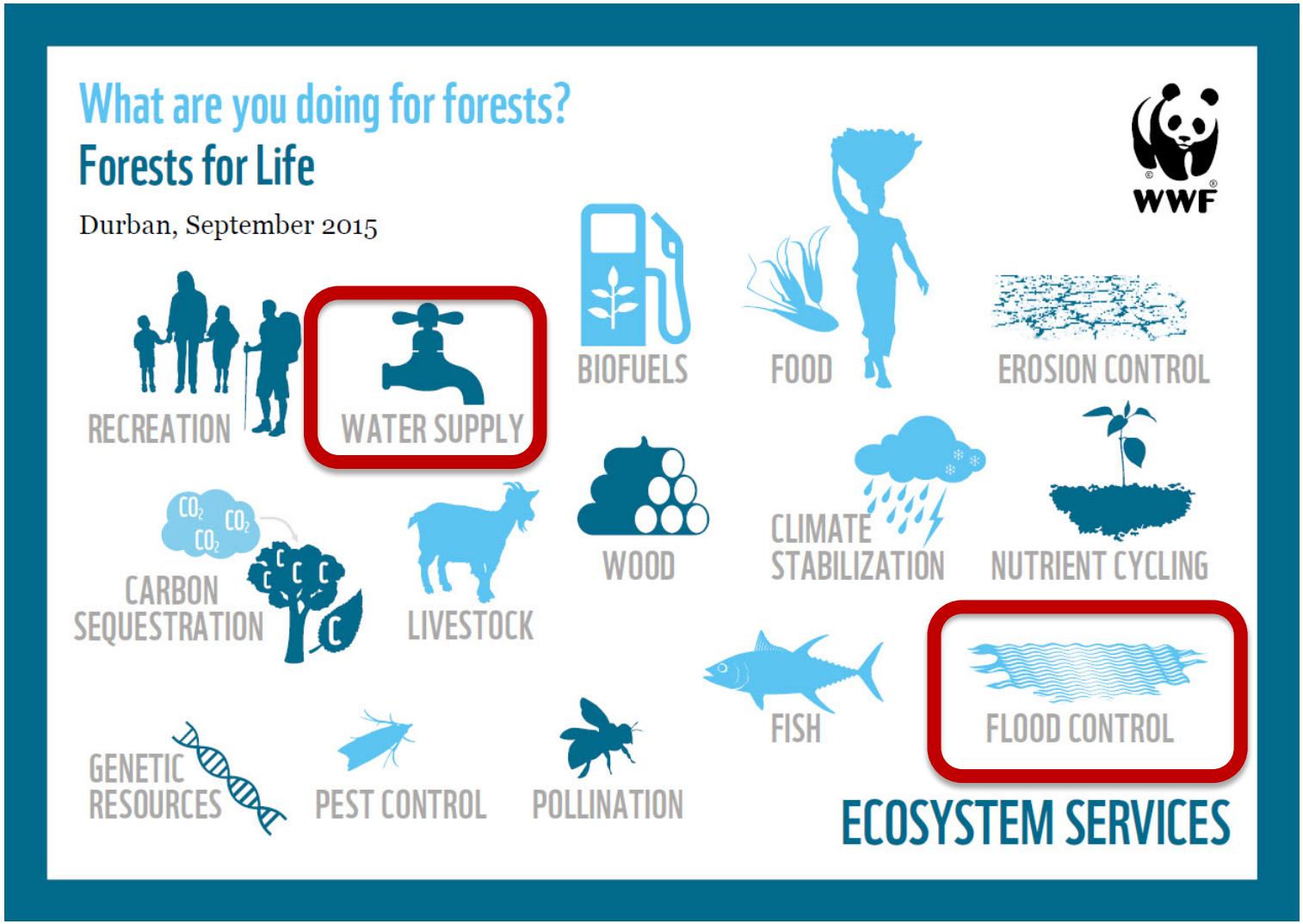
Forests and Flood Reduction

Daniel L. McLaughlin and Brian van Eerden

Forest Ecosystem Services

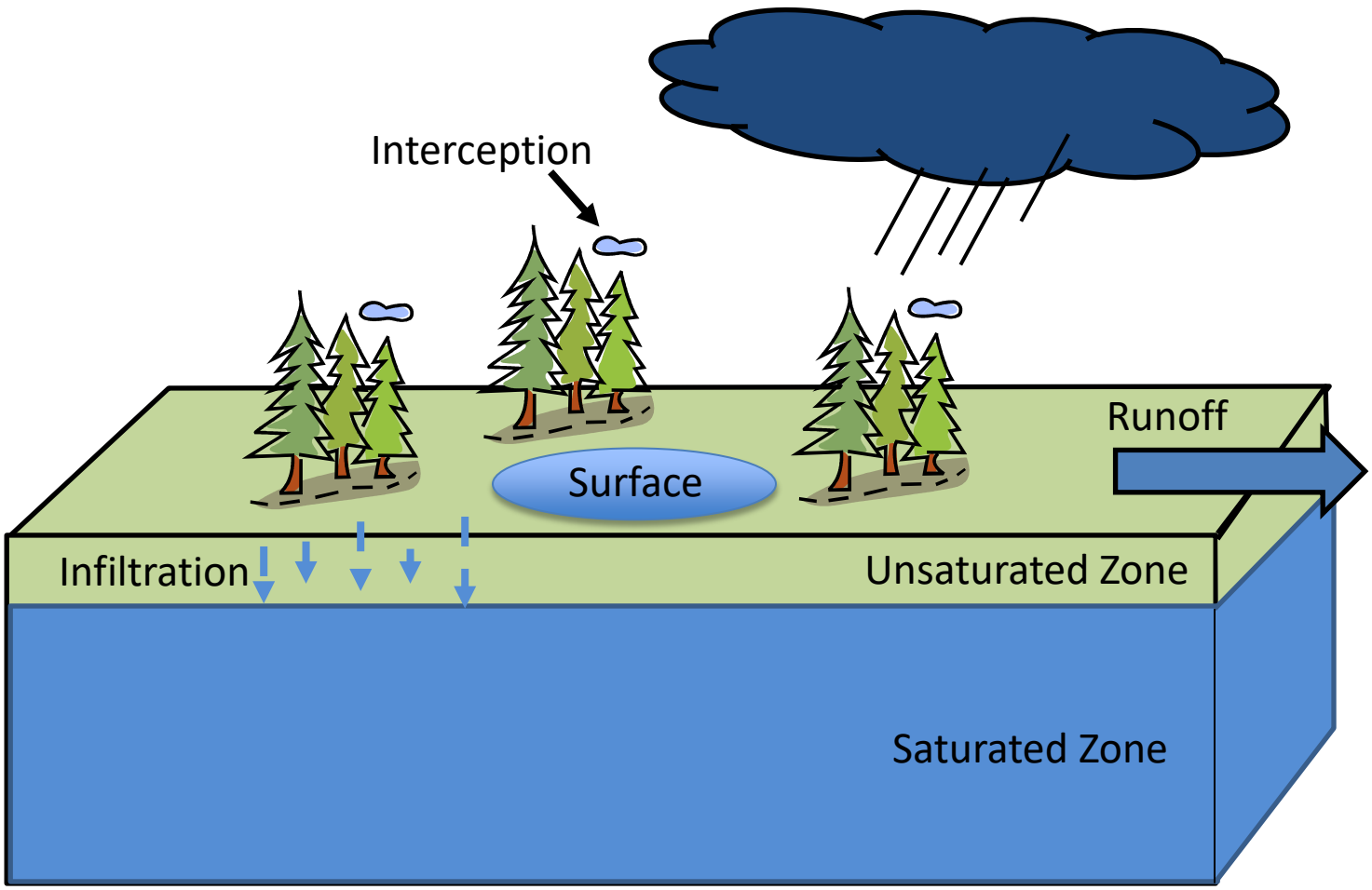


Forests and Water

They Capture, Store, and Use Water

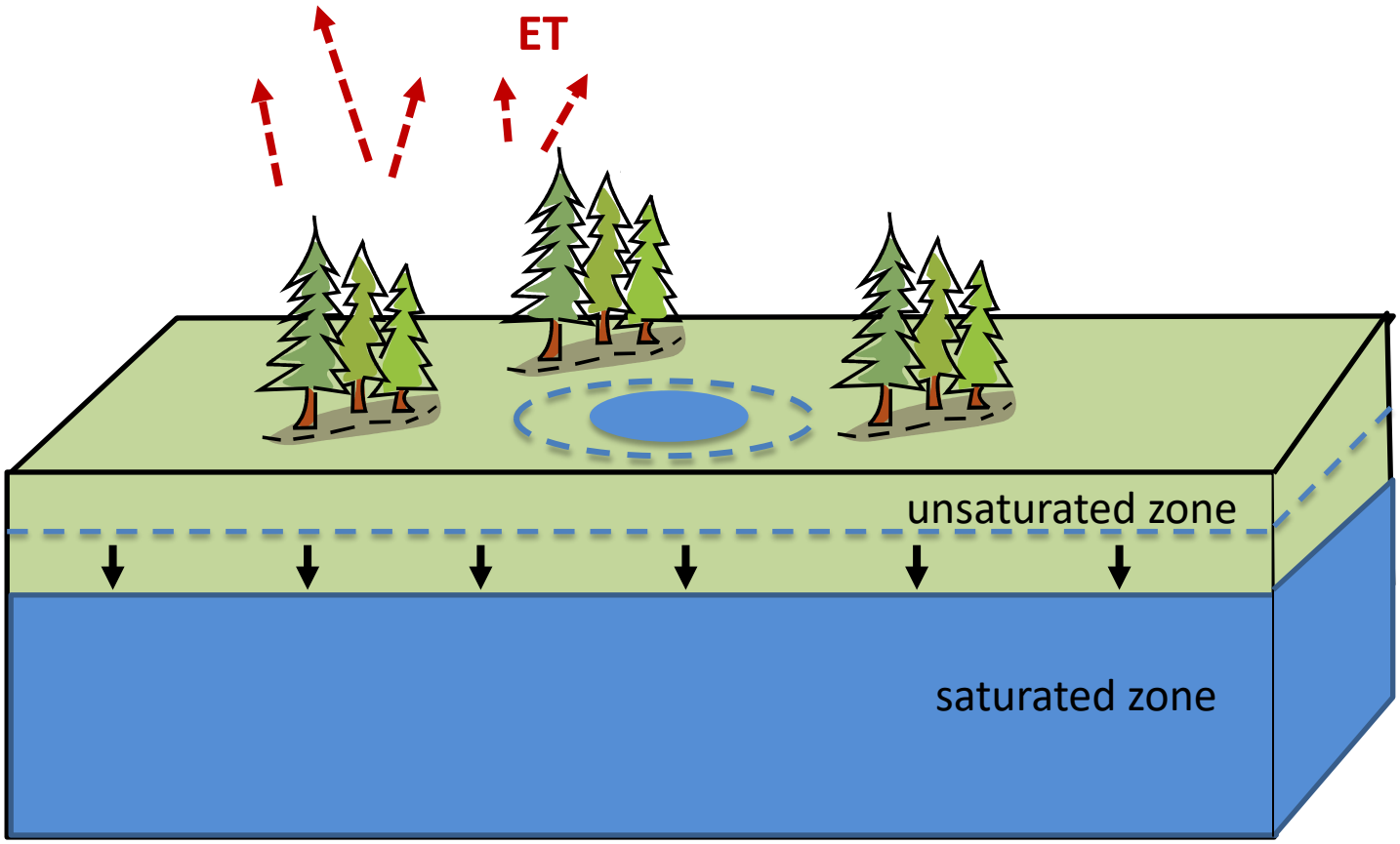
Forests and Water

STORAGES *= Interception + Surface + Soil Infiltration*

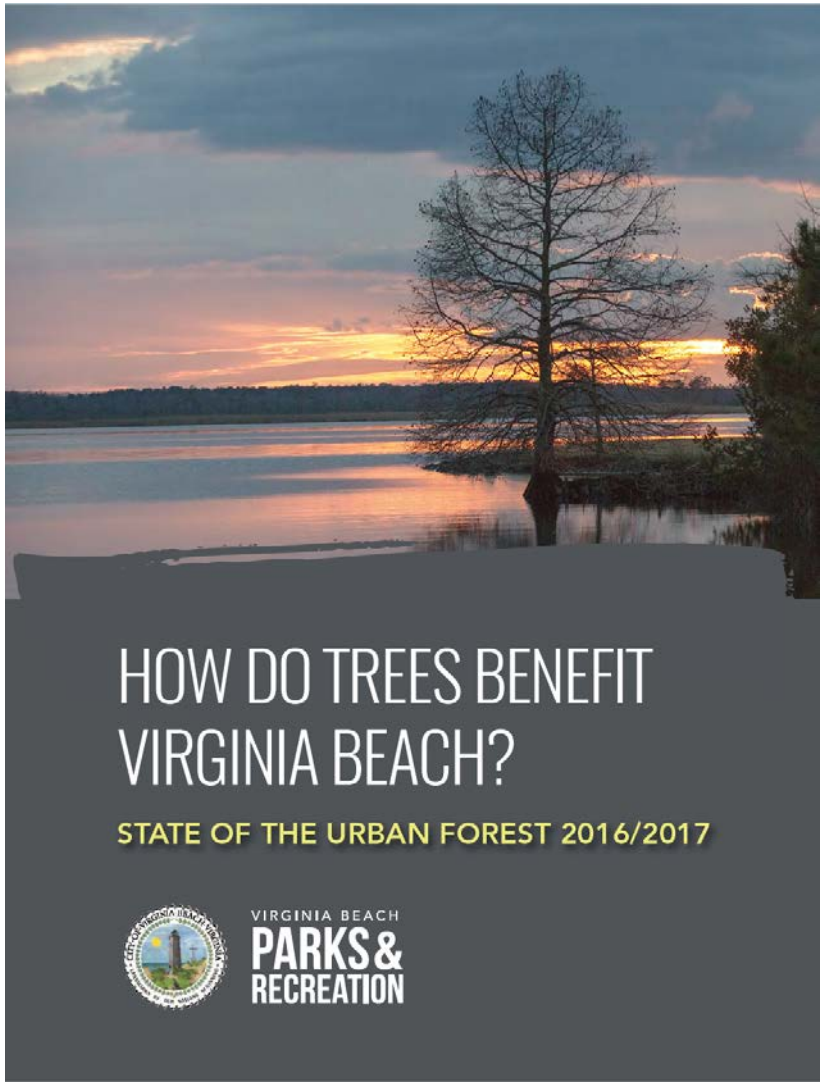


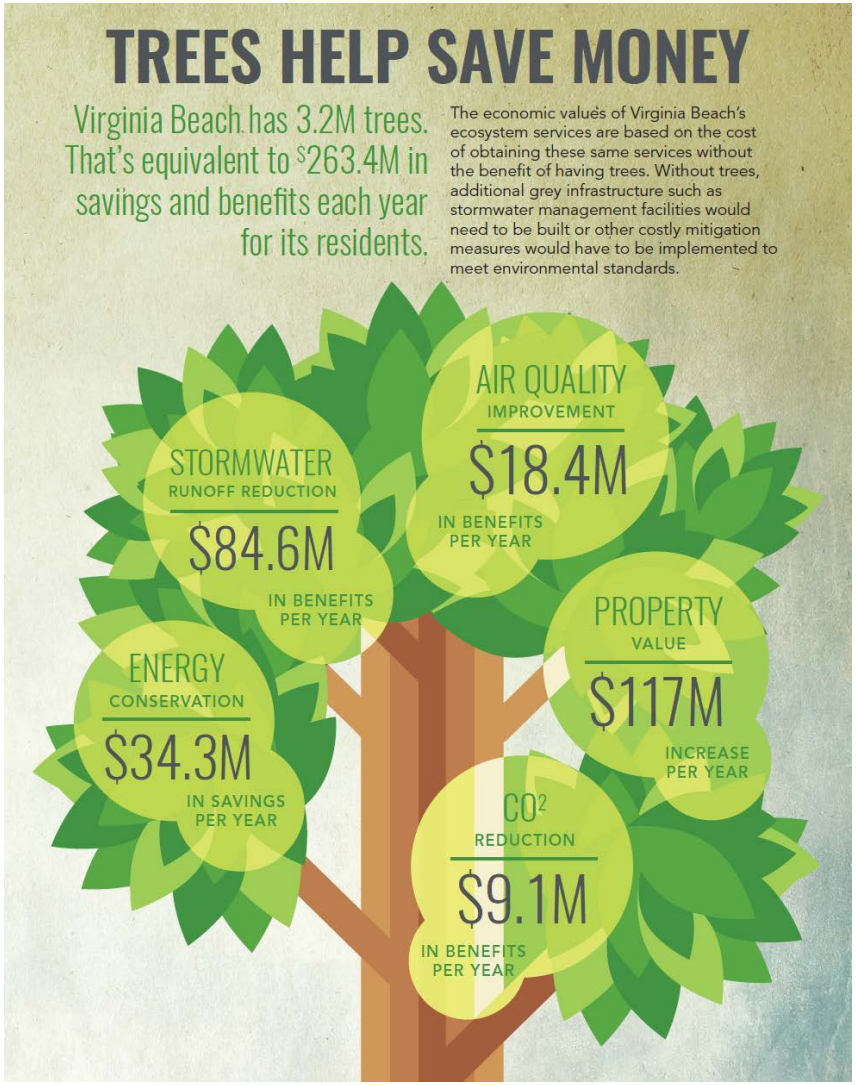
Forests and Water

***Evapotranspiration (ET)**: Plant water use and evaporation*
→ Replenishes Storage Capacity

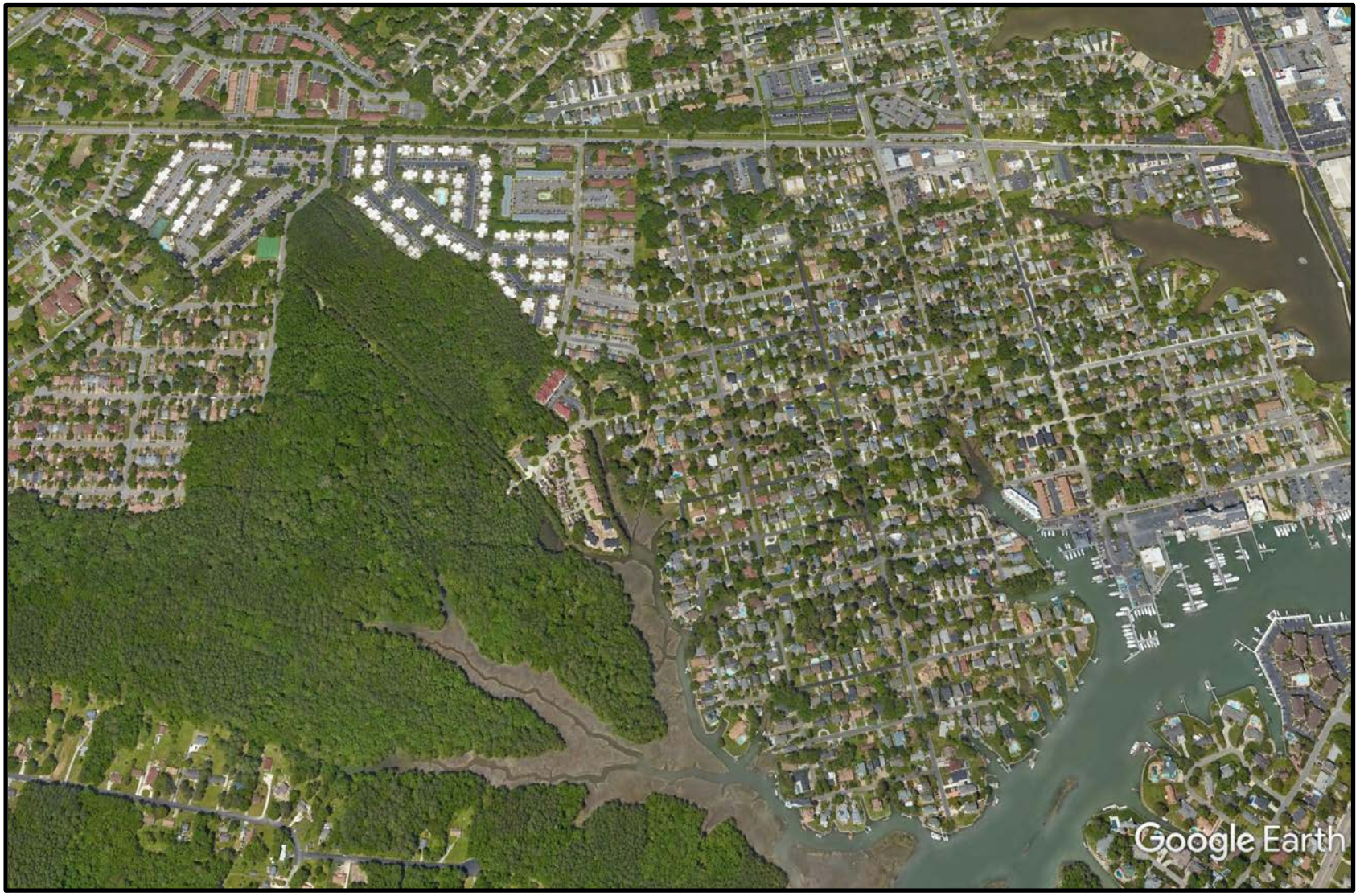


Role of Urban Forests

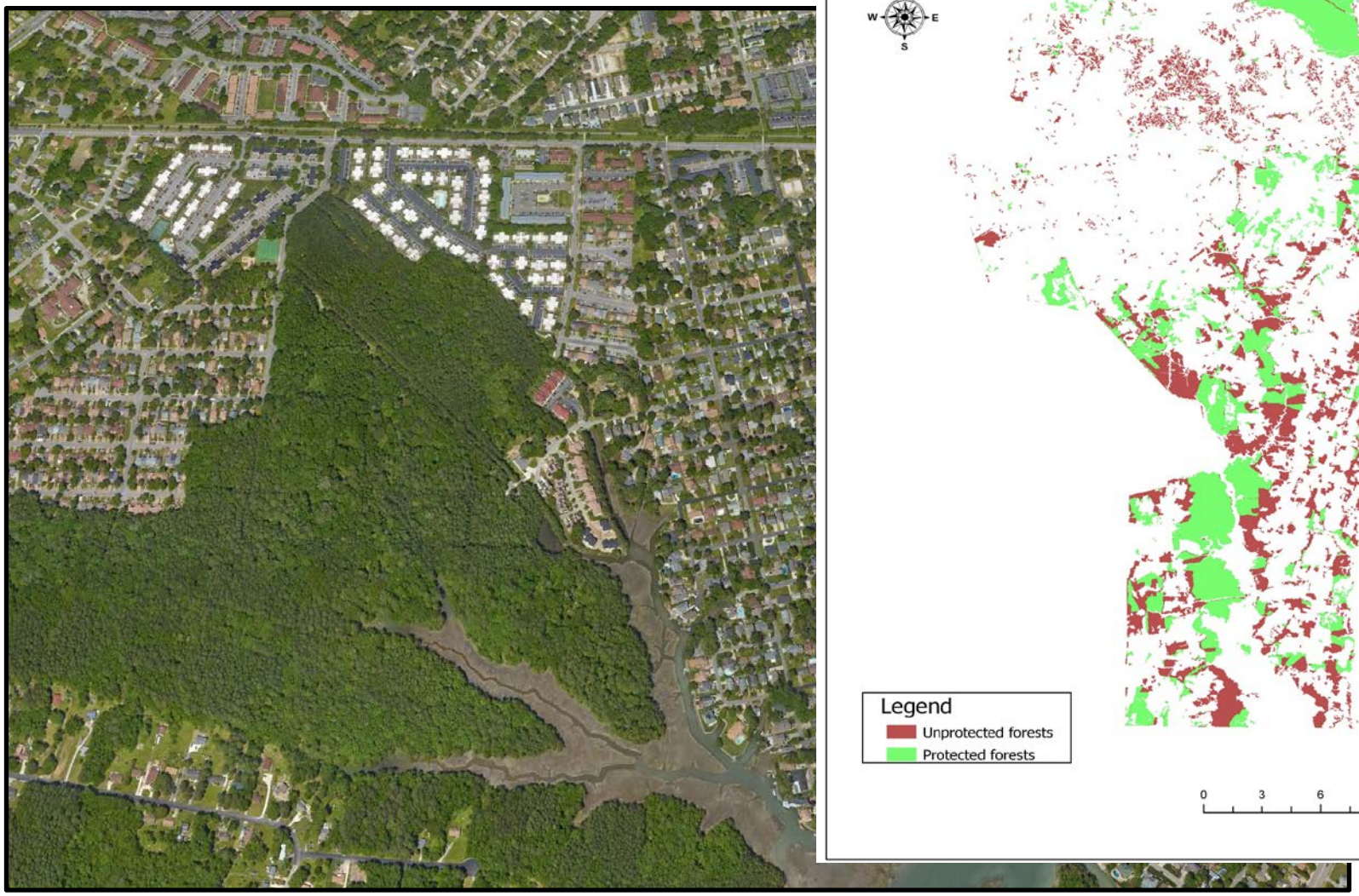




MORE Than Just Street Trees!



Role of Urban Forests in VA Beach



Forests for Flood Reduction

Objectives:

1) Quantify flood reduction services

2) New tool to target conservation efforts

Data Needs

<u>Surface Storage</u>
Topography

<u>Soil Storage</u>
Soil Type and Depth

<u>Evapotranspiration</u>
Land Cover Attributes and Water Availability

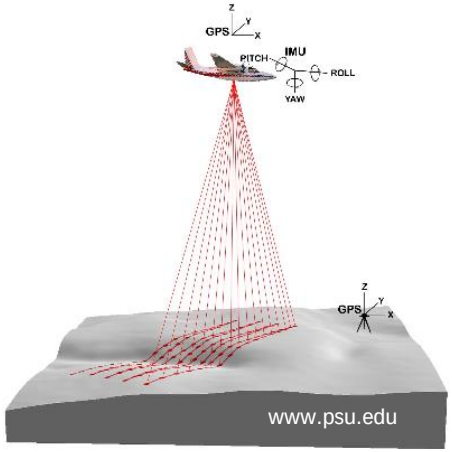
Flood Reduction Potential

Data Needs

<u>Surface Storage</u>
Topography

<u>Soil Storage</u>
Soil Type and Depth

<u>Evapotranspiration</u>
Land Cover Attributes and Water Availability

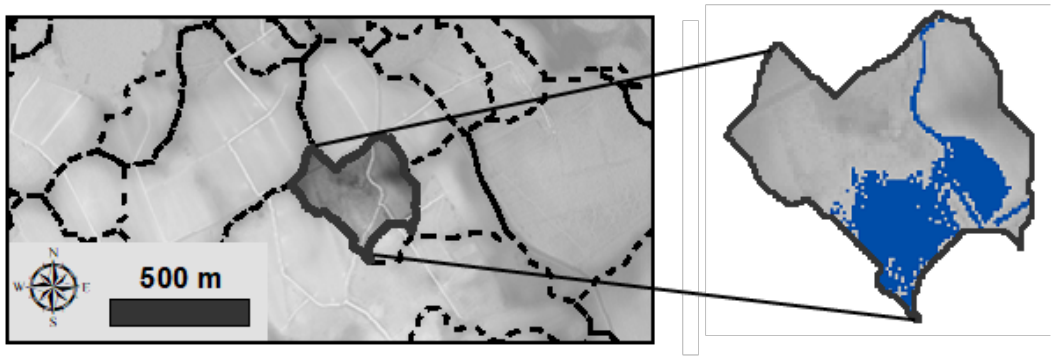


Data Needs

<u>Surface Storage</u>
Topography

<u>Soil Storage</u>
Soil Type and Depth

<u>Evapotranspiration</u>
Land Cover Attributes and Water Availability

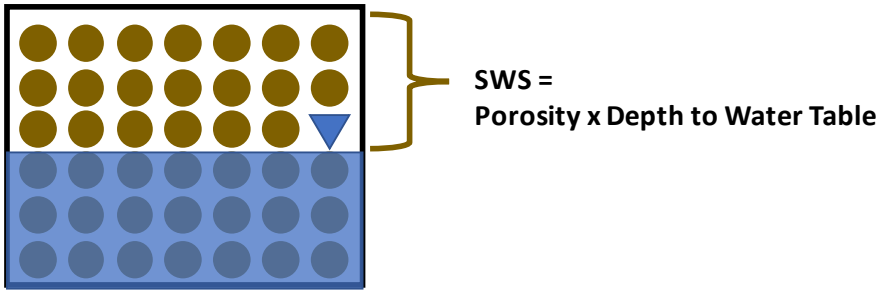


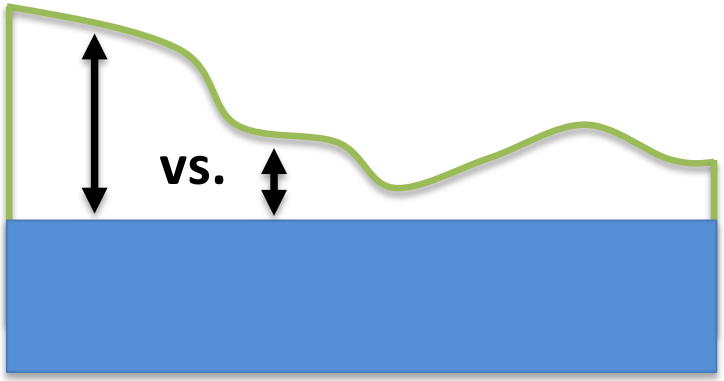
Data Needs

Surface Storage
Topography

Soil Storage
Soil Type and Depth

Evapotranspiration
Land Cover Attributes and Water Availability





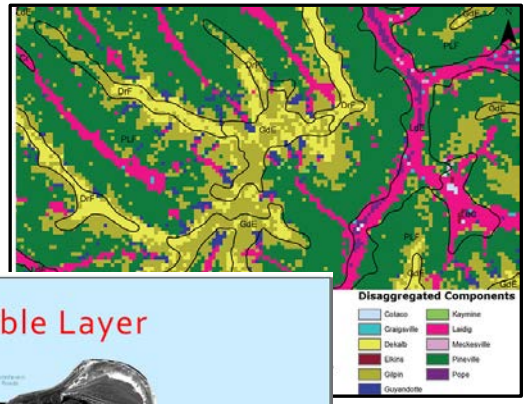
Data Needs

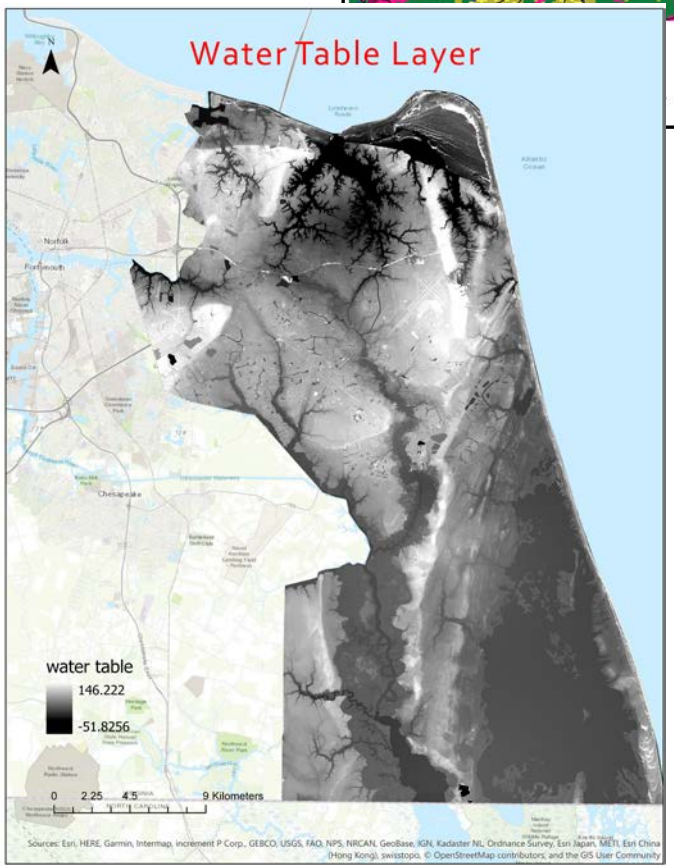
<u>Surface Storage</u>
Topography

<u>Soil Storage</u>
Soil Type and Depth

<u>Evapotranspiration</u>
Land Cover Attributes and Water Availability

NRCS SSURGO



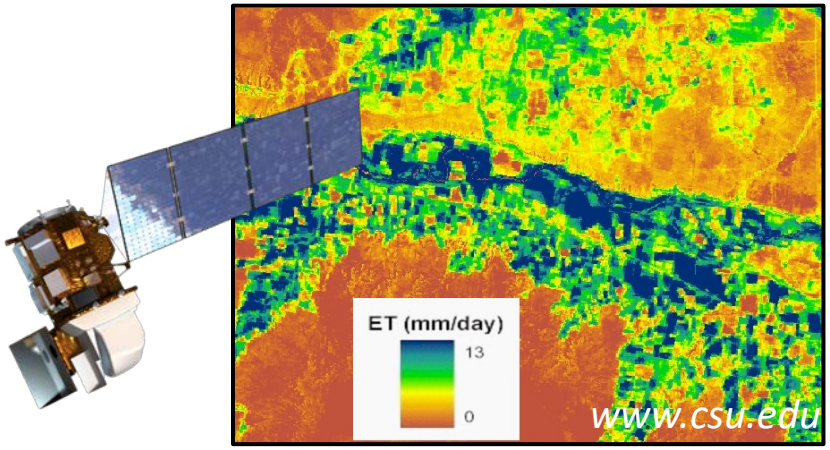


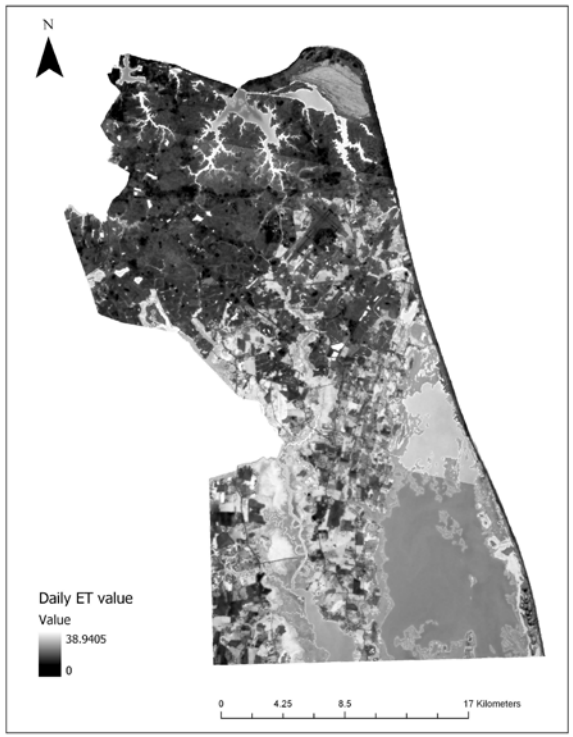
Data Needs

Surface Storage
Topography

Soil Storage
Soil Type and Depth

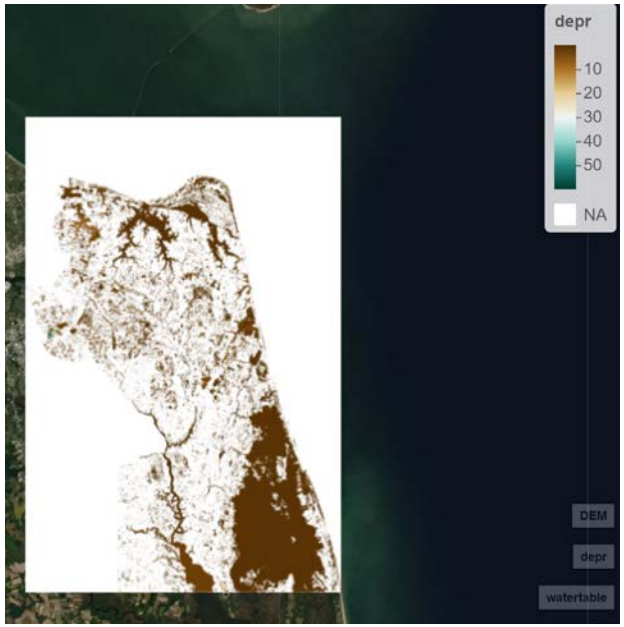
Evapotranspiration
Land Cover Attributes and Water Availability





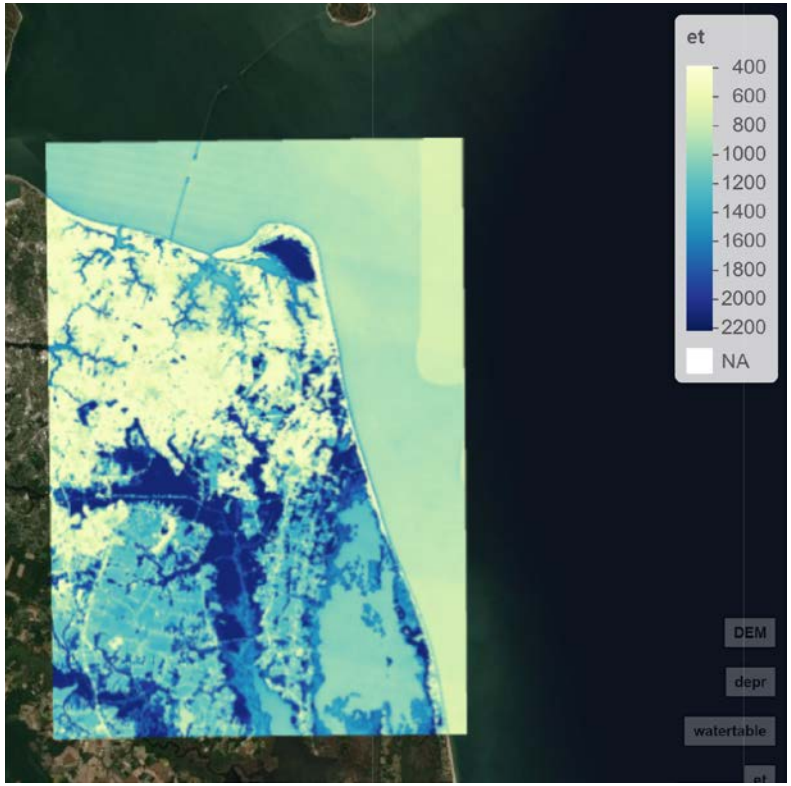
Spatial Data for Water Storage and Removal

Depressional Water Storage



Soil Water Storage

Evapotranspiration



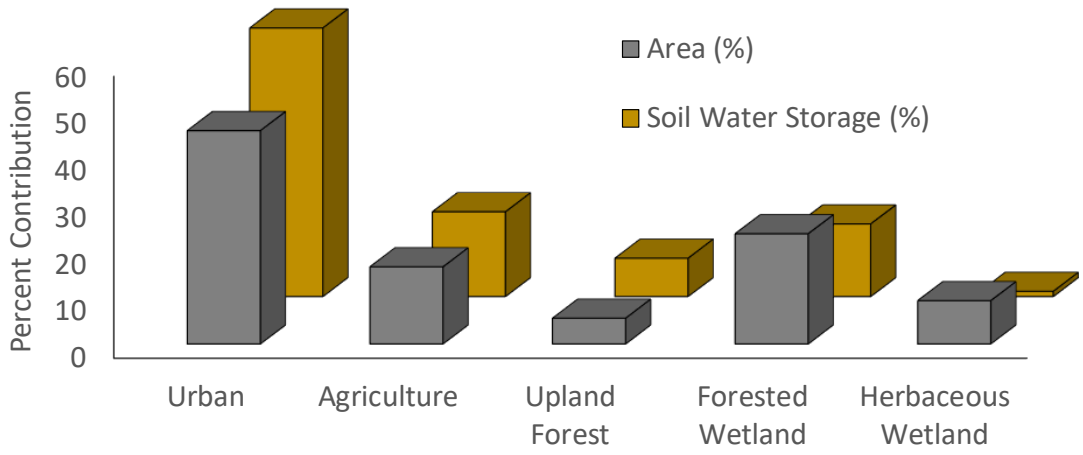
Forests for Flood Reduction

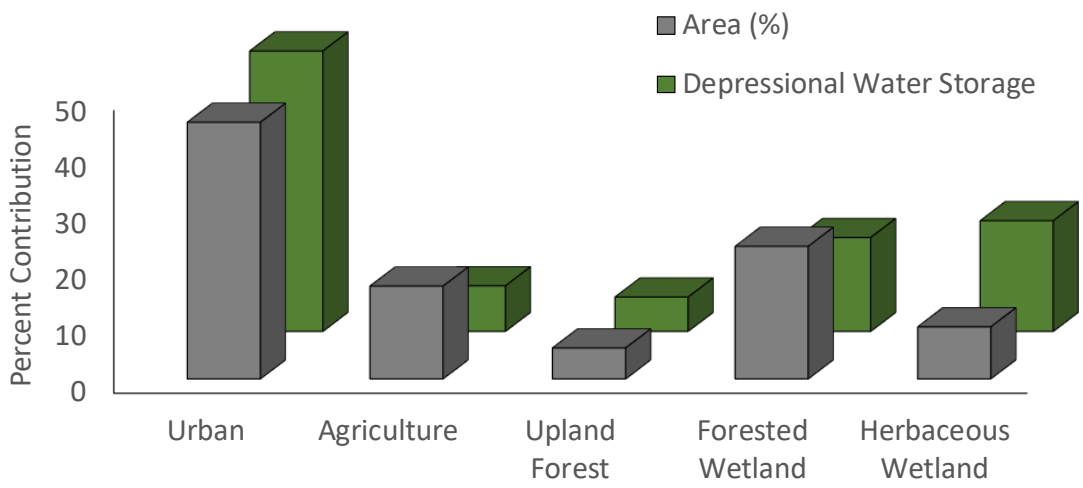
Objectives:

1) Quantify flood reduction services

2) New tool to target conservation efforts

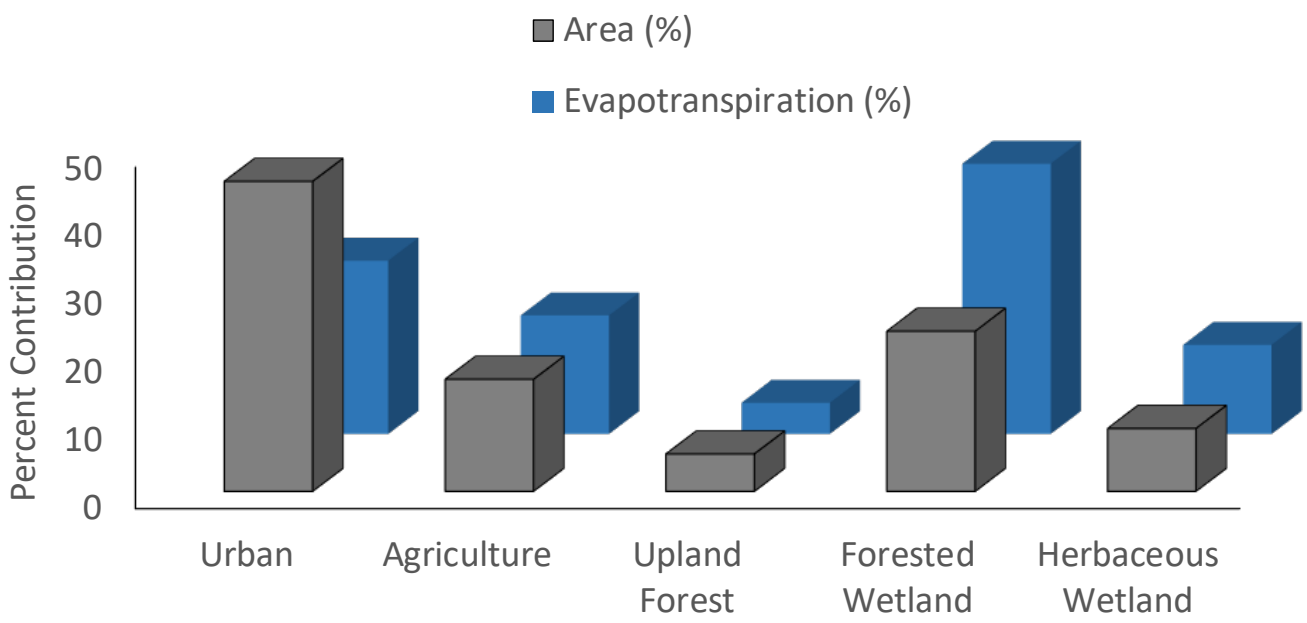
Flood Reduction Services in VA Beach





Driven by mean and land area

Flood Reduction Services in VA Beach



Wetland Forest: ca. 20% of area; 40% of water pumping!!

But, Value of Urban Greenspace!

But, Value of Urban Greenspace!

Urban Subcategories:

	Developed, Open Space	Developed, Low-Intensity	Developed, Medium-Intensity	Developed, High-Intensity
Area (%)	34.55	41.66	18.76	5.03
SWS (mm)	1347	1062	561	182
DWS (mm)	175	170	150	84
ET (mm)	758	587	543	528

But, Value of Urban Greenspace!

Urban Subcategories:

	Developed, Open Space	Developed, Low-Intensity	Developed, Medium-Intensity	Developed, High-Intensity
Area (%)	34.55	41.66	18.76	5.03
SWS (mm)	1347	1062	561	182
DWS (mm)	175	170	150	84
ET (mm)	758	587	543	528

But, Value of Urban Greenspace!

Urban Subcategories:

	Developed, Open Space	Developed, Low-Intensity	Developed, Medium-Intensity	Developed, High-Intensity
Area (%)	34.55	41.66	18.76	5.03
SWS (mm)	1347	1062	561	182
DWS (mm)	175	170	150	84
ET (mm)	758	587	543	528

But, Value of Urban Greenspace!

Urban Subcategories:

	Developed, Open Space	Developed, Low-Intensity	Developed, Medium-Intensity	Developed, High-Intensity
Area (%)	34.55	41.66	18.76	5.03
SWS (mm)	1347	1062	561	182
DWS (mm)	175	170	150	84
ET (mm)	758	587	543	528

But, Value of Urban Greenspace!

Urban Subcategories:

	Developed, Open Space	Developed, Low-Intensity	Developed, Medium-Intensity	Developed, High-Intensity
Area (%)	34.55	41.66	18.76	5.03
SWS (mm)	1347	1062	561	182
DWS (mm)	175	170	150	84
ET (mm)	758	587	543	528

But, Value of Urban Greenspace!

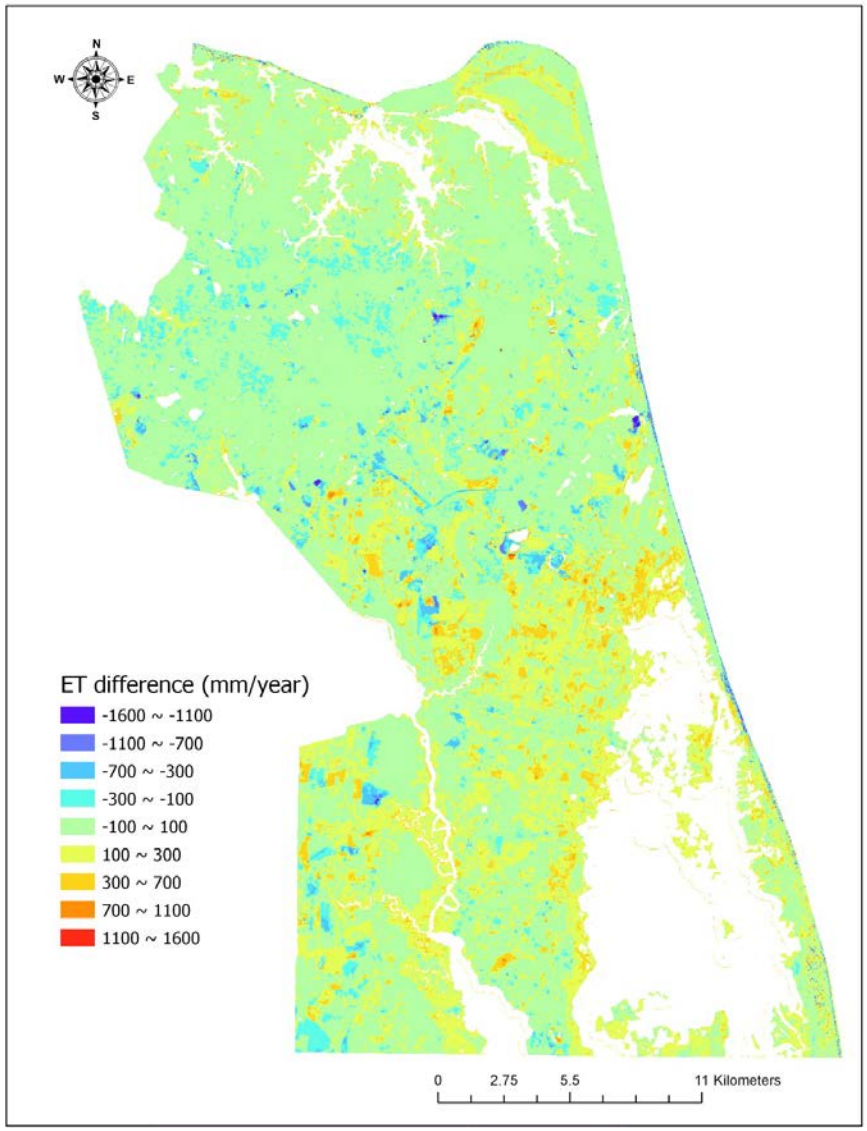
Urban Subcategories:

	Developed, Open Space	Developed, Low-Intensity	Developed, Medium-Intensity	Developed, High-Intensity
Area (%)	34.55	41.66	18.76	5.03
SWS (mm)	1347	1062	561	182
DWS (mm)	175	170	150	84
ET (mm)	758	587	543	528

All services decrease with development

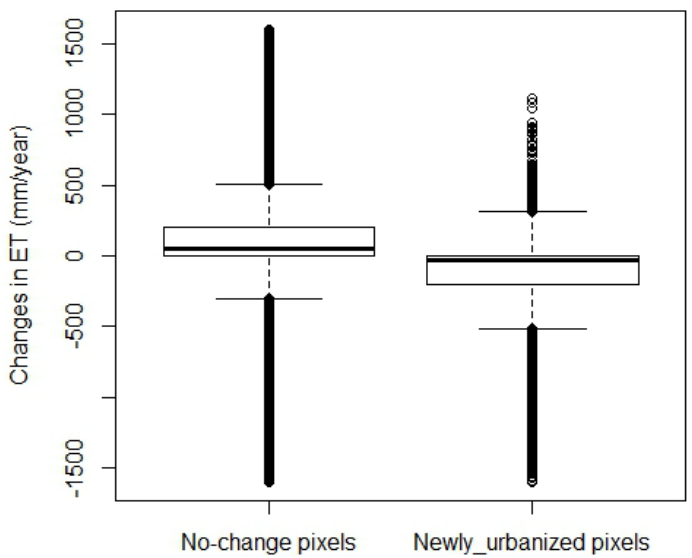
Land Use and ET Change

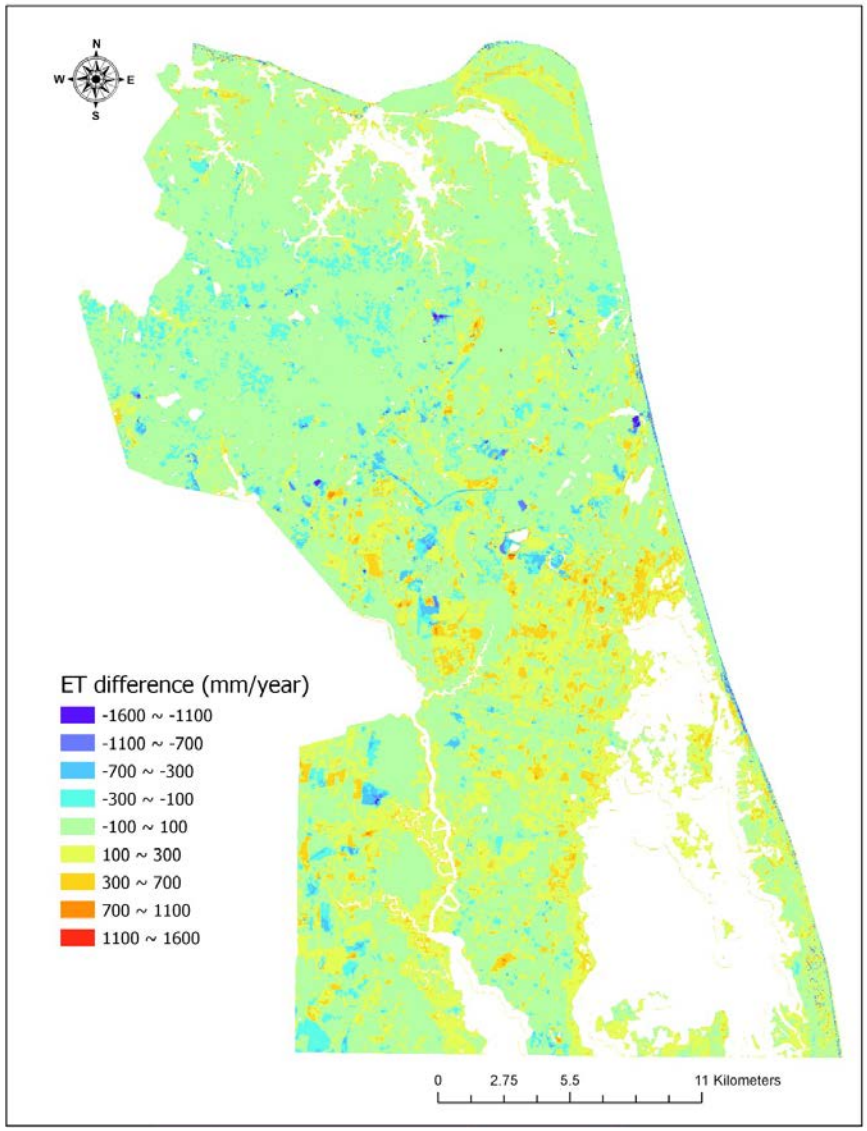
Only 3% increase in urban area over 20 years



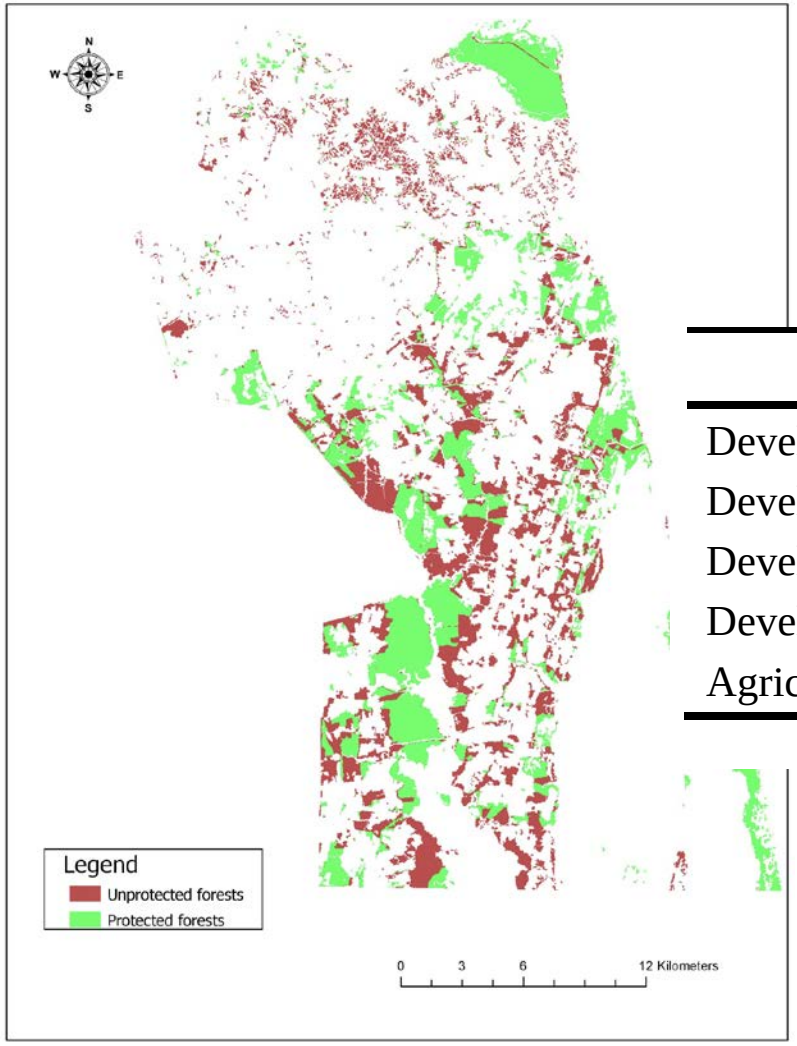
Land Use and ET Change

For those pixels, ET decreased





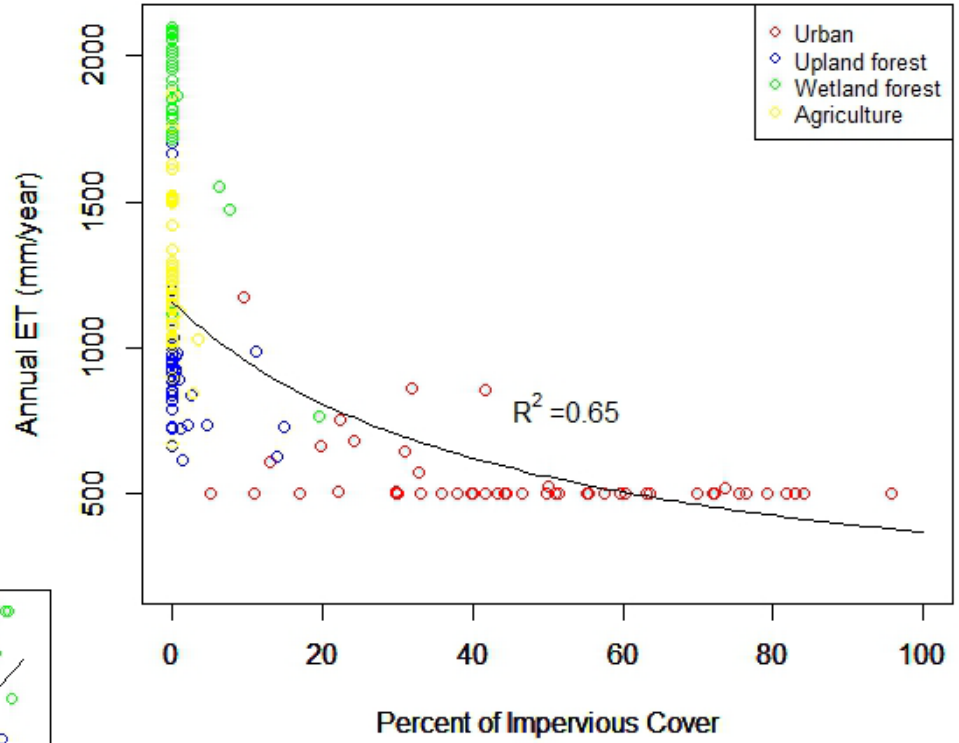
Scenarios of Forest Loss and ET

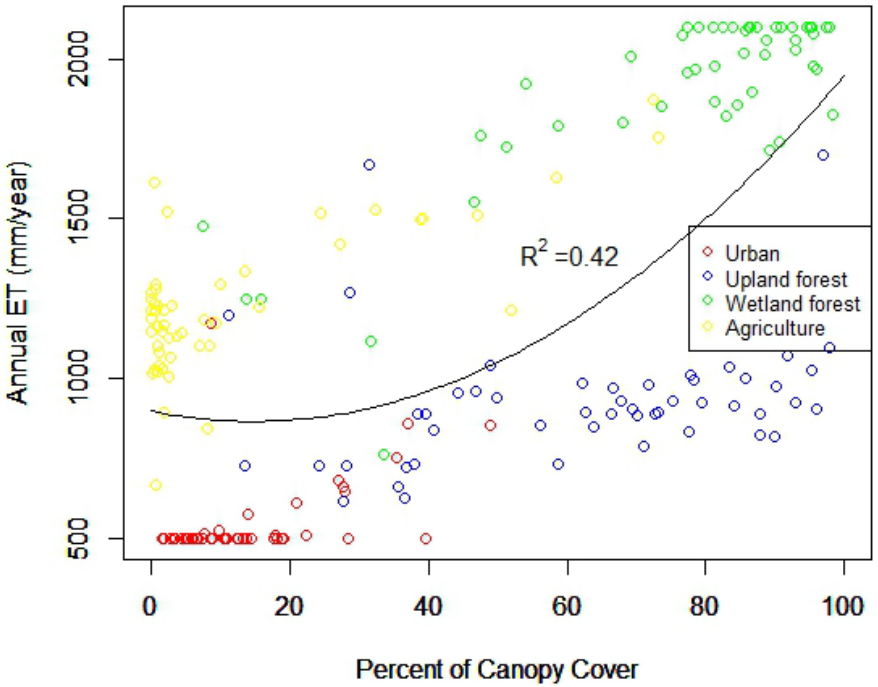


	Relative Change in ET (%)
Developed, open space	-23.70
Developed, low intensity	-28.41
Developed, medium intensity	-29.62
Developed, high intensity	-30.03
Agriculture	-11.27

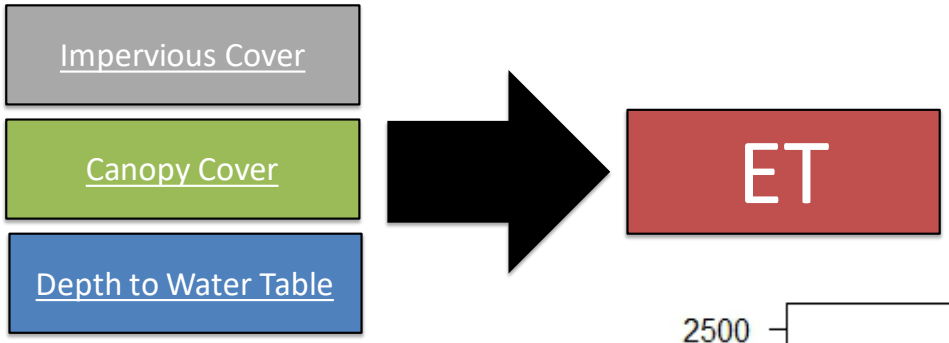
Drivers of ET for a Predictive Model

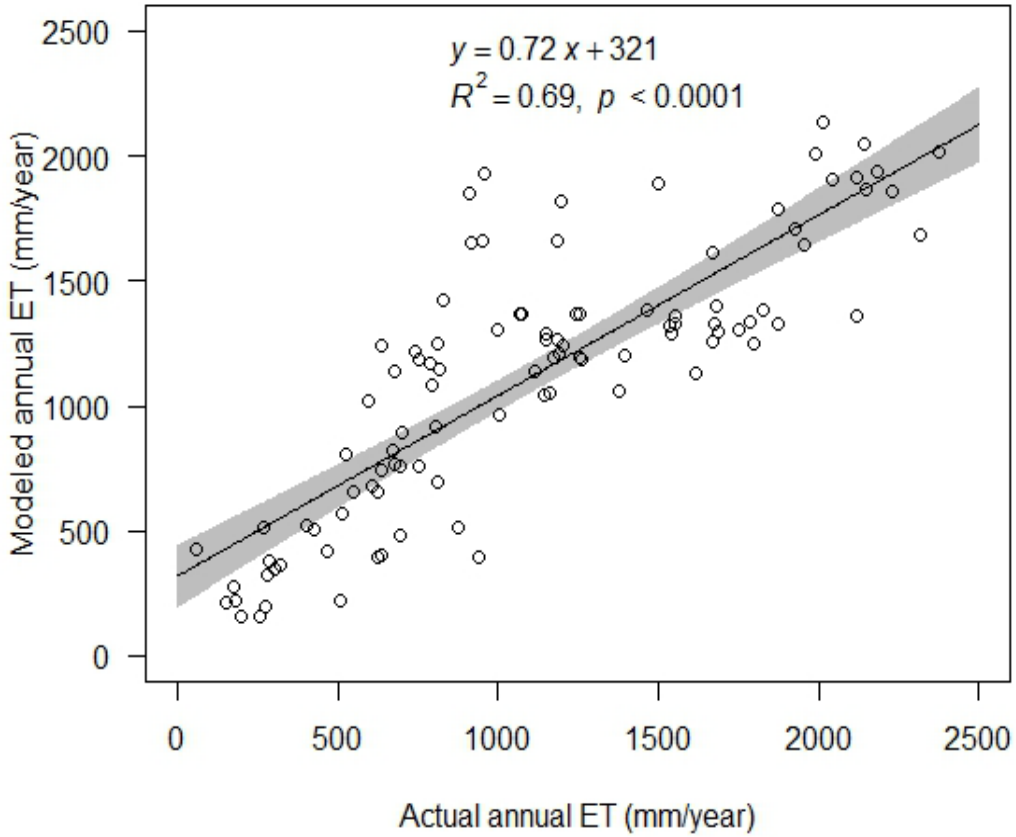
ET Drivers:


Urban
Upland forest
Wetland forest
Agriculture
R^2 =0.65
Annual ET (mm/year)
500
1000
1500
2000
0
20
40
60
80
100
Percent of Impervious Cover


R^2 =0.42
Urban
Upland forest
Wetland forest
Agriculture
Annual ET (mm/year)
500
1000
1500
2000
0
20
40
60
80
100
Percent of Canopy Cover

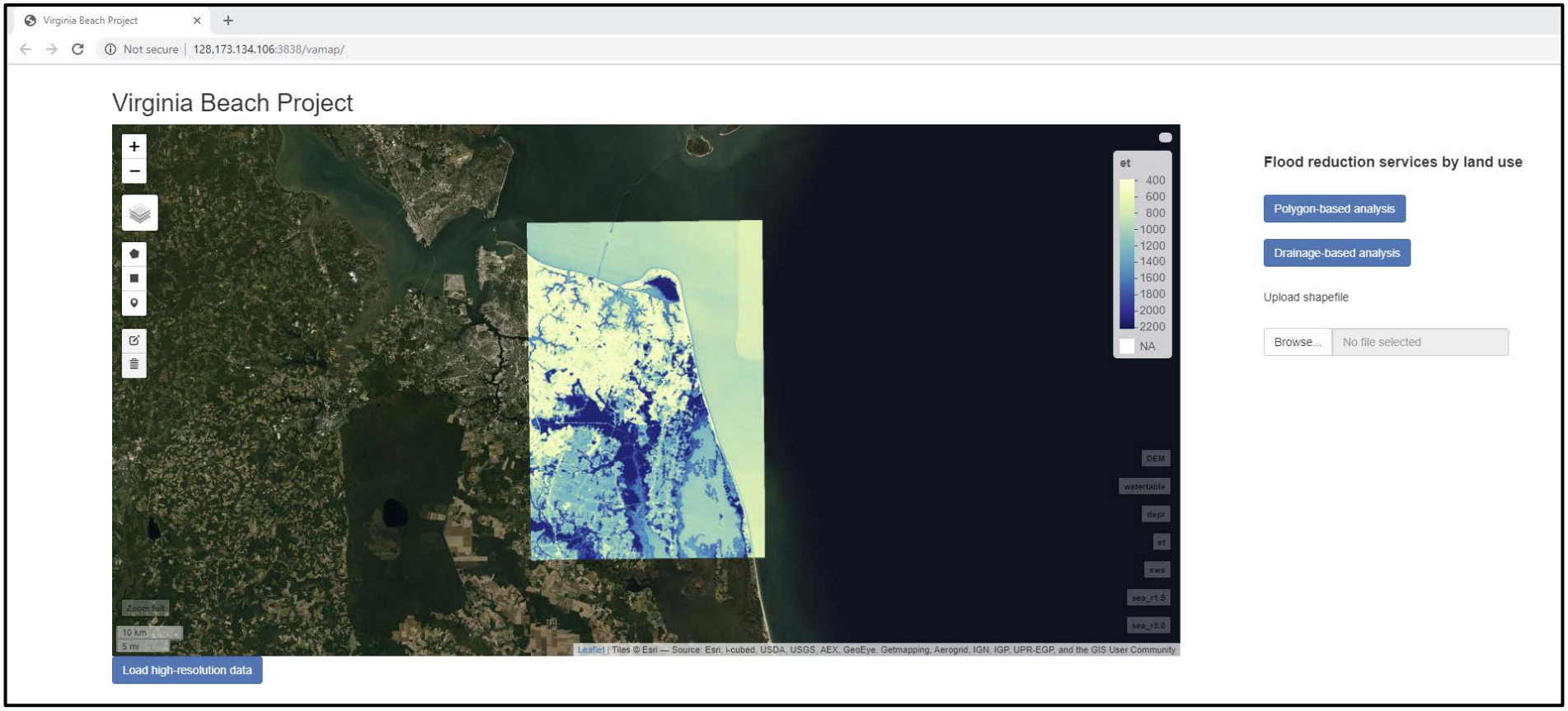
A Predictive Model for ET





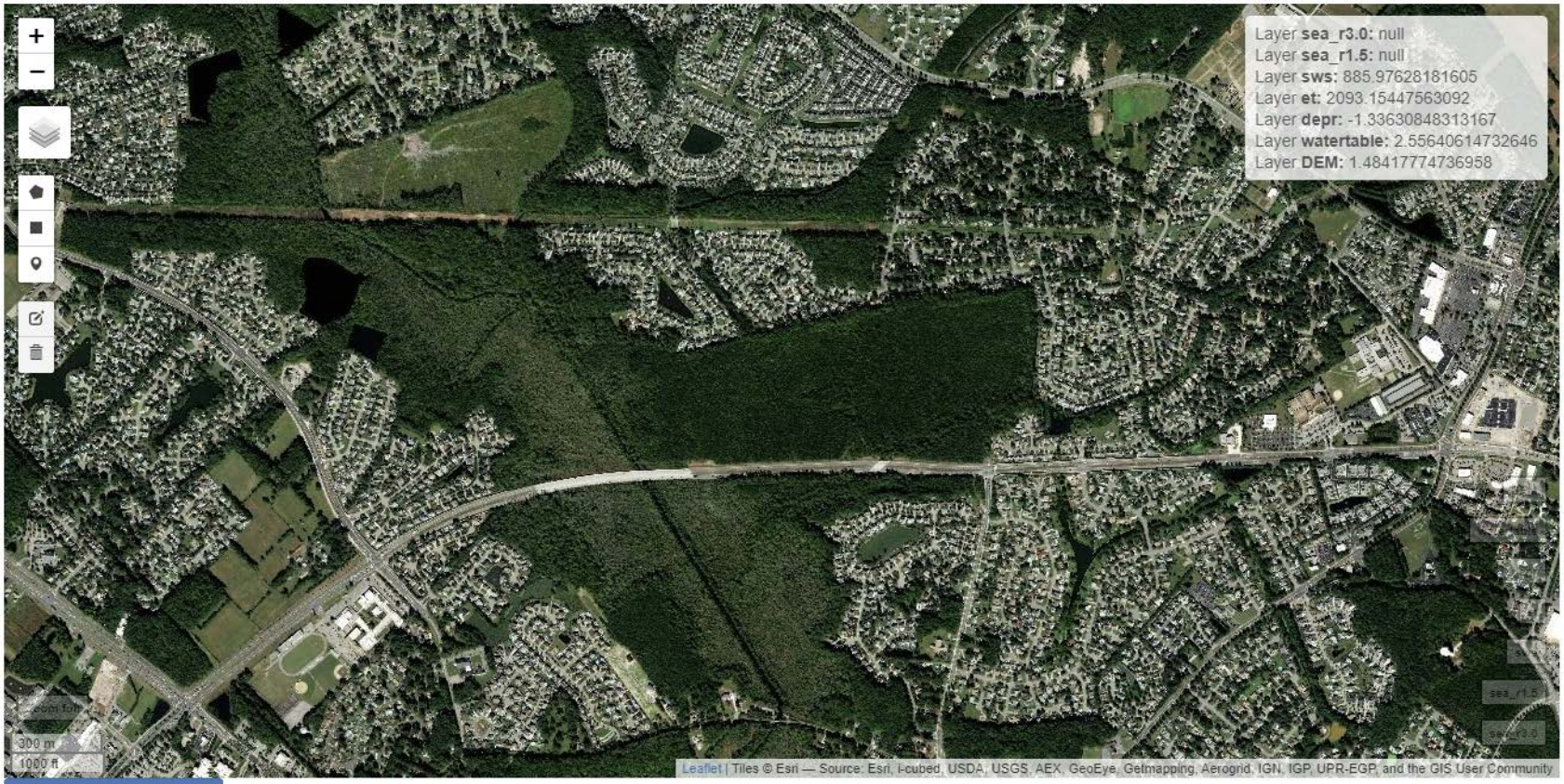
The Tool: Data Integration and Processing for Users

Data Integration and Processing for Users



Data Integration and Processing for Users

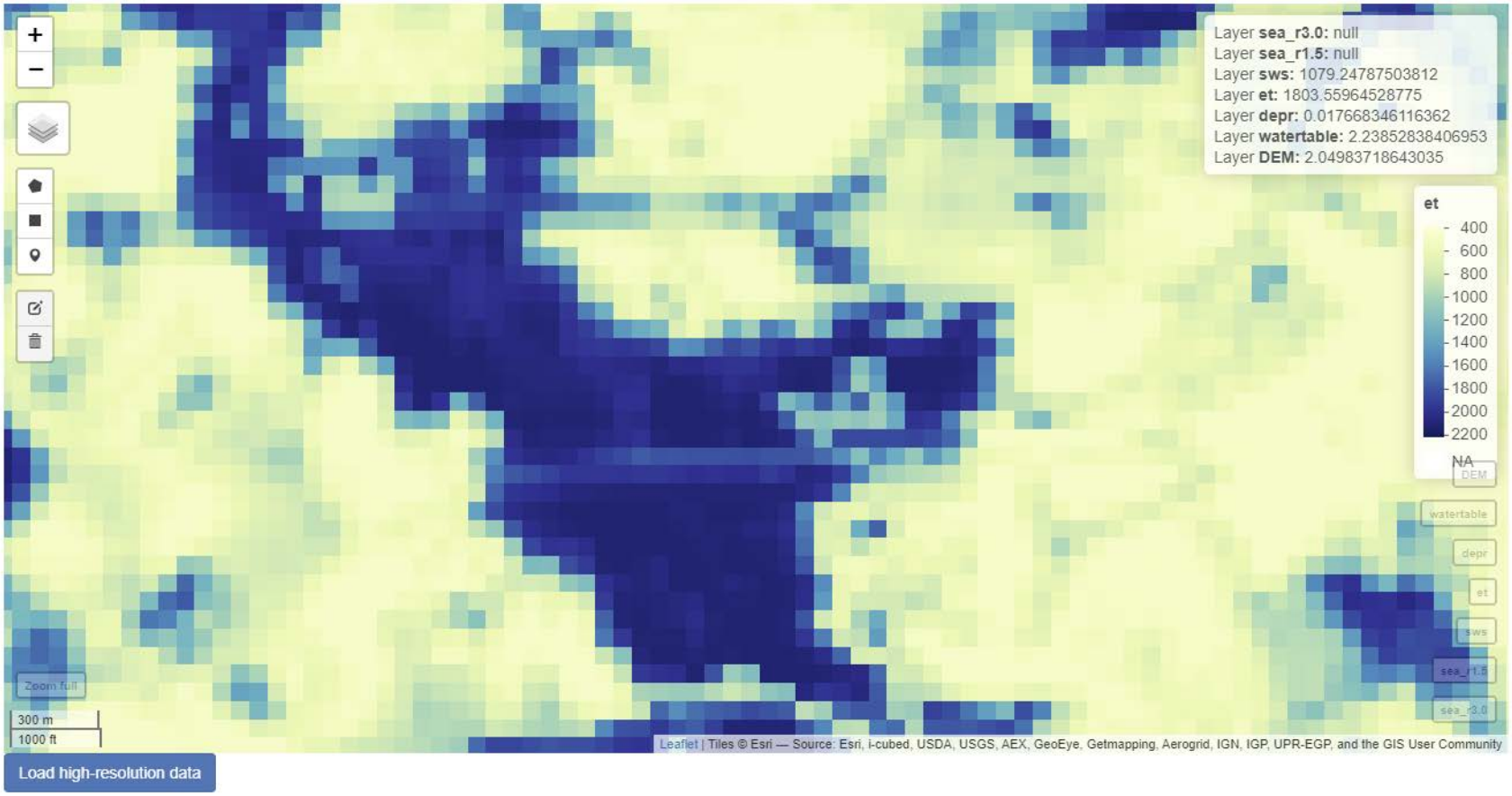
Virginia Beach Project



Load high-resolution data

Data Integration and Processing for Users

Virginia Beach Project



User-defined Areas

Virginia Beach Project

Load high-resolution data

Polygon-based analysis

Please draw a polygon in the study area using the drawing tools (polygon, rectangle, or circle) located on the left side of data visualization panel

Drainage-based analysis

Upload shapefile

Browse... No file selected

Land cover distribution

forest%	urban%	ag%	grass%	Total area (m2)
62.41	20.61	NA	16.98	1411125.00

ET distribution (% by land use)

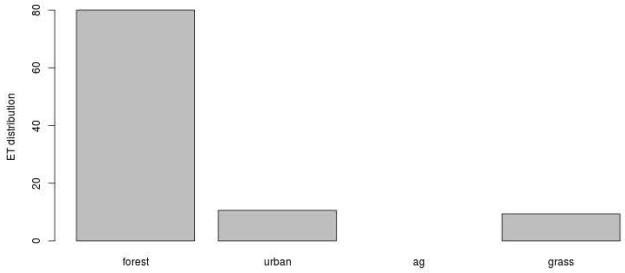
forest	urban	ag	grass	Mean (mm/year)
80.02	10.61	NA	9.37	1255.79

Soil Water Storage (% by land use)

forest	urban	ag	grass	Mean (mm)
62.79	19.49	NA	17.73	553.54

Depressional storage (% by land use)

forest	urban	ag	grass	Mean (mm)
55.36	17.54	NA	27.10	15.28



%lc_of_interest	%lc_other	Total area m2
96.58	3.42	1461050.00

User-defined Areas

Virginia Beach Project

Load high-resolution data

Flood reduction services by land use

Polygon-based analysis

Drainage-based analysis

Please place a point in the study area using the drawing tools (place marker) located on the left side of data visualization panel

Upload shapefile

Browse... No file selected

Land cover distribution

forest%	urban%	ag%	grass%	Total area (m2)
78.57	18.89	NA	2.54	339725.00

ET distribution (% by land use)

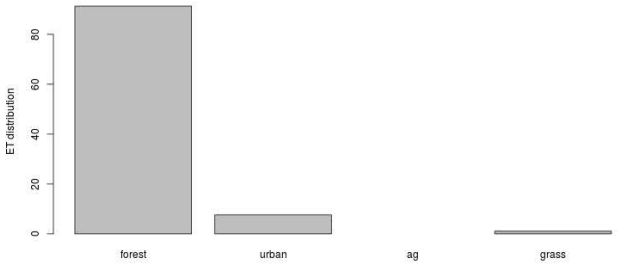
forest	urban	ag	grass	Mean (mm/year)
91.31	7.61	NA	1.07	1557.23

Soil Water Storage (% by land use)

forest	urban	ag	grass	Mean (mm)
90.67	6.29	NA	3.04	746.99

Depressional storage (% by land use)

forest	urban	ag	grass	Mean (mm)
72.47	27.33	NA	0.20	2.86



Take-Homes:

- Data availability supports **new quantification** of flood reduction services in VA Beach and other localities
- Wetland forests: ca. 40% of the cumulative ET but ca. 20% of area
- Wetland forests: ca. 15% and 16% of SWS and DWS
- Upland forests area coverage (and thus contributions) is low
- Land use change, particularly urbanization, reduces ET
- Loss of unprotected forests: 11-30% loss in current forestland ET
- Predictive models of ET can be developed for downscaling estimates

Future Work:

Findings support conservation/restoration efforts, but to guide stormwater and urban planning requires:

- Downscaling estimates to inform stormwater crediting
  - — Sub-meter LULC data for predictive modeling of specific services
- Inform green infrastructure design to incorporate forest features
  - — Geospatial data and hydrologic modeling for event-based simulations
- Further refine scenario modeling and tool applications for operational use
  - — Incorporate downscaling, event modeling, and other ecosystem services
- **Extend work to other flood-prone localities!!!**

Scenarios of Forest Loss and ET

Sea Level Rise Scenarios	Relative to Cumulative Landscape ET (%)	Relative to Cumulative Forest ET (%)
0.46 m (1.5 ft)	-10.68	-24.17
0.91 m (3.0 ft)	-19.96	-45.17