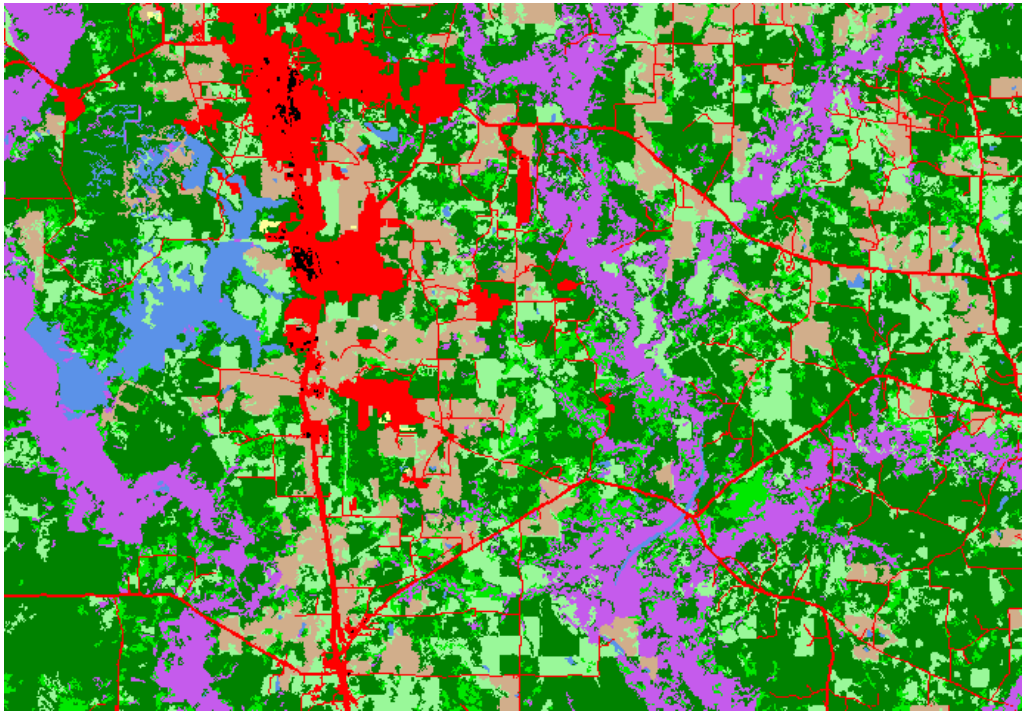


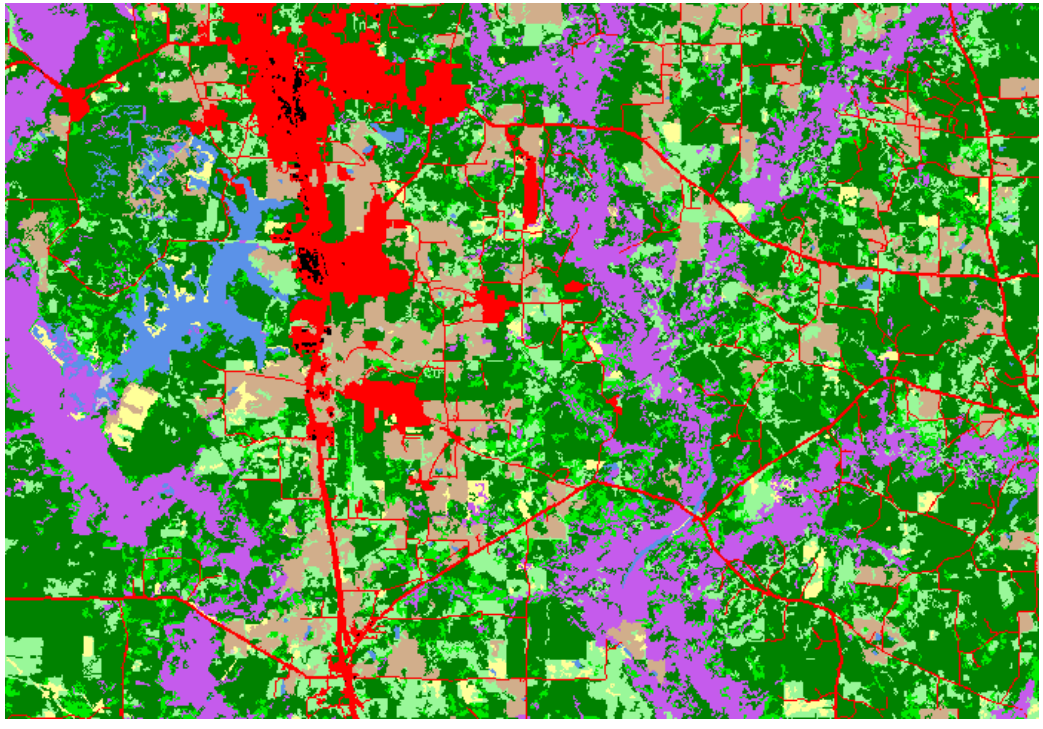
1992



2006



2001



2011

Analysis

- Look for a higher Ratio of flood pixels to non-flood pixels
  - This is the number of pixels that changed within areas that flooded divided by number of pixels that did not flood
  - For this study we are looking only at pixels where a change type occurred more times in areas that flooded than in areas that did not
  - Tables are summarized to show only results where ratio(R) > 1
  - The higher the ratio, the more likely the change type is flood induced, we are defining flood induced change as changes that happened more often within flooded areas than outside of flooded areas
- For this analysis Frequently Flooded Areas are defined as areas that are observed as flooded more than once in the 20-year dataset
- Water-related LC changes should generally have high ratios in flooded areas
- Interesting relationships for discussion in the tables are delineated in red
- There are many other ways to analyze these tables, this is just one method
- Some of the change is due to classification error, particularly in the 1992 dataset, but NLCD accounts for most error in the other dates by implementing a change-based LC update approach

Results: 1992-2001 Flood Frequency Impact on Land Cover, Summarized Table

				Observed Water Frequency %															
Bivariate Change Classes 1992-2001	**Ratio of flood pixels to non-flood**	**Hectares**	***Total Pixels***	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Forest Deciduous to Water	**2.600894398**	**2983.59**	45897	12746	3023	3310	2515	2468	1747	1647	1519	1300	949	901	763	715	583	488	489
Forest Evergreen to Water	**1.977819348**	**1998.27**	33429	11226	2493	2637	1868	1747	1313	1087	1175	757	670	646	585	508	447	399	379
Barren Sparsely Vegetated to Water	**2.719965428**	**283.23**	4304	1157	174	195	106	85	74	56	53	43	46	40	36	29	30	33	35
Urban to Water	**2.045454545**	**16.2**	268	88	11	11	9	13	6	7	2	1	5	1	2	0	4	1	1
Agriculture (Other) to Barren/Sparsely Vegetated	**1.036324123**	**300.42**	6559	3221	221	211	188	141	113	100	95	82	59	66	73	53	57	37	57
Agriculture (Other) to Water	**3.336931432**	**4423.77**	63883	14730	3131	2749	2161	2997	1961	1923	1725	1890	1440	1340	1228	1112	1030	836	794
Wetlands/Salt Pans to Barren/Sparsely Vegetated	**1.354978355**	**28.17**	544	231	27	25	10	8	9	4	10	7	7	15	7	3	9	9	5
Wetlands/Salt Pans to Water	**2.49600517**	**3823.83**	59509	17022	3927	5457	4617	4021	3293	2593	2182	1862	1332	1168	954	707	629	551	500
Water to Forest Deciduous	**1.444412648**	**908.55**	17084	6989	878	688	537	481	439	385	367	379	373	400	327	340	434	325	313
Water to Forest Evergreen	**1.090754448**	**2135.25**	45476	21751	2832	1762	1192	932	784	701	664	551	567	602	531	440	421	363	435
Water to Scrub/Shrub	**1.280404355**	**740.97**	14663	6430	493	398	274	211	209	171	190	175	150	151	170	154	158	122	139
Water to Grassland	**2.920353982**	**29.7**	443	113	9	5	2	6	7	7	9	14	17	8	3	10	12	7	3
Water to Barren/Sparsely Vegetated	**215.6626506**	**1611**	17983	83	18	34	52	47	76	87	76	110	132	163	183	160	205	284	322
Water to Agriculture (Other)	**3.537665744**	**2185.11**	31142	6863	1558	1212	998	1031	969	844	786	775	786	863	838	774	760	690	646
Water to Wetlands/Salt Pans	**4.644571204**	**2125.17**	28697	5084	1556	1290	972	804	759	660	586	596	502	558	462	484	512	488	499

Results: 2001-2006 Flood Frequency Impact on Land Cover, Summarized Table

				Observed Water Frequency %															
Bivariate Change Classes 2001-2006	**Ratio of flood pixels to non-flood**	**Hectares**	***Total Pixels***	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Forest Deciduous to Water	**1.911242604**	**87.21**	1476	507	0	87	24	32	39	15	17	23	25	8	19	27	16	11	22
Forest Evergreen to Water	**1.96043956**	**80.28**	1347	455	0	92	33	27	43	25	19	32	21	17	15	20	7	21	23
Scrub/Shrub to Water	**3.44295302**	**92.34**	1324	298	0	78	36	28	32	15	11	26	18	13	24	13	20	20	21
Grassland to Water	**5.166666667**	**2.79**	37	6	0	4	0	5	1	0	1	0	0	0	0	0	1	0	1
Barren Sparsely Vegetated to Forest Deciduous	**2.615384615**	**9.18**	141	39	0	8	5	1	2	0	0	0	0	1	1	0	1	1	1
Barren Sparsely Vegetated to Forest Evergreen	**1.157772622**	**44.91**	930	431	0	47	1	30	30	8	17	19	17	16	25	15	19	16	16
Barren Sparsely Vegetated to Scrub/Shrub	**4.923076923**	**28.8**	385	65	0	22	0	18	11	1	5	4	4	11	19	8	13	8	8
Barren Sparsely Vegetated to Grassland	**10.43589744**	**36.63**	446	39	0	17	4	24	11	5	12	2	2	7	5	9	10	5	10
Barren Sparsely Vegetated to Agriculture (Other)	**1.11627907**	**17.28**	364	172	0	33	2	8	8	1	8	3	0	2	5	2	6	4	2
Barren Sparsely Vegetated to Wetlands/Salt Pans	**30.44444444**	**49.32**	566	18	0	36	8	2	14	7	11	31	30	17	11	14	13	15	8
Barren Sparsely Vegetated to Water	**17.40677966**	**92.43**	1086	59	0	24	0	19	13	2	17	5	5	17	8	13	6	5	7
Agriculture (Other) to Water	**6.577540107**	**442.8**	5668	748	0	183	78	62	127	67	59	98	60	69	68	65	63	99	84
Wetlands/Salt Pans to Agriculture (Other)	**1.631051176**	**424.53**	7609	2892	0	263	62	147	211	38	254	180	37	155	130	51	127	100	76
Wetlands/Salt Pans to Water	**1**	**89.01**	1978	989	0	100	20	18	34	10	20	20	13	12	20	11	12	12	31
Water to Forest Deciduous	**3.181818182**	**9.45**	138	33	0	14	3	2	6	6	3	2	4	2	1	2	1	2	2
Water to Forest Evergreen	**1.934235977**	**90**	1517	517	0	153	29	55	48	21	41	29	24	26	14	21	12	17	10
Water to Scrub/Shrub	**6.339285714**	**223.65**	2877	392	0	87	10	39	51	17	38	38	22	40	35	22	54	43	44
Water to Grassland	**7.795803067**	**1738.62**	21796	2478	0	1049	328	942	828	348	579	551	321	505	434	330	504	351	401
Water to Barren/Sparsely Vegetated	**33.21066667**	**1120.86**	12829	375	0	144	47	45	73	38	71	129	44	140	78	110	106	62	91
Water to Urban	**1.84**	**20.7**	355	125	0	25	12	4	5	8	3	2	3	1	0	7	2	1	4
Water to Agriculture (Other)	**4.055555556**	**19.71**	273	54	0	10	7	3	4	1	4	4	0	3	7	1	3	1	0
Water to Wetlands/Salt Pans	**17.88744138**	**3089.34**	36245	1919	0	777	368	787	780	356	496	621	404	526	479	392	594	497	498

Results: 2006-2011Flood Frequency Impact on Land Cover, Summarized Table

				Observed Water Frequency %																
Bivariate Change Classes 2006-2011	**Ratio of flood pixels to non-flood**	**Hectares**	***Total Pixels***	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Forest Deciduous to Water	**4.110465116**	**63.63**	879	172	0	50	0	29	0	13	1	15	4	11	7	2	9	7	10
Forest Evergreen to Water	**3.775700935**	**72.72**	1022	214	0	45	0	28	1	29	1	24	9	13	5	12	19	12	8
Scrub/Shrub to Water	**6.383116883**	**88.47**	1137	154	0	32	1	22	0	16	4	17	2	13	6	2	7	4	3
Grassland to Wetlands/Salt Pans	**1.114355231**	**41.22**	869	411	0	52	0	31	0	46	3	23	7	6	7	5	3	2	9
Grassland to Water	**15.5**	**200.88**	2376	144	0	51	1	36	0	21	4	23	7	21	11	17	14	13	10
Barren Sparsely Vegetated to Grassland	**1.083832335**	**16.29**	348	167	0	6	0	39	0	7	1	6	7	14	10	1	3	2	1
Barren Sparsely Vegetated to Wetlands/Salt Pans	**11**	**2.97**	36	3	0	0	0	2	0	0	0	2	0	4	3	4	1	0	3
Barren Sparsely Vegetated to Water	**62.5**	**157.5**	1778	28	0	14	0	5	0	6	1	4	5	1	6	3	3	1	5
Agriculture (Other) to Water	**9.676056338**	**185.49**	2274	213	0	121	1	63	1	53	11	39	24	21	38	44	60	69	25
Wetlands/Salt Pans to Water	**3.576923077**	**8.37**	119	26	0	8	0	3	0	5	0	1	1	1	2	2	2	2	1
Water to Forest Deciduous	**6.565217391**	**108.72**	1392	184	0	47	1	26	1	23	0	14	8	7	9	7	13	11	13
Water to Forest Evergreen	**4.18630137**	**137.52**	1893	365	0	50	1	40	0	22	2	16	6	15	15	5	10	1	8
Water to Scrub/Shrub	**11.61863354**	**841.77**	10158	805	0	180	12	101	10	75	15	87	40	50	49	26	63	38	43
Water to Grassland	**4.88589398**	**489.42**	6551	1113	0	248	1	155	4	125	10	127	56	83	84	58	74	49	75
Water to Barren/Sparsely Vegetated	**39.07619048**	**738.54**	8416	210	0	40	2	31	4	28	4	16	14	17	27	10	30	7	29
Water to Urban	**1.935483871**	**16.2**	273	93	0	20	0	15	0	5	0	3	1	3	0	2	0	5	1
Water to Agriculture (Other)	**3.071625344**	**100.35**	1478	363	0	23	1	22	0	23	2	16	5	13	3	10	17	8	10
Water to Wetlands/Salt Pans	**13.2887538**	**393.48**	4701	329	0	56	0	28	1	19	1	20	9	14	16	7	10	13	13

Results: 2001-2011 Flood Frequency Impact on Land Cover, Summarized Table

				Observed Water Frequency %															
Bivariate Change Classes 2001-2011	**Ratio of flood pixels to non-flood**	**Hectares**	***Total Pixels***	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Forest Deciduous to Water	**3.538314176**	**166.23**	2369	522	120	71	45	31	28	33	32	29	28	34	18	25	34	23	24
Forest Evergreen to Water	**3.867961165**	**179.28**	2507	515	127	64	63	52	45	27	41	36	33	33	33	36	37	33	27
Scrub/Shrub to Water	**6.442675159**	**182.07**	2337	314	84	53	22	29	19	21	19	15	10	29	24	23	22	23	27
Grassland to Water	**5.545454545**	**5.49**	72	11	1	2	0	1	2	0	0	1	1	0	1	1	0	0	0
Barren Sparsely Vegetated to Forest Deciduous	**2.58974359**	**9.09**	140	39	9	5	3	0	0	1	0	2	2	0	1	0	3	0	0
Barren Sparsely Vegetated to Scrub/Shrub	**7.343283582**	**44.28**	559	67	21	21	10	8	14	8	14	25	13	10	14	22	24	16	23
Barren Sparsely Vegetated to Grassland	**10.10638298**	**42.75**	522	47	18	13	7	10	8	23	12	15	12	10	6	11	13	22	13
Barren Sparsely Vegetated to Agriculture (Other)	**1.10326087**	**18.27**	387	184	32	8	7	7	3	6	3	3	3	3	2	3	6	5	5
Barren Sparsely Vegetated to Wetlands/Salt Pans	**31.5**	**51.03**	585	18	36	9	10	11	25	17	12	19	21	18	29	17	27	21	23
Barren Sparsely Vegetated to Water	**43.22580645**	**120.6**	1371	31	7	2	9	3	3	3	5	7	6	6	6	4	4	6	7
Agriculture (Other) to Water	**9.540656205**	**601.92**	7389	701	215	133	105	98	77	126	190	127	109	104	87	82	92	76	87
Wetlands/Salt Pans to Barren/Sparsely Vegetated	**1.429906542**	**27.54**	520	214	57	18	17	13	11	7	11	7	6	9	6	9	7	10	4
Wetlands/Salt Pans to Agriculture (Other)	**1.858819076**	**441.99**	7553	2642	177	143	169	194	149	163	156	182	175	176	132	142	118	95	111
Wetlands/Salt Pans to Water	**1.751987281**	**99.18**	1731	629	91	31	20	12	19	15	10	9	18	9	12	15	8	16	16
Water to Forest Deciduous	**14.20588235**	**130.41**	1551	102	29	15	12	13	14	16	15	16	9	12	16	8	14	12	11
Water to Forest Evergreen	**4.478723404**	**265.23**	3605	658	182	116	60	110	52	45	46	30	33	38	24	33	29	21	24
Water to Scrub/Shrub	**16.25531915**	**1237.68**	14598	846	268	140	140	124	124	113	89	90	100	108	72	88	85	83	85
Water to Grassland	**7.66381236**	**1852.65**	23271	2686	1174	1204	874	823	652	629	555	515	463	533	389	441	450	379	398
Water to Barren/Sparsely Vegetated	**38.53212851**	**1727.01**	19687	498	171	80	83	102	130	148	109	87	63	60	51	81	105	76	105
Water to Urban	**2.923076923**	**44.46**	663	169	57	22	14	14	9	10	9	7	14	7	7	12	4	7	7
Water to Agriculture (Other)	**4.335443038**	**123.3**	1686	316	70	25	16	19	12	12	12	14	12	11	16	18	10	11	9
Water to Wetlands/Salt Pans	**20.54035639**	**3527.19**	41099	1908	844	1016	838	790	679	711	619	708	708	691	590	556	522	427	457

Results: 1992-2011 Flood Frequency Impact on Land Cover, Summarized Table

				Observed Water Frequency %															
Bivariate Change Classes 1992-2011	**Ratio of flood pixels to non-flood**	**Hectares**	***Total Pixels***	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Forest Deciduous to Water	**4.105095541**	**3132.27**	43281	8478	6851	4591	2471	1663	1422	1189	910	882	802	754	602	533	568	515	509
Forest Evergreen to Barren/Sparsely Vegetated	**1.136511376**	**566.46**	11832	5538	4360	524	240	207	127	93	83	69	54	54	30	31	34	39	27
Forest Evergreen to Water	**3.973054367**	**2255.94**	31375	6309	6573	3462	1720	1346	1066	957	783	700	661	564	470	452	419	378	322
Barren Sparsely Vegetated to Water	**4.33875**	**312.39**	4271	800	412	216	111	106	63	67	60	58	54	53	41	50	52	35	43
Urban to Water	**3.189655172**	**16.65**	243	58	32	16	9	7	2	4	5	3	0	3	3	2	2	2	0
Agriculture (Other) to Water	**5.246142542**	**4498.2**	59507	9527	5577	4176	3015	2298	1944	1516	1382	1307	1442	1274	979	979	883	873	884
Wetlands/Salt Pans to Barren/Sparsely Vegetated	**1.573216521**	**113.13**	2056	799	330	102	45	52	19	32	23	23	13	12	20	11	13	10	14
Wetlands/Salt Pans to Water	**4.165457333**	**3668.31**	50544	9785	11071	7235	3499	2350	1950	1455	1041	903	811	703	605	514	453	416	385
Water to Forest Deciduous	**3.090839304**	**1087.11**	15987	3908	2789	762	461	432	449	367	370	504	450	385	323	249	210	196	186
Water to Forest Evergreen	**3.143694723**	**2847.15**	41698	10063	11141	2480	1110	1003	803	665	581	547	517	467	394	373	372	341	348
Water to Scrub/Shrub	**5.362934363**	**2000.16**	26368	4144	2785	637	300	322	255	200	201	208	190	172	204	166	175	144	164
Water to Grassland	**12.91829356**	**1607.94**	19249	1383	1376	450	239	228	205	198	213	218	246	208	194	186	170	189	211
Water to Barren/Sparsely Vegetated	**138.1576577**	**2760.39**	30893	222	90	57	35	64	60	69	87	111	158	198	202	247	327	349	394
Water to Urban	**1.477692526**	**468**	8719	3519	1926	271	127	113	84	64	66	57	62	55	48	46	48	55	37
Water to Agriculture (Other)	**5.810555675**	**2437.47**	31744	4661	3010	1459	742	909	761	660	655	616	587	647	640	649	762	888	847
Water to Wetlands/Salt Pans	**23.56200747**	**5112.72**	59219	2411	3411	2243	1224	1231	1056	910	842	793	720	705	625	620	585	616	577

Urban Results: Urban Gains and Losses in Frequently Flooded Areas, 1992 – 2011

				Observed Water Frequency %															
Bivariate Change Classes 1992-2011	**Ratio of flood pixels to non-flood**	**Hectares**	***Total Pixe***	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Forest Deciduous to Urban	**0.232001597**	**6068.25**	358048	290623	64969	844	240	195	98	97	89	82	47	36	31	46	38	26	34
Forest Evergreen to Urban	**0.454989022**	**13092.3**	465192	319722	143086	1288	165	157	95	63	47	45	55	28	23	19	19	17	15
Scrub/Shrub to Urban	**#DIV/0!**	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Grassland to Urban	**0.062609343**	**151.38**	28547	26865	1570	26	6	6	4	6	2	4	5	5	6	3	2	5	1
Barren Sparsely Vegetated to Urban	**0.37675275**	**718.2**	29161	21181	7152	325	96	66	31	38	19	18	18	15	11	11	9	7	4
Urban to Forest Deciduous	**0.196794301**	**19.89**	1344	1123	179	18	4	2	3	2	2	2	0	1	0	0	0	0	0
Urban to Forest Evergreen	**0.270076726**	**47.52**	2483	1955	426	30	16	6	6	6	4	3	1	4	2	0	2	2	3
Urban to Scrub/Shrub	**0.14893617**	**10.08**	864	752	83	10	6	4	0	1	0	0	0	0	0	1	0	0	0
Urban to Grassland	**0.208928571**	**10.53**	677	560	100	7	4	1	0	2	0	0	0	0	0	0	1	0	1
Urban to Barren/Sparsely Vegetated	**0.819494585**	**20.43**	504	277	109	27	12	3	6	7	1	3	5	3	4	0	1	1	2
Urban to Urban	**0.149574422**	**4089.96**	349266	303822	42354	992	313	217	163	129	70	66	72	74	52	57	48	47	42
Urban to Agriculture (Other)	**0.212958183**	**74.25**	4699	3874	561	139	31	37	11	5	2	5	4	8	3	4	1	1	2
Urban to Agriculture (Rice)	**#DIV/0!**	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Urban to Wetlands/Salt Pans	**0.417322835**	**9.54**	360	254	66	14	6	9	1	1	0	0	1	1	1	0	0	0	0
Urban to Wetland/Mangrove	**#DIV/0!**	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Urban to Water	**3.189655172**	**16.65**	243	58	32	16	9	7	2	4	5	3	0	3	3	2	2	2	0
Urban to Ice/Snow	**#DIV/0!**	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Urban to Cloud/Shadow	**#DIV/0!**	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture (Other) to Urban	**0.084349154**	**4718.7**	674013	621583	47812	1801	525	398	276	168	131	110	97	83	89	61	62	47	34
Agriculture (Rice) to Urban	**#DIV/0!**	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wetlands/Salt Pans to Urban	**0.398429073**	**1296.54**	50563	36157	12544	656	216	168	111	84	64	64	42	33	23	19	11	26	13
Wetlands/Mangrove to Urban	**#DIV/0!**	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water to Urban	**1.477692526**	**468**	8719	3519	1926	271	127	113	84	64	66	57	62	55	48	46	48	55	37

Urban Results: Urban Gains and Losses in Frequently Flooded Areas, 1992 – 2011

1992 – 2011 Urban Results	Acres	Percent of Total Urban inside frequently flooded areas	Percent of Total Urban in the Study Area
Urban loss inside areas that have flooded	208.89	1%	0%
Urban gain inside areas that have flooded	26513.37	85%	15%
Urban no change in areas that have flooded	4089.96	13%	2%
Total Urban inside frequently flooded areas (2011)	31194.36		
Total Urban in the Study Area (2011)	179615.7		

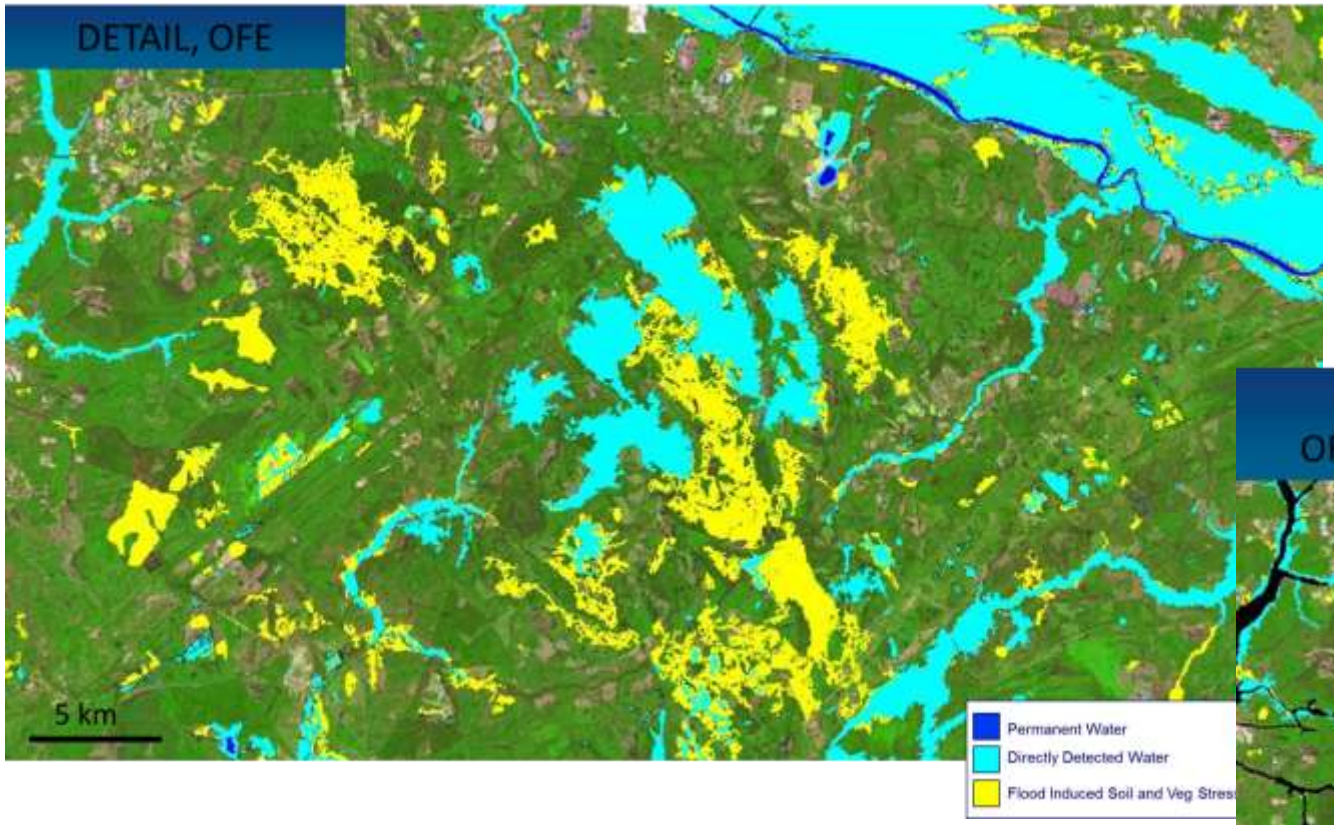
Discussion & Conclusions

- This study shows there is a relationship between some LC change types and areas that frequently flood, and indicates what change types occur
- The Barren Class is the most impacted by flooding
  - Barren often changes to other vegetated categories in pixels that have been flooded multiple times
  - Substantial net gain in Barren features in each of the date pairs tested, and 2760 ha gain in Barren features over the entire study time period
  - Barren changed in the flood areas much more than it changed outside of the flood areas
  - 566 ha of forest was lost to barren, which is more than happened outside the flooded areas,
  - This is probably due to harvesting of trees in flood plain, but could also be due to damage to forests by flooding
- Nearly twice the amount of Agriculture was lost to Water (~4500 ha) as was gained from Water (2437 ha) during the full study period

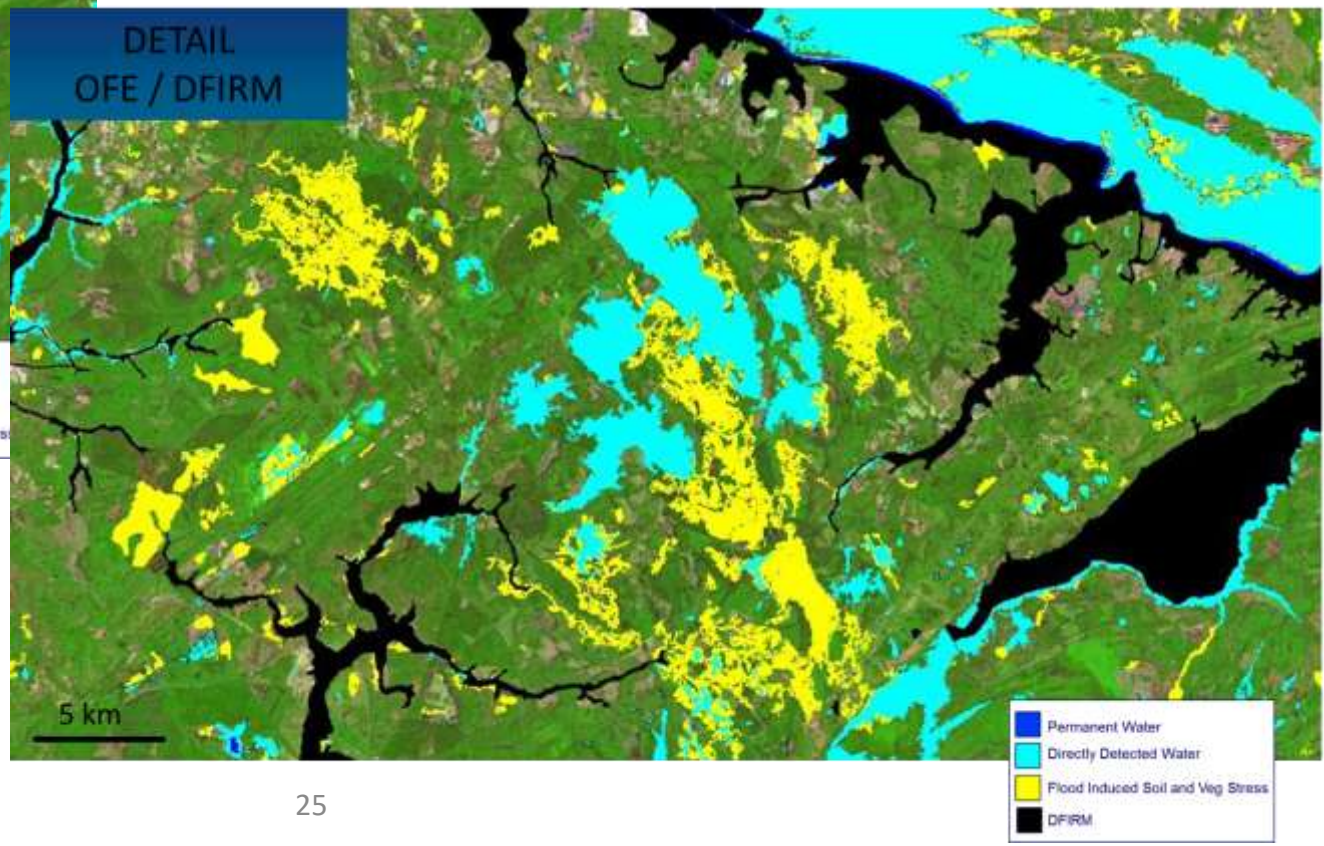
Conclusions - Urban

- In every date pair, in flooded pixels, there was some Water which changed to Urban, usually around 16 ha, except between 2001 and 2011, there was 44 ha of Urban growth
- Over the entire study period, there was a loss of ~17 ha of Urban features to Water, but this was outweighed by the gain in Urban from Water (468 ha)
- The only Urban change that was significantly due to flooding was Urban to Water or Water to Urban
- Any gain in Urban within the areas of frequent flooding around the Red River should be investigated! This indicates building in flood prone areas during the period of study, and this data maps those locations
- Pixels showing a loss of Urban should also be investigated as they may represent total destruction of urban structures from flood, but so few pixels, probably within margin of error which is mainly due to classification error
- According to this data, as of 2011, 85% of the Urban features within the frequently flooding areas have been built between 1992 and 2011

Applications to Floodplain Management



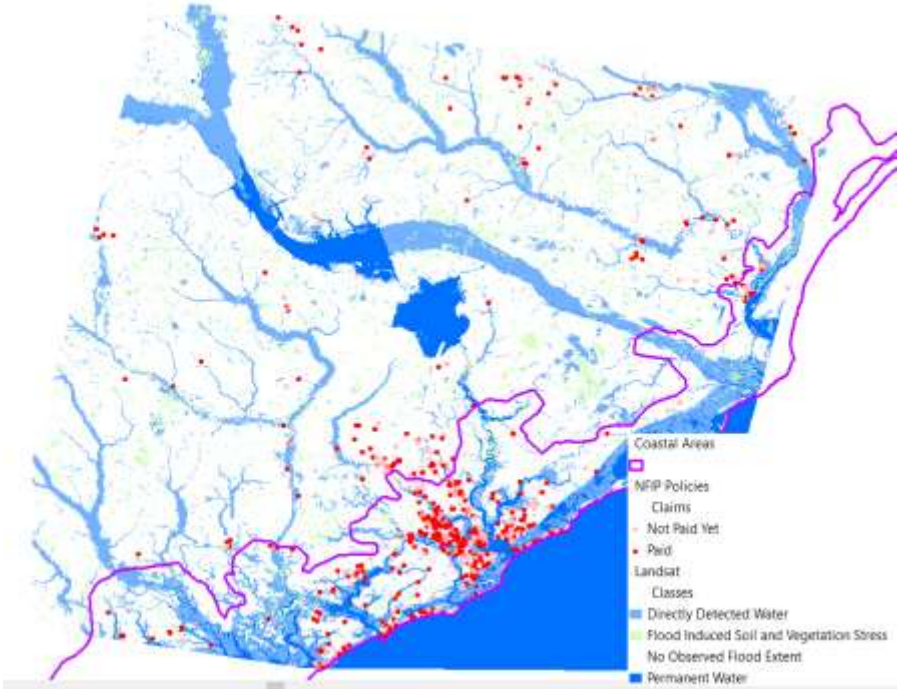
Example 1: Charleston, SC



Applications to Flood Insurance and Mitigation

Example 1: Charleston, SC

Within Landsat Footprint				Coastal Areas of Footprint		
Zone Category	Total Policies	Claims Filed as of 12/31/16	Claims Paid as of 12/31/16	Total Policies	Claims Filed as of 12/31/16	Claims Paid as of 12/31/16
NFIP FIRM Flood Zones						
Minimal	13554	192	114	9986	92	53
Moderate	3339	37	23	3135	28	16
SFHA	55754	1668	979	52979	1521	883
Undetermined	870	20	13			
Total	73517	1917	1129	66100	1641	952
Landsat Classes						
<Null>	5	0	0	5	0	0
Directly Detected Water	1090	35	23	964	24	15
Flood Induced Soil and Vegetation Stress	2149	76	40	1941	71	38
No Observed Flood Extent	70262	1806	1066	63180	1546	899
Permanent Water	11	0	0	10	0	0
Total	73517	1917	1129	66100	1641	952
Total Flooded	3250	111	63	2915	95	53



Future Study

- This study should be done for many areas in order to understand the variability of flood frequency impact on land cover
- May leave out 1992 NLCD due to inconsistencies
- Determine if there are regional trends in impact
  - i.e. sources of flooding are different in coastal versus inland flood plain environments, so impact on class change may be different
- Other analyses can be done using this information, we just looked at any percent inundation > 0, but maybe specific quantities of inundations correlate to specific land cover change
- Validate study by tracking the changes in the imagery and with flood data, thus quantifying the accuracy of this analysis
- Conduct a study focusing only on Urban in the frequently flooded areas for each of the date pairs to determine more precisely the range of dates of when new construction occurred
- Many more conclusions will be validated and documented in a future paper

Questions?

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