IEc

INDUSTRIAL ECONOMICS, INCORPORATED

# Ecosystem Service Valuation and the InVEST Tool: Wetlands in Delaware

Maura Flight, Chip Paterson,
Industrial Economics, Inc.

natural capital PROJECT

# Agenda

- Trends in Ecosystem Service Valuation
- Introduction to the InVEST Tool
- InVEST Application for Wetlands in Delaware
- Ongoing and Future InVEST Work

# The Issue

- Ecosystems provide a wide array of goods and services of value to people.
  - Climate regulation
  - Water supply
  - Water purification
  - Flood protection
  - Food and fiber production
  - Recreational opportunities
  - Aesthetic and cultural values
  - Biodiversity
- These values are often not observable in markets and are therefore difficult to factor into decision-making quantitatively.
- Failure to incorporate ecosystem service values may lead to inefficient decision-making.

# Key Challenges

"The fundamental challenge of valuing ecosystem services lies in providing an explicit description and adequate assessment of the links between the structures and functions of natural systems, the benefits derived by humanity, and their subsequent values." (NRC 2005)

- Many inputs/outputs
- Spatial and temporal variation
- Complex biophysical relationships
- Translation to economically relevant ecosystem changes
- Consistency with economic principles/theory

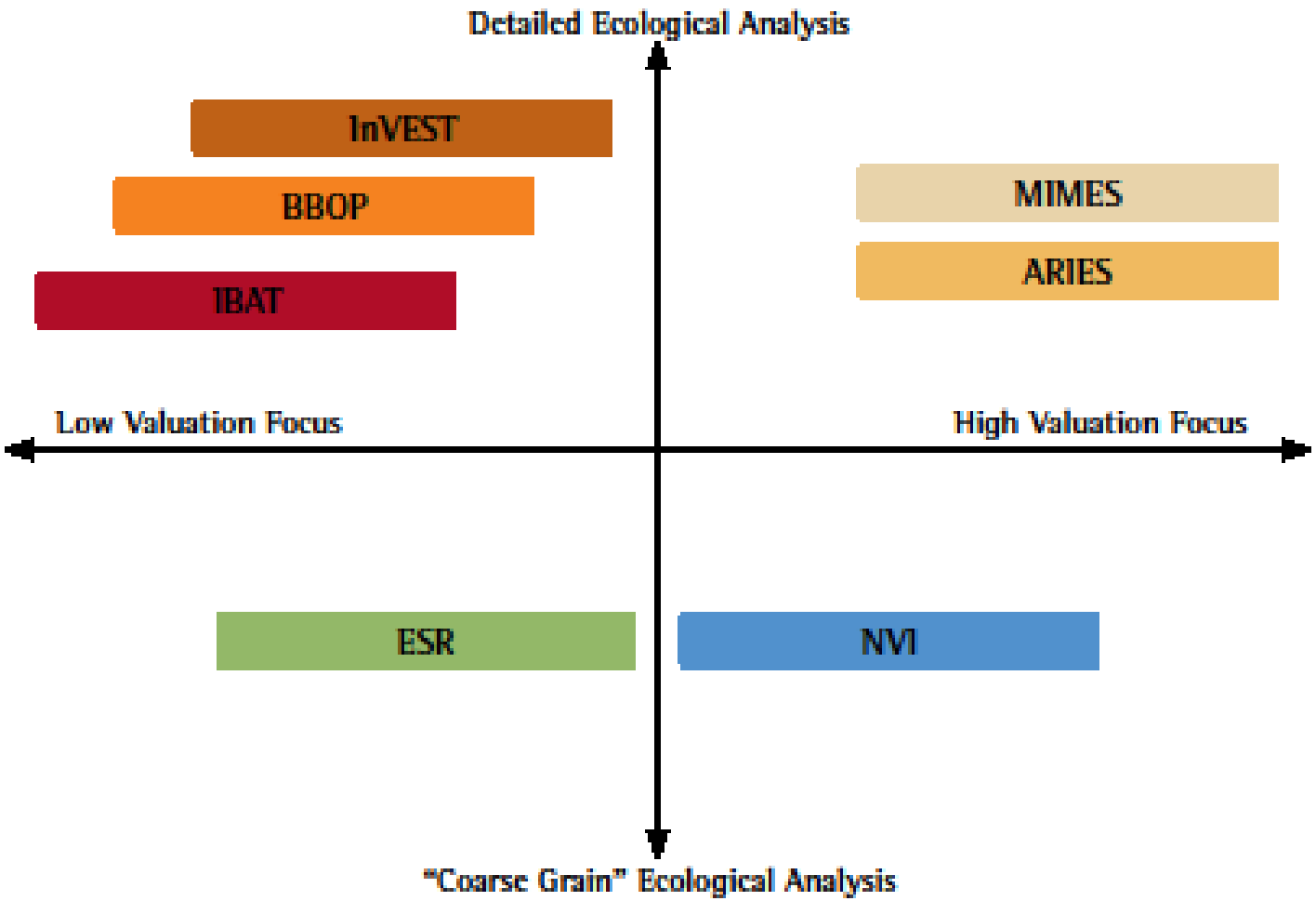
# Approaches to Valuing Ecosystem Services

- A 1997 Nature article (Costanza, et al) valued the earth's ecosystems at $33 trillion.
- Economic issues with approach:
  - Ignores budget constraints
  - Fails to account for net values
  - Fails to account for site-specific factors affecting value of services
- Ecological issues with approach:
  - Scaling approach assumes all acres of a particular ecosystem created equal
  - Fails to account for site specific factors affecting production of services

# The Arms Race of Ecosystem Service Models

| User Interface | Model Name |
|---|---|
| GIS model | InVEST |
| | MIMES |
| | AIRES |
| | IBAT |
| | ATEAM |
| Set of Structured Questions and/or Workbook | NVI |
| | ESV |
| | ESR |
| | BBOP |

# Comparison of Ecological v. Economic Emphasis




Source: Waage, et. al. 2008.

# Overview: InVEST Approach

- Integrated Valuation of Ecosystem Services and Tradeoffs
  - Series of open-source GIS models
  - Multiple services
  - Spatially explicit
  - Site-specific biological/physical data
  - Driven by policy-relevant scenarios
  - Biophysical and economic endpoints

# InVEST Application for Delaware Study

- Wetlands in Delaware have been subject to degradation and destruction from development activities and agricultural activities, among other threats.
- DNREC is proposing a wetland management strategy to the State Legislature in 2011.
- Our clients agreed with our approach of emphasizing ecological and economic integrity over big numbers. This was largely an experiment for them and they were very involved throughout the process.
- We integrated a broad array of site-specific ecological data into the Natural Capital Project's ecosystem service model framework (InVEST) to highlight the less transparent values of wetlands and to inform future wetland management.

# Our Approach to Modeling Wetland Service Provision

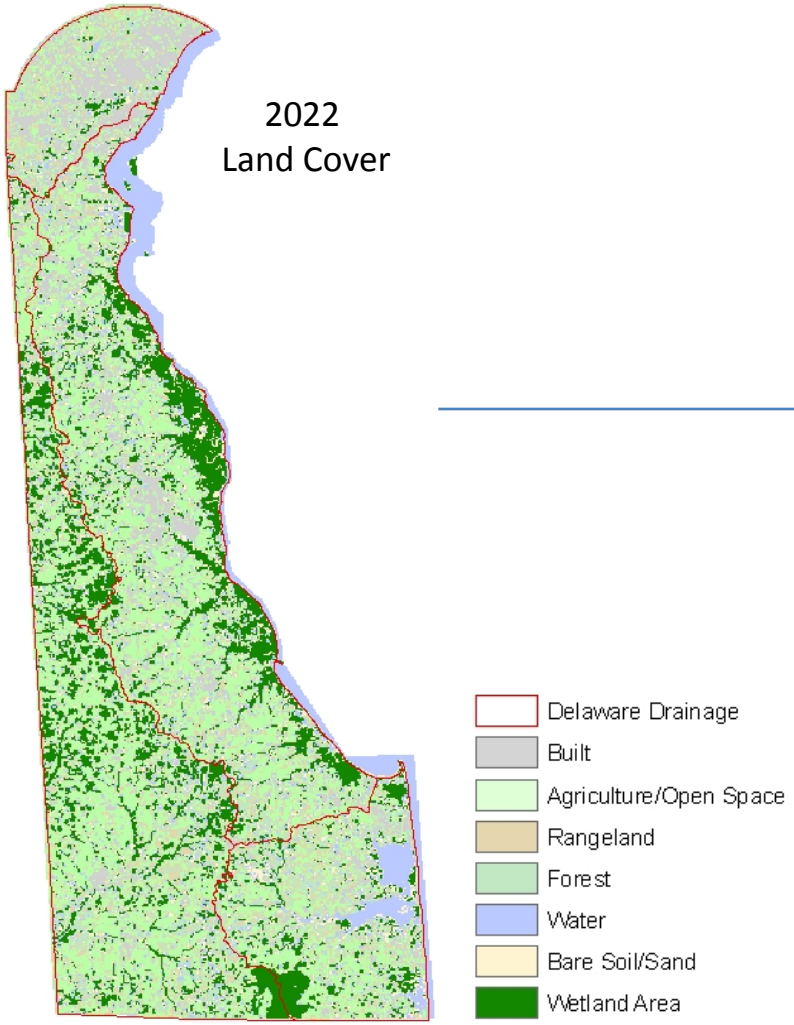
- Motivated by policy-relevant question.
- Landscape level – study covers the entire State.
- Focus on integrating ecological data at refined spatial scale – 30 X 30 meter scale.
- Consider interaction with all surrounding land uses.
- Recognition of net change in services associated with conversion of wetlands to developed and agricultural land uses.

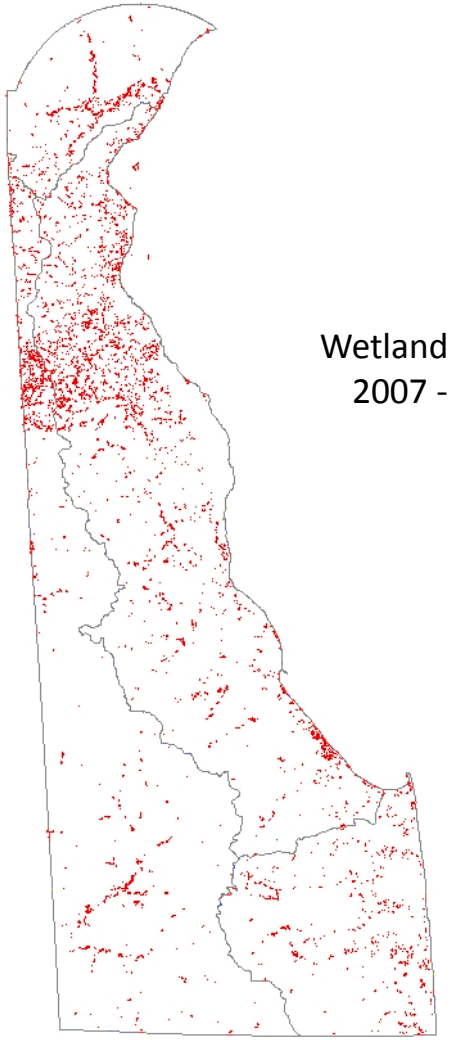
| SERVICE | BIOPHYSICAL CHANGE | ECONOMIC VALUE |
|---|---|---|
| **Carbon Storage:** | Tons of C Stored | Social Cost of C |
| **Water Purification:** | N and P Loading<br>Sediment Loading | Avoided Treatment Costs |
| **Biodiversity:** | Level of Habitat Threat | |
| **Flood Control:** | Storm Peak<br>Coastal Storm Surge | Avoided Damages (Land and Property Values) |

# Definition of Baseline and Alternative

- Baseline is current statewide land-use/land cover (LULC)
- Analysis is organized at drainage level (four principal)
- Identify past trends in wetland loss/conversion: nature, location and rate, 1992 to 2007
- Land Change Modeler- Idrisi Taiga Software
- Hold all other land use changes constant
- Project trends through 2022- this represents “no additional protection” alternative

# Wetland Losses under 2022 Alternative Scenario



# Carbon Storage Model

- Purpose: Quantifies the carbon storage capacity of a given landscape.

- Method: Quantify carbon pools by land use class- per hectare for above- and belowground biomass and soils.

- Primary Data Requirements:
  - Carbon storage capacity by land use
  - The social cost of carbon per ton (Tol, 2009 = $118/ton)

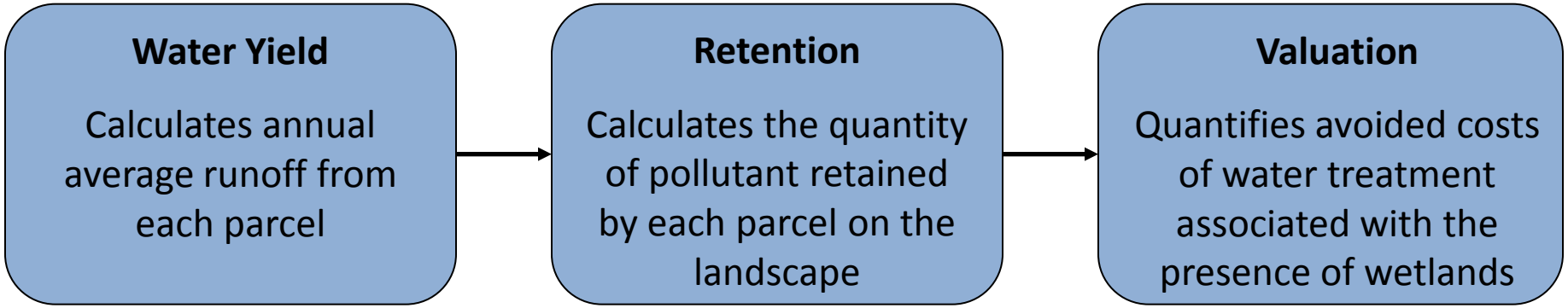
# Carbon Model: Results by Drainage

2007 to 2022 Future Wetland Loss Scenario

| Drainages | Total Carbon Lost (metric ton) | Total Value Lost (PV, 3%) |
|---|---|---|
| Piedmont | 23,275 | $2,390,000 |
| Delaware Bay | 99,314 | $10,200,000 |
| Chesapeake Bay | 47,669 | $4,890,000 |
| Inland Bays | 24,159 | $2,480,000 |
| **Statewide** | **194,417** | **$19,900,000*** |

# Water Purification Models

- Purpose: Calculate the amount of nutrients (nitrogen and phosphorus) and/or sediment retained and exported to waterways across a given landscape to determine a change in water quality.
- Method: Three linked models



# Water Yield Model Data Requirements

| Data Element | Definition/Purpose in Model | Source |
|---|---|---|
| **MAPS** | | |
| Precipitation ($P_x$) | Estimate of average annual rainfall (mm) | Delaware Environmental Observing System (DEOS) data* |
| Reference Evapotranspiration ($ETO_x$) | Potential loss of water from soil due to evaporation from soil and transpiration of a reference vegetation cover (alfalfa) (mm) | DEOS data * |
| Soil Depth ($SD_x$) | Average soil depth per cell (mm) | USDA, NRCS, Soil Survey Geographic Database (SSURGO)* |
| Plant Available Water Content ($PAWC_x$) | Fraction of water than can be stored in soil profile for plants' use | SSURGO* |
| **TABLE DATA** | | |
| Root Depth | Maximum root depth for vegetated land use classes (mm) | Literature Review |
| Evapotranspiration coefficient | Land use specific number to translate reference evapotranspiration to actual | Allen, R. G., et al. 1998. |

* Site-specific data

# Nutrient Retention Model Data Requirements

| Data Element | Definition/Purpose in Model | Source |
|---|---|---|
| **MAPS** | | |
| DEM | Digital Elevation Model | USGS for Delaware* |
| Water Yield | From previous step | InVEST* |
| **TABLE DATA** | | |
| Nutrient Loading | Average loading of nutrient in kg/ha/year | Site specific loading rates by land use type from DNREC * |
| Vegetation Filtering Values | Capacity of a land cover type to retain the pollutant as a function of the vegetation type | Literature Review |

* Site-specific data

# Soil Retention Data

| Data Element | Definition/Purpose in Model | Source |
|---|---|---|
| **MAPS** | | |
| Rainfall Erosivity | Index variable of erosion potential as a function of rainfall intensity and duration | USGS, SSURGO* |
| Soil Erodibility | Susceptibility of soil particles to detachment and transport | USGS, SSURGO* |
| **TABLE DATA** | | |
| C Factor | Crop/vegetation management factor | Literature Review |
| Sediment Retention Efficiencies | Capacity of a land cover type to retain sediment as a function of the vegetation type | Literature Review |

* Site-specific data

# Water Purification: Results by Drainage

| Drainages | % Change in N | % Change in P | % Change in Sediment | Total Value Lost 2007-2022 (PV, 3%) |
|---|---|---|---|---|
| Piedmont | 1.5% | 1.2% | 0.9% | $1,140,000 |
| Delaware Bay | 1.9% | 1.4% | 2.5% | $4,310,000 |
| Chesapeake Bay | 0.8% | 0.6% | 0.7% | $2,830,000 |
| Inland Bays | 0.8% | 0.4% | 0.9% | $1,380,000 |
| **Statewide** | **1.2%** | **0.9%** | **1.3%** | **$9,670,000** |

# Flood Protection Model

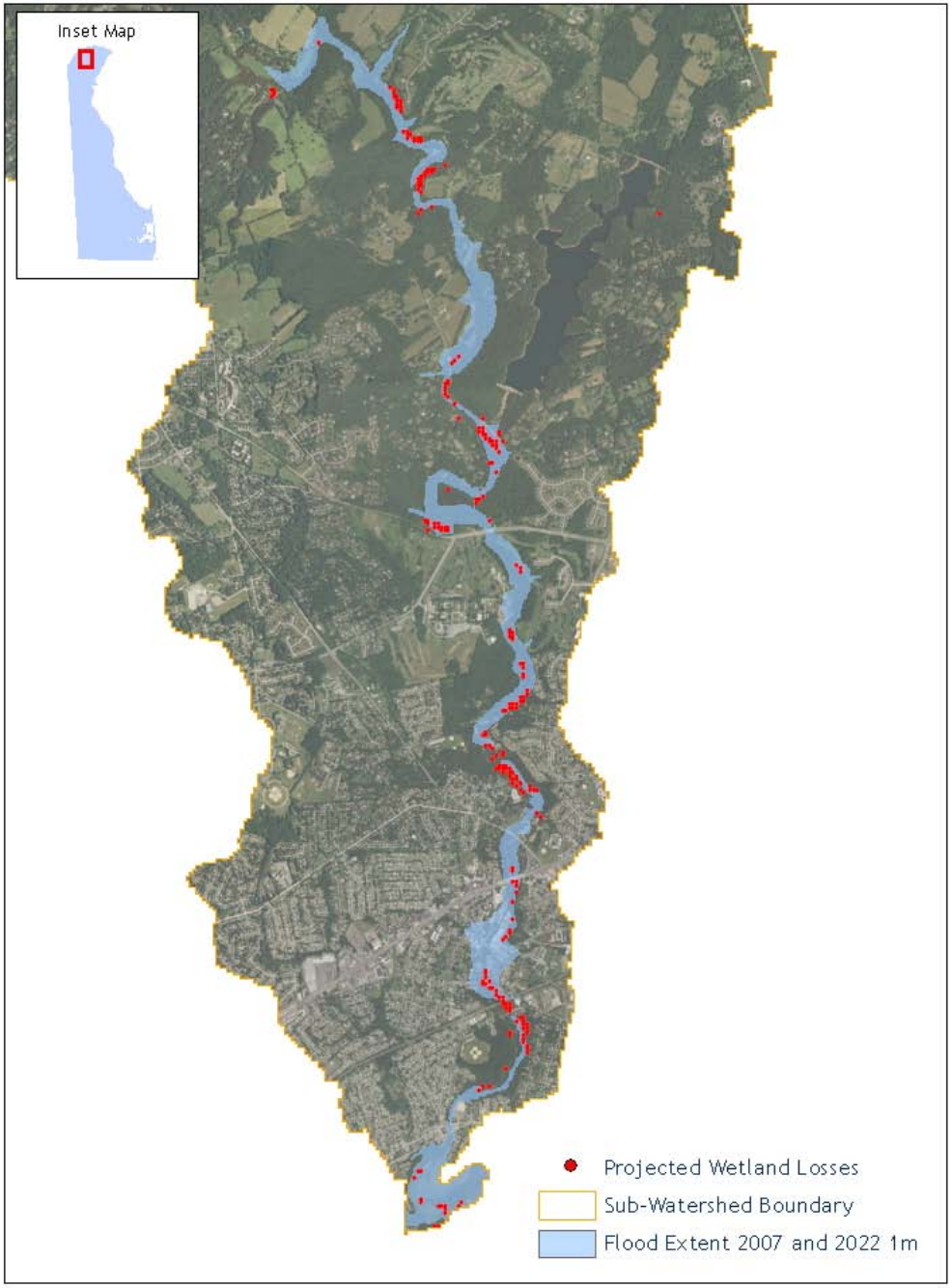
- Purpose: The inland flood control model translates the volume of water added to a landscape for a particular storm event into flood areas and flood heights.

- Primary Data Requirements:
  - Storm depth associated with a given rainfall event
  - Wetland depth
  - Land cover specific velocity (roughness coefficients) and curve numbers to estimate runoff
  - Estimates of damages associated with varying flood heights (e.g., on houses, cropland)

# Case Study Approach

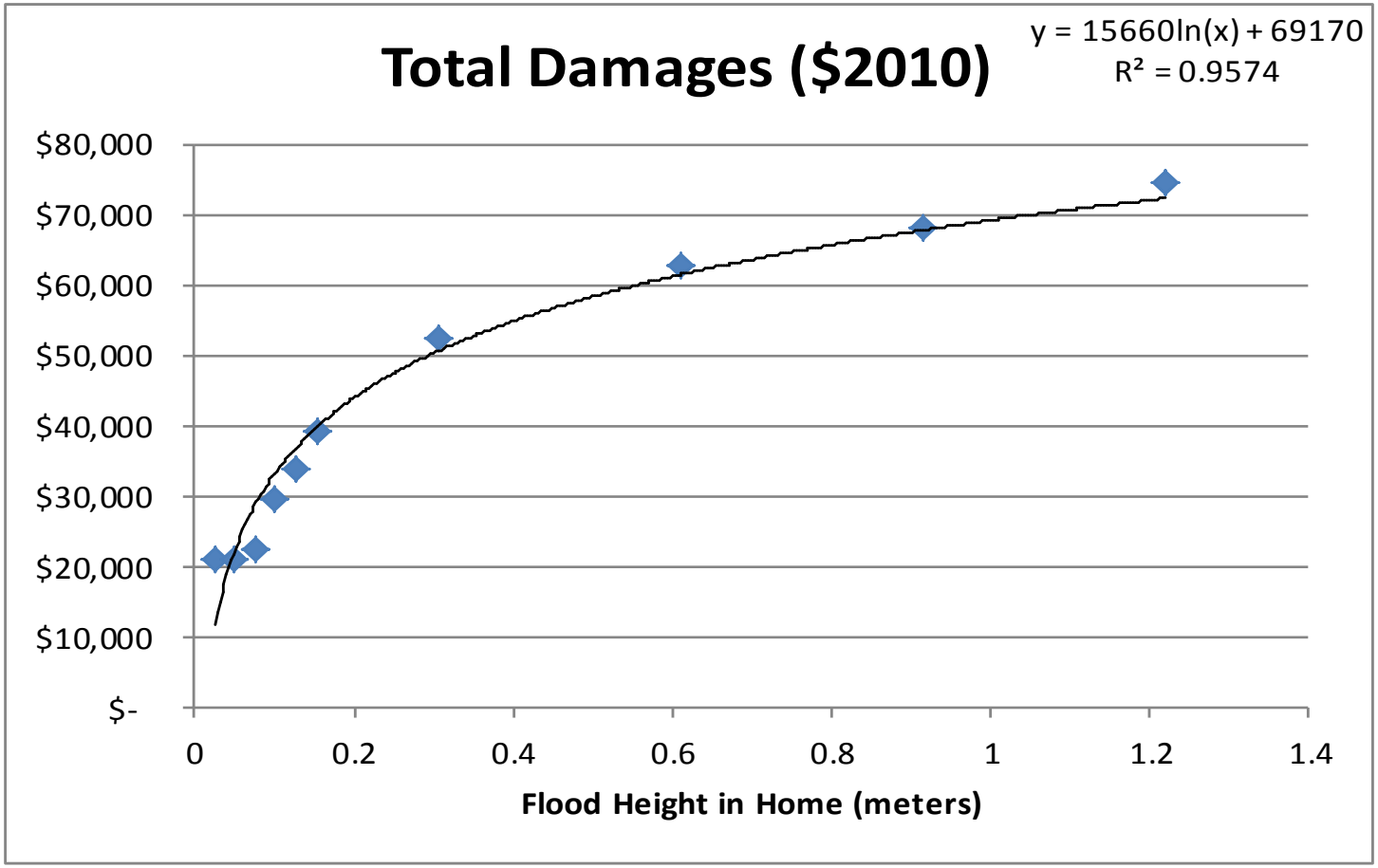
- Mapped change in flood area and flood heights at four case study sites across the state.
- At one site, incremental flooding overlapped residential development (Red Clay Creek Watershed).
- Valuation exercise was therefore focused within the one watershed.

Red Clay Creek Watershed
2007 and 2022 Flood Extent Scenario (1 m wetland depth)



# Damage as a Function of Flood Height

- FEMA NFIP data on total damages associated with various flood levels in 2,000 home.



# Inland Flooding: Results

- Expected value of incremental flooding damages due to wetland loss associated with a 25 year storm even at Red Clay Creek from 2007 through 2022:

| | LOW | HIGH |
|---|---|---|
| **Increased Impact of 25 year Event in 2022 (undiscounted)** | $2,860 | $84,470 |
| **Present Value 2007-2022 (3%)** | $720 | $21,200 |

- Range based on assumptions regarding wetland depth, number of flooded homes, and foundation height of homes.

- Present value results take into account probability of storm occurrence each year from 2007-2022.

# Coastal Storm Protection Model

- Purpose: Applies information on the rate at which wetlands attenuate storm surge to estimate changes in coastal flood associated with a storm event.

- Primary Data Requirements:
  - Baseline coastal flood area and flood heights
  - Wetland storm surge attenuation rate
  - Estimates of damages to houses associated with varying flood heights

# Coastal Storm Protection Model

- We began with DNREC's map of coastal floods associated with varying SLR scenarios.
- Applied MHHW plus 1.5 meter water height scenario as a proxy for coastal flooding following a storm event (comparable in inland inundation levels with annual coastal storm events recorded by DEOS).
- Assume a marginal surge attenuation rate of 1 m per 13 km
  - Source: Four observations of observed attenuation rates associated due to presence along the Louisiana coast.

# Coastal Surge Protection: Results by Drainage

| Drainages | Total Value Lost 2007-2022 (PV, 3%) |
|---|---|
| Delaware Bay | $7,340 - $116,000 |
| Inland Bays | $40,300 - $185,000 |
| **Statewide** | **$47,600 - $301,000** |

- Same valuation method as inland flood example. Range based on assumptions regarding number of flooded homes, and foundation height of homes.

- Results take into account probability of surge occurrence each year.

# Biodiversity (Wildlife Habitat) Model

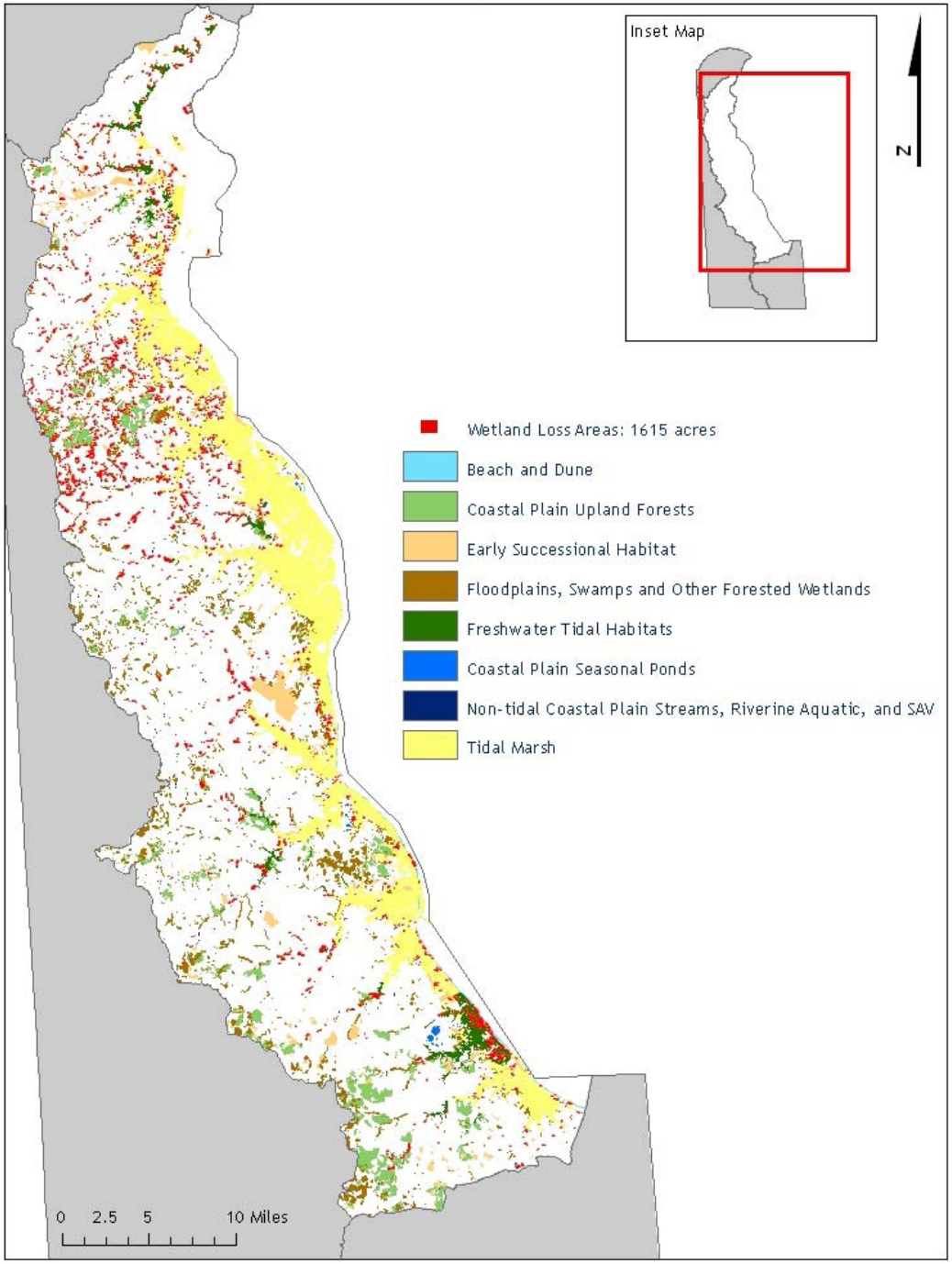
- Purpose: Evaluate how our forecast wetland losses affect the quantity and quality of habitats in Delaware.

- Primary Data Requirements:
  - Spatial distribution of ecologically important habitats across the state (10 key habitat types)
  - Spatial distribution of "threats" particular to each habitat type
  - Maximum distance from habitat at which a threat may degrade habitat
  - Relative sensitivity of particular habitats to the various threats

# Biodiversity (Wildlife Habitat) Model

- Map land use threats (e.g., residential and commercial development, fire regimes, mining, transportation and utility projects, agricultural operations) against key habitats across the state.
- Estimate baseline state of degradation as a function of habitat proximity and sensitivity to the various land use threats.
- Estimate incremental level of habitat degradation due to conversion of wetland to new land use threats.
- Relate habitat types to state Species of Greatest Conservation Need.

# Delaware Bay Drainage - Key Wildlife Habitats



# Biodiversity (Wildlife Habitat) Results

- Variable by habitat type and drainage.
- Habitat loss ranged up to 5.6% (swamps and forested wetlands in Piedmont drainage).
- Habitat degradation increased by up to 8.4% (freshwater tidal habitats in Piedmont drainage).
- Absent site-specific information on a change in the populations willingness to pay for biodiversity/habitat protection due to the change in degradation level, InVEST does not include a valuation component for biodiversity.

# Obstacles and Lessons

- While the ultimate goal is to provide an open source model, some the models (e.g., the marine models) are in early stages of development (Tier 1 – no valuation component).
- Iterative Process - Incorporating feedback on initial results from local experts.
- Our results are more conservative than a schedule-based ecosystem value approach but are more intuitive and defensible.
- InVEST is generating a lot of attention due to the focus on consistency in adhering to both ecological and economic principles.

# Ongoing and Future Work with InVEST

- We are partnering with NatCap on a three year project for DoD to evaluate how InVEST can help inform natural resource management decisions at multiple installations across the country. This will involve beta testing some of the marine models.

- Massachusetts Department of Ecological Restoration interested in evaluating flood protection benefits of dam removal and wetland restoration projects. This would likely involve a hybrid approach (using some InVEST models and doing some work outside of the model.

- Preparing manuscript for submission to Ecological Economics.