Remote Sensing for Lake Management

Assessment of Water Quality of a Eutrophic Lake in North Central Florida

***Prepared for*:**

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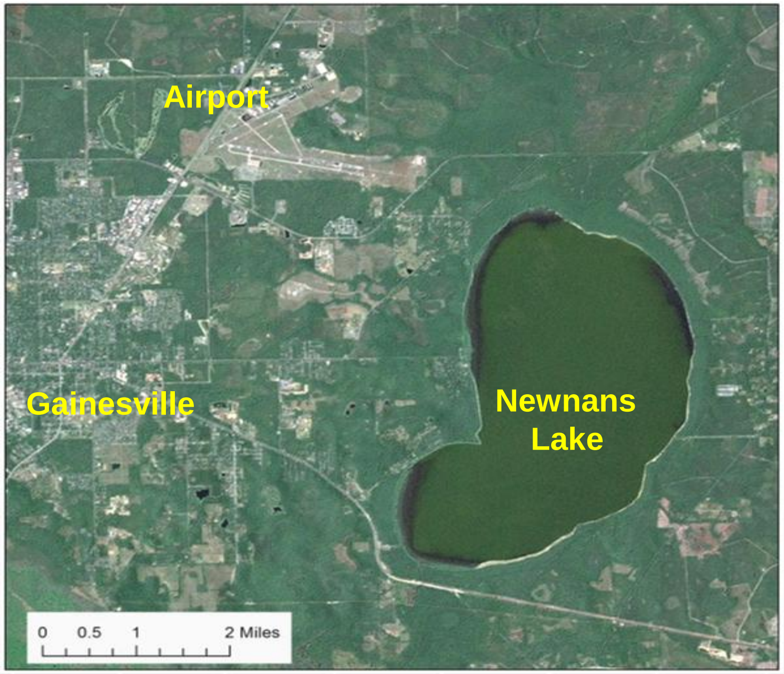
Overview & Objective

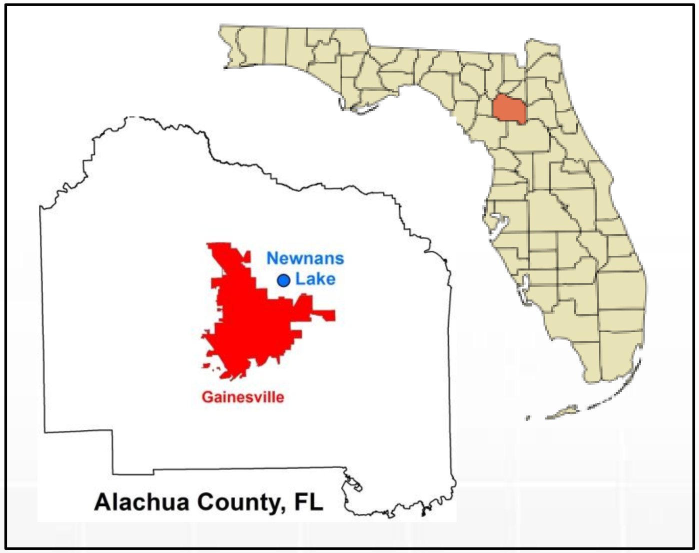
Determine if remote sensing data can be used to assess water quality for shallow eutrophic lakes in North Central Florida

- ***In Situ* data collection**
- **Satellite imagery**
- **Remote sensing used effectively to assess water quality in deep (> 15 ft) northern lakes ***
- **Determine applicability of deep water model to shallow lakes (< 10 ft)**

* Remote Sensing Methods for Lake Management: A Guide for Resource Managers and Decision-Makers, NALMS, Madison, WI, 2009

Study Area – Newnans Lake





Hydrological Features

FEATURE	VALUE
Area (acres)	6,600
Average Depth (ft)	4.4
Maximum Depth (ft)	11.5
Volume (ac-ft)	29,000
Average Stage (ft NGVD)	66.5

SJRWMD Tech Pub. SJ2010-1

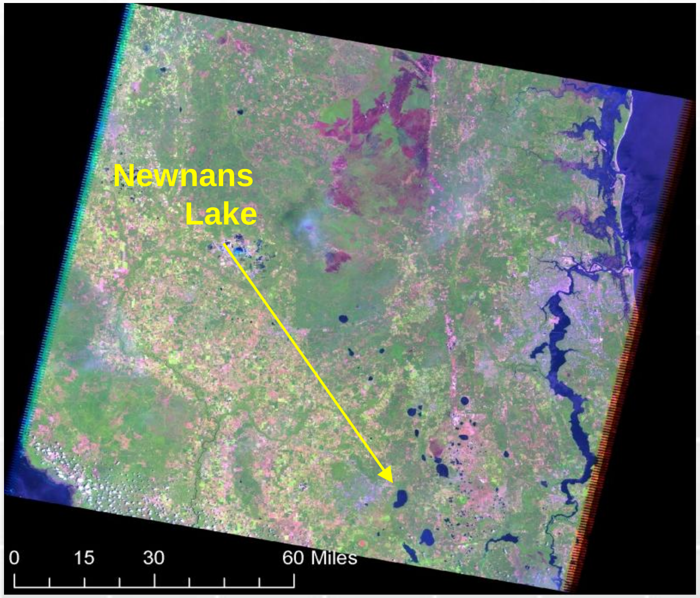
SHRUG Seven Hills Regional User Group for GIS

SDI System Dynamics International

Landsat 5 Thematic Mapper Imagery

Spectral Band (μm)	Band Descriptor	Spatial Resolution (m)	Radiometric Resolution (bits)	Swath Width (km)	Repeat Orbit (days)	Cost per Image ($)
0.45 - 0.52	Blue (TM1)	30	8	180	16	Free
0.52 - 0.60	Green					
0.63 - 0.69	Red (TM3)					
0.76 - 0.90	Near IR					
1.55 - 1.75	SWIR					
2.08 - 2.35	LWIR					
10.4 - 12.5	Thermal IR	120				

- **Available at http://glovis.usgs.gov (as GeoTiff)**
- **Spatial resolution (≈ 0.1 hectare) suitable for mapping in-lake variability**
- **Wide spatial extent**
- **Relatively high temporal resolution**
- **False Natural Color image shown – bands 5,4,3 (SW IR Color Composite)**



0% Clouds

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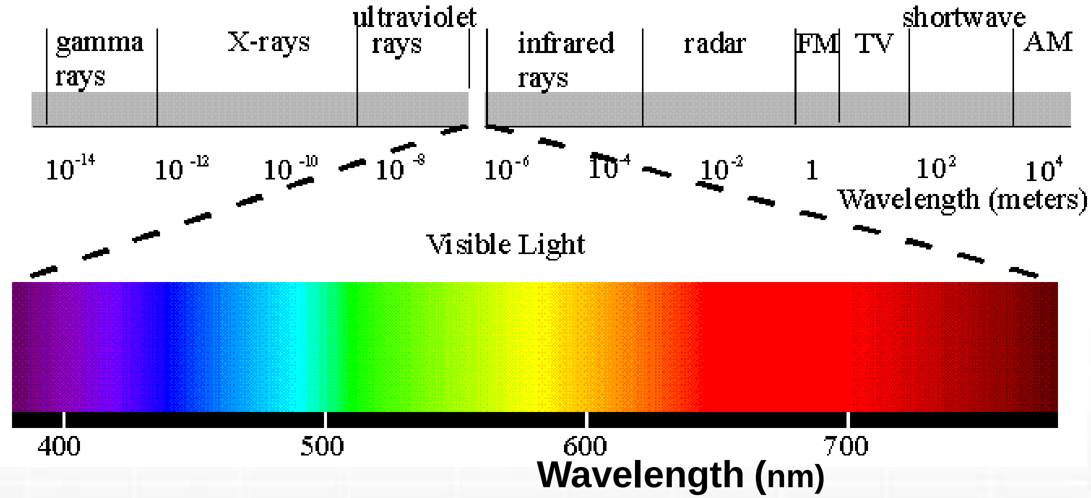
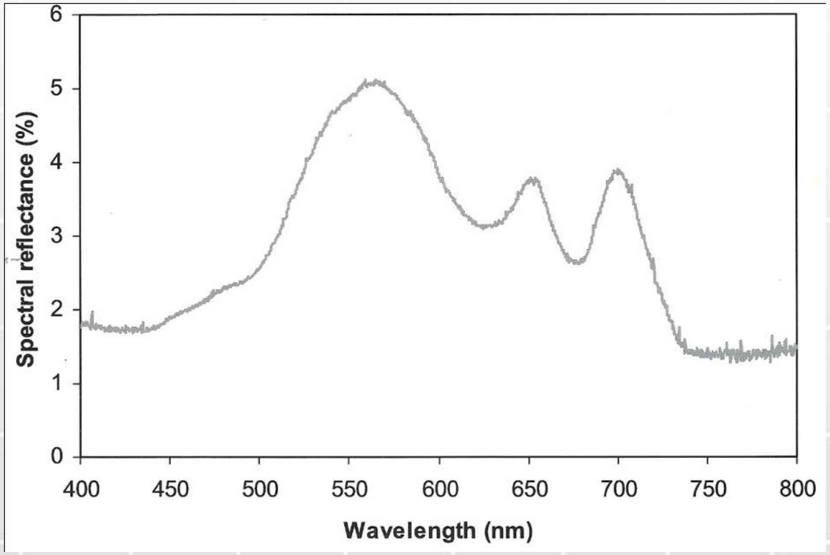
Electromagnetic Spectrum



Spectral Reflectance of Eutrophic Lake



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Landsat Processing Workflow

1. Access USGS web site and download zipped Landsat data file
2. Unzip and import seven *.TIF files in ERDAS Imagine and convert to *.img files
3. Form composite image from seven *.img files
4. Create “chip” of composite image of just Newnans Lake and surrounding area
5. Perform unsupervised classification on image chip using eight classes
6. Add image chip and classified image chip into ArcMap. Perform Select-by-Attribute query on classified chip to select only classified water feature
7. Use water feature as mask to perform Extract-by-Mask on image chip, thereby rendering a water-only raster comprising the seven spectral TM bands
8. For water-only raster, determine mean values of TM1 (blue) and TM3 (red) bands (Properties → Symbology → Statistics)

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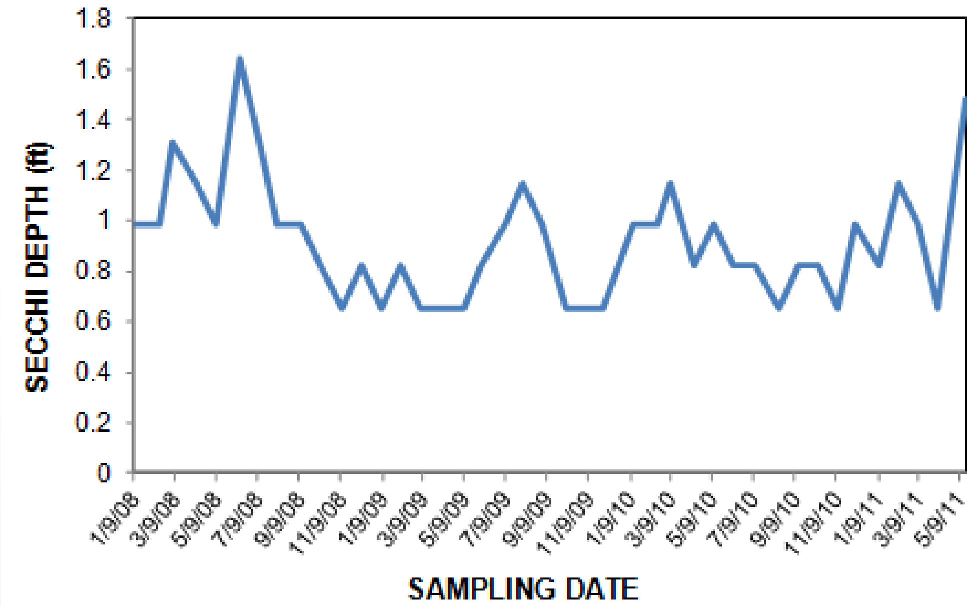
In Situ Data (Secchi Depth, SD)



SAMPLEID	COLLECTDATE	SAMPLETYPE	ANALYTENAME	RESULTVALUE	UNITS
L20080785-005	3/6/2008	VERT-INT	Secchi	0.4	m
L20080975-005	4/9/2008	VERT-INT	Secchi	0.35	m
L20081130-001	5/8/2008	VERT-INT	Secchi	0.3	m
L20081298-005	6/12/2008	VERT-INT	Secchi	0.5	m
L20081441-005	7/10/2008	VERT-INT	Secchi	0.4	m
L20081612-001	8/7/2008	VERT-INT	Secchi	0.3	m
L20081786-005	9/10/2008	VERT-INT	Secchi	0.3	m
L20090052-002	10/9/2008	VERT-INT	Secchi	0.25	m
L20090272-001	11/11/2008	VERT-INT	Secchi	0.2	m
L20090423-004	12/9/2008	VERT-INT	Secchi	0.25	m
L20090566-001	1/8/2009	VERT-INT	Secchi	0.2	m
L20090696-001	2/5/2009	VERT-INT	Secchi	0.25	m
L20090845-002	3/4/2009	VERT-INT	Secchi	0.2	m

Courtesy of SJRWMD

- **Secchi depth, turbidity, chlorophyll *a*, total suspended solids**
- **High temporal resolution**

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Data Summary

Landsat Image Filename (Path 17/Row 39)	Image Acquisiton Date	Mean TM1	Mean TM3	*In Situ* Data Collection Date	*In Situ* Secchi Depth Value (ft)
LT50170392009034GNC01	2/3/2009	43.95	14.33	2/5/2009	0.82
LT50170392010309GNC01	11/5/2010	46.54	15.62	11/9/2010	0.66
LT50170392011008EDC00	1/8/2011	40.95	13.29	1/11/2011	0.82
LT501703920110040GNC01	2/9/2011	47.48	14.59	2/8/2011	1.15
LT50170392011072GNC01	3/13/2001	53.43	19.12	3/8/2011	0.98

LT50170392011072GNC01

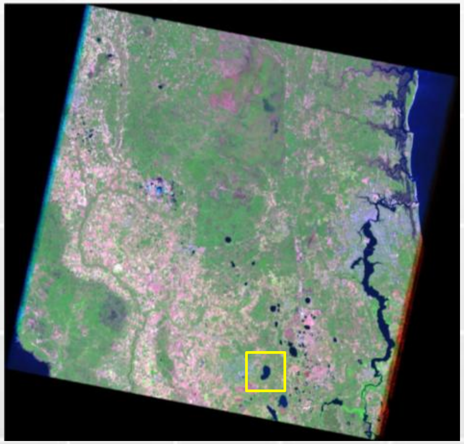
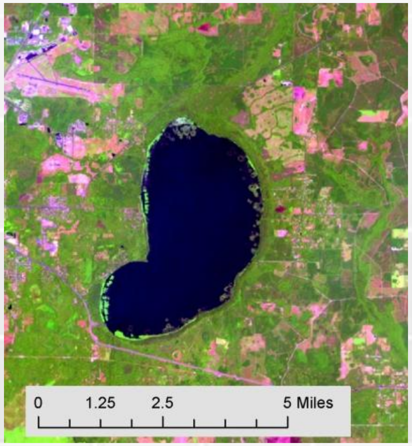
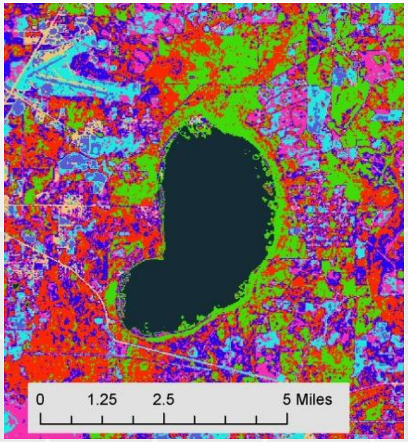


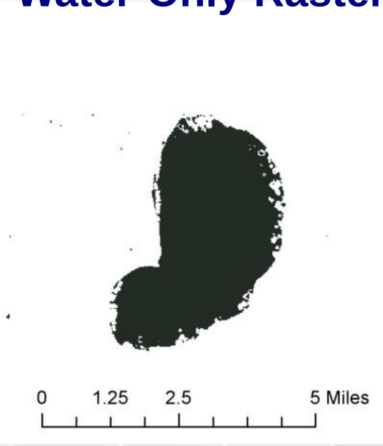
Image Chip



Classified Chip



Water-Only Raster



Calibrate TM data with *in situ* SD measurements and use that relationship to predict SD from other TM data

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Model Formulation

- **Determine applicability of model used to predict water quality for deep Northern lakes**

$$\ln(SD) = a(TM1) + b(TM1/TM3) + c$$

- **Perform multiple regression analysis in Excel to estimate model coefficients based on TM and *in situ* calibration data**

Regression Statistics	
Multiple R	0.997262864
R Square	0.99453322
Adjusted R Square	0.983599661
Standard Error	0.029374361
Observations	4

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-6.263222	0.474338156	-13.2041	0.048122
X Variable 1	-0.0027597	0.006069129	-0.45472	0.728309
X Variable 2	2.00887574	0.154562162	12.9972	0.048885

Estimated Model Coefficients:

a = -0.0027597 b = 2.00887574 c = -6.26322

Model Prediction

- **Use estimated coefficients to predict Secchi Depth based on TM1 and TM3 data**

- **Model yielded poor prediction of Secchi Depth**

ln(SD) = -0.002759(53.43) + 2.00887(53.43/19.12) – 6.26322

ln(SD) = -1.022, so SD = 0.36 ft (vs. 0.98 ft, actual value)

- **Why did model perform poorly?**
  - Insufficient number of calibration samples?
  - Northern lake model not appropriate for Florida lakes?
    - Reflectance from vegetation, sediment, and lake bottom affects spectral signatures
    - Time interval between Landsat image acquisition and *in situ* data collection more critical for shallow lakes since water quality can change abruptly based on weather conditions (thunderstorms, runoff, etc.)

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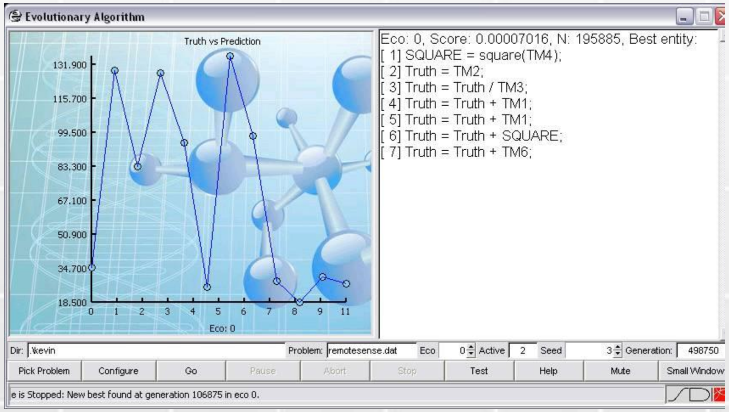
What’s a Possible Solution?

- **Develop model that considers:**
  - All seven TM spectral bands
  - Alternative water quality metrics (e.g., chlorophyll *a,* turbidity, TSS)

Water Quality Metric = f(TM1, TM2, …, TM7)

- **Use genetic algorithm to estimate functional relationship (i.e., model) between TM data and *in situ* water quality metric**

- **Hypothetical example shown on next chart**



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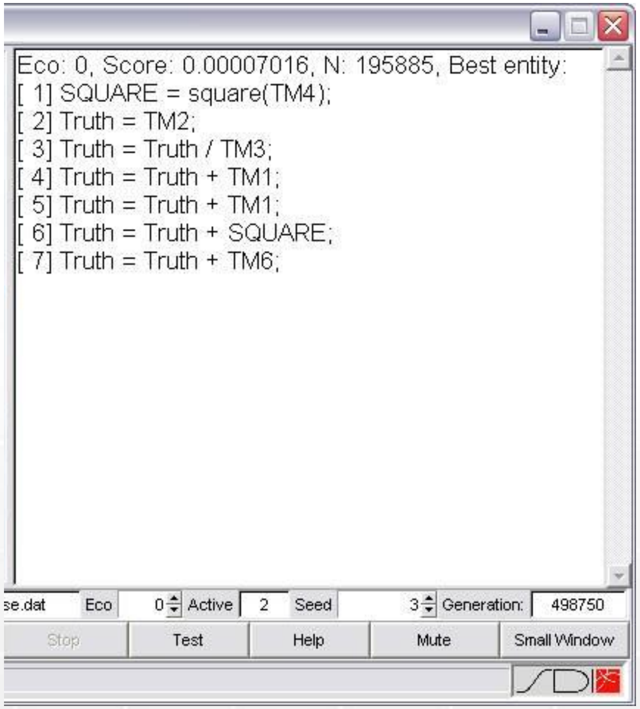
Genetic Algorithm Illustration

Hypothetical Data

Water Quality Metric (Truth)	TM1	TM2	TM3	TM4	TM5	TM6	TM7
29.9	2	6	7	4	3	9	1
94.8	4	9	12	9	7	5	5
63.0	8	4	4	6	7	10	1
93.7	5	5	7	9	3	2	3
70.8	8	11	4	7	9	3	6
23.3	4	7	3	2	8	9	3
99.5	8	6	4	9	2	1	5
73.0	9	9	3	7	9	3	3
25.3	7	5	4	2	4	6	6
18.5	4	3	2	1	9	8	7
26.7	1	2	3	4	7	8	9
24.4	7	4	9	1	5	9	6

Genetic Algorithm Solution



Pseudo-code reduces to:

$$\text{Truth} = 2(TM1) + (TM2/TM3) + (TM4)^2 + TM6$$

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Questions?