Monitoring Water Quality and Modeling Nutrient Dynamics for Tallapoosa Watershed Using Remote Sensing and GIS

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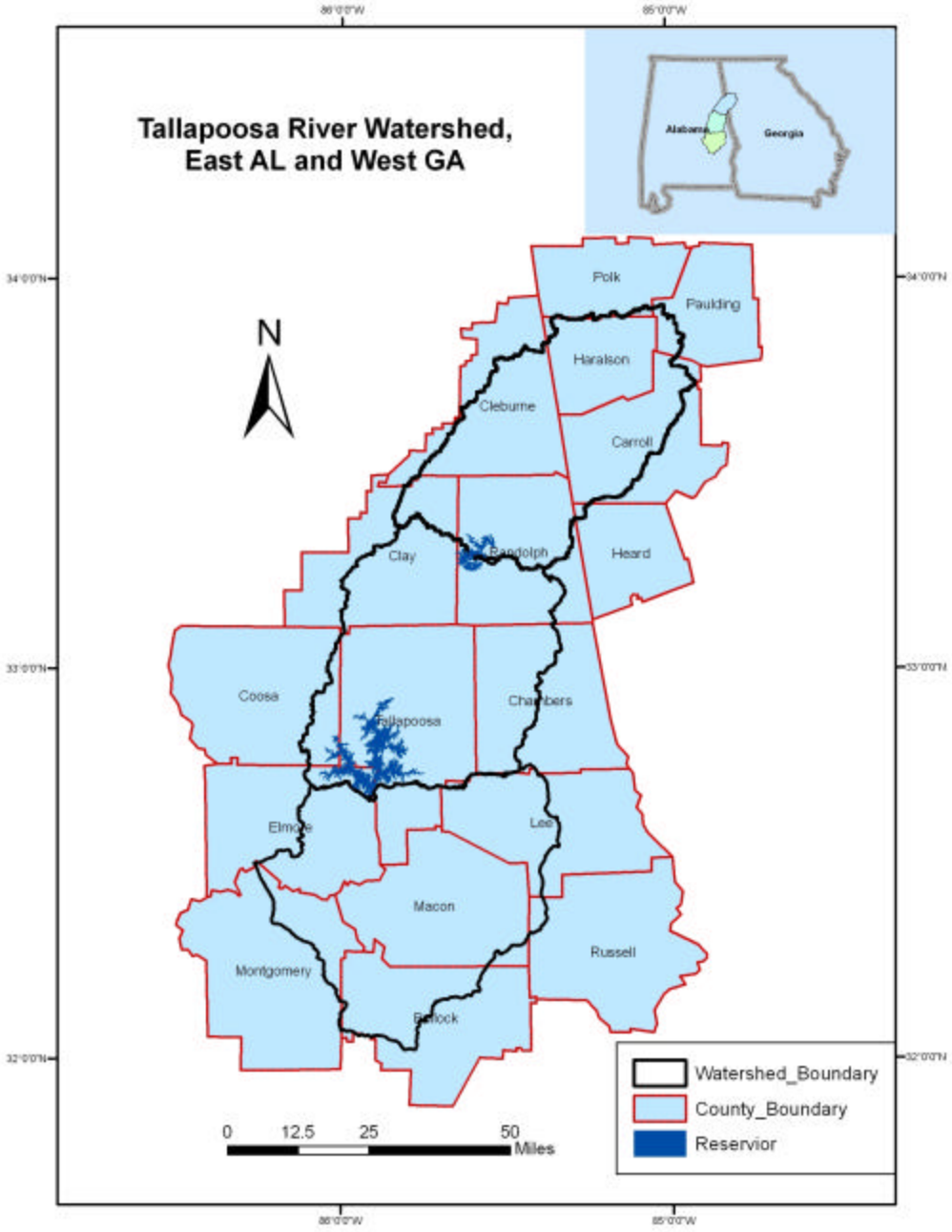
And
John Glasier
Lake Watch of Lake Martin

Goal of Tallapoosa Watershed Project

- To integrate standard methods, high-tech (remote sensing and GIS), and low-tech analytical capabilities to assess nutrient dynamics in the Tallapoosa Watershed

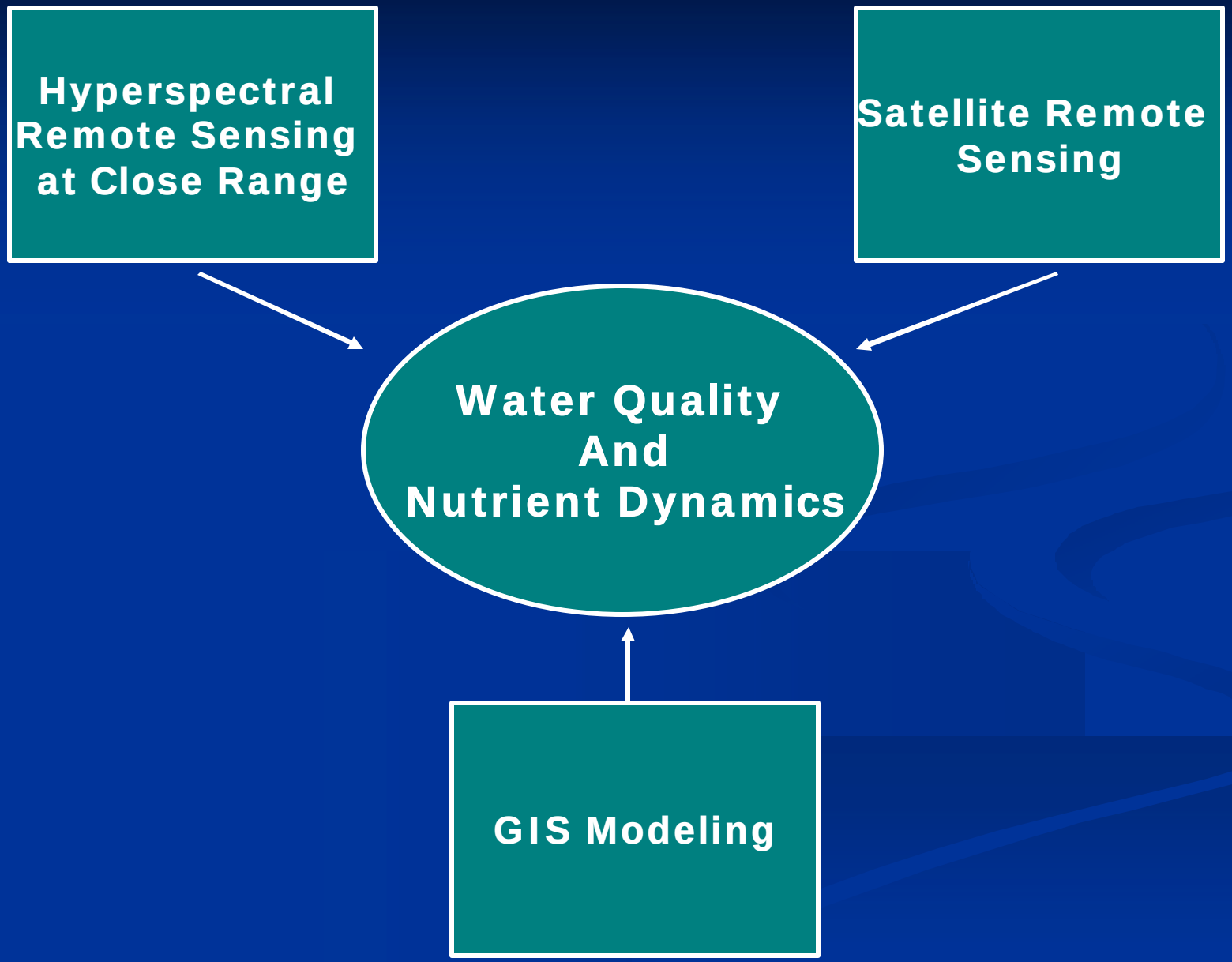

Tallapoosa River Watershed,
East AL and West GA
Alabama
Georgia
N
Polk
Paulding
Haralson
Cleburne
Carroll
Clay
Randolph
Heard
Coosa
Tallapoosa
Chambers
Elmore
Lee
Macon
Russell
Montgomery
Bullock
0 12.5 25 50
Miles
Watershed_Boundary
County_Boundary
Reservior

Tallapoosa Watershed

- Its total length of 235 miles drains a watershed area of 4,680 square miles. Only 720 square miles lie in Georgia accounting for 15% of the total land area. The remaining 3,960 square miles lie in Alabama accounting for 85% of the land area.

Objectives of Applying Remote Sensing and GIS Techniques

- Applying high-tech capabilities including close-range hyperspectral radiometric sampling, remotely sensed satellite imagery and GIS resources to model:
  - The trophic states of Lakes Martin and Harris
  - Sources and amounts of nutrient loading within the watershed


Hyperspectral Remote Sensing at Close Range
Satellite Remote Sensing
Water Quality And Nutrient Dynamics
GIS Modeling

Objectives of Hyperspectral Remote Sensing-Spectral Reflectance Measurement

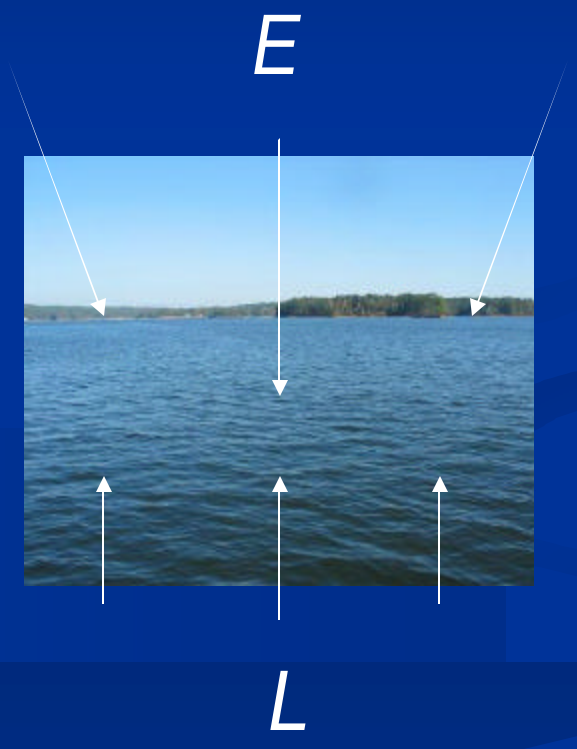
- To study the spectral characteristics of Lake Martin and Lake Harris
- To associate the spectral characteristics with major water quality parameters
- To develop algorithms of estimating major water quality parameters using spectral reflectance
- To provide insight to the satellite remote sensing of water quality

Handheld Spectroradiometers

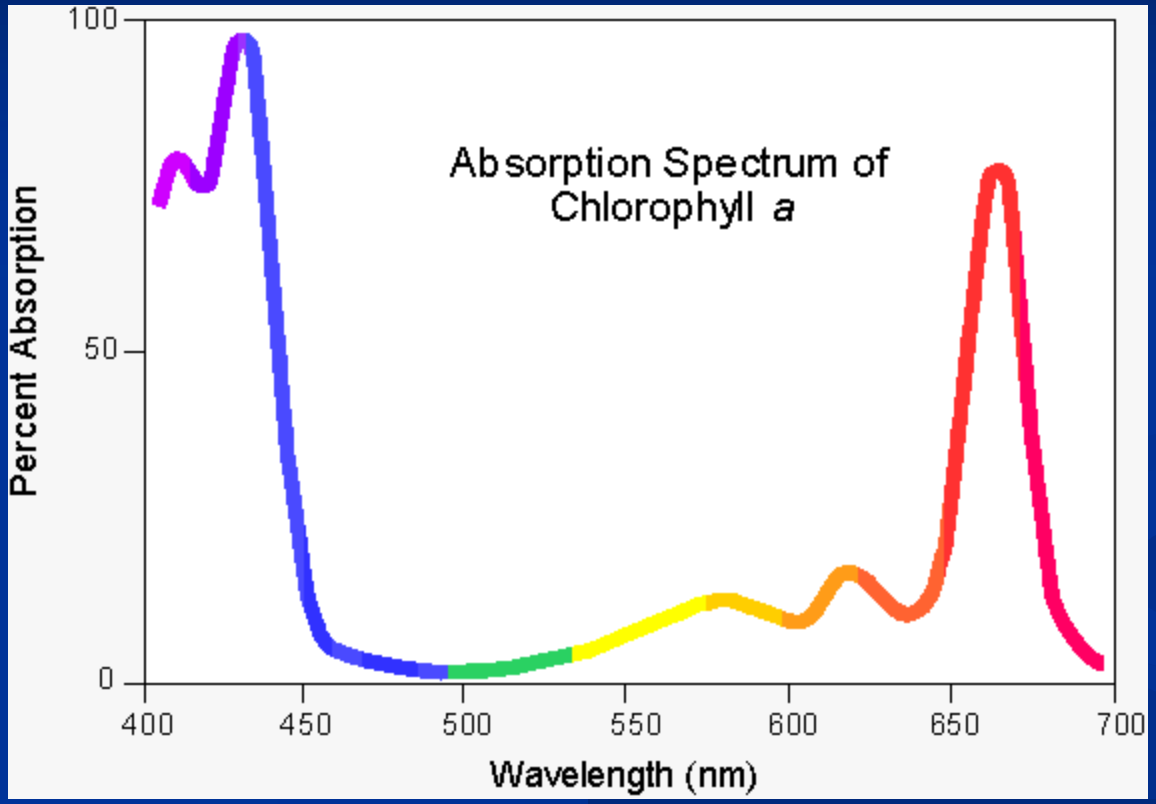
- ASD VNIR FieldSpec Spectrometer
  - UA Department of Geography
  - Wavelength Range (nm): 350-1150 (701 channels)
- The StellarNet EPP2000 Spectrometer
  - LWLM
  - Wavelength Range (nm): 350-850 (1000 channels)

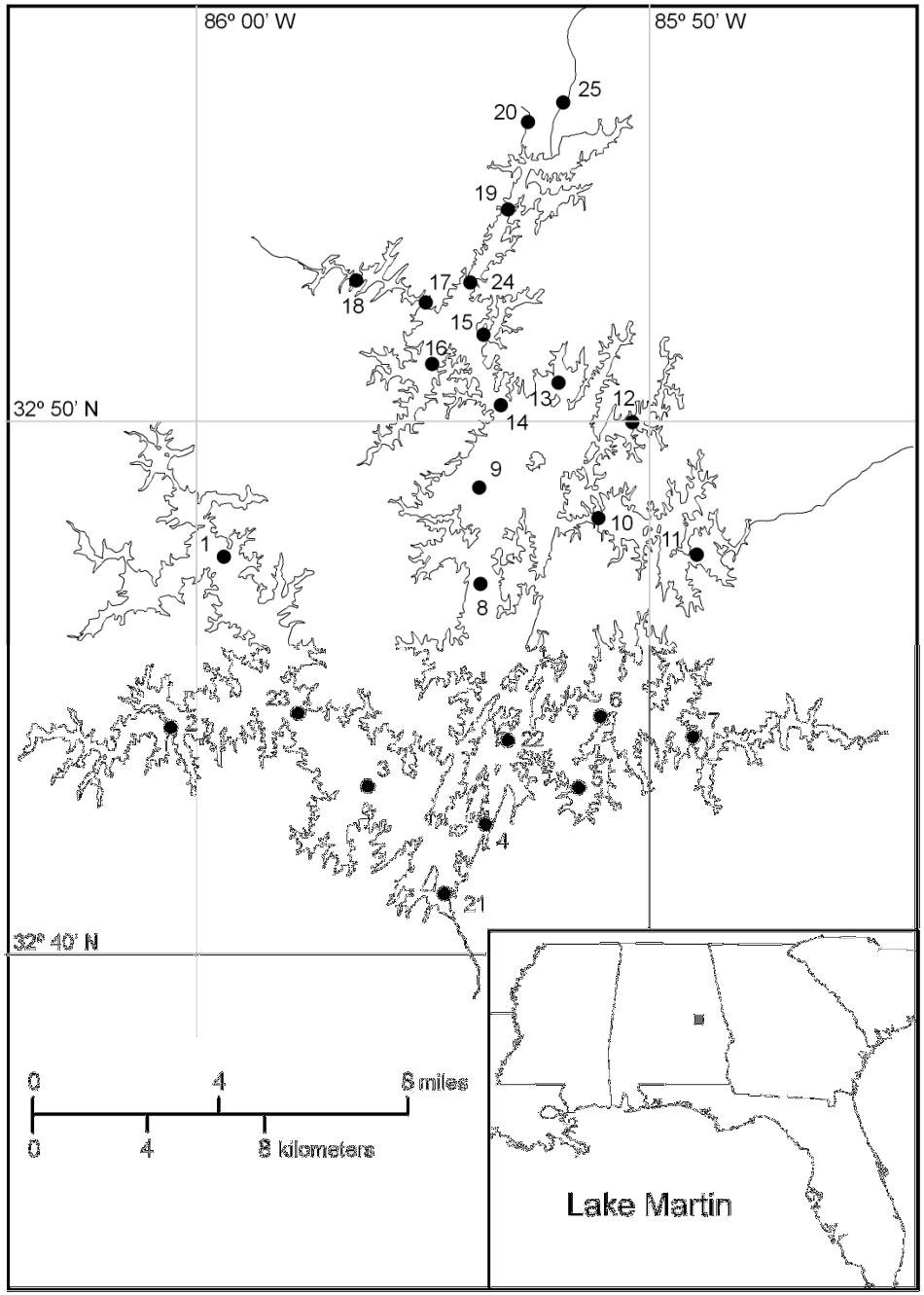
Reflectance (%) Calculation

$$r = \frac{L_{\uparrow}}{E_{\downarrow}}$$

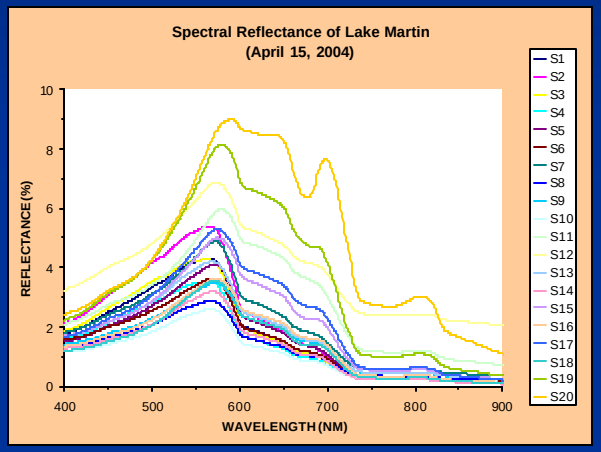


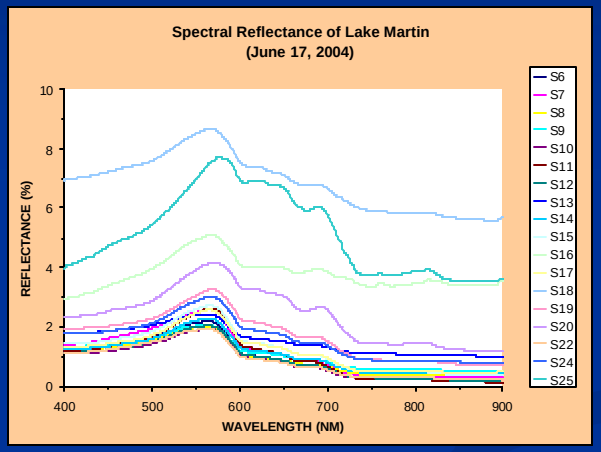
L: is upwelling radiance
E: is downwelling irradiance

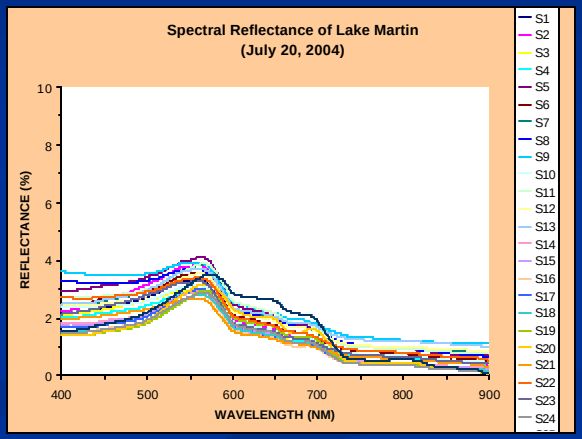

Absorption Spectrum of
Chlorophyll a
Percent Absorption
100
50
0
400
450
500
550
600
650
700
Wavelength (nm)

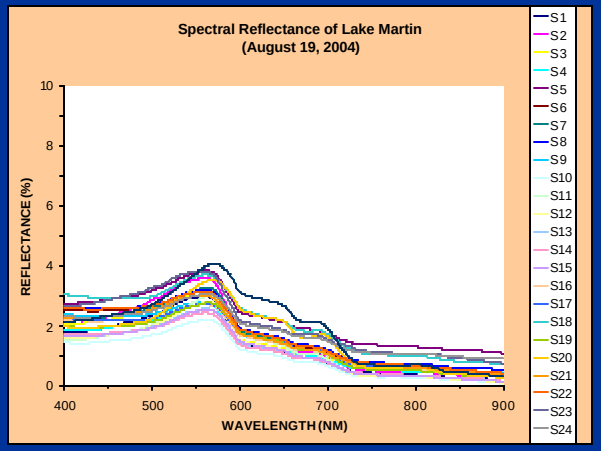

86° 00' W
85° 50' W
32° 50' N
32° 40' N
25
20
19
17
24
18
15
16
13
12
14
9
10
11
1
8
23
6
7
22
3
5
4
21
0
4
8 miles
0
4
8 kilometers
Lake Martin

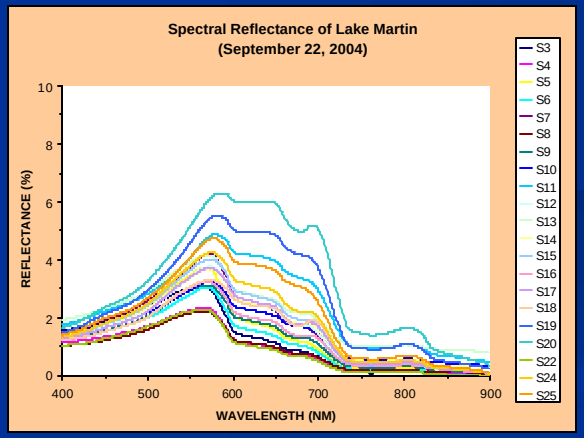
Spectral Reflectance of Lake Martin

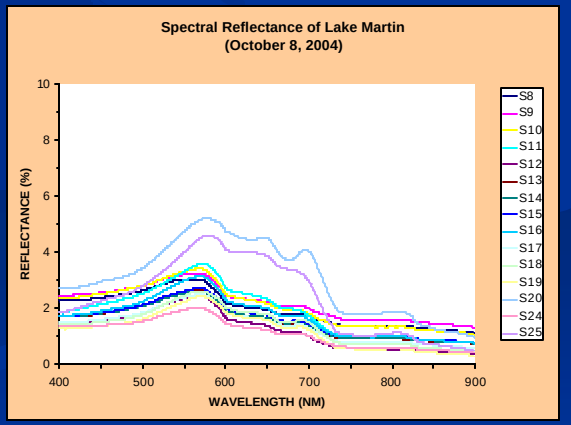




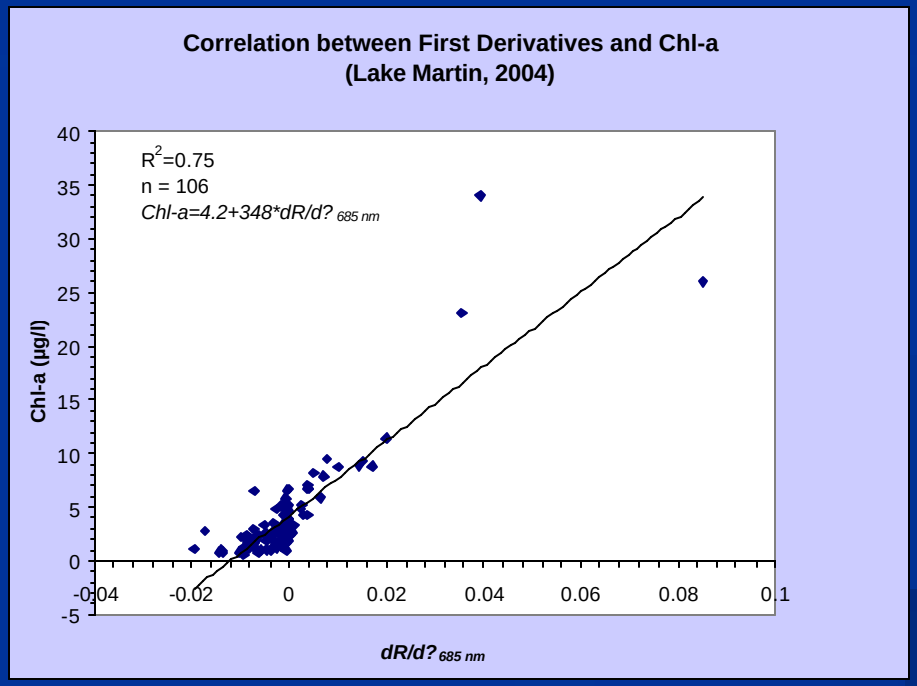


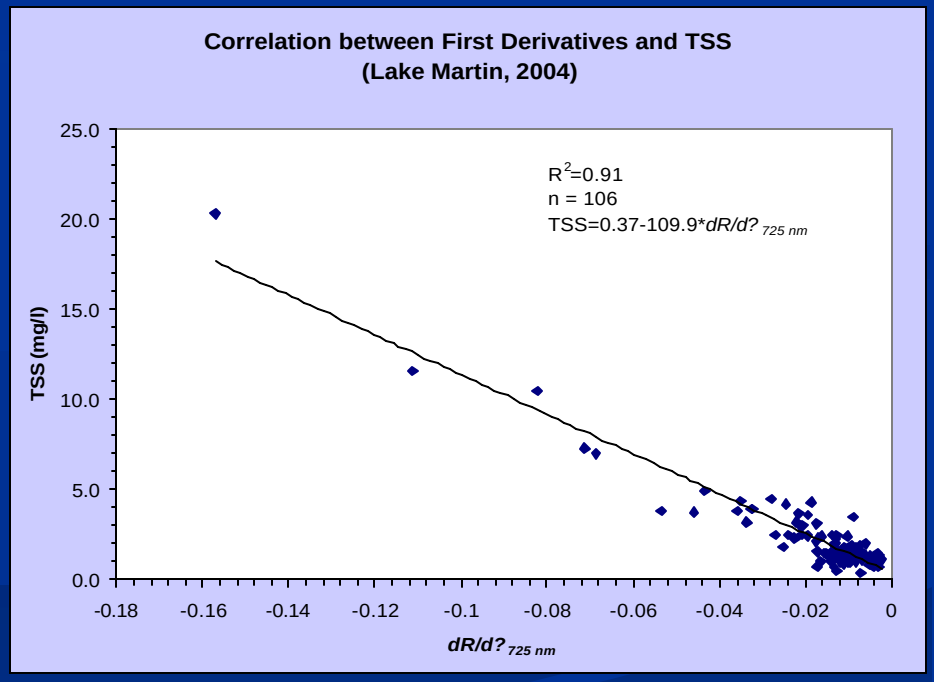


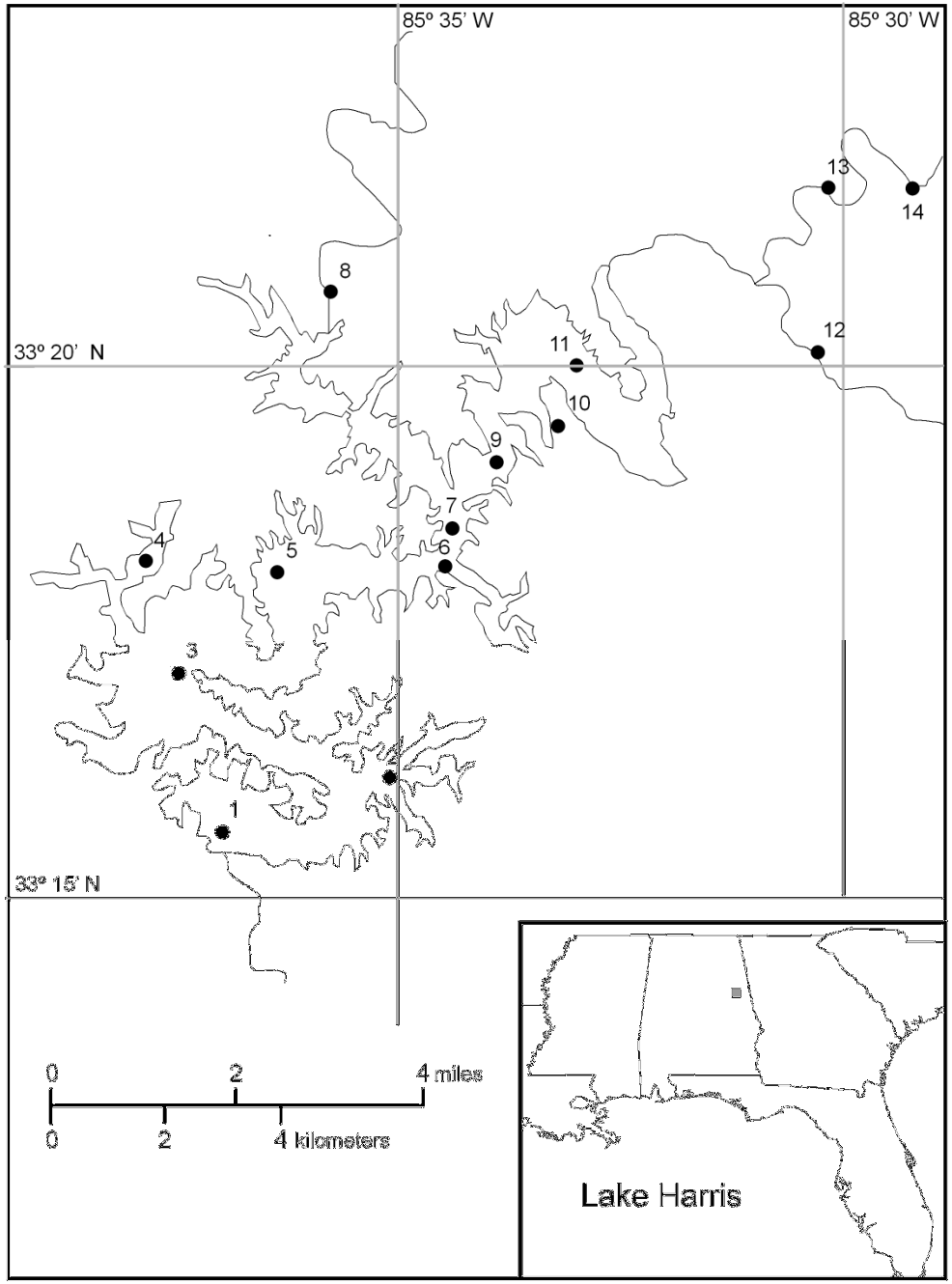




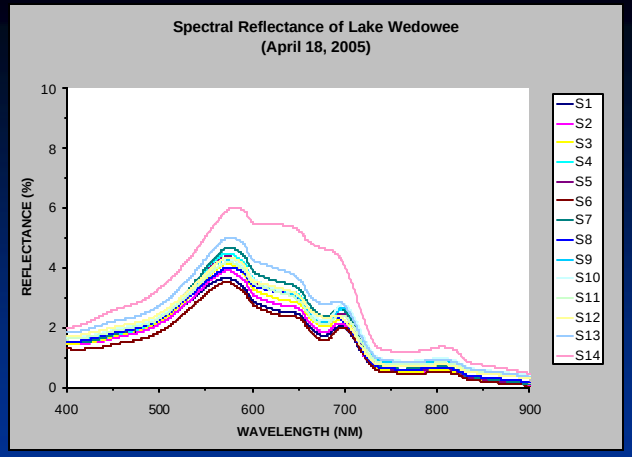
Derivative Models of Estimating Chl a and TSS for Lake Martin

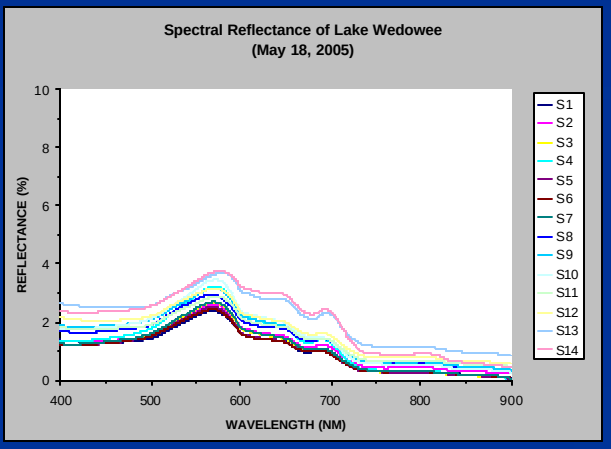


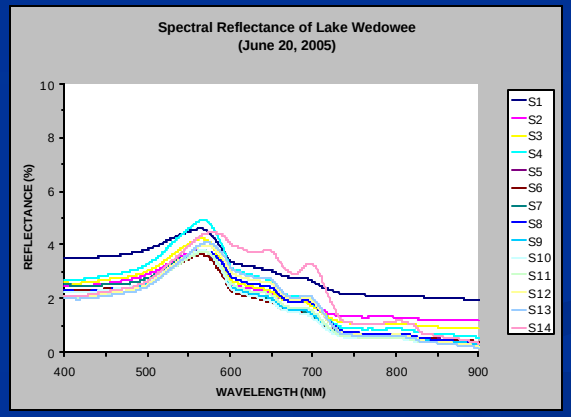


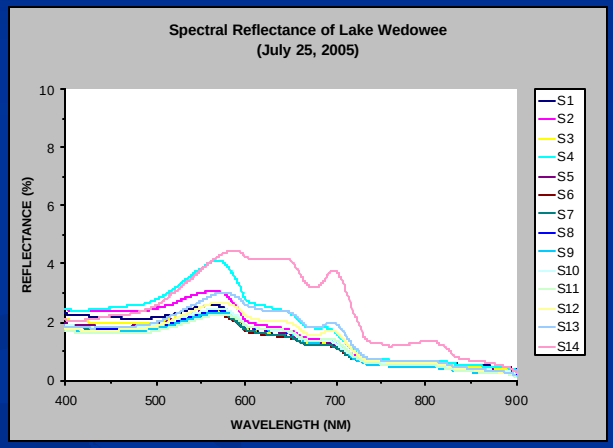

85º 35' W
85º 30' W
33º 20' N
33º 15' N
1
2
3
4
5
6
7
8
9
10
11
12
13
14
0
2
4 miles
0
2
4 kilometers
Lake Harris

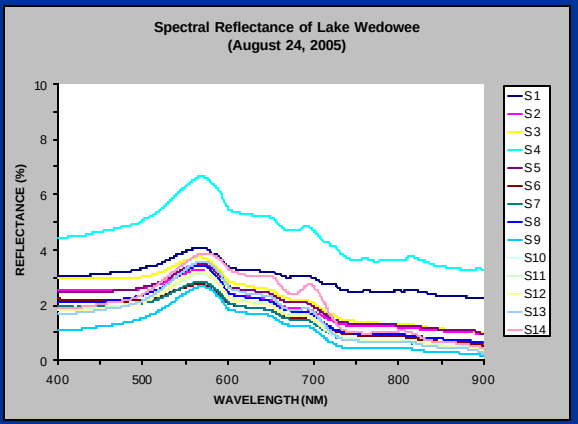
Spectral reflectance of Lake Harris

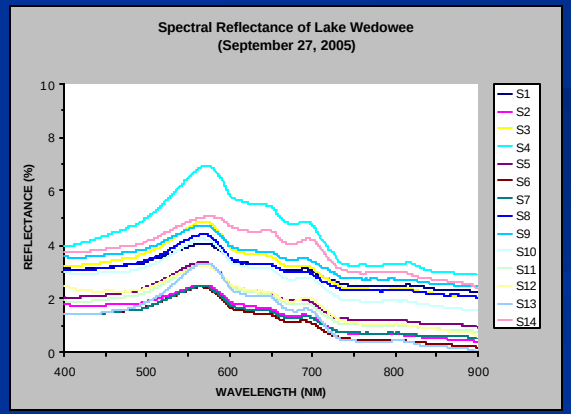


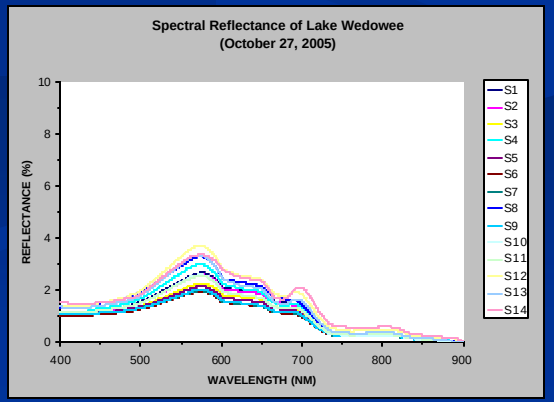




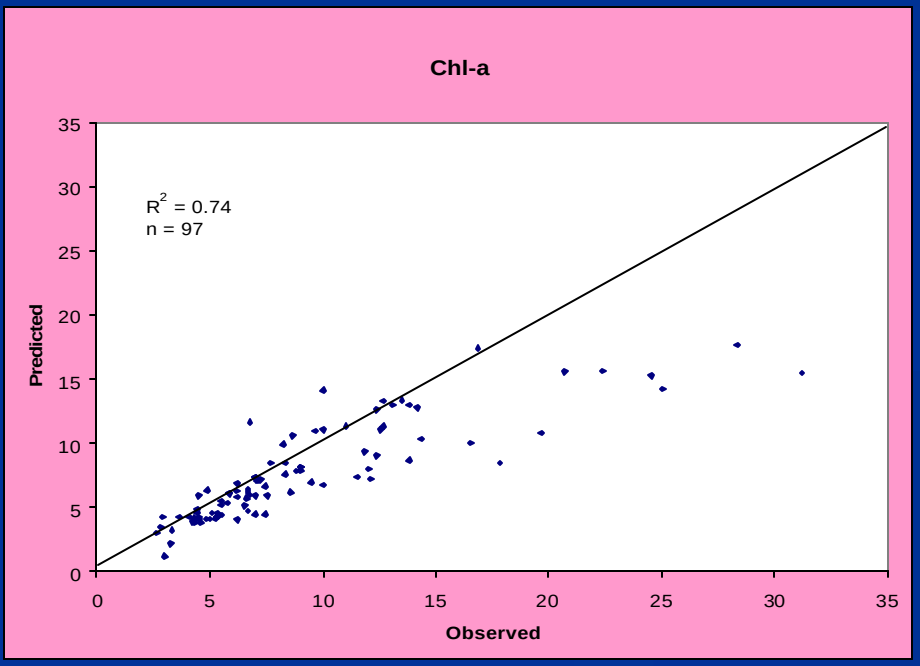


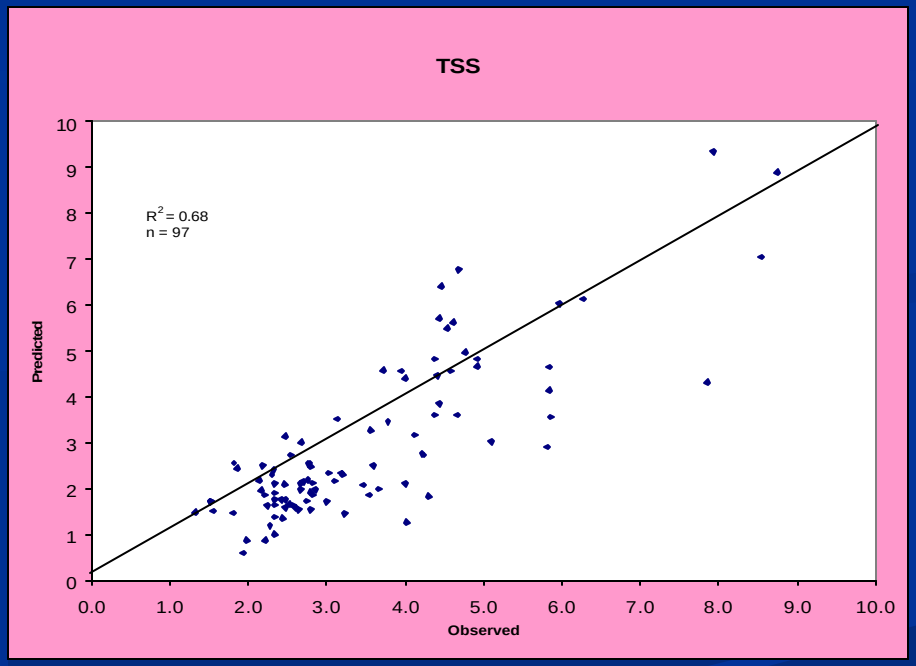






Estimating Chl a and TSS for Lake Harris

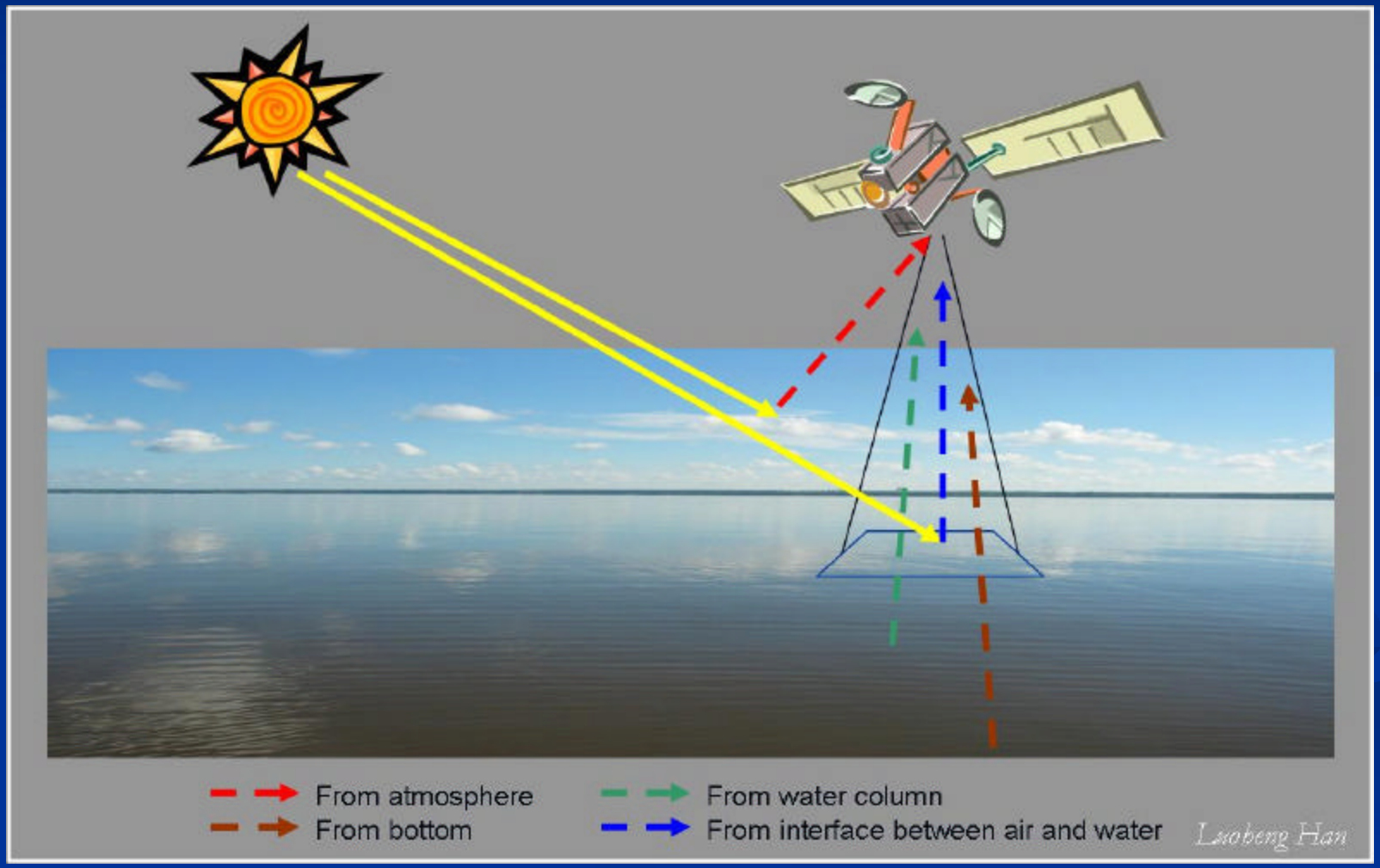




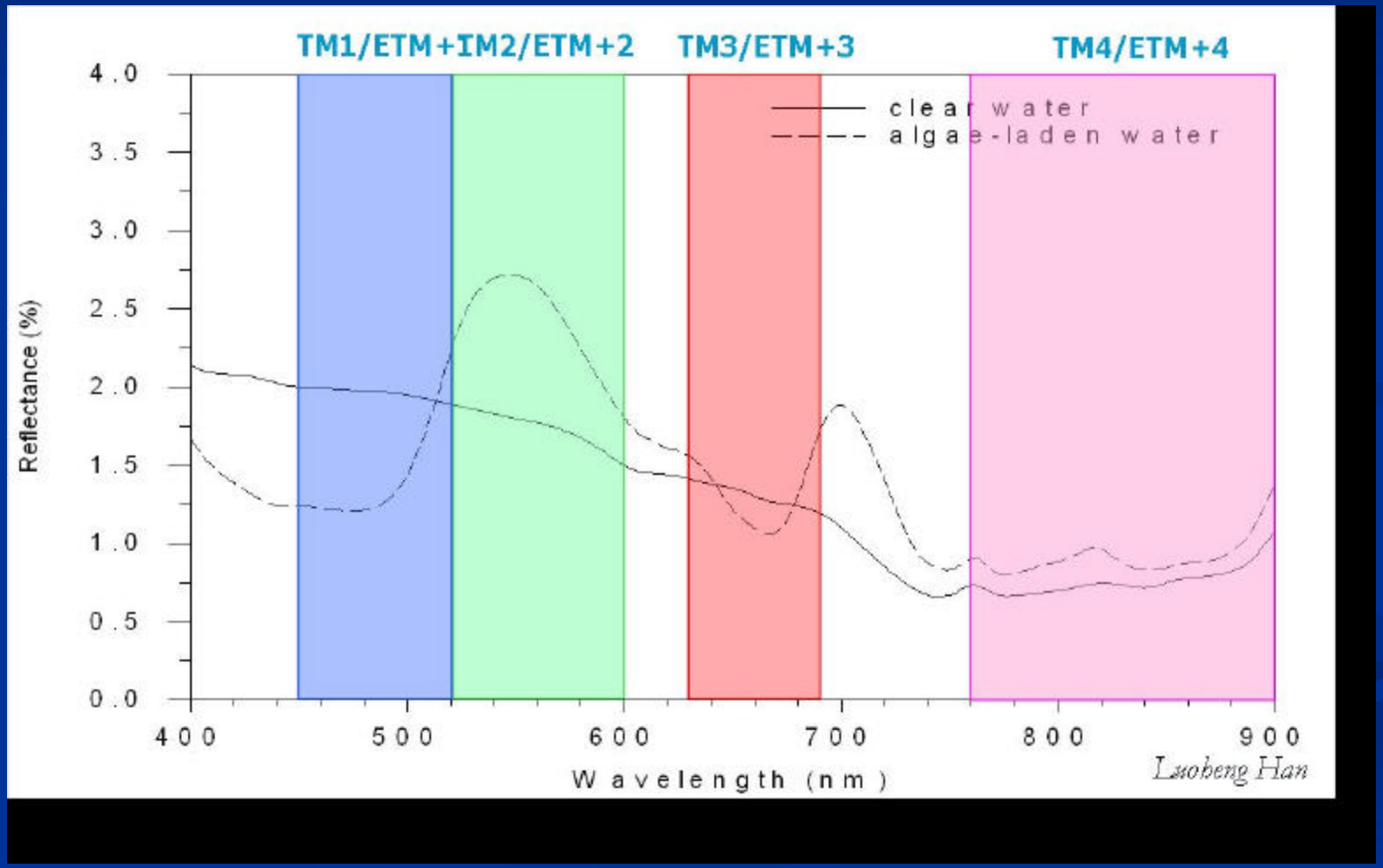
Objectives of Satellite Remote Sensing

- To model and map chlorophyll a and trophic state
- To derive and map land use and land cover

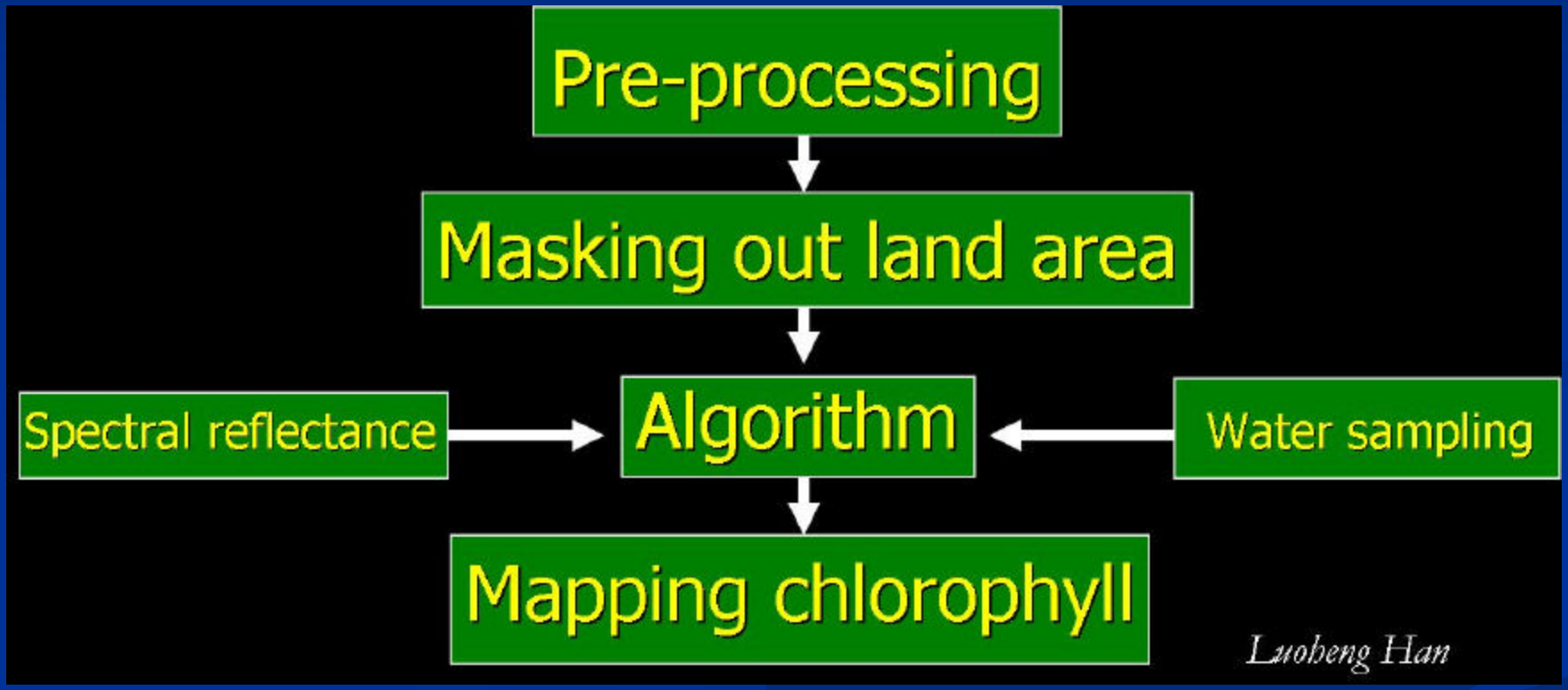
Principle of Satellite Sensing of Water

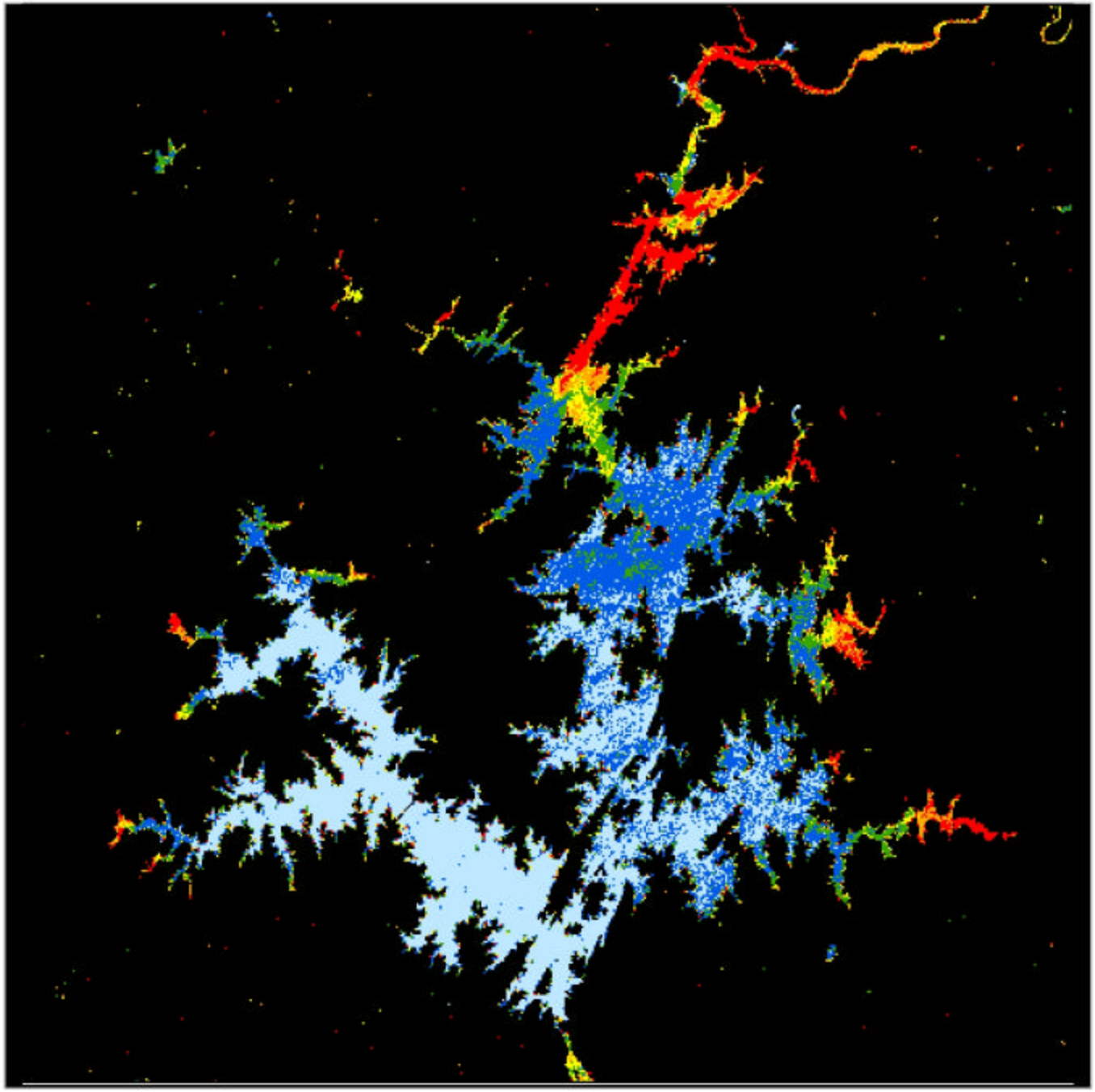


TM/ETM+ Bands vs. Chlorophyll Spectral Characteristics



Deriving Chl a from Landsat TM





Lake Martin Chlorophyll-a

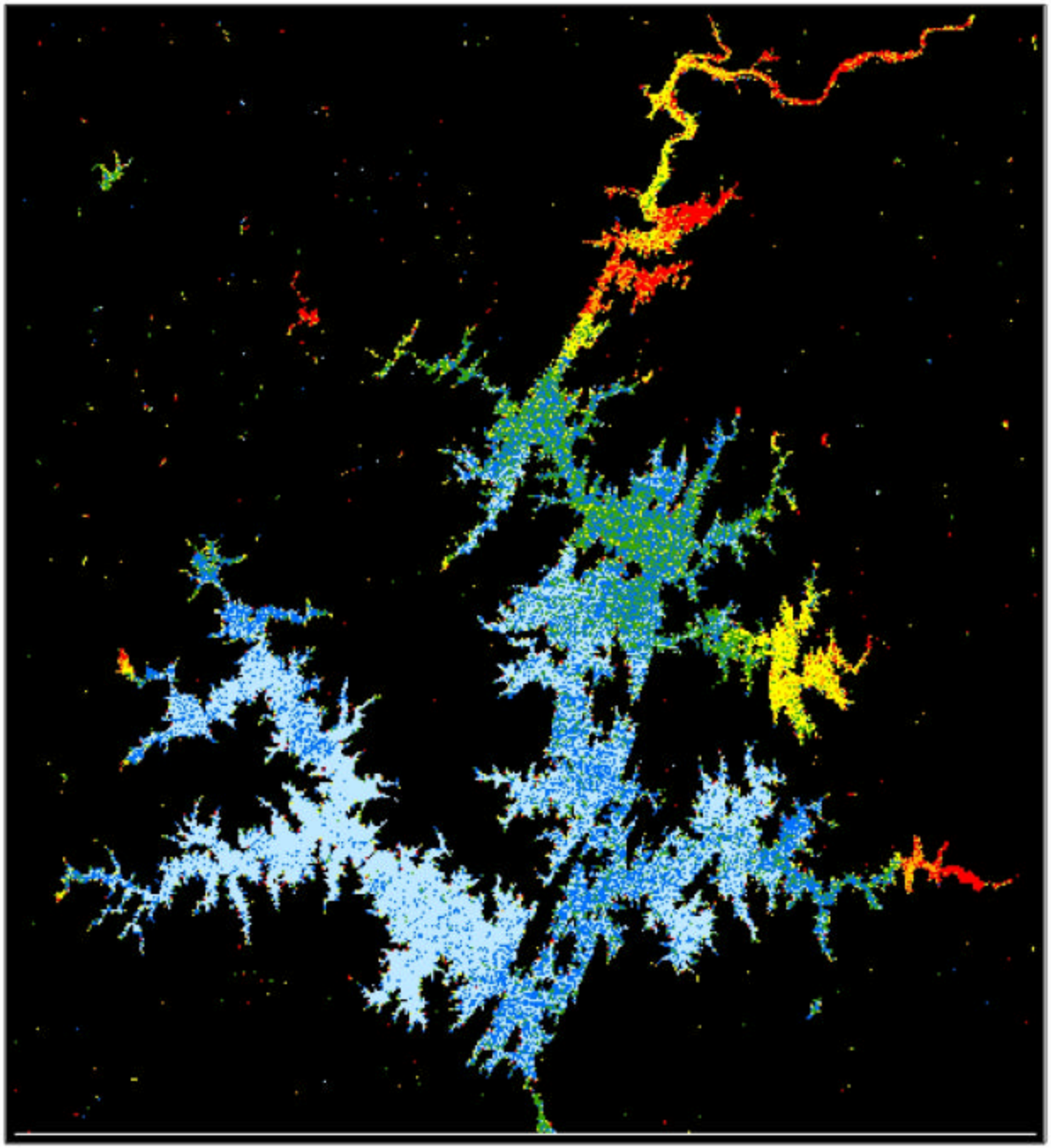
(Derived from April 15, 2004 Landsat-TM satellite image)

0 1.5 3 6 Kilometers

N

Chlorophyll-a micrograms/liter

- < 1.6
- 1.6 - 2.9
- 2.9 - 4.5
- 4.5 - 6.4
- 6.4 - 8.0
- > 8.0



Lake Martin Chlorophyll-a

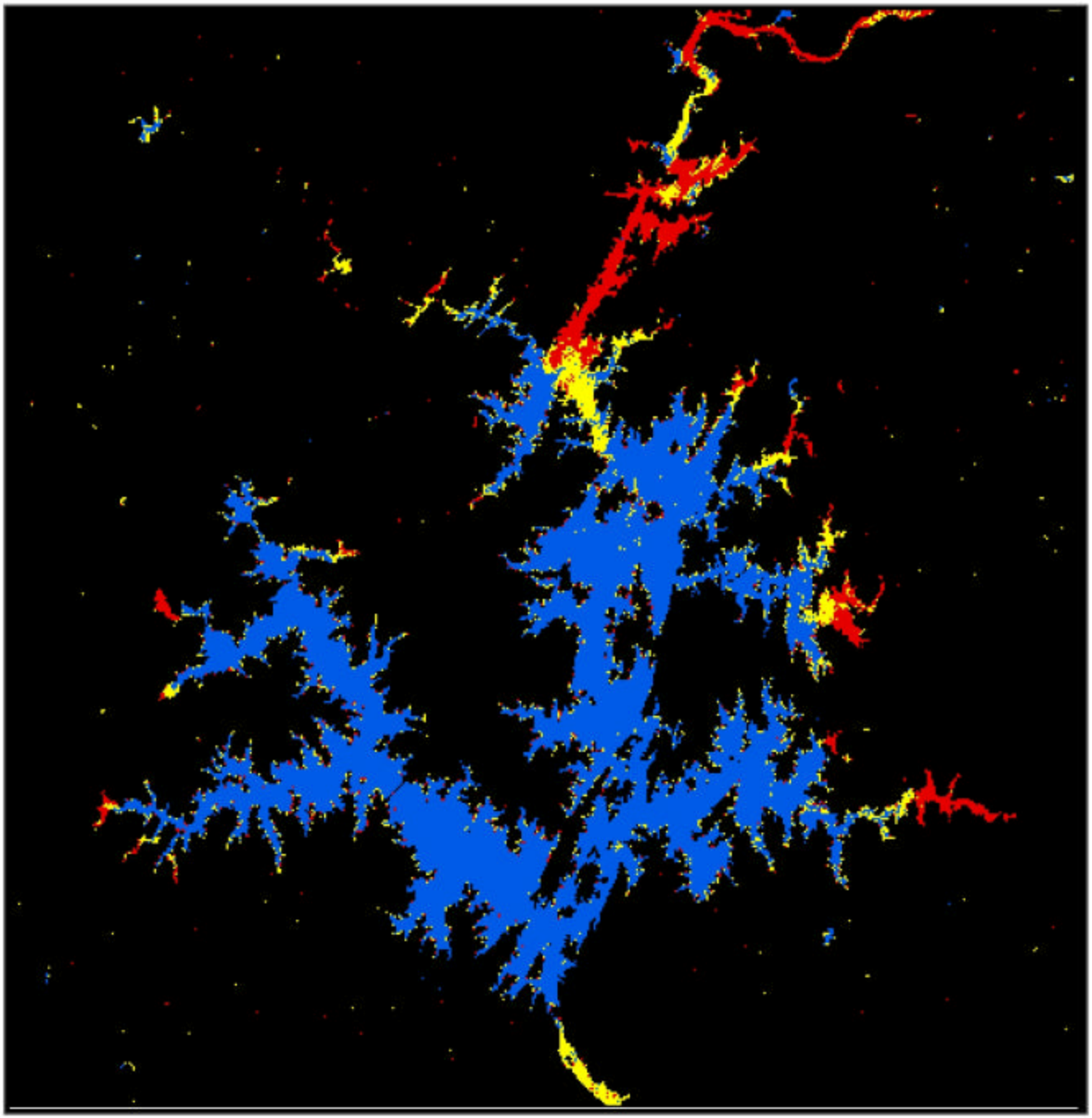
(Derived from September 22, 2004 Landsat-TM satellite image)

0 1.5 3 6 Kilometers

N

Chlorophyll-a micrograms/liter

- < 1.6
- 1.6 - 2.9
- 2.9 - 4.5
- 4.5 - 6.4
- 6.4 - 8.0
- > 8.0



Lake Martin Trophic State

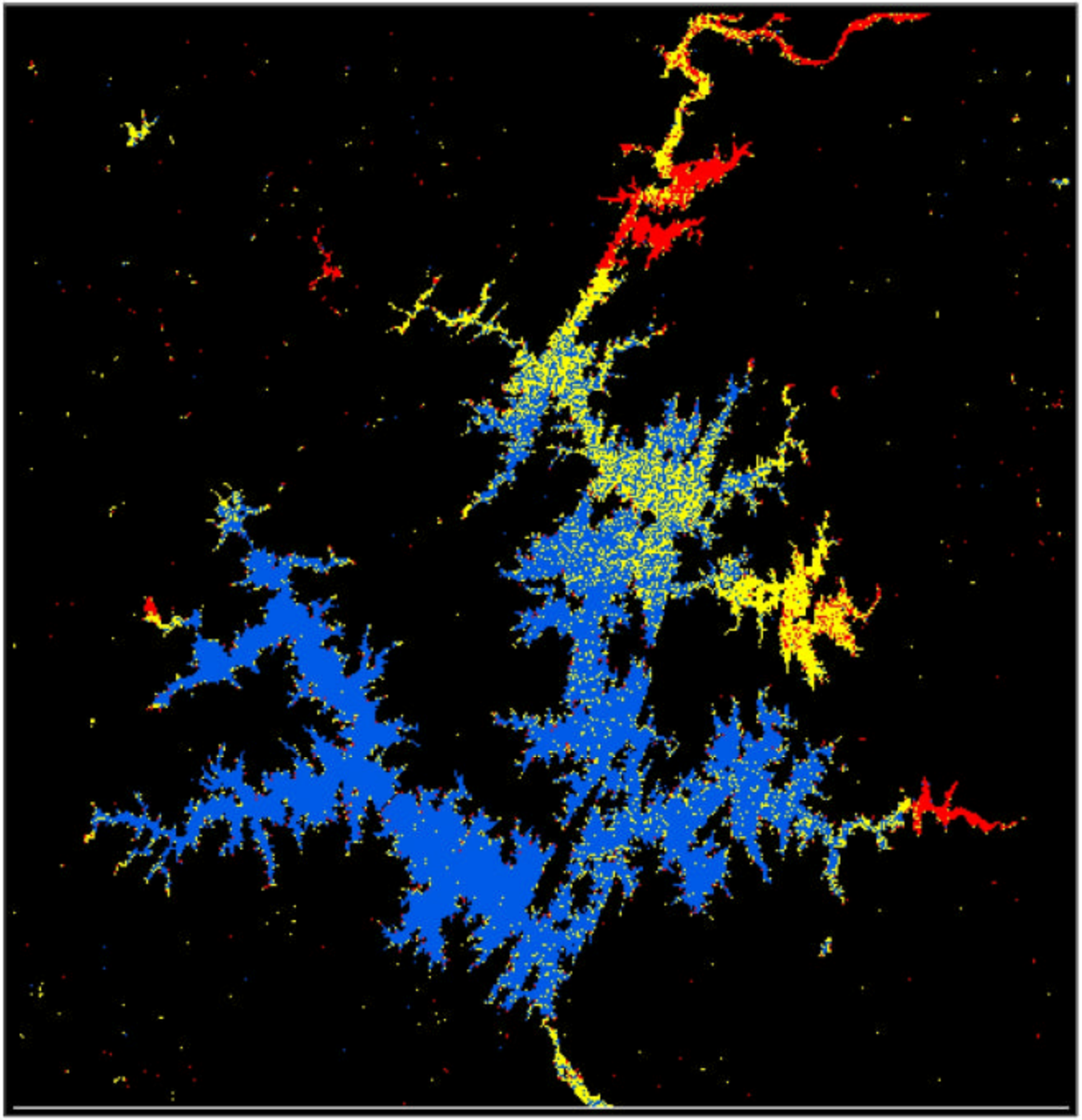
(Derived from April 15, 2004 Landsat-TM satellite image)

0 1.5 3 6 Kilometers

N

Trophic State

- Oligotrophic
- Mesotrophic
- Eutrophic



Lake Martin Trophic State

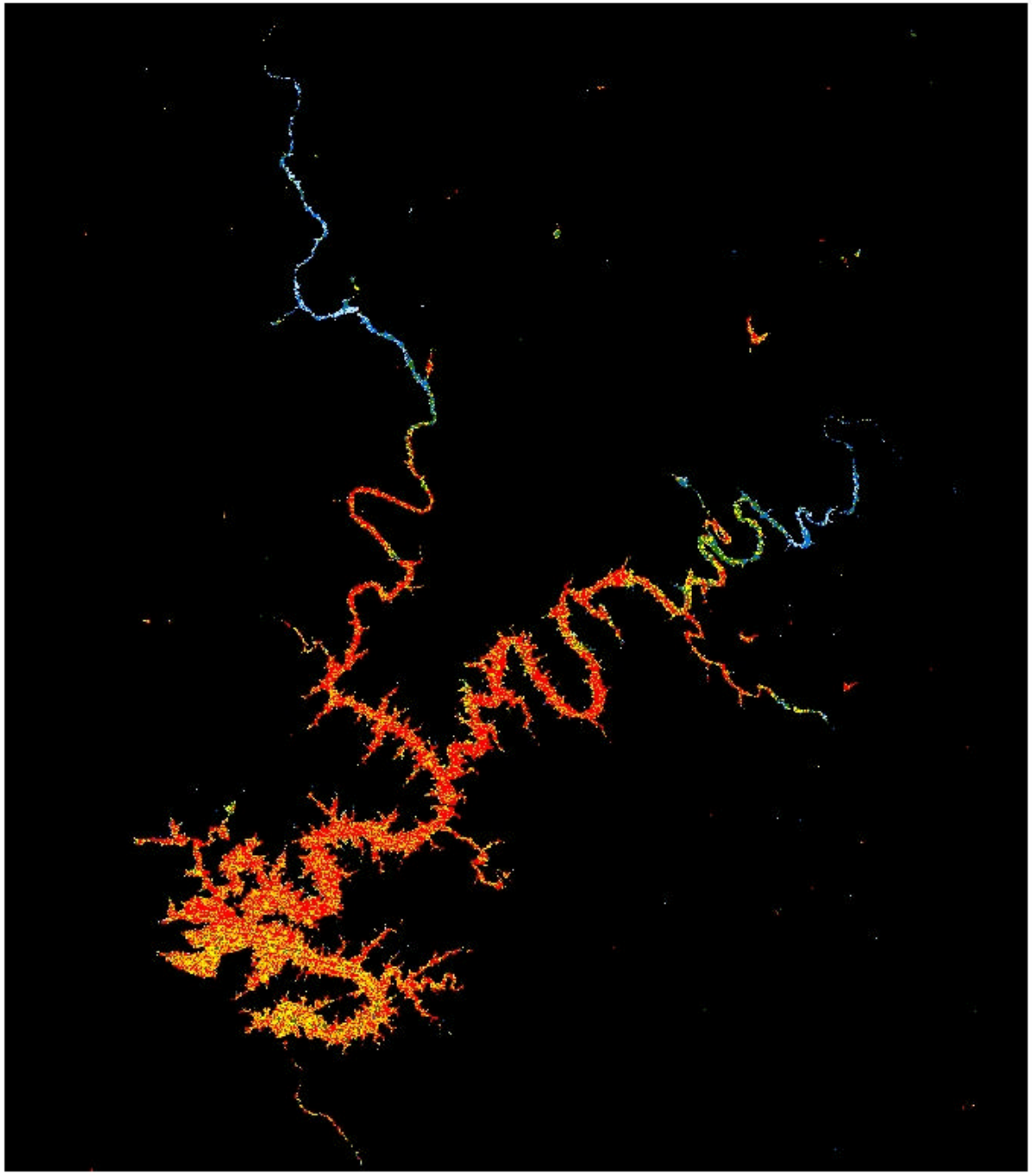
(Derived from September 22, 2004 Landsat-TM satellite image)

0 1.5 3 6 Kilometers

N

Trophic State

- Oligotrophic
- Mesotrophic
- Eutrophic



Lake Harris (Wedowee) Chlorophyll-a

(Derived from April 18, 2005 Landsat-5 TM satellite image)

N

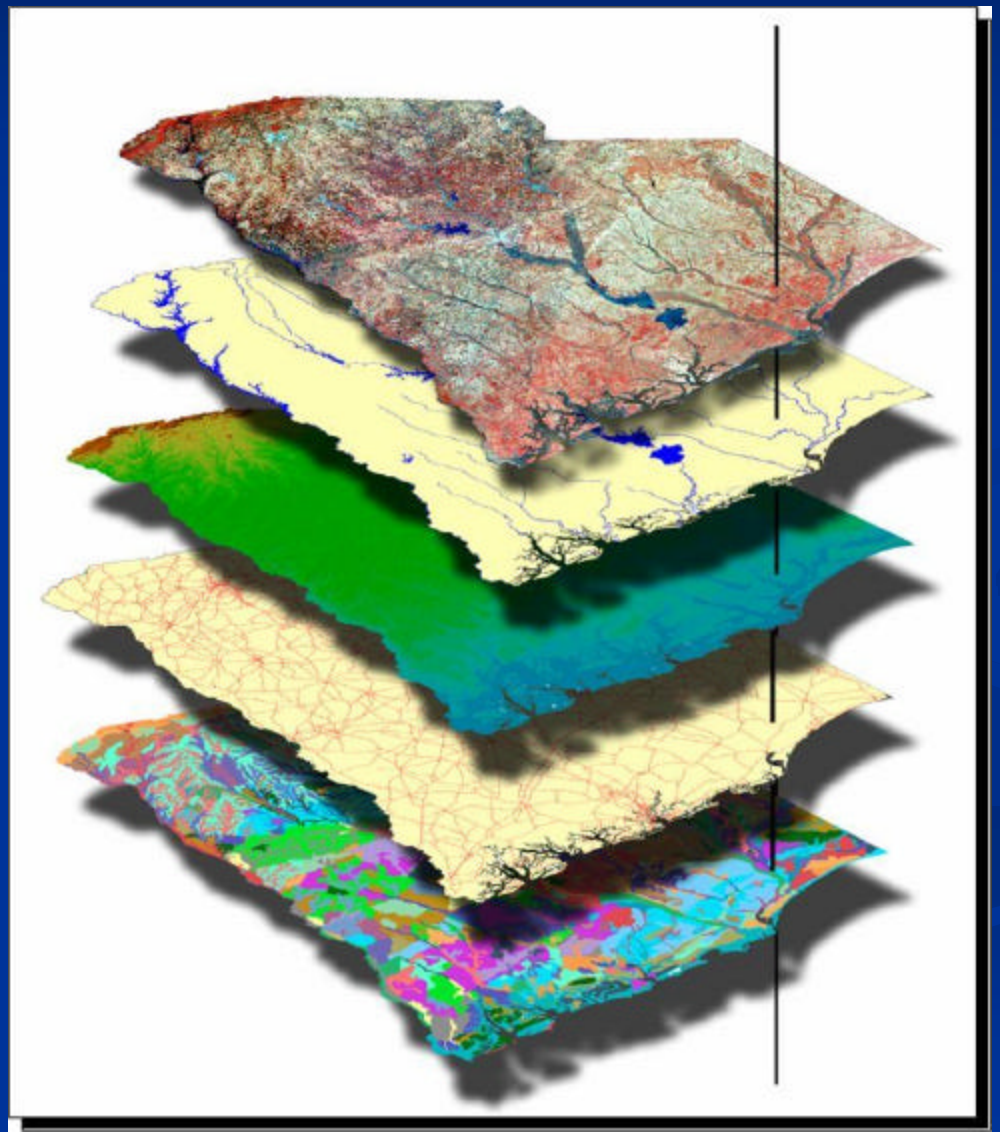
0 1 2 4 6 8 Kilometers

Chlorophyll-a

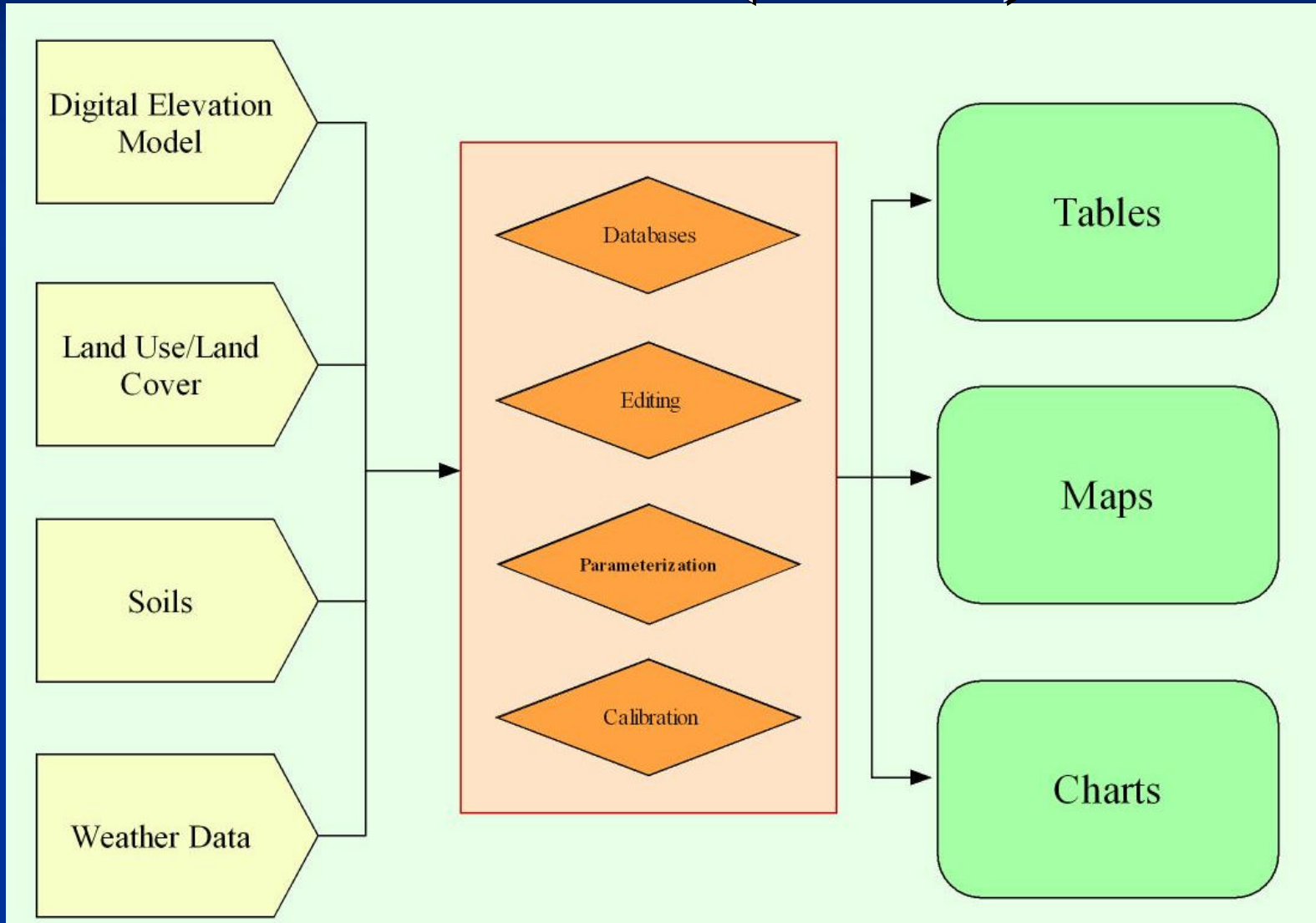
Value

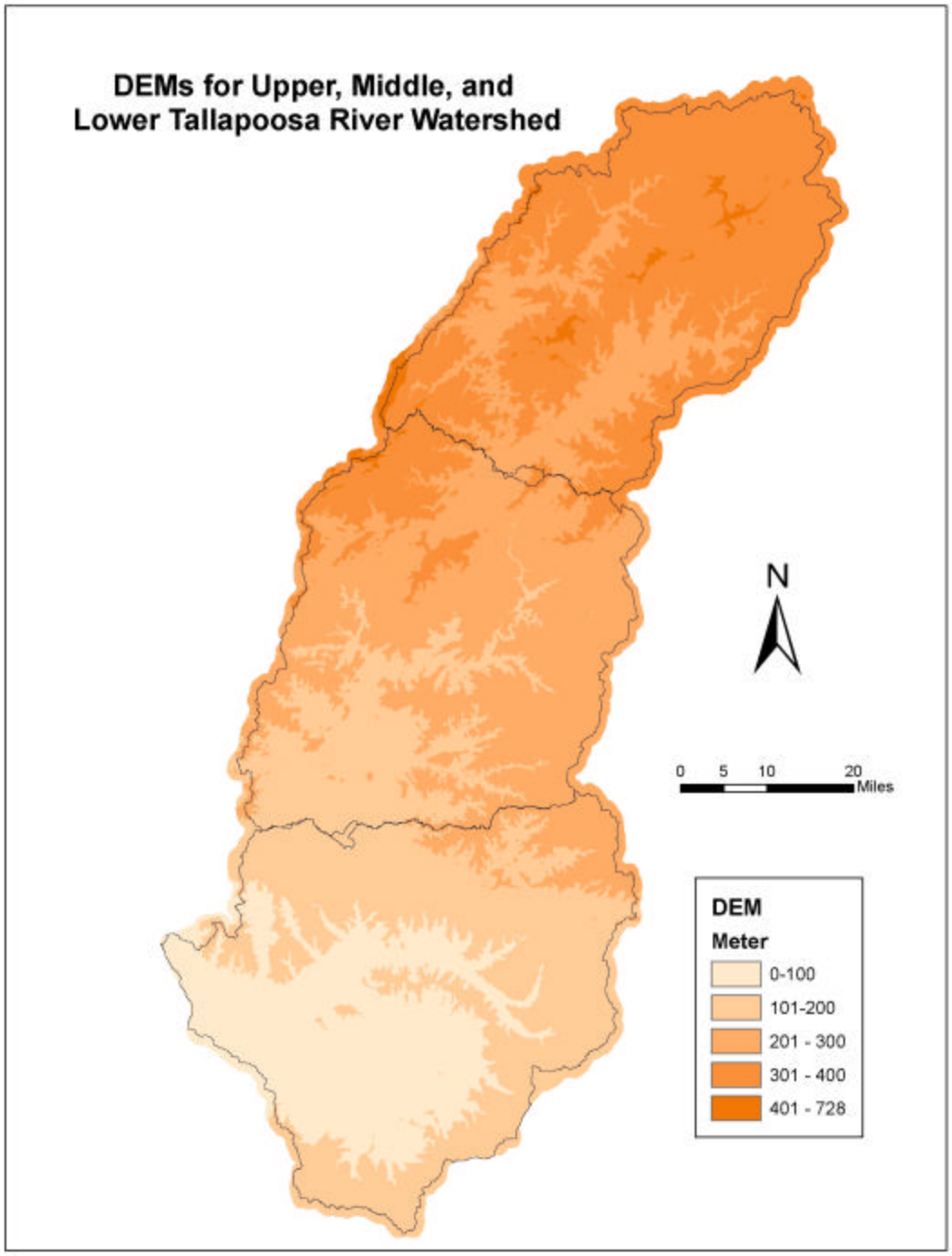
- < 1.5
- 1.5 - 4.9
- 4.9- 8.7
- 8.7 - 12.0
- 12.0 - 14.7
- > 14.7

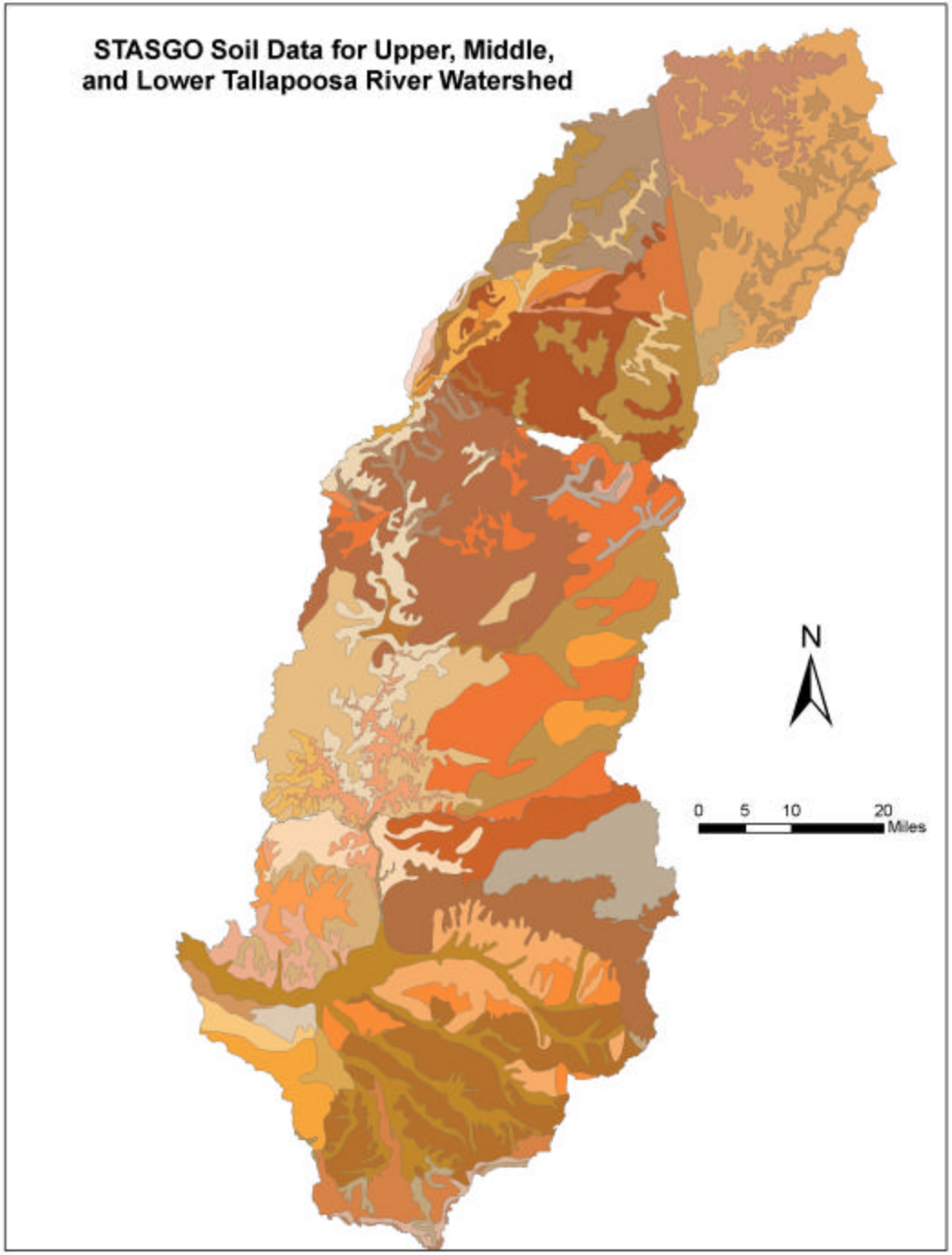
Modeling Nutrient Dynamics Using GIS



Framework of Soil & Water Assessment Tool (SWAT) model




DEMs for Upper, Middle, and
Lower Tallapoosa River Watershed
N
0 5 10 20
Miles
DEM
Meter
0-100
101-200
201 - 300
301 - 400
401 - 728


STASGO Soil Data for Upper, Middle,
and Lower Tallapoosa River Watershed
N
0 5 10 20
Miles

Historically Recorded Weather Data

Precipitation

Microsoft Excel - PCP

File Edit View Insert Format Tools Data
Window Help Nitro PDF

D16

	A	B	C	D	E
1	DATE	PCP			
2	1/1/2005	0.0			
3	1/2/2005	0.0			
4	1/3/2005	0.0			
5	1/4/2005	0.0			
6	1/5/2005	0.0			
7	1/6/2005	4.1			
8	1/7/2005	0.0			
9	1/8/2005	6.4			
10	1/9/2005	0.0			
11	1/10/2005	0.0			
12	1/11/2005	0.0			
13	1/12/2005	0.0			
14	1/13/2005	37.1			
15	1/14/2005	0.5			
16	1/15/2005	0.0			
17	1/16/2005	0.0			
18	1/17/2005	0.0			
19	1/18/2005	0.0			
20	1/19/2005	0.0			
21	1/20/2005	0.0			
22	1/21/2005	0.0			
23	1/22/2005	0.0			
24	1/23/2005	0.0			
25	1/24/2005	0.0			
26	1/25/2005	0.0			
27	1/26/2005	0.0			
28	1/27/2005	0.0			

Sheet1 Sheet2 She

NUM

Temperature

Microsoft Excel - Alexander

File Edit View Insert Format Tools Data
Window Help Nitro PDF

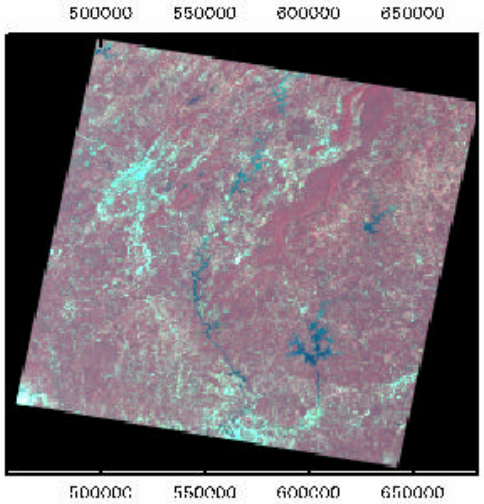
L11

	A	B	C	D	E
1	DATE	MAX	MIN		
2	1/1/2005	21.7	6.7		
3	1/2/2005	21.7	10.0		
4	1/3/2005	22.8	8.9		
5	1/4/2005	22.8	7.8		
6	1/5/2005	20.0	7.8		
7	1/6/2005	18.9	8.9		
8	1/7/2005	18.9	10.6		
9	1/8/2005	18.9	2.8		
10	1/9/2005	18.9	1.7		
11	1/10/2005	17.8	3.9		
12	1/11/2005	22.2	8.9		
13	1/12/2005	20.6	13.9		
14	1/13/2005	21.1	11.7		
15	1/14/2005	11.7	3.9		
16	1/15/2005	12.8	1.1		
17	1/16/2005	12.2	-3.9		
18	1/17/2005	3.9	-6.1		
19	1/18/2005	6.7	-6.1		
20	1/19/2005	7.8	-5.0		
21	1/20/2005	15.0	-3.9		
22	1/21/2005	20.6	1.1		
23	1/22/2005	17.2	-4.4		
24	1/23/2005	0.0	-6.1		
25	1/24/2005	8.9	-8.9		
26	1/25/2005	16.7	-2.8		
27	1/26/2005	20.6	6.7		
28	1/27/2005	12.8	2.8		

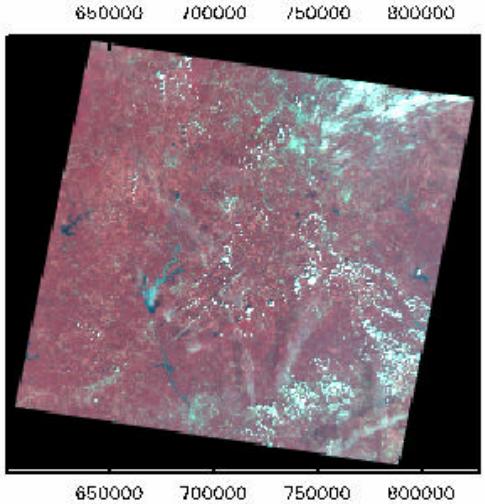
Sheet1 Sheet2 She

NUM

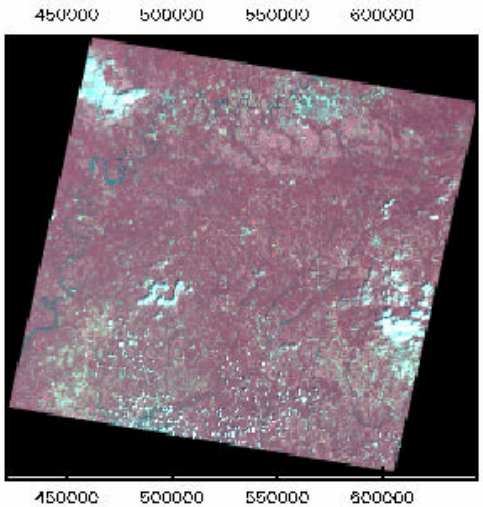
Four Multi-temporal Landsat TM Scenes Used



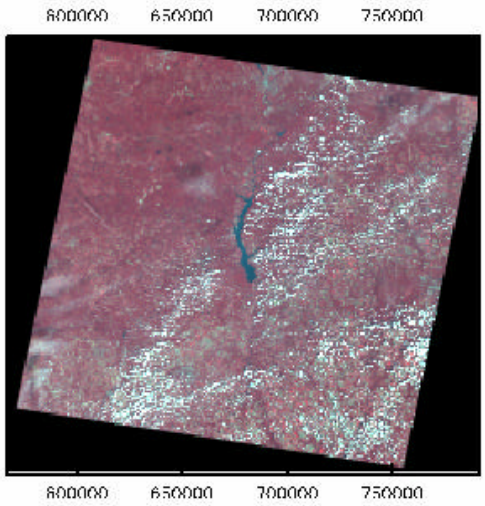
Upper Left



Upper Right



Lower Left



Lower Right

Scale

50 0 50 Kilometers

50 0 Miles

N

Product Information:

Standard False Color Composite
Spatial Resolution: 30 x 30 m
Coverage Area: 185 x 185 km
Acquisition Date:
Upper and Lower Left: Sep. 22nd 2004
Upper and Lower Right: Oct. 1st 2004

Land Use and Land Cover Types

Evergreen Forest

Mixed Forest

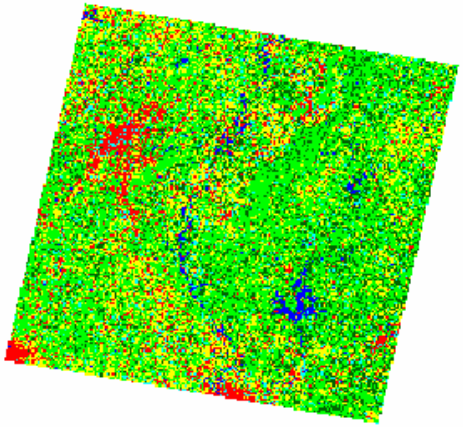
Water (Lake Harris)

Agriculture Land

Barren Land

Urban

Classification Results of Four Multi-temporal TM Scenes Before Any Preprocessing Procedure



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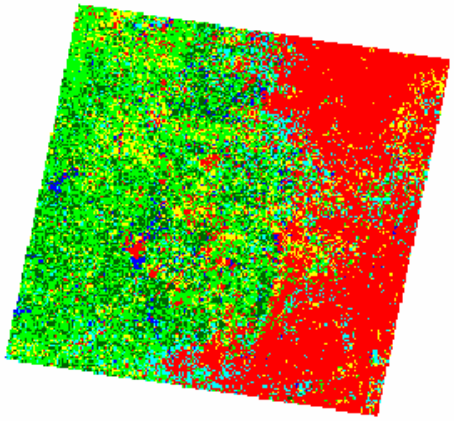
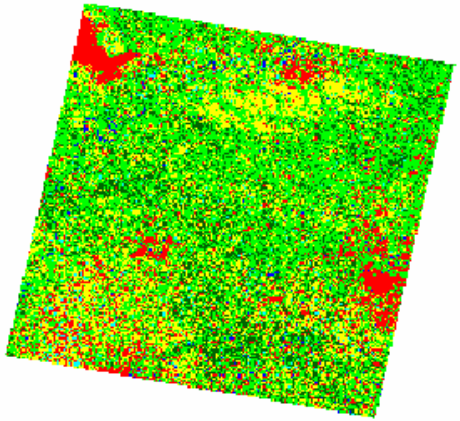


Upper Right



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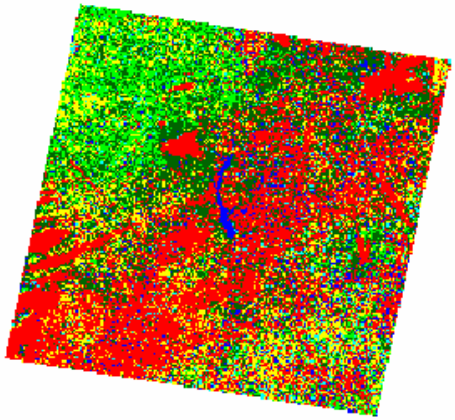

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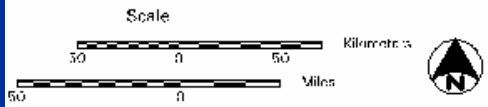
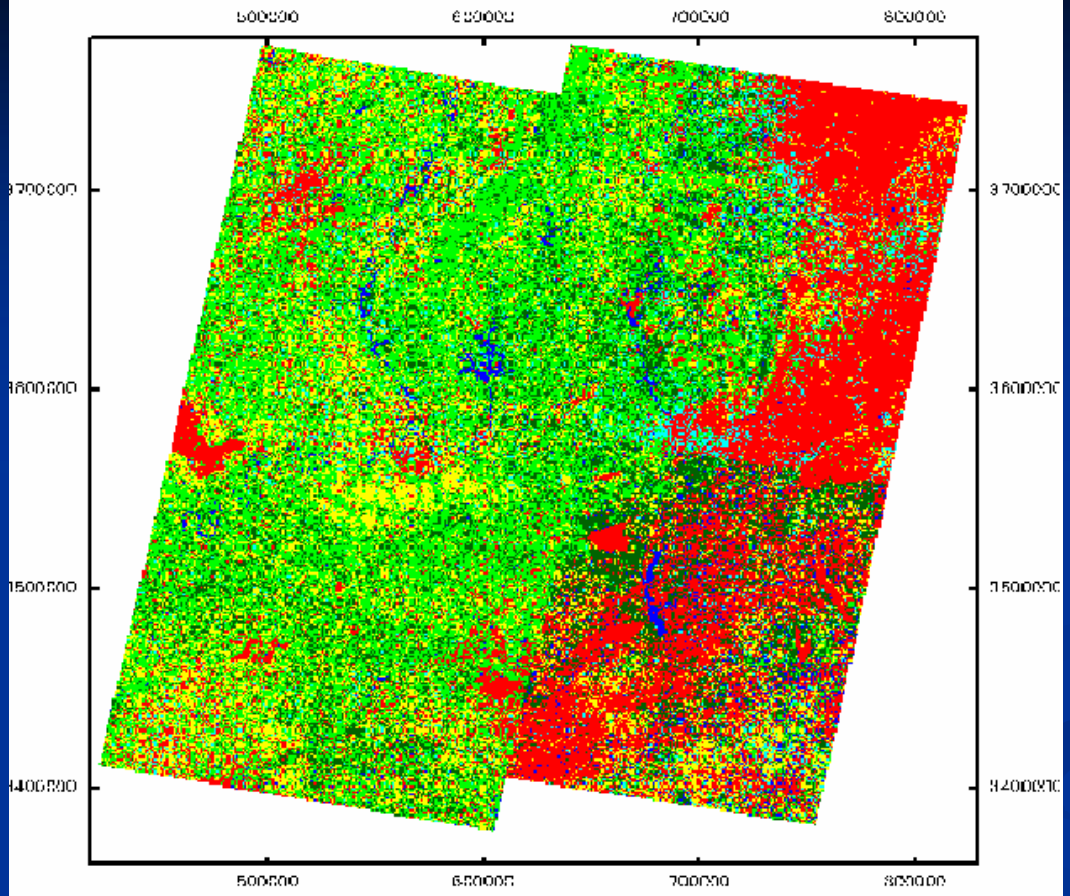
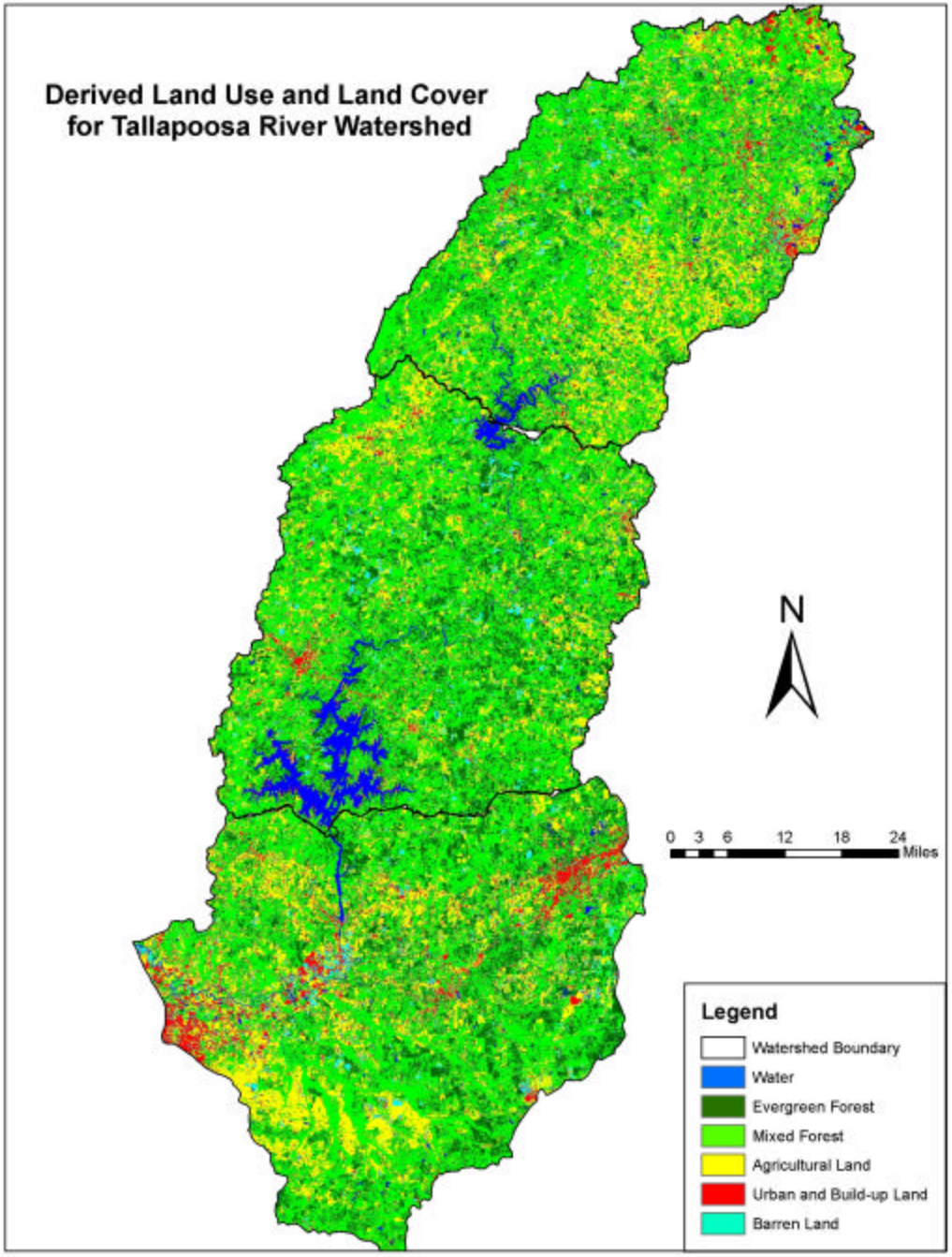


Mosaic of Four Land Use/Land Cover Images




Derived Land Use and Land Cover
for Tallapoosa River Watershed
N
0 3 6 12 18 24
Miles
Legend
Watershed Boundary
Water
Evergreen Forest
Mixed Forest
Agricultural Land
Urban and Build-up Land
Barren Land

Accuracy Assessment

Table 1. Error Matrix of Land Use and Land Cover Classification Derived from Landsat TM Data

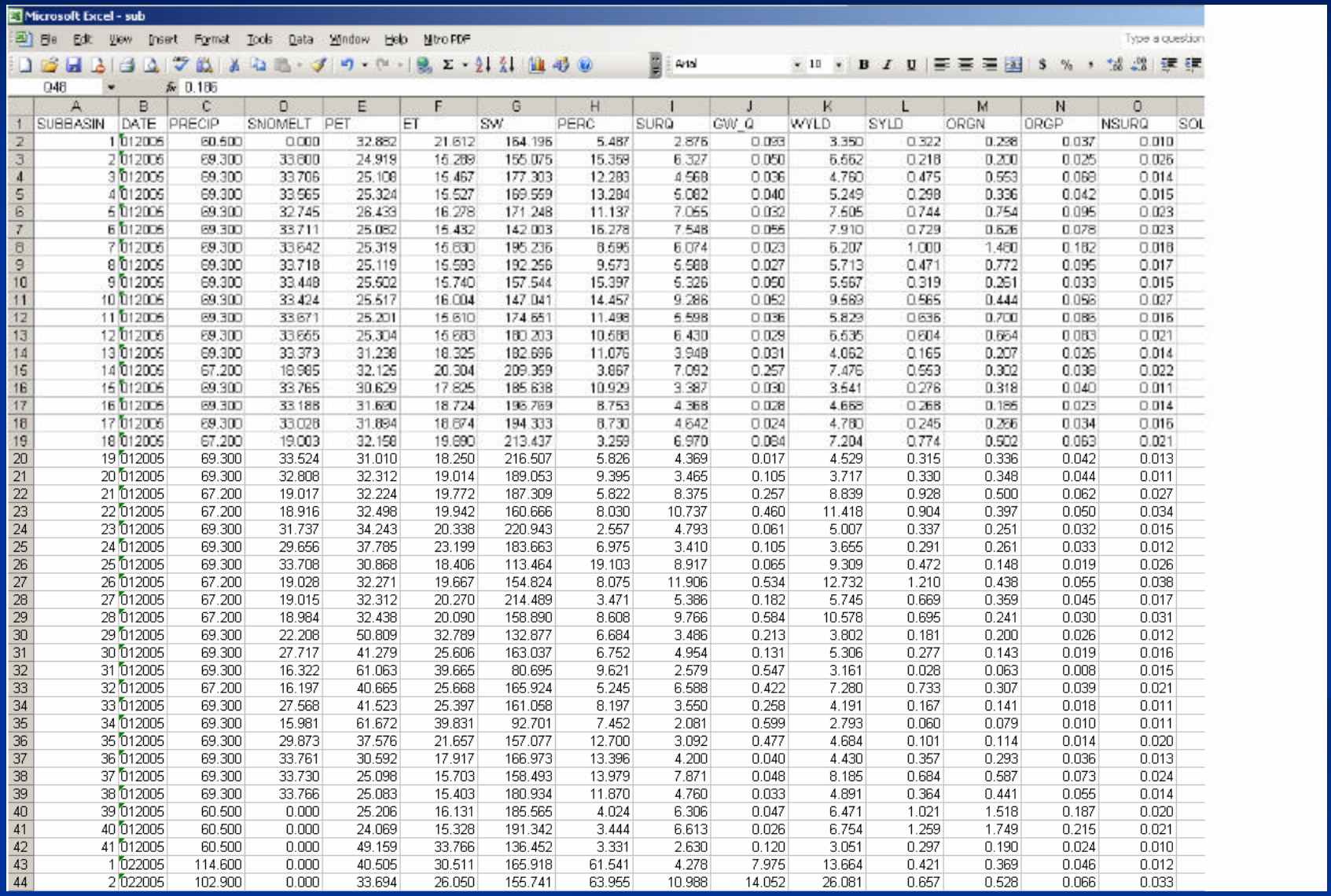
	Reference Data						
Classification	**Agriculture Land**	**Water**	**Barren Land**	**Evergreen Forest**	**Mixed Forest**	**Urban**	**Row Total**
Agriculture Land	34	0	1	0	0	0	35
Water	0	2	0	0	0	0	2
Barren Land	5	0	3	0	0	0	8
Evergreen Forest	0	0	3	12	1	0	16
Mixed Forest	0	0	1	2	11	0	14
Urban	0	0	0	0	0	11	11
Column Total	39	2	8	14	12	11	86
Overall Accuracy	=	73	/	86	=	**84.88%**	

Producer's Accuracy			**User's Accuracy**		
Agriculture Land	87.18	%	Agriculture Land	97.14	%
Water	100.00	%	Water	100.00	%
Barren Land	37.50	%	Barren Land	37.50	%
Evergreen Forest	85.71	%	Evergreen Forest	75.00	%
Mixed Forest	91.67	%	Mixed Forest	78.57	%
Urban	100.00	%	Urban	100.00	%

Computation of K_{hat} Coefficient

Total of Points	86		
Total of Correctly Classified	73	K_{hat} =	**80.30%**
Sum of Multiplied Totals	1722		

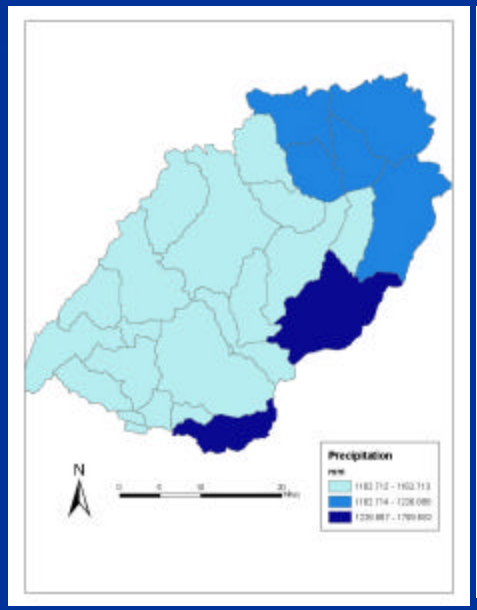
SWAT Output Table

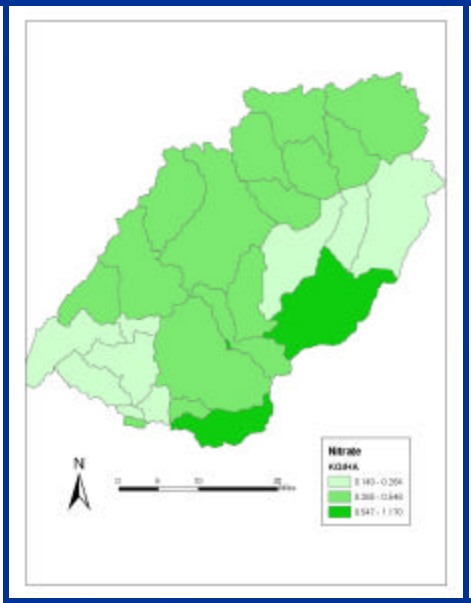


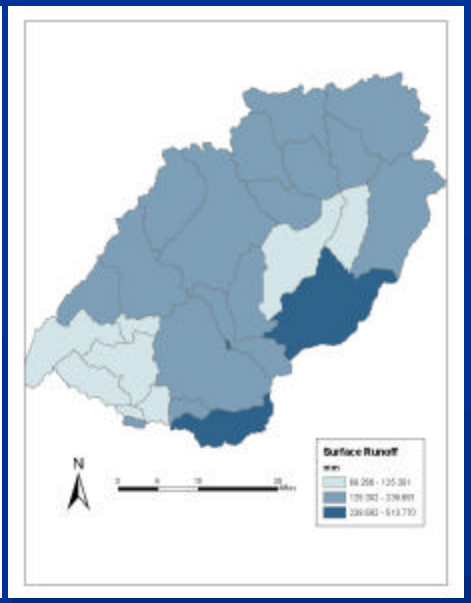
Microsoft Excel - sub

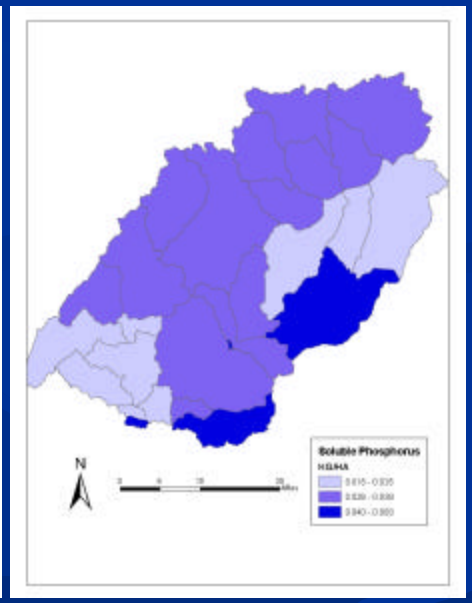
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	
1	SUBBASIN	DATE	PRECIP	SNOMELT	PET	ET	SW	PERC	SURQ	GW_Q	WYLD	SYLD	ORGN	ORGP	NSURQ	SOL
2	1	012006	60.500	0.000	32.882	21.612	164.196	5.487	2.876	0.093	3.350	0.322	0.238	0.037	0.010	
3	2	012006	69.300	33.600	24.919	16.289	155.075	15.359	6.327	0.050	6.662	0.218	0.200	0.025	0.026	
4	3	012006	69.300	33.706	25.108	15.467	177.303	12.283	4.568	0.036	4.760	0.475	0.553	0.068	0.014	
5	4	012006	69.300	33.565	25.324	15.527	169.559	13.284	5.082	0.040	5.249	0.298	0.336	0.042	0.015	
6	5	012006	69.300	32.745	26.439	16.278	171.248	11.137	7.065	0.032	7.605	0.744	0.754	0.095	0.023	
7	6	012006	69.300	33.711	25.082	15.432	142.003	16.278	7.548	0.055	7.910	0.729	0.626	0.078	0.023	
8	7	012006	69.300	33.642	25.319	15.630	195.236	8.695	6.074	0.023	6.207	1.000	1.460	0.182	0.018	
9	8	012006	69.300	33.718	25.119	15.593	192.256	9.573	5.588	0.027	5.713	0.471	0.772	0.095	0.017	
10	9	012006	69.300	33.448	25.602	15.740	157.544	15.397	5.326	0.050	5.567	0.319	0.261	0.033	0.015	
11	10	012006	69.300	33.424	25.517	16.004	147.041	14.457	9.286	0.052	9.683	0.565	0.444	0.056	0.027	
12	11	012006	69.300	33.671	25.201	15.610	174.651	11.498	5.598	0.036	5.823	0.636	0.700	0.086	0.016	
13	12	012006	69.300	33.665	25.304	15.683	180.203	10.686	6.430	0.029	6.635	0.604	0.664	0.083	0.021	
14	13	012006	69.300	33.373	31.238	18.325	182.696	11.076	3.948	0.031	4.062	0.165	0.207	0.025	0.014	
15	14	012006	67.200	18.985	32.125	20.304	209.359	3.867	7.092	0.257	7.476	0.553	0.302	0.038	0.022	
16	15	012006	69.300	33.765	30.629	17.825	185.638	10.929	3.387	0.030	3.541	0.276	0.318	0.040	0.011	
17	16	012006	69.300	33.188	31.680	18.724	196.769	8.753	4.368	0.028	4.668	0.268	0.186	0.023	0.014	
18	17	012006	69.300	33.028	31.894	18.674	194.333	8.730	4.642	0.024	4.780	0.245	0.266	0.034	0.016	
19	18	012006	67.200	19.003	32.158	19.690	213.437	3.259	6.970	0.084	7.204	0.774	0.502	0.063	0.021	
20	19	012005	69.300	33.524	31.010	18.250	216.507	5.826	4.369	0.017	4.529	0.315	0.336	0.042	0.013	
21	20	012005	69.300	32.808	32.312	19.014	189.053	9.395	3.465	0.105	3.717	0.330	0.348	0.044	0.011	
22	21	012005	67.200	19.017	32.224	19.772	187.309	5.822	8.375	0.257	8.839	0.928	0.500	0.062	0.027	
23	22	012005	67.200	18.916	32.498	19.942	160.666	8.030	10.737	0.460	11.418	0.904	0.397	0.050	0.034	
24	23	012005	69.300	31.737	34.243	20.338	220.943	2.557	4.793	0.061	5.007	0.337	0.251	0.032	0.015	
25	24	012005	69.300	29.656	37.785	23.199	183.663	6.975	3.410	0.105	3.655	0.291	0.261	0.033	0.012	
26	25	012005	69.300	33.708	30.868	18.406	113.464	19.103	8.917	0.065	9.309	0.472	0.148	0.019	0.026	
27	26	012005	67.200	19.028	32.271	19.667	154.824	8.075	11.906	0.534	12.732	1.210	0.438	0.055	0.038	
28	27	012005	67.200	19.015	32.312	20.270	214.489	3.471	5.386	0.182	5.745	0.669	0.359	0.045	0.017	
29	28	012005	67.200	18.984	32.438	20.090	158.890	8.608	9.766	0.584	10.578	0.695	0.241	0.030	0.031	
30	29	012005	69.300	22.208	50.809	32.789	132.877	6.684	3.486	0.213	3.802	0.181	0.200	0.026	0.012	
31	30	012005	69.300	27.717	41.279	25.606	163.037	6.752	4.954	0.131	5.306	0.277	0.143	0.019	0.016	
32	31	012005	69.300	16.322	61.063	39.665	80.695	9.621	2.579	0.547	3.161	0.028	0.063	0.008	0.015	
33	32	012005	67.200	16.197	40.665	25.668	165.924	5.245	6.588	0.422	7.280	0.733	0.307	0.039	0.021	
34	33	012005	69.300	27.568	41.523	25.397	161.058	8.197	3.550	0.258	4.191	0.167	0.141	0.018	0.011	
35	34	012005	69.300	15.981	61.672	39.831	92.701	7.452	2.081	0.599	2.793	0.060	0.079	0.010	0.011	
36	35	012005	69.300	29.873	37.576	21.657	157.077	12.700	3.092	0.477	4.684	0.101	0.114	0.014	0.020	
37	36	012005	69.300	33.761	30.592	17.917	166.973	13.396	4.200	0.040	4.430	0.357	0.293	0.036	0.013	
38	37	012005	69.300	33.730	25.098	15.703	158.493	13.979	7.871	0.048	8.185	0.684	0.587	0.073	0.024	
39	38	012005	69.300	33.766	25.083	15.403	180.934	11.870	4.760	0.033	4.891	0.364	0.441	0.055	0.014	
40	39	012005	60.500	0.000	25.206	16.131	185.565	4.024	6.306	0.047	6.471	1.021	1.518	0.187	0.020	
41	40	012005	60.500	0.000	24.069	15.328	191.342	3.444	6.613	0.026	6.754	1.259	1.749	0.215	0.021	
42	41	012005	60.500	0.000	49.159	33.766	136.452	3.331	2.630	0.120	3.051	0.297	0.190	0.024	0.010	
43	1	022005	114.600	0.000	40.505	30.511	165.918	61.541	4.278	7.975	13.664	0.421	0.369	0.046	0.012	
44	2	022005	102.900	0.000	33.694	26.050	155.741	63.955	10.988	14.052	26.081	0.657	0.528	0.066	0.033	

SWAT Outputs of UTW

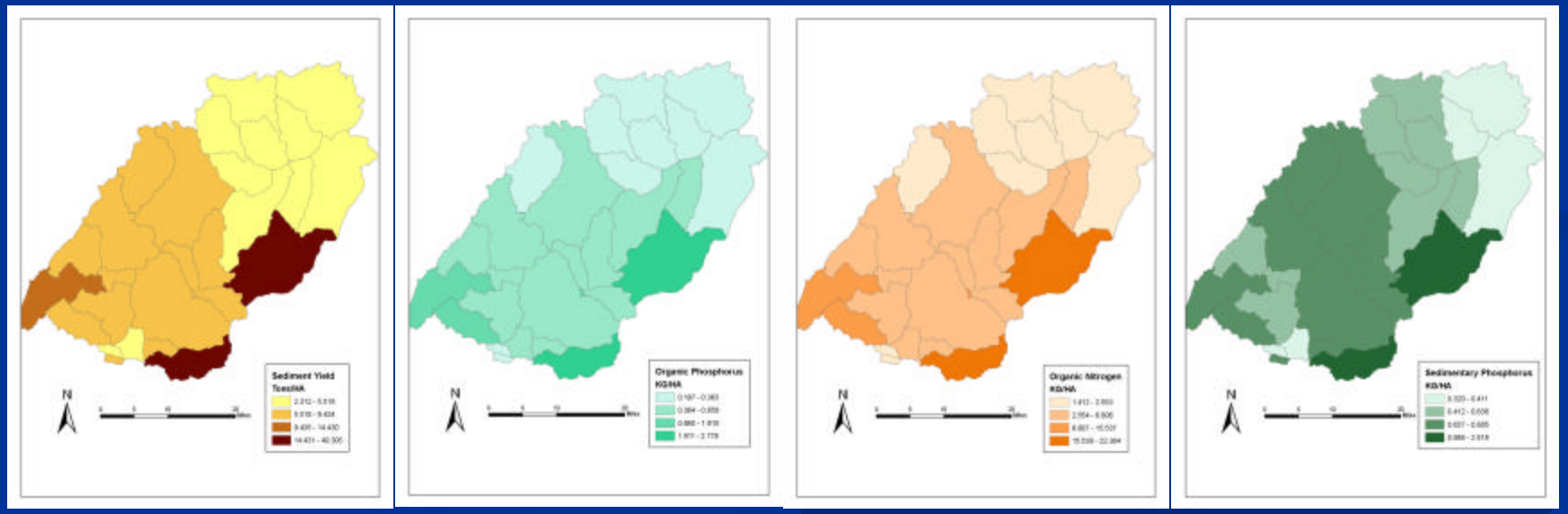








SWAT Outputs of UTW, cont'd



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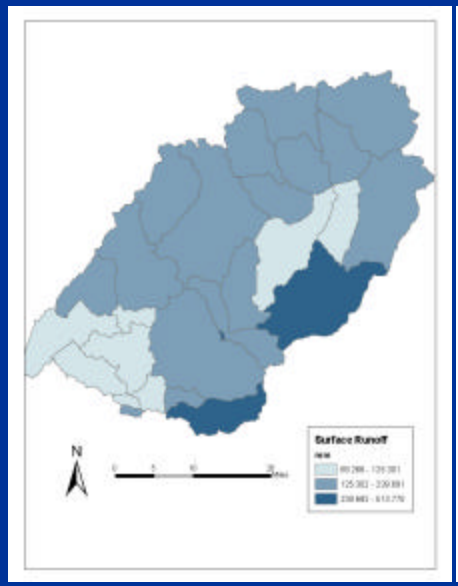
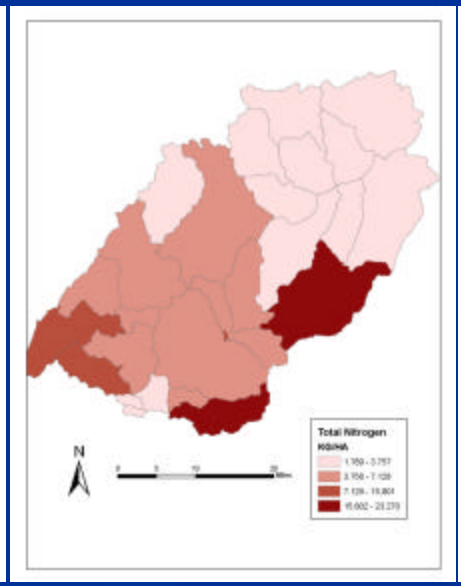
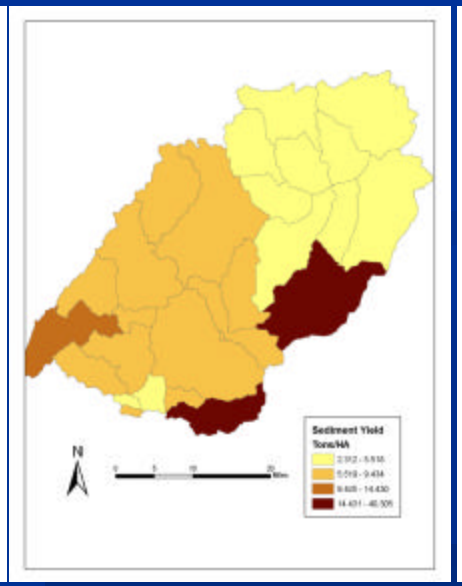
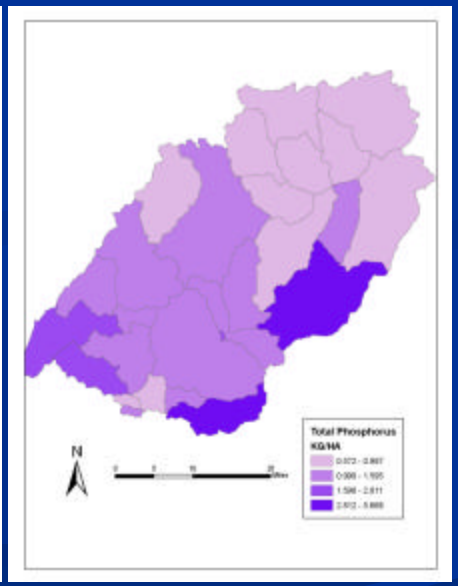


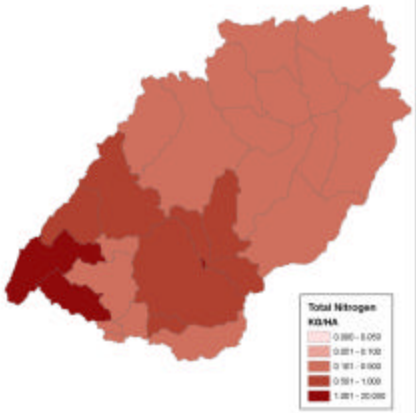




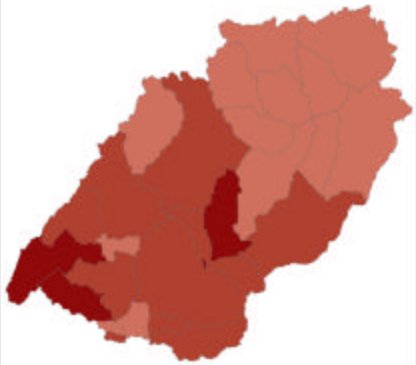


Monthly TN for UTW

January

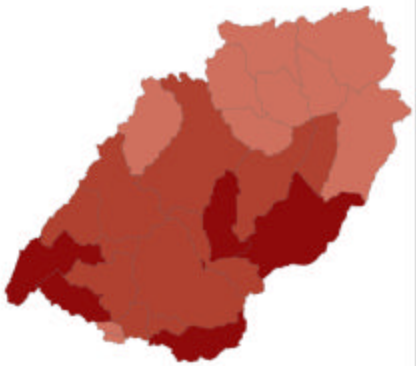


February

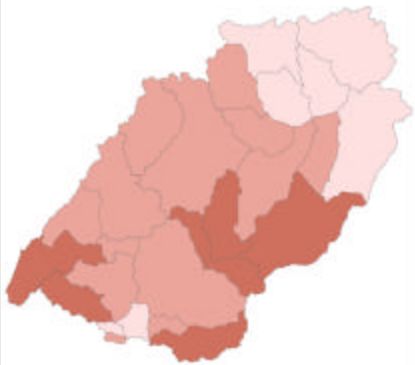


March

April



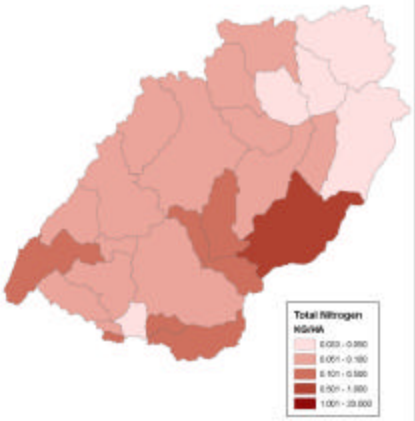
May



June

Monthly TN for UTW, cont'd

July



August

September

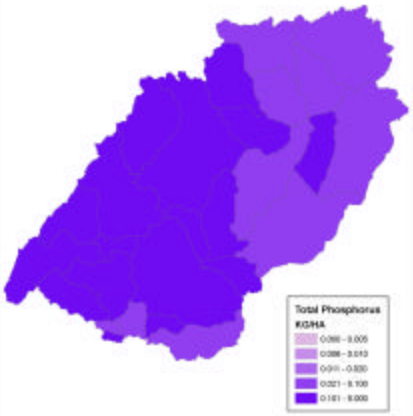
October

November

December

Monthly TP for UTW

January

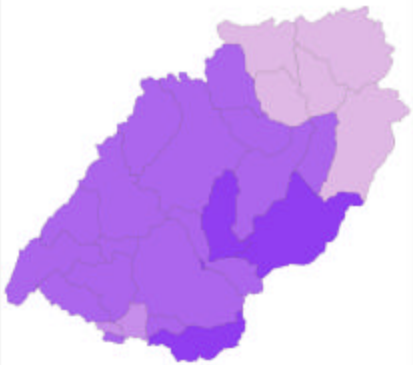


February

March

April

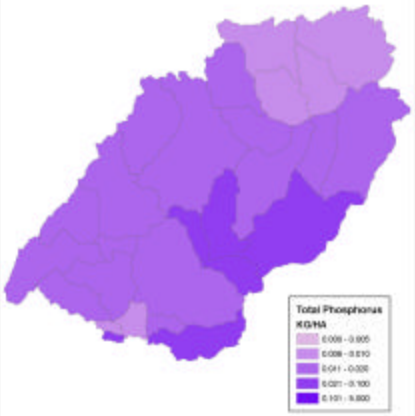
May



June

Monthly TP for UTW, cont'd

July



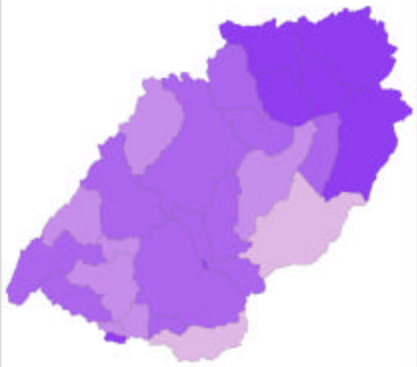
August

September

October

November

December



Conclusions

- Spectral reflectance collected with handheld spectroradiomters may be an practical alternative to standard sampling with regard to estimating some water quality parameters, e.g., chlorophyll
- Satellite imagery are useful in mapping optically active water quality parameters
- GIS based nutrient dynamic models can provide insight to a watershed with regard to the source of nutrients and water quality

Acknowledgements

- This project is funded by the USDA, Cooperative Research, Education and Extension System (CSREES)
- Gang Wang, a graduate research assistant at University of Alabama, assisted in SWAT and GIS modeling