DEVELOPING A MECHANISTIC UNDERSTANDING OF TREE ISLANDS: LESSONS LEARNED FROM NEARLY A DECADE OF STUDYING AN EVERGLADES PHYSICAL MODEL.

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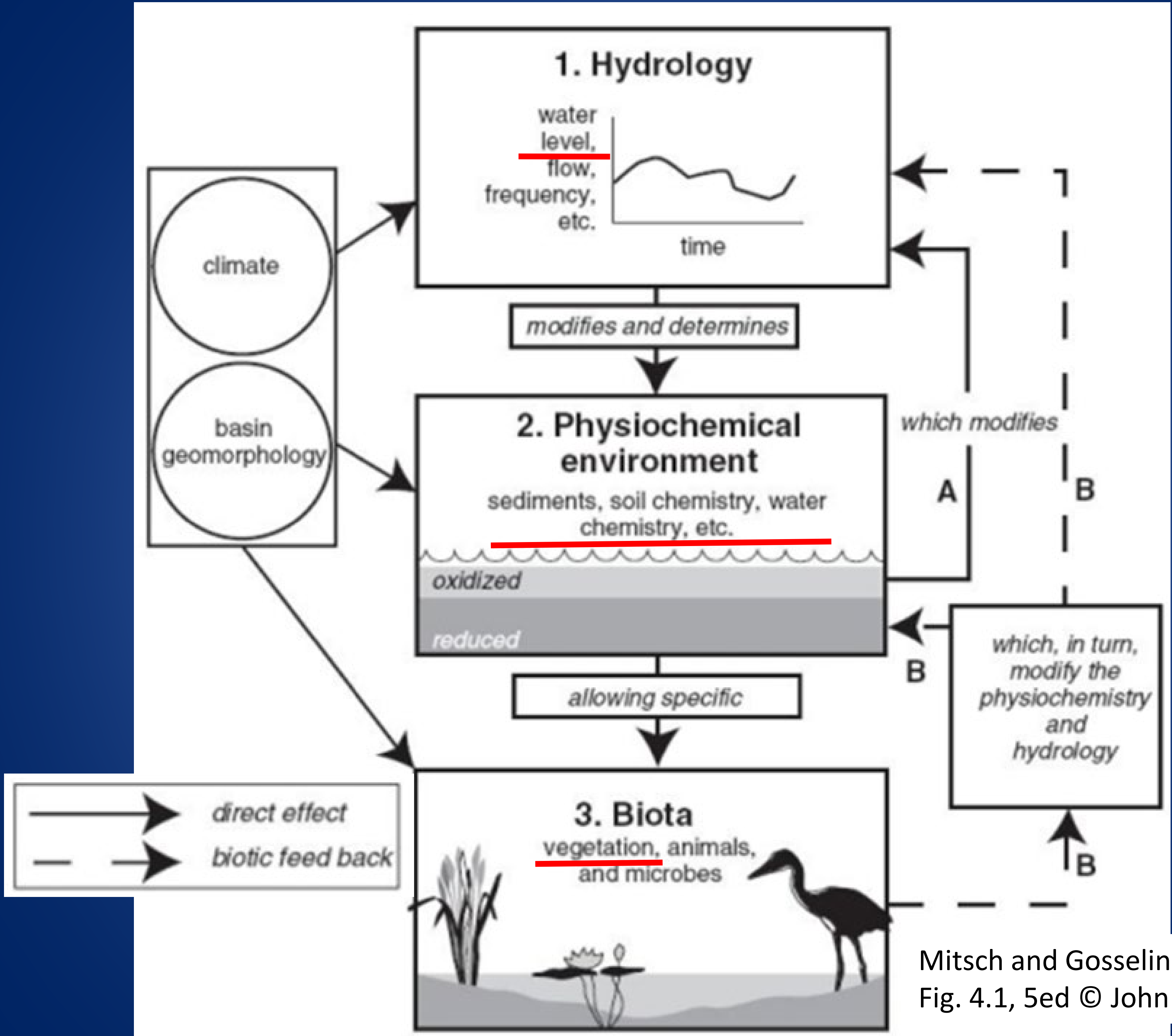
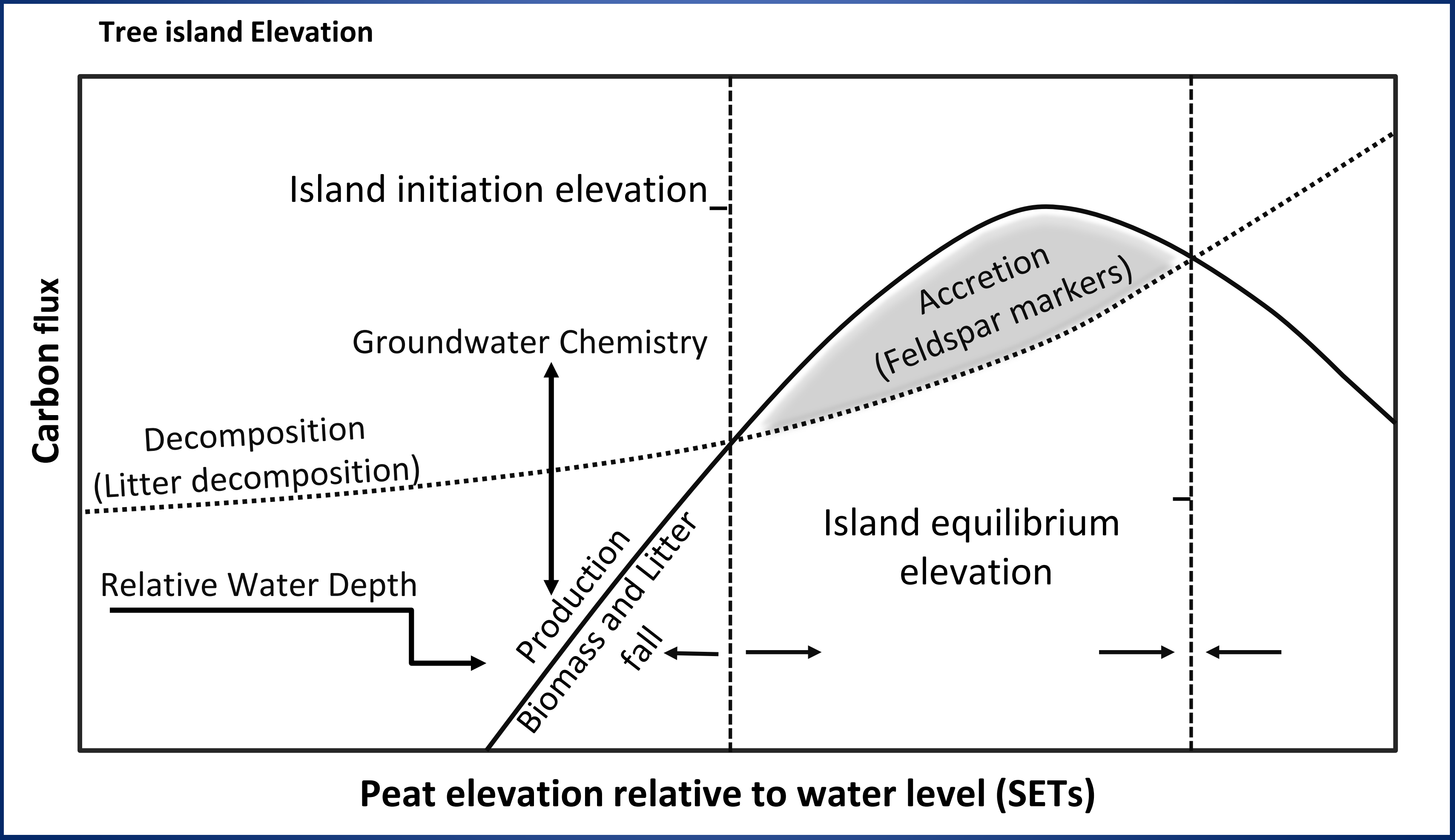
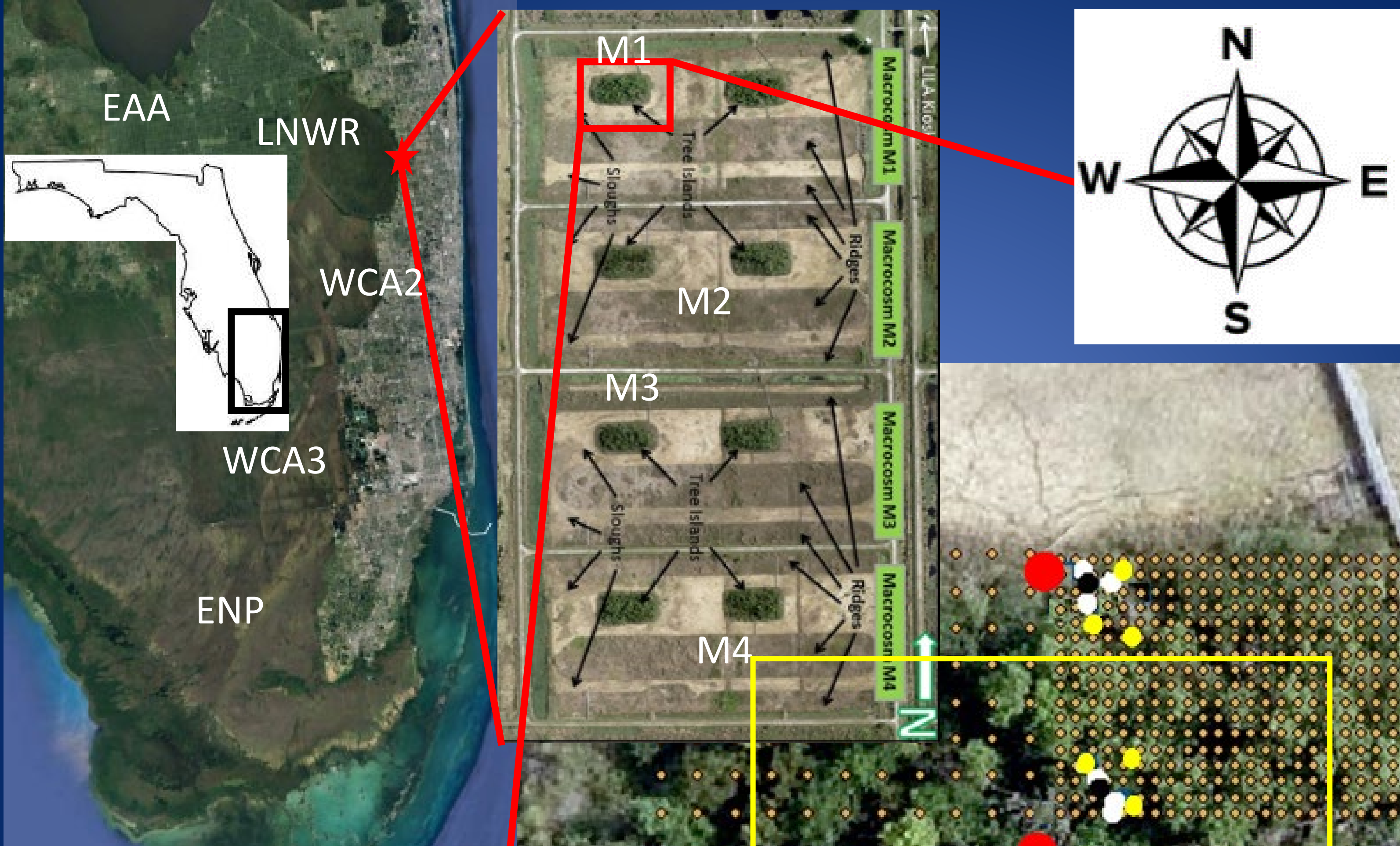


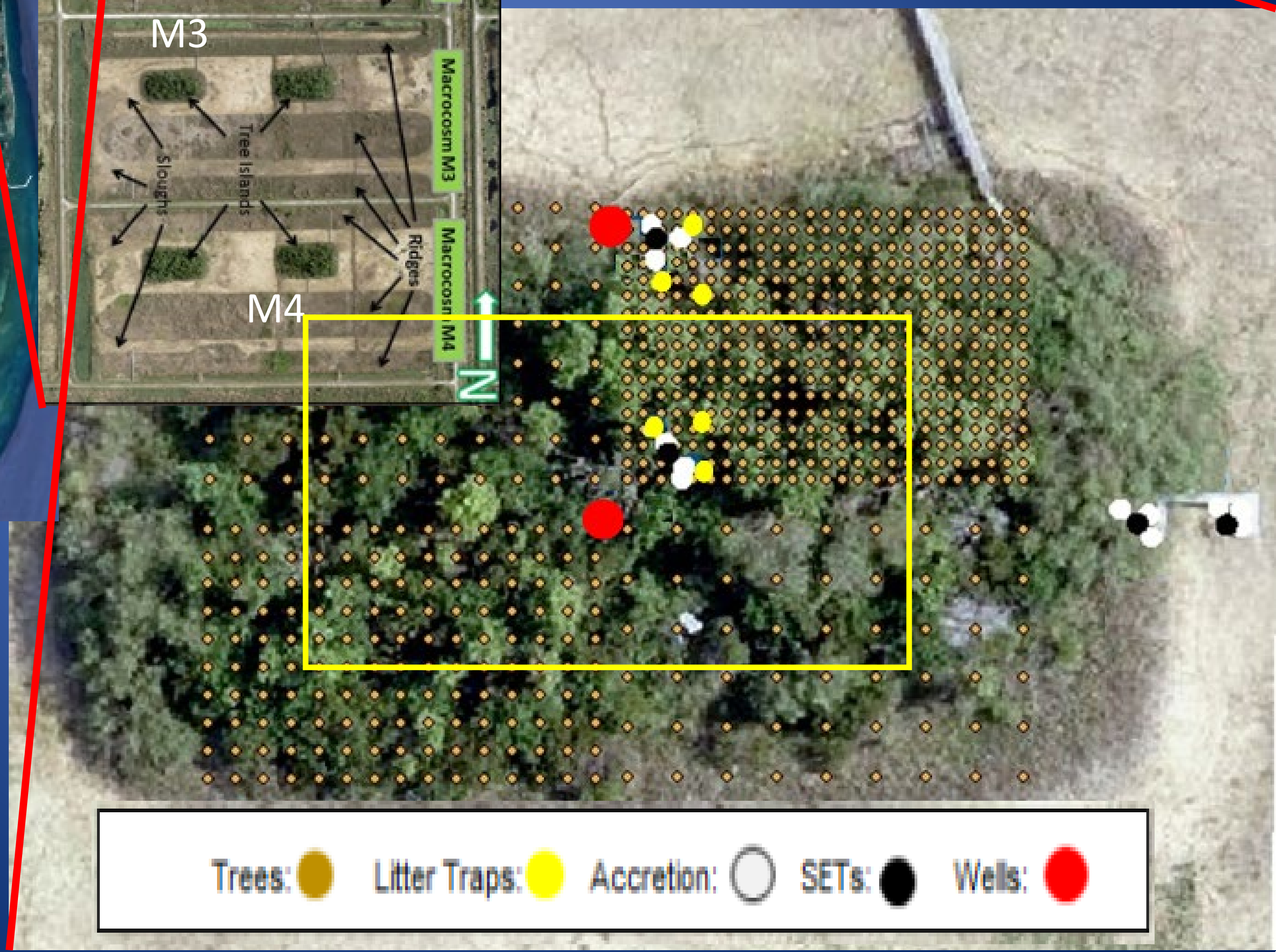
Mitsch and Gosselink, Wetlands, Fig. 4.1, 5ed © John Wiley & Sons

The development and persistence of functioning tree islands in wetland ecosystems is a result of self-organizing feedback mechanisms involving biomass production, fluxes of water and nutrients, and soil formation (accretion).



Adapted from Fig. 4 Larsen et al., 2011 Crit Rev Environ Sci Technol. 41 (S1):344-381





Since 2005.
2006 and 2007 – 717 seedlings per each of 8 islands.

- Understand processes that lead to tree island “self-organization” with the potential to inform successful restoration.

- To test the hypothesis that hydrologic conditions (RWD) influence tree island components, we used data collected between 2009-2016 (starting nominally 2 years after tree planting in 2006 and 2007) and compared higher elevation tree island centers (“drier”) to lower elevation tree island edges.

- We hypothesized that there would be a directional response between tree island components and RWD and that the establishment and strength of these interactions would vary through time. Therefore, when possible data were grouped into the early development stage (2009-2012) and a later establishment stage (2013-2016).

Variable Description (36 total)

Relative Water Depth (RWD)

Center and Edge

Water Depth to soil surface (WD)

Groundwater Levels in wells (WL)

Tree Biomass

Groundwater Physicochemistry

Temperature (TEMP)

Conductivity (COND)

pH

Alkalinity, bicarbonate, HCO3- (ALK)

Chloride, Cl^- (CL)

Sulfate, SO_4^{2-} (SO4)

Calcium, Ca_2^+ (Ca)

Magnesium, Mg^+ (Mg)

Potassium, K^+ (K)

Sodium, Na^+ (Na)

Nitrate, NO_3^- (NO3)

Nitrite, NO_2^- (NO2)

Nitrate + Nitrite, $NO_3^- + NO_2^-$ (NN)

Ammonia, NH_4^+ (NH4)

Total Phosphorus (TP)

Soluble Reactive Phosphorus (SRP)

Total Organic Carbon (TOC)

δD

δ18O

Litterfall

Annual Litterfall (LFA)

Total Accumulated Litterfall (TLF)

Standing Litter (SL)

Soil Accretion and Elevation Change

Total Soil Accretion (TSA)

Annual Soil Accretion (ASA)

Total Soil Elevation Change (SET)

Annual Soil Elevation Change (ASET)

Soil Physicochemistry

Total Phosphorus (TP_s)

Total Nitrogen (TN_s)

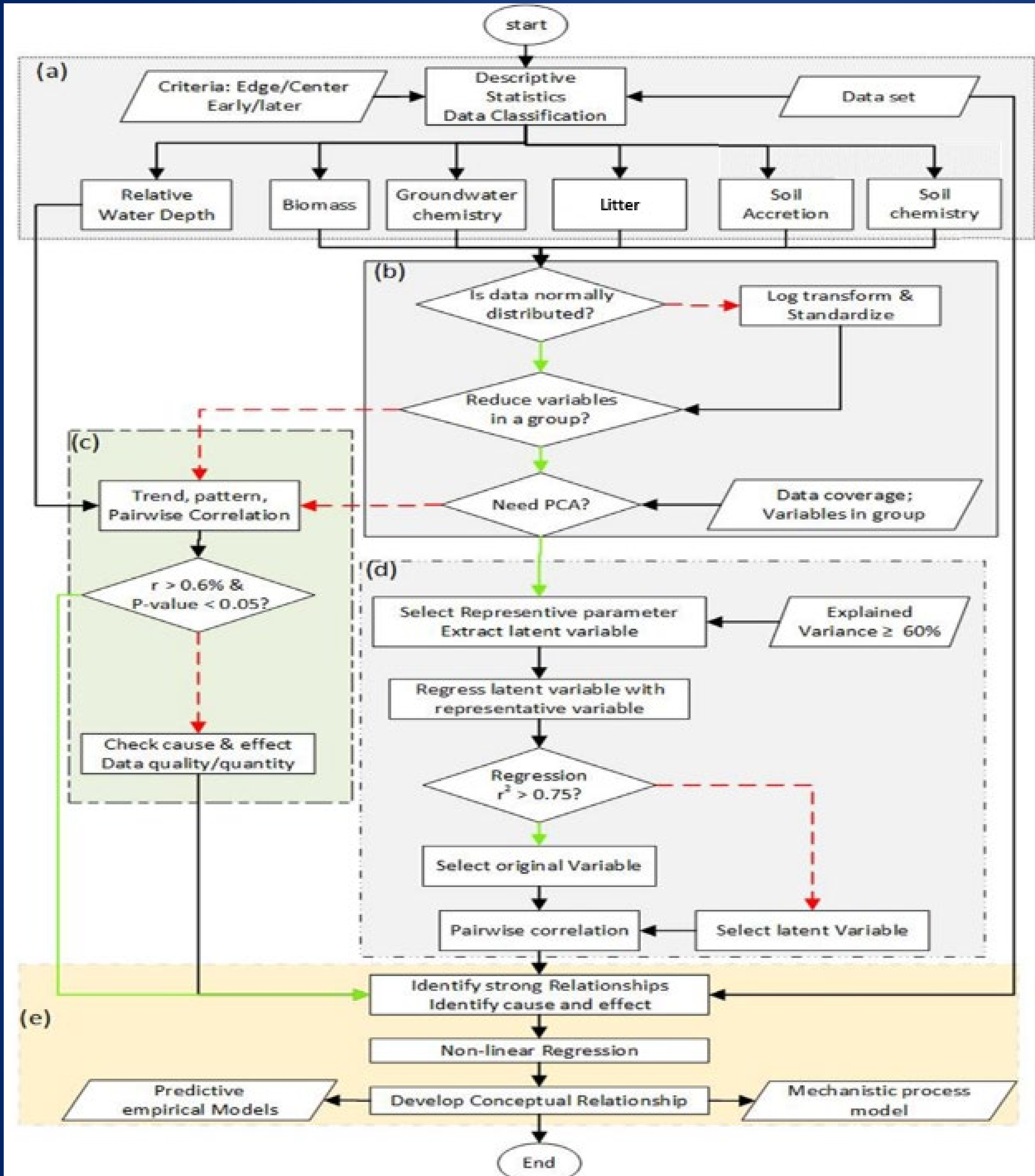
Total Carbon (TC_s)

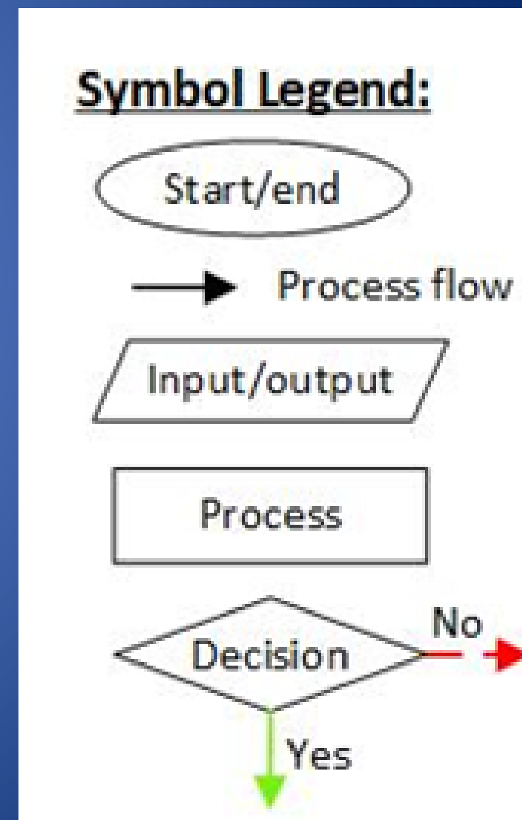
Organic Matter (OM_s)

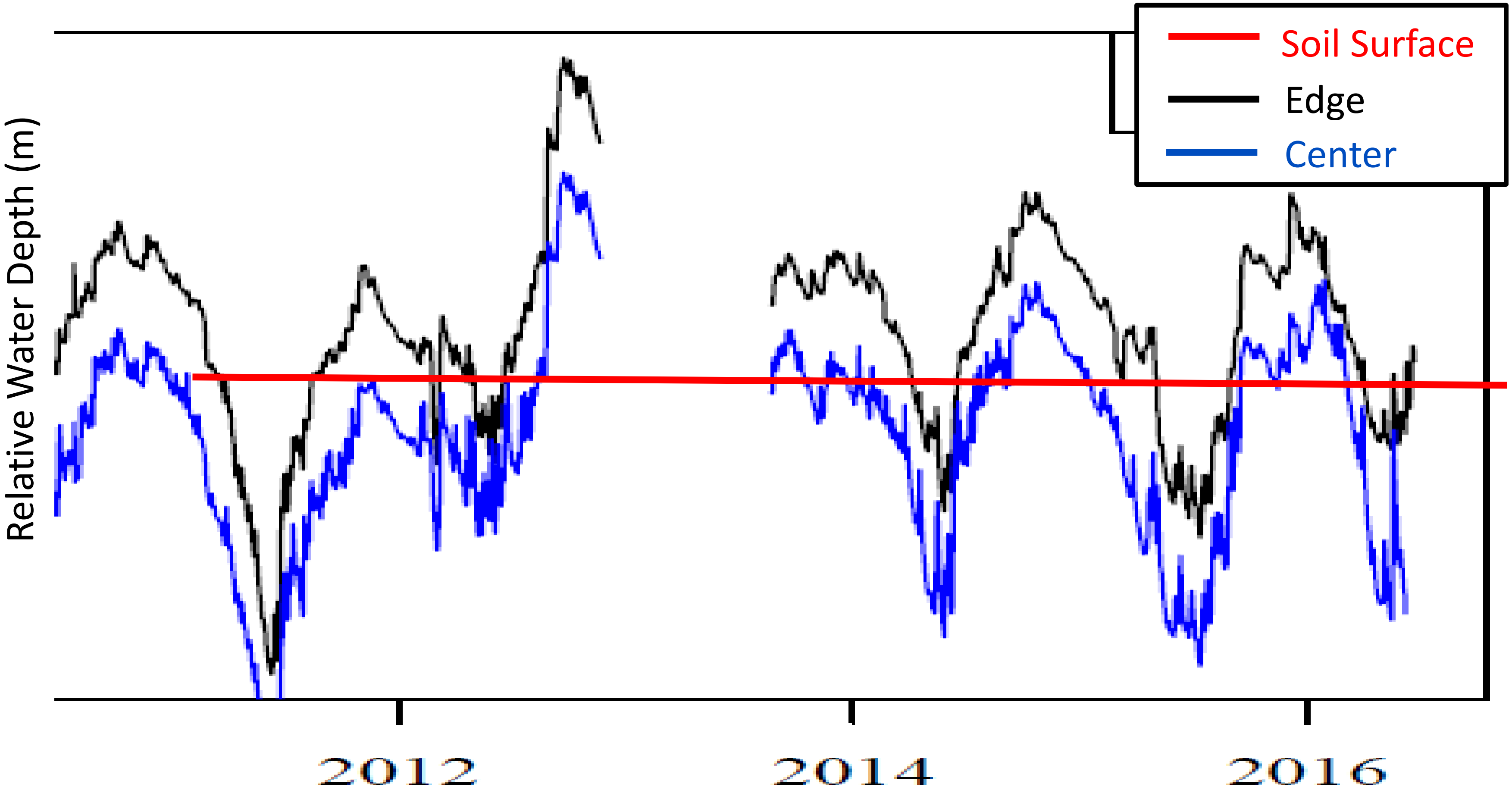
pH (pH_s)

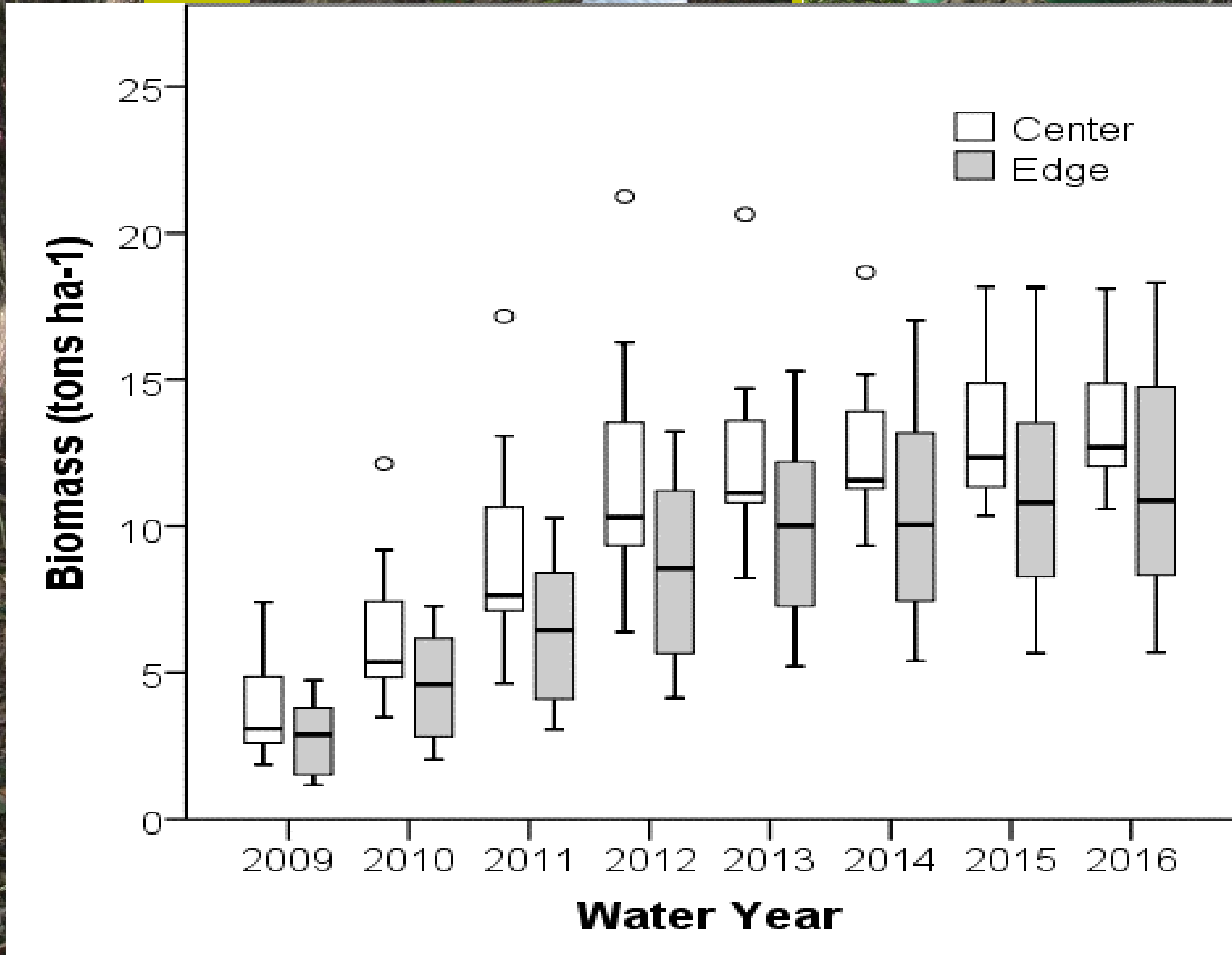
Fraction dry (Frac Dry)

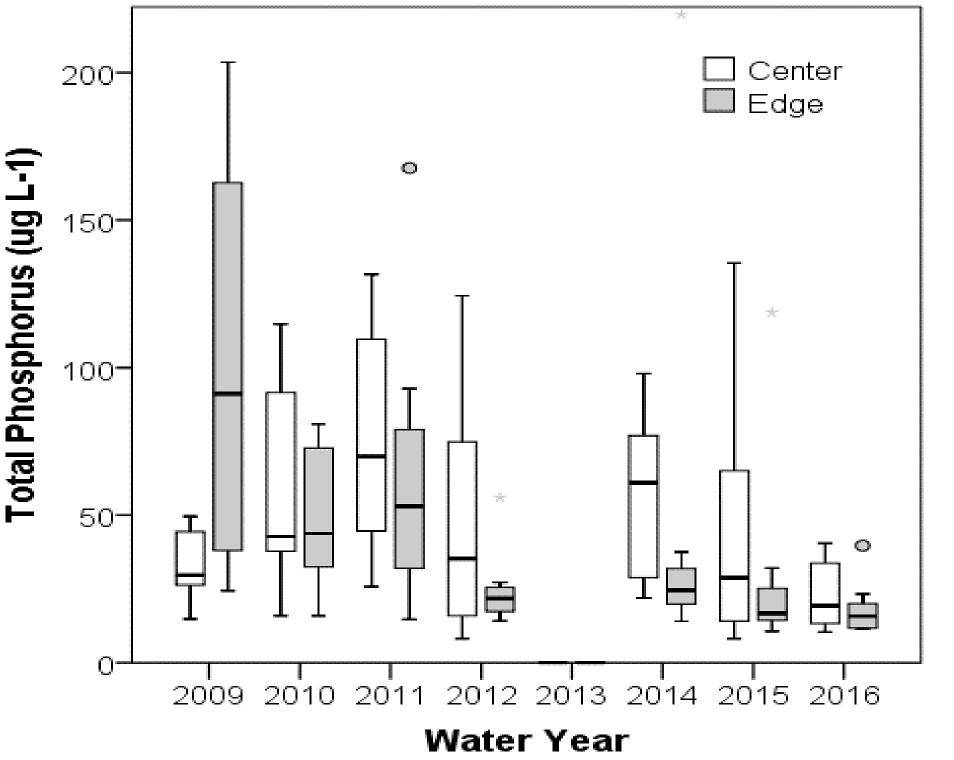
Field Bulk Density (FBD)


start
(a)
Criteria: Edge/Center Early/later
Descriptive Statistics Data Classification
Data set
Relative Water Depth
Biomass
Groundwater chemistry
Litter
Soil Accretion
Soil chemistry
(b)
Is data normally distributed?
Log transform & Standardize
Reduce variables in a group?
Need PCA?
Data coverage; Variables in group
(c)
Trend, pattern, Pairwise Correlation
r > 0.6% & P-value < 0.05?
Check cause & effect Data quality/quantity
(d)
Select Represenive parameter Extract latent variable
Explained Variance ≥ 60%
Regress latent variable with representative variable
Regression r² > 0.75?
Select original Variable
Pairwise correlation
Select latent Variable
(e)
Identify strong Relationships Identify cause and effect
Non-linear Regression
Predictive empirical Models
Develop Conceptual Relationship
Mechanistic process model
End

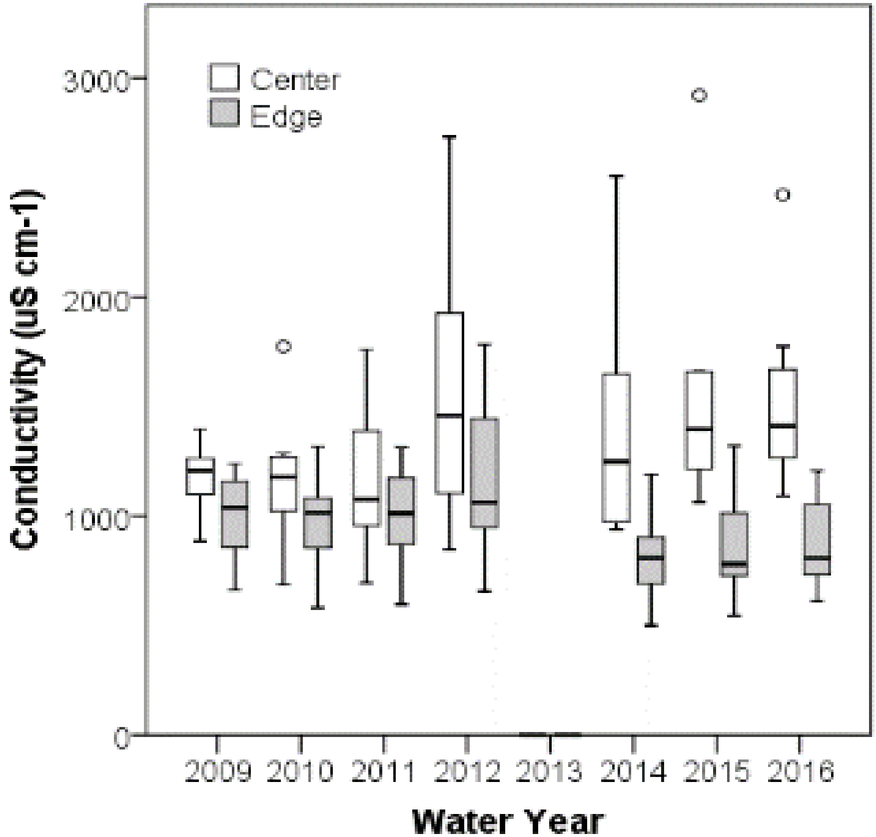

Symbol Legend:
Start/end
Process flow
Input/output
Process
Decision
No
Yes


Soil Surface
Edge
Center
Relative Water Depth (m)
2012
2014
2016

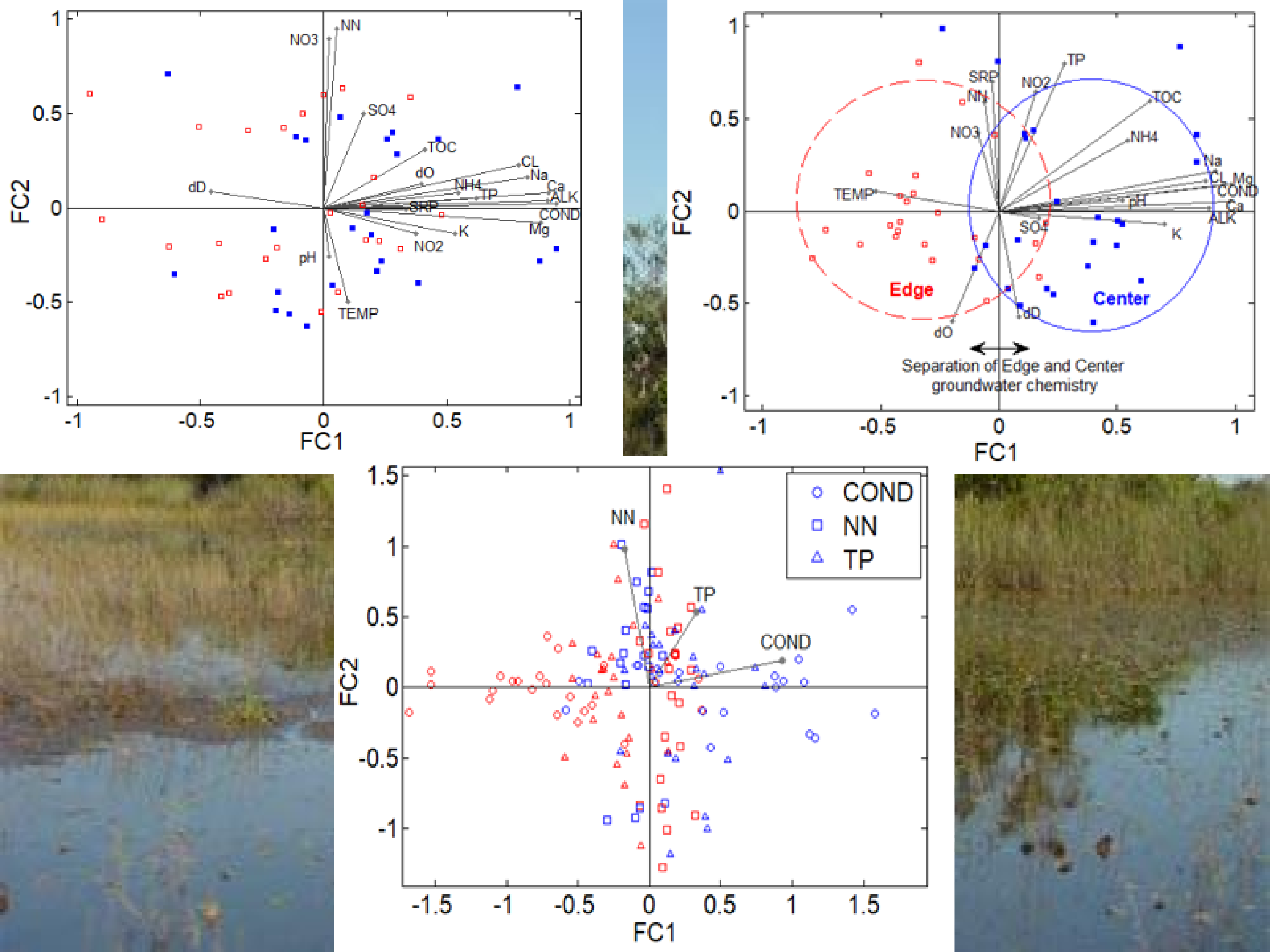

Biomass (tons ha-1)
0
5
10
15
20
25
Center
Edge
2009
2010
2011
2012
2013
2014
2015
2016
Water Year



Total Phosphorus (ug L-1)
0
50
100
150
200
Center
Edge
2009
2010
2011
2012
2013
2014
2015
2016
Water Year

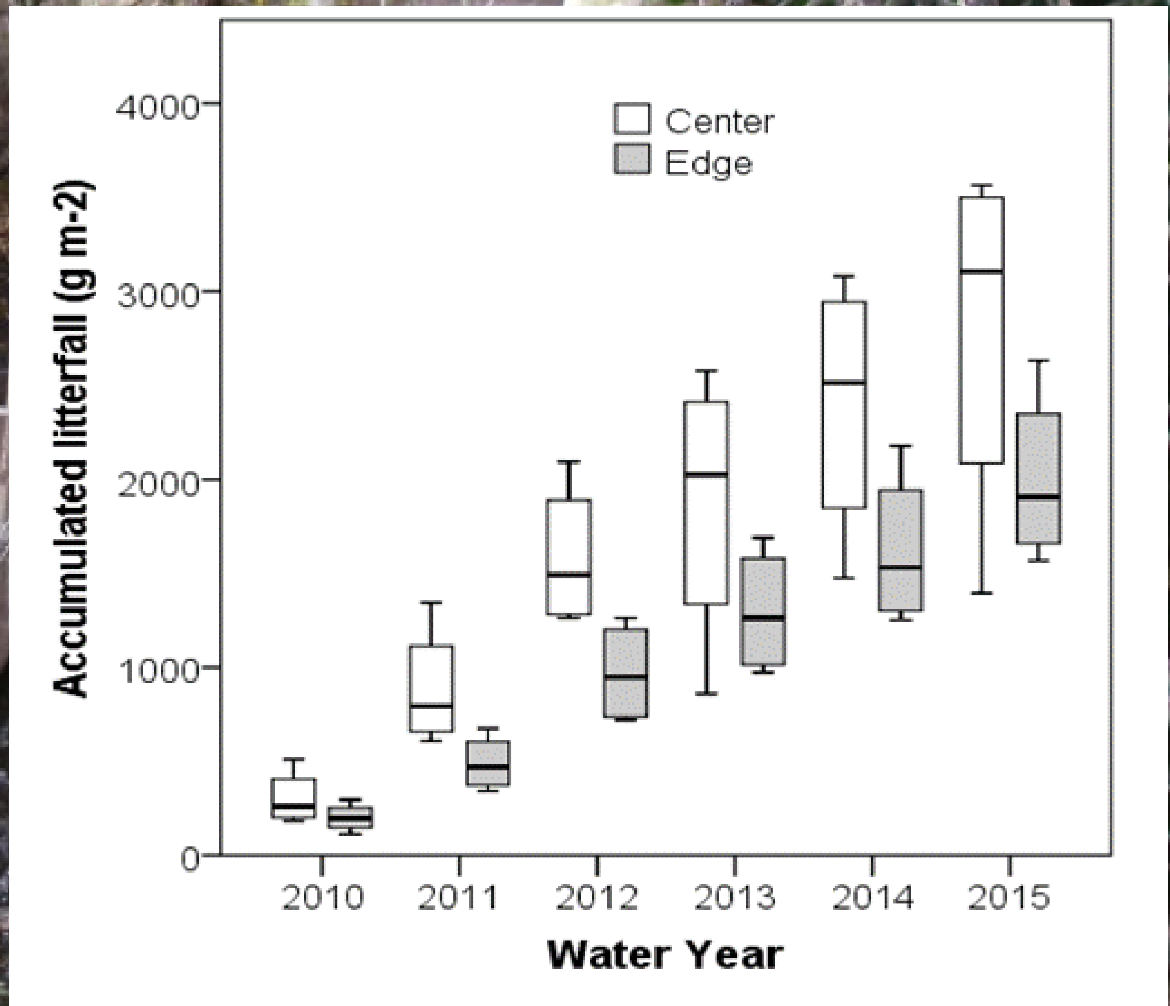


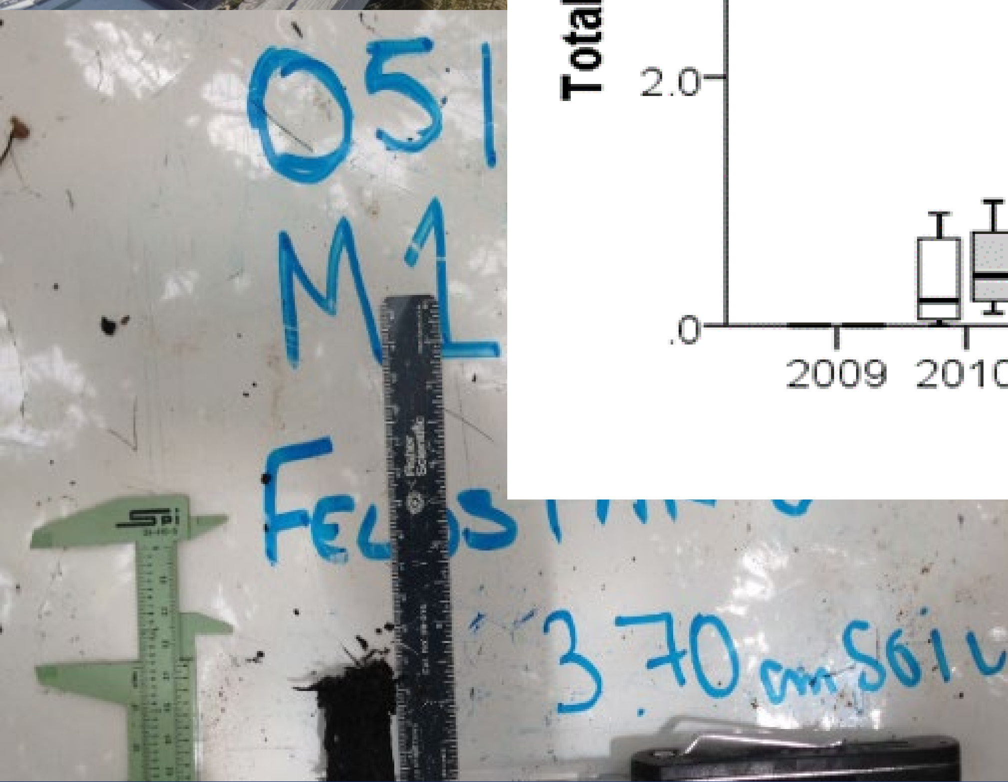
Conductivity (uS cm-1)
0
1000
2000
3000
Center
Edge
2009
2010
2011
2012
2013
2014
2015
2016
Water Year



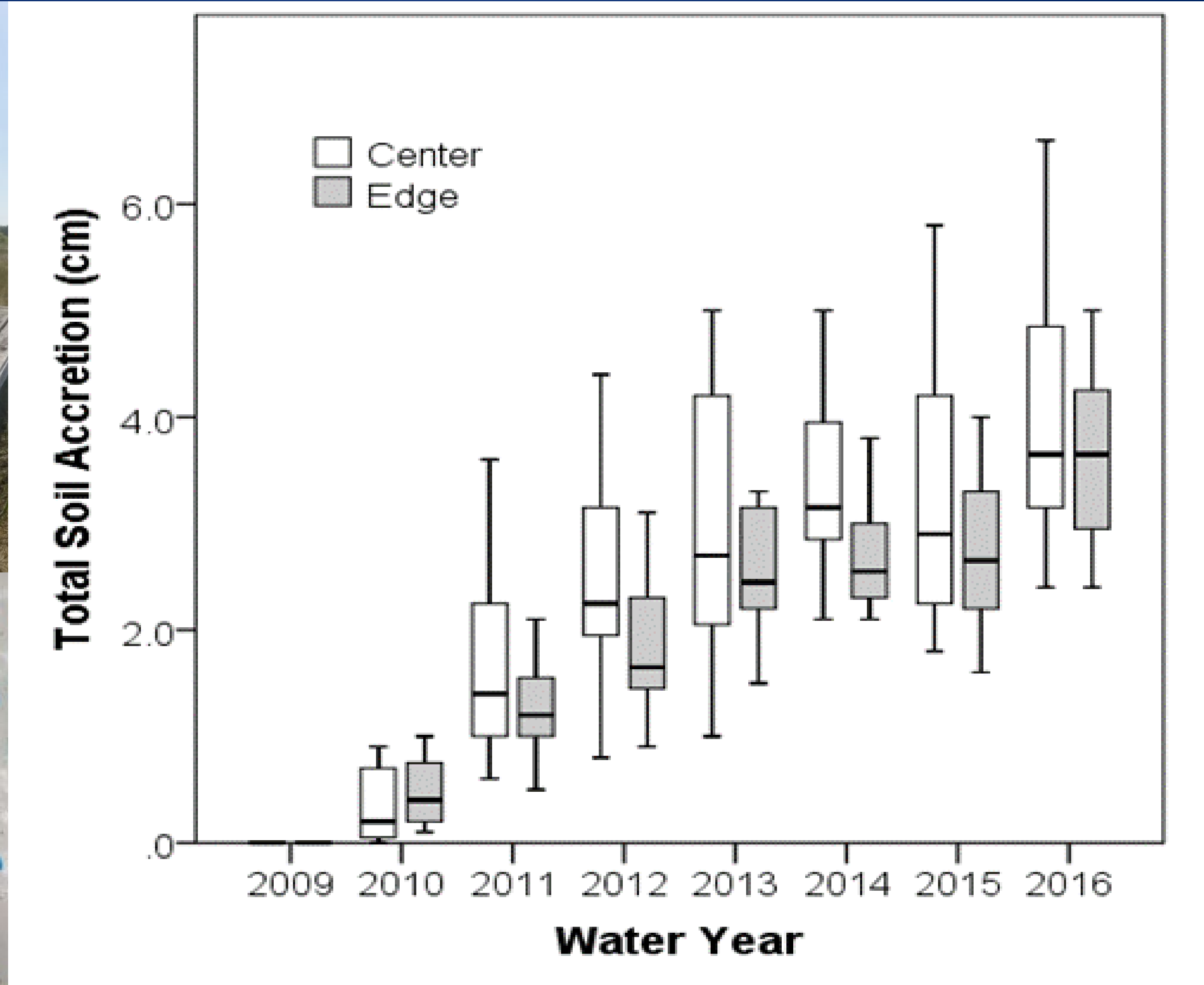
FC1
FC2
NN
NO3
SO4
TOC
CL
Na
dO
NH4
TP
Ca
ALK
SRP
COND
Mg
dD
K
NO2
pH
TEMP
FC1
FC2
TP
SRP
NO2
NN
TOC
NO3
NH4
Na
CL
Mg
COND
TEMP
pH
Ca
ALK
SO4
K
Edge
Center
dD
dO
Separation of Edge and Center groundwater chemistry
FC1
FC2
COND
NN
TP
NN
TP
COND


Litter Traps
11/14/15 BS
M2 HH1



Center
Edge
Accumulated litterfall (g m-2)
0
1000
2000
3000
4000
2010
2011
2012
2013
2014
2015
Water Year



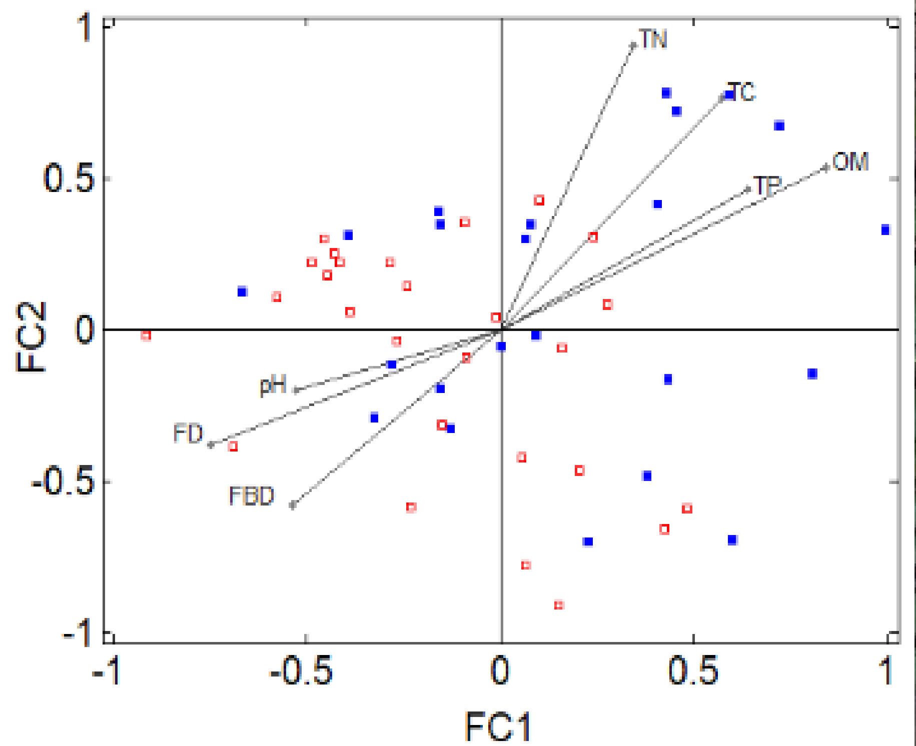
051
M1
3.70 cm soil



Center
Edge
Total Soil Accretion (cm)
6.0
4.0
2.0
.0
2009
2010
2011
2012
2013
2014
2015
2016
Water Year

Principal component analysis eigenvectors for the three principal components of soil physicochemistry data. Percent Variance explained by each principal component is in brackets [%] with bold values representing high absolute values for variables having the greatest potential to represent soil physicochemistry in the PCA.

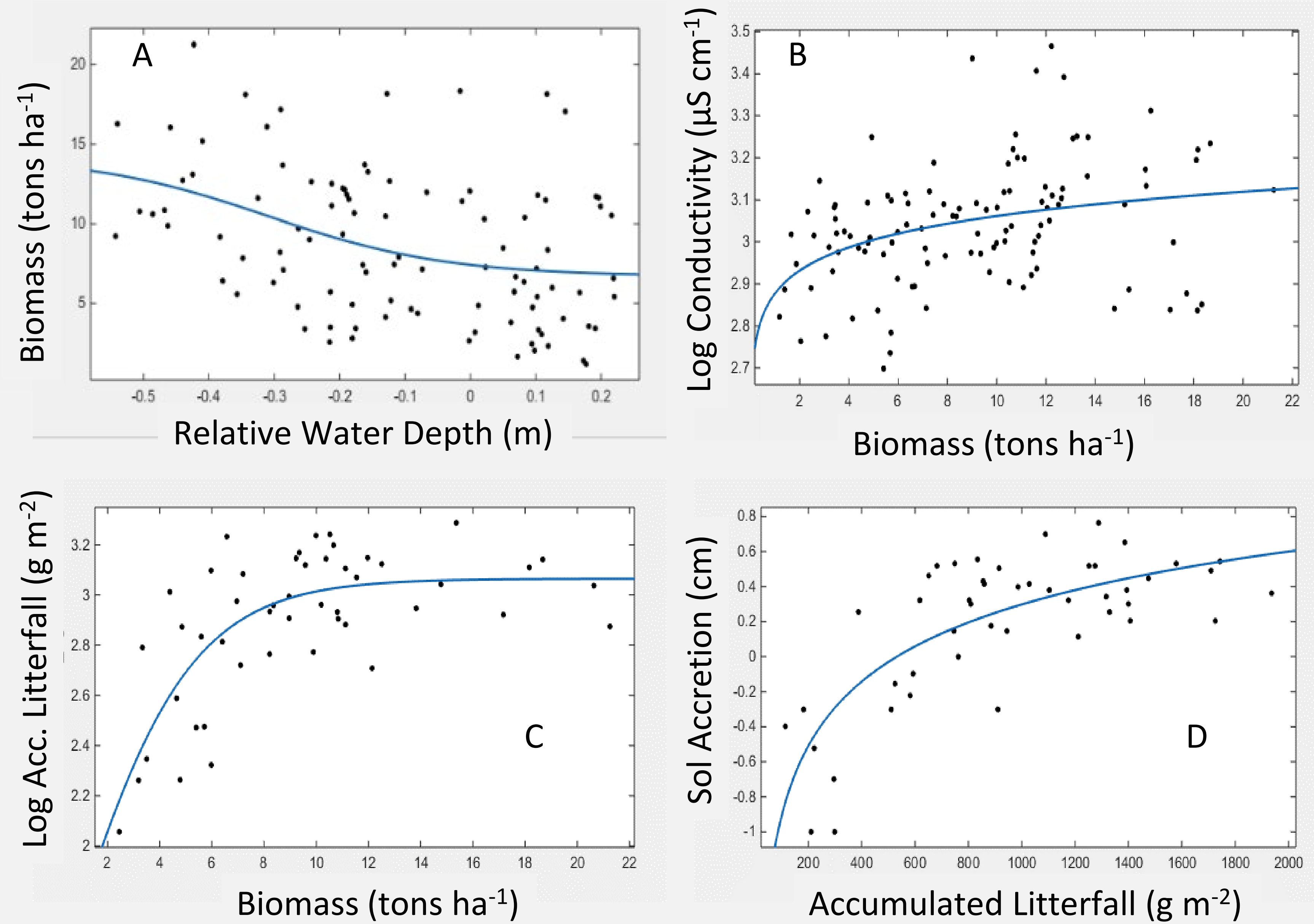
	PC1	PC2	PC3
Variables	[71]	[12.3]	[6.1]
TP_s	0.35	0.41	-0.33
TN_s	**0.40**	0.20	0.58
TC_s	**0.43**	0.10	0.37
OM_s	**0.43**	-0.02	-0.09
FracDry	**-0.38**	0.22	0.61
FBD	**-0.38**	-0.09	0.12
pH_s	-0.24	**0.85**	-0.16

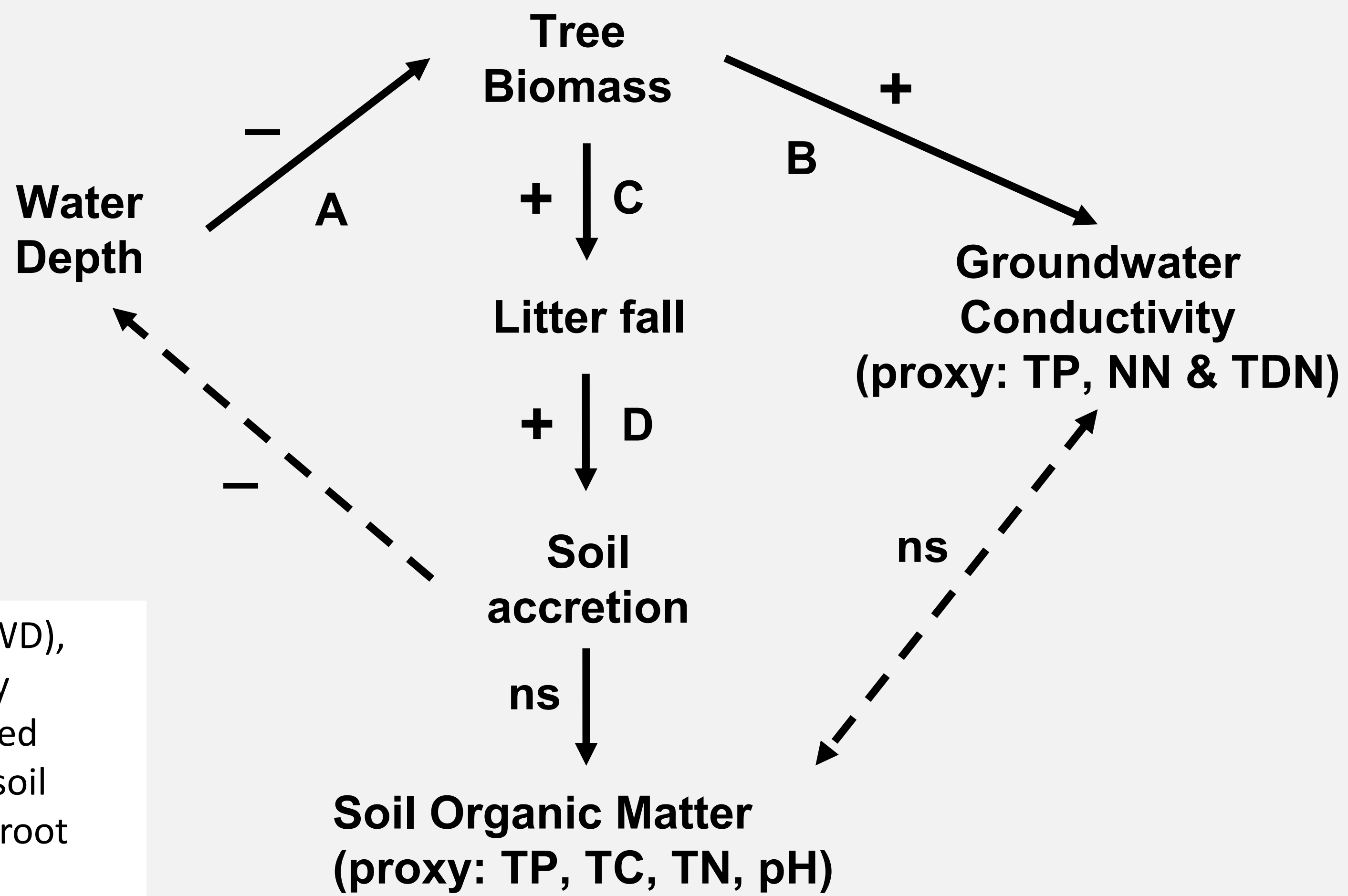


Relationships between Variables

Two-tailed Pearson correlation coefficient (r) of relative water depth (RDW, m), and the log-transformed values of all other data including: biomass (tons ha^{-1}), groundwater conductivity (uS cm^{-1}), groundwater total P (GW TP, mg L^{-1}), total accumulated litterfall (g m^{-2}), total soil accretion (cm), total soil elevation change (cm), and soil organic matter (Soil OM, g g^{-1}). Bold values are significant at $p \leq 0.05$. Bold and italic values are significant at $p \leq 0.01$.

	Rel. Water Depth (RWD)	Tree Biomass	Conductivity (COND)	GW TP	Litter-fall (TLF)	Total Soil Accretion (TSA)	Soil Elevation Change (SET)
Tree Biomass	***-0.401***						
COND	***-0.579***	***0.349***					
GW TP	0.016	-0.124	***0.371***				
Litterfall (TLF)	-0.117	***0.658***	0.206	-0.276			
Total Soil Accretion (TSA)	**-0.220**	***0.595***	0.187	-0.182	***0.757***		
Soil Elevation Change (SET)	**0.455**	0.064	-0.122	**-0.377**	0.436	***0.438***	
Soil OM	**0.367**	-0.124	-0.206	-0.084	0.190	0.058	0.272


A
B
C
D
Biomass (tons ha-1)
Relative Water Depth (m)
Log Conductivity (µS cm-1)
Biomass (tons ha-1)
Log Acc. Litterfall (g m-2)
Biomass (tons ha-1)
Sol Accretion (cm)
Accumulated Litterfall (g m-2)



Relative water depth (RWD), biomass (B), conductivity (COND), total accumulated litterfall (TLF), and total soil accretion (TSA). RMSE = root mean square error.

Path	Equations	r^2	RMSE
A	$B = 14.3 - 71.8 / (9.5 + e^{-7.3RWD})$	0.16	4.31
B	$\text{Log (COND)} = 2.88B^{0.027}$	0.12	0.14
A+B	$COND = 637 + 104B / (e^{0.07B + 1.37RWD})$	0.30	376
	$\text{Log(COND)} = 44.7 / (13.8 + e^{2.5RWD})$	0.35	0.12
C	$\text{Log(TLF)} = 2.69 / (0.88 + e^{-0.42B})$	0.53	0.20
D	$\text{Log (TSA)} = 4.0 - 0.87(TLF)^{-0.12}$	0.57	0.28
C+D	$TSA = 0.26 + 0.001(TLF) + 0.006B^2$	0.54	0.92

- We developed a conceptual model of emerging tree island behavior based on observed relationships among tree island hydrology, vegetation dynamics, biogeochemistry, and soil development. Our model suggests that hydrologic conditions leads to preferential tree growth at higher elevations. Transpiration by the developing tree canopy increases groundwater and nutrient uptake, and ion exclusion. Through tree growth, nutrients are immobilized in plant biomass, some of which is deposited as litter or root production, adding to the surface soil, increasing soil organic matter and nutrient content, and tree island elevation through soil accretion.
- The model that arises from this analysis supports the establishment of feedback mechanisms within a decade of initial tree growth and development. Fully coupled hydro-biogeochemical feedbacks may take centuries or more to form, but we showed that within the first decade of tree island establishment, the biota, groundwater chemistry, and surface soil accretion and physicochemistry show quantifiable "self-organization".