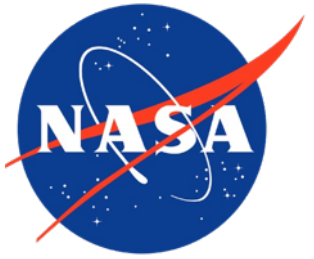
Cryptic carbon: wetland identification under perennial forest cover enhances spatially explicit modeling of soil carbon stock



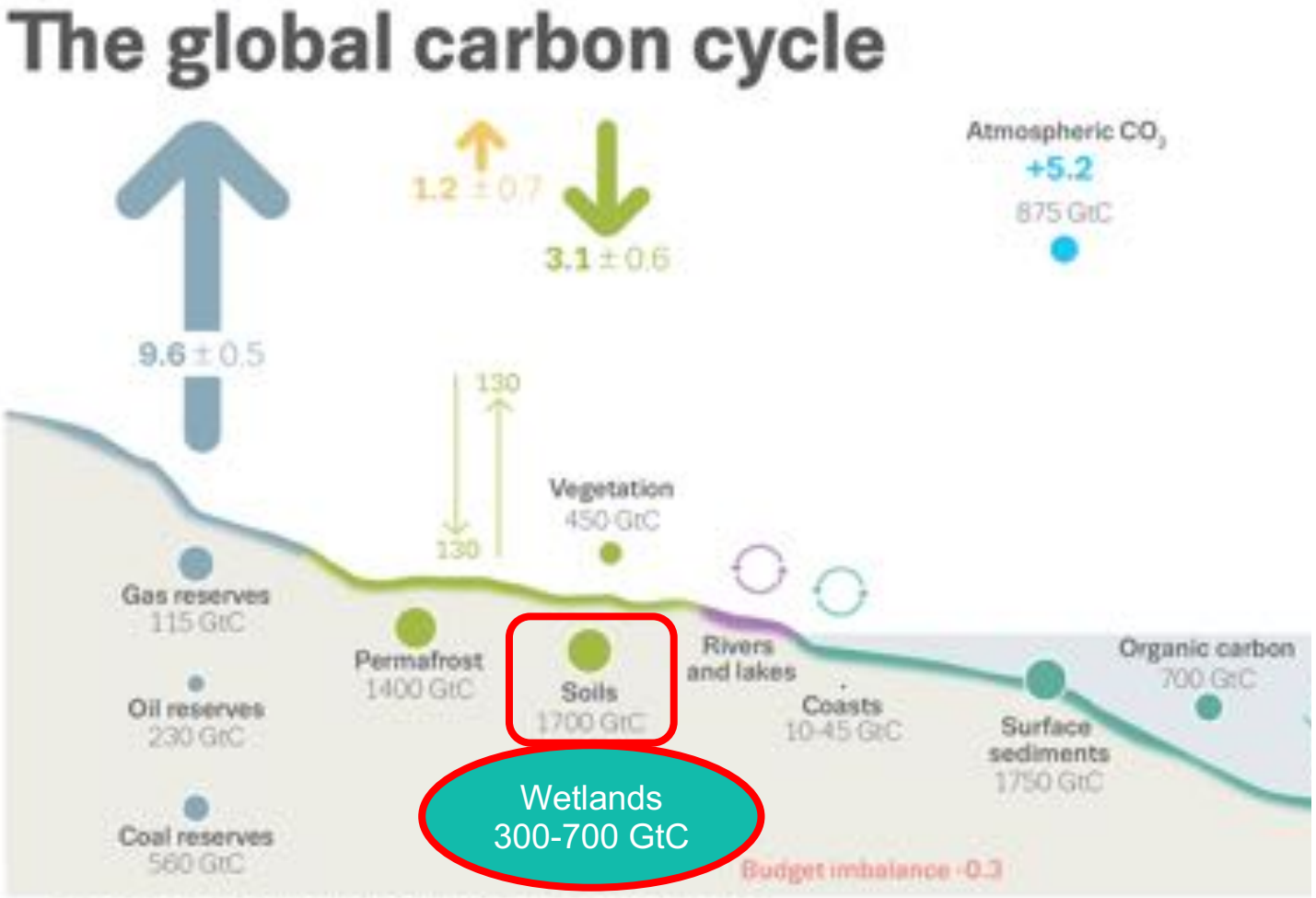
Anthony J. Stewart[1] Meghan Halabisky[1], Chad Babcock[2], David E Butman[1], David V D'Amore[3], and L. M. Moskal[1]

(1)University of Washington, (2)University of Minnesota, (3) USDA Forest Service

Traditional Lands of the Hoh, Quinault, Quileute, and Coast Salish Indigenous People

Outline

- Current results from Hoh River Watershed
  - Data collection
  - Modeling
  - Wetland carbon stocks
- Planned future work
  - Additional WA study areas
  - Disturbance evaluation
  - Upscaling to state/region
  - Soil carbon quality



Inland Wetland Carbon "Teal Carbon"

Nahlik and Fennessey 2016

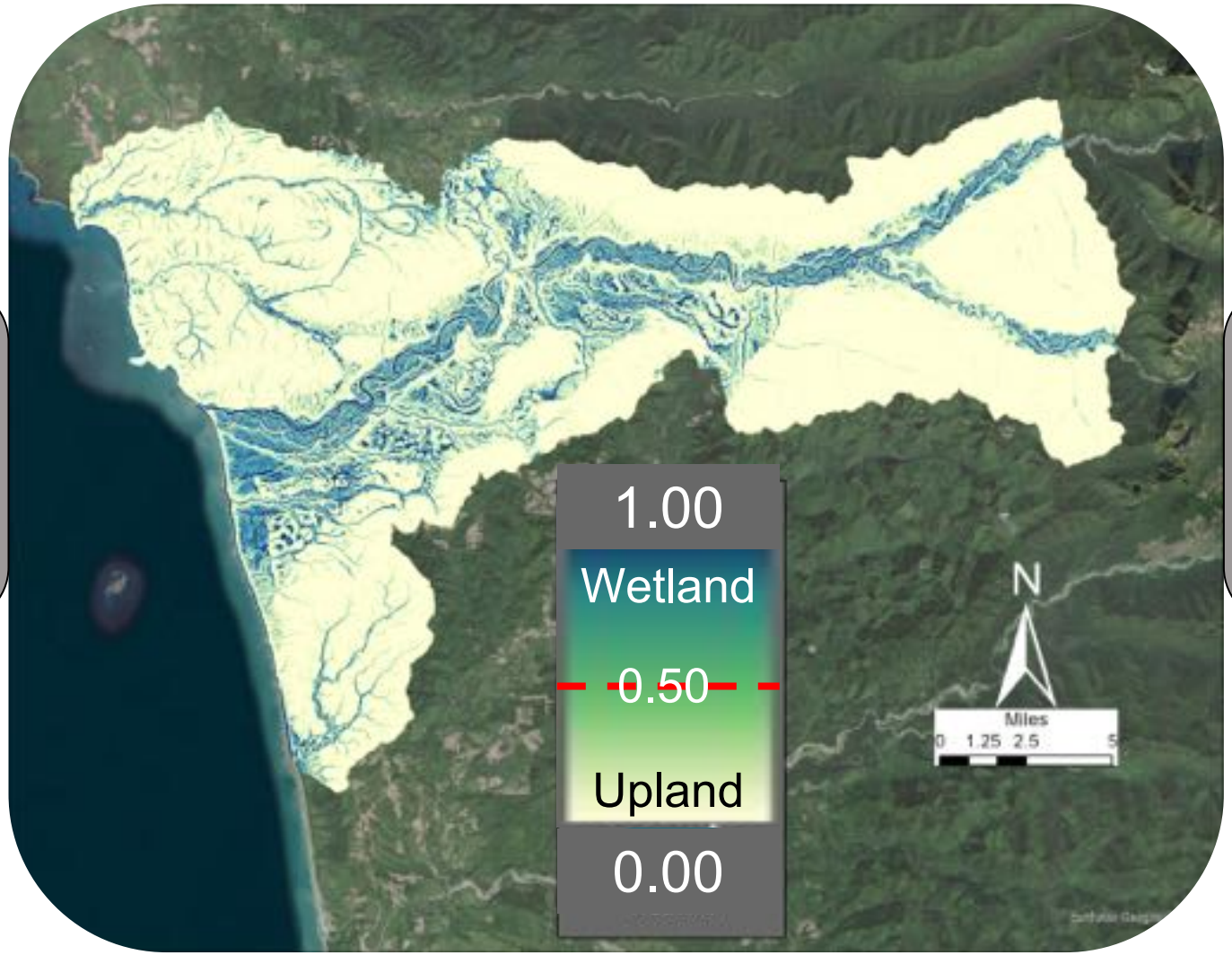
Wetlands store **20-30% of global soil carbon** despite occupying only **5-8% of the land surface**

Friedlingstein et al., 2022; Campbell et al., 2022; Lal, 2008; Poulter et al., 2022

Wetland Intrinsic Potential (WIP) Tool

Wetland to Upland Probability

WIP is flexible and inclusive



How can WIP be used to model soil carbon stocks? “Cryptic Carbon”

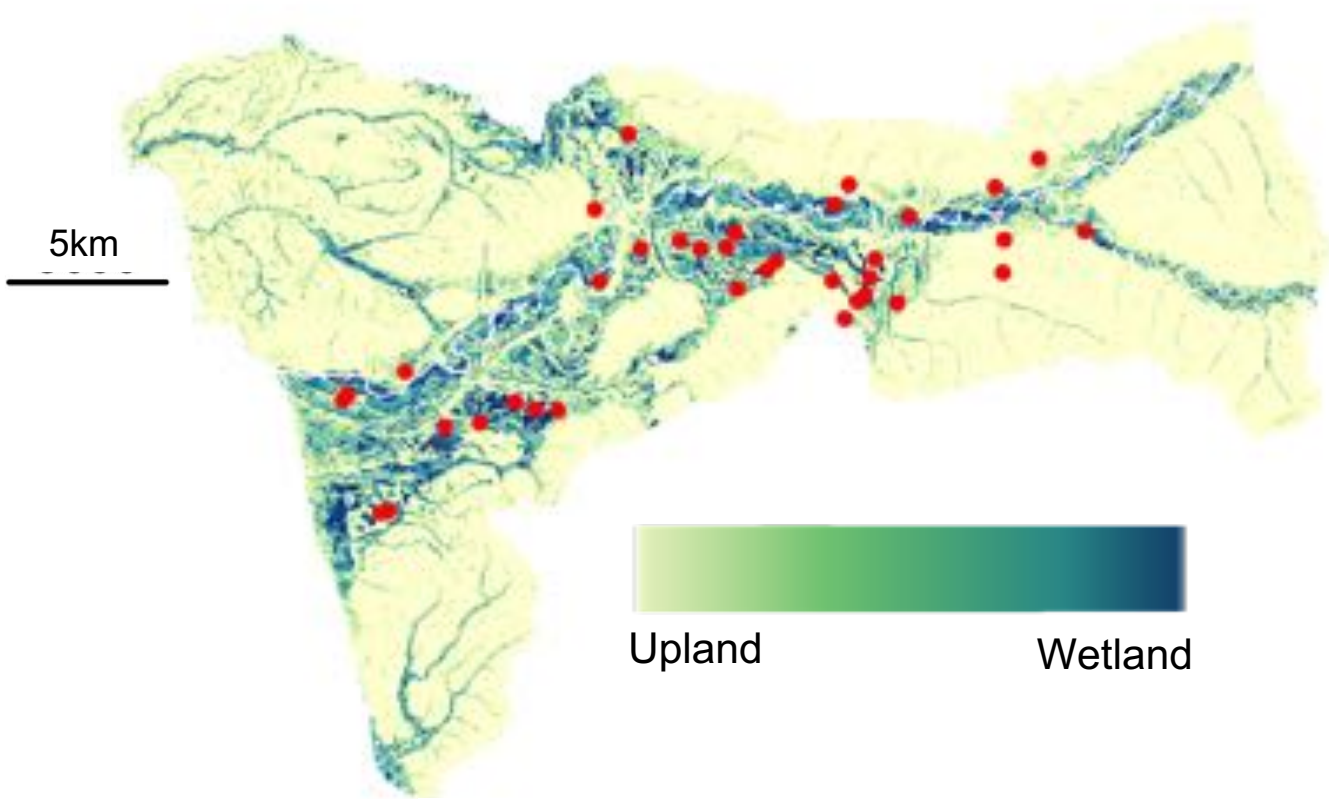
Fieldwork for Cryptic Carbon Sampling

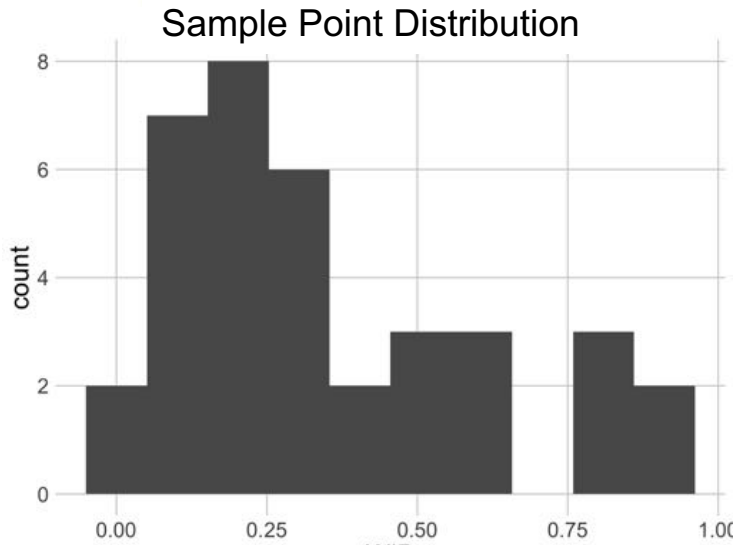
Thanks to:
Claire Johnson, Hazel Sanders, Abby Nesper, Thomas Kakatsakis

36 Soil Pits in 22 Workdays

Soil pit characterization

- 1m Depth or more
- Soil survey (horizons, color, texture)
- Vegetation survey (hydrophytic)
- Top level HGM and Cowardin classification
- Bulk Density and Total Carbon sampling





Upland and Wetland Soils

WIP = 3%

WIP = 7%

WIP = 62%

WIP = 87%

Mesic soils
10%<WIP<50%

WIP = 11%

WIP = 21%

WIP = 27%

WIP = 32%

WIP = 47%

Fieldwork for Cryptic Carbon Sampling

Thanks to:
Claire Johnson, Hazel Sanders, Abby Nesper, Thomas Kakatsakis

36 Soil Pits in 22 Workdays

Soil pit characterization

- 1m Depth or more
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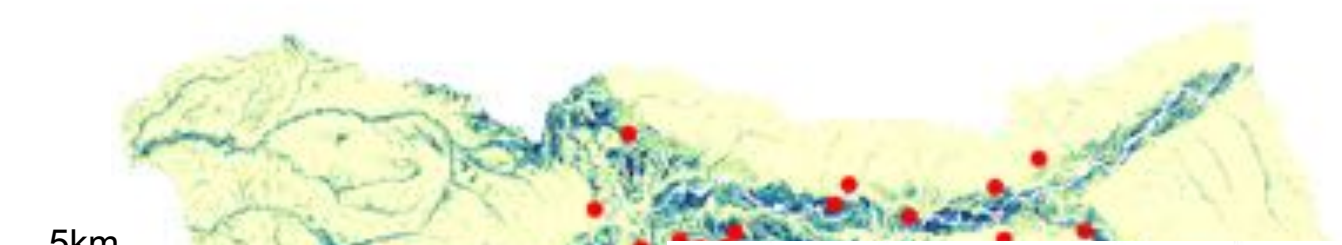
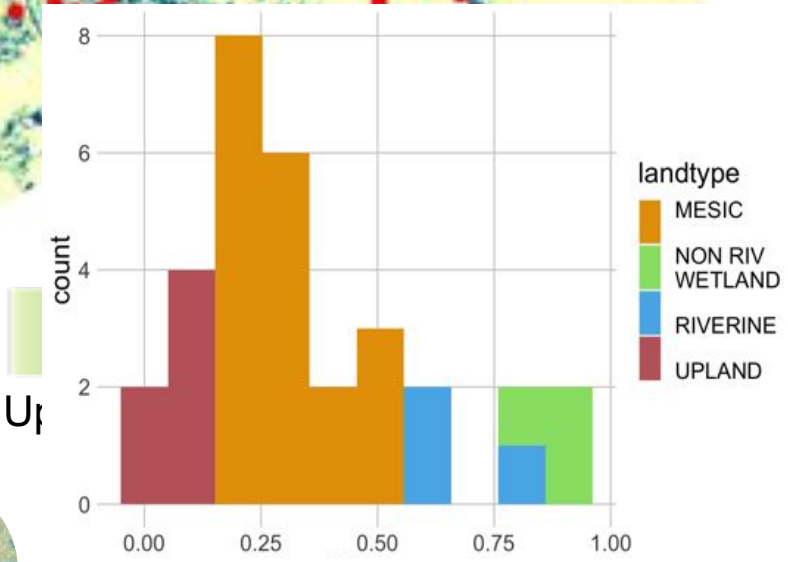
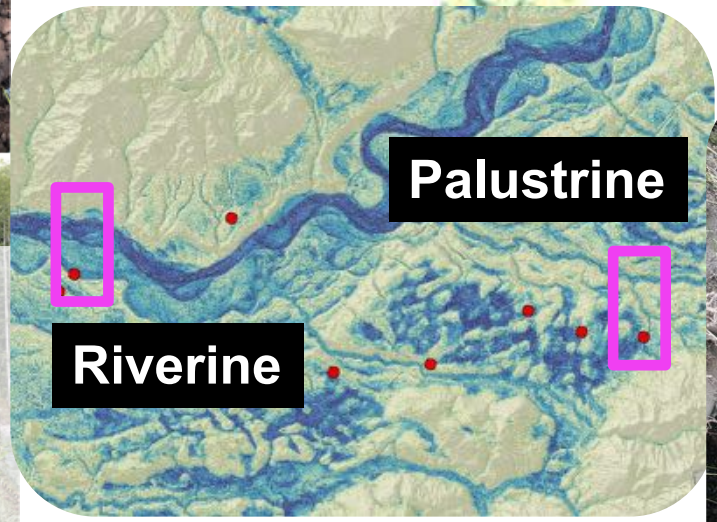
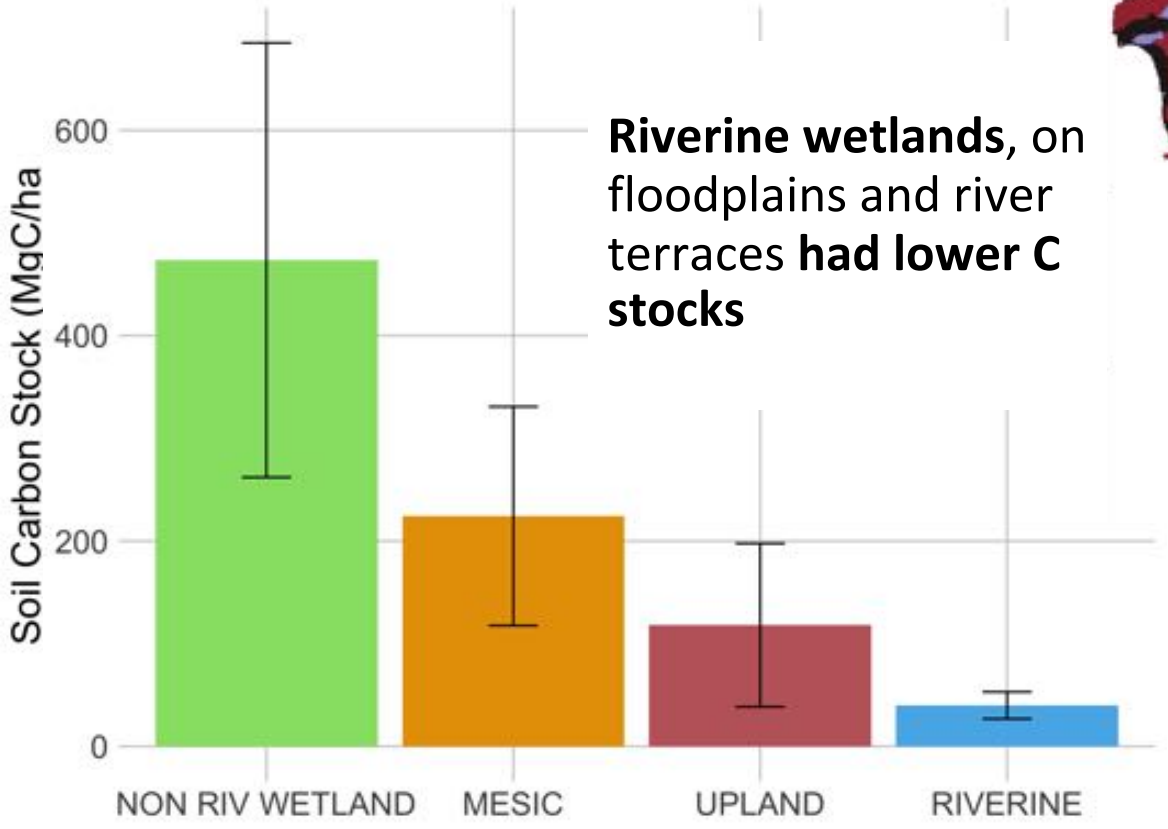




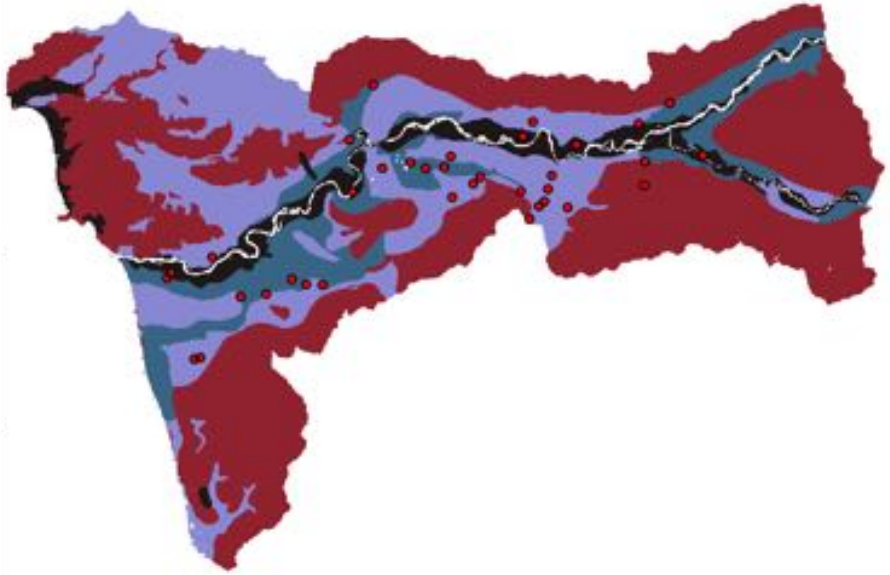


Wetland and Land Type Groups Soil Carbon Stocks



Riverine wetlands, on floodplains and river terraces **had lower C stocks**

WA DNR Geologic Age Differentiates Wetland Types



Geology Age

Riverine

Quaternary Riverine

Palustrine/Mesic

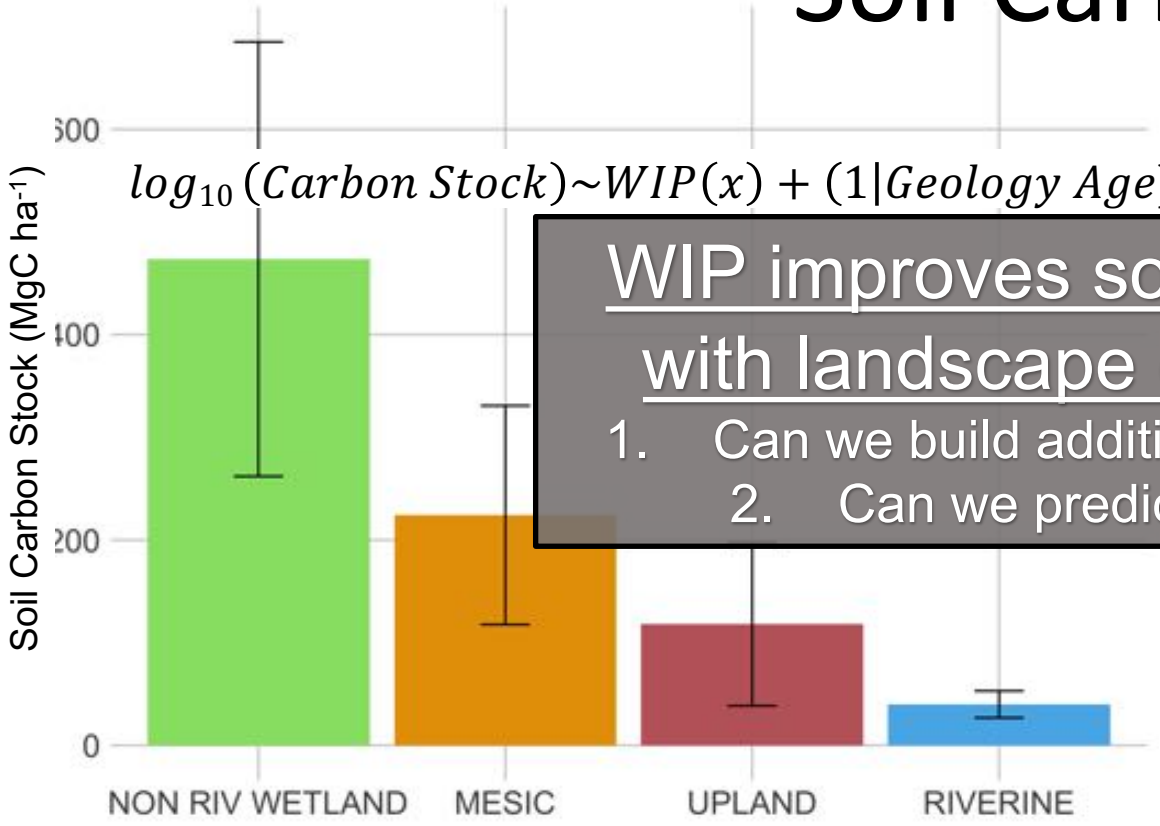
Miocene/Eocene

Quaternary Alluvium

Quaternary Clastic

Continuous Landscape Prediction of Soil Carbon Stocks

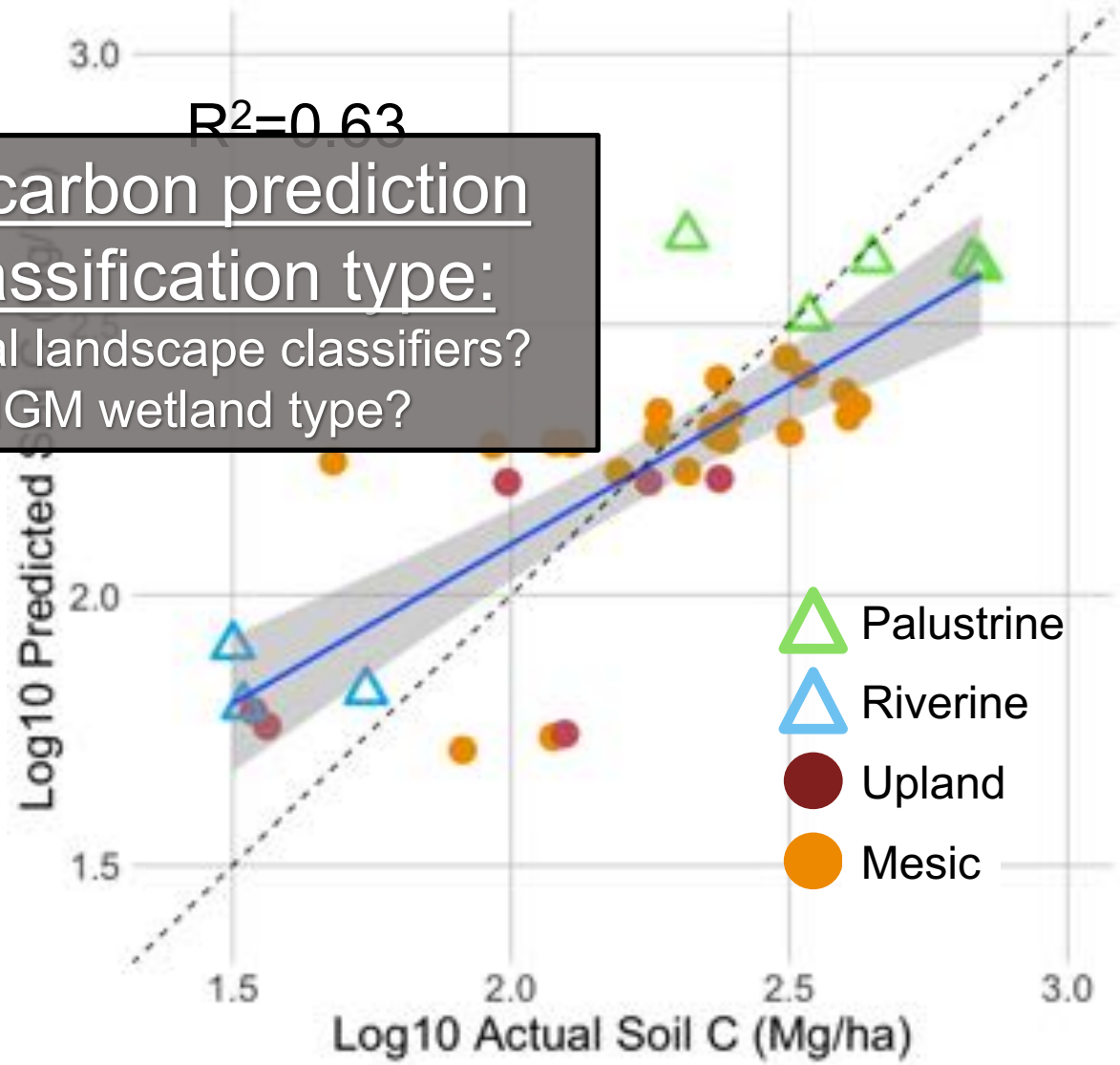
$$log_{10}(Carbon\ Stock) \sim WIP(x) + (1|Geology\ Age)$$



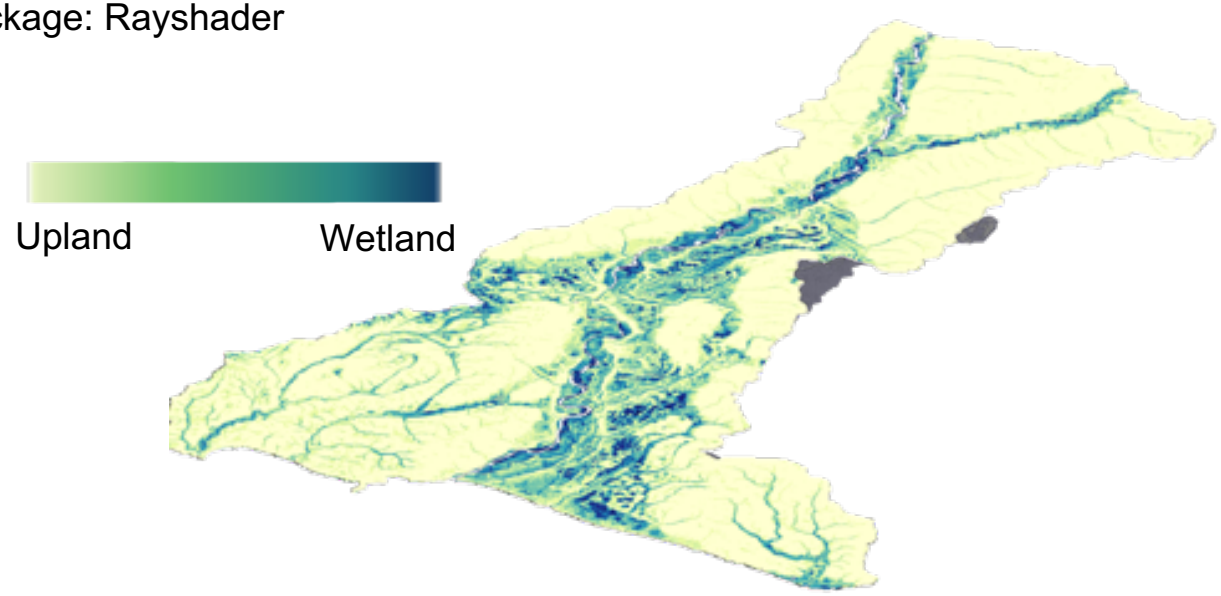
WIP improves soil carbon prediction with landscape classification type:

1. Can we build additional landscape classifiers?
2. Can we predict HGM wetland type?

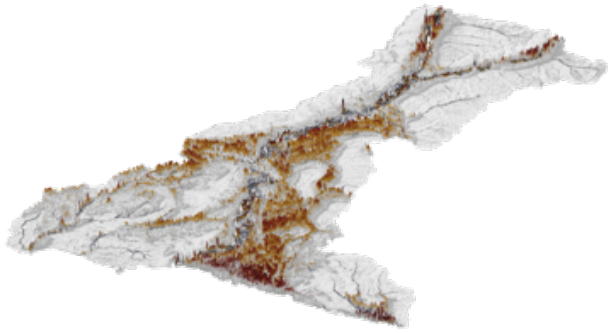
Predictor	t Value	P
WIP Score	11.085	<0.005
Surficial Geology	3.092	<0.005



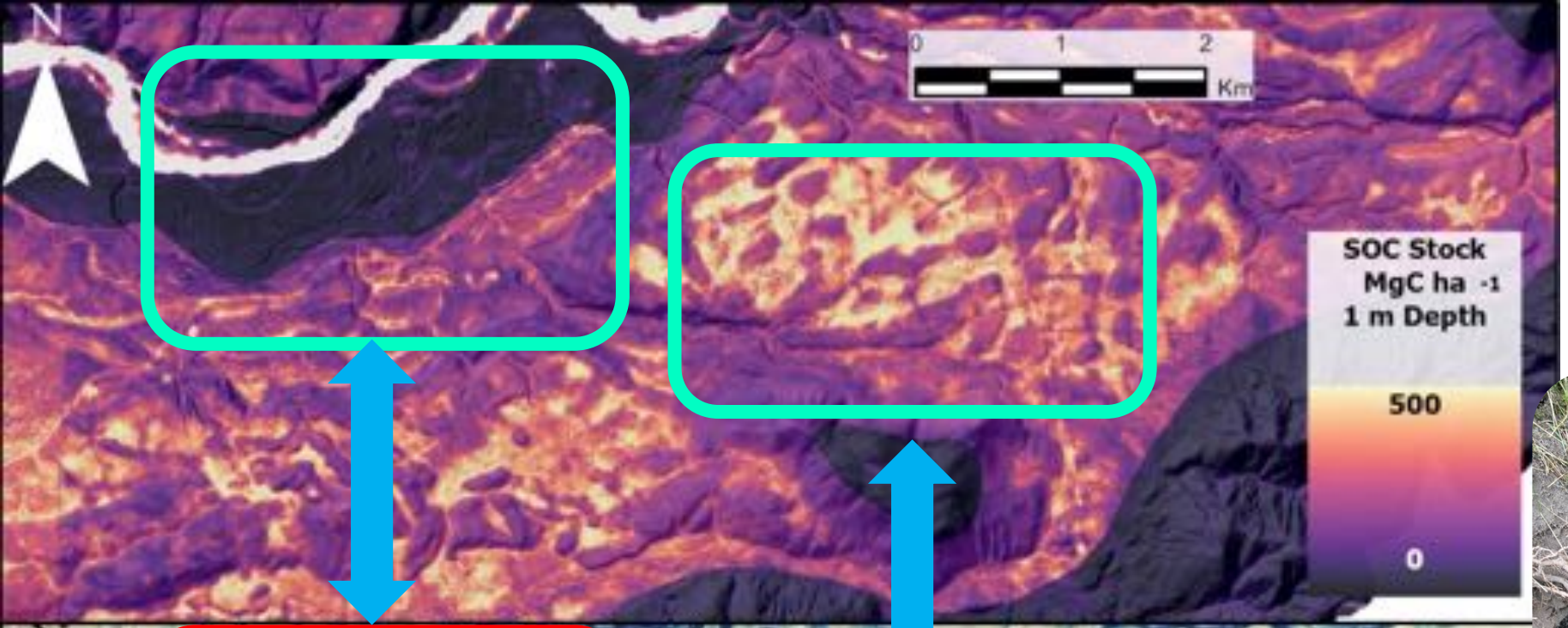
R Package: Rayshader



Cryptic Carbon Mapping Results



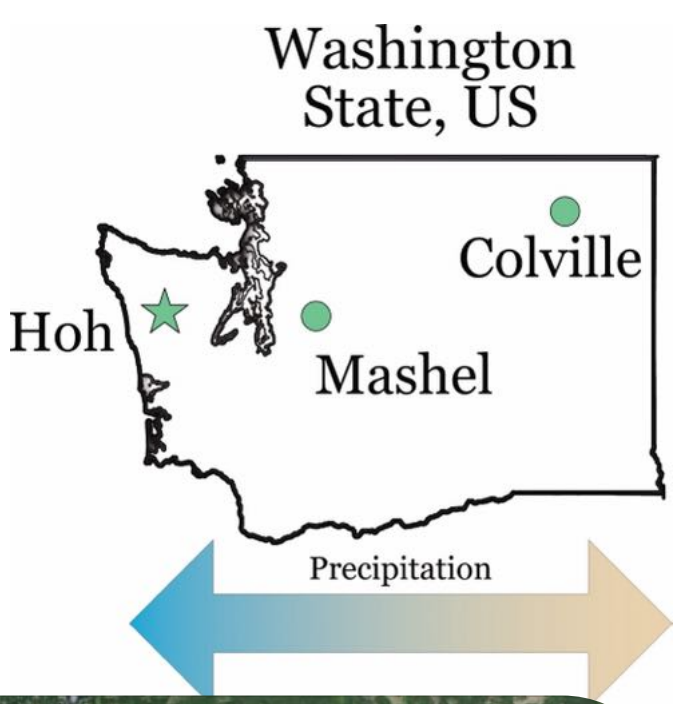
	Total Landscape	WIP Wetlands	NWI Wetlands	WIP Included With NWI Wetlands
Surface Area (ha)	68,135	**6,114** (9%)	**5,401** (8%)	**9,803** (+181%)
Total Soil Carbon (TgC)	9.6	**1.8** (19.2%)	**1.0** (9.8%)	**2.3** (+246%)
Average Soil Carbon Density (MgC ha^{-1})	140.4	**296.8**	**178.2**	**238.6** (+70%)

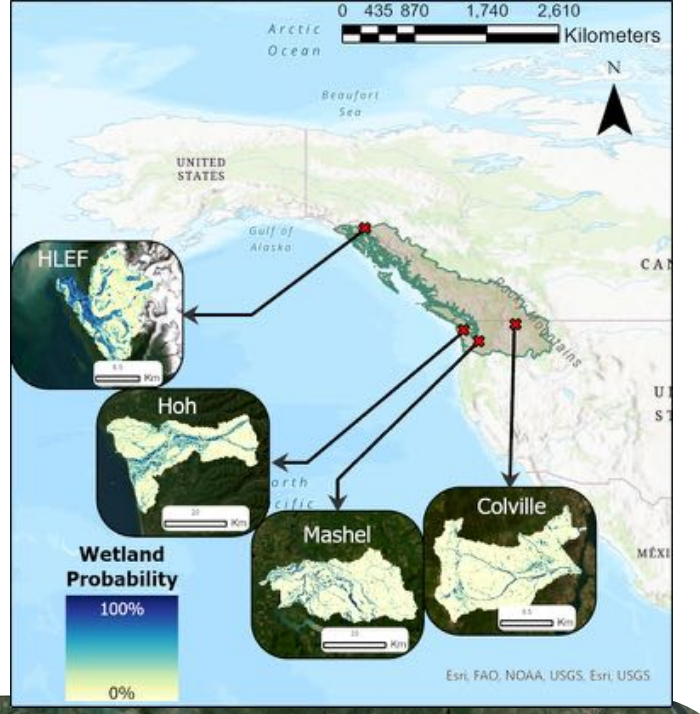


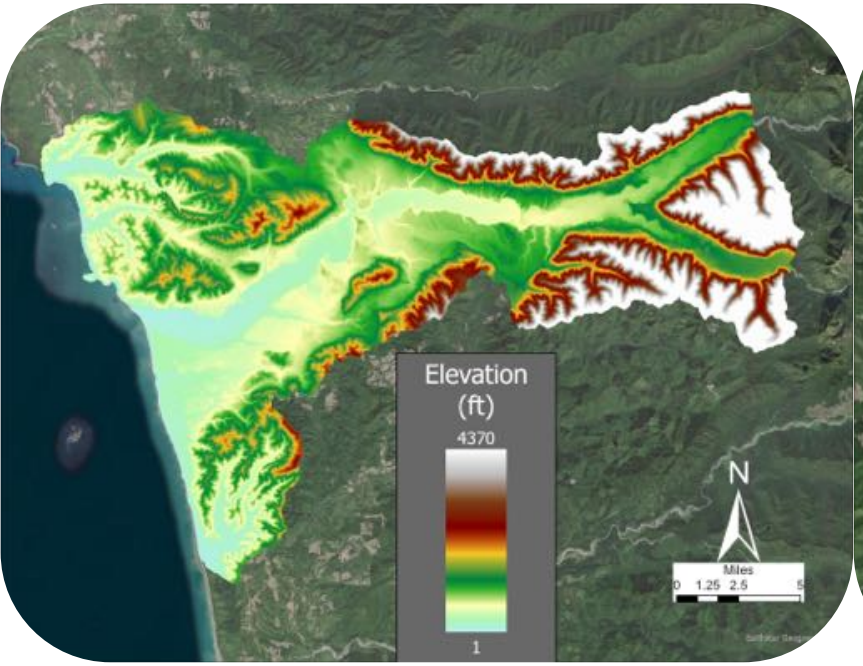
Riverine

Palustrine

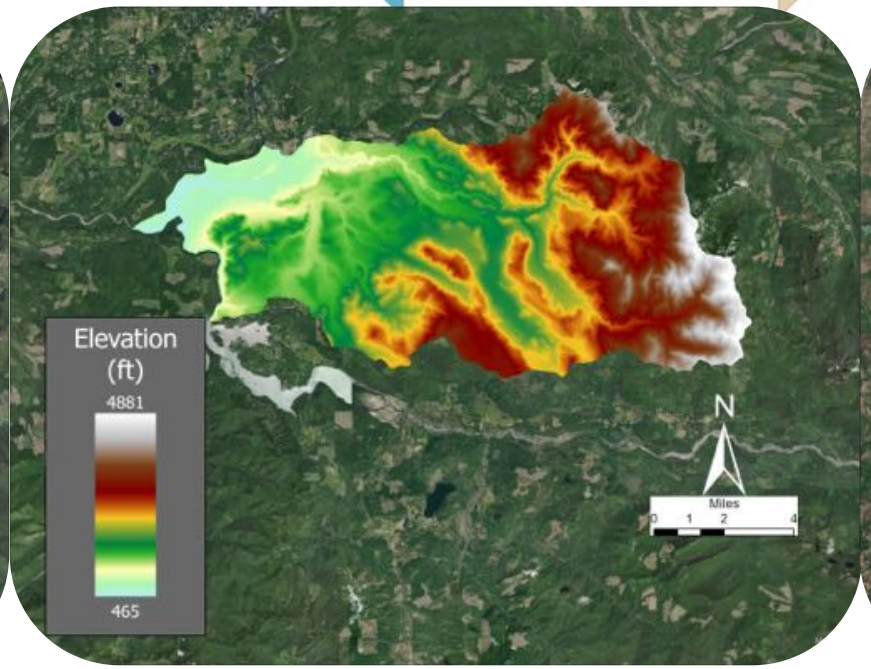
Additional Study Areas:



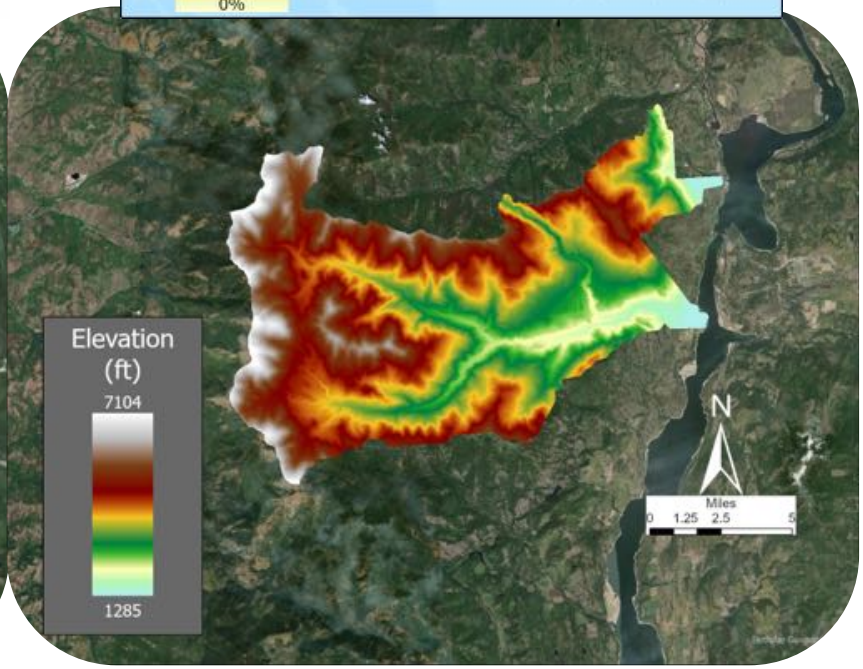




Hoh



Mashel

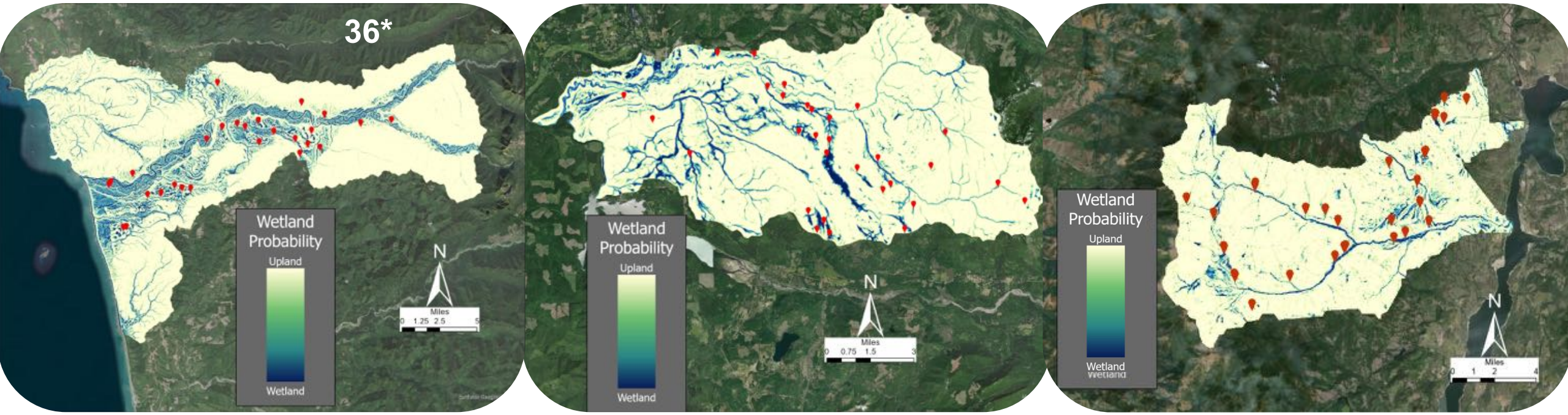


Colville

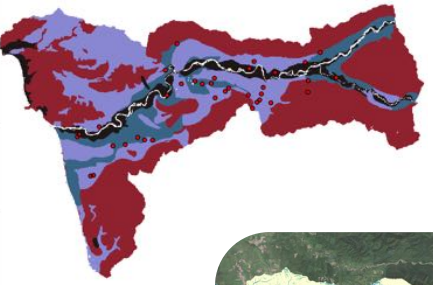
Hoh

Mashel

Colville

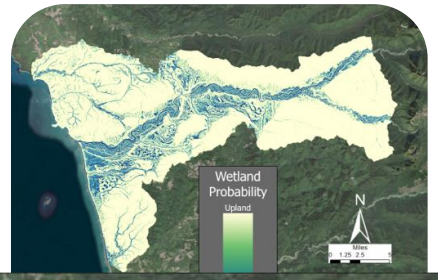


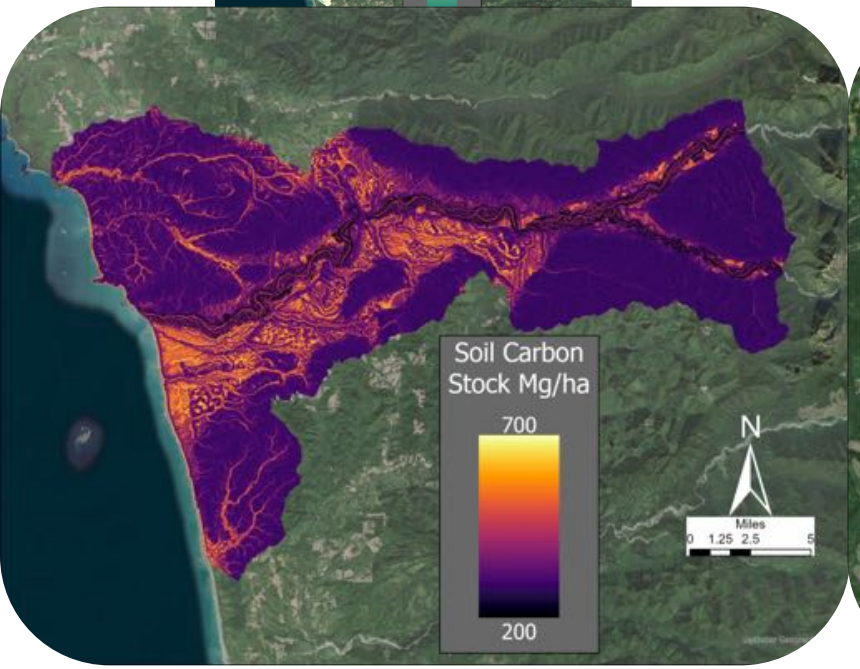
2020 – 2021 Soil Carbon Sampling
96 soil pit locations, stratified across wetland probability



Soil Carbon Modeling

Hoh

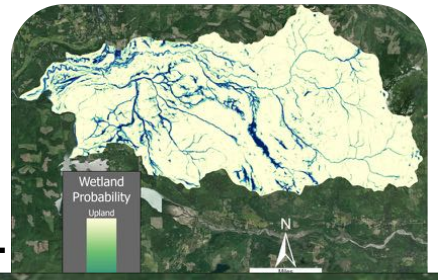


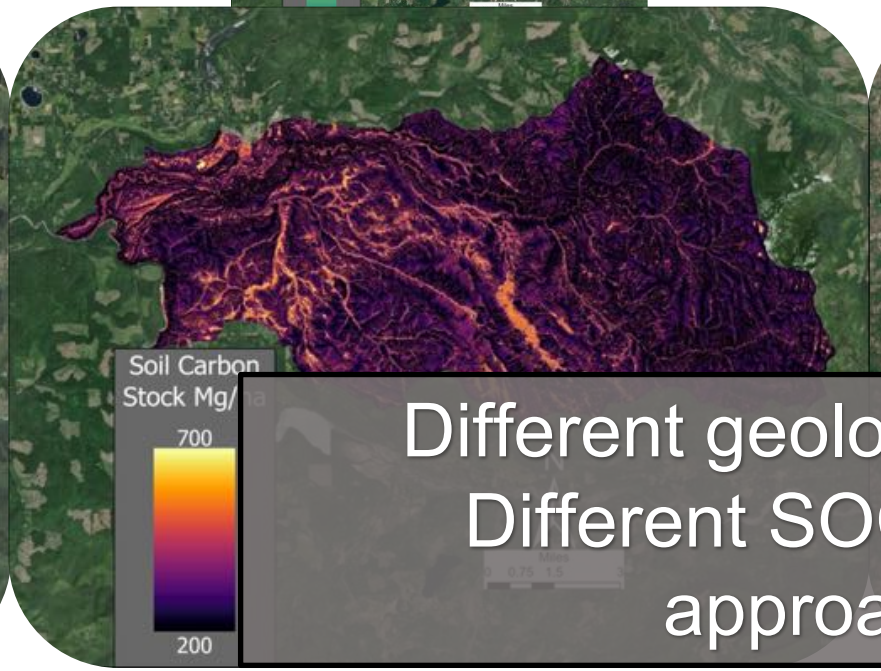


Fixed Effects:
- Wetland Probability

Random Effect:
- Surficial Geology

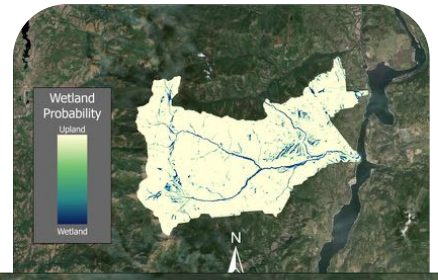
Mashel

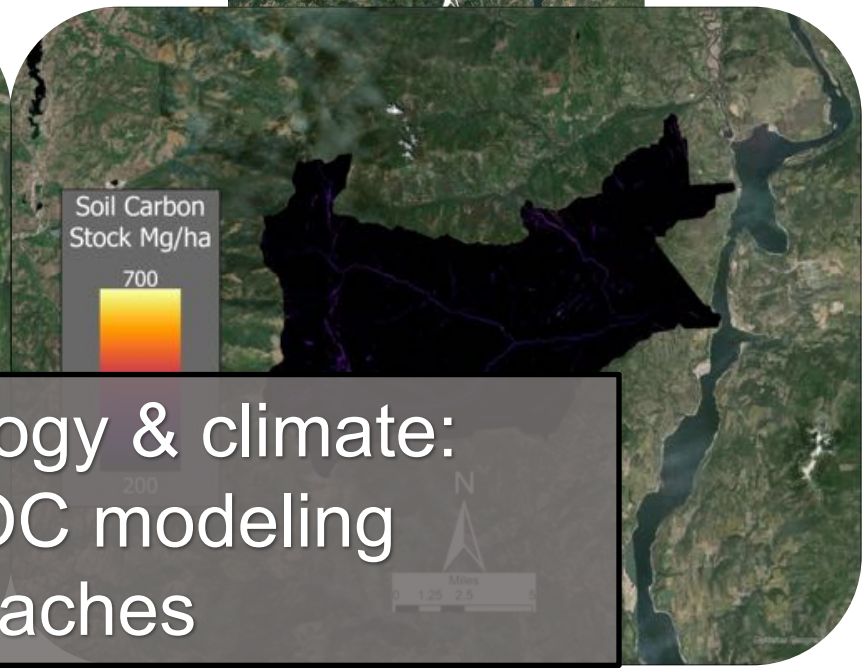




Fixed Effects
- sqrt(Depth to Water)
- sqrt(Specific Catchment Area)
- Wetland Probability
- Topographic Wetness Index

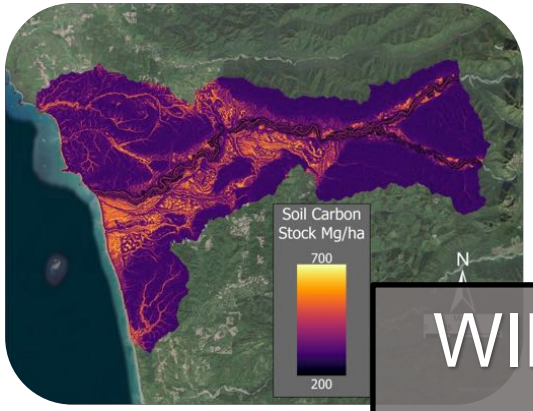
Colville

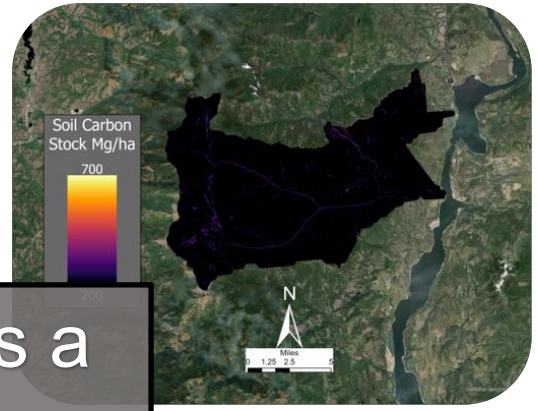




Fixed Effects
- Slope/Gradient
- Wetland Probability
- sqrt(Specific Catchment Area)
- Topographic Wetness Index

Different geology & climate:
Different SOC modeling approaches





WIP with additional stratifying factors is a predictor for soil carbon:

- Geology/Landform
- Biome/Forest Type

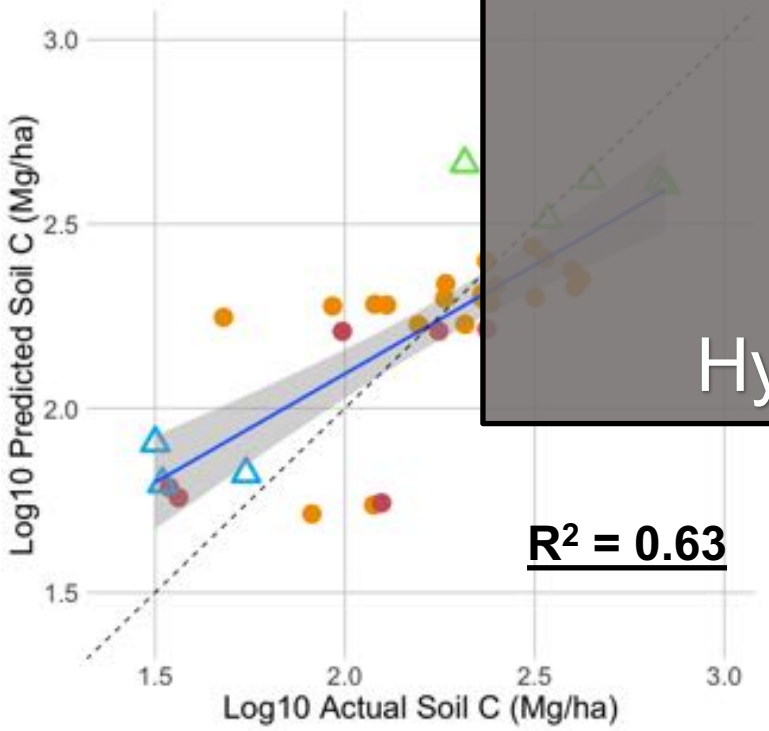
Wetlands

Hydrogeomorphic Classification

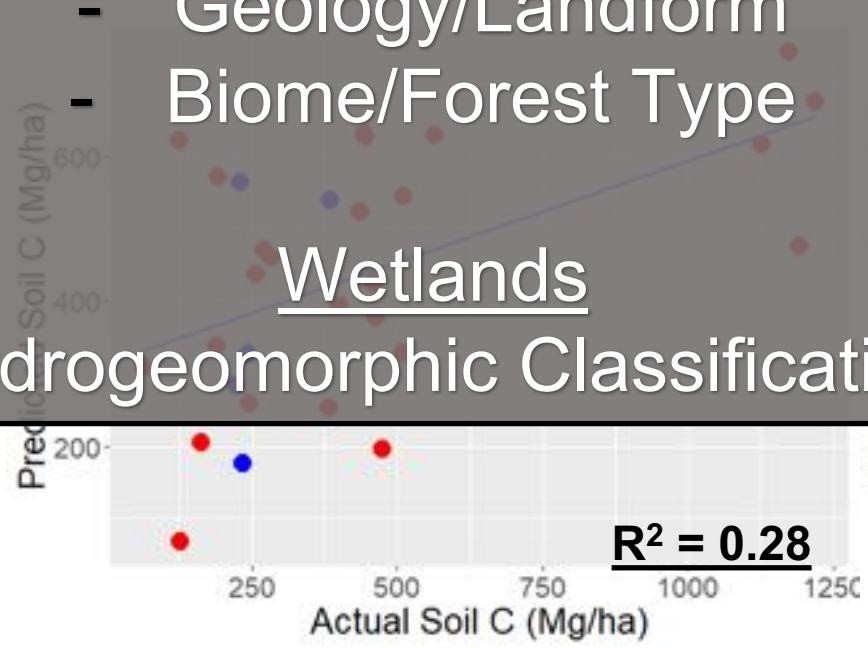
Hoh

Masnel

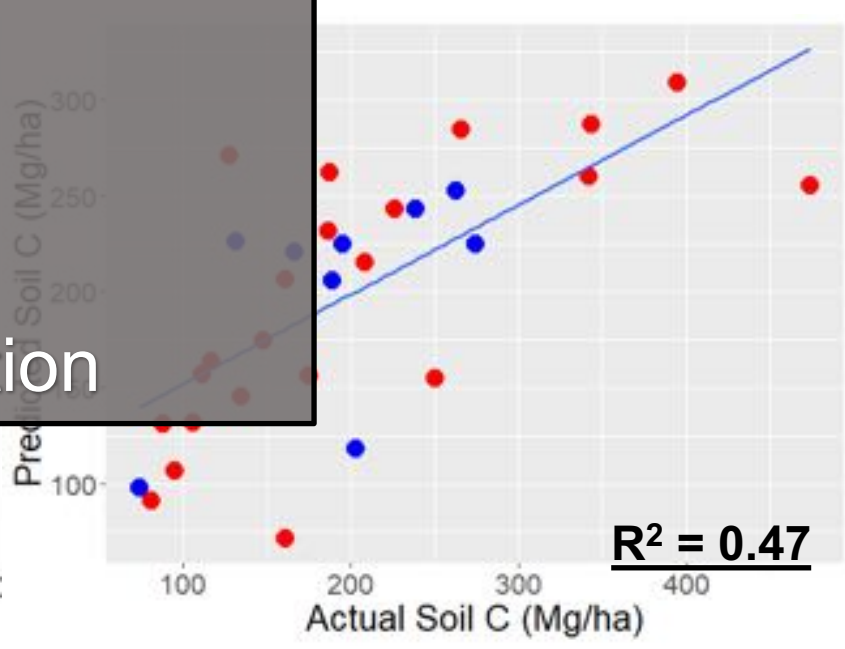
Colville



$R^2 = 0.63$



$R^2 = 0.28$

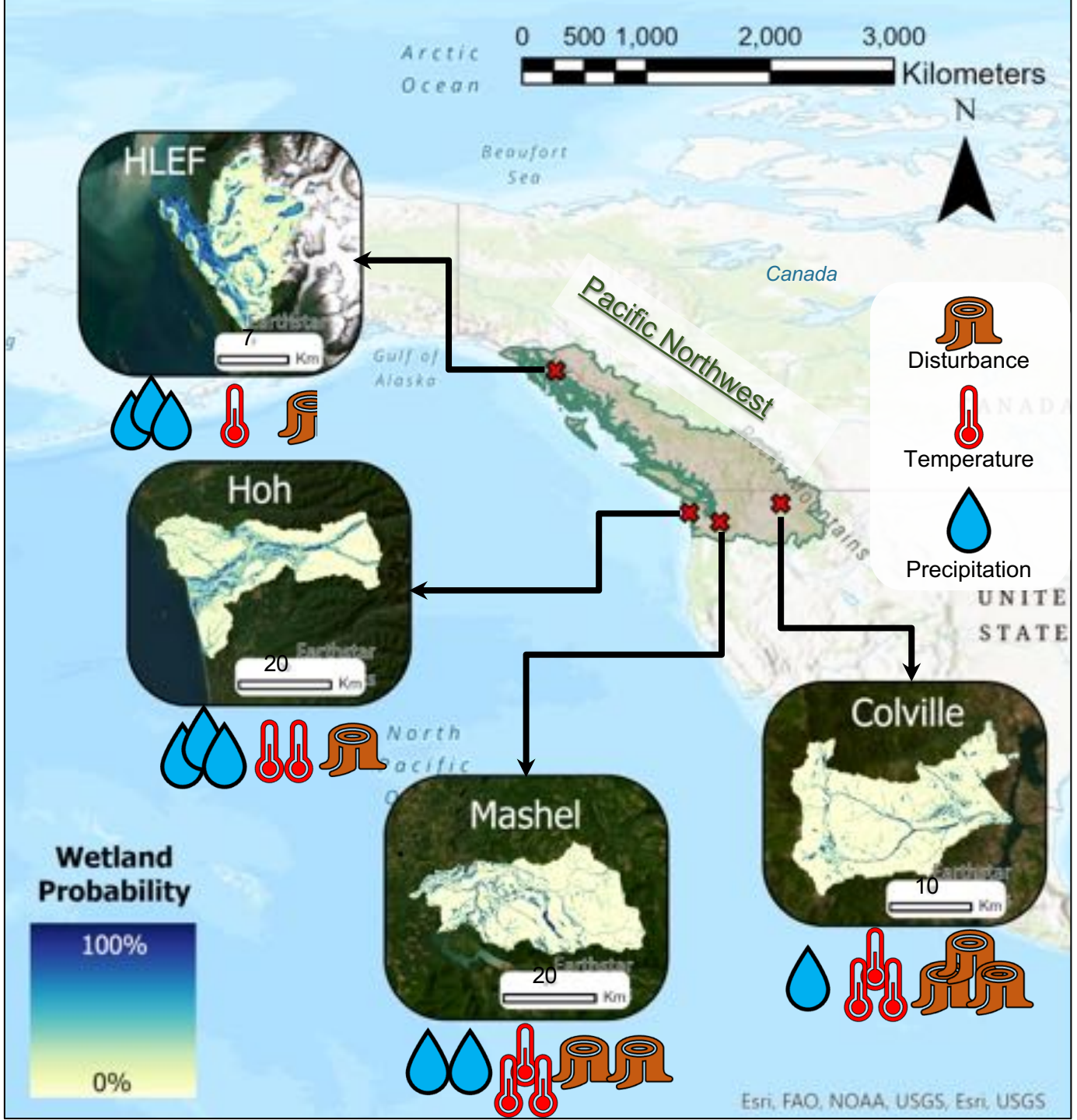


$R^2 = 0.47$

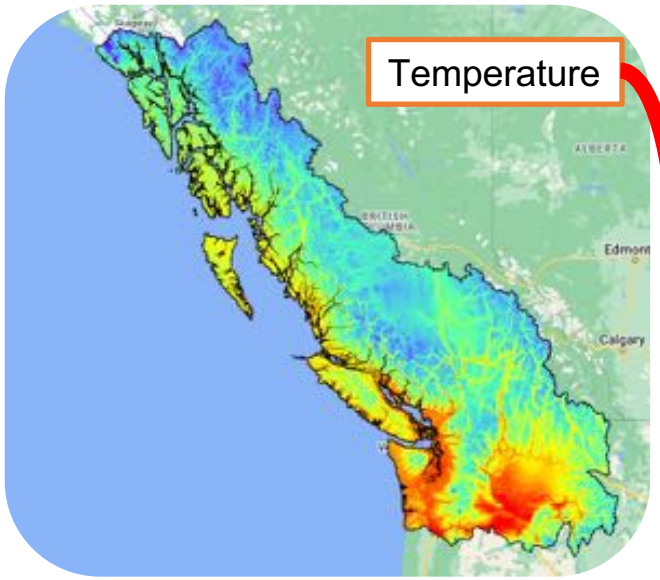
Non-Riverine

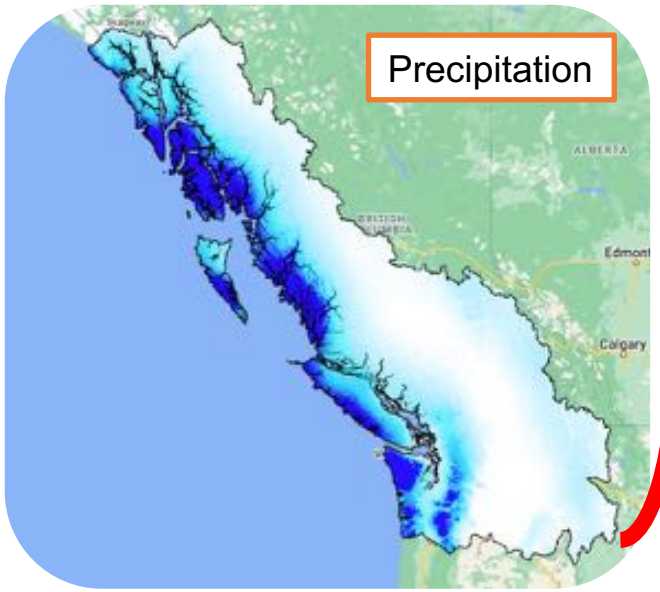
Riverine

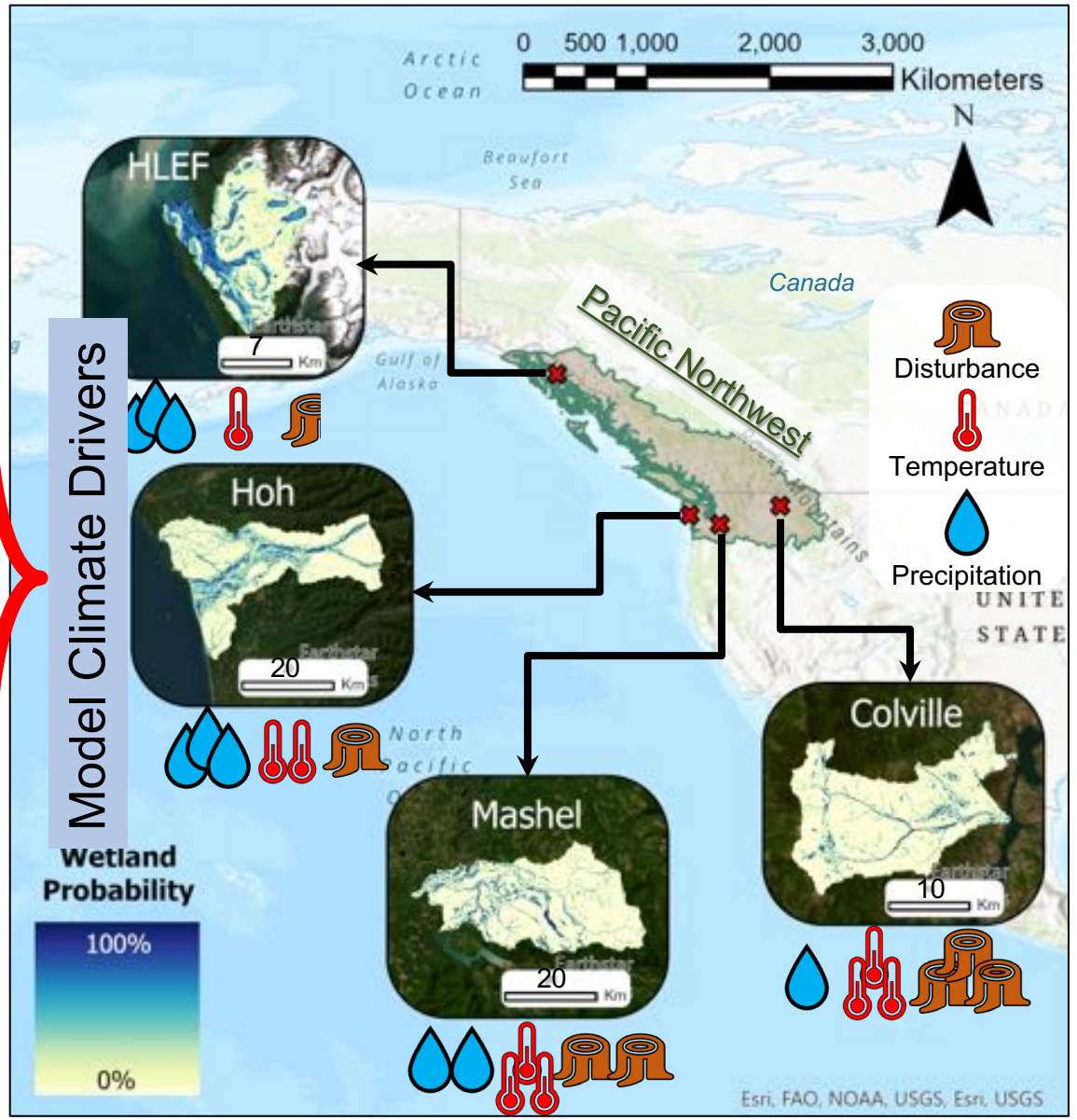
Future Analysis: Climate and Disturbance Vulnerability



Climate Vulnerability

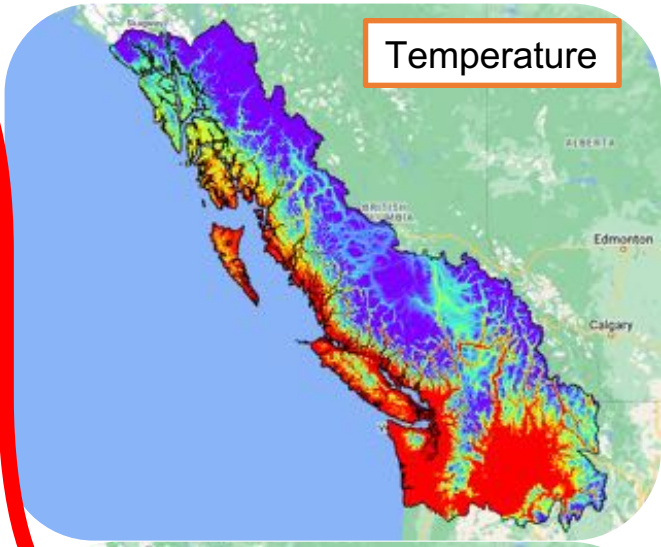


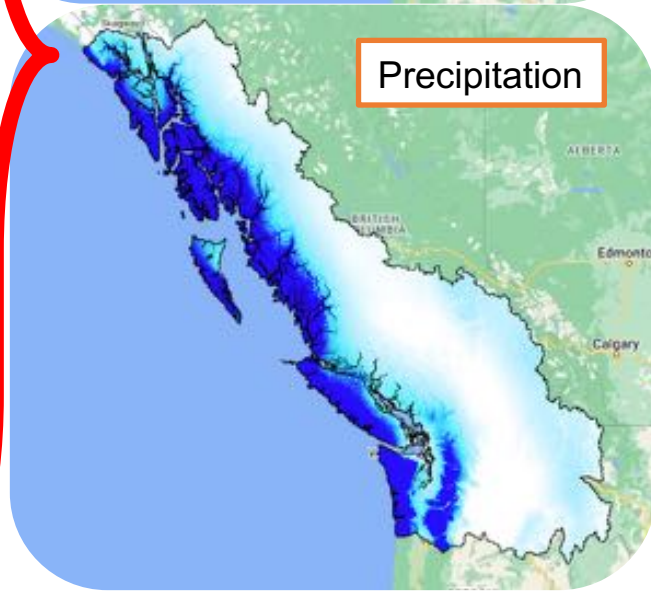




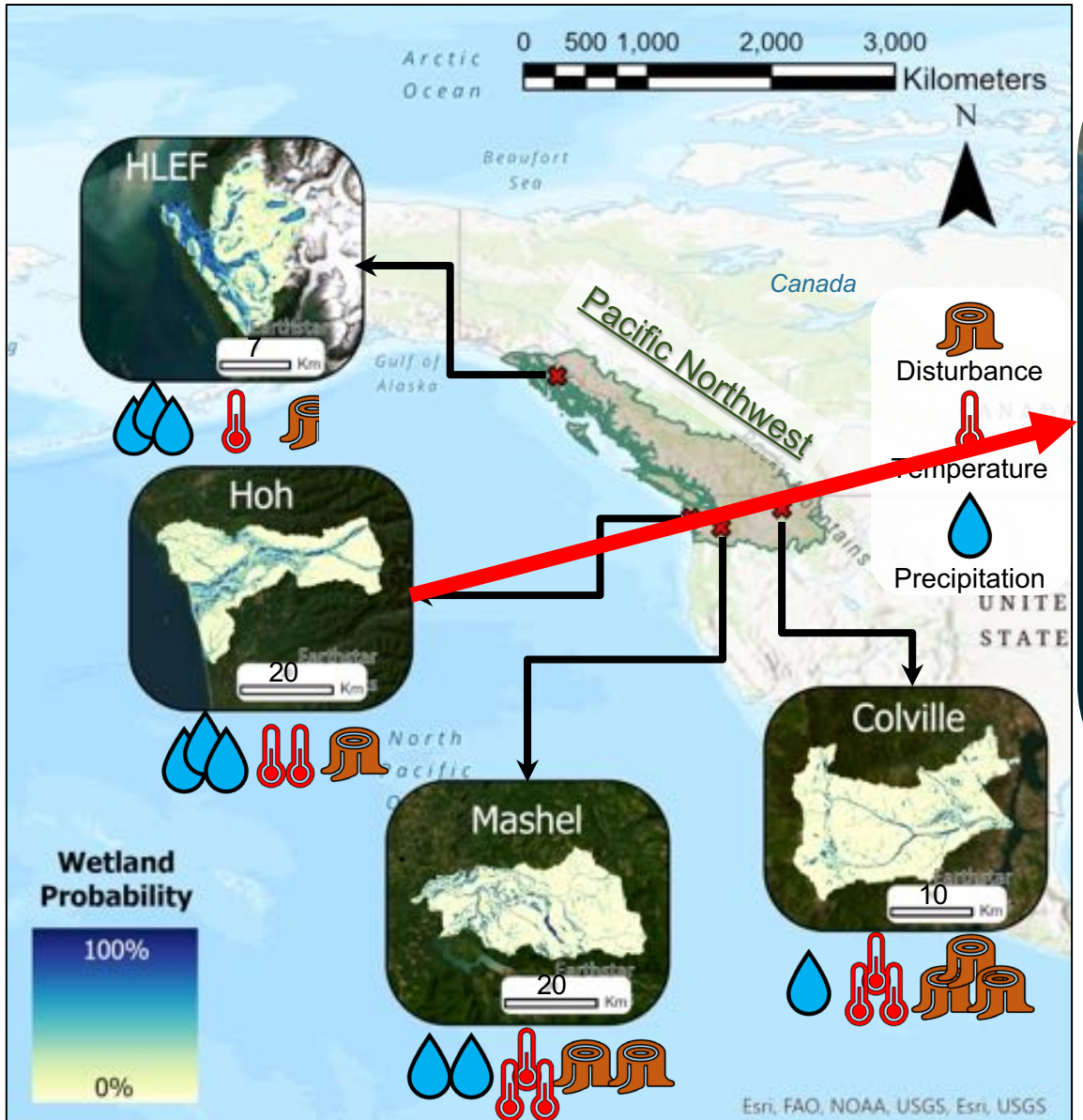
Projected Climate Scenarios

*** Not actual data

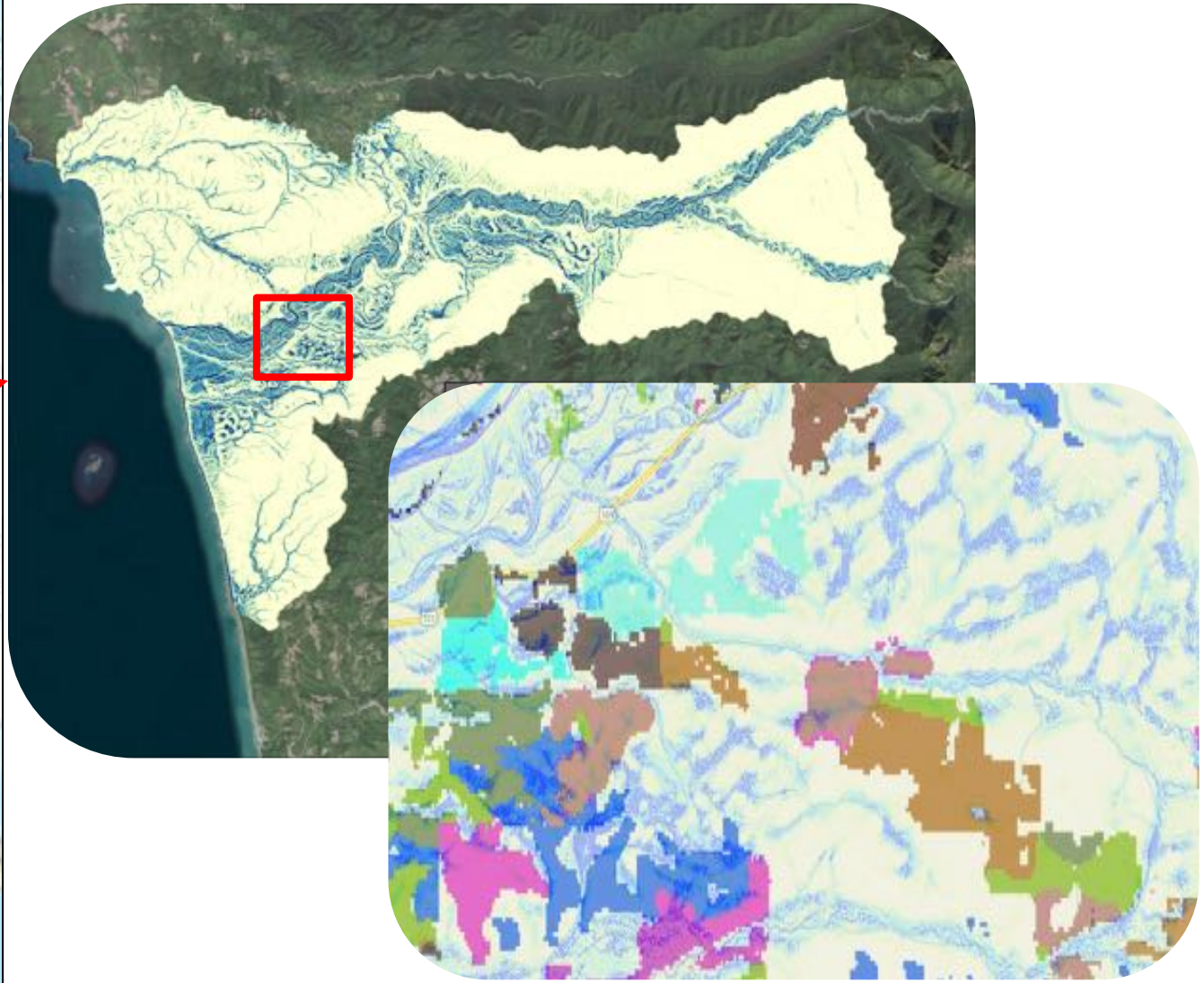




Disturbance Vulnerability

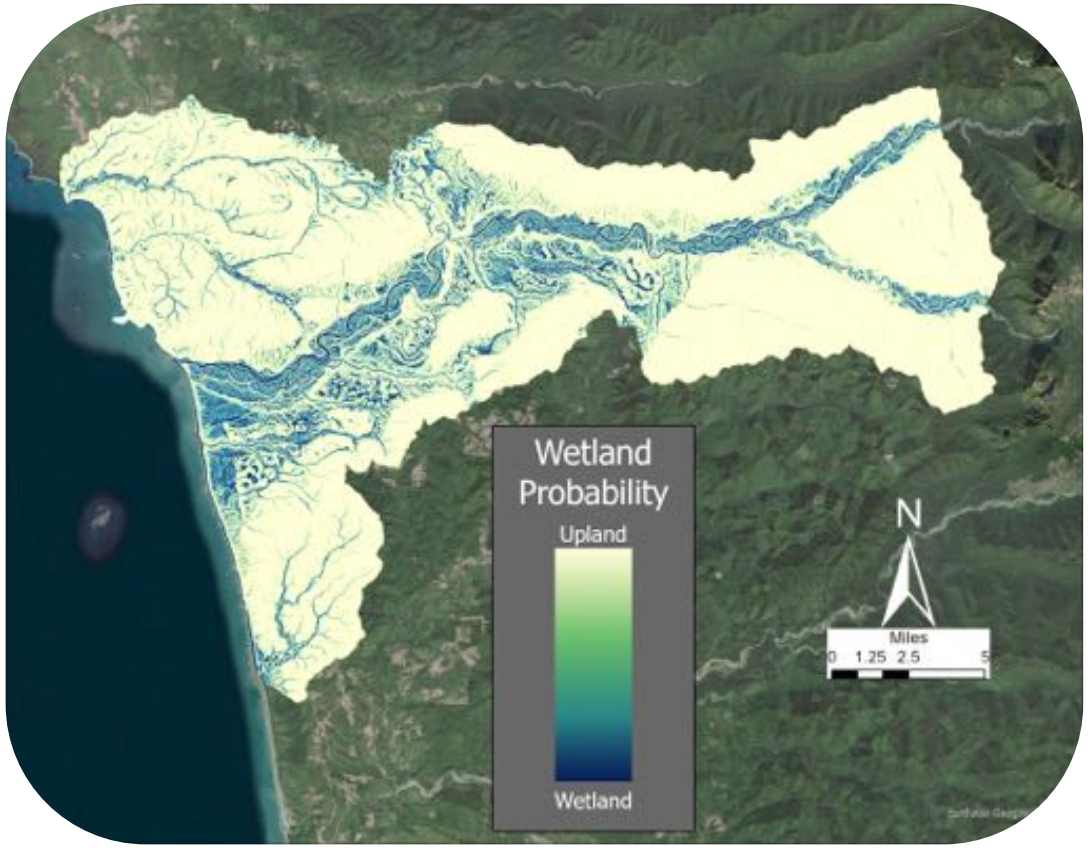


Remote Sensing Land Cover Change

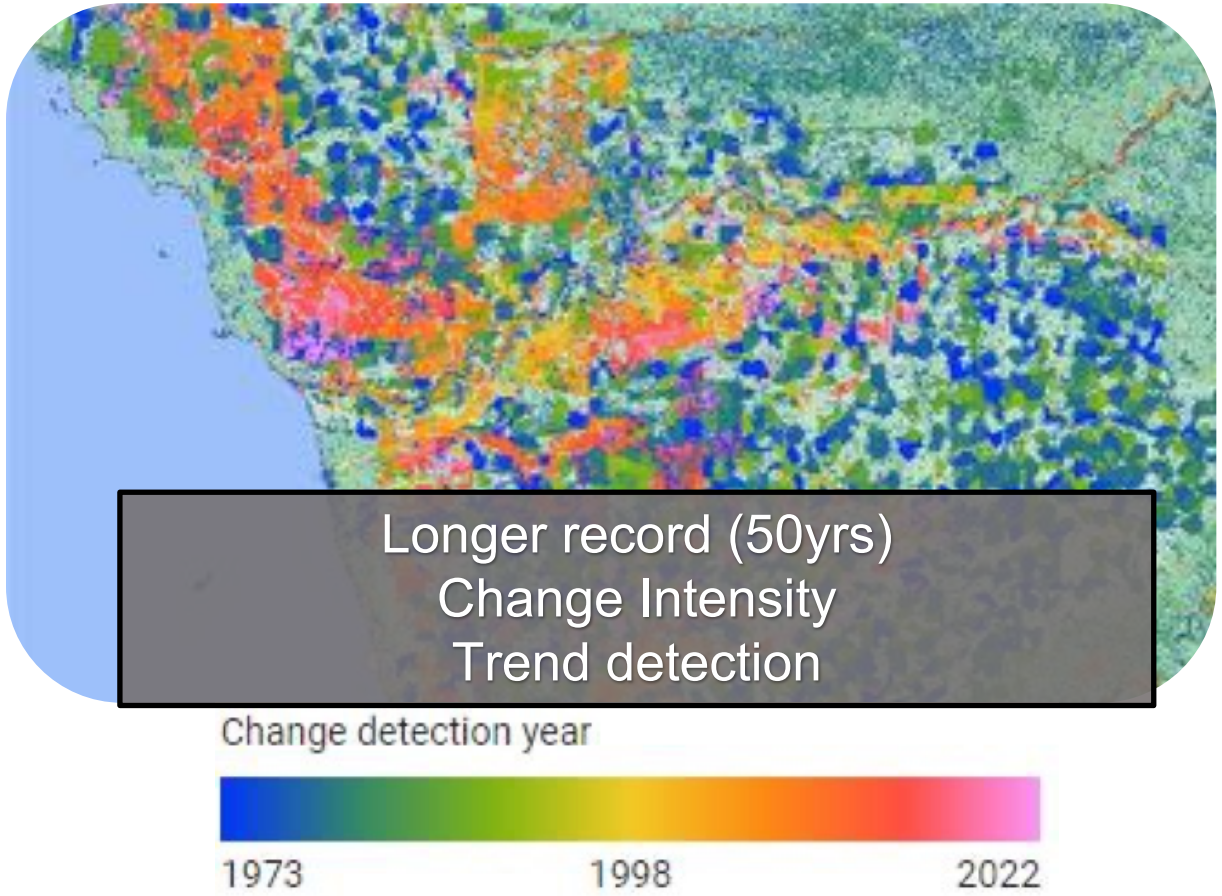


Hansen et al., 2013 Forest Gain/Loss Annually Since 2000

Disturbance Vulnerability

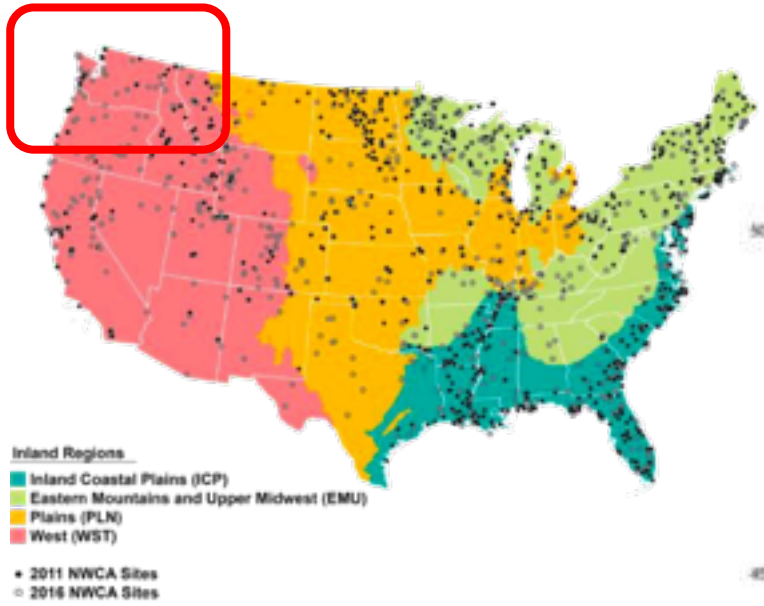


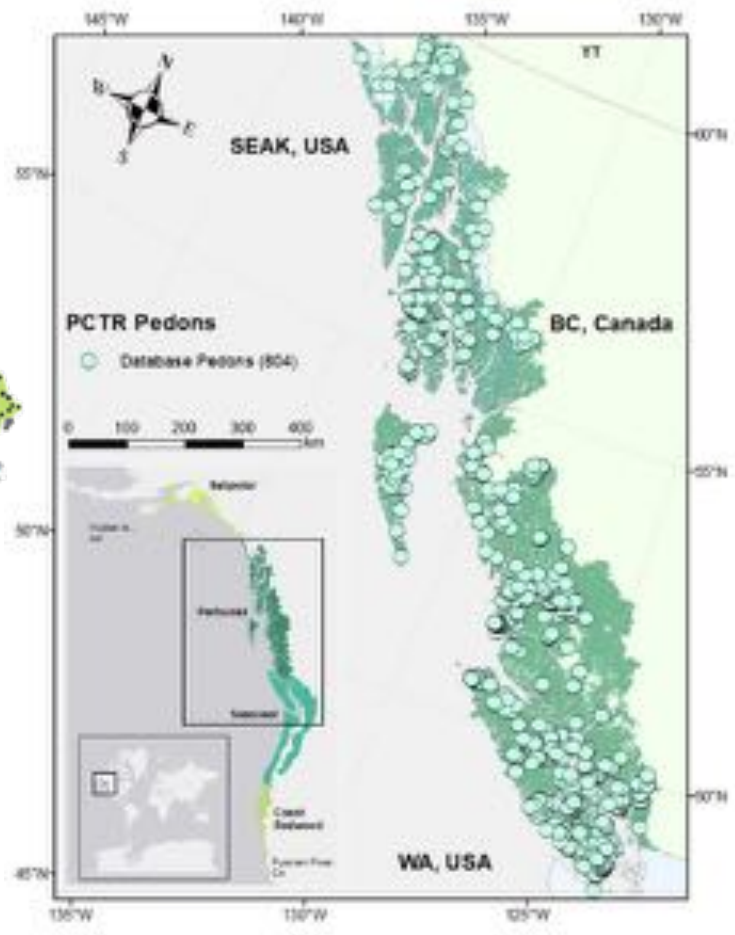
Justin Braaten & Meghan Halabisky
Landtrendr – Landsat Archive, change characteristics



Future Plans: Upscaling with open data

National Wetland Condition Assessment

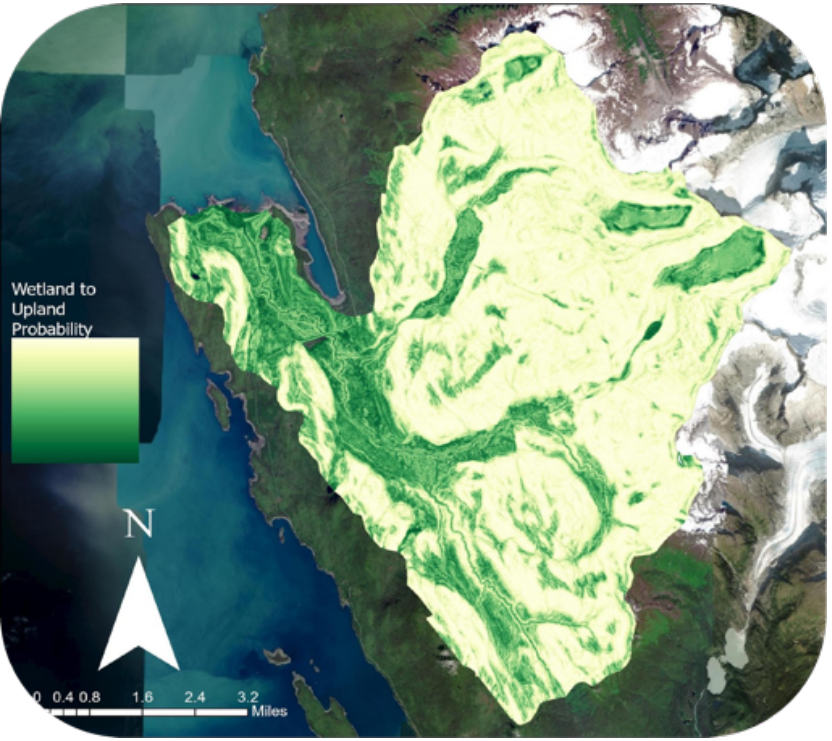




McNicol et al., 2019

Future Plans: Soil Carbon Quality

Heen Latinee Experimental Forest
Juneau, AK

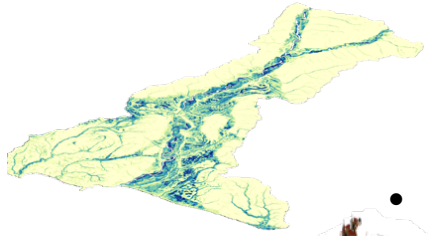


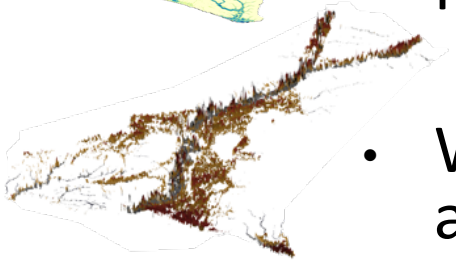
Density Fractionation

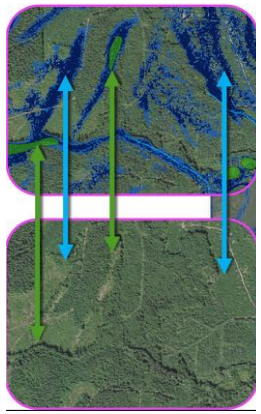
Heavy Mineral-Associated
(Stable)

Light Free Particulate
(Vulnerable)

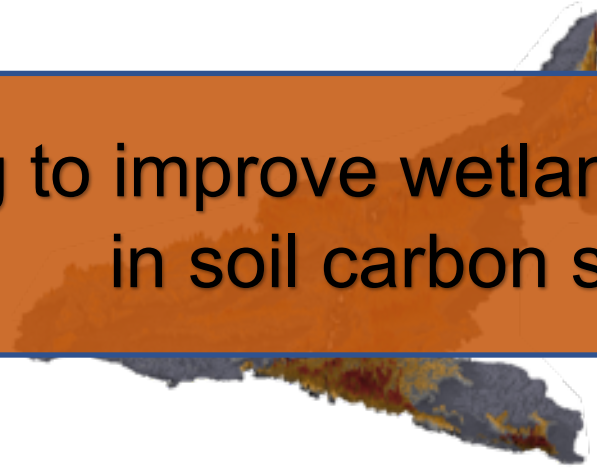
Conclusions







- Remote sensing approaches help identify wetland areas
  - Screening areas to add to current inventories (NWI)
- Wetland probability can help address hidden wetland extent and underestimates of wetland soil carbon stock
- Future efforts benefits from additional field validation data for remote sensing products
  - Disturbance detection



Working to improve wetland representation in soil carbon stocks

Acknowledgements:

- Maureen Duane, UW SEFS RSGAL Lab
- Dr. Amanda Nahlik, US EPA
- Dr. Amy Yahnke, WA DOE
- Frances Biles, USDA Forest Service PNW
- Dongsen Xue, UW Analytical Services Center
- Joe Rocchio, WA DOE

Check out more Teal Carbon

Email: ajs0428@uw.edu
Twitter: ajstewart04
Website: ajs0428.github.io

References

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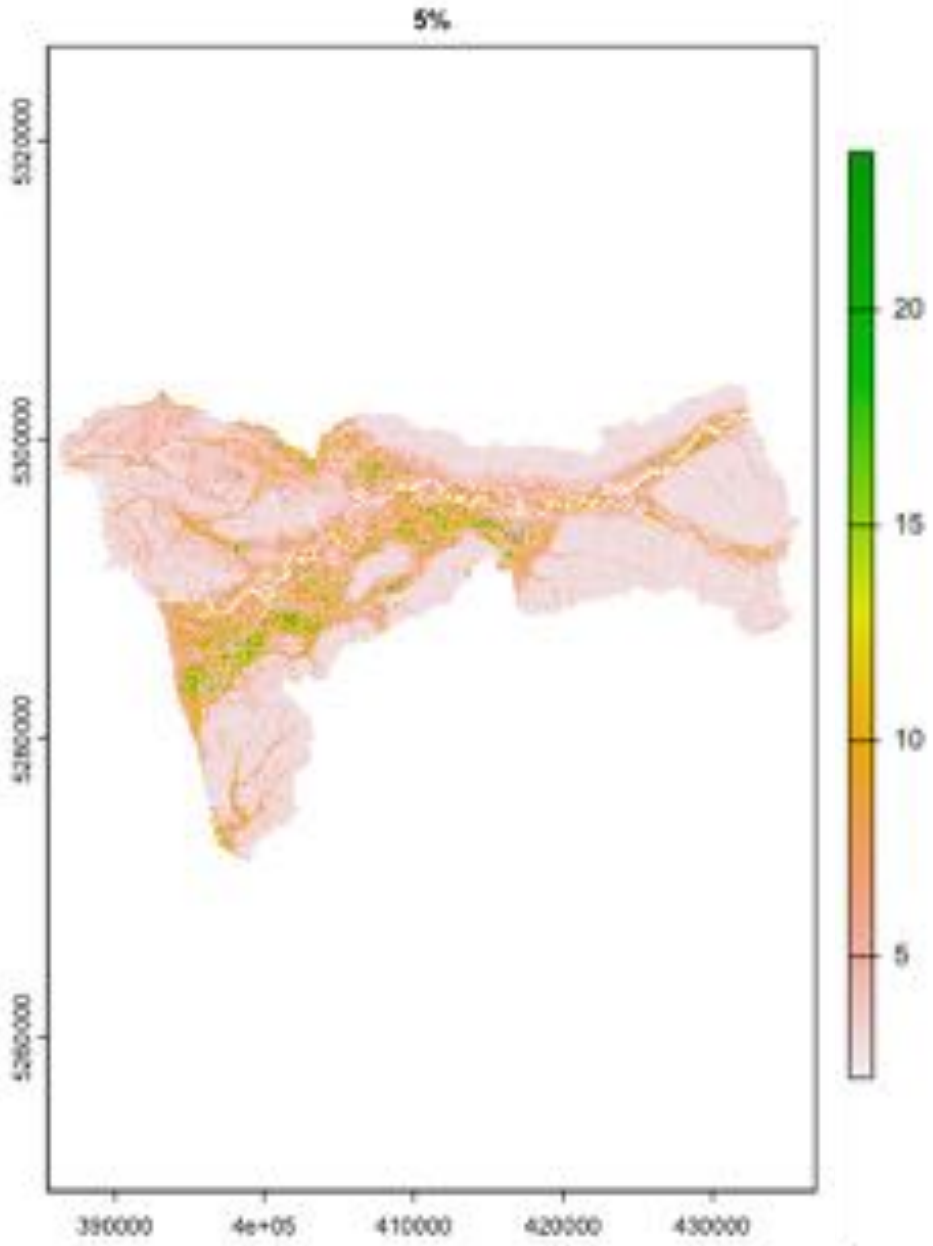
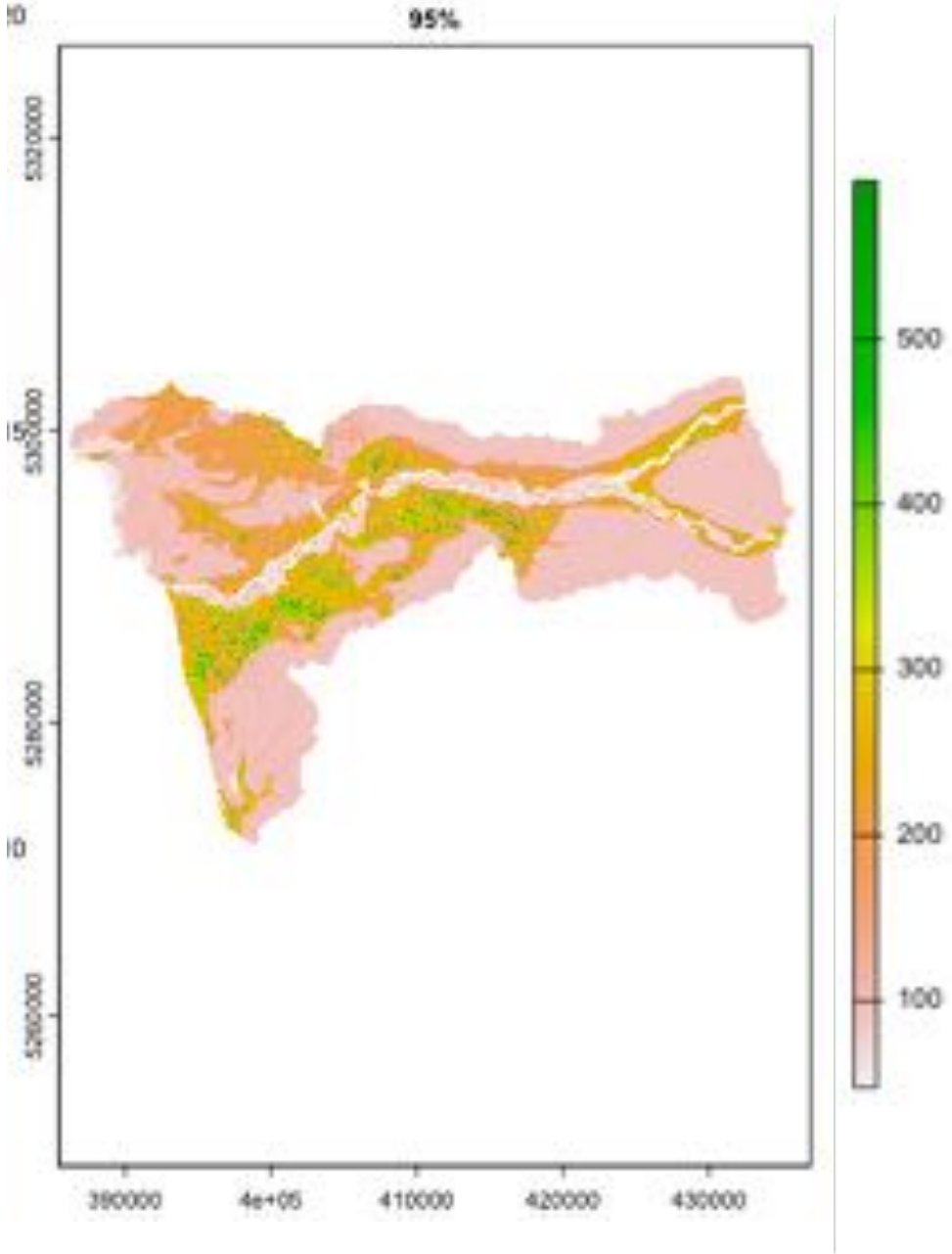
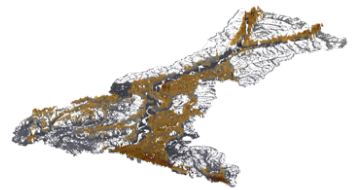
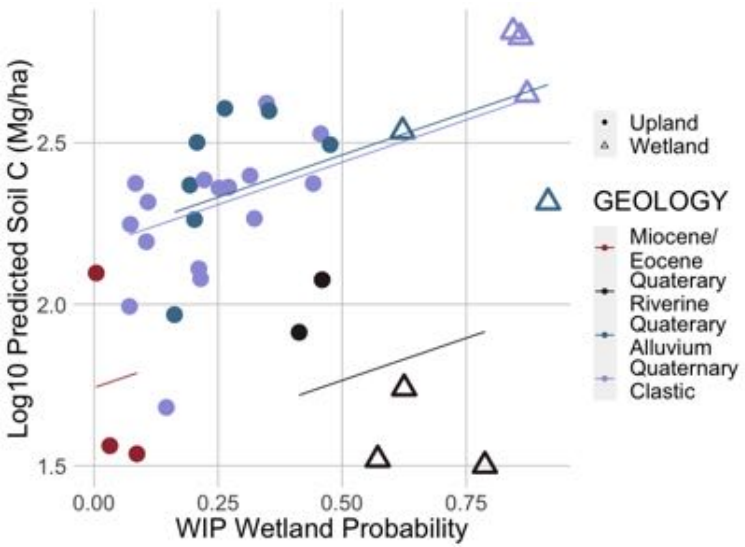




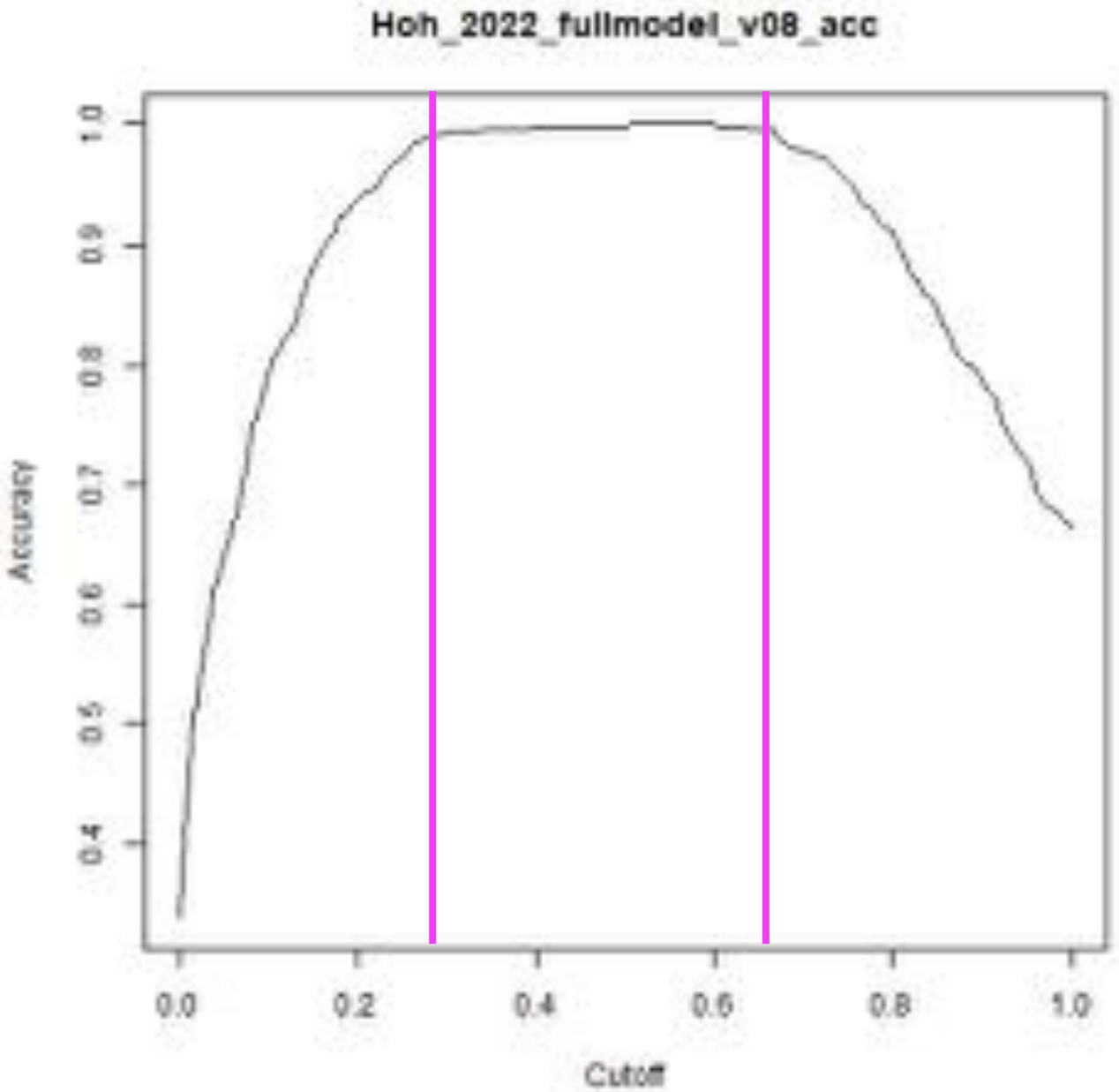


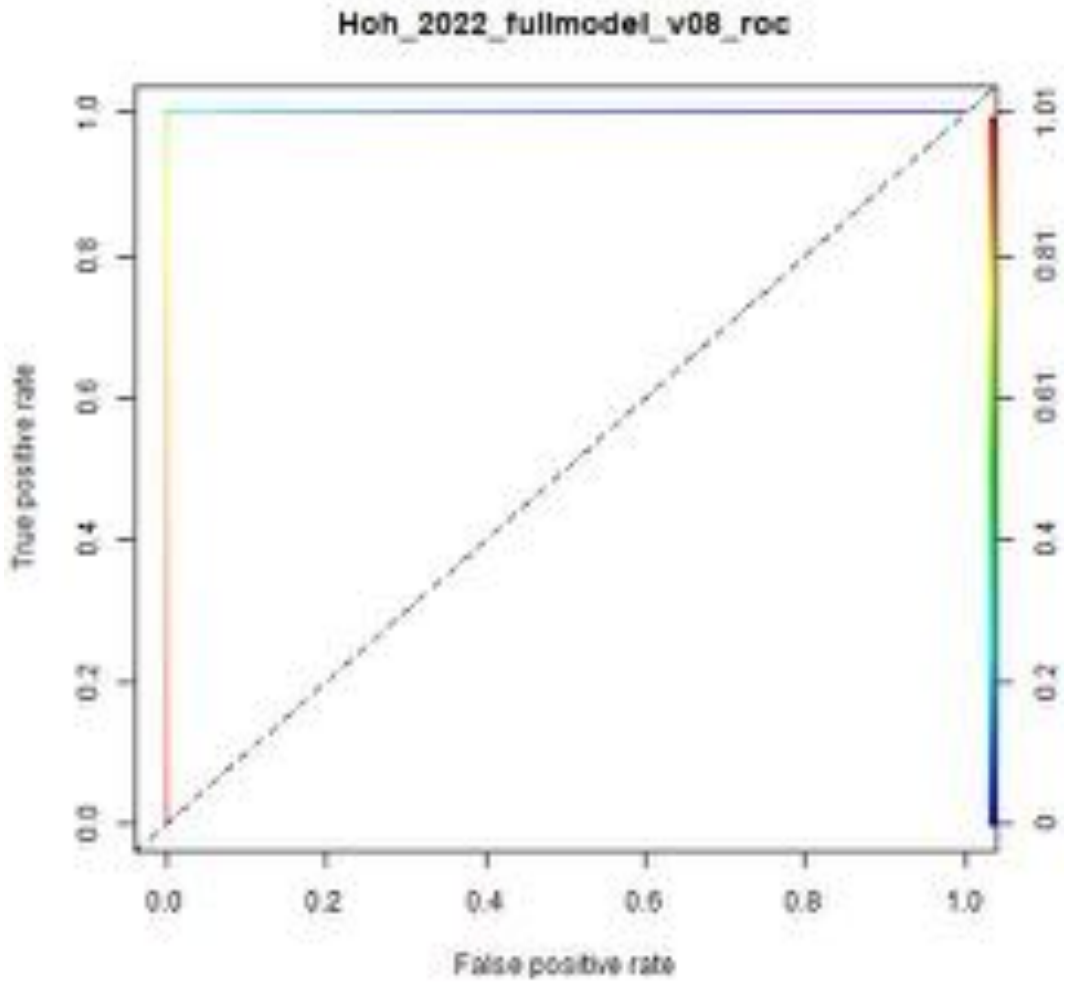
Mesic	Upland
21,155 (31.0%)	**40,866** (60.0%)
3.8 (38.9%)	**4.1** (41.9%)
175.7	**100.6**

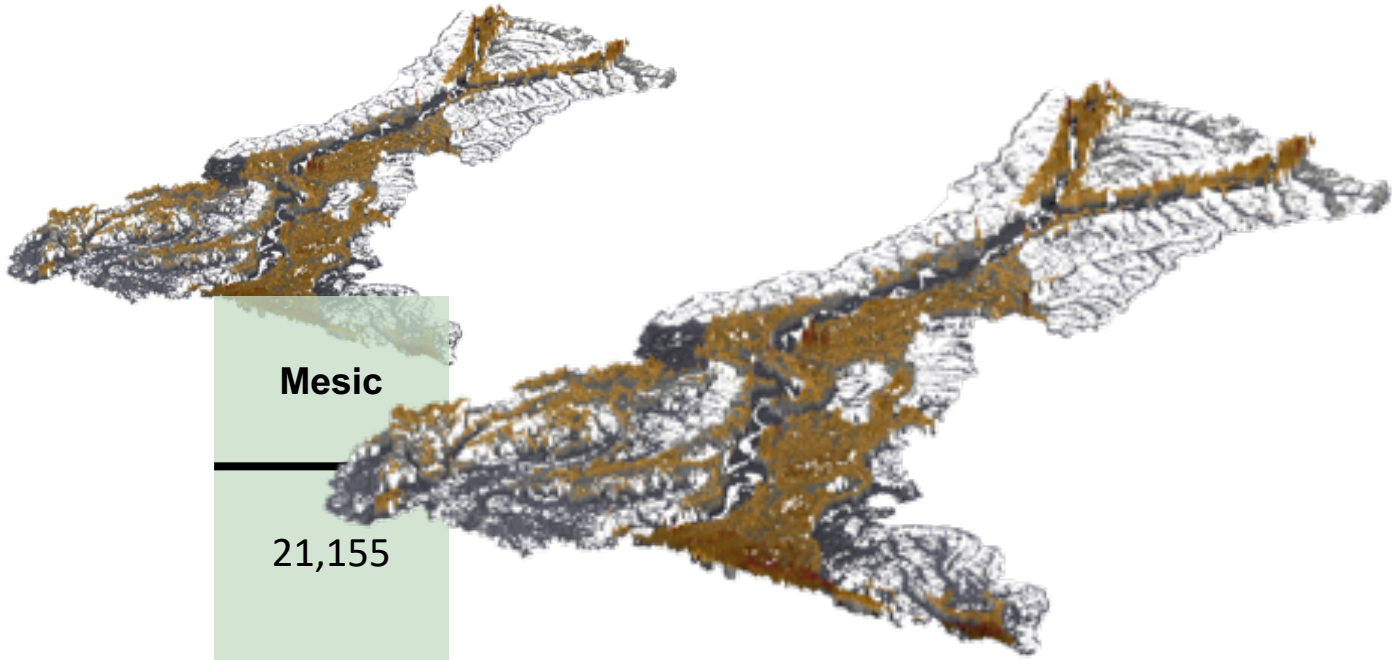
	log10(CARBON_1M)		
Predictors	*Estimates*	*CI*	*p*
(Intercept)	2.08	1.75 – 2.41	**<0.001**
WIP	0.13	0.05 – 0.22	**0.004**
Random Effects			
σ^2	0.05		
$\tau_{00\ GEO}$	0.09		
ICC	0.64		
N_{GEO}	4		
Observations	36		
Marginal R^2 / Conditional R^2	0.109 / 0.680		



	log10(CARBON_1M)		
Predictors	*Estimates*	*CI*	*p*
(Intercept)	2.07	1.70 – 2.44	**<0.001**
WIP	0.11	0.01 – 0.20	**0.033**
TWI	0.05	-0.03 – 0.14	0.218
DTW RIV [1]	0.01	-0.26 – 0.28	0.921
Random Effects			
σ^2	0.05		
$\tau_{00\ GEO}$	0.09		
ICC	0.64		
N_{GEO}	4		
Observations	36		
Marginal R^2 / Conditional R^2	0.120 / 0.682		


Hoh_2022_fullmodel_v08_acc
Accuracy
Cutoff
0.0
0.2
0.4
0.6
0.8
1.0
0.4
0.5
0.6
0.7
0.8
0.9
1.0


Hoh_2022_fullmodel_v08_roc
True positive rate
False positive rate
0.0
0.2
0.4
0.6
0.8
1.0
0
0.2
0.4
0.6
0.8
1.01



Mesic
21,155
31.0%
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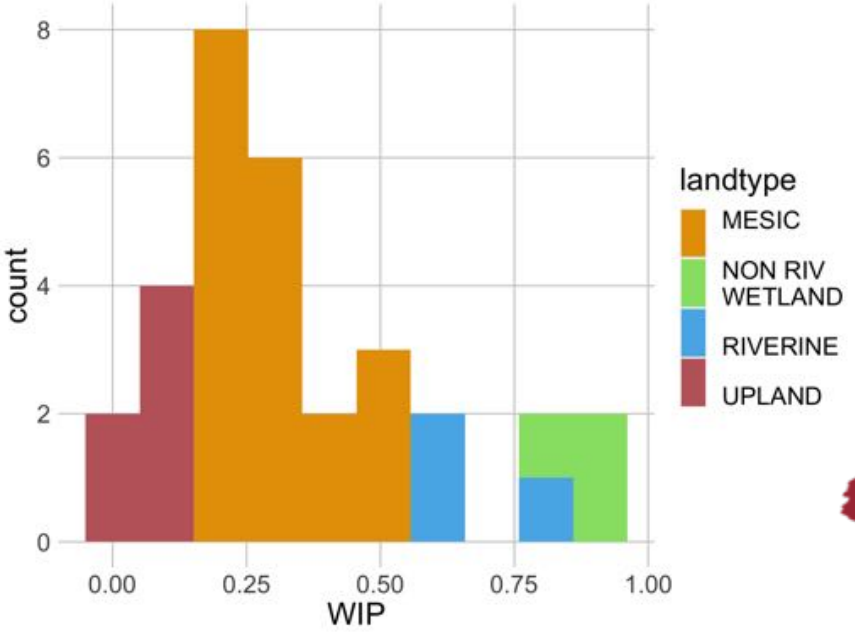
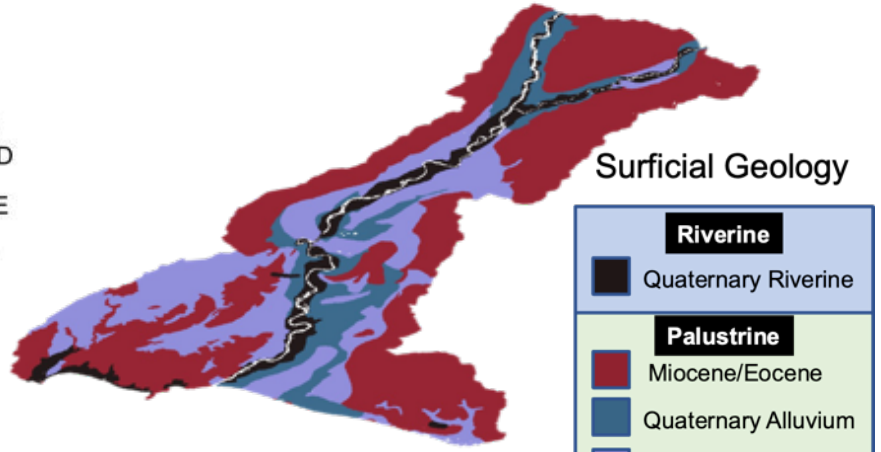
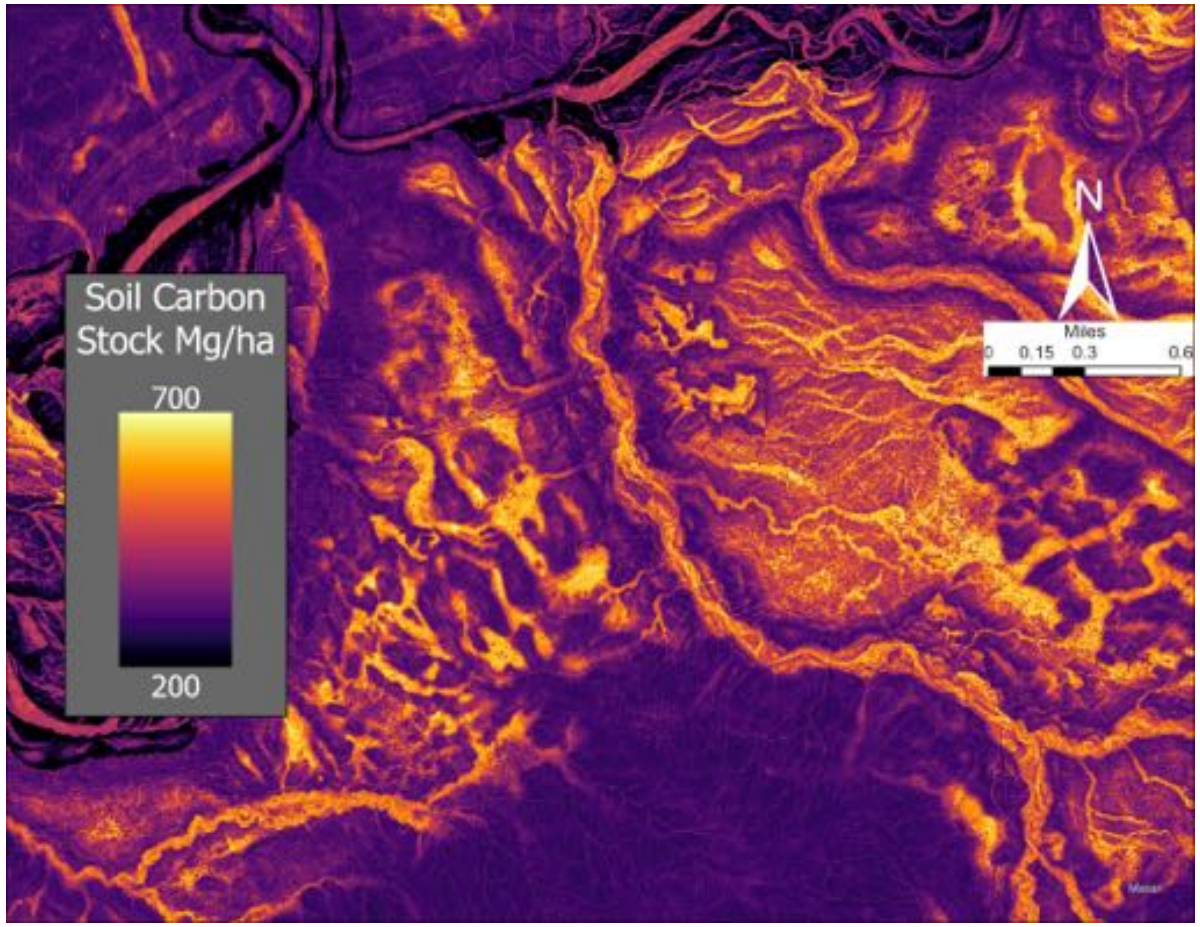




Further Questions

- How much landscape is misclassified as not-wetland at greater extents and larger scales?
- Are these cryptic wetlands and carbon more vulnerable to land use change and other disturbance?
- Across the upland to wetland gradient how stable is the soil carbon stock? Are mesic areas more stable but hold less soil carbon?

Soil Carbon Estimates at the Management Scale



SoilGrids 250m*30cm depth Hengl et al., 2017