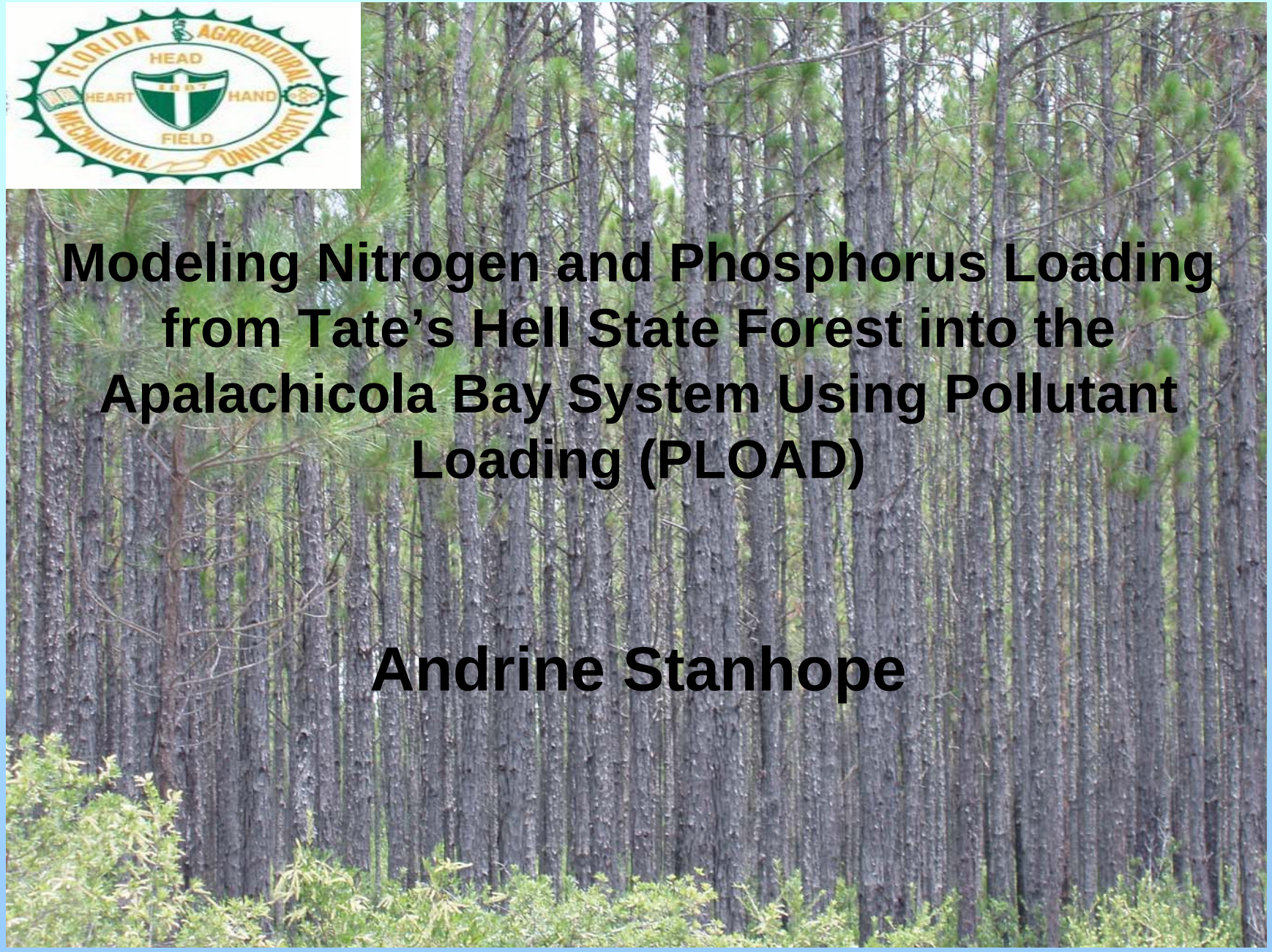


Modeling Nitrogen and Phosphorus Loading from Tate's Hell State Forest into the Apalachicola Bay System Using Pollutant Loading (PLOAD)

Andrine Stanhope

Modeling Nitrogen and Phosphorus Loading Using Pollutant Loading Estimator (PLOAD)

Introduction

- As water drains from land surface, it transports residues which may be enriched with a variety of contaminants

- Transport of such contaminants to downstream environments is a water quality issue of national concern
  - Accumulate through sedimentation, or biological uptake
  - Degrade their component species and amenities they provide

- Knowledge of constituent loads is important in Watershed Assessments and Total Maximum Daily Loads (TMDLS)

- Models are used to support development of TMDLs, typically to estimate source loading inputs
  - evaluate receiving water quality
  - determine load allocation to sources so that receiving water quality standards are met

Modeling Nitrogen and Phosphorus Loading Using Pollutant Loading Estimator (PLOAD)

Introduction – Cont'd

- Models are computer codes expressing mathematical relationships that simulate physical and chemical processes occurring under environmental settings in a watershed

- Watershed loading models simulate
  - generation and movement of pollutants from point of origin on land surfaces to points of discharge into receiving water bodies

- Often times certain information is not available and processes (defined by coefficients) from previous studies are used initially until field measurements are performed

Modeling Nitrogen and Phosphorus Loading Using Pollutant Loading Estimator (PLOAD)

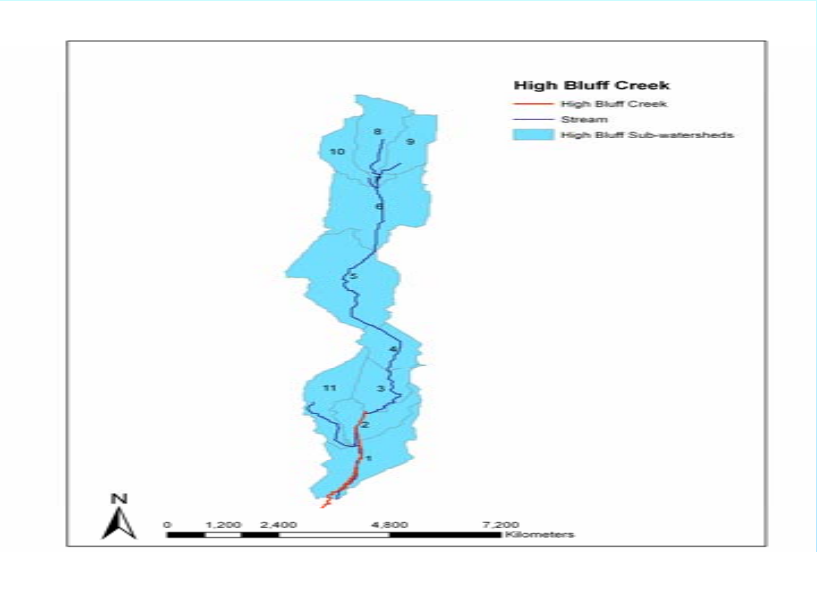
PLOAD

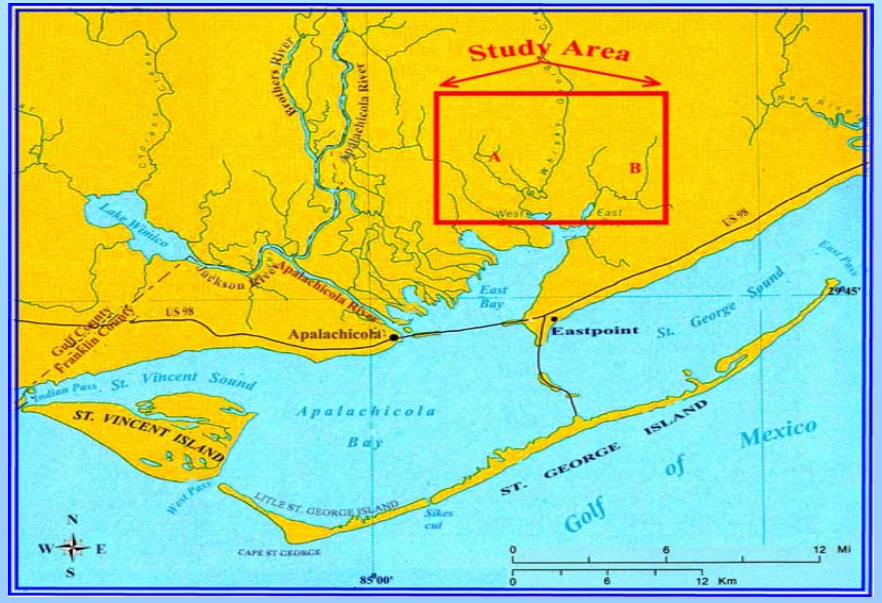
- Is one of five models within Better Assessment Science Integrating Point and Non-Point Sources (BASINS) 4.0 software
- Simple geographic information system (GIS) watershed pollutant loading model that
  - estimates point and non-point sources of pollution on an annual average basis for any user-specified pollutant including total suspended solids, nutrients, metals and fecal coliform
- The user may calculate NPS loads using either the export coefficient (EC) or the EPAs Simple Method Approach which uses Event Mean Concentrations (EMCs)

Materials and Methods

Watershed Description

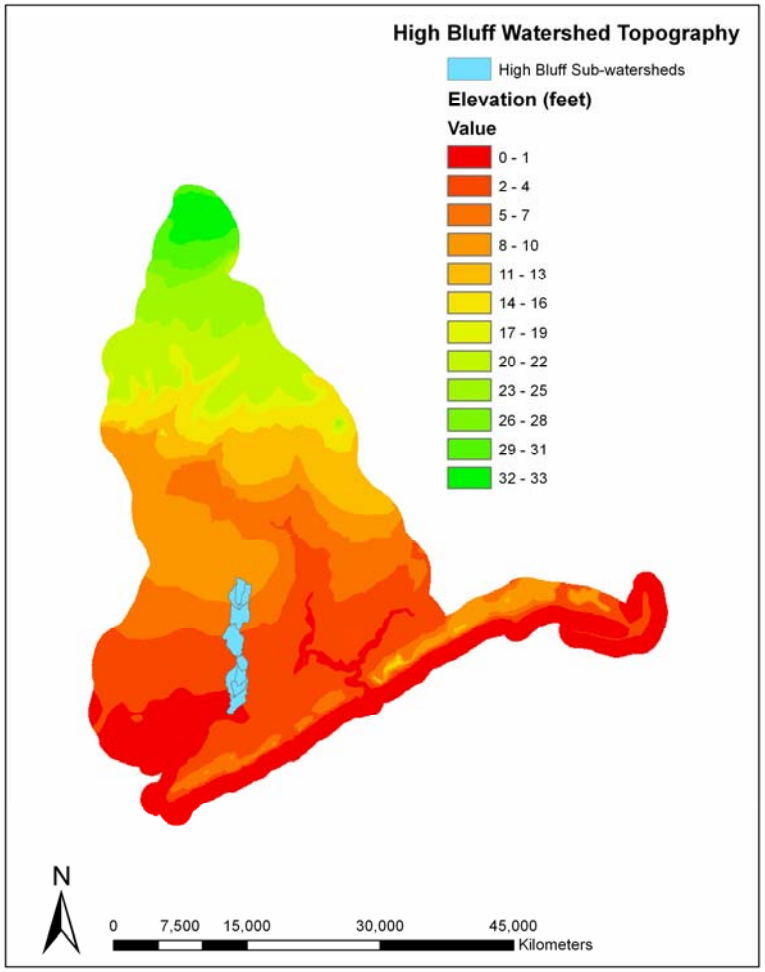
- HBW watershed 3887 ha
- High Bluff Creek located at the southern tip of the watershed drains an area of 520 ha (331 acre)
- HBC enters the northern part of East Bay
- Forest cover dominant land-use ranging from evergreen, mixed, forested and non-forested wetlands





Materials and Methods – Cont'd

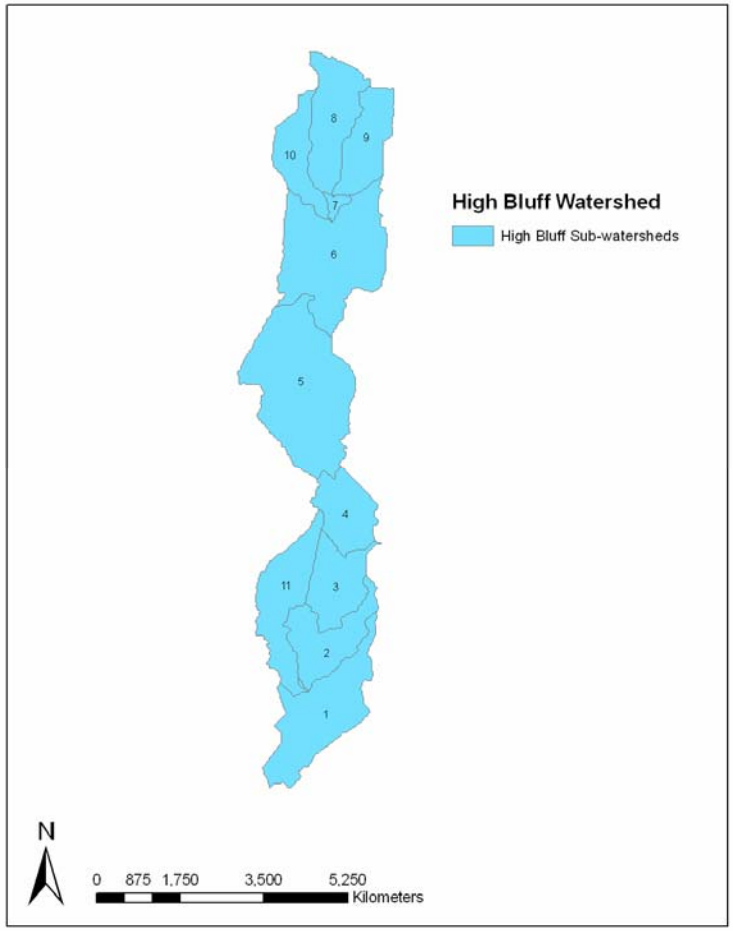
Watershed Description – Cont'd



- The watershed elevation ranges from 0-4m (0-13ft)
- The area has long hot summers and cool winter like conditions
- Rainfall patterns normally follow a summer (June – September) and late fall to late spring (December – March) wet season
- The area is subjected to violent weather conditions including storms and hurricanes

Materials and Methods – Cont'd

Model Input Data Description



- The GIS segment of the model, which included the land-use data, DEM and a delineated watershed was first generated in BASINS 4.0
  - Land-use/land-cover spatial data was first downloaded form the geographic information retrieval and analysis system (GIRAS)
  - A DEM for the area was then downloaded into the system
  - The watershed was then manually delineated and then subdivided into 11 sub-watersheds
  - PLOAD model was then selected

Materials and Methods – Cont'd

Model Input Data Description – Cont'd

Within PLOAD there are 7 tabs

- General ppt LU EC/EMC Point Source BMPs Bank Erosion

EC method

Step 1. General Tab

- Select Export Coefficient
- Highlight the pollutants of concern
- Select LU type (GIRAS)

- ppt tab (nothing to specify)
- Land use tab (nothing to specify – PLOAD knows to load the necessary GIRAS land use tiles from BASINS

Step 2. Export Coefficient Tab

- Table shows EC (lb/acre) for each land use category and each pollutant – these are starting values and not necessarily appropriate (edit as needed)

Step 3. Click generate to execute PLOAD Layers will appear showing PLOAD Estimated Pollutant Loads for selected pollutants

Materials and Methods – Cont'd

- EMC Method

General ppt LU EC/EMC Point Source BMPs Bank Erosion

Step 1. General Tab

- Select Event Mean Concentration
- Highlight the pollutants of concern
- Select LU type (GIRAS)

Step 2. ppt Tab

- User may enter annual ppt as either single value or value for each sub-basin
- Single value option – enter annual ppt and ratio of storm producing events (default 0.9)
- Value for each sub-basin option – enter ppt for each sub-basin

- Land use (nothing to specify)

Step 3. EMC Tab (edit table accordingly values are mgL^{-1})

Step 4. Click generate to execute PLOAD Layers will appear showing PLOAD Estimated Pollutant Loads for selected pollutants

Materials and Methods – Cont'd

Export Coefficients (kg.ha/yr)				
TN	**TP**	**Nitrate**	**Ammonium**	**PO4**
3.75	0.30			
Event Mean Concentration (mg/L)				
5.99	0.23	0.03	0.78	0.20

EC were changed in the PLOAD table to those reported in the literature by Bondelid etal 2001 (Coastal coniferous forests) for TN and TP for NO_3, NH_4 and PO_4 those generated by PLOAD were used (none found in the literature)

EMC values were those derived from water quality analysis

Materials and Methods – Cont'd

Pollutant Loading Calculation Equations

To estimate annual load using the Export Coefficient Method

$$Lp = \sum u(Lpu * Au)$$

where

$Lp =$ Pollutant load, lbs;

$Lpu =$ Pollutant loading rate for land use type lbs/acre/year and

$Au =$ Area of land use type acres

- (The PLOAD generated data were converted to metric units)

Materials and Methods – Cont'd

Pollutant Loading Calculation Equations- Cont'd

When the EMC method is used the two following equations are used within the system

$$Rvu = 0.05 + (0.009 * Iu)$$

where

Ruv = Runoff Coefficient for land use type $inches_{run\text{-}off}/inches_{rain}$;

Iu = Percent Imperviousness

$$Lp = \sum u(P * Pj * Rvu * Cu * Au * 2.72/12)$$

where

Lp = Pollutant load, lbs;

P = Precipitation, inches/year

Pj = Ratio of storms producing runoff (default = 0.9)

Rvu = Runoff Coefficient for land use type , inchesrun/inchesrain

Cu = Event Mean Concentration for land use type , mgL-1; and

Au = Area of land use type , acres

2.27 = Conversion factor

12 = Conversion factor (inches to feet)

Results and Discussion

This Study	Estimated Model Loading Rates, $kgha^{-1}yr^{-1}$				
	TN	TP	NO_3^-	PO_4^-	NH_4
Export Coefficient method	2.20	0.20	0.09	0.06	0.39
Event Mean Conc. method	15.2	0.38	0.09	0.27	1.13

Land-use	**Annual Loading Rates (kg/ha/yr) (Literature)**				
	TN	TP	NO_3^-	PO_4^-	NH_4
Silviculture*	2.99	0.47			
Upland Forest*	2.99	0.47			
Dodd et al 1992					
Silviculture**	0.85	0.02	0.09		0.03
Silviculture**	1.8	0.10	0.54		0.10
Silviculture**	4.27	0.17	0.99		0.07
Silviculture**	2.61	0.07	0.15		0.12
Thorpe, et al., 1998					
Undisturbed forest	3.6 - 6.0	0.20 - 0.35	0.10 - 0.40		0.60 - 0.90
Dodd et al 1992					
Pine Plantation	4.7	0.49	0.64		0.41
Pine Plantation	5.6	0.47	0.52		0.38
Pine Plantation	6	0.52	0.38		0.69
Martin and Herrmann 1998					

**Apalachicola River Watershed, FL

* St, Marks/Wakulla Watersheds, FL

Results and Discussion – Cont'd

- The EC method showed lower loading rates than the EMC method

- The EC values used in the model were coefficients representative of national averages, while the EMC method utilized actual measurements (mgL^{-1}) observed from the water samples

- With the exception of TN and NH_4-N from the EMC model, the loading rates of the pollutants for both models are comparable to loading rates reported in the literature

- NH_4-N loading rates were much higher than nitrate because of the reducing conditions at the study site

Results and Discussion – Cont'd

Model Limitation

- As with any model there are limitations to the use of the EC and EMC method
- The applicability of applying ECs or EMCs for different land uses developed in one part of the country for use in another region
- Wide variations can exists in values not only regionally but on a local scale
- Averaging national ECs and EMCs numbers from a variety of geographically disbursed studies can yield differing results
- Some of the coefficients published more than 25 years ago is quite possible that current forestry practices have since changed
- When EC values are selected from the literature they cannot be verified fully for ones study site without considerable expenditure on field experimental work

Conclusions

- The EC estimated pollutant loading rates were lower than the EMC rates
- This may have been due to the fact that the EC values used were coefficients representative of the region and were not site specific
- Also the EC loading rates were lower because the EMC values were more representative of the values observed at the impacted site
  - i.e. the EMC values used to drive the model were concentrations observed in the water column throughout the duration of the study and therefore provide an estimate of pollutant export that are closer to the “true” but unknown value for the watershed.

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Questions

Modeling Nitrogen and Phosphorus Loading Using Pollutant Loading Estimator (PLOAD)

- Load is the quantity of the constituent transported by a river past the point of measurement during a specified time period ($kgyr^{-1}$) (constituent conc. x stream discharge)
- TMDL is the allowable load of any pollutant that a river or stream can receive and still meet applicable water quality standards and support its designated use/s