VULNERABILITY AND THE COST OF WETLAND LOSS

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CNREP

HURRICANES

- Hurricane Damages
  - $ Billions in damage

- Economic Impacts
  - Loss of valuable capital
  - Cost of response and recovery efforts
  - Interruption of commerce

NOAA

VULNERABILITIES

- What drives vulnerability to *hurricane damage*?

- Hurricane Regimes
  - Potential for increased frequency/intensity of tropical cyclones
- Population Growth
  - Smart growth
- Wetland Loss*
  - Rapid land loss

FEMA

WETLANDS AS BUFFERS

- Wetlands are known to attenuate damage from storms
  - Evident in physical science literature
  - Noted in economic literature

- Motivation for billions of dollars in (proposed) restoration projects
  - 5,000 km lost

- Importance of Economic Valuation

THE "MASTER PLAN" STATES

- The plan seeks to "reduce economic losses from storm surge flooding" and "promote a sustainable coastal by harnessing the natural processes of the system" primarily through the maintenance and restoration of coastal wetlands.

- "An in depth evaluation of ecosystem services would include a dollars and cents component that captures how much these services are worth monetarily."

- "We did NOT include this economic aspect of ecosystem services in the master plan analysis. Models to analyze this aspect were not readily available, and we did not have enough time to develop them ourselves."

OBJECTIVES

- Estimate the value of the protective ES provided by coastal wetlands in Louisiana
- Explore how wetland loss and influences vulnerability to hurricane damage

DAMAGE MODELING

- Approach: production function analysis
  - Creation of a function that describes damages
  - Wetlands, population and storms are modeled as productive inputs
- Referred to as Expected Damage Function (EDF)
  - Used for assessing vulnerability/risk and for wetland valuation
- Model the interrelationships between factors

THE DAMAGE FUNCTION

$$log(y) = \alpha \, x_1^{\beta_1} x_2^{\beta 2} x_3^{\beta 3}$$

$$log(y) \; = \; \alpha[\sum \rho_{ij}(x_{ij1}^{\beta 1})](x_{ij2}^{\beta 2}) \; (x_{ij3}^{\beta 3}),$$

- damage function where…
  - y = damages
  - X_1 = maximum sustained winds at landfall for parish i
  - X_2 = estuarine and marine wetlands per coastal mile for parish i
  - X_3 = population for parish i, year of storm
  - β_1 = parameters for the storm intensity term
  - β_2 = parameters for the wetland area term
  - β_3 = parameter for population term
  - ρ_{ij} = probability of storm j in parish i

DAMAGE DATA

- NOAA National Climatic Data Center (NCDC)
  - Estimates include damages for multiple parishes (counties)
- Computer Simulation results
  - To achieve distribution at parish-scale
- 118 impacts from 13 storms and 13 parishes (1997-2008)

National Geographic

UMCES

DATA

- Population
  - US Census Bureau
- Hurricane intensity data
  - 60-second maximum sustained winds, NCDC
- Wetland data
  - NOAA Coastal Change Analysis Program
  - Cowerdin, et al. (1979)

RESULTS

Variable	Coefficient	Std. Err.	t	P>t	95% CI (LB)	95% CI (UB)
Alpha	4.413	1.855	2.38	0.019	0.738	8.089
Wind	0.293	0.053	5.53	<.001	0.188	0.398
Wetlands	-0.058	0.028	-2.10	0.038	-0.114	-0.003
Population	0.037	0.018	2.05	0.031	-0.049	-0.024

WETLAND VALUATION

- Use of EDF for ecosystem service valuation
  - Ecosystem service: mitigation of hurricane damages
  - Wetlands as “natural infrastructure” for risk reduction
  - Though deriving marginal values, MV,

$$MV = e^{\hat{y}} - e^{\hat{y}`}$$

where, expected log of damages,

$$\hat{y} = F(x_1, x_2, x_3)$$

and,

$$\hat{y}` = F(x_1, x_2 - 1, x_3).$$

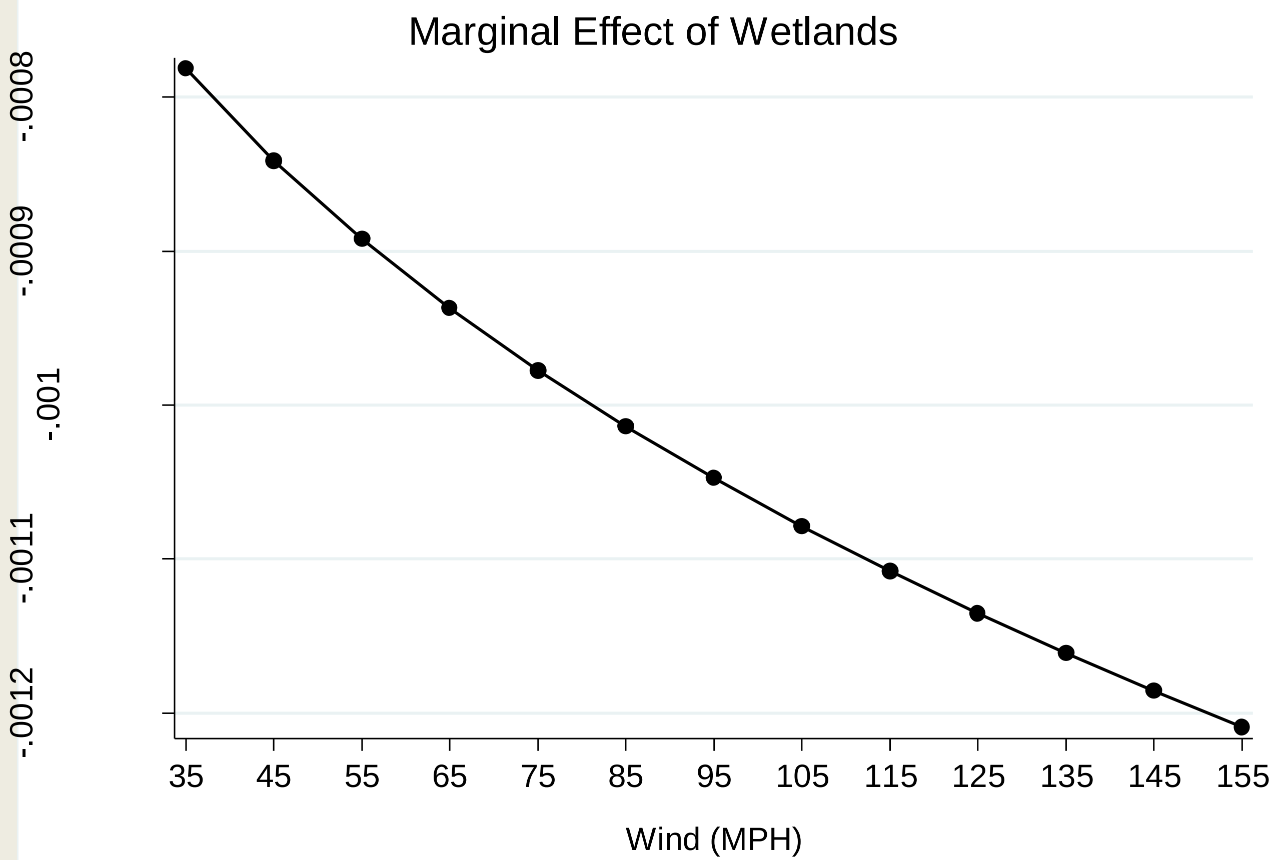
RESULTS

Value	TS	Category 1	Category 2	Category 3	Category 4*	Category 5*	∑
Ha/km/storm	$69	$746	$2,341	$4,813	$5,084	$5,265	
Ha/km/year	$22	$143	$232	$384	$143	$114	
Annual Unit Value							$1,038
NPV (r=5, t=50)							$19,897
NPV (r=0, t=50)							$51,899

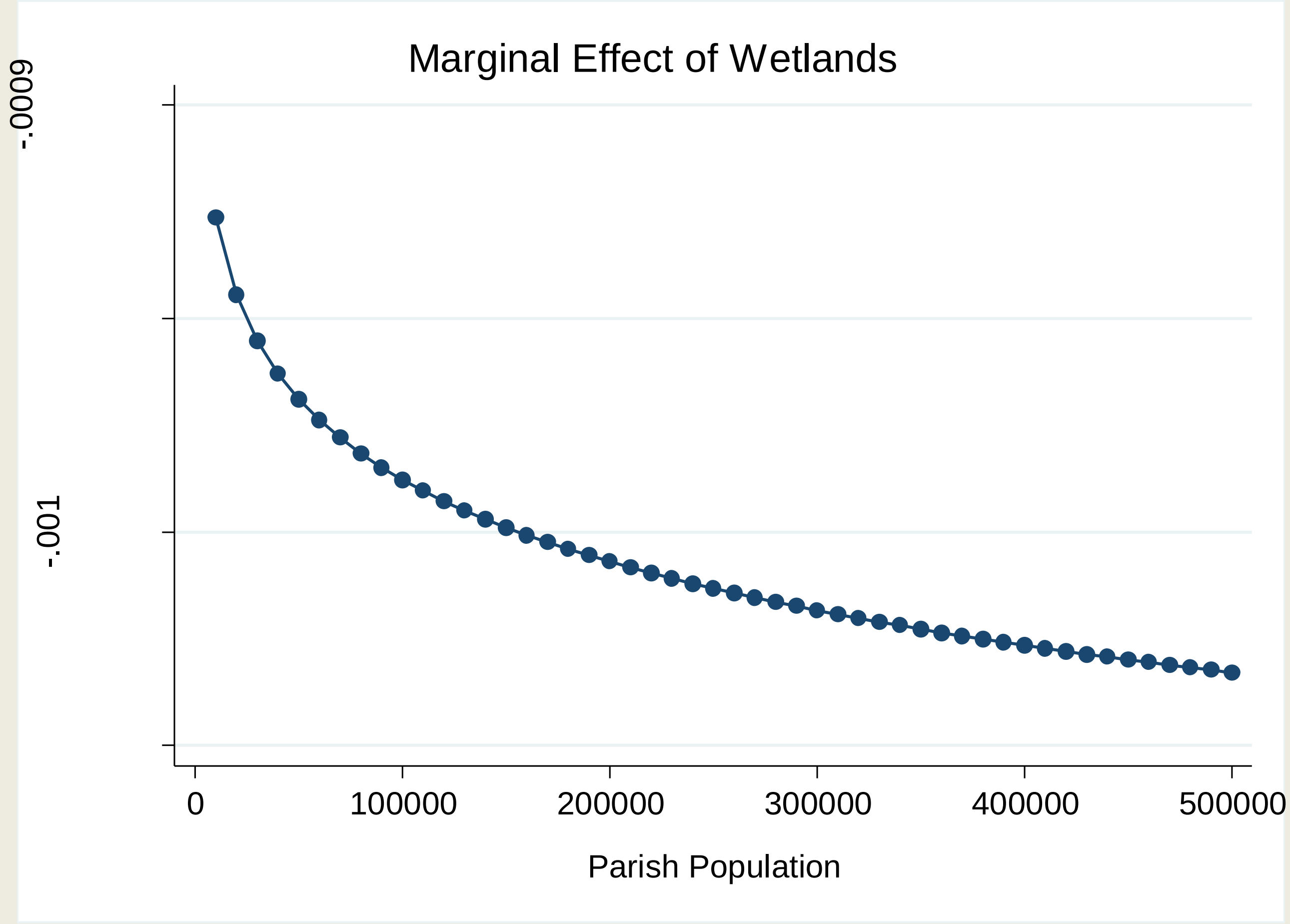
RESULTS

Parish	Annual Marginal Value
Cameron	$279
Iberia	$984
Jefferson	$21,168
Lafourche	$1,260
Orleans	$133,941
Plaquemines	$5,076
St. Bernard	$1,797
St. Charles	$230
St. John TB	$1,529
St. Mary	$2,297
St. Tammany	$4,804
Terrebonne	$980
Vermilion	$2,071

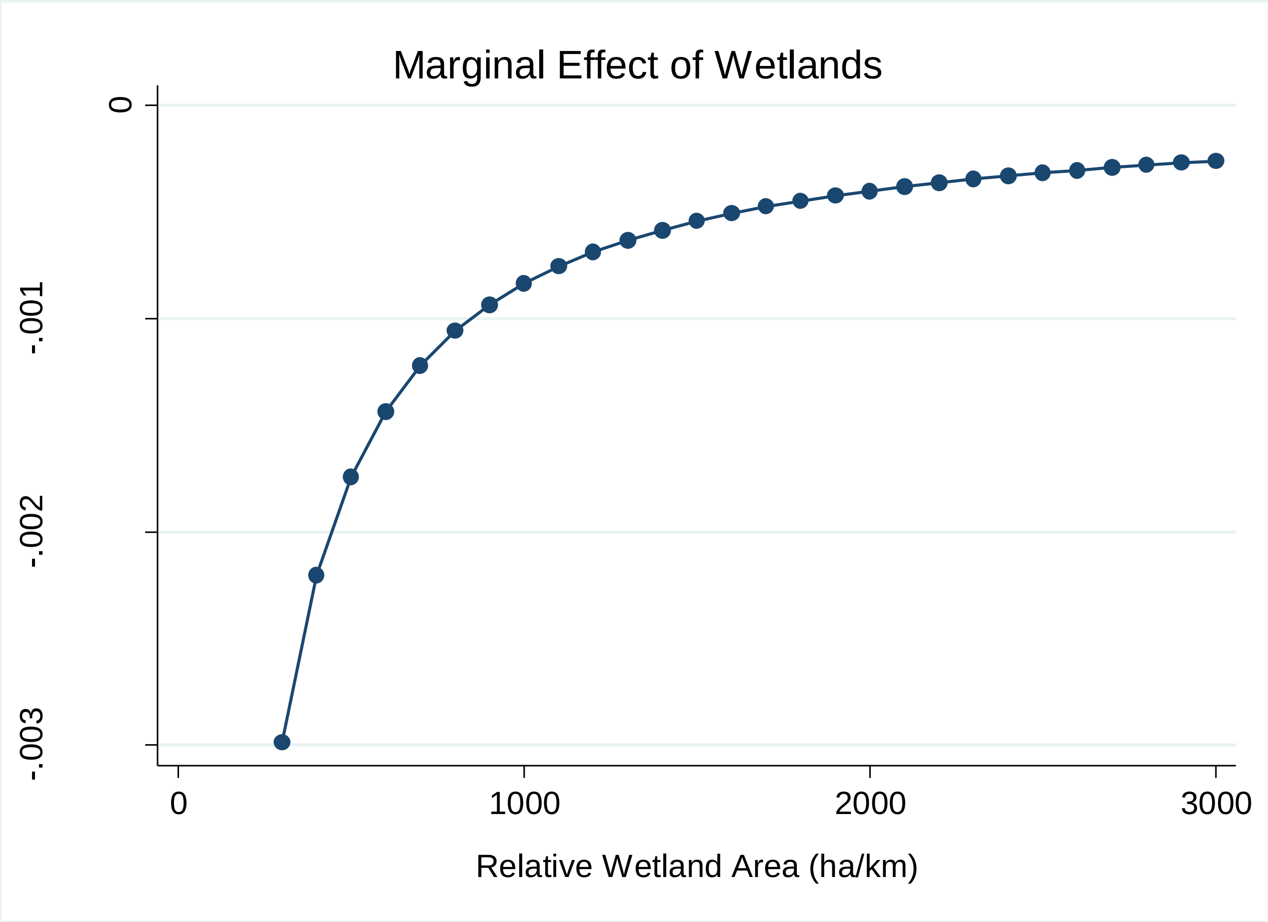
MARGINAL EFFECT OF WETLANDS



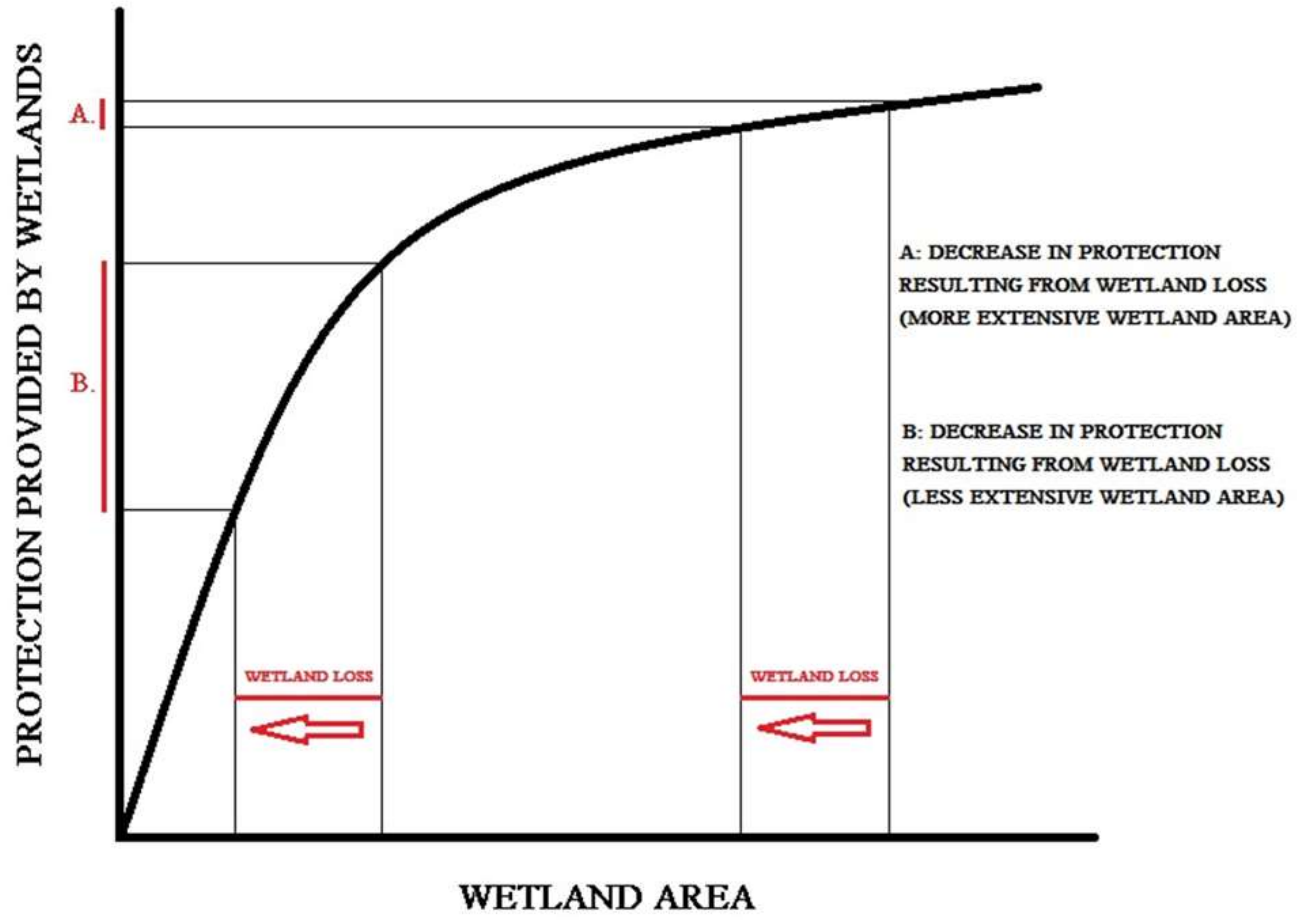
MARGINAL EFFECT OF WETLANDS



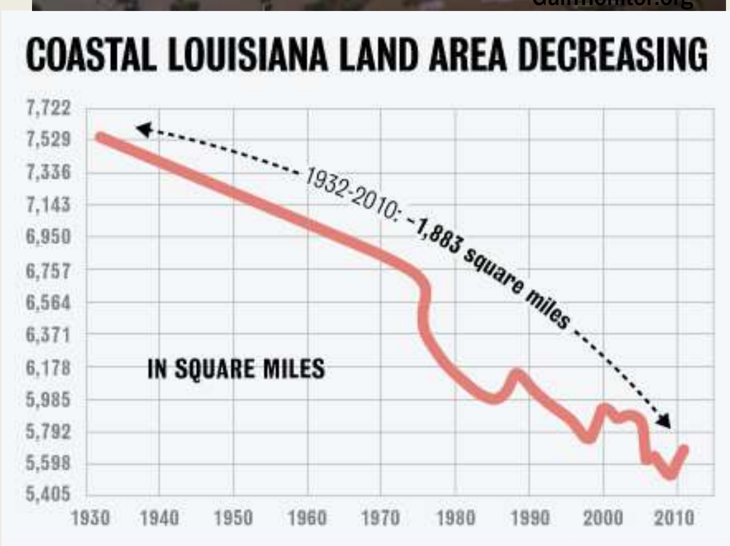
MARGINAL EFFECT OF WETLANDS



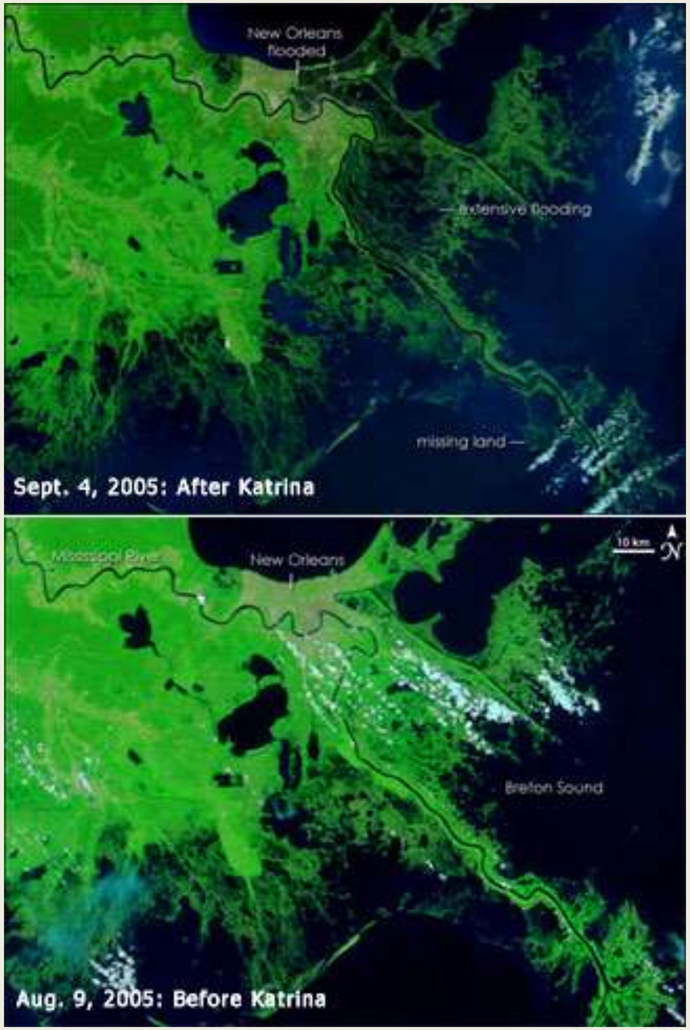
DIMINISHING MARGINAL PRODUCT

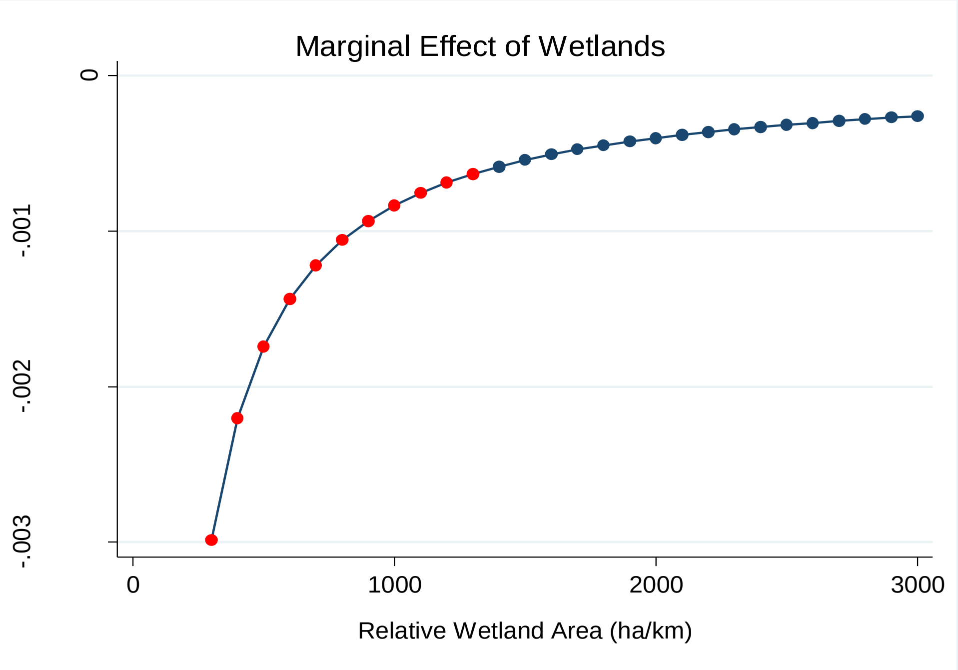


WETLAND LOSS



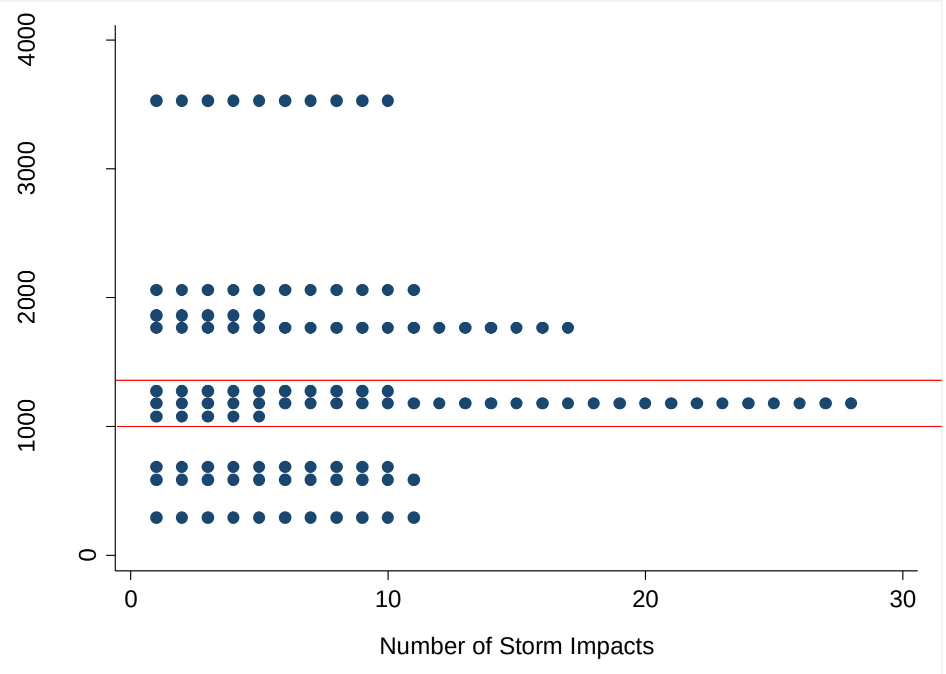
Source: USGS THE TIMES-PICAYUNE

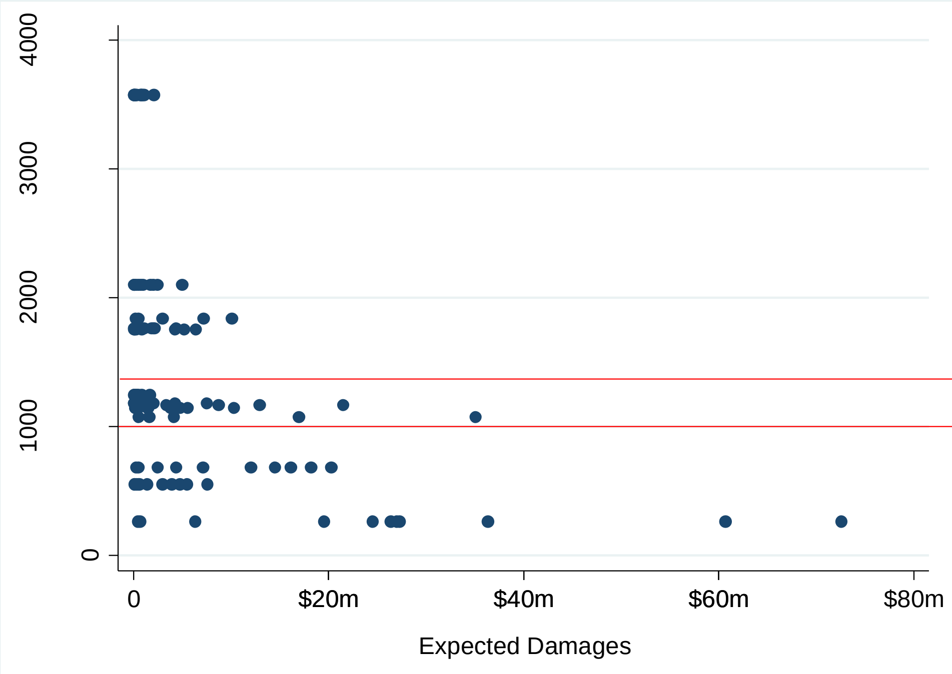




Tipping Point?

- Wetland loss today is far more costly than in the past.
- LA is reaching a threshold where the cost of wetlands loss is more severe
- Wetland loss today is increasing vulnerability more than ever before





DISCUSSION AND CONTEXT

- Wetlands loss has persisted for years
  - 4900 km^2 since 1930
- 27% of Louisiana's coastal population lives in a parish at the "tipping point"
- The football field cliché - At 1 football field per hour…
  - Economic vulnerability to hurricane damage increases
  - $12,000/day;
  - $1 Billion every 5 - 10 years
- Cost of wetland loss since 1930 could be matched in next 20-30 years

CONCLUSION

- EDF useful for valuation/vulnerability assessment in a variety of contexts
  - These results are similar to prior valuations and those from the models used by CPRA
- Louisiana is a special case in coastal vulnerability
  - Land loss drives vulnerability increases
- Wetland loss is the only factor addressed here that can be feasibly addressed at the local/regional level
  - Limiting population is politically infeasible an not entirely desirable
  - Even global emissions reductions would have little effect on storms

QUESTIONS, COMMENTS, SUGGESTIONS

This project was supported by Agriculture and Food Research Initiative Competitive Grant no. 2012-38420-30202 from the USDA National Institute of Food and Agriculture.

Parish	Expected annual damage	Relative Wetland Area	Population
Cameron	$621,267	1753	6,744
Iberia	$2,108,856	1839	73,878
Jefferson*	$14,793,680	681	434,767
Lafourche	$2,549,634	1760	97,141
Orleans*	$34,634,159	265	378,715
Plaquemines*	$3,172,508	552	23,550
St. Bernard	$2,371,352	**1142**	43,482
St. Charles	$1,008,168	3577	52,617
St. John the Baptist	$2,210,172	**1244**	43,761
St. Mary	$2,813,662	**1072**	53,543
St. Tammany	$6,156,833	**1181**	242,333
Terrebonne	$2,377,357	2099	112,749
Vermilion	$2,764,846	**1167**	59,253
Total	$77,582,494	18333	1,622,533

VULNERABILITY

- Annualization of the EDF
  - Estimates annual vulnerability
  - Based on data from 1851-2006

$$\log(y) = \alpha\left[\sum \rho_{ij}\left(x_{ij1}^{\beta 1}\right)\right]\left(x_{ij2}^{\beta 2}\right)\left(x_{ij3}^{\beta 3}\right),$$

Where ρ_{ij} is the probability of storm *j* in parish *i*

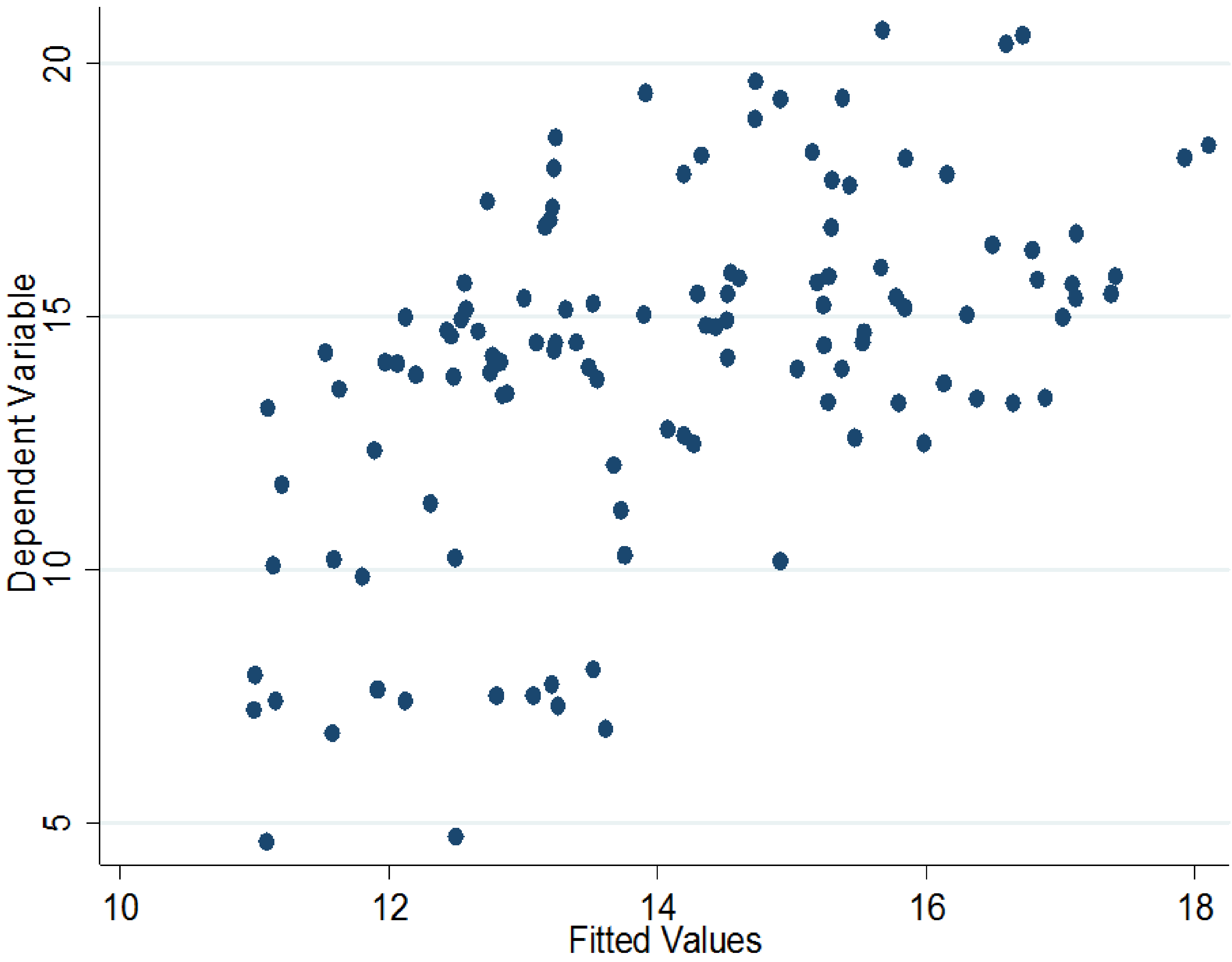
Probabilities and Return Intervals	Tropical Storm	Category 1 Impacts	Category 2 Impacts	Category 3 Impacts	Category 4 Impacts	Category 5 Impacts
Parish Impacts	148	89	46	37	13	10
% of Impacts	43.15%	25.95%	13.41%	10.79%	3.79%	2.92%
Annual Probability	31.93%	19.20%	9.92%	7.98%	2.80%	2.16%
Return Interval	3.13	5.21	10.08	12.53	35.65	46.35

RESULTS (WETLAND SCENARIO)

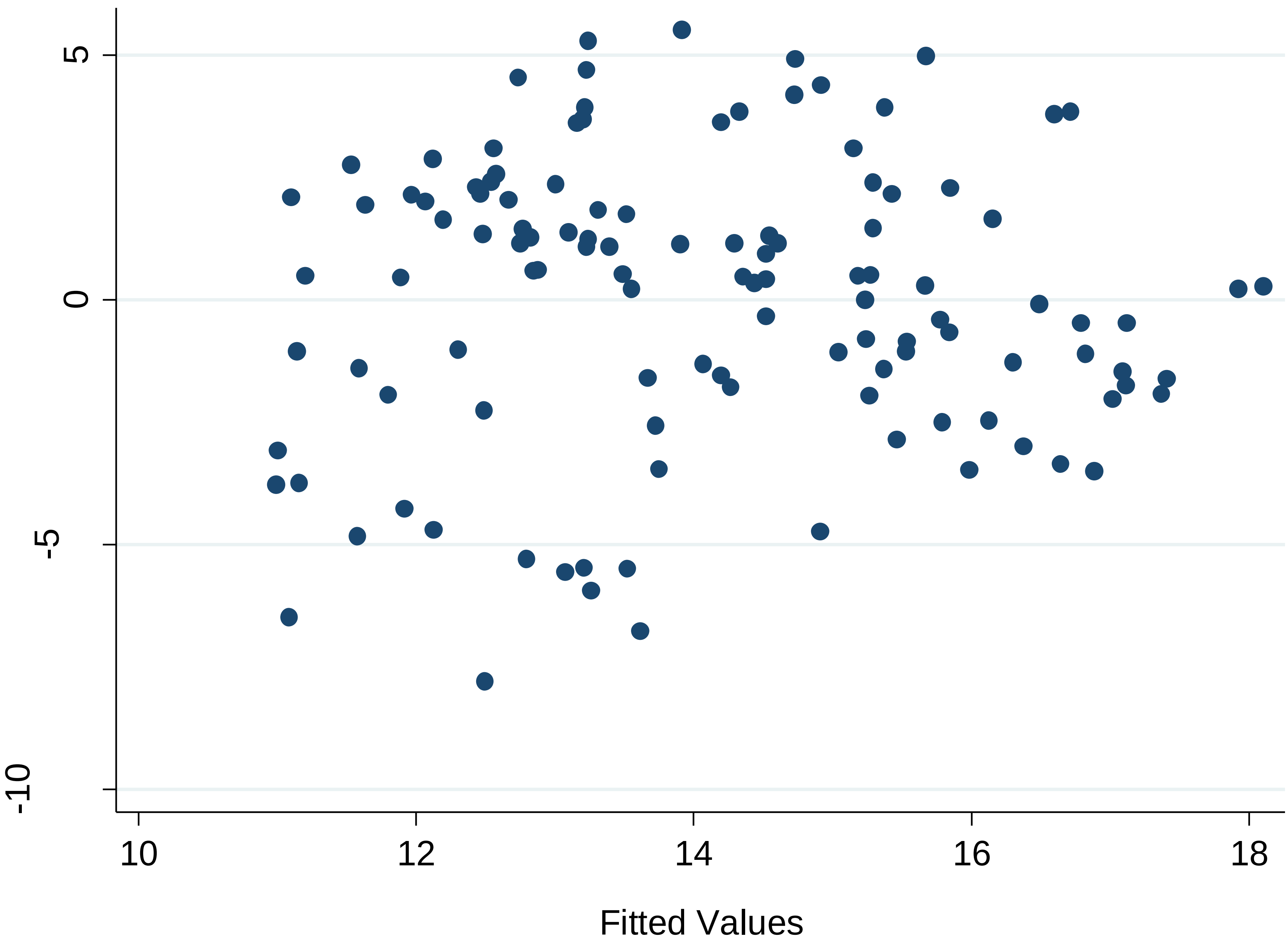
Parish	Expected Annual Damage	Wetland Scenario x 80%	Wetland Scenario x 120%	Wetland Scenario
Cameron	$621,267	$641,751	$652,602	$647,123
Iberia	$2,108,856	$2,094,496	$2,087,398	$2,090,941
Jefferson	$14,793,680	$15,513,201	$15,901,104	$15,704,656
Lafourche	$2,549,634	$2,591,130	$2,612,445	$2,601,739
Orleans	$34,634,159	$37,440,052	$39,023,827	$38,215,293
Plaquemines	$3,172,508	$3,425,973	$3,570,264	$3,496,487
St. Bernard	$2,371,352	$2,470,927	$2,524,297	$2,497,295
St. Charles	$1,008,168	$1,021,027	$1,027,600	$1,024,302
St. John the B	$2,210,172	$2,312,573	$2,367,861	$2,339,853
St. Mary	$2,813,662	$2,682,922	$2,622,449	$2,652,303
St. Tammany	$6,156,833	$6,383,124	$6,503,119	$6,442,522
Terrebonne	$2,377,357	$2,425,794	$2,450,847	$2,438,249
Vermilion	$2,764,846	$2,811,095	$2,834,868	$2,822,926
Total	$77,582,494	$81,814,066	$84,178,680	$82,973,689

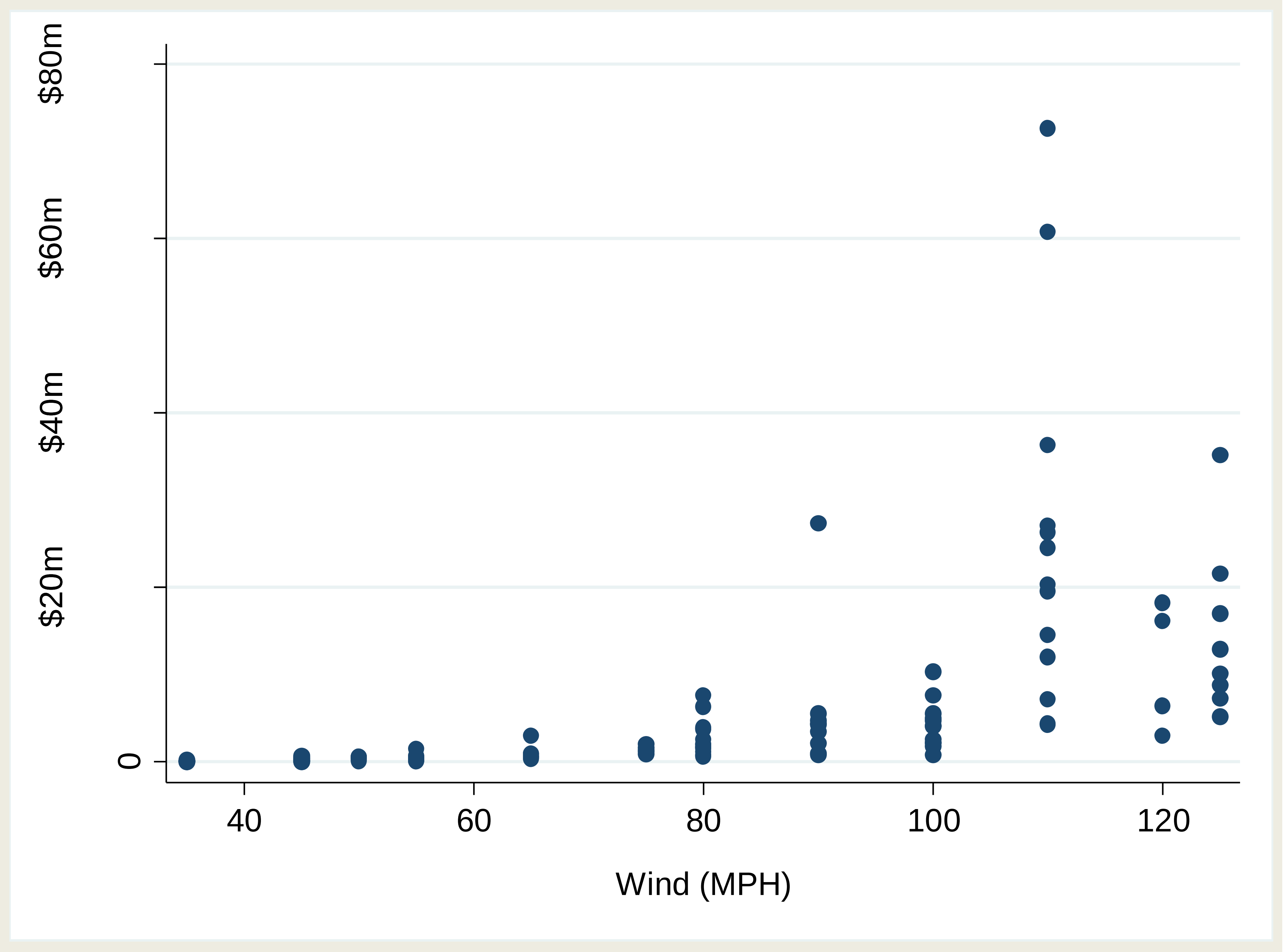
COMPOUND SCENARIO

Parish	Present	Future Scenarios			
	Annual Expected Damage	Wetland Scenario	Hurricane Scenario	Population Scenario	Compound Scenarios
Cameron	$621,267	$647,123	$684,548	$595,991	$669,605
Iberia	$2,108,856	$2,090,941	$2,344,400	$2,140,919	$2,432,449
Jefferson	$14,793,680	$15,704,656	$16,680,652	$15,189,528	$17,556,597
Lafourche	$2,549,634	$2,601,739	$2,838,326	$2,537,449	$2,887,269
Orleans	$34,634,159	$38,215,293	$39,294,136	$34,873,738	$40,602,783
Plaquemines	$3,172,508	$3,496,487	$3,537,344	$3,461,519	$3,949,460
St. Bernard	$2,371,352	$2,497,295	$2,638,466	$2,422,340	$2,755,170
St. Charles	$1,008,168	$1,024,302	$1,114,775	$1,075,607	$1,214,727
St. John TB	$2,210,172	$2,339,853	$2,457,871	$2,664,552	$3,033,191
St. Mary	$2,813,662	$2,652,303	$3,134,494	$2,484,822	$2,826,867
St. Tammany	$6,156,833	$6,442,522	$6,898,042	$8,242,631	$9,476,257
Terrebonne	$2,377,357	$2,438,249	$2,645,196	$2,519,290	$2,866,425
Vermilion	$2,764,846	$2,822,926	$3,079,720	$2,775,220	$3,160,296
Total	$77,582,494	$82,973,689	$87,347,971	$80,983,606	$93,431,098
Increase		$5,391,195	$9,765,477	$3,401,112	$20,023,580
50-year NPV of Increase		$3.7 Billion	$6.7 Billion	$2.3 Billion	$13.8 Billion
Scenario Source		CCAP, 2010	CPRA, 2012	Blanchard, 2010	

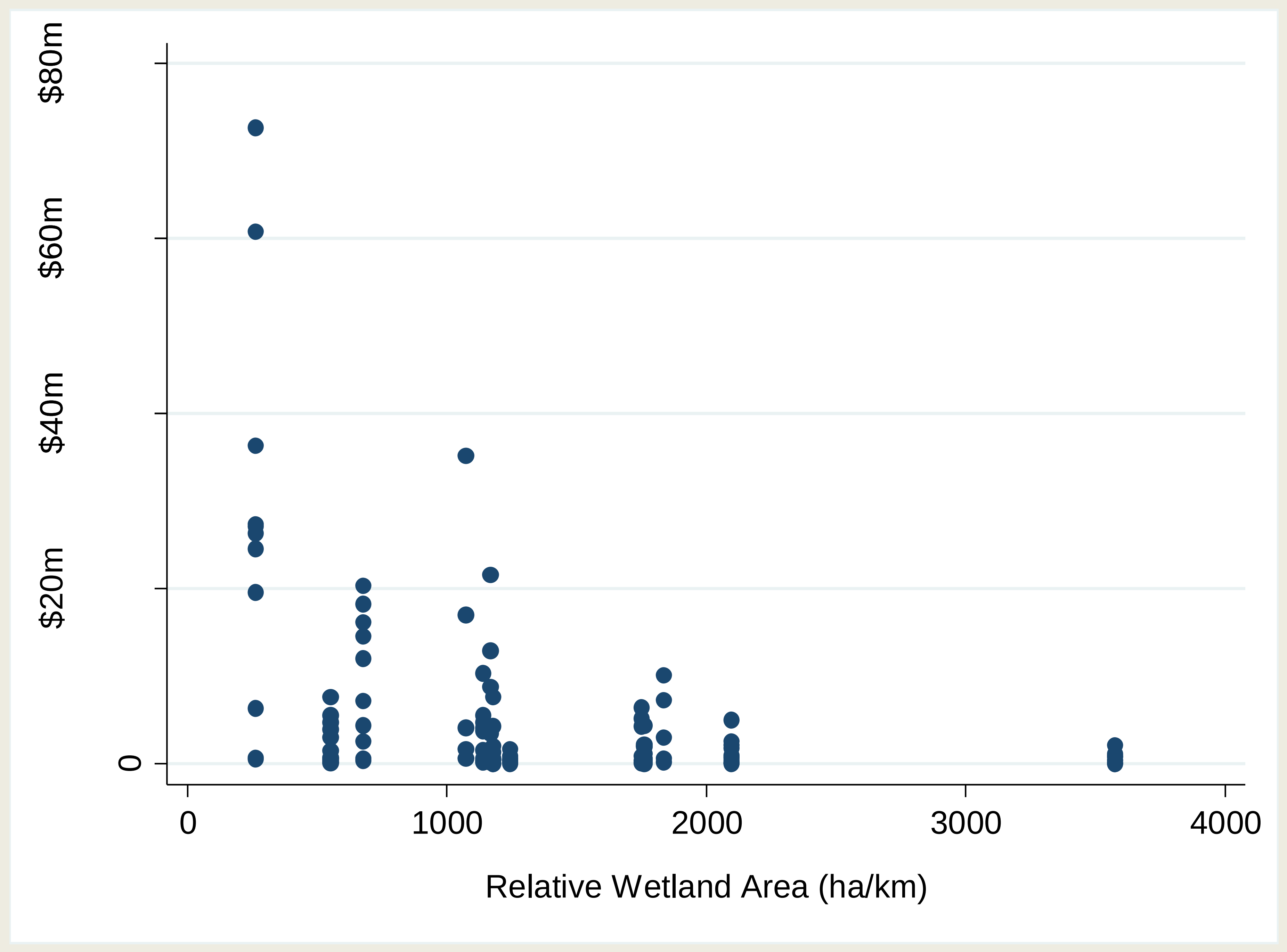


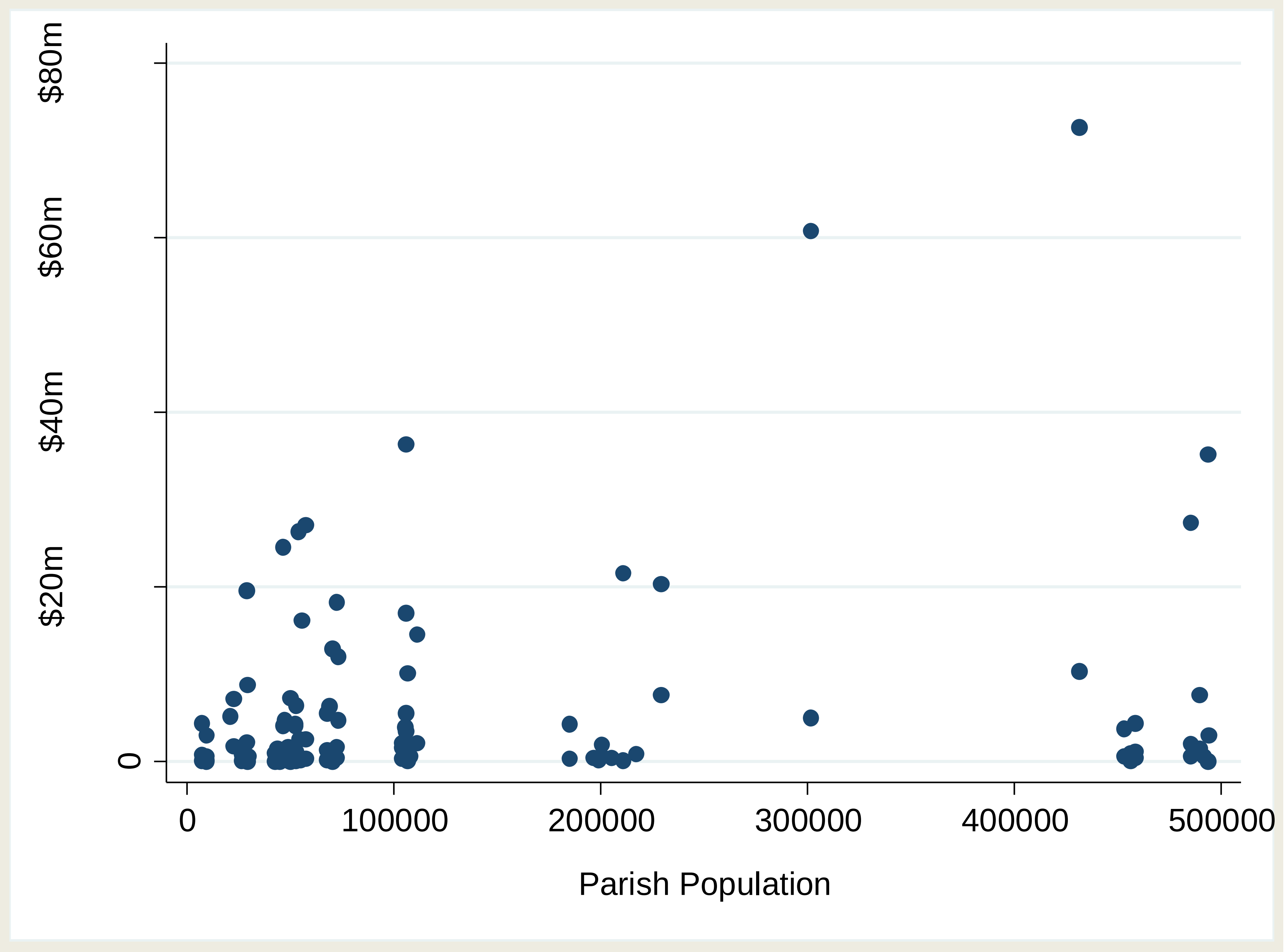
Dependent Variable
Fitted Values
20
15
10
5
10
12
14
16
18


5
0
-5
-10
10
12
14
16
18
Fitted Values



$80m
$60m
$40m
$20m
0
40
60
80
100
120
Wind (MPH)


$80m
$60m
$40m
$20m
0
0
1000
2000
3000
4000
Relative Wetland Area (ha/km)


$80m
$60m
$40m
$20m
0
0
100000
200000
300000
400000
500000
Parish Population

NCDC VS. HAZUS

- NCDC
  - Private property
  - Public infrastructure
  - Commercial facilities
  - In conjunction with…
    - EMA
    - Insurance
    - Utilities
    - USACE
- HAZUS
  - Commercial
  - Industrial
  - Residential
  - Essential facilities
  - Transportation
  - Utilities