# Identifying Critical Source Areas to Enhance Water Quality: Integrated Analysis to Reveal Key Variables and Thresholds in Choctawhatchee

**Shubo Fang, Tesfay Gebremicael, Matthew J Deitch**

# Introduction

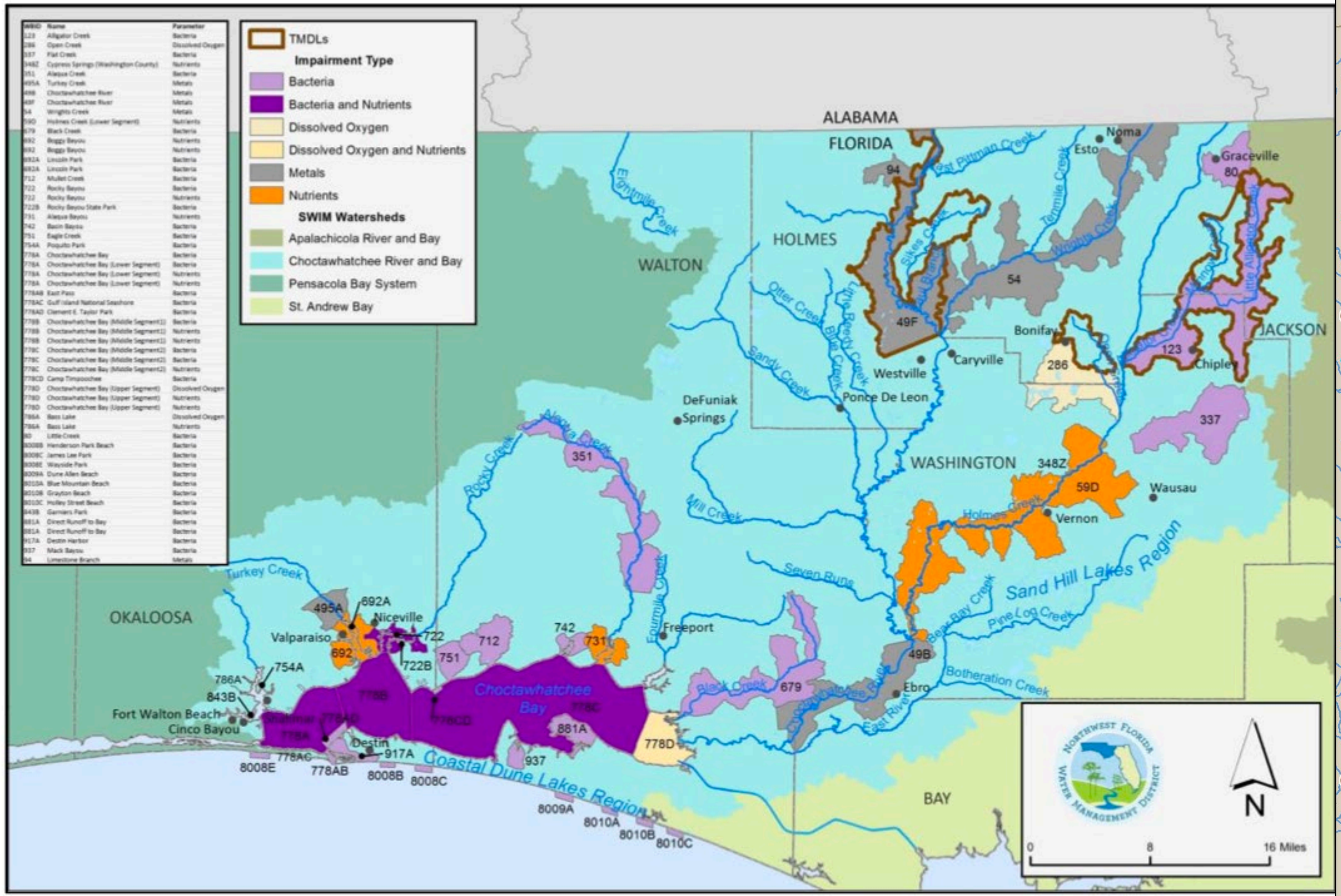
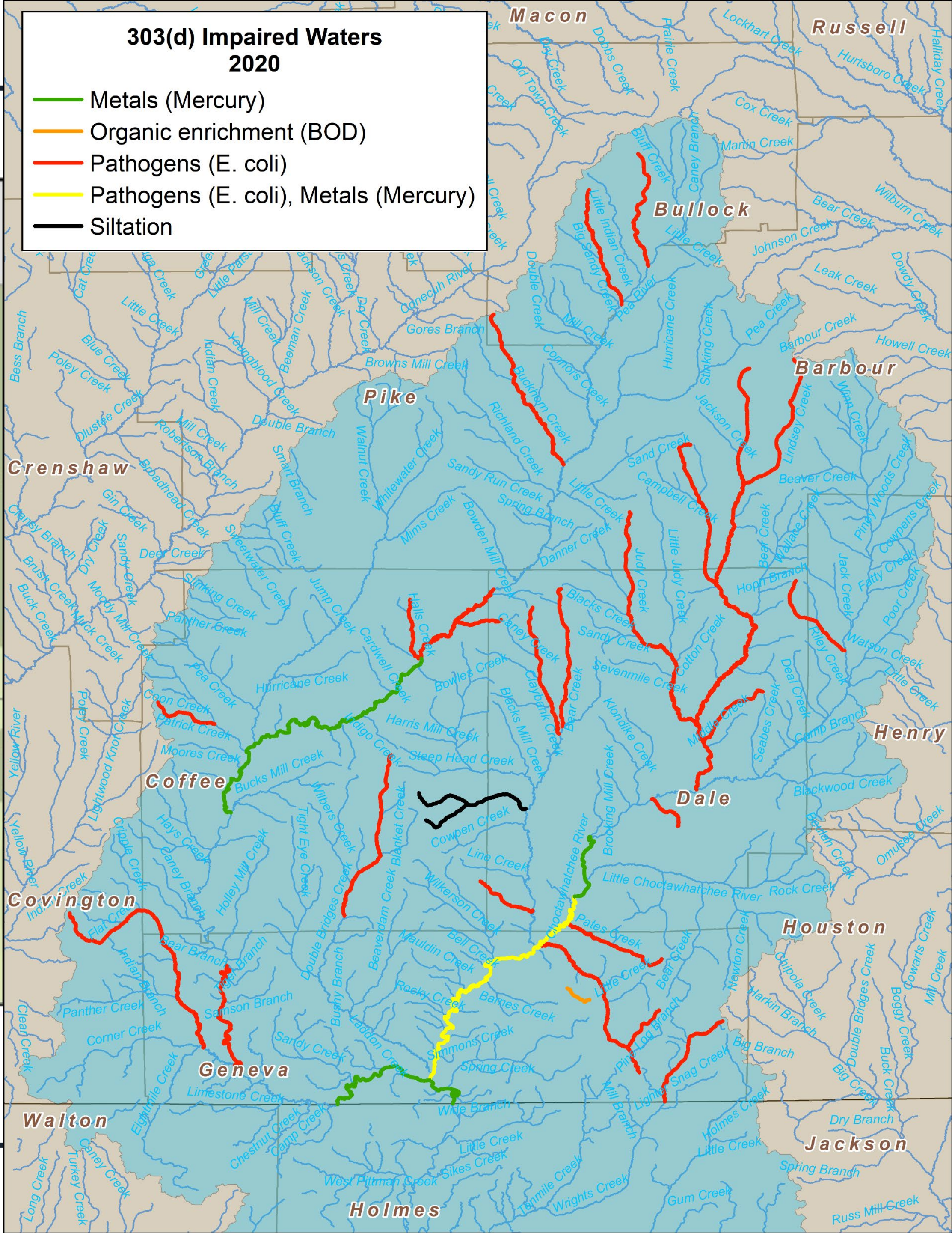



**Figure 3-1 Impaired Waters in Florida's Portion of the Watershed**




By: *Choctawhatchee Bay Estuary Program Technical Advisory Committee, 2021*

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# Introduction

- A comprehensive project was launched in 2020 to identify and implement methods to assess impacts and stressors in the estuary systems of Florida Panhandle.

- The project has been working with stakeholders to
  - Identify main stressors
  - Develop conceptual models,
  - Develop adaptive management frameworks,
  - Understand how land management impacts the water quality of estuaries
  - Develop predictive tools to examine how management actions could reduce impacts

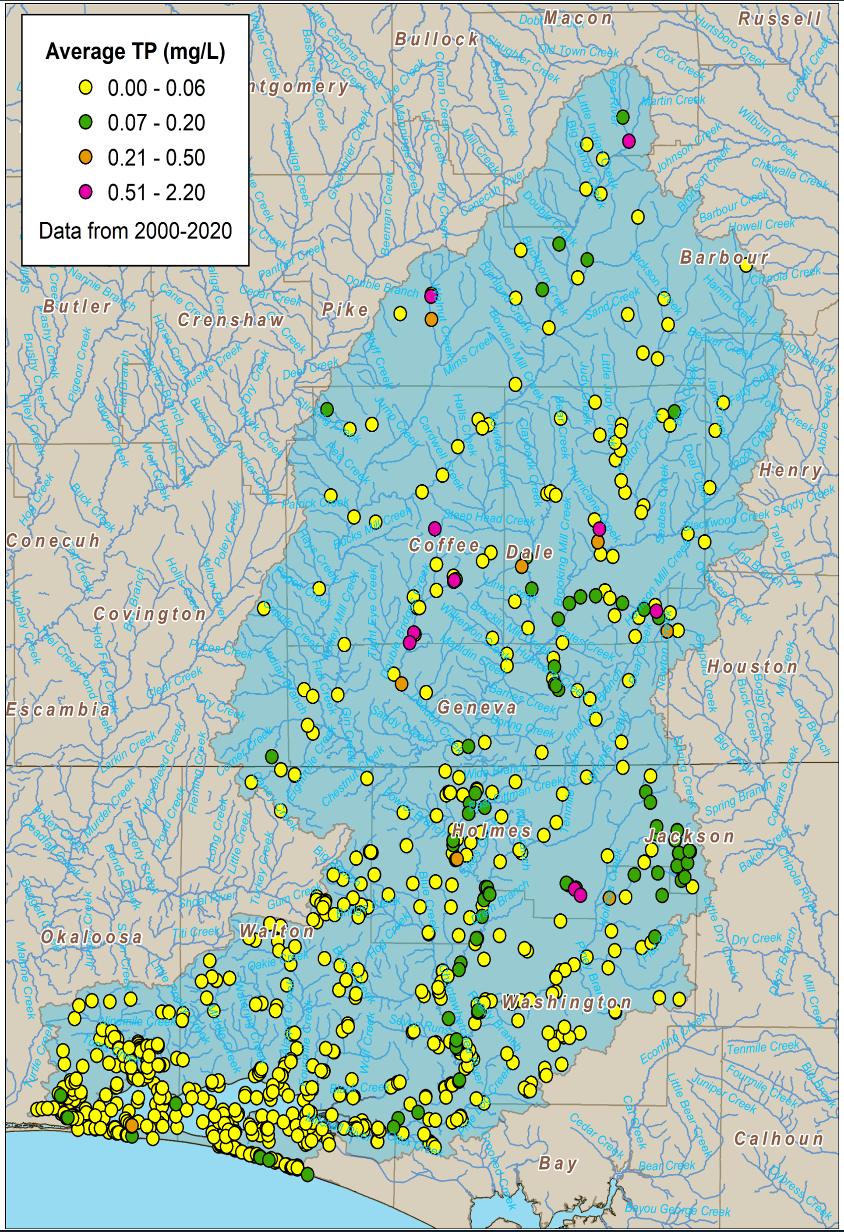
# Common stressors across the Florida Panhandle

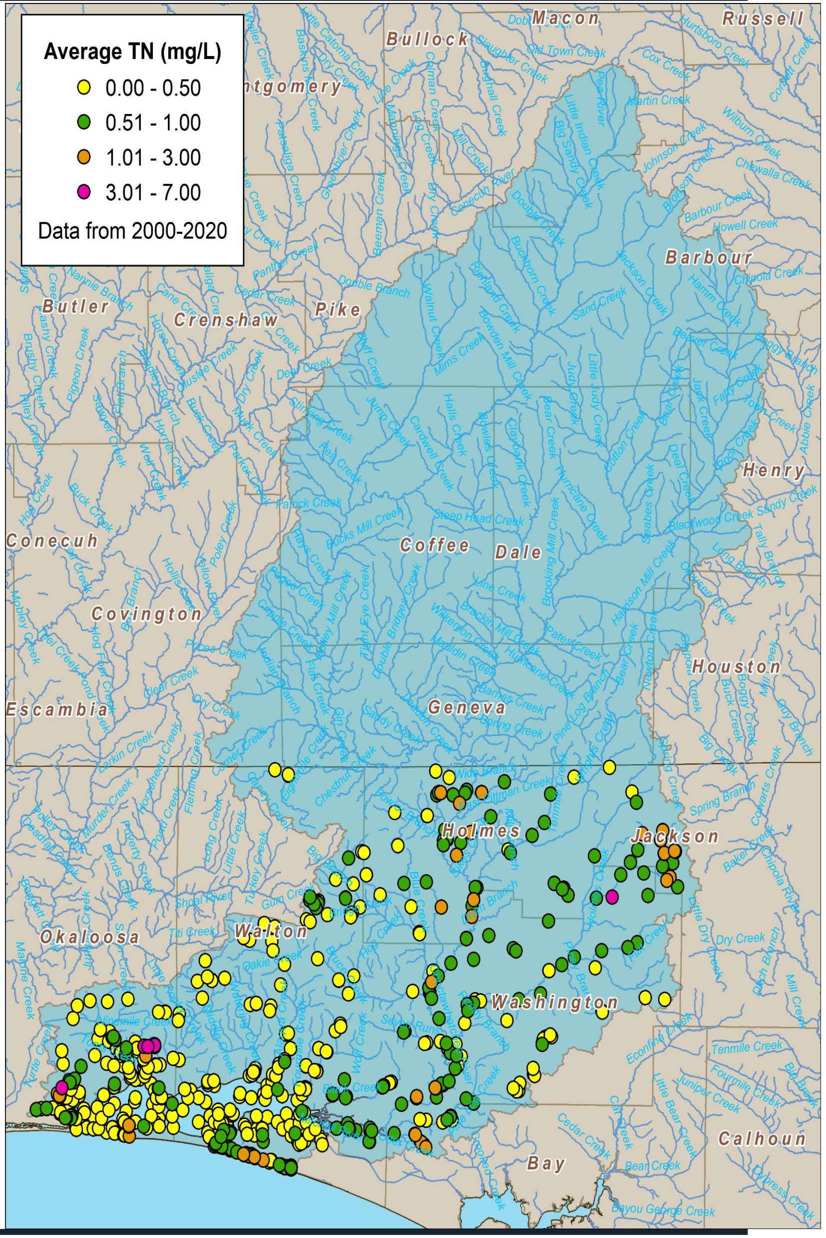
- Upland and coastal developments
- Nutrients and sediment loads (**non-point sources**)
- Land use change
- Hydrology
- Stormwater and runoff
- Unpaved roads
- Degraded septic tanks
- Loss of habitat
- Sea level rise and flooding
- Pathogens
- Shoreline hardening

Choctawhatchee

# Distributed hydrological model

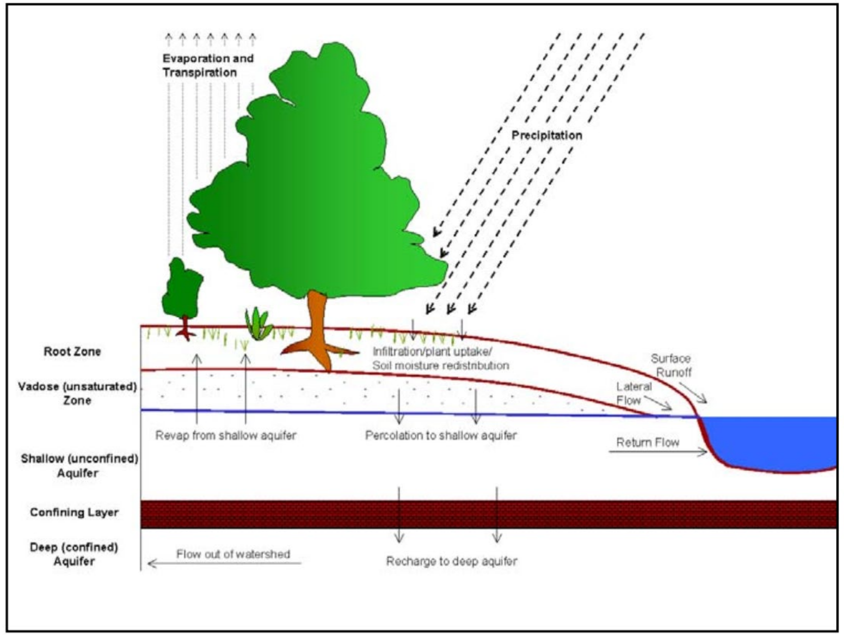
- Identifying the critical areas of non-point sources of pollutants from watersheds is important to reduce inflows
- Develop and prioritize best management practices and restoration projects to reduce nutrient flows in water bodies

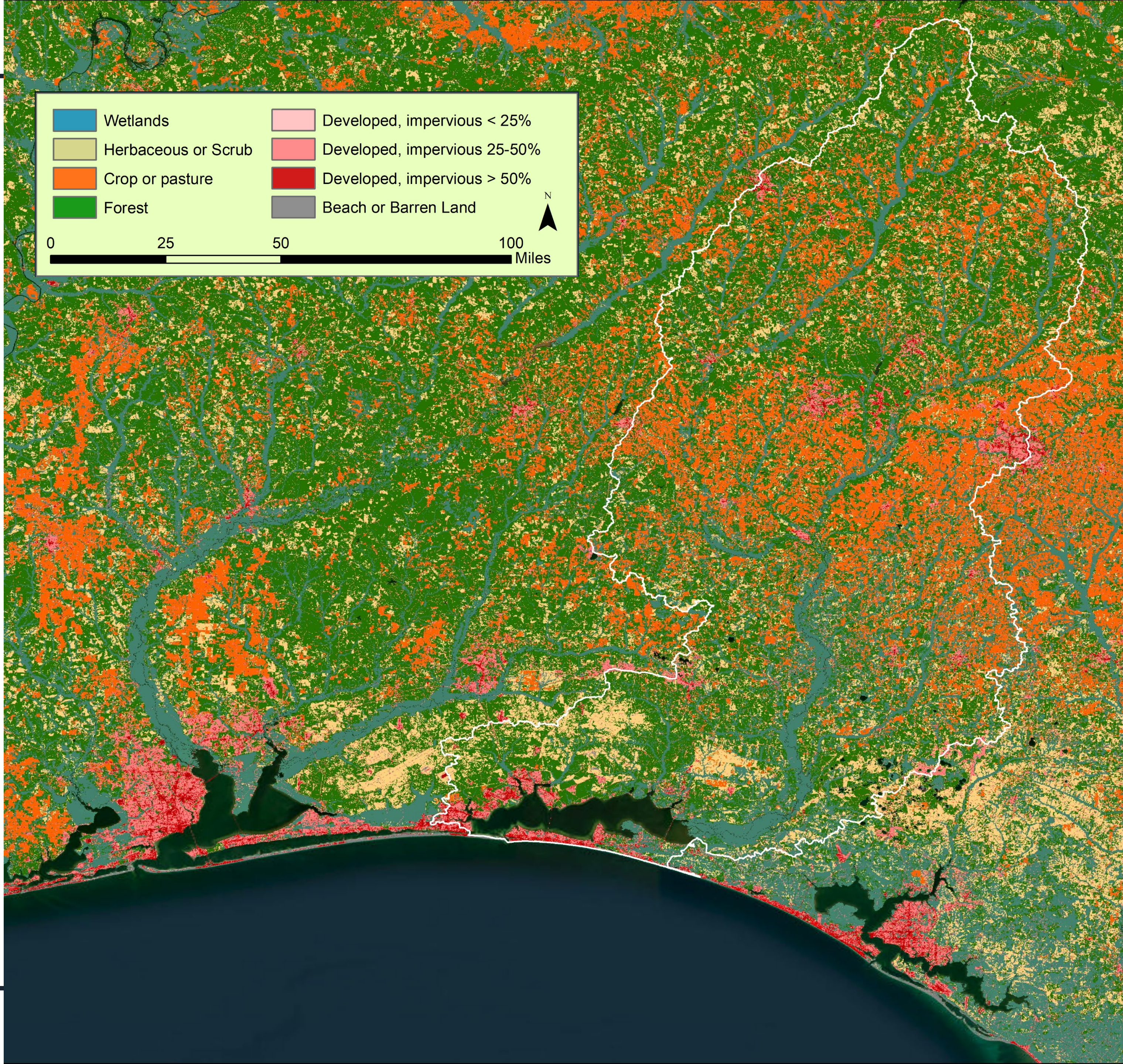


Soil and Water Assessment Tool (SWAT) is widely used to estimate nutrient origin and delivery from the landscape.

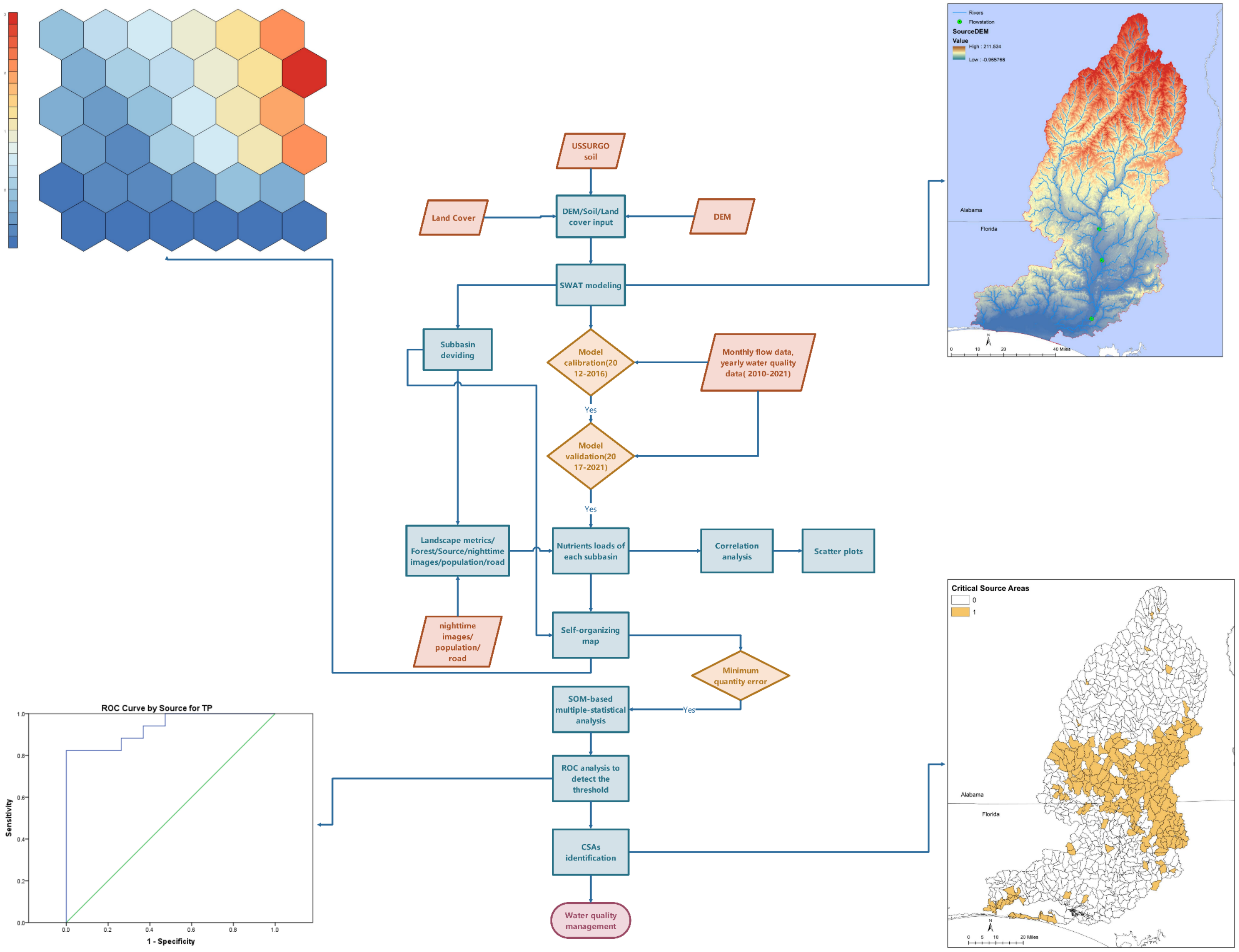
Model includes adjustable parameters for internal algorithms



# Working flow

1, SWAT modeling
2, SWAT-based subbasin analysis
3, Self-organizing mapping
4, SOM-based subbasin analysis
5, ROC analysis
6, CSAs identification

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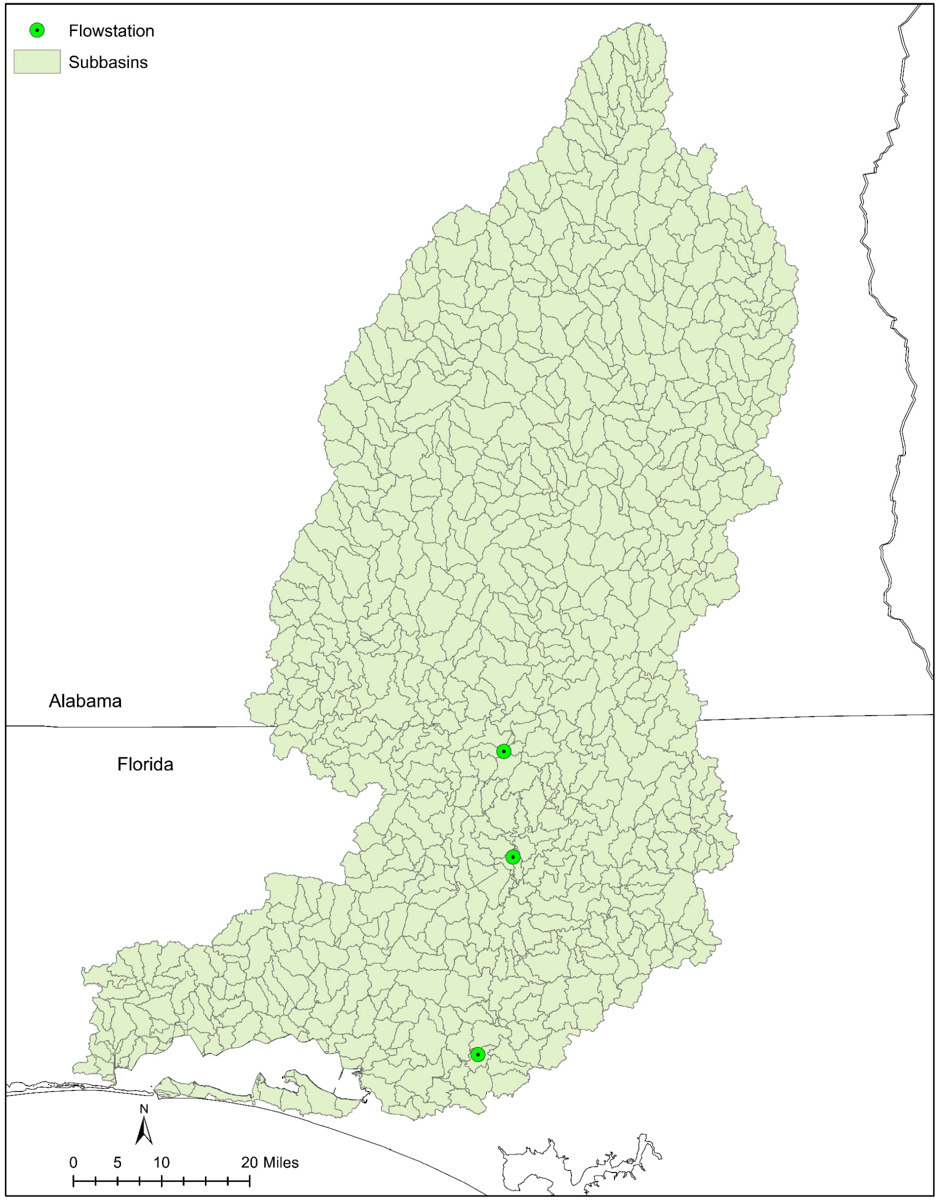
# Model development (SWAT)

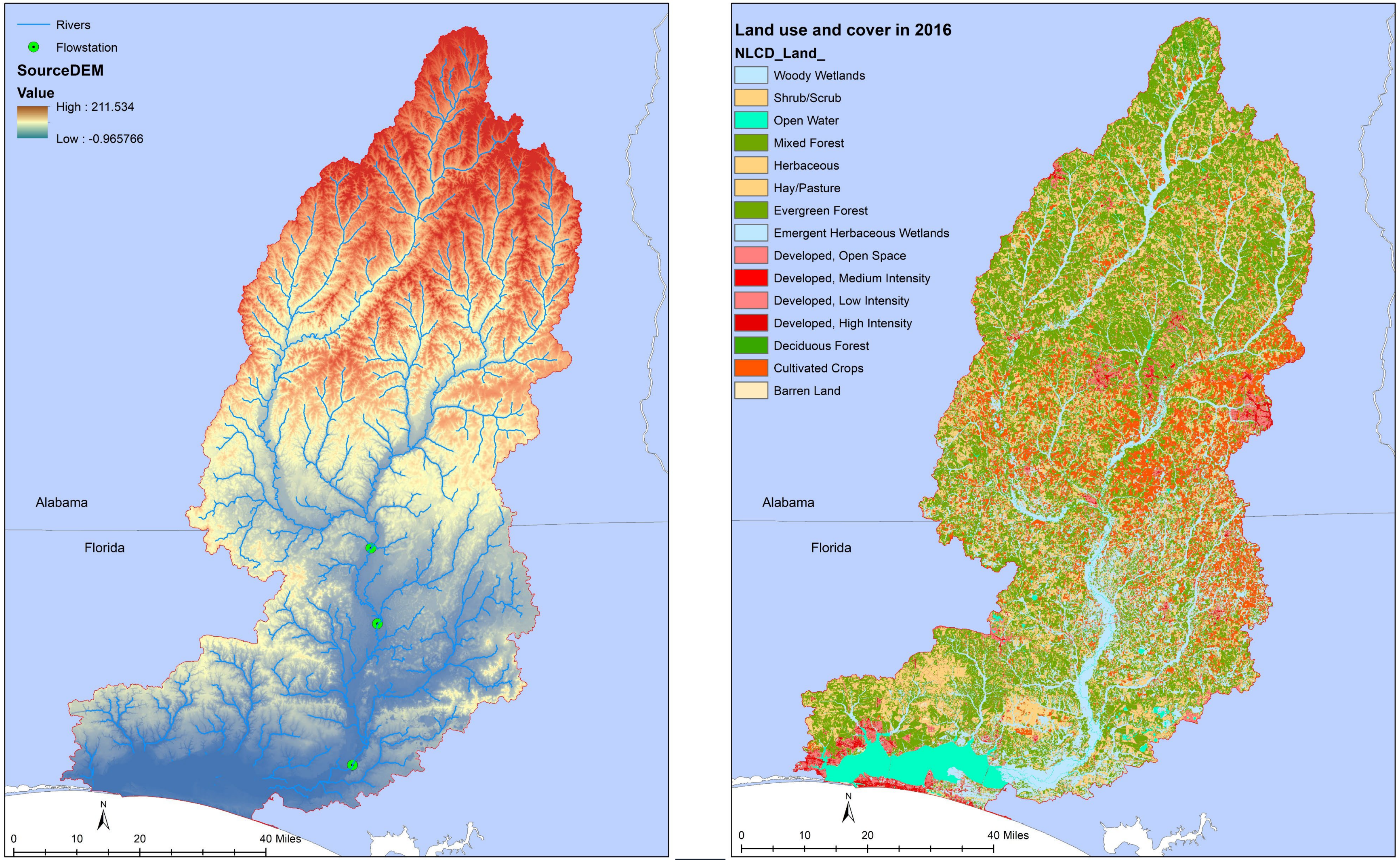
Model inputs

- DEM of STRM 30 meter
- Land use data NLCD (2016)
- Soil data from SURGO
- Climate data (2010 – 2021)
- Discharge data (2010-2021)
- Water quality data (2010-2021)

863 Sub-basin
3195 HRUs



# Calibration and Validation

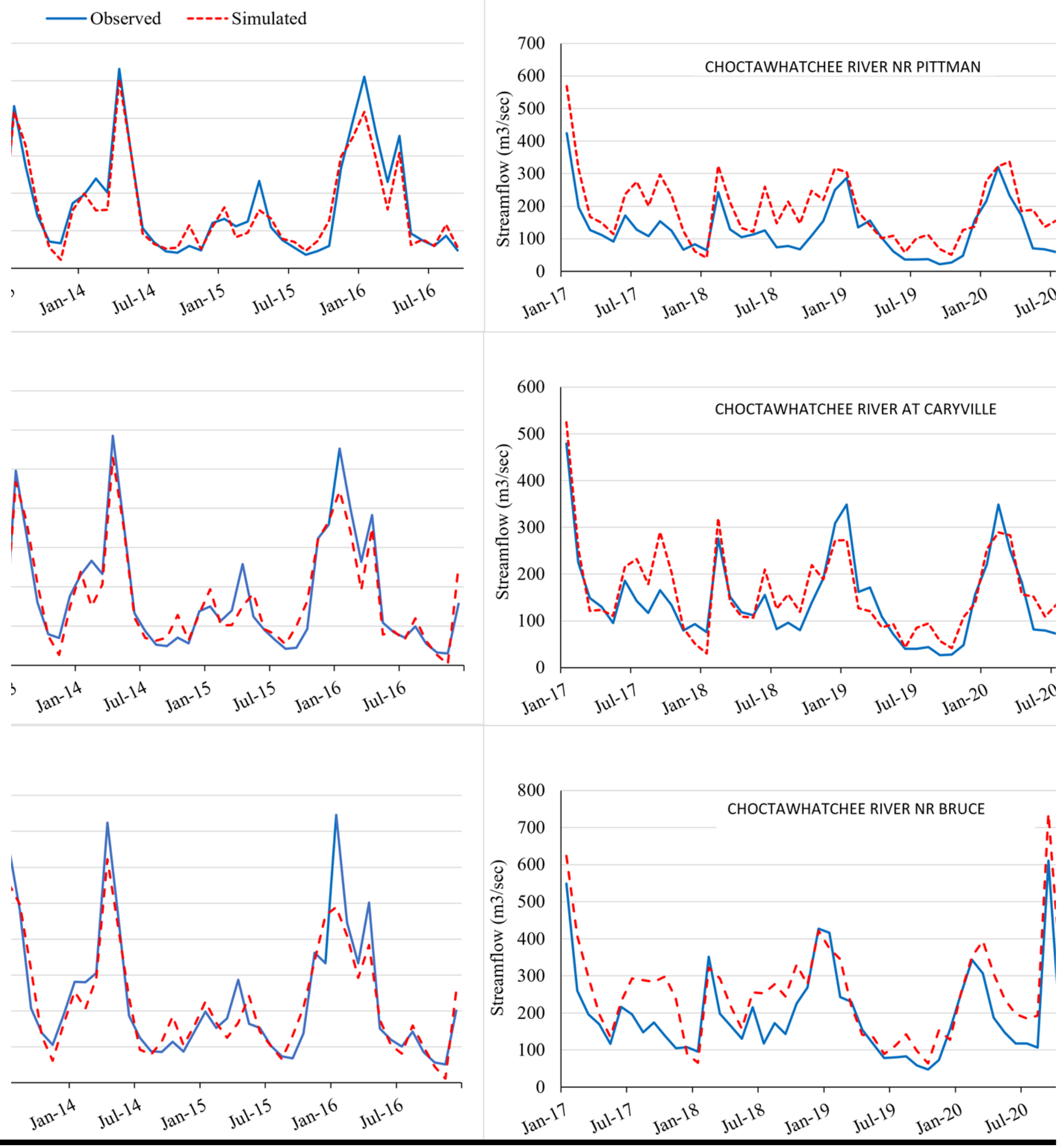



## Table 1 Model performance on monthly streamflow and annual water quality variables at multi-locations in the Choctawhatchee watersheds

| Variables | Sub-basin | Calibration | | Validation | |
|---|---|---|---|---|---|
| | | NSE | $R^2$ | NSE | $R^2$ |
| Streamflow | CHOCTAWHATCHEE RIVER NR PITTMAN (02365200) | 0.81 | 0.84 | 0.47 | 0.82 |
| | CHOCTAWHATCHEE RIVER AT CARYVILLE (02365500) | 0.81 | 0.86 | 0.84 | 0.86 |
| | CHOCTAWHATCHEE RIVER NR BRUCE (02366500) | 0.84 | 0.84 | 0.66 | 0.81 |
| Total Nitrogen | CHOCTAWHATCHEE RIVER NR PITTMAN (02366500) | 0.57 | 0.62 | 0.69 | 0.73 |
| Total Phosphorus | CHOCTAWHATCHEE RIVER NR BRUCE (02366500) | 0.4 | 0.47 | 0.57 | 0.61 |

# SWAT modeling

Flow Calibration and validation

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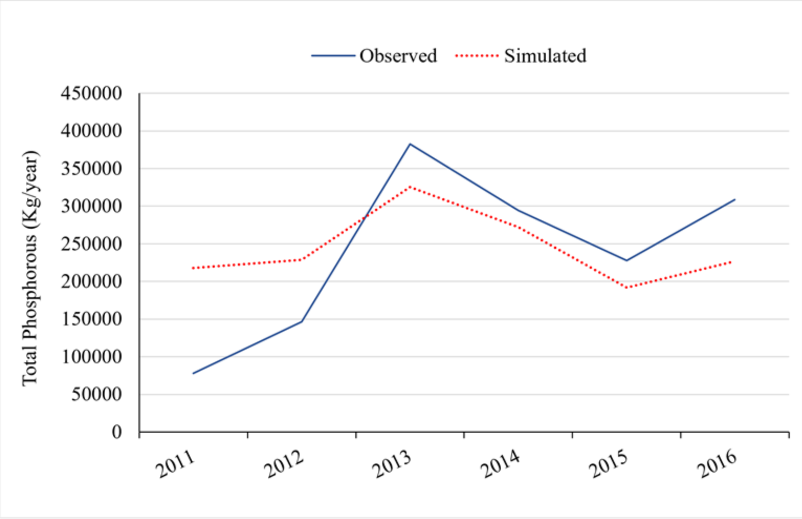
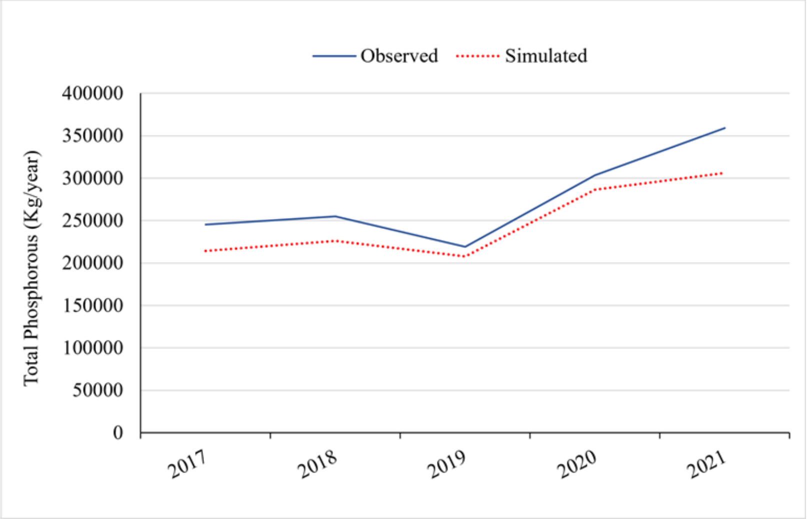
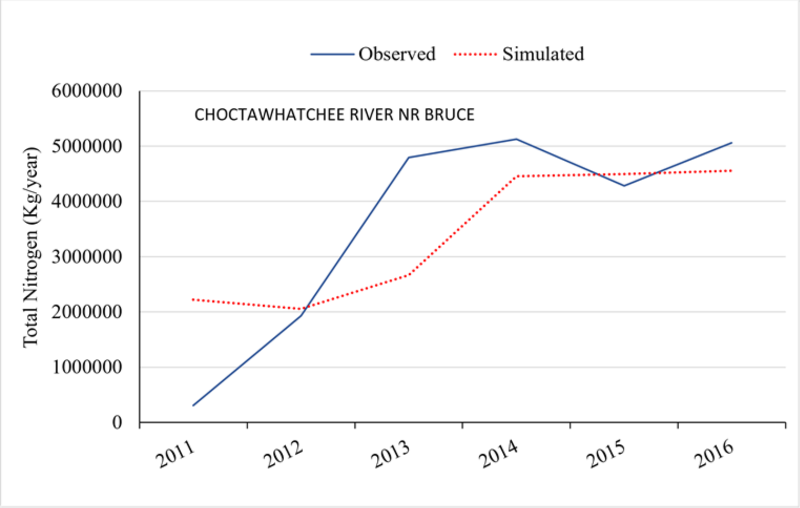
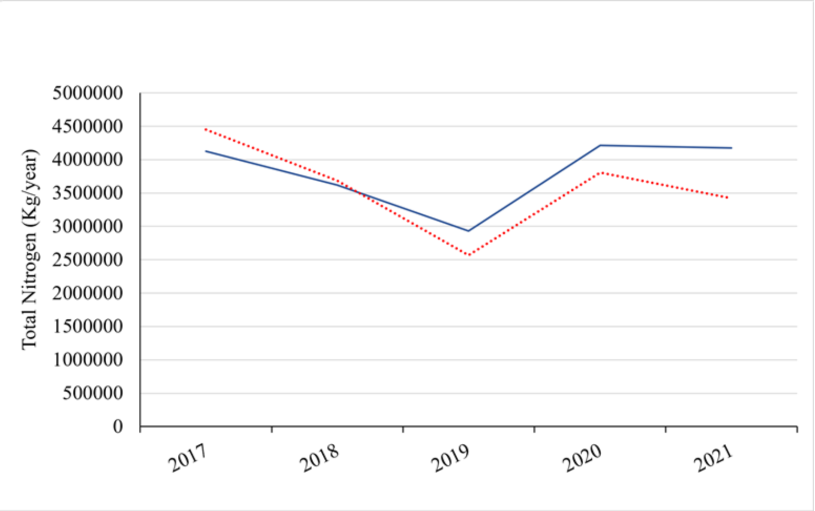
# SWAT modeling

Water quality Calibration and validation

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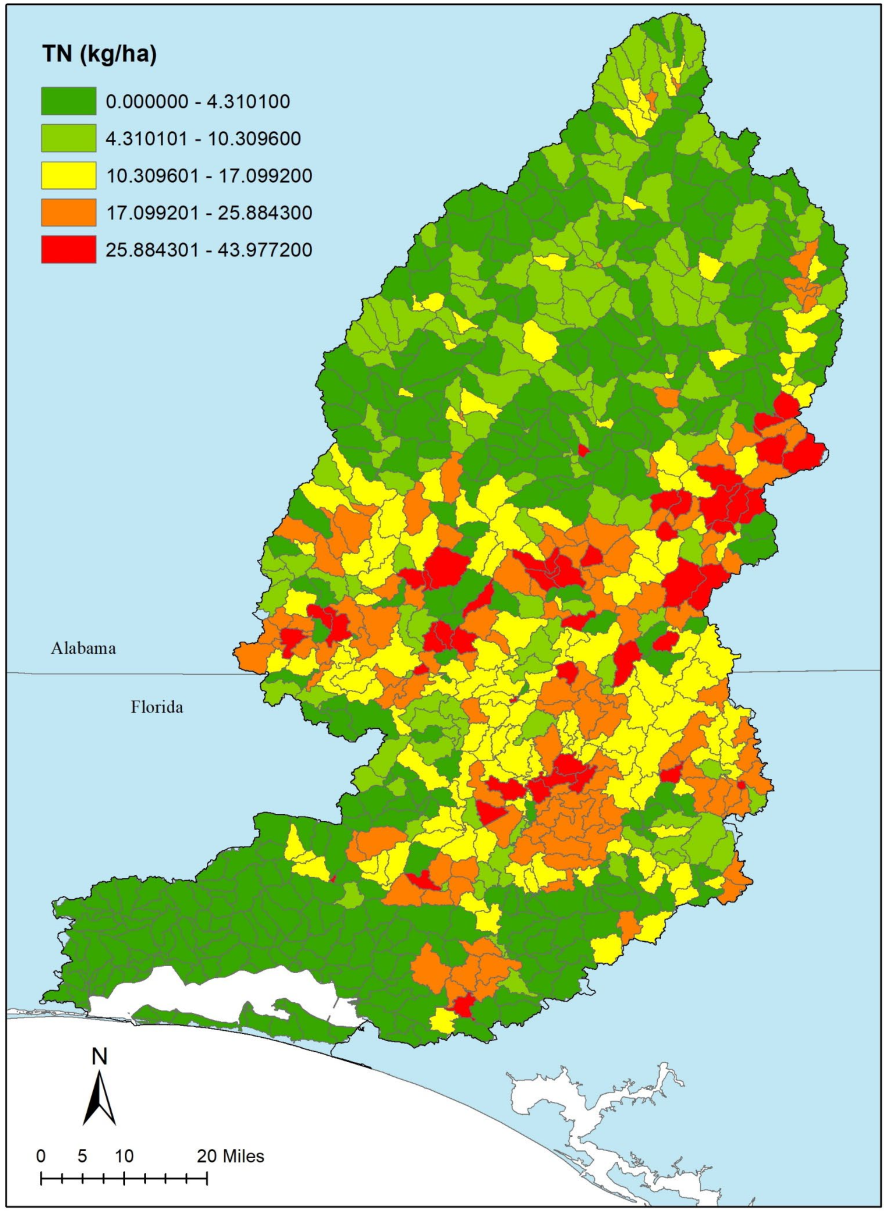
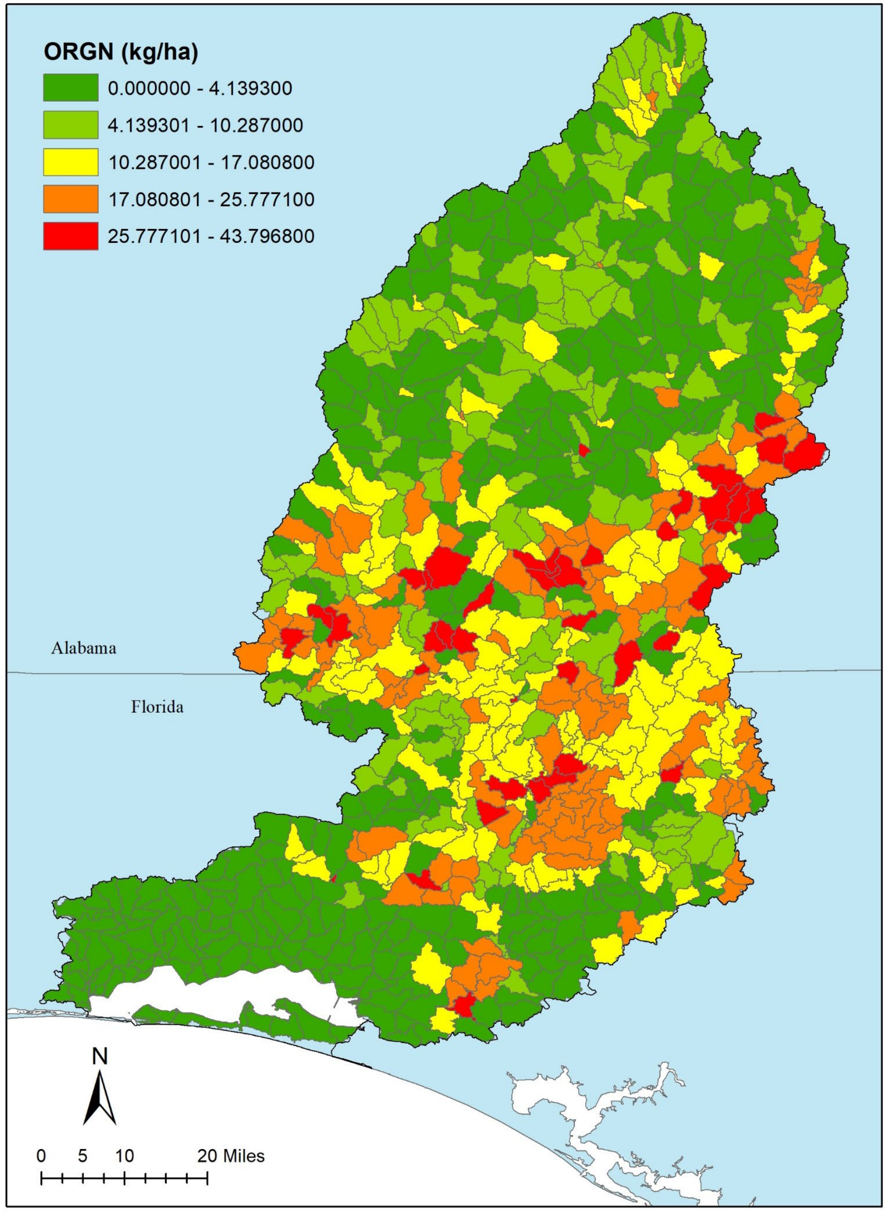
# Nitrogen

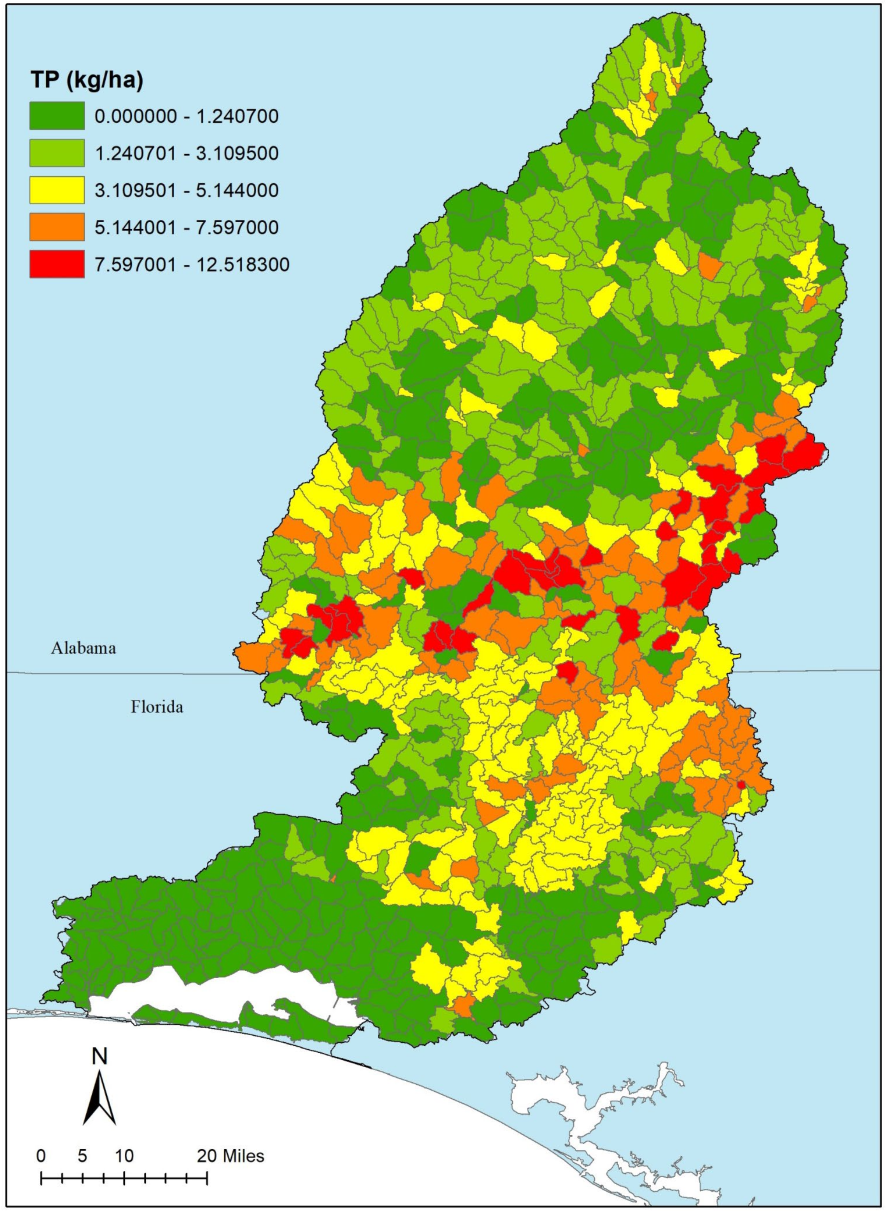
TN and Organic nitrogen of subbasin(average of 2012-2021)

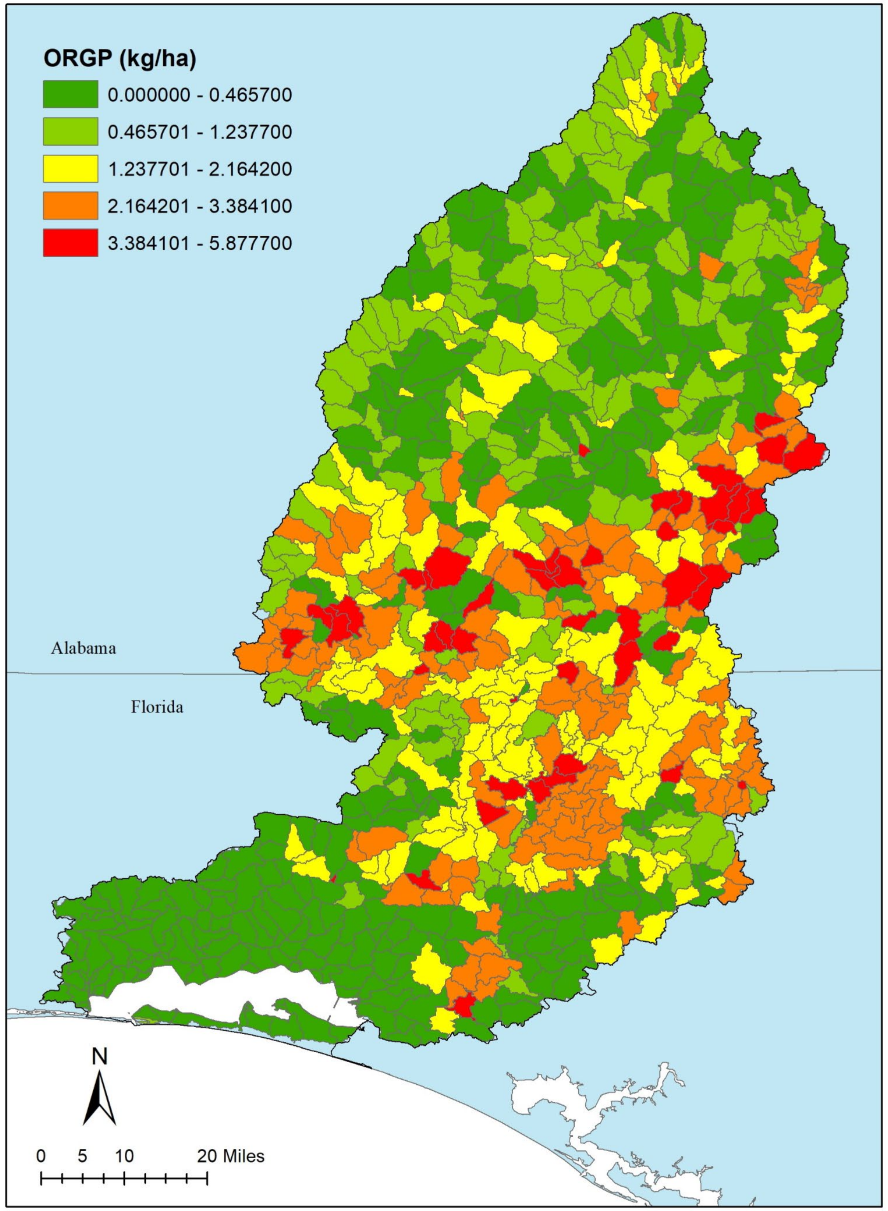


# Phosphorous

TP and Organic phosphorous of subbasin(AV of 2012-2021)

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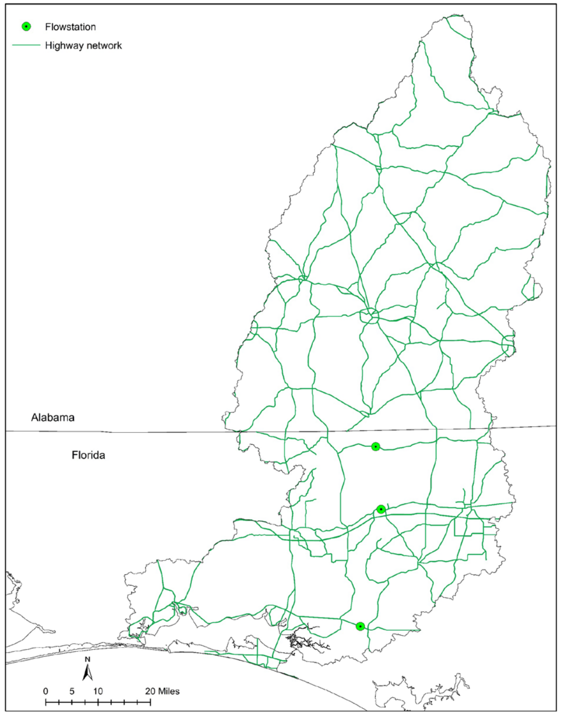
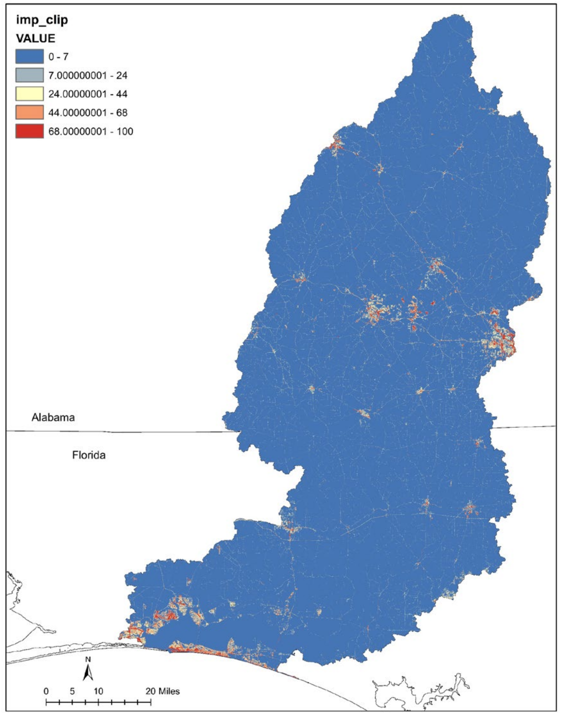
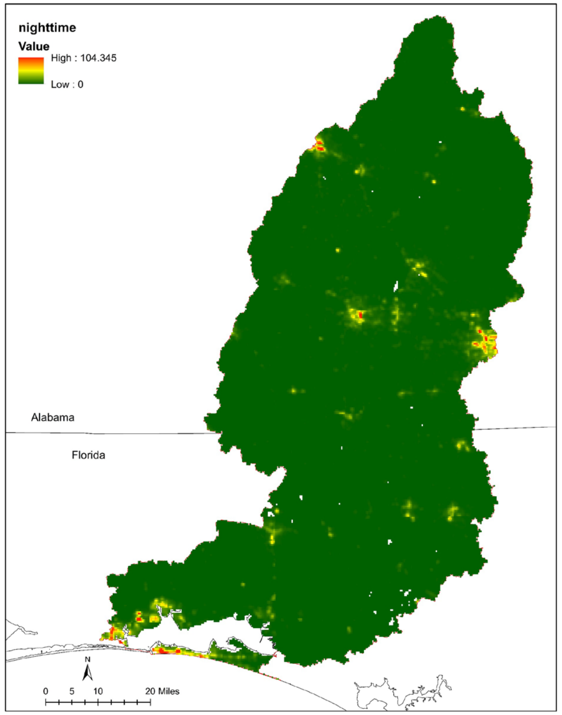
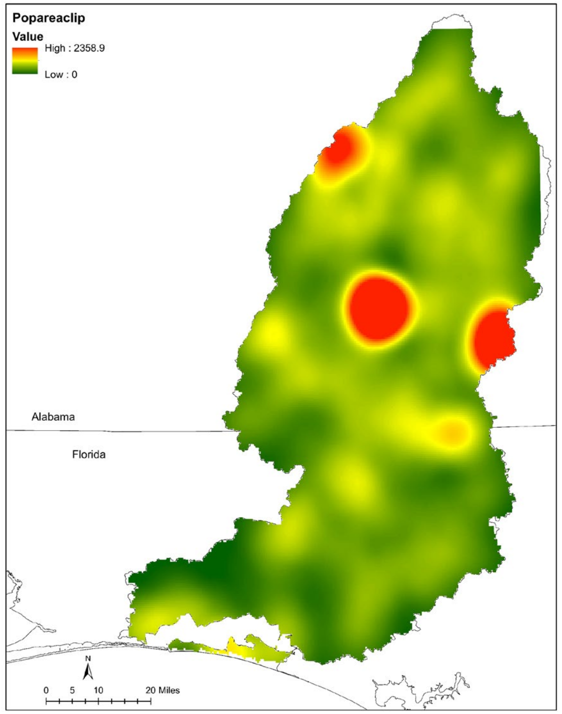
# What factors influencing water quality

# Road, impervious surface, nighttime RS, and populated area

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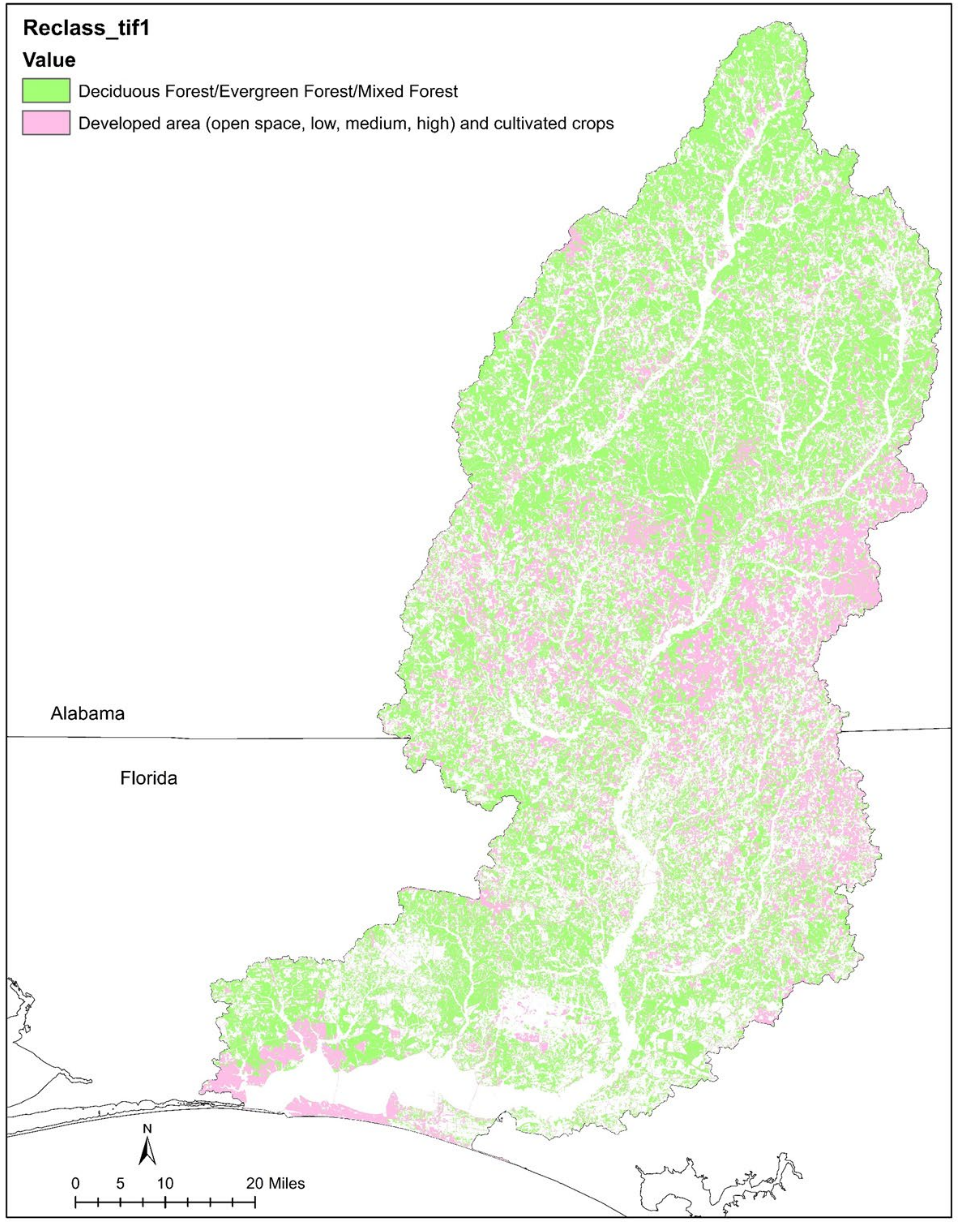
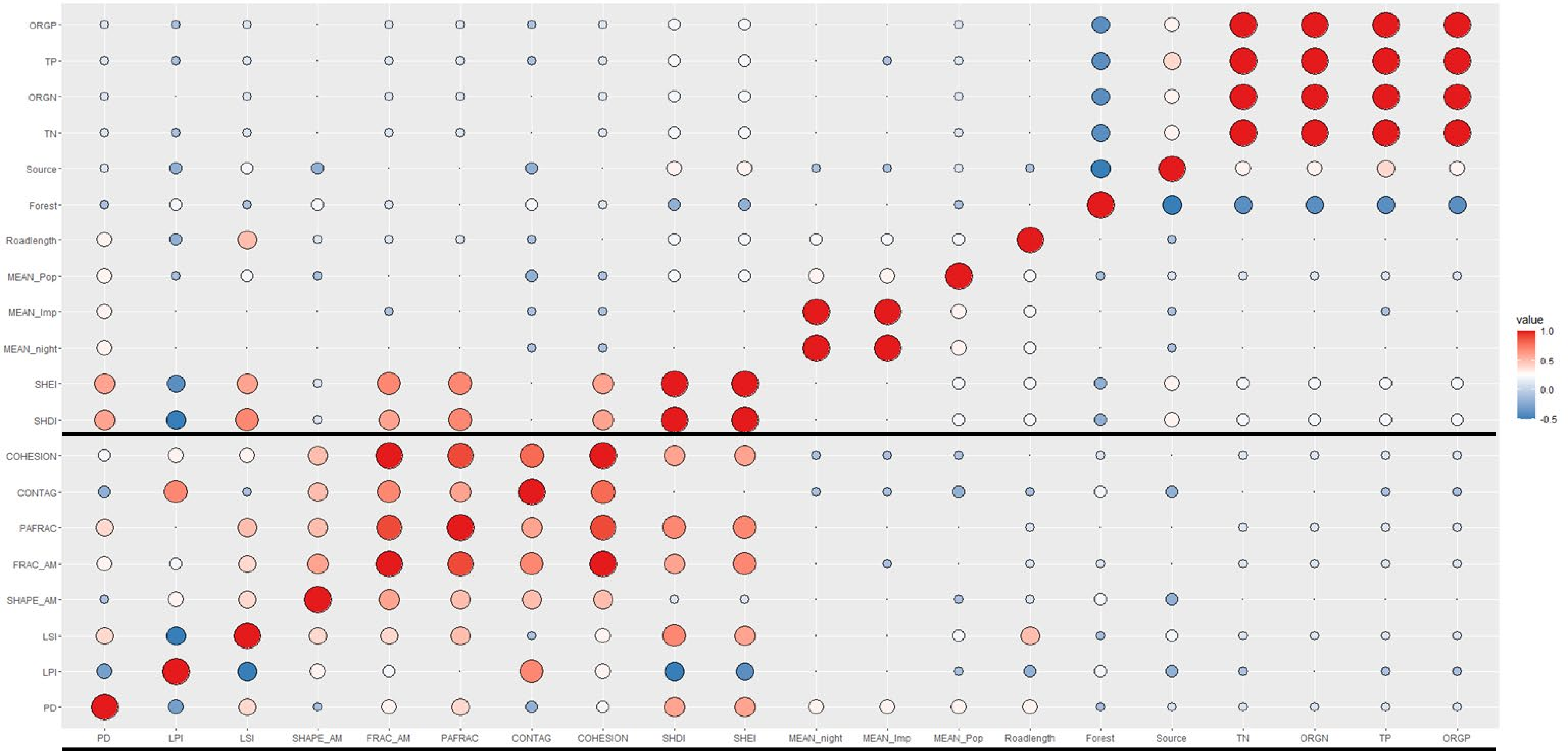
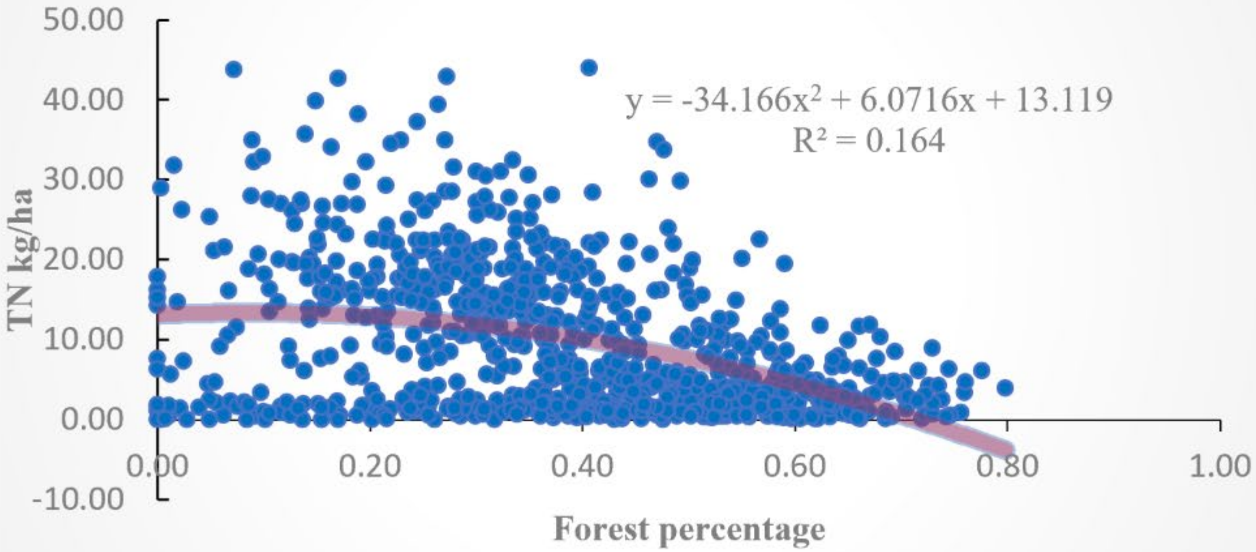
# LULC reclassification

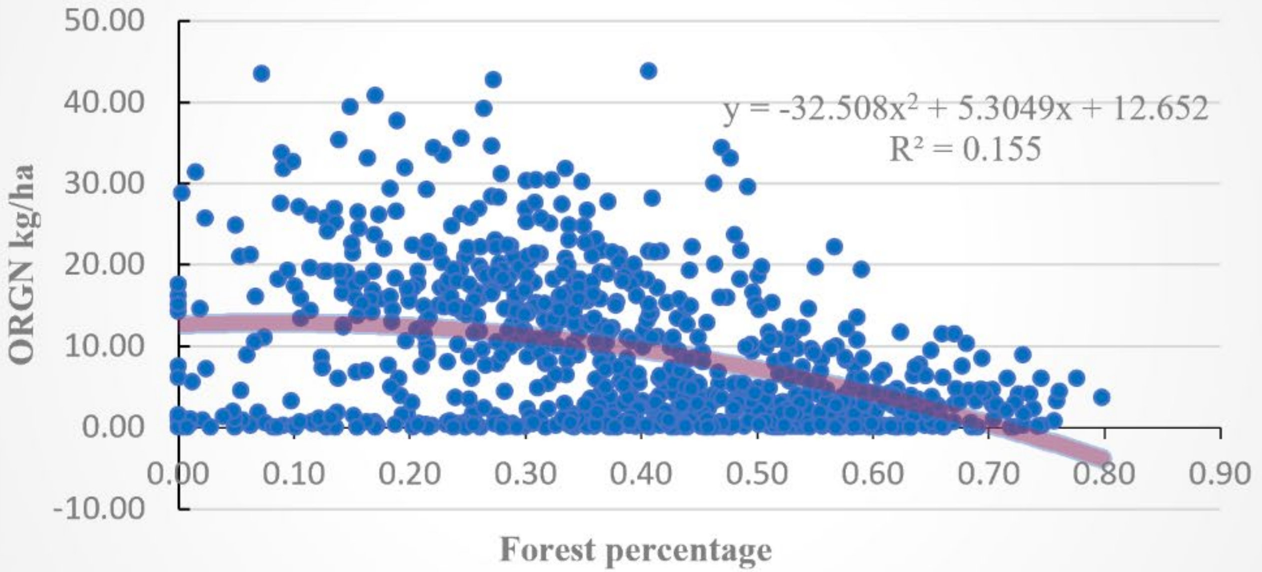
. Forest

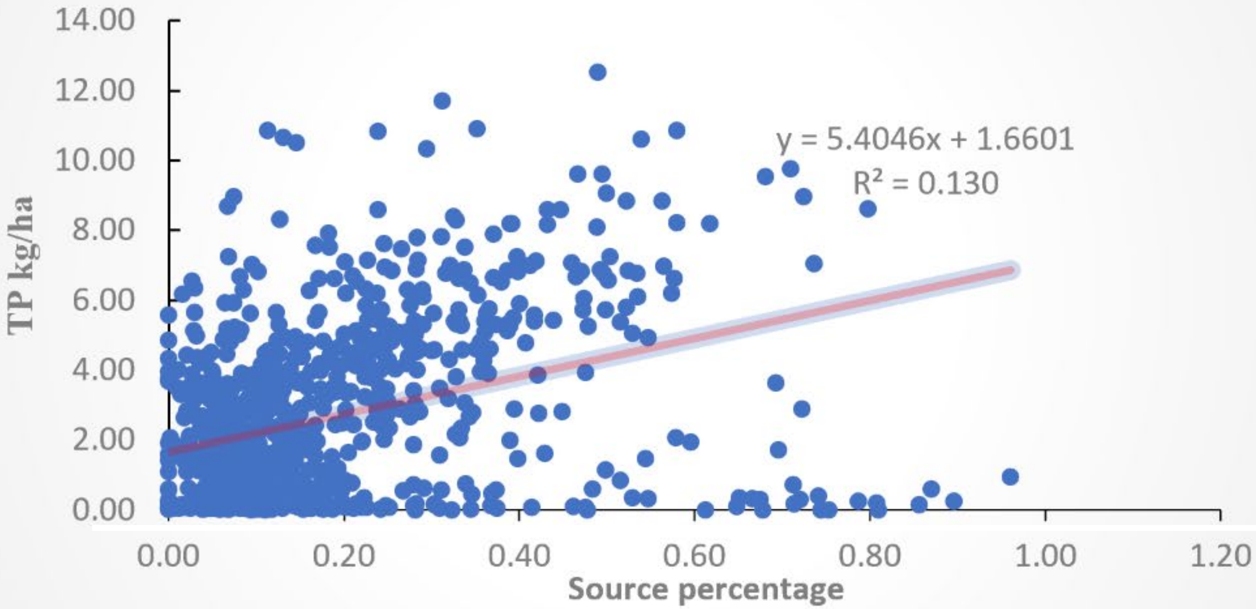
. Developed areas and cultivated crops (Source)

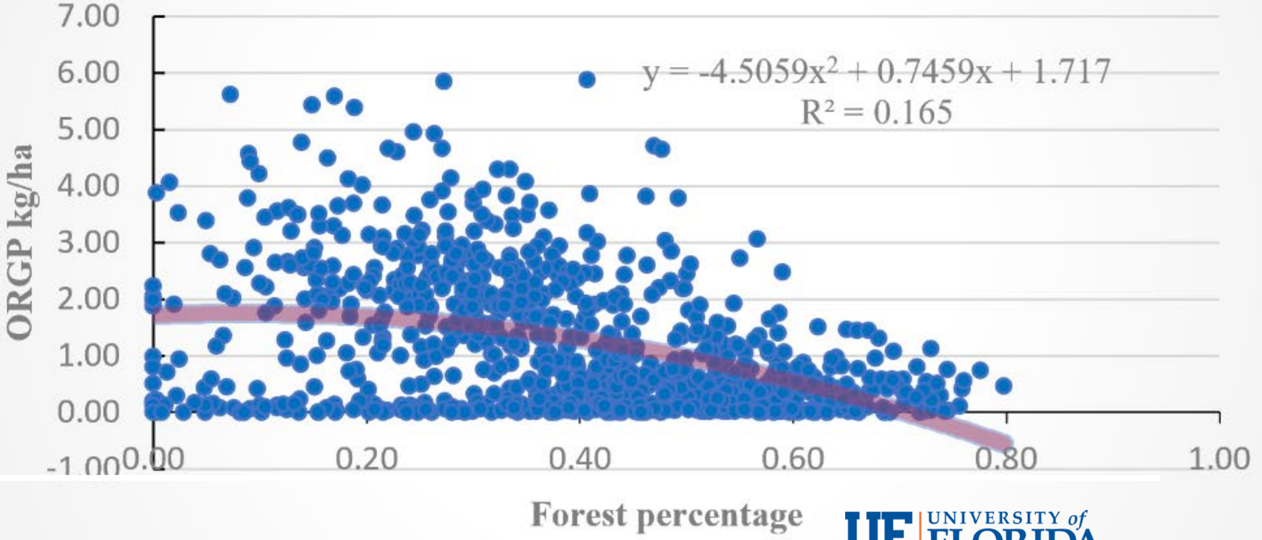



ORGP
TP
ORGN
TN
Source
Forest
Roadlength
MEAN_Pop
MEAN_Imp
MEAN_night
SHEI
SHDI
COHESION
CONTAG
PAFRAC
FRAC_AM
SHAPE_AM
LSI
LPI
PD
PD
LPI
LSI
SHAPE_AM
FRAC_AM
PAFRAC
CONTAG
COHESION
SHDI
SHEI
MEAN_night
MEAN_Imp
MEAN_Pop
Roadlength
Forest
Source
TN
ORGN
TP
ORGP
value
1.0
0.5
0.0
-0.5

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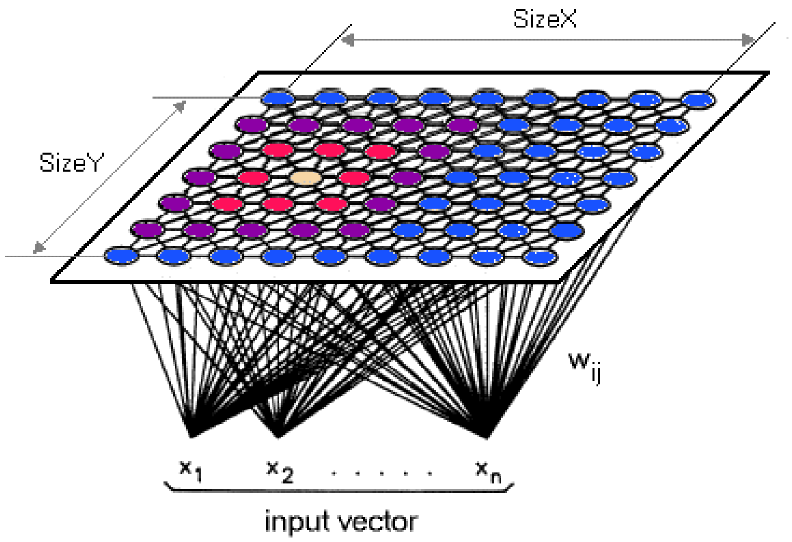
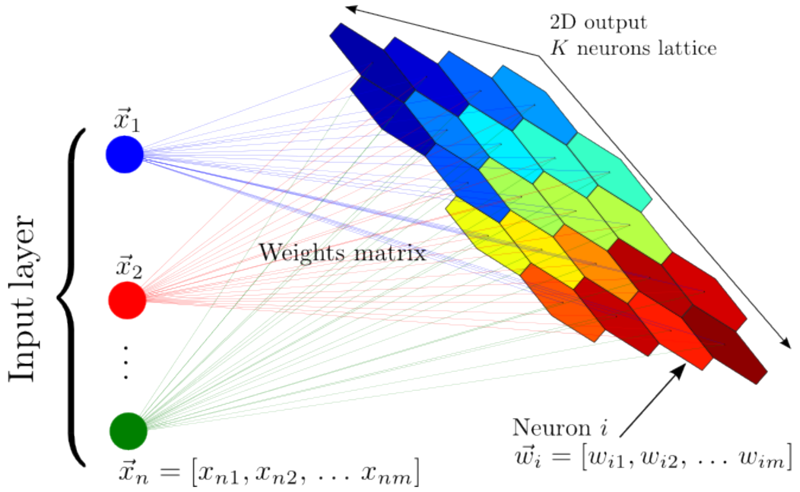
# Self-organizing maps

# Self Organizing Maps

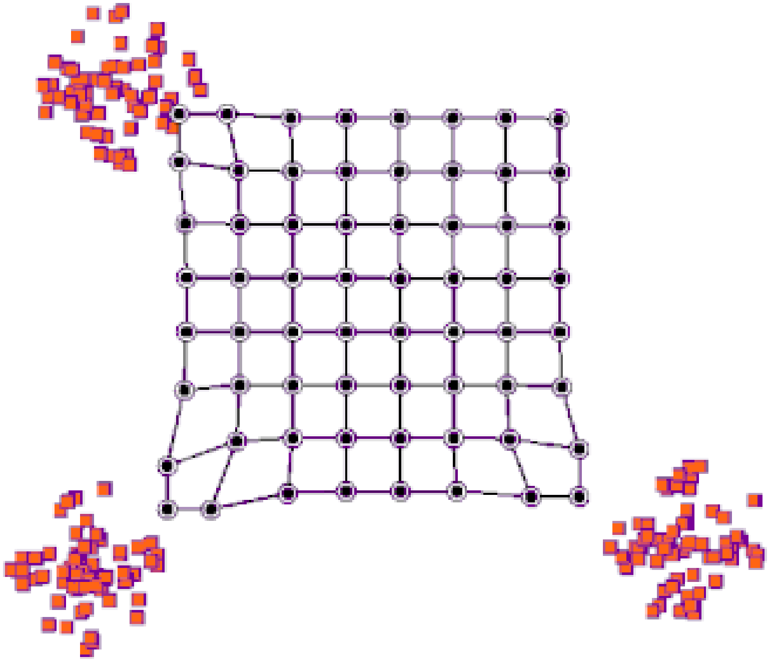
- SOMs are neural networks that employ **unsupervised machine** learning methods, mapping their **weights** to conform to the given input data with a goal of representing **multidimensional** data in an **easier** and **understandable** form for the human eye.
- Neurons that lie close to each other represent clusters with similar properties

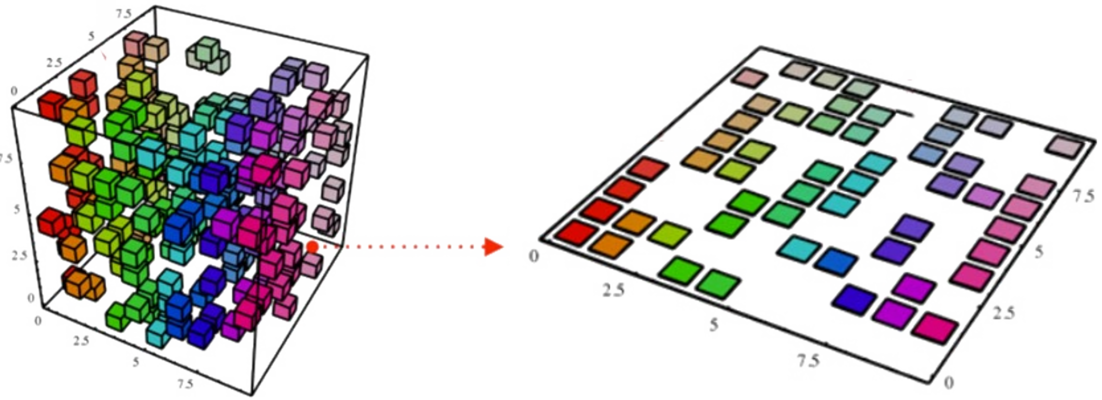


# SOM training

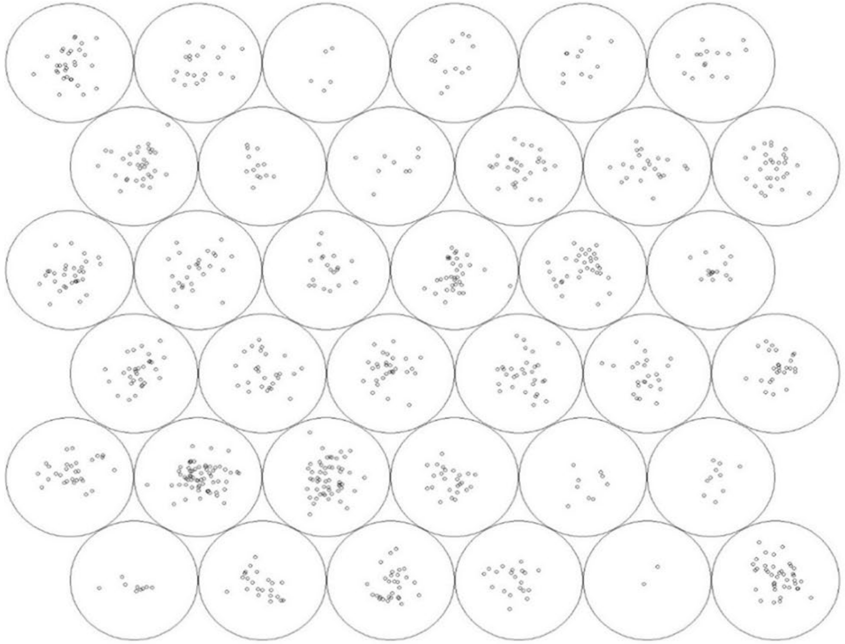
Training process of SOM on a two-dimensional data set

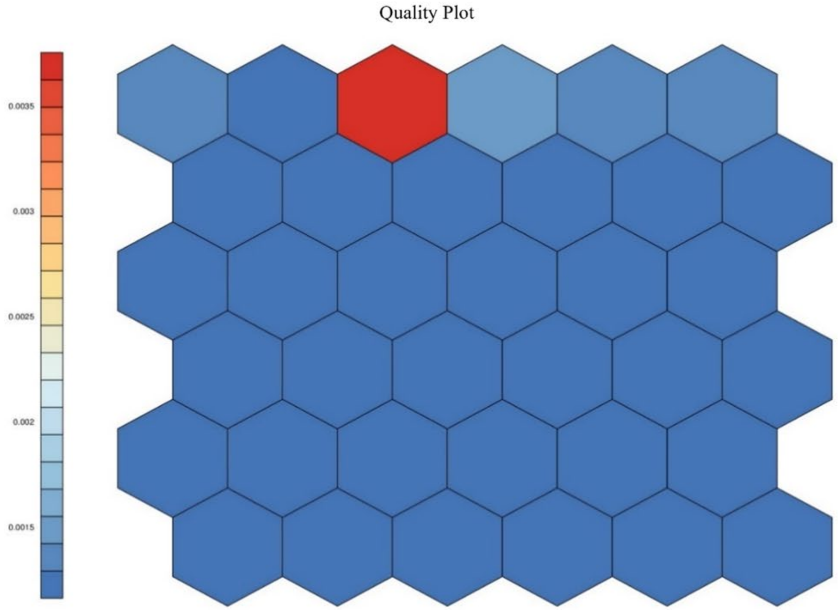




# SOM optimizing

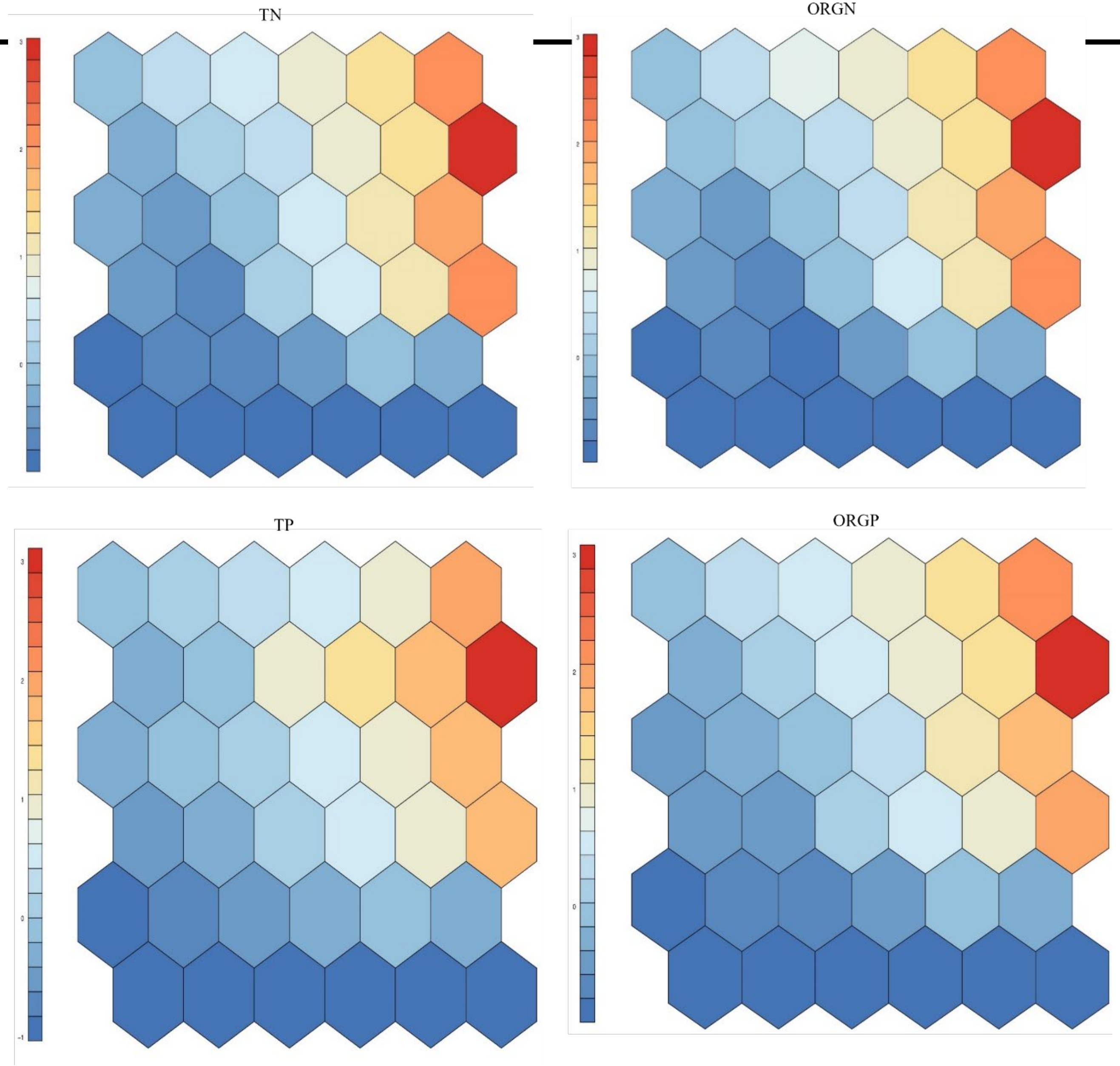
Self-organizing map (SOM) of the total 863 subbasins. The quality plot of the trained SOM showed that the SOM with 6*6 neurons was reliable for representing the water quality data (the lowest value of quantitative error, QE)





# Water quality

The SOM of the water quality datasets revealed that TN, ORGN, TP, and ORGP exhibited similar patterns.

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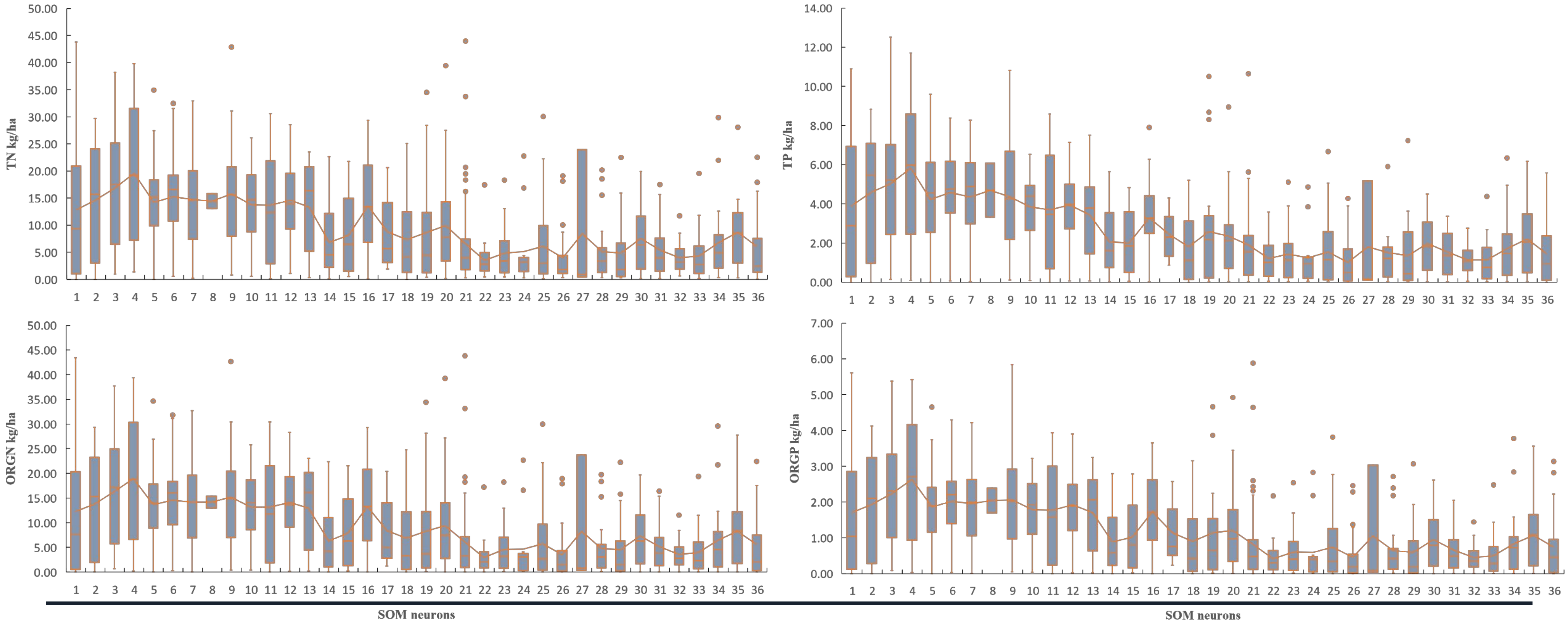
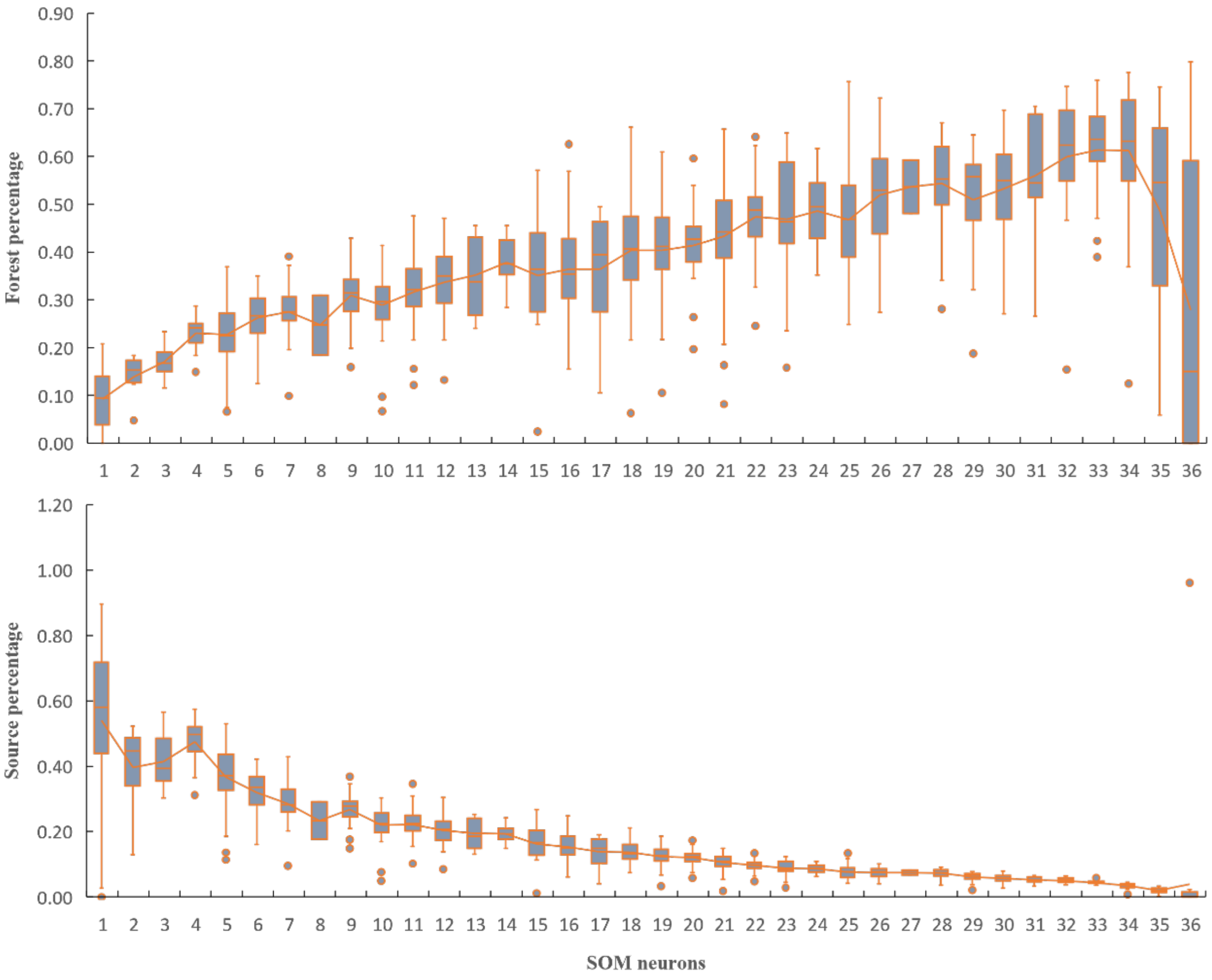
# Box plots for nitrogen and phosphorus of each SOM neurons.



Box plots for forest land cover and Source land use percentage of each SOM neurons.



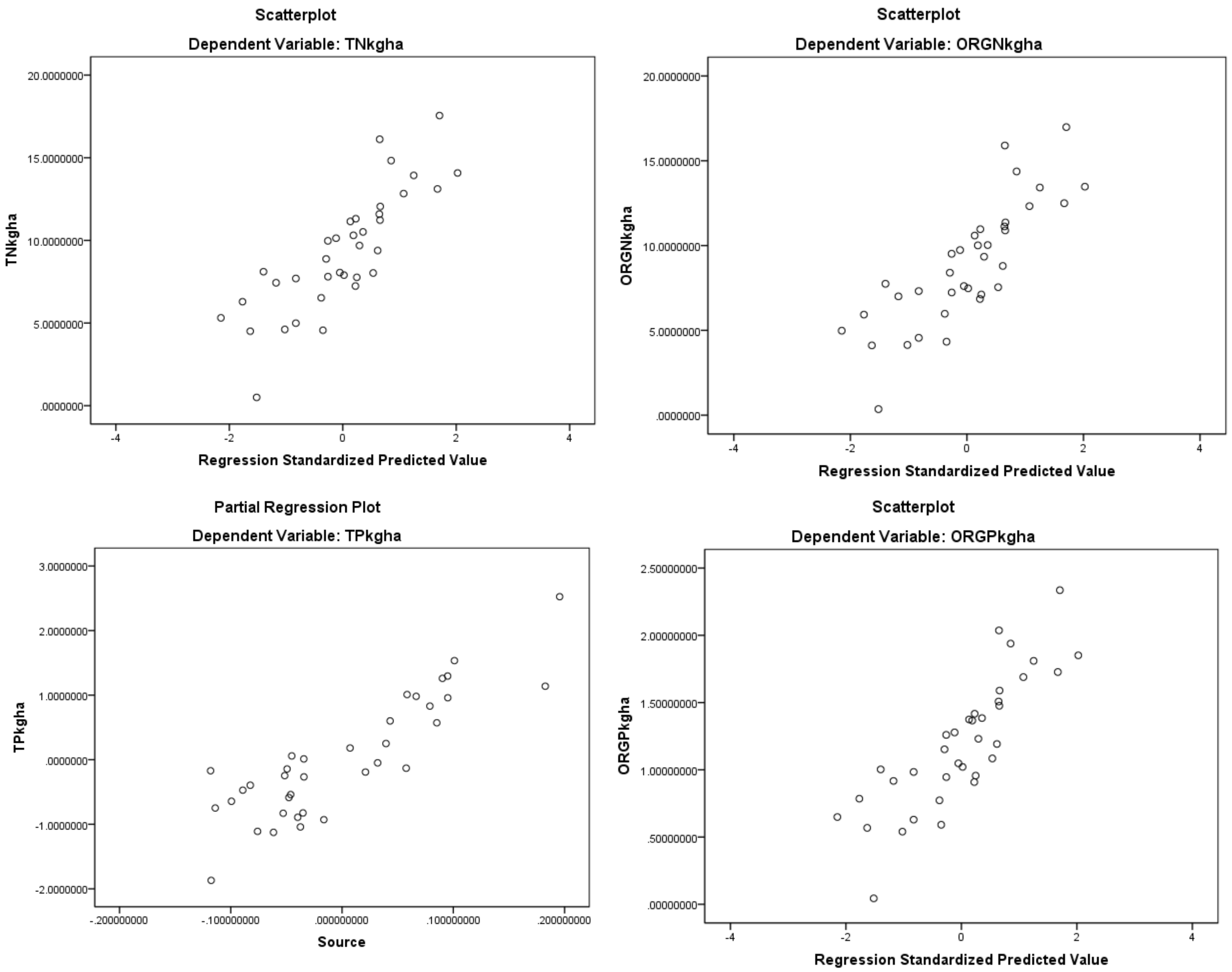
| Dependent | Independent | Ad_R2 | F | Equation |
|---|---|---|---|---|
| TN | Forest | 0.672 | 72.786*** | TN = -37.557*Forest +23.635 |
| ORGN | Forest | 0.661 | 69.222*** | ORGN =-36.796*Forest +22.902 |
| TP | Source | 0.752 | 107.132*** | TP = 10.465 *Source +0.741 |
| | Source, MEAN_pop | 0.786 | 65.189*** | TP = 9.864 *Source +0.001* MEAN_pop +0.400 |
| ORGP | Forest | 0.695 | 80.081*** | ORGP = -5.113*Forest +3.144 |

# SOM-based regression analysis

Table 1 The self-organizing maps (SOM) based linear regression analysis between water quality and the independent variables

Note: * $p < 0.05$, *** $p < 0.001$; TN, total nitrogen; ORGN, organic nitrogen; TP, total phosphorus; ORGP, organic phosphorus; Forest, percentage of forest in a subbasin; Source, percentage of developed areas (including high, medium and low density) and cultivated crops in a subbasin; MEAN_pop, popularized areas in a subbasin; PAFRAC, perimeter-area fractal dimension

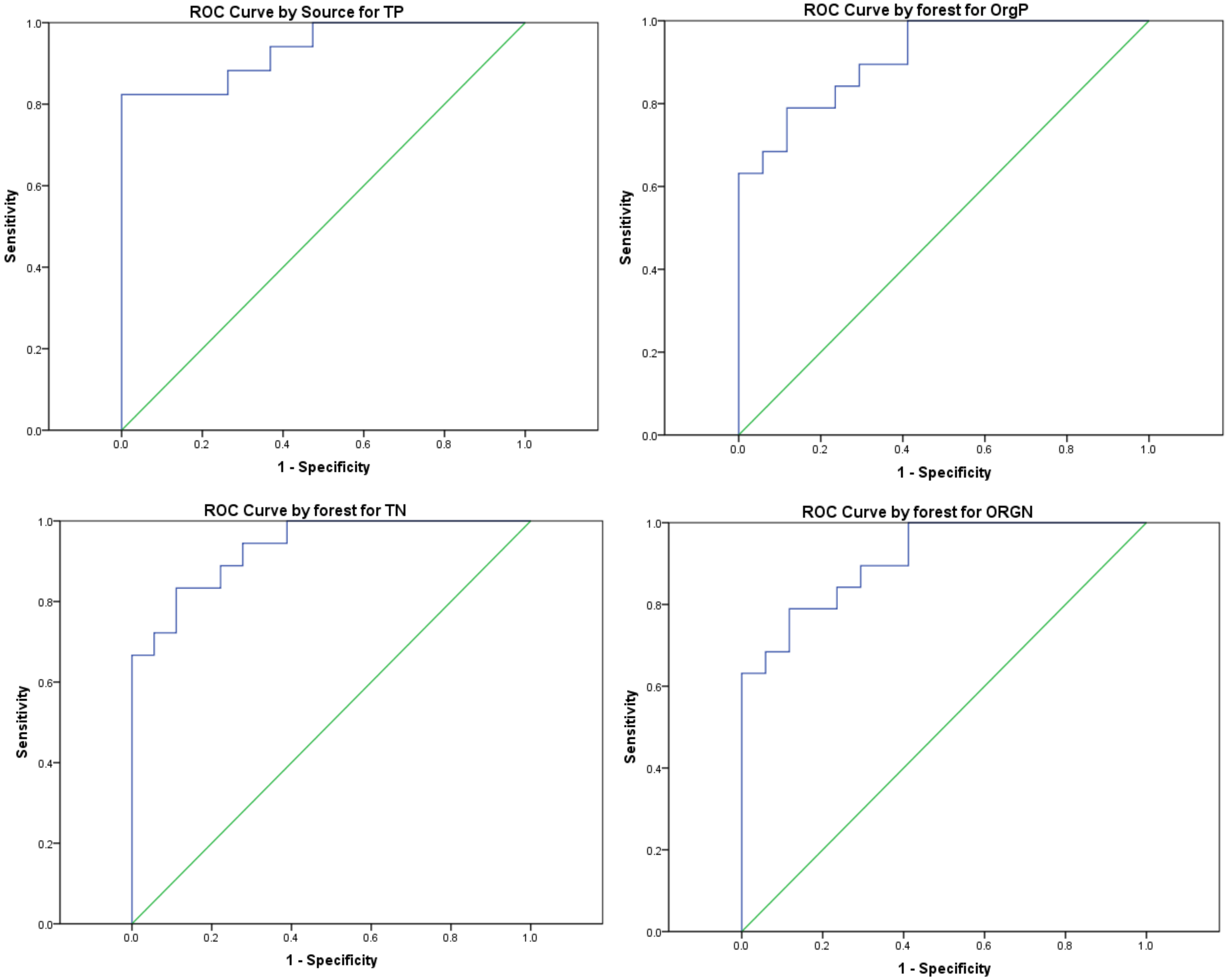
SOM-based scatterplots for water quality indicators



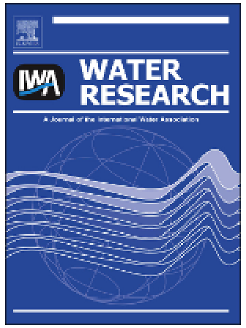
# Thresholds detection by ROC analysis

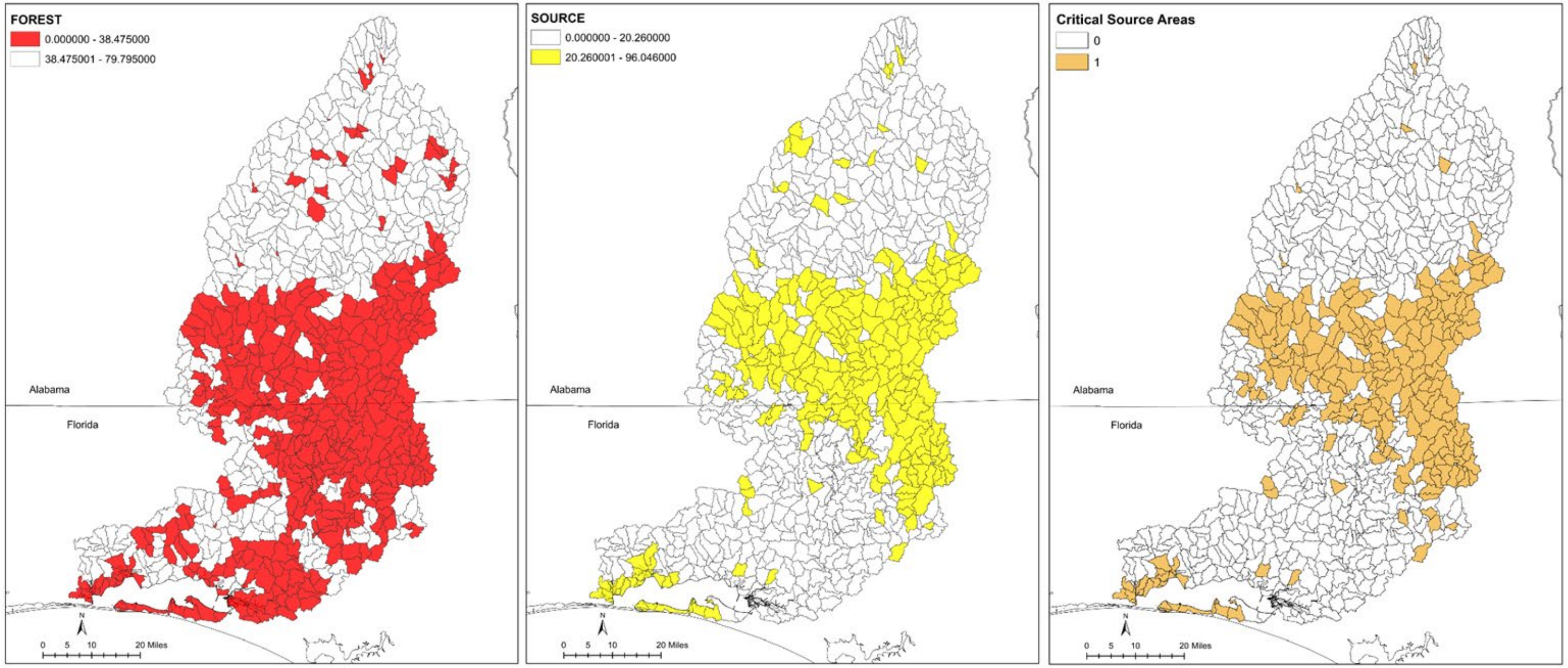
. Forest 37.47%

. Source 20.26%



# CSAs and performance




Potential critical sources areas (CSAs) identification as those with forest percentage < 37.47% (red), those with Source percentage > 20.26% (yellow), and those meeting both criteria (orange)


**Water Research** (2024), doi: [https://doi.org/10.1016/j.watres.2024.121286](https://doi.org/10.1016/j.watres.2024.121286)


- ✓ Red 46% of the total area, but 67% of total TN loads for the whole basin
- ✓ Yellow 33% of the total area, but 54% of the total loads
- ✓ Orange 28% of the total area, but 47% of the TN, and 50% of the TP loads of the whole

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# LULC of Choctawhatchee

It seems the story is not so bad according to our research!!

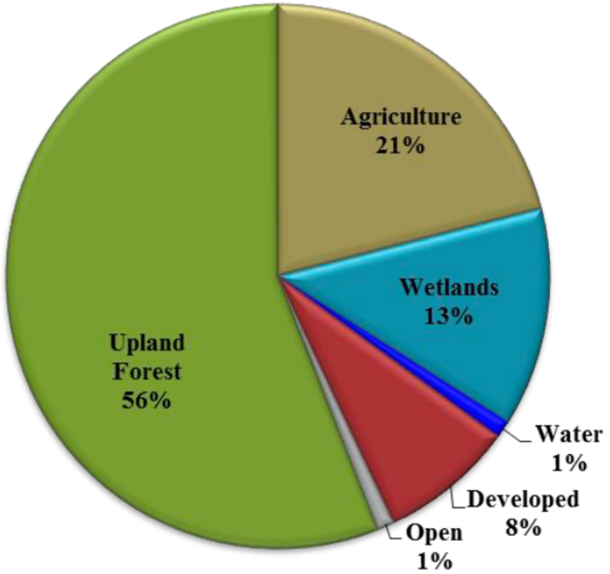


**Figure 2-6 Land Cover in the Greater Choctawhatchee Watershed (Alabama and Florida)**
Sources: FDEP 2015a; MRCL NLCD 2011

**Table 2-1 2012-2013 Land Use and Land Cover in the Choctawhatchee River and Bay Watershed (Florida Only)**

| Land Use Category | Square Miles | Percent of Basin |
|---|---|---|
| Agriculture | 334 | 1.3 |
| Developed | 191 | 9.1 |
| Open Land | 42 | 2.0 |
| Upland Forests | 1,032 | 49.2 |
| Water | 28 | 15.9 |
| Wetlands | 469 | 22.4 |

Source: FDEP 2015a

By: *Choctawhatchee Bay Estuary Program Technical Advisory Committee, 2021*

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# Take away

- ✓ Forest and Source percentages play a critical role in regulating water quality with a threshold effects
- ✓ SOMs provided a powerful tool for data clustering and dimension reduction, aiding in the identification of driving factors and spatial patterns of water quality
- ✓ By the methods initiated in this study it is found 37.46% and 20.26% are the detected thresholds of forest and Source respectively

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# Thank you!

Shubo Fang
PhD
sfang1@ufl.edu
Tel: 2255731686

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