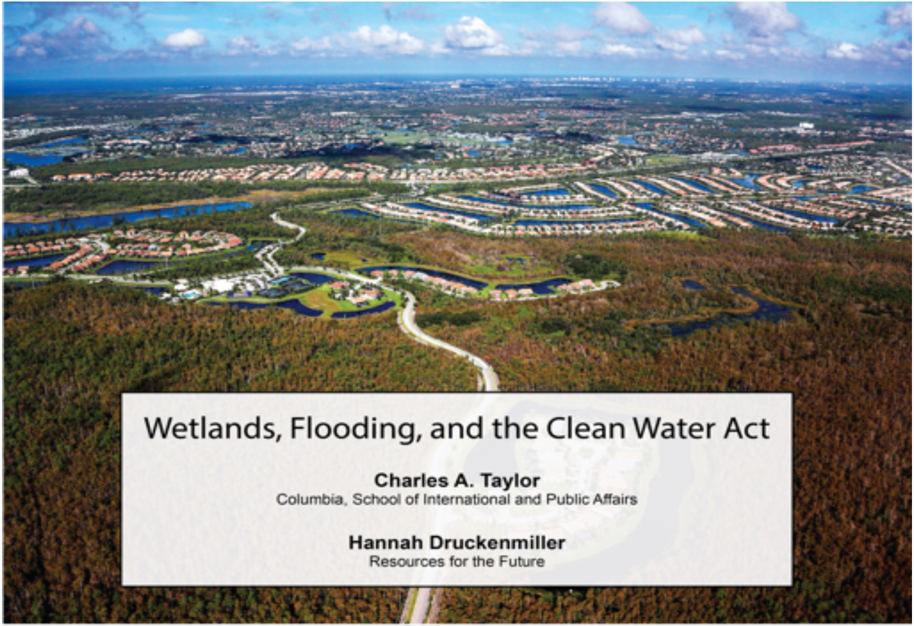

Wetlands, Flooding, and the Clean Water Act

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Context

Clean Water Act (CWA) is the primary law regulating US waters—and by extension land use

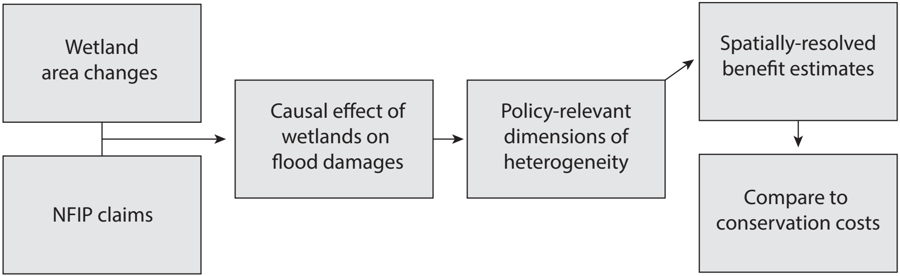
Wetlands are regulated under Section 404 $\rightarrow$ costly permit required to dredge/fill “waters of the United States” (WOTUS).

In 2020, the EPA and Army Corps narrowed the definition of WOTUS to exclude **isolated wetlands** (those lacking a surface water connection)

This rollback could affect $\sim$50% of US wetlands (Sullivan et al. 2019).

This study

We estimate the value of wetlands for **flood mitigation** across the US.



Existing Evidence

Relationship between coastal wetlands and hurricane damages is well-studied:

→ Engineering models by US Army Corps, FEMA quantify reductions in storm surge given a particular land use

→ Empirical evaluations find one hectare of coastal wetlands reduces annual hurricane damages by ∼\$8,000 (Costanza et al. 2008; Narayan et al 2017; Sun and Carson 2020)

But the existing literature does not:

→ Evaluate inland and freshwater wetlands (95% of US wetlands)

→ Examine more typical flood events (16× more inland flood than hurricane PDDs)

→ Assert or test causal mechanisms

EPA cited lack of empirical evidence of wetlands benefits in 2020 rule change.

Empirical Challenge

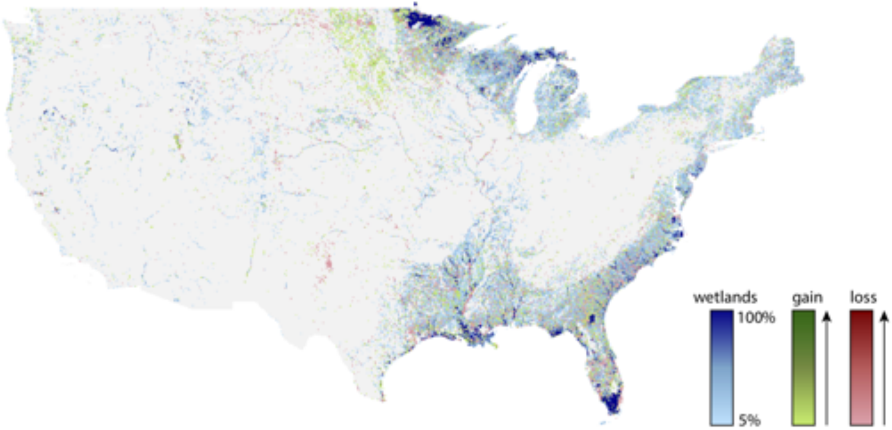
Wetland spatial extent is associated with other factors that drive flood damage dynamics.

Cross-sectional: Locations with wetter climates have more wetlands and are also more likely to experience flooding.

Time-varying: Locations with population growth are more likely to see a reduction in wetlands (i.e., urban expansion) and increase in flood claims (i.e., more assets exposed).

Data: National Land Cover Database

Wetland area changes for the period 2001 to 2016



Wetlands span 47 million hectares (6% of conterminous US)

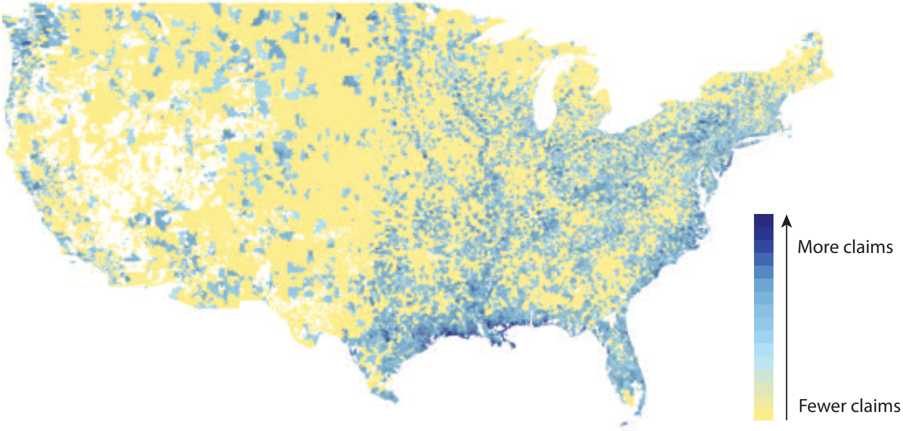
Data: National Hydrography Dataset

Distance of all wetlands from the water surface network

Same resource used by EPA and Army Corps in Section 404 determinations

Data: National Flood Insurance Program

Zip code-level flood insurance claims from the NFIP



Long Differences

$$\Delta F_{is} = \beta \Delta W_{is} + \theta \Delta \mathbf{X}_{is} + \alpha_s + \epsilon_{is}$$

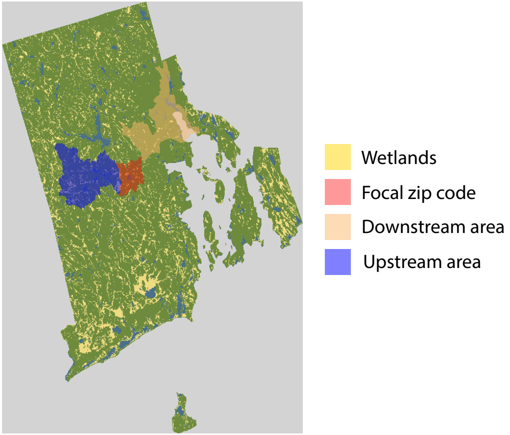
- ΔF_{is} is change in NFIP claims in zip code i and state s between 2001 and 2016.
- ΔW_{is} is change in wetland area (ha) between 2001 and 2016, or
  - $\Delta wetland^{GAIN}$ indicates an **increase** in wetland area
  - $\Delta wetland^{LOSS}$ indicates a **decrease** in wetland area
- $\Delta \mathbf{X}$ is a vector of covariates including changes in population, income, housing units, housing value, developed area, CRS governance
- α_s is state fixed effects to control for unobserved state-level trends
- i indexes zip code and s indexes state
- standard errors clustered by county

Additional estimation approach using a 5-year panel

Upstream-Downstream DiD

Data: National Hydrography Dataset

Classify wetland area changes upstream vs. downstream of each zip code



Utilizing water flow matrix of HUC-12 within HUC-4 watersheds

Upstream-Downstream DiD

$$\Delta F_{is} = \beta \Delta W_{is} + \gamma \Delta W_{is}^{UP} + \lambda \Delta W_{is}^{ALL}$$
$$+ \theta \Delta \mathbf{X}_{is} + \alpha_s + \epsilon_{is}$$

- ΔW is the change in wetland area **within** zip code i
- ΔW^{UP} is the change in **upstream** wetlands
- ΔW^{ALL} is the change in wetlands in the watershed
- $\Delta \mathbf{X}$ is a vector of covariates (same as Long Difference)

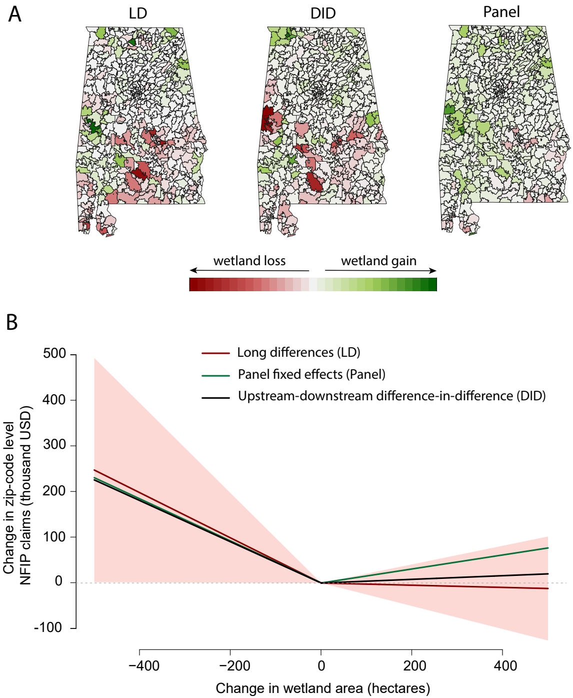
λ accounts for watershed-level time-varying factors driving both changes in wetlands and flood claims. β is the effect of "local" wetlands (directly comparable to long difference parameters). γ is differential effect of upstream wetlands, the "direct protective services"

$\rightarrow$ No difference in real estate development upstream vs downstream

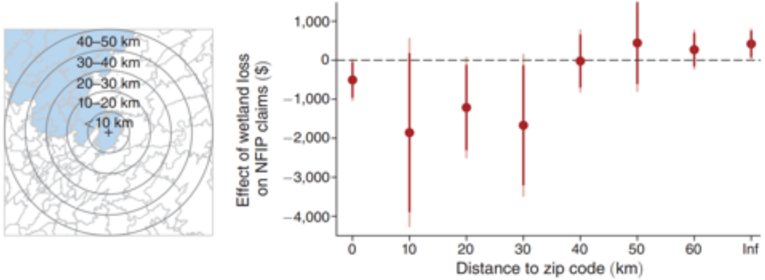
Results: Effect of wetland changes on flood damages

	Dependent variable: Zip code-level NFIP claims (USD)					
	LD	DID	Panel	LD	DID	Panel
Wetland effects						
Local wetland change (ha)	−229.2	−157.5	−180.9			
	(127.7)	(102.1)	(83.6)			
Local wetland gain (ha)				−24.1	40.0	153.6
				(116.4)	(74.7)	(220.9)
Local wetland loss (ha)				−495.3	−452.0	−461.7
				(250.8)	(247.4)	(272.4)
Upstream wetland change (ha)		−498.7				
		(211.3)				
Upstream wetland gain (ha)					−71.3	
					(77.0)	
Upstream wetland loss (ha)					−810.7	
					(342.0)	
Fixed effects	State	State	Zip, Year	State	State	Zip, Year
Observations	25,735	24,476	93,111	25,735	24,476	93,111

SE are clustered by county.


A
LD
DID
Panel
wetland loss
wetland gain
B
Long differences (LD)
Panel fixed effects (Panel)
Upstream-downstream difference-in-difference (DID)
500
400
300
200
100
0
-100
Change in zip-code level NFIP claims (thousand USD)
−400
−200
0
200
400
Change in wetland area (hectares)

Results: Spatial lag model

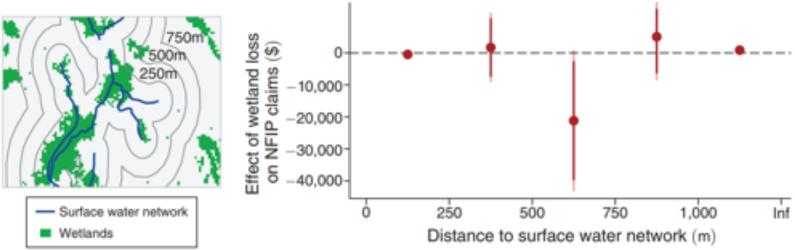


→ One hectare of wetland loss increases NFIP claims by $1,900

→ Value of wetlands to local property owners (same zip) is $<$ 30% of the total benefits

→ $600M in annual NFIP claims (23%) due to wetland loss since 2001 (331,000 ha)

Results: Distance to water surface network



→ Wetlands intermediate distances from water surface network have highest benefits.

→ Consistent with hydrological concept of wetlands "acting like a sponge"

→ At odds with rule change that eliminates federal protections for "isolated" wetlands

→ E.g., contested thresholds on WOTUS rule ranged from 500 to 1,200 meters

Heterogeneity dimensions

(1) By ecoregion

Greatest impact:

→ East of 100th meridian

→ Great Plains

→ Eastern Temperate Forests

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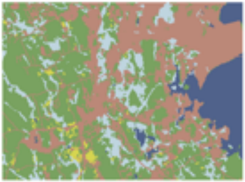
(2) By ultimate land use



Greatest impact:

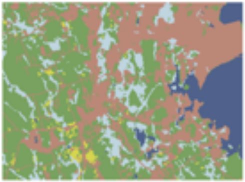
→ Where wetlands are converted to developed area

Heterogeneity dimensions

(1) By ecoregion

Greatest impact:
- → East of 100th meridian
- → Great Plains
- → Eastern Temperate Forests

(2) By ultimate land use



Greatest impact:
- → Where wetlands are converted to developed area

(3) By precipitation

Greatest impact:
- → During extreme rainfall events (3+ sigma monthly rainfall)

Flood mitigation value vs. conservation costs

(1) Wetland benefits and conservation costs depend on local development:

→ Wetland benefits: more exposed properties, higher potential flood mitigation value

→ Conservation costs: More populated areas have higher real estate value

(2) Allow wetland effects to vary by level of development:

$$\Delta F_{is} = g(\Delta W_{is}^{GAIN} | D_{is}) + l(\Delta W_{is}^{LOSS} | D_{is}) + \theta \Delta \mathbf{X}_{is} + \alpha_s + \epsilon_{is}$$

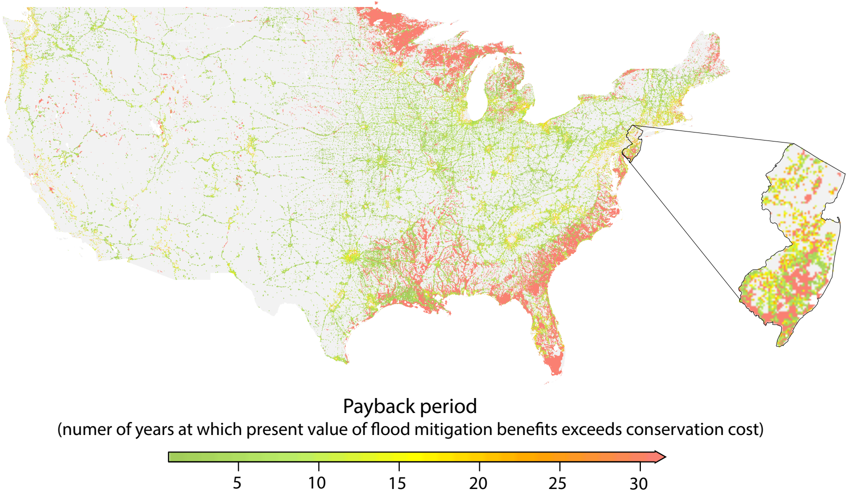
→ $D =$ quintile of sample-period mean % developed area in a zipcode

(3) Conservation costs using high-res land value maps (Nolte 2020).

→ Mean value across all US wetlands: $12,700 per hectare

→ Wetlands lost between 2001 and 2016: $31,6000 per hectare

Flood mitigation value vs. conservation costs



For 50% of US wetland area, the societal benefits from reduced flooding outweigh the cost of buying the land within 5 years.

Taylor & Druckenmiller

Summary

Context

- Wetland regulation under CWA Section 404 is highly controversial
- A 2020 rule change rolled back federal protections for wetlands, citing lack of empirical evidence on wetland benefits in EPA's CBA
- Subject of upcoming Supreme Court case

Our Findings

- One hectare of wetland loss increases NFIP claims by **$1,840**
    - Increases to $8,000 in developed areas
    - Increases to $12,000 if the wetland converted to built-up land
- No detectable effect of wetland area gains, calling into question the Compensatory Mitigation Program (i.e., mitigation banking).
- Most valuable wetlands **lack** direct surface water connection to a stream/river, at odds with the 2020 rule change
- Lower bound on value (non-NFIP floods, water quality, habitat, recreation)