Ecological Conditions of US National Parks: Enabling Decision Support Through Monitoring, Analysis, and Forecasting

Sponsored by:

NASA Applications Program: Decision Support through Earth-Sun Science Research Results Project

and

NPS I&M Program

Overall Study Goal

Integrate the routine acquisition and analysis of NASA ESS products and other data sources into the NPS I&M process and use these NASA products to evaluate and forecast ecological condition of US National Parks.

Study Objectives

Select landscape-level indicators consistent with high-priority “vital signs” and identify the boundaries of the greater park ecosystem appropriate for these indicators.

Establish procedures to incorporate existing spatial data and products from Terrestrial Observation and Prediction System (TOPS) and other (NASA) sources.

Add value to data sets by using ecological knowledge to guide the analysis, evaluation, and communication.

Integrate the data acquisition, analysis, forecasting, and display of these ecosystem changes into the NPS I&M’s decision support framework.

NASA PALMS – Closeout call #1

Expectations

- Regular engagement of PALMS and NPS staff
- Consistent staff
- Provide data and methods
- “tech transfer” to
  - Ecologists – analyses and interpretation
  - GIS/Tech – workshops / documentation

Our ‘adaptive management’ strategy

- Sustained engagement with Network and park to evaluate results
- Develop park-specific integrative ‘story’
- Emphasize SOPs to facilitate transfer to I&M protocols
- Avoid unnecessary meetings

Closeout call goals and schedule

Call 1 – April

- ‘First look’ at final results
- Discuss ‘delivery strategy’
- Familiarization with data and analyses
- Identify engaging story line(s)
- Identify obvious gaps

Call 2 – June

- Refined analyses; more formal presentation
- Fleshed out ‘Story’ outline
- Reality check
- Feedback from NPS on SOPs, indicators, analyses

Call 3 – September

- Synthetic and integrative park stories fully drafted
- Finalized SOPs and other products
- Data, scripts, etc all available on NPS PALMS web site
- Identify follow-on issues and projects (out of scope of PALMS)

PALMS NPS NASA Joint project - Mozilla Firefox

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National Park Service
Nature & Science

National Park Service
U.S. Department of the Interior

PALMS - NPS-NASA Park Monitoring Project

NPS » Nature & Science » Inventory & Monitoring » Vital Signs Monitoring » Land Cover Land Use

Nature & Science

I&M Home
- NARSEC Home
- NARSEC 2007 Proceedings
- Landscpale Scale Monitoring

Parks: Nature & Science

PALMS - Park Analysis and Monitoring Support

A joint project of the NPS, Montana State University, Woods Hole Research Institute, Colorado State University, and NASA Ames Research Center

This site describes the PALMS project, and provides access to project products, related and supporting publications, instructions to access data, presentations, reports, and associated project materials. As products mature and are finalized, they will be uploaded and available via the NPS NRInfo portal via IRMA (intranet only).

Ecological condition of US National Parks: Enhancing decision support through monitoring, analysis, and forecasting

PALMS Products

Key documents

PALMS Fact Sheet, 2008.
NASA Project Proposal, 2005.
PALMS Assessment Report, 2009.
PALMS Indicator Summary table March 2009

Procedures and Standard Operating Procedures (SOPs)

Goetz, S.J. and G. Fiske. 2009. PALMS SOP – GIS Methodology for mapping Biotic Integrity and Indicator Taxa across watersheds in the eastern USA. National Park Service, Fort Collins, CO.
Goetz, S.J. and G. Fiske. 2010. PALMS SOP – Estimating Impervious Cover Change. National Park Service, Fort Collins, CO.
Piekielek, N.B., C. Davis and A. Hansen 2010. PALMS SOP - Ecosystem type change and fragmentation: from pre Euro-American settlement to present day. Inventory and Monitoring Program, Natural Resource Program Center, National Park Service, Fort Collins, CO.

http://science.nature.nps.gov/im/monitor/lulc/palms/index.cfm

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http://science.nature.nps.gov/im/monitor/lulc/palms/index.cfm

Tools and Data

Eventually, all relevant PALMS final documents, tools, datasets, and associated will be incorporated into IRMA. In the meantime, this is the place to find these.

Ecosystem type and change Arc tools

Protected-area centered ecosystems (PACE) Arc tools
PACE example results xls sheets
The PACE data sets are too large to serve here - contact Nate Piekielek or John Gross.

Presentations

George Wright Society Poster, April 2009.
Project summmary, May 2009.

Presentations from the Santa Fe project meeting 2007

Goetz-Hansen. Study introduction and overview (655 KB).
Goetz. Mid-Atlantic hydrology (6.8 MB).
Theobald. Rocky Mountain land use (980 KB).
Melton-Namani. TOPS overview (2.4 MB).
Gross. Evaluation and Benchmarking reports (70 KB).
Melton-Namani. TOPS - Yosemite (5.4 MB).

Most Relevant Publications

Goetz, S. and G. Fiske. 2008. Linking the diversity and abundance of stream biota to landscapes in the Mid-Atlantic USA. Remote Sensing of Environment 112:4075-4085.

Hansen, A. J. and R. DeFries. 2007. Ecological mechanisms linking protected areas to surrounding lands. Ecological Applications 17:974-988.

Jantz, P., Goetz, S.J., and Jantz, C. A., 2005. Urbanization and loss of resource lands in the Chesapeake Bay watershed. Environmental Management Vol. 36, No. 6, pp. 808-825.

Jones, D.A., A.J. Hansen, K. Bly, K. Doherty, J.P. Verschuyl, J.I. Paugh, R. Carle, and S.J. Story. 2009. Monitoring land use and cover around parks: a conceptual approach. Remote Sensing of Environment, 113:1346-1356.

Theobald, D. M. 2005. Landscape patterns of exurban growth in the USA from 1980 to 2020. Ecology and Society 10.

Theobald, D. M., S. J. Goetz, J. B. Norman, and P. Jantz. 2009. Watersheds at risk to increased impervious surface cover in the conterminous United States. Journal of Hydrologic Engineering 14:362-368.

White, M. A., K. M. De Beurs, K. Didan, and 18 others. 2009. Intercomparison, interpretation, and assessment of

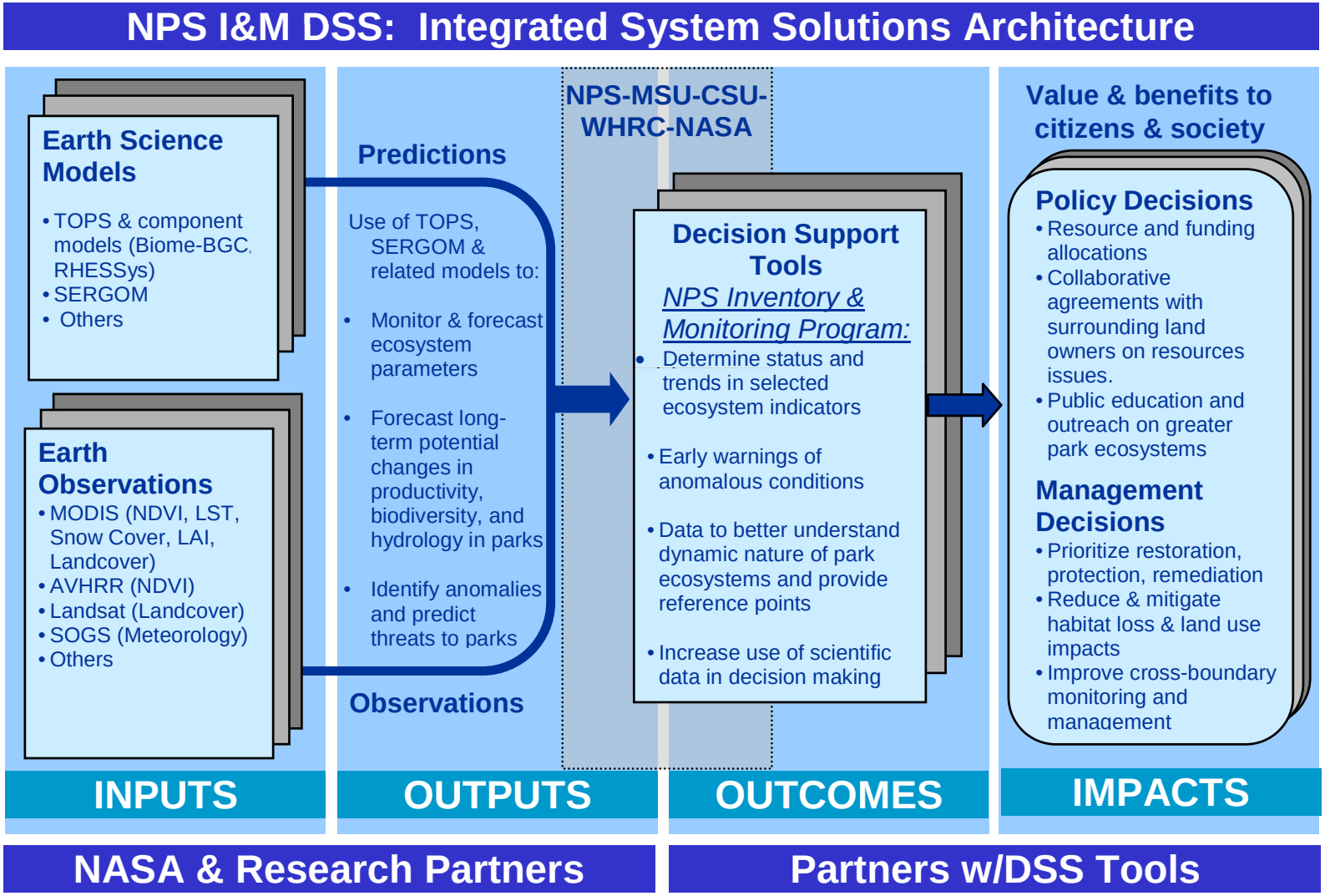
PALMS Indicators – April 2010

Level	Category	Indicator	Extent	Resolution
Air and Climate	Weather and Climate	Phenology (NDVI, annual anomaly)	US 48	1 km (all); 8 & 16 day
		Climate gridded daily 2000-8	YOSE	1 km
		Climate scenarios (monthly)	YOSE, DEWA, GYE, US48	12 km
Water	Stream health	Sensitive taxa	DEWA	1:24K, 1:100K
Landscape dynamics	Land Cover	Ecosystem type composition Summary by spatial scale	DEWA, ROMO, YELL, YOSE	30 m
		Bird hotspots and key habitat types	GYE	1 km
		Impervious cover change	DEWA	30 m
		Housing density class (1940 – 2100, decadal)	US48	100 m
		Landscape connectivity of forests	Eastern US	270 m
		Pattern of natural landscapes	US 48	270 m
		Past to future modeling	DEWA	30 m
	Extreme Disturbance Events	Fire effects via changes in NDVI/EVI, FPAR/LAI	DEWA, ROMO, YELL, YOSE	1 km; monthly anomalies / persistent; annual trends
	Primary Production	GPP/NPP TOPS GPP	DEWA, ROMO, YELL, YOSE	1 km daily and/or monthly summaries
	Monitoring area	Greater park ecosystem boundaries	DEWA, ROMO, YELL, YOSE	30 m
	Land use	Land use	US48	90 m

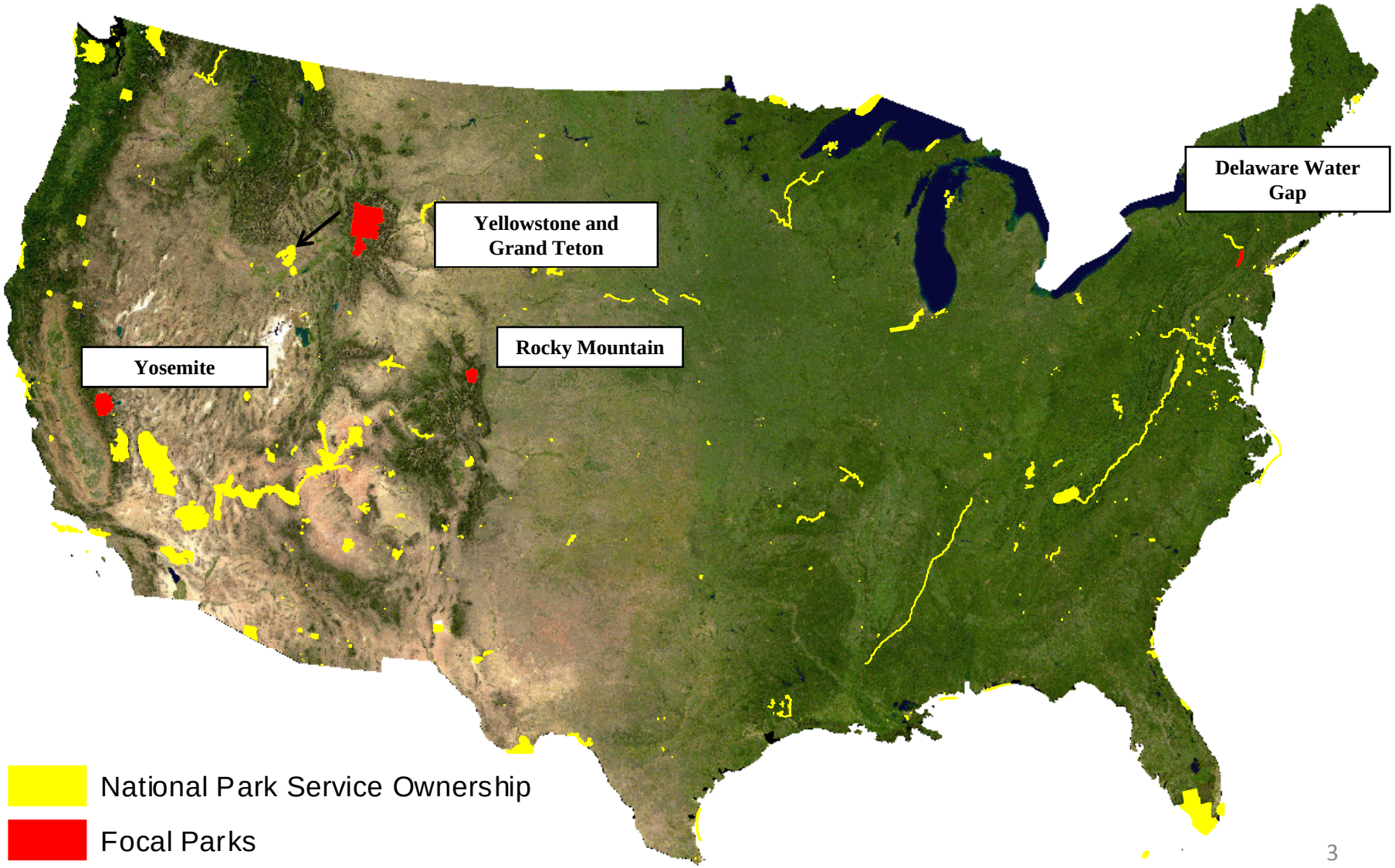
PALMS Science Team

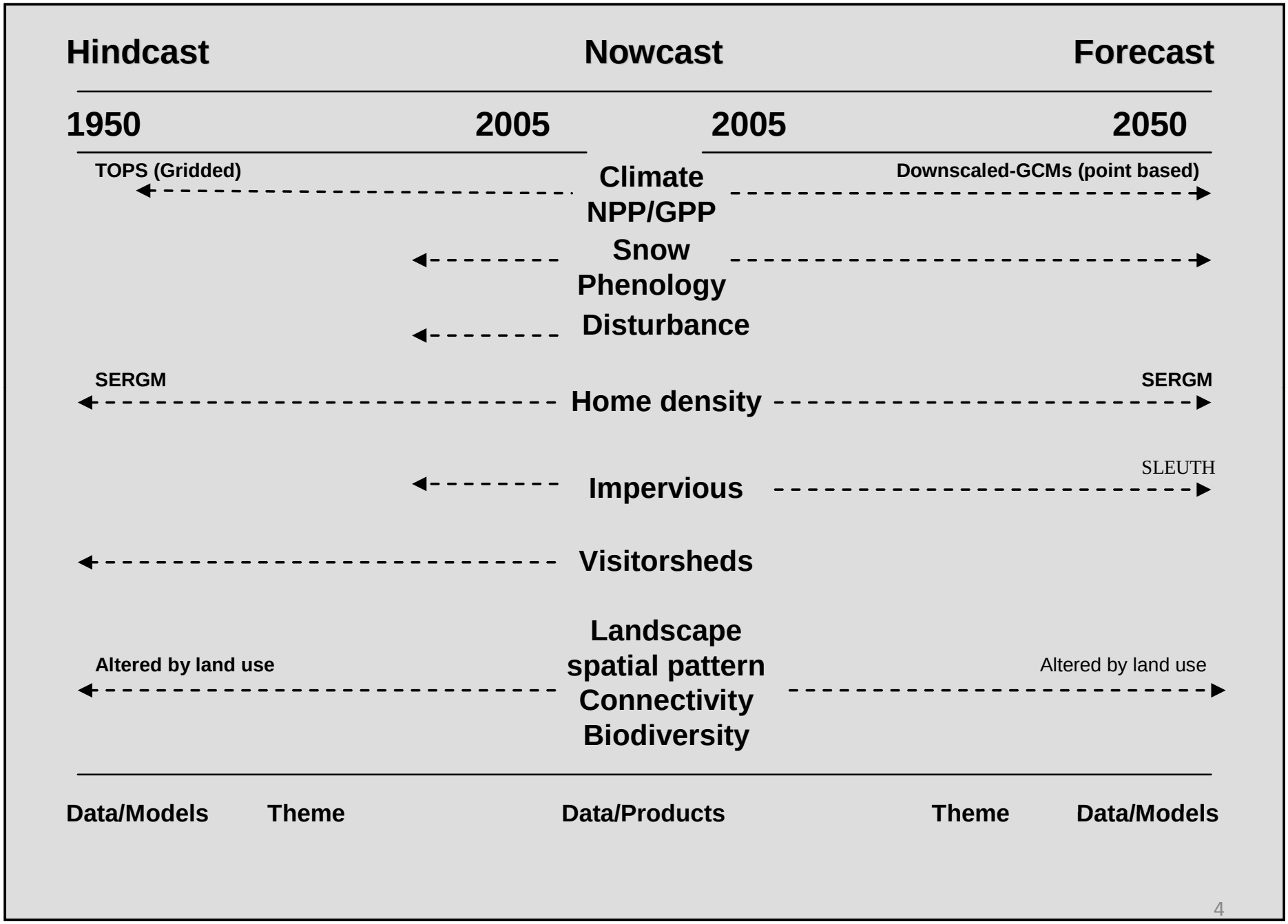
Name	Role	Lead Responsibilities
Andrew Hansen	P.I.	Overall coordination; Indicators and ecosystem boundaries; Habitat modeling
Scott Goetz	Co-P.I.	Land cover and use analysis; Hydrology modeling
John Gross	Co-P.I.	Coordination with NPS I&M; Benchmarking and performance standards; Integration of results into management
David Theobald	Co-P.I.	Land cover and use modeling; Land cover and use analysis; GIS tools with ModelBuilder
Forrest Melton	Co-P.I.	Data interface with TOPS; Climate modeling; NPP and hydrology modeling
Rama Nemani	Co-P.I.	Data interface with TOPS, Climate modeling; NPP and hydrology modeling
Nathan Piekielek	Gr Student	Indicators and ecosystem boundaries; Habitat modeling
Robert Daley	NPS	Integration with Greater Yellowstone Network
Billy Schweiger	NPS	Integration with Rocky Mountain Network
Matthew Marshall	NPS	Integration with Eastern Rivers and Mtns Network
Bill Kuhn	NPS	Integration with Sierra Network
Linda Mutch	NPS	Integration with Sierra Network
Andi Heard	NPS	Integration with Sierra Network

Study Design



Pilot National parks




Hindcast
Nowcast
Forecast
1950
2005
2005
2050
TOPS (Gridded)
Climate
Downscaled-GCMs (point based)
NPP/GPP
Snow
Phenology
Disturbance
SERGM
Home density
SERGM
SLEUTH
Impervious
Visitorsheds
Landscape
spatial pattern
Altered by land use
Altered by land use
Connectivity
Biodiversity
Data/Models
Theme
Data/Products
Theme
Data/Models

Overview

The US NPS Inventory and Monitoring Program is developing scientifically sound information on the status and trends of national park condition. NASA data and products can have potential to enhance the success of the NPS I&M effort. Our goal of the project is to integrate the routine acquisition and analysis of NASA products and other data into the NPS I&M Program.

Objectives and status:

Objective 1. Identify NASA and other products useful to park monitoring

- Products list finalized through workshops with NPS

Objective 2. Delineate the boundaries of the protected area centered ecosystems appropriate for monitoring.

- Methods were developed and deployed for 12 national parks
- Draft boundaries were reviewed twice by NPS
- Final boundaries were completed
- A manuscript has been reviewed by NPS and is now nearly ready for submission for publication.

Objective 3. Add value to these data sets for understanding change through analysis and forecasting.

-The majority of products are completed.

-Remaining products and analyses are scheduled for completion in May 2010

Objective 4. Deliver these products and a means to integrate them into the NPS I&M decision support framework.

-Methods are being prepared as NPS Standard Operating Procedures.

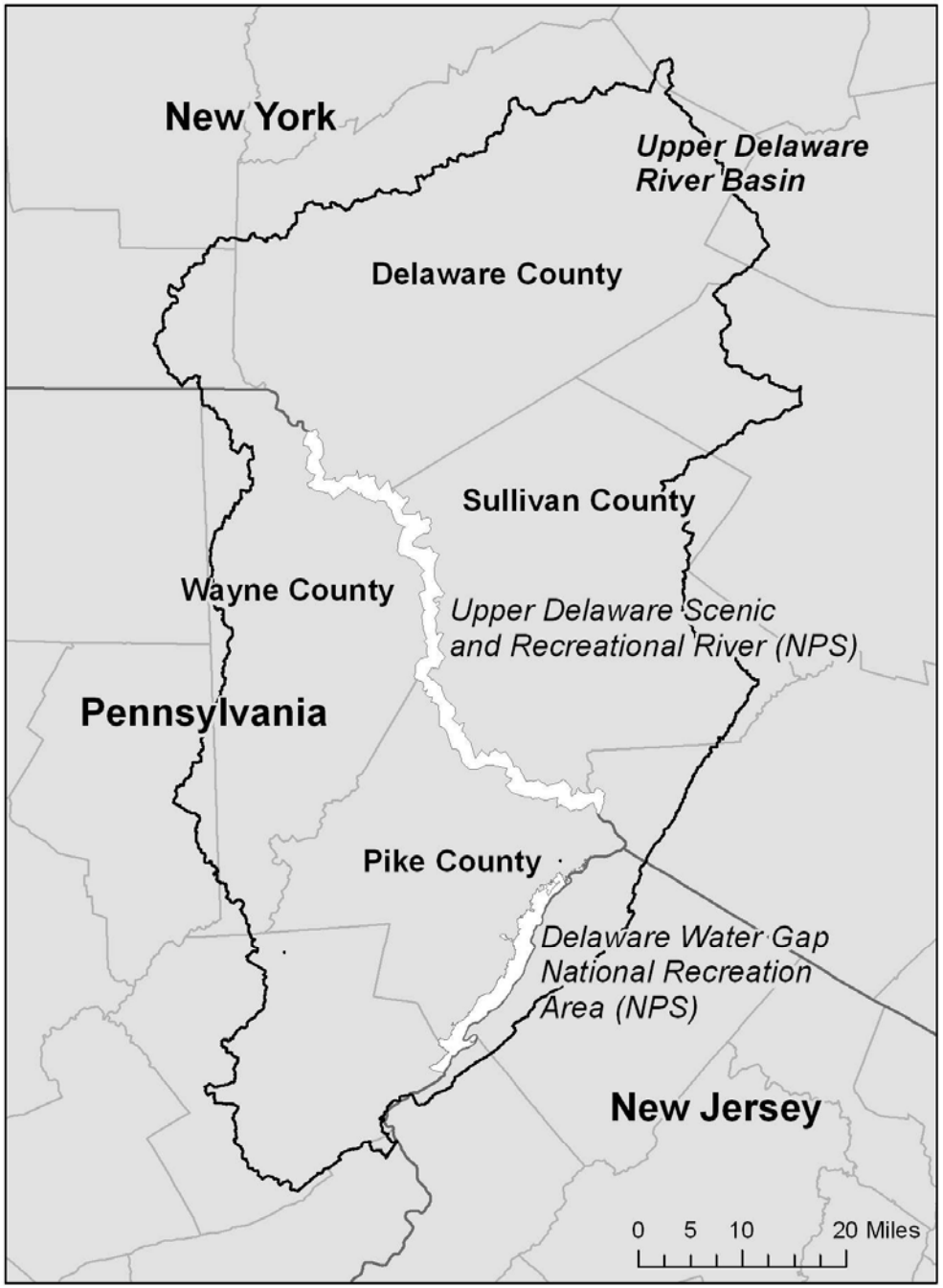
-Data will be compiled and described within an ARC GIS geodata base.

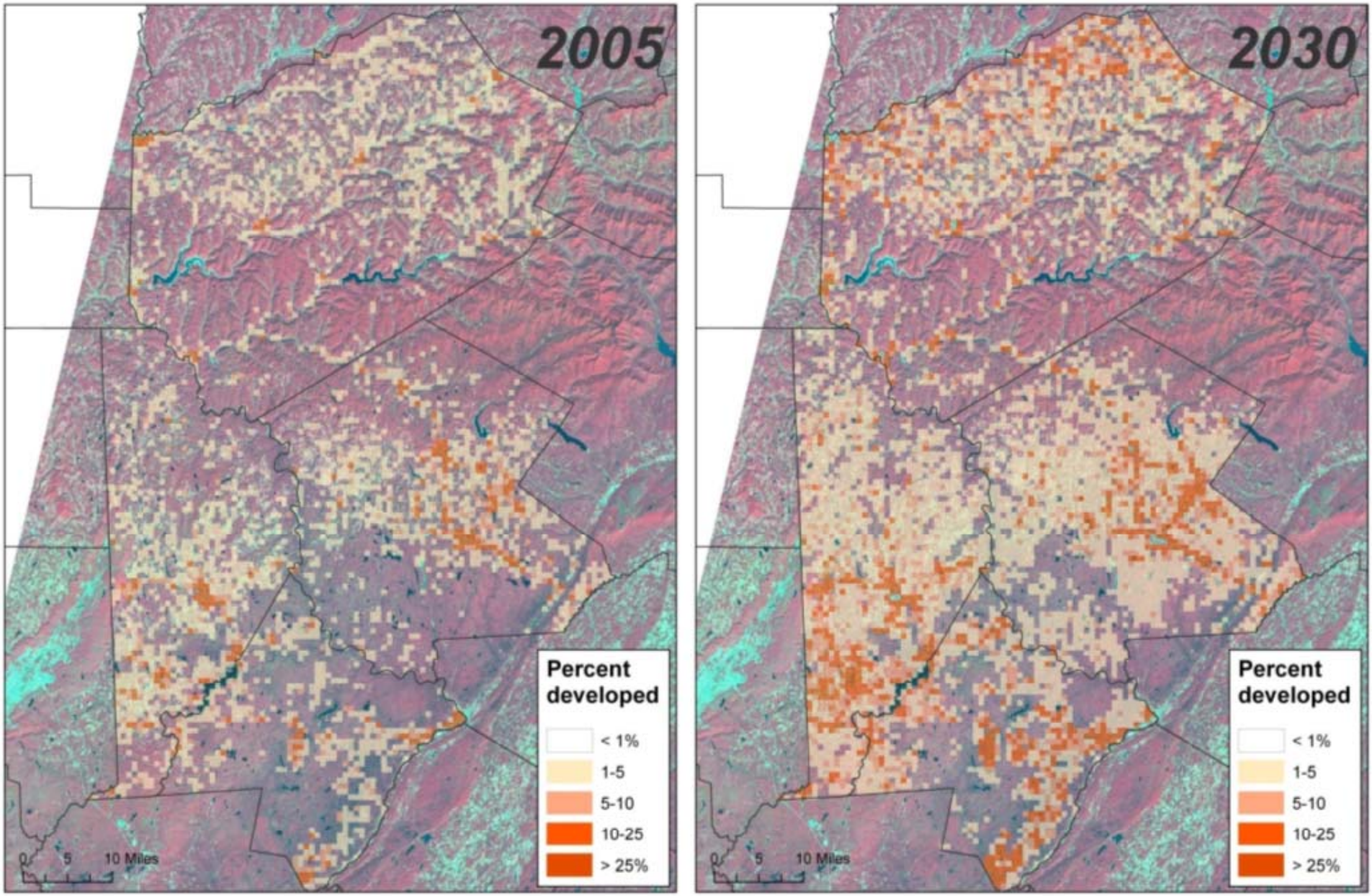
-A series of three conference calls will be held with NPS I&M and NPS staff April to September 2010 to review, interpret, and finalize the results.

-Summary documents will use the results to communicate “stories” about condition and trends in the parks and surrounding areas.

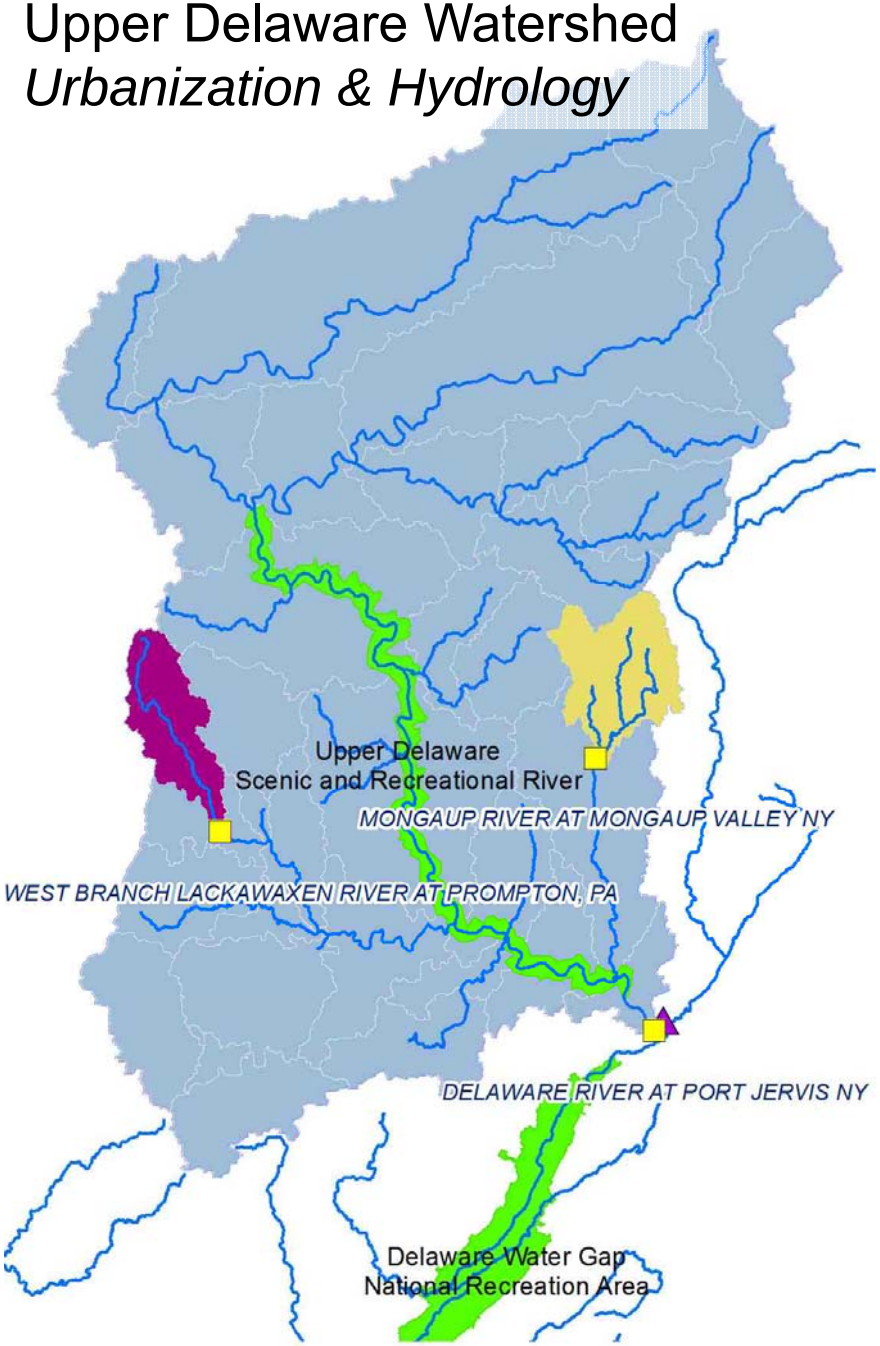
-SOPS, the Geodatabase, summary reports of results, and publications will be delivered through the NPS I&M National Office and through the internet browser ECOCAST.

- A final survey of the NPS I&M collaborators will be used as the basis for a final report to NASA.


New York
Upper Delaware River Basin
Delaware County
Sullivan County
Wayne County
Upper Delaware Scenic and Recreational River (NPS)
Pennsylvania
Pike County
Delaware Water Gap National Recreation Area (NPS)
New Jersey
0 5 10 20 Miles


2005
Percent developed
< 1%
1-5
5-10
10-25
> 25%
0 5 10 Miles
2030
Percent developed
< 1%
1-5
5-10
10-25
> 25%
0 5 10 Miles

Upper Delaware Watershed
Urbanization & Hydrology

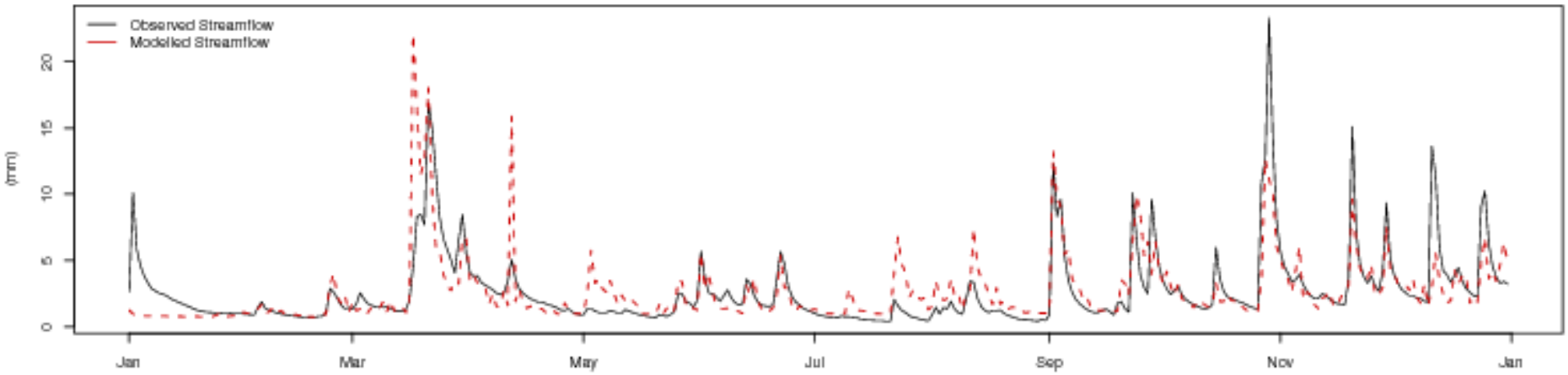


USGS Flow Gage
Met Station
Streams
National Park Service
Mongaup Basin
Prompton Basin
Sub-basin delineation
Port Jervis Basin

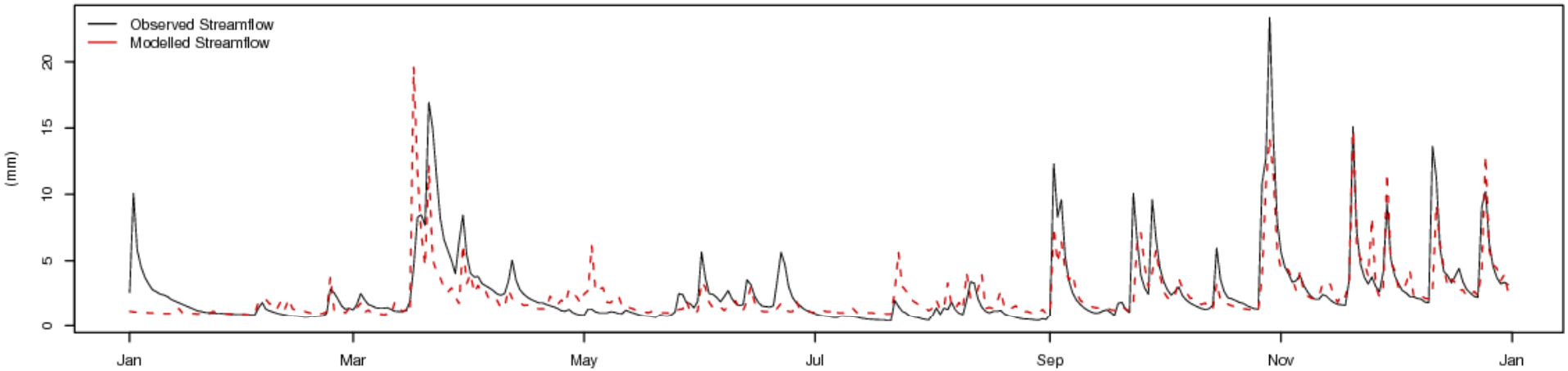
0 5 10 20 Miles

Calibration of RHESSys Model (Prompton basin)

Regional Hydro-Ecologic Simulation System

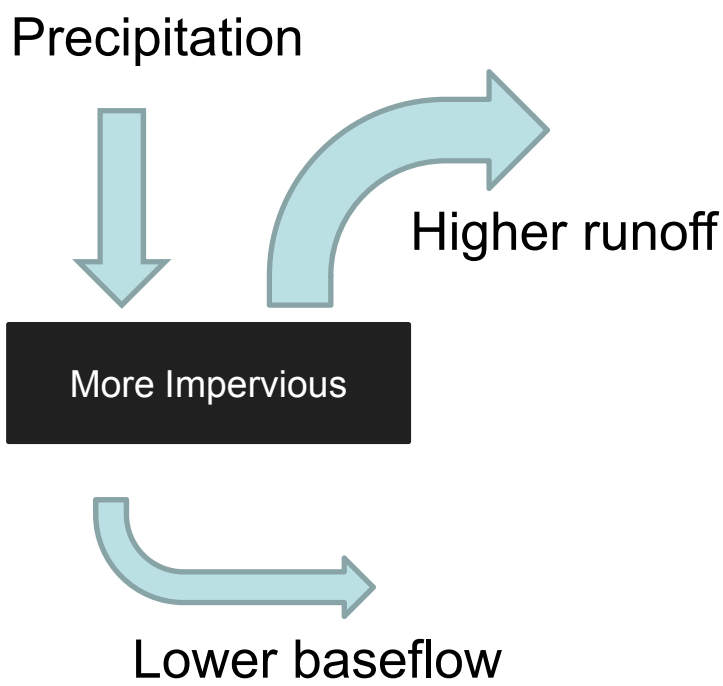


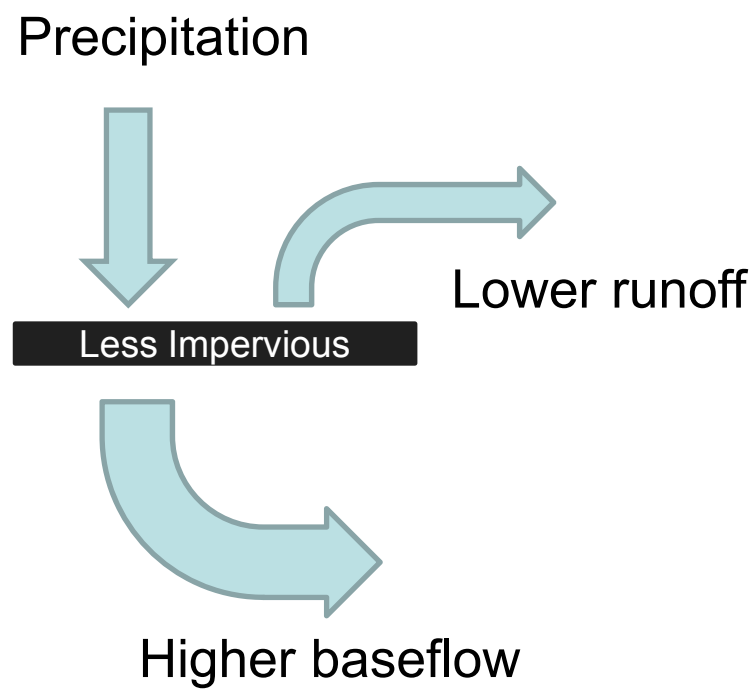
Testing Calibrated Model (Mongaup basin)



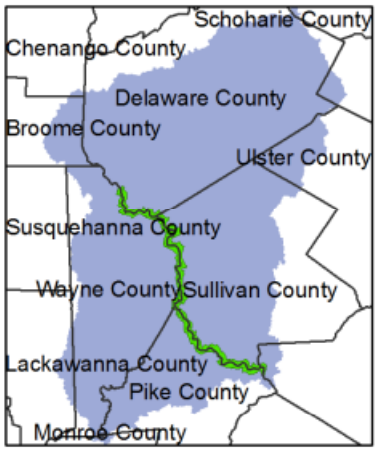
Modeling Impacts of peri-urbanization on Streams

Impervious cover affects both the hydraulic conductivity (how much) and flow routing (where to).

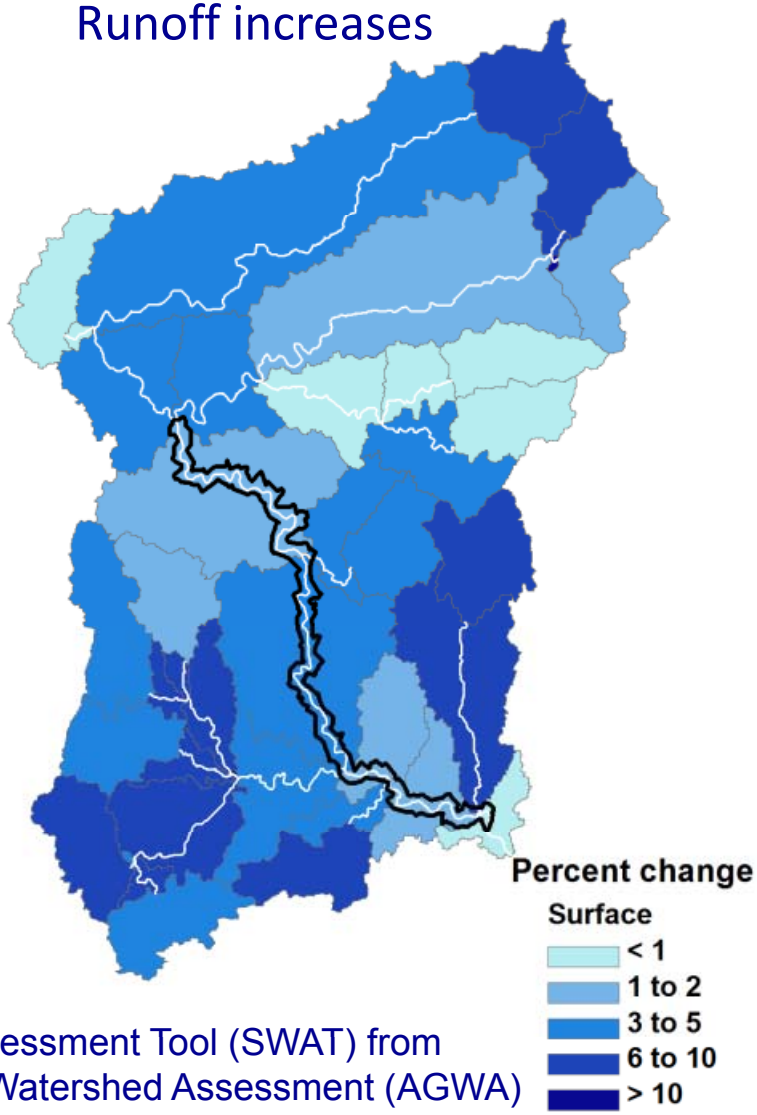




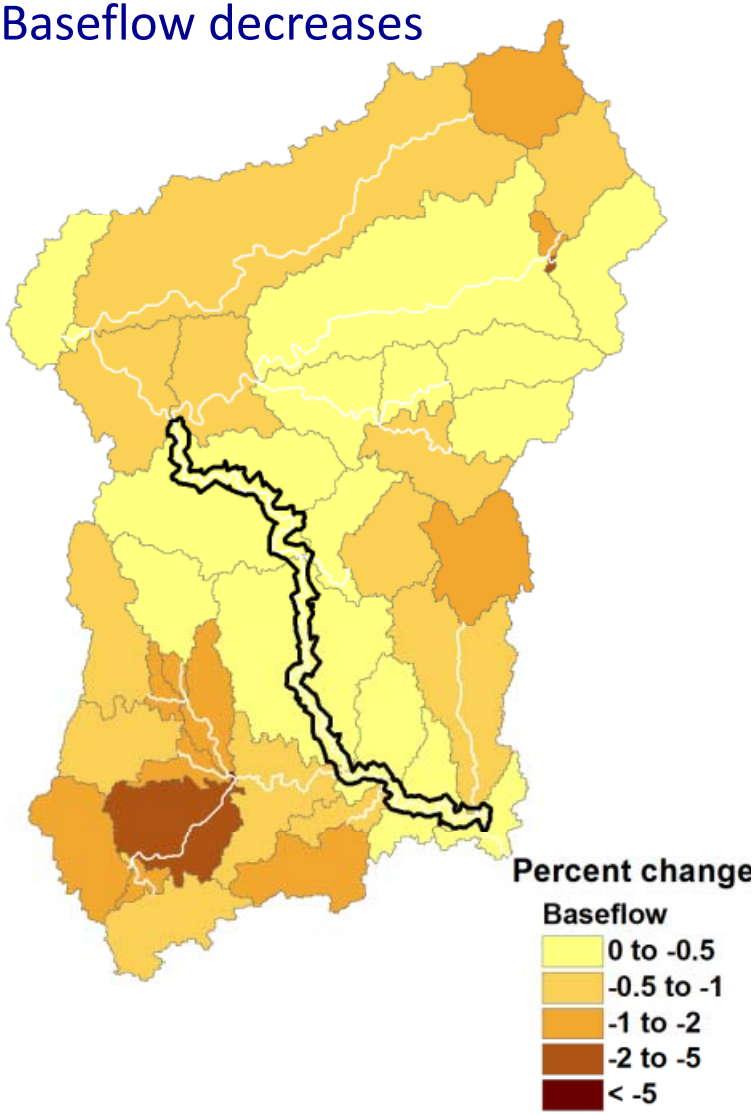
Predicted Hydrologic Change under Future High Urban Growth Scenario



Runoff increases

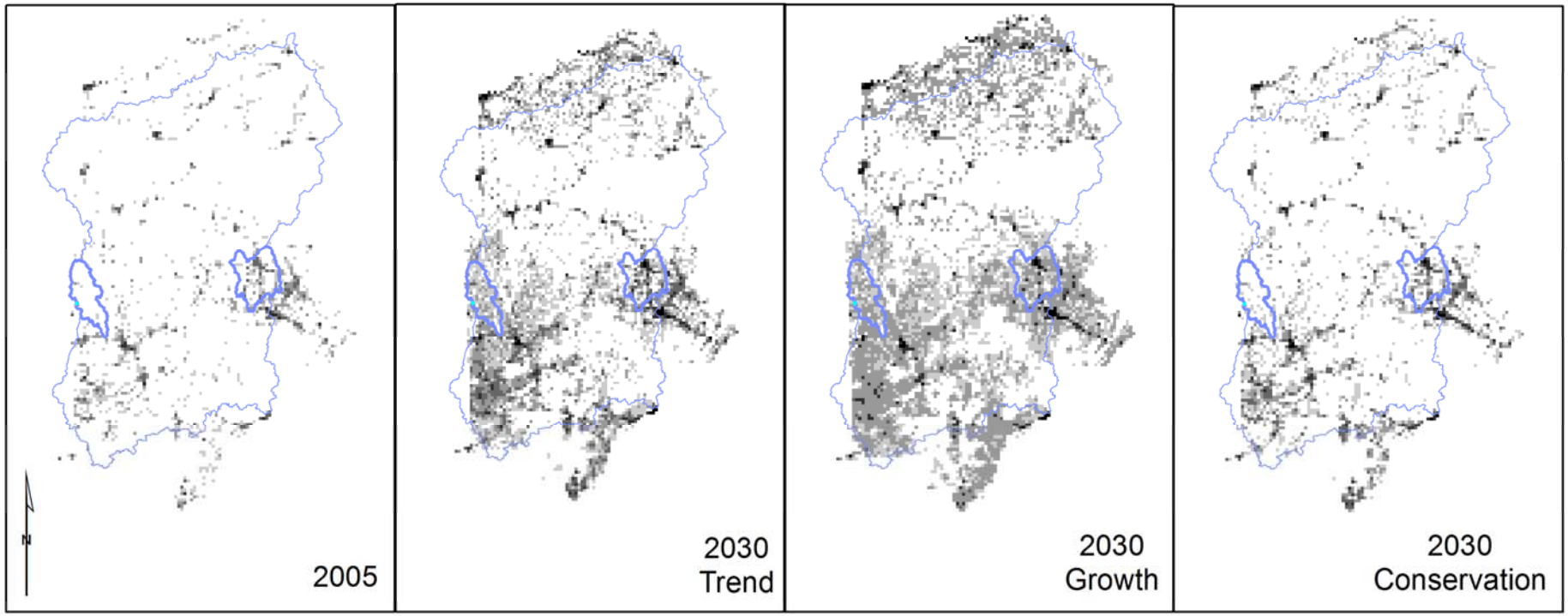


Baseflow decreases



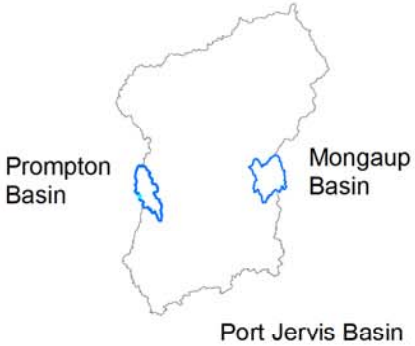
Soil and Water Assessment Tool (SWAT) from
Automated Geospatial Watershed Assessment (AGWA)

Current & Future Urbanization - Upper Delaware Watershed

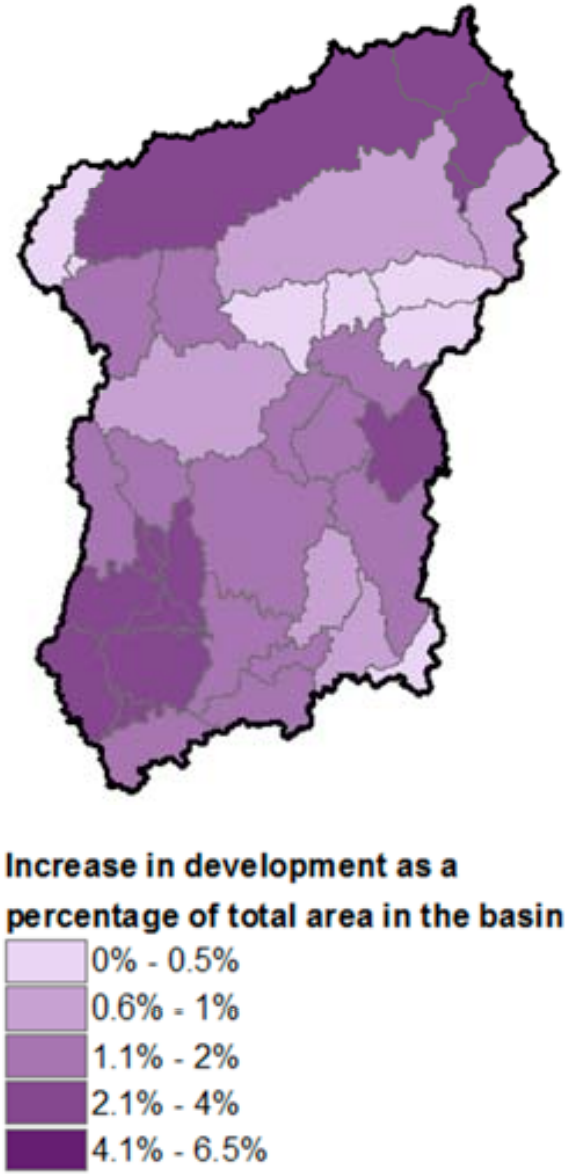


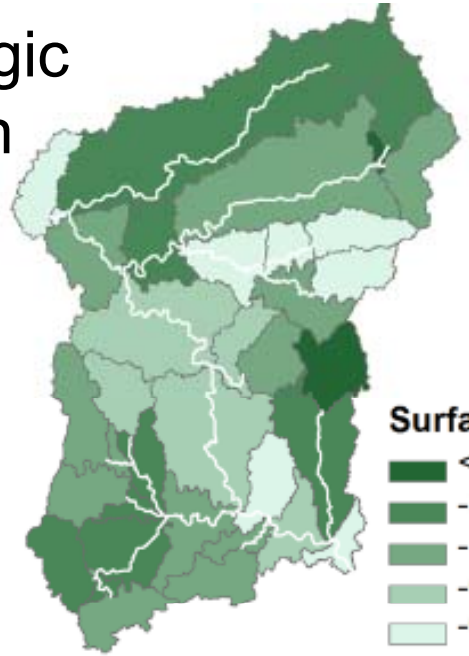
0 10 20 40 60 Kilometers

Percent urban
land within
1 km x 1 km cells

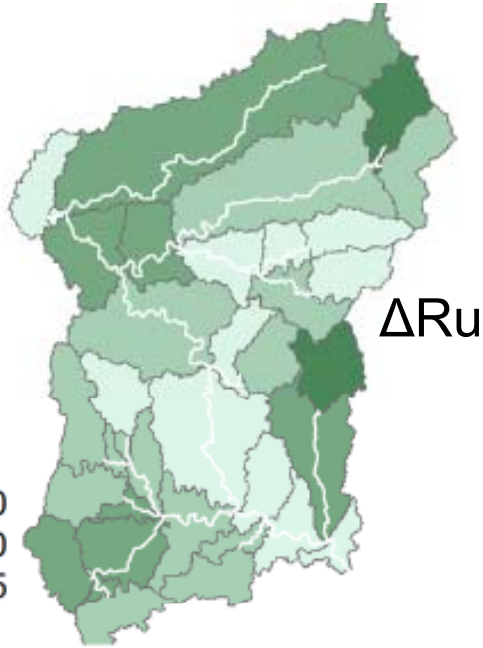


Modeling Future Hydrologic Impacts of Urbanization





Conservation – Growth

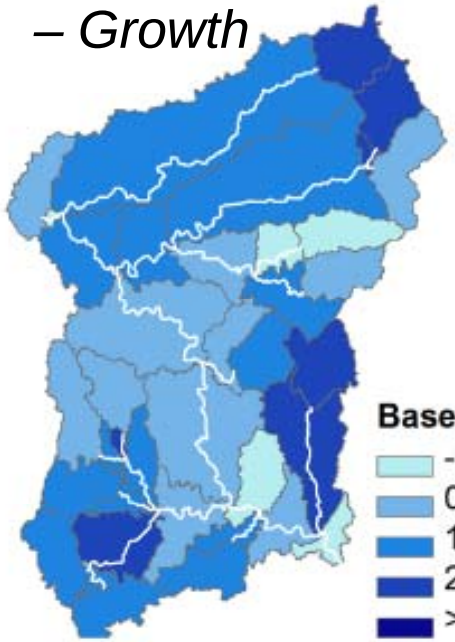


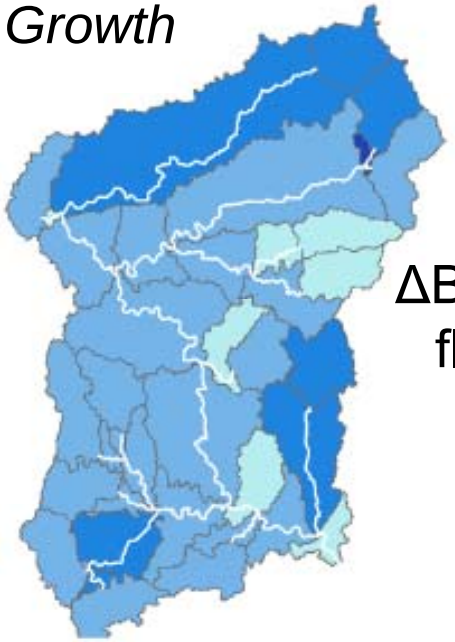
Current Trend – Growth

ΔRunoff

Surface

- <= -4.0
- -3.9 - -2.0
- -1.9 - -1.0
- -0.9 - -0.5
- -0.4 - 0.0

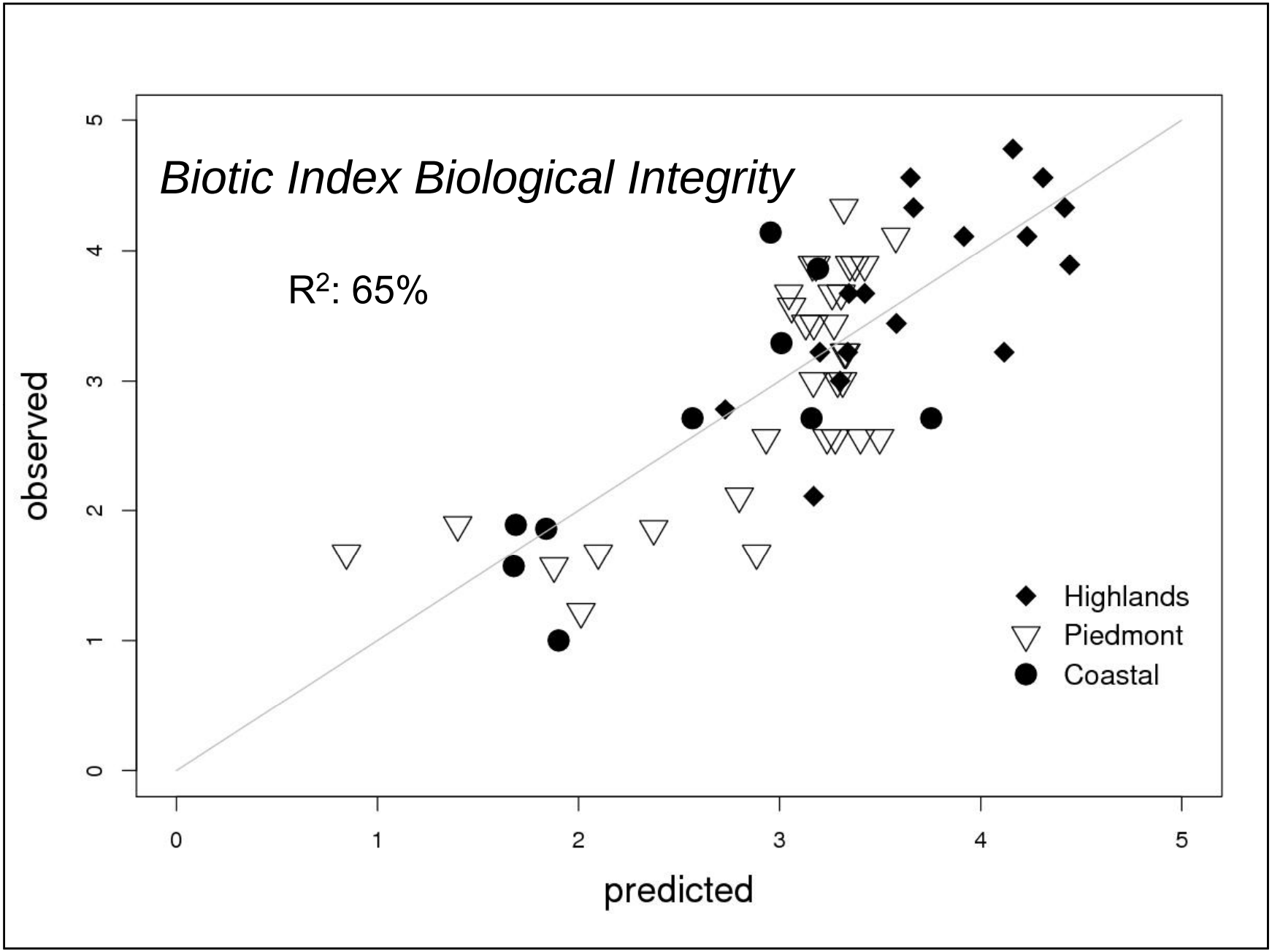




ΔBase-flow

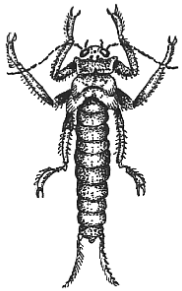
Baseflow

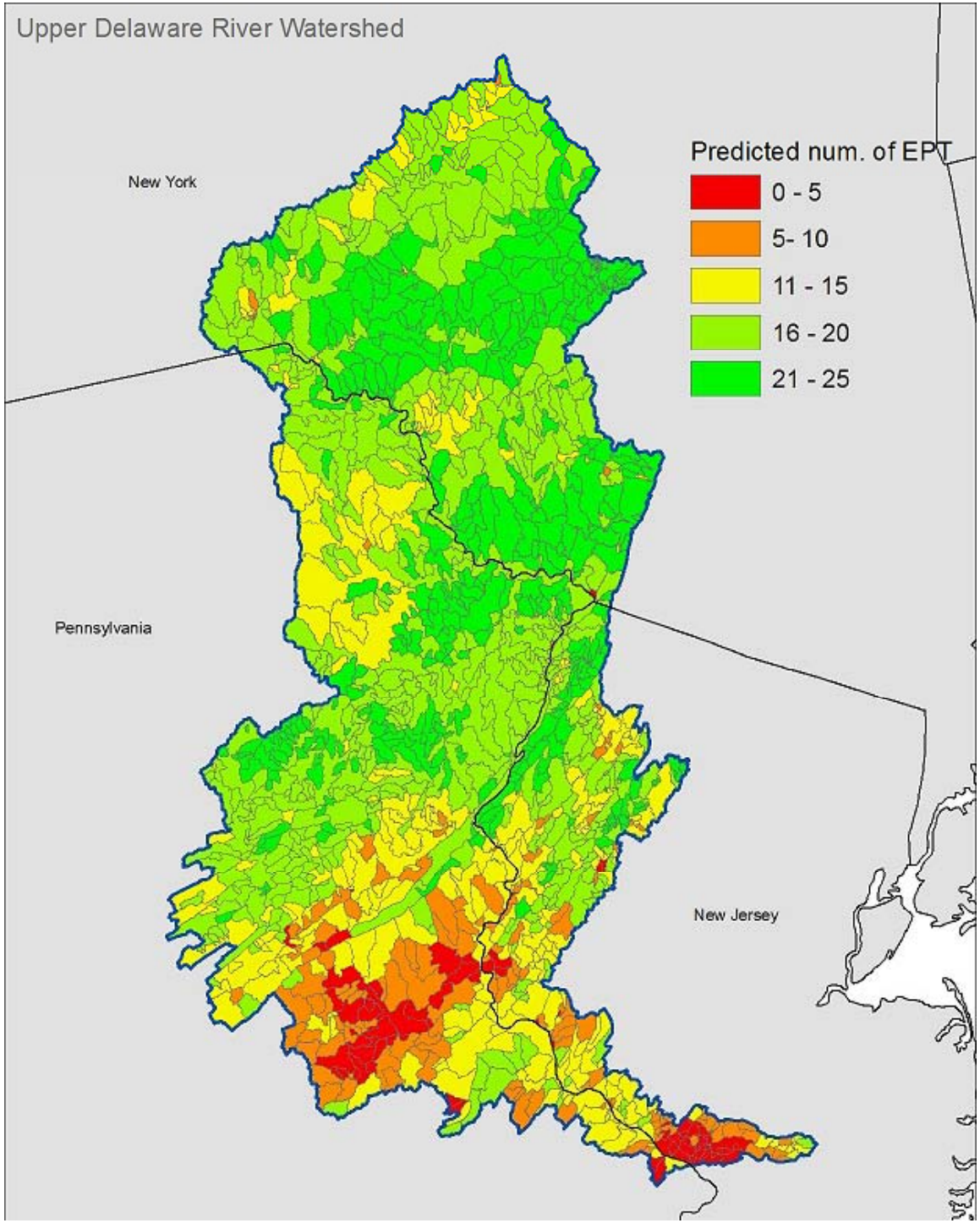
- -0.2 - 0.1
- 0.2 - 1.0
- 1.1 - 2.0
- 2.1 - 5.0
- > 5


Biotic Index Biological Integrity
R2: 65%
observed
predicted
0
1
2
3
4
5
Highlands
Piedmont
Coastal

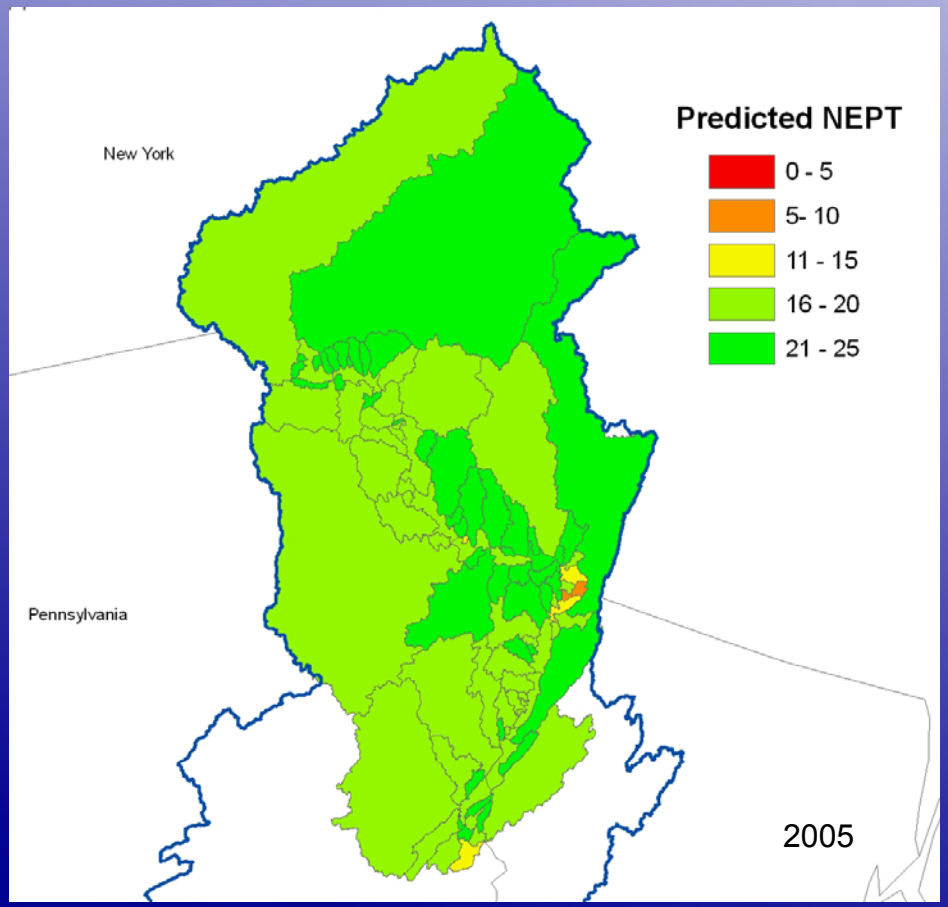
Predicted Richness of Sensitive Taxa (benthic) for small watersheds encompassing the Upper Delaware & Delaware Water Gap Parks

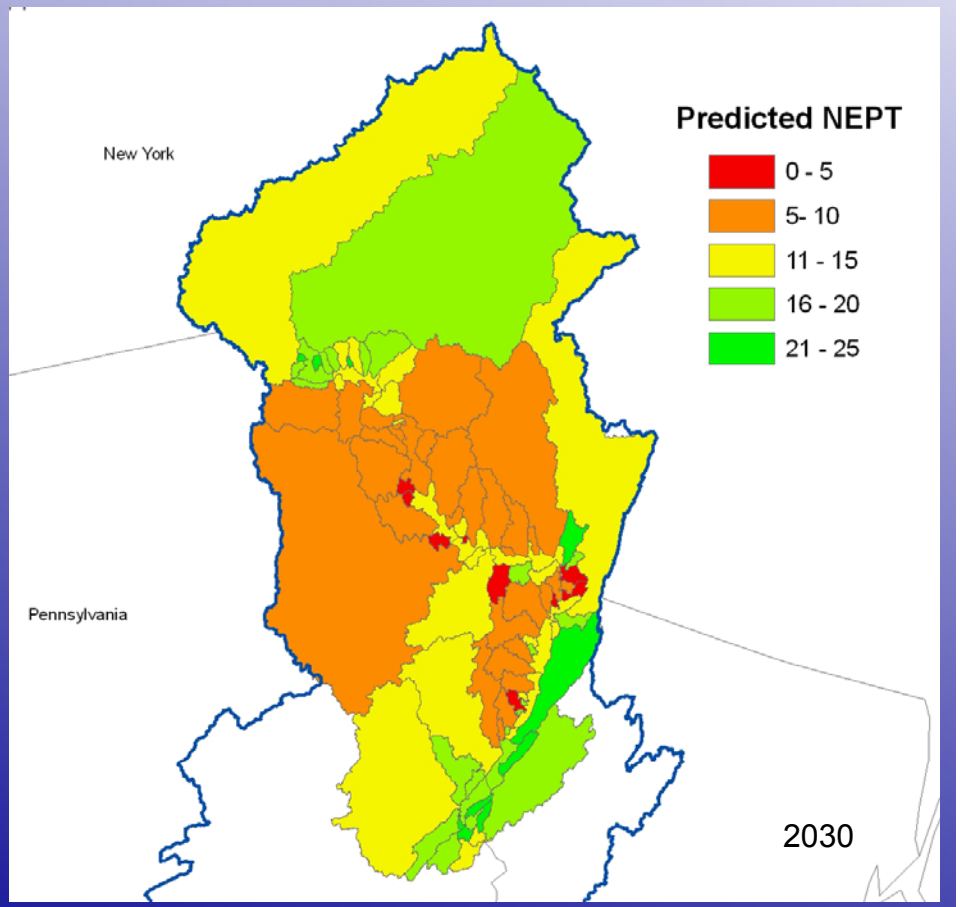
Red = low / bad
Green = high / good





Future Predictions of the Richness of Sensitive Taxa in 2030 under “Growth” Scenario

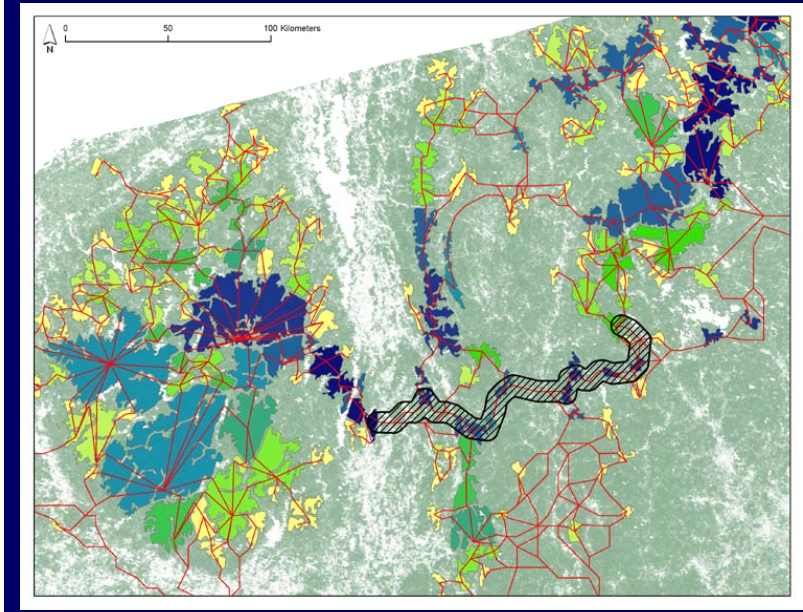




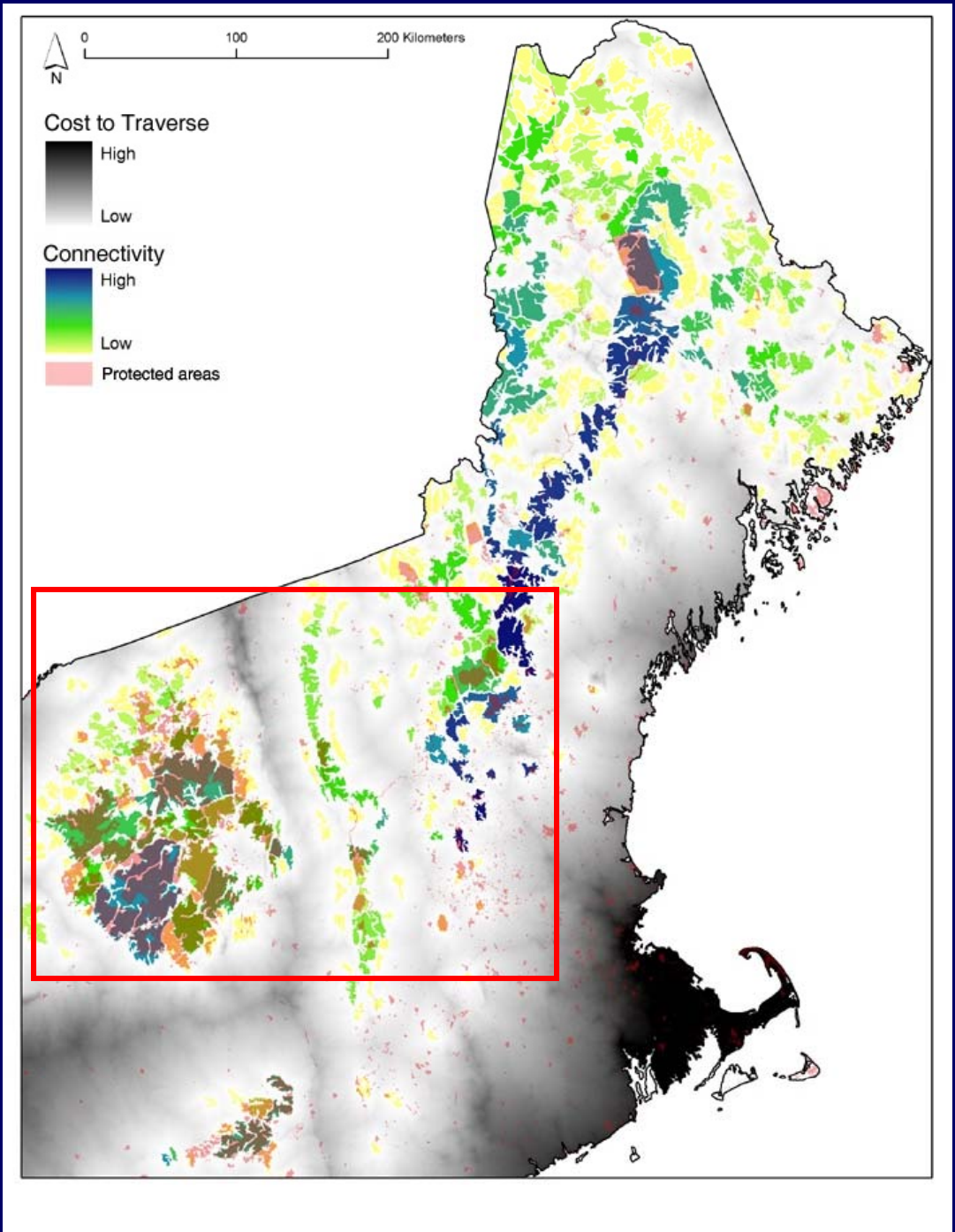
Red = low / bad
Green = high / good

THE WOODS HOLE RESEARCH CENTER

Habitat Connectivity across the Northeastern United States

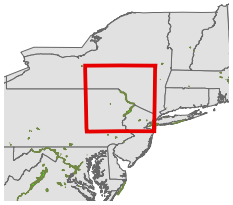


Connectivity and Patch habitat importance change as ***urbanization*** expands and ***climate change*** alters habitat suitability..



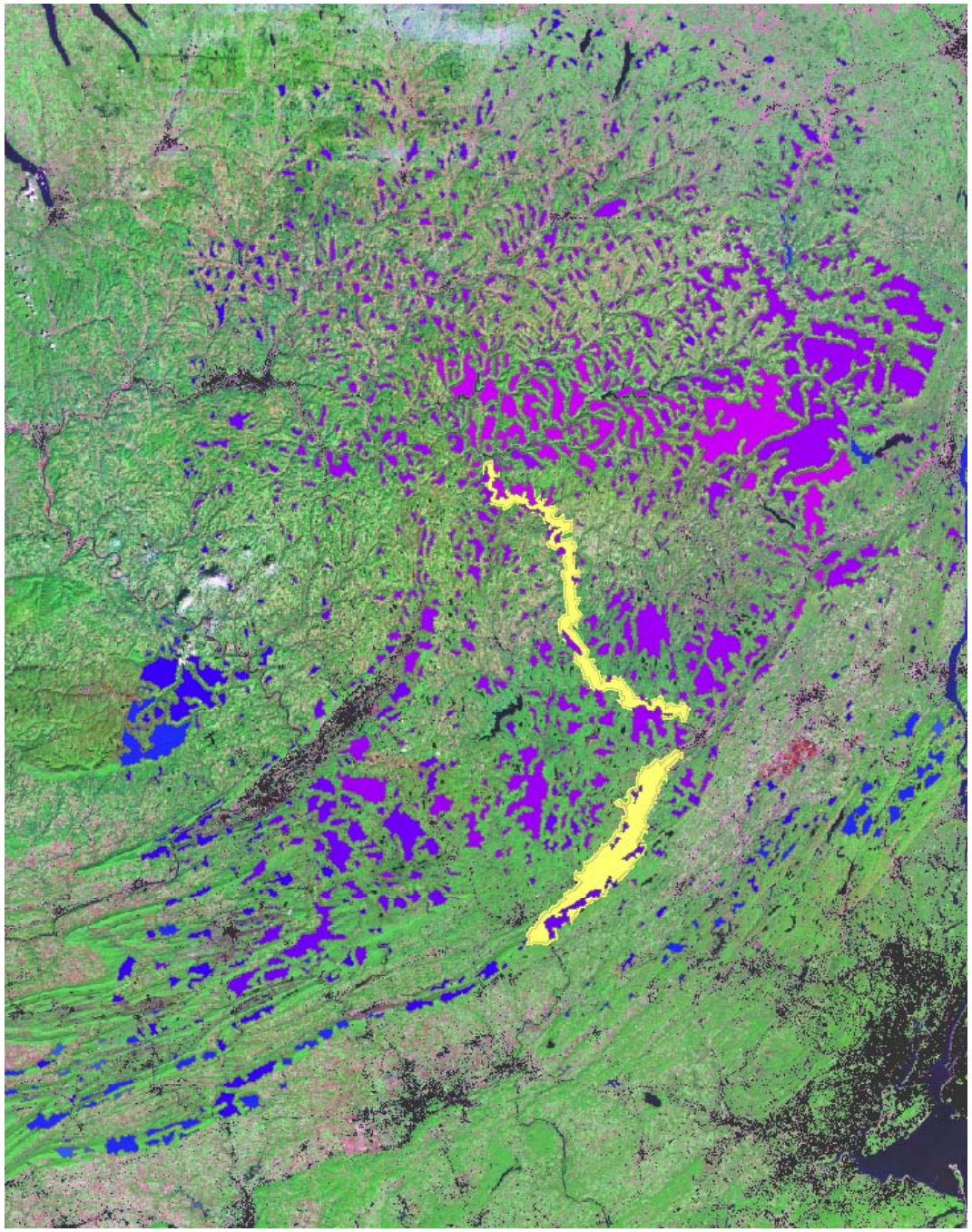
Connectivity of Core Habitat Areas around UPDE / DEWA

Connectivity and Patch habitat importance change as residential development expands..



Patch Connectivity

- 0.02 - 0.10
- 0.11 - 0.20
- 0.21 - 0.30
- 0.31 - 0.40
- 0.41 - 0.50
- 0.51 - 0.60
- 0.61 - 0.70
- 0.71 - 0.80
- 0.81 - 0.90
- 0.91 - 1.00
- Delaware River parks



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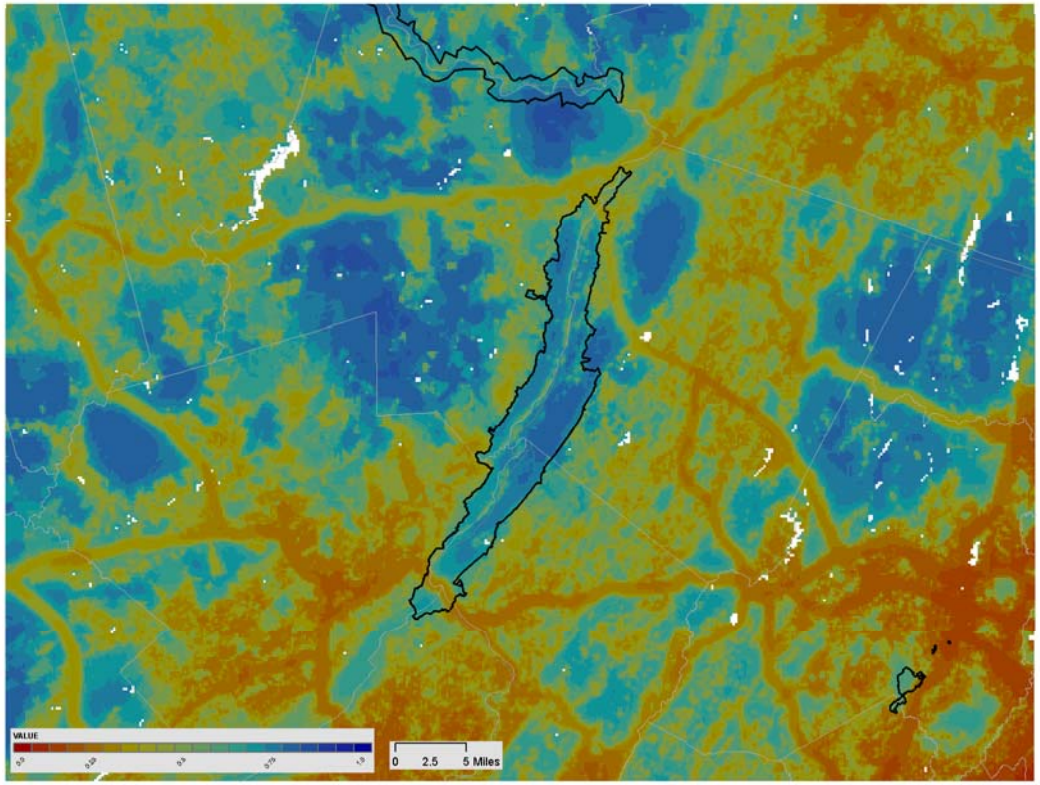
Landscape dynamics: Pattern of natural landscapes

What: Measures the natural landscape context

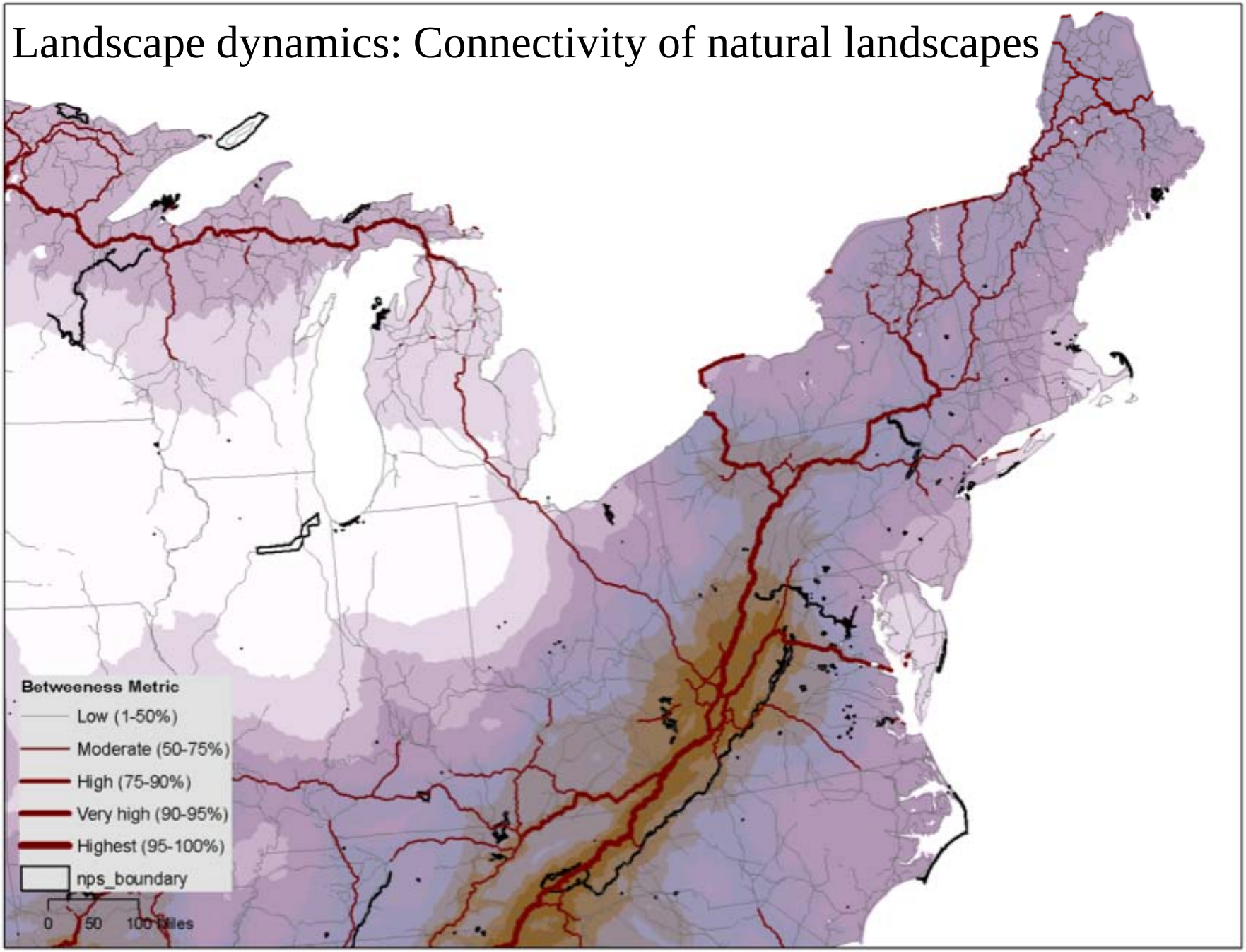
Why: Movement of plants & animals and ecological processes connect to adjacent landscapes beyond the park boundary

Stressors: Land use change, climate change

DEWA scores higher than its ecoregion, but is declining from 0.6811 in 1992 to 0.6631 in 2001 to 0.6123 in 2030.



Landscape dynamics: Connectivity of natural landscapes



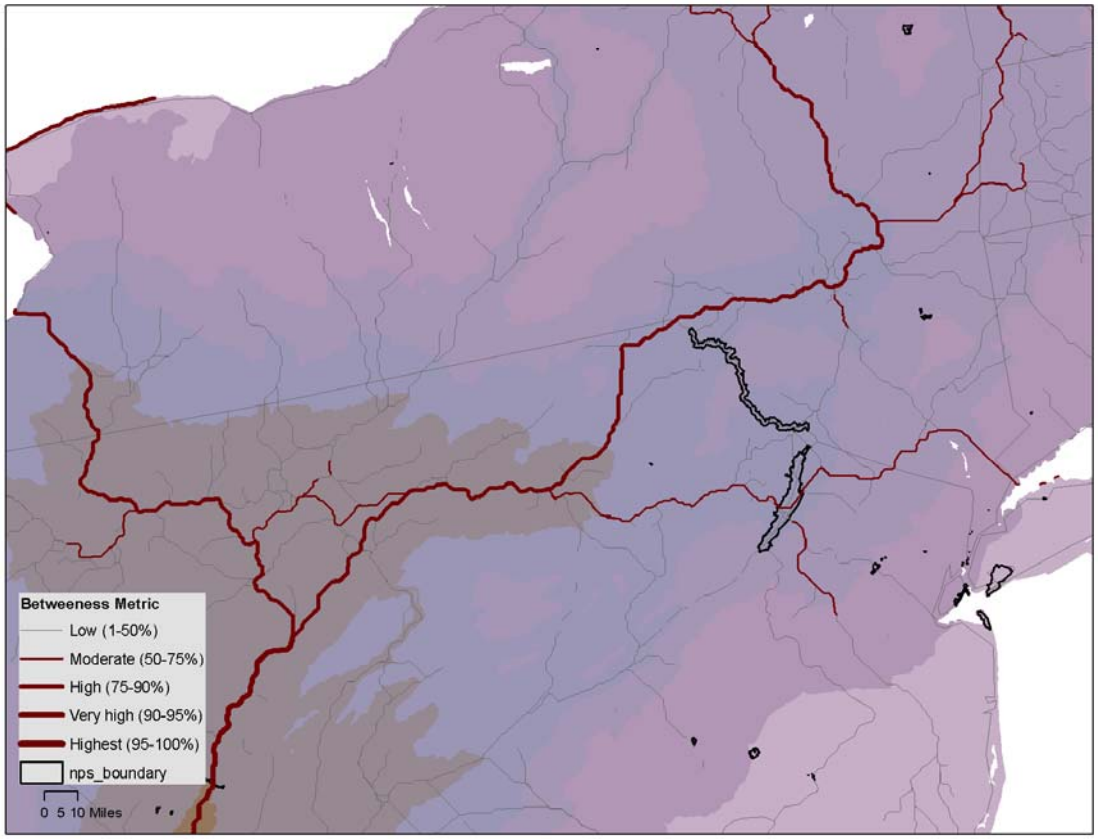
Landscape dynamics: Connectivity of natural landscapes

What: Measures the connectivity of natural landscapes

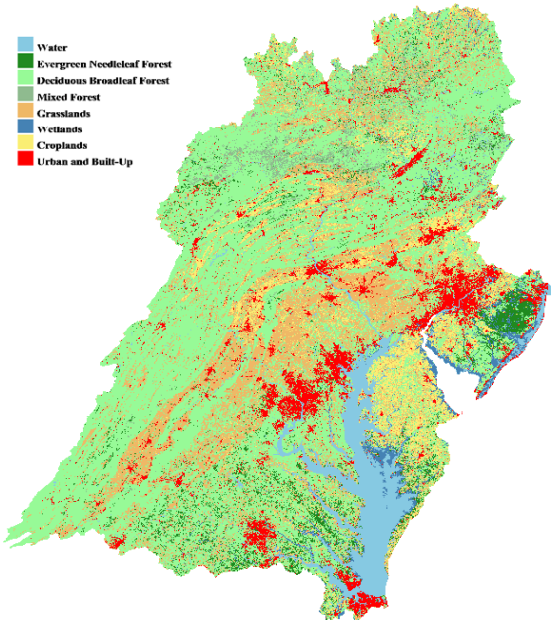
Why: Movement of plants & animals and ecological processes connect to adjacent landscapes beyond the park boundary

Stressors: Land use change, climate change

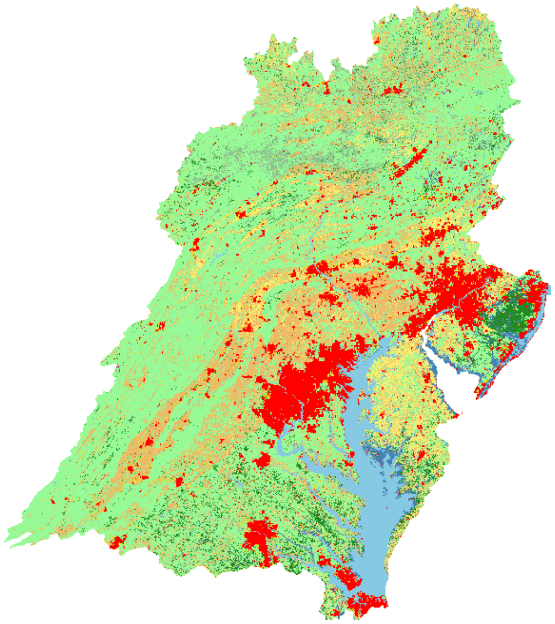
DEWA is situated along a minor pathway that provides greater than average connectivity (compared nationwide) and serves as a key location of connectivity to a major corridor along the Appalachians.



Assessing Impacts of Land Use Change

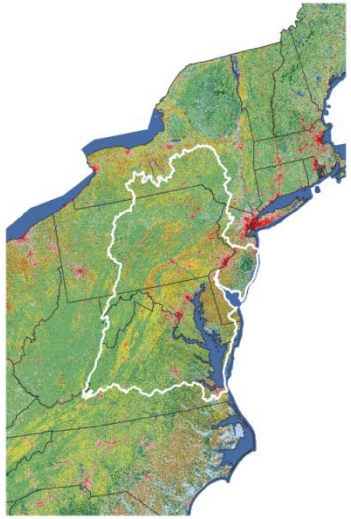


Baseline (2000)



Forecast (2030)

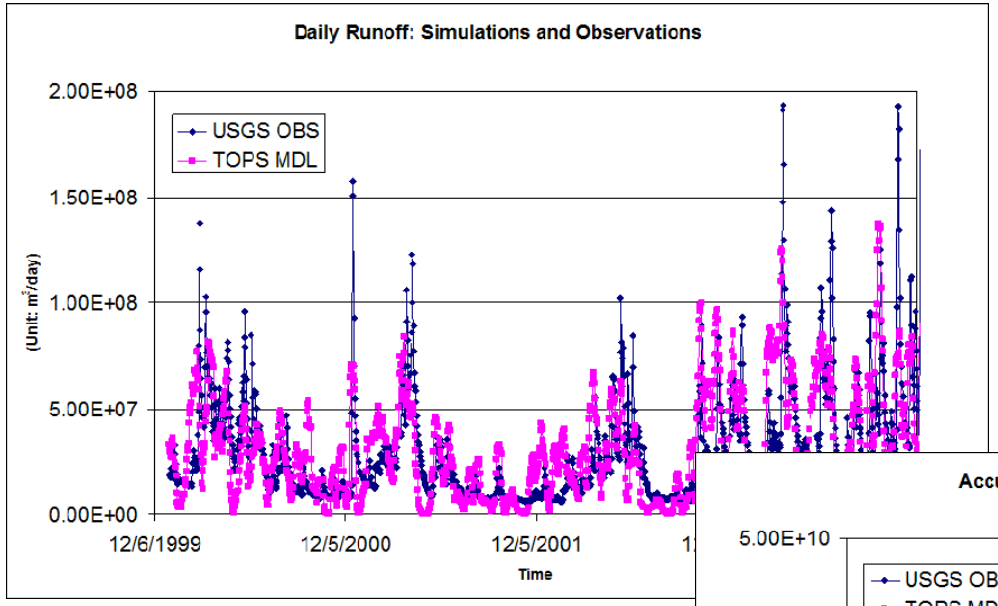
Increase in urban land cover (shown in red) from 2000 to 2030. The 2000 map is derived from the NLCD 2001 data, and the 2030 map is derived from SERGoM estimates using a threshold for impervious surface area of 10% to delineate urban areas.



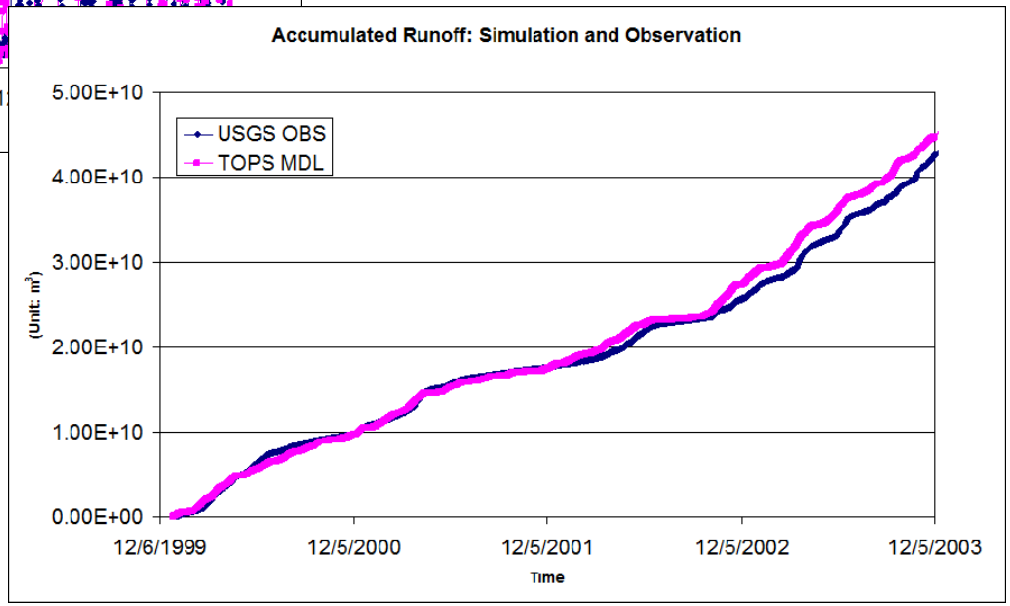
Study Area

Application of TOPS to assess combined impacts of climate and land use change on ecosystem hydrology and productivity, and the potential for land use planning and urban BMPs to mitigate impacts.

Assessing Impacts of Land Use Change

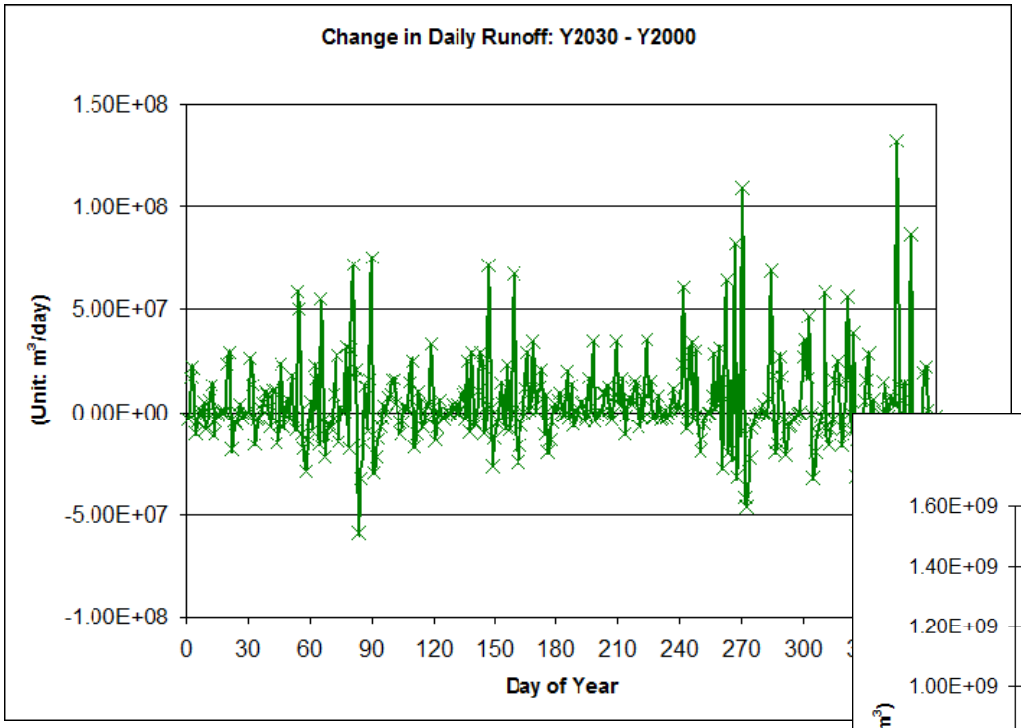


Initial results of study using TOPS to examine climate and land use change impacts in the Chesapeake and Delaware watersheds. Results shown do not include potential climate change impacts.

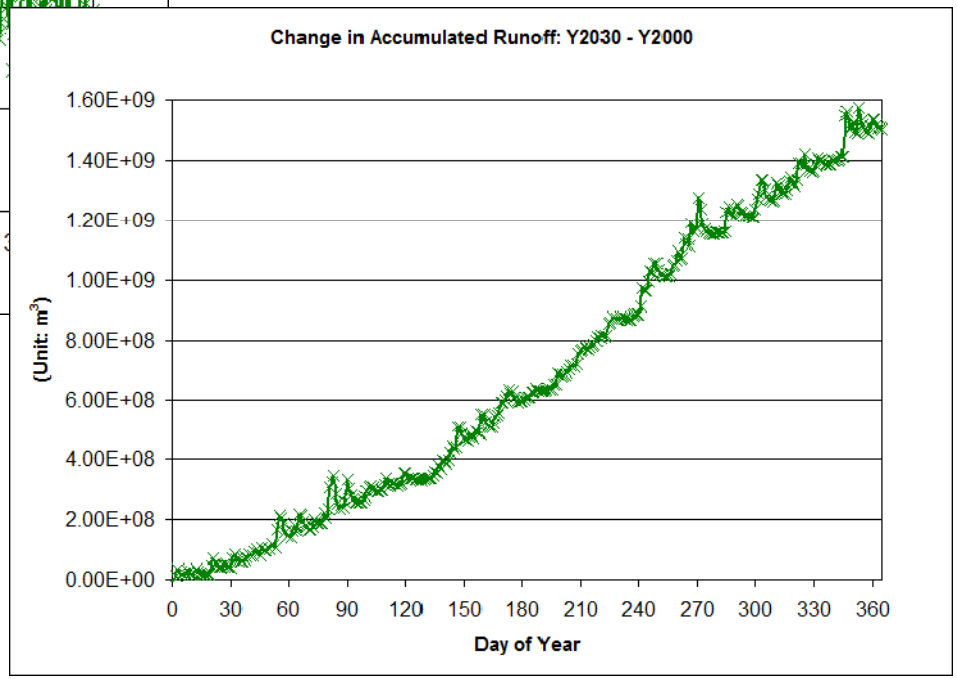


Comparison of predicted daily (above) and cumulative runoff (right) from TOPS against observed runoff from the USGS stream gauge at Trenton for 2000-2003.

Impacts of Land Use Change on Runoff

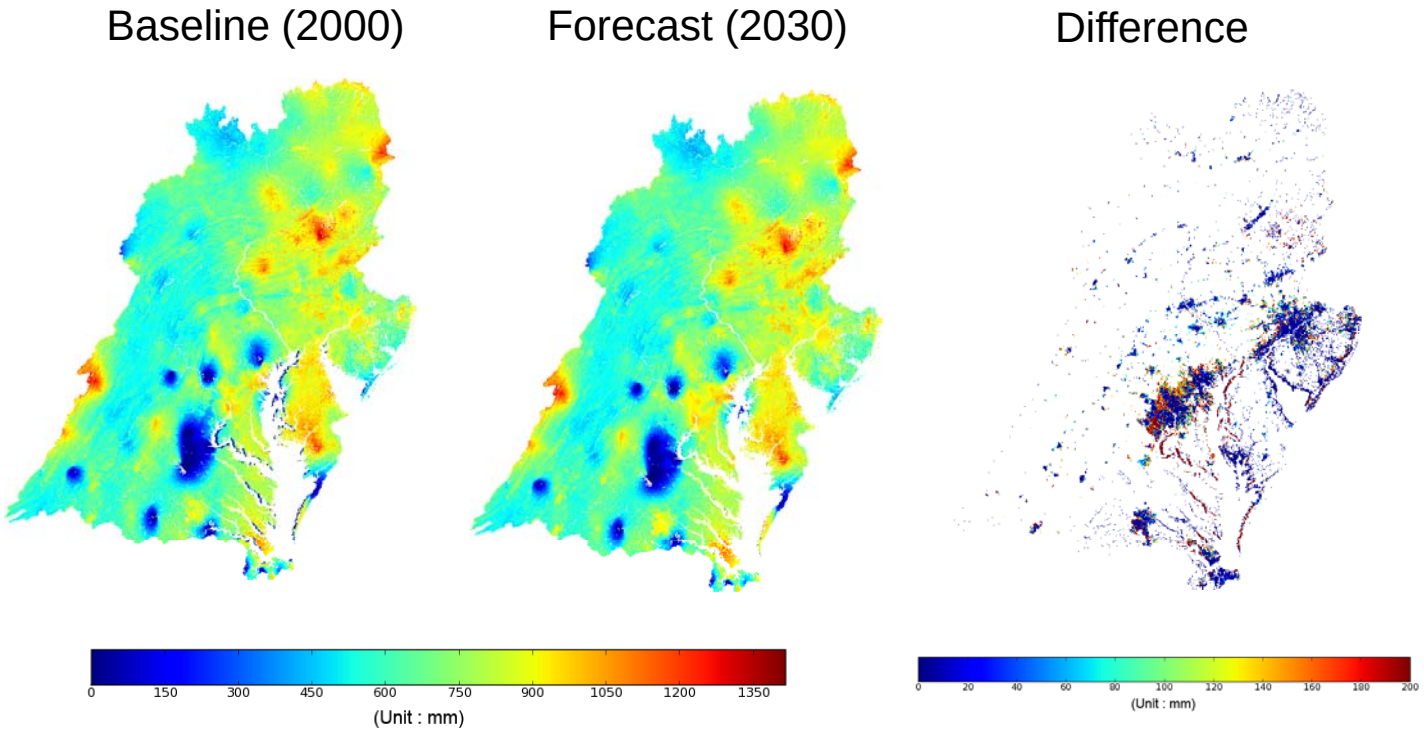


Potential for increases in runoff per storm event of up to 15% over baseline (2000).



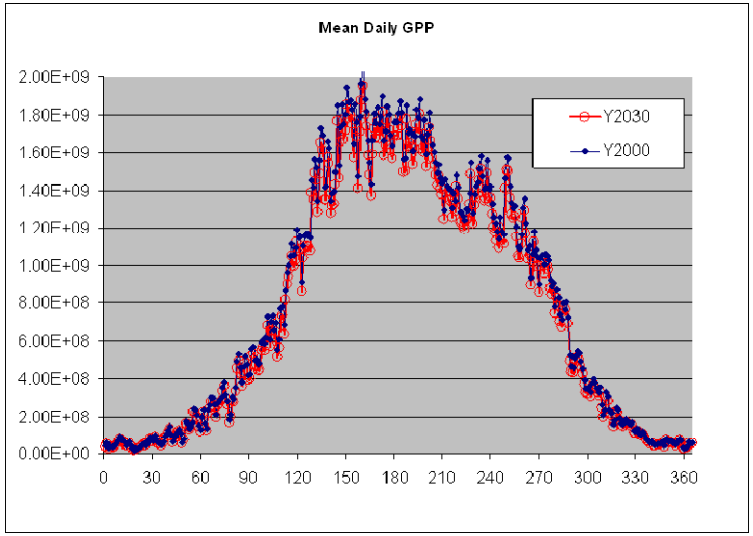
The cumulative change in total runoff for the forecast (2030) versus the baseline (2000) scenarios. Total estimated increase in runoff of approximately 1% over the baseline.

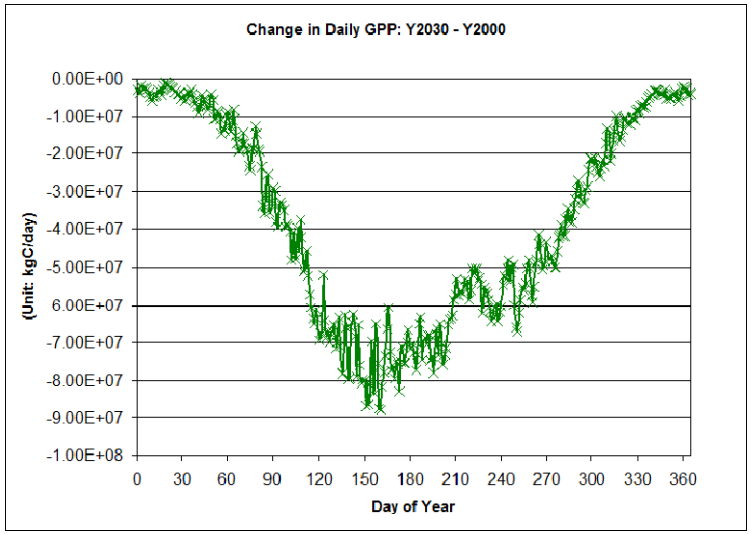
Impacts of Land Use Change on Runoff

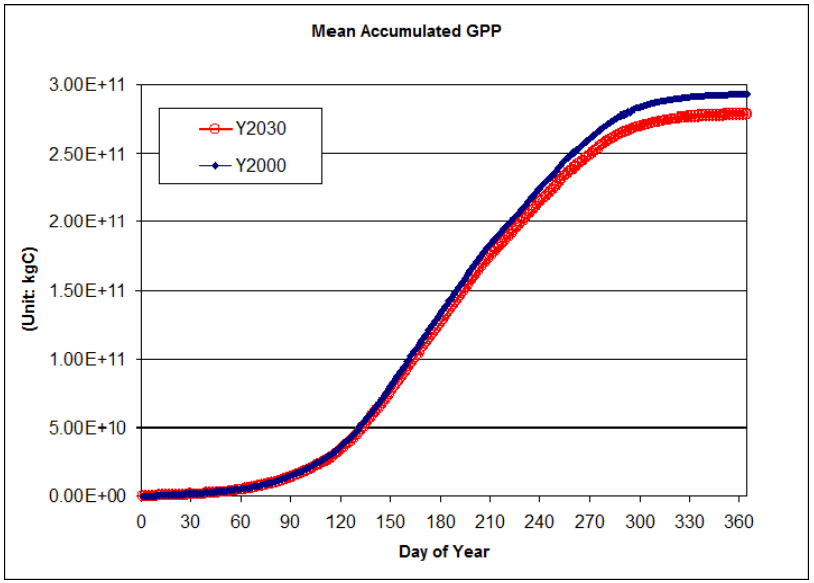


The average annual total runoff for the baseline (2000) and forecast (2030) scenarios, and the projected increase in average annual runoff, expressed in depth of water in mm.

Assessing Impacts of Land Use Change on Productivity



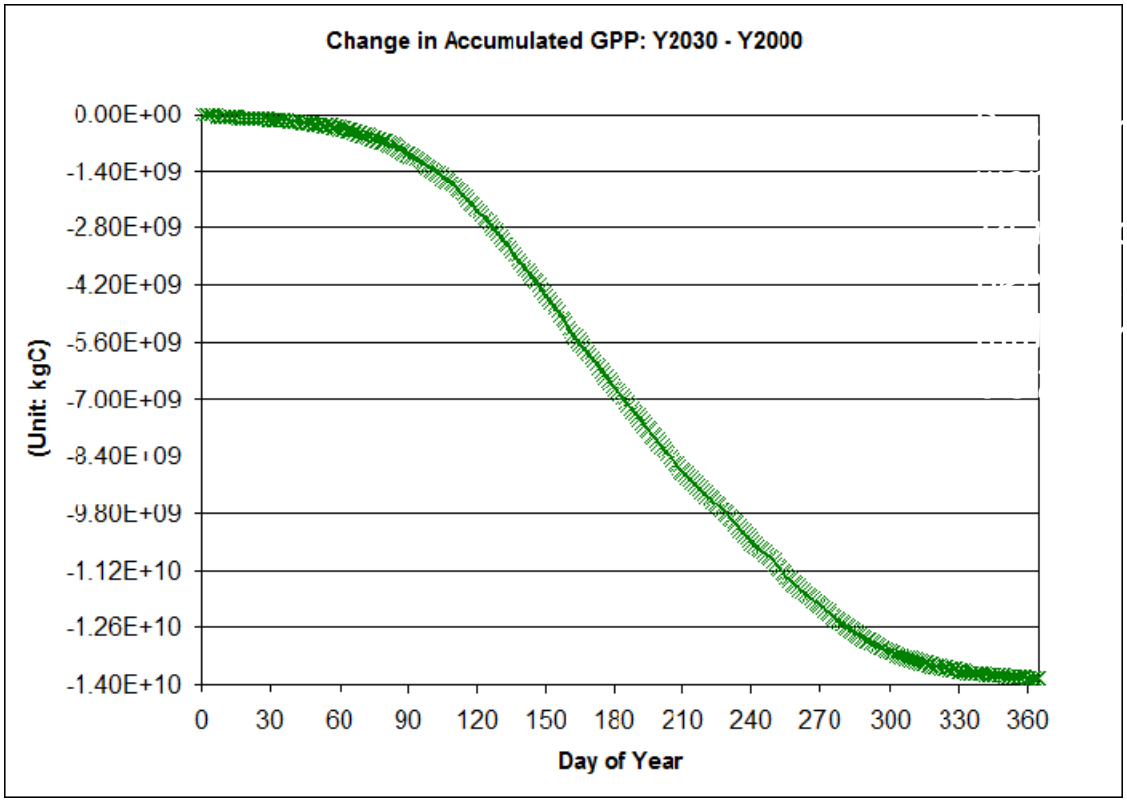




Forecasted average cumulative GPP over the four year simulation periods. Average cumulative GPP for the study region for both the baseline (2000) and forecast (2030) scenarios.

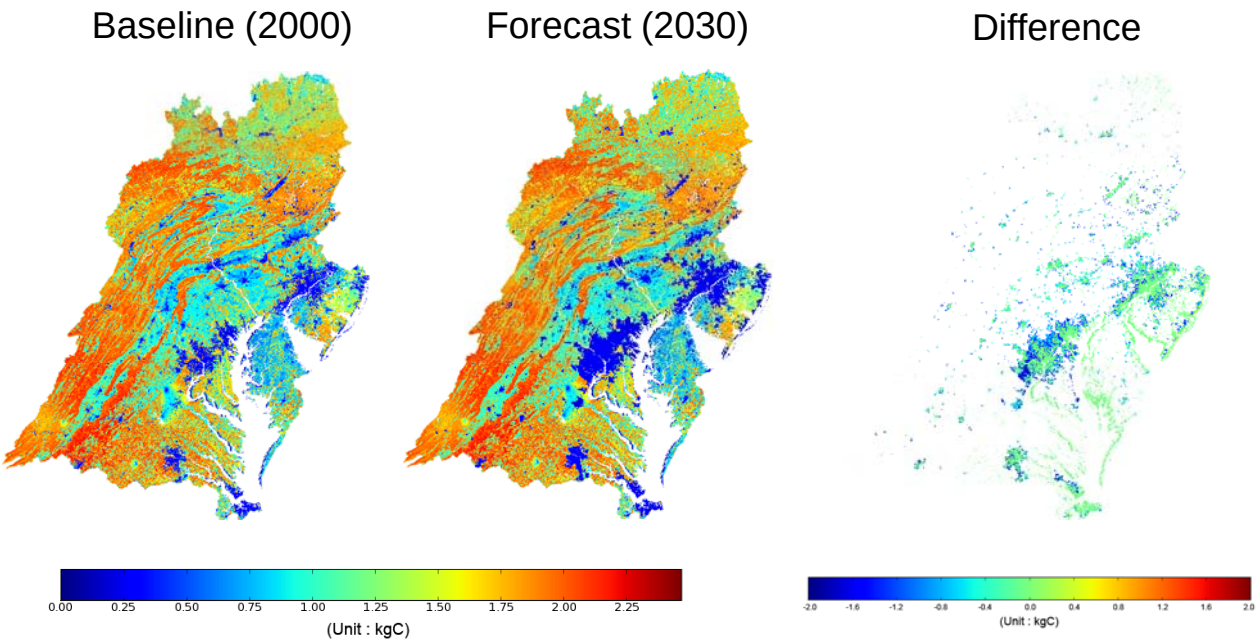
Forecasted change in average daily GPP for the forecast (2030) versus the baseline (2000) period. Units are expressed in kg of carbon per day.

Assessing Impacts of Land Use Change on Productivity



Forecasted change in average cumulative GPP over the four year simulation periods. Under 'worst-case' scenario, potential loss in gross primary productivity of 14 million metric tons per year.

Assessing Impacts of Land Use Change on Productivity



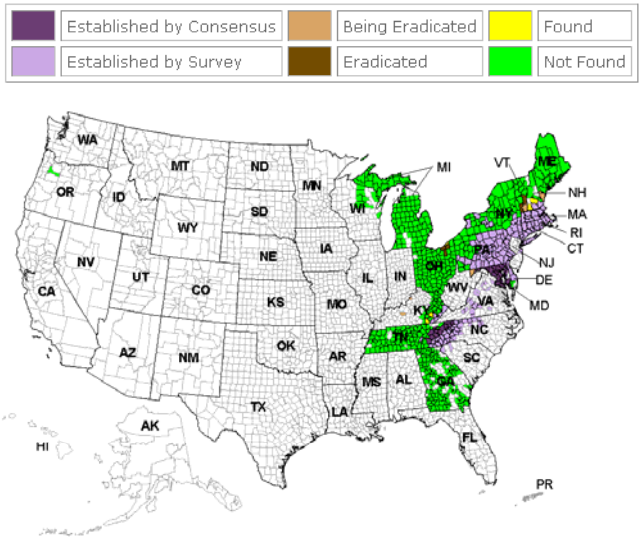
The average annual total GPP for the baseline (2000) and forecast (2030) scenarios, and the projected decrease in average annual GPP, expressed in kg of carbon.

Landscape Dynamics: Trends in Vegetation Indices

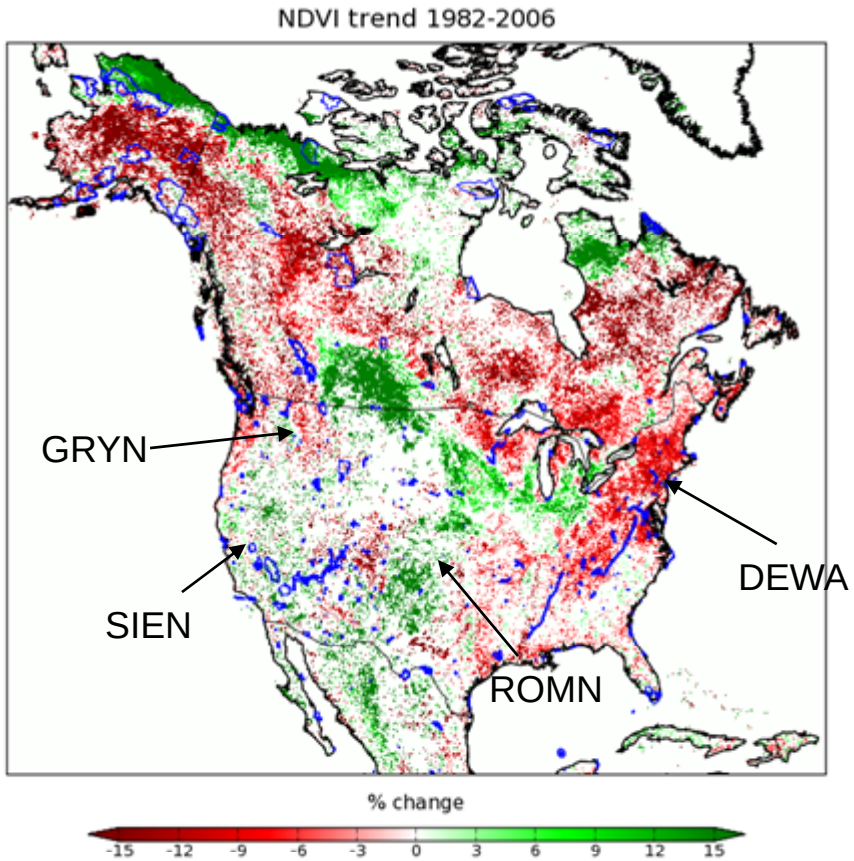
What: Measures trends in maximum annual Normalized Difference Vegetation Index (NDVI) data derived from 25+ year satellite data record

Why: Gradually emerging changes in response to ecosystem stress can be difficult to detect. Changes in maximum NDVI are quantitative indicators of shifts in vegetation condition, and provide integrated indicator for combined biogenic and anthropogenic stressors.

Stressors: Land use change, major wildfires, drought / climate, insect infestations and tree diseases



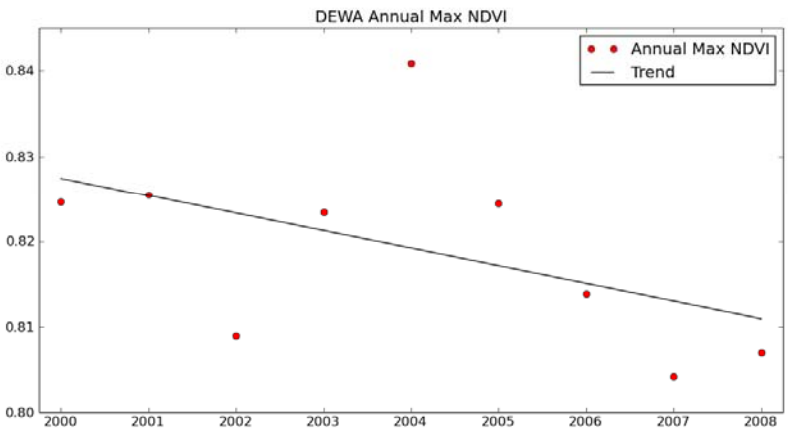
Reported Status of
Hemlock Woolly Adelgid - Adelges tsugae



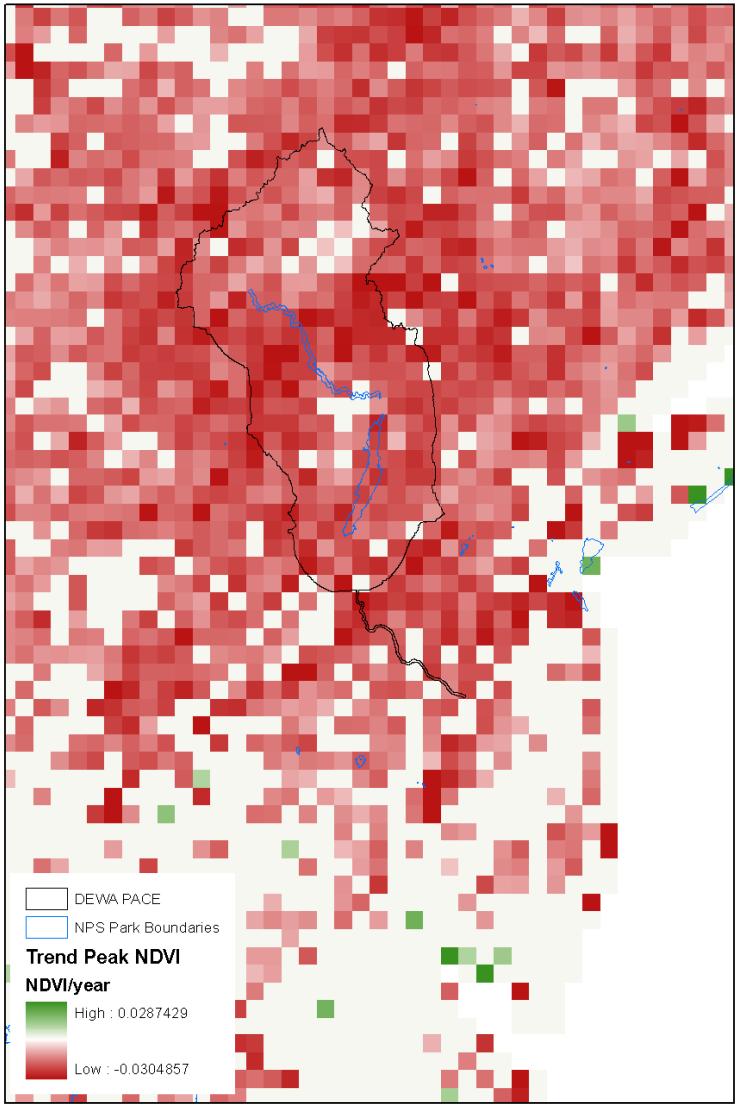
Trend in Peak NDVI

Landscape dynamics: Trends in Vegetation Indices

Summary: Potential drivers of observed declines in maximum annual NDVI in DEWA / UPDE include both widespread infestation of the Hemlock Woolly Adelgid (*Adelges tsugae*) and urban expansion in regions surrounding the parks. Observed declines of ~0.3% per year also apparent in MODIS data record.



DEWA Annual Average
Peak NDVI from MODIS (2000-2008)



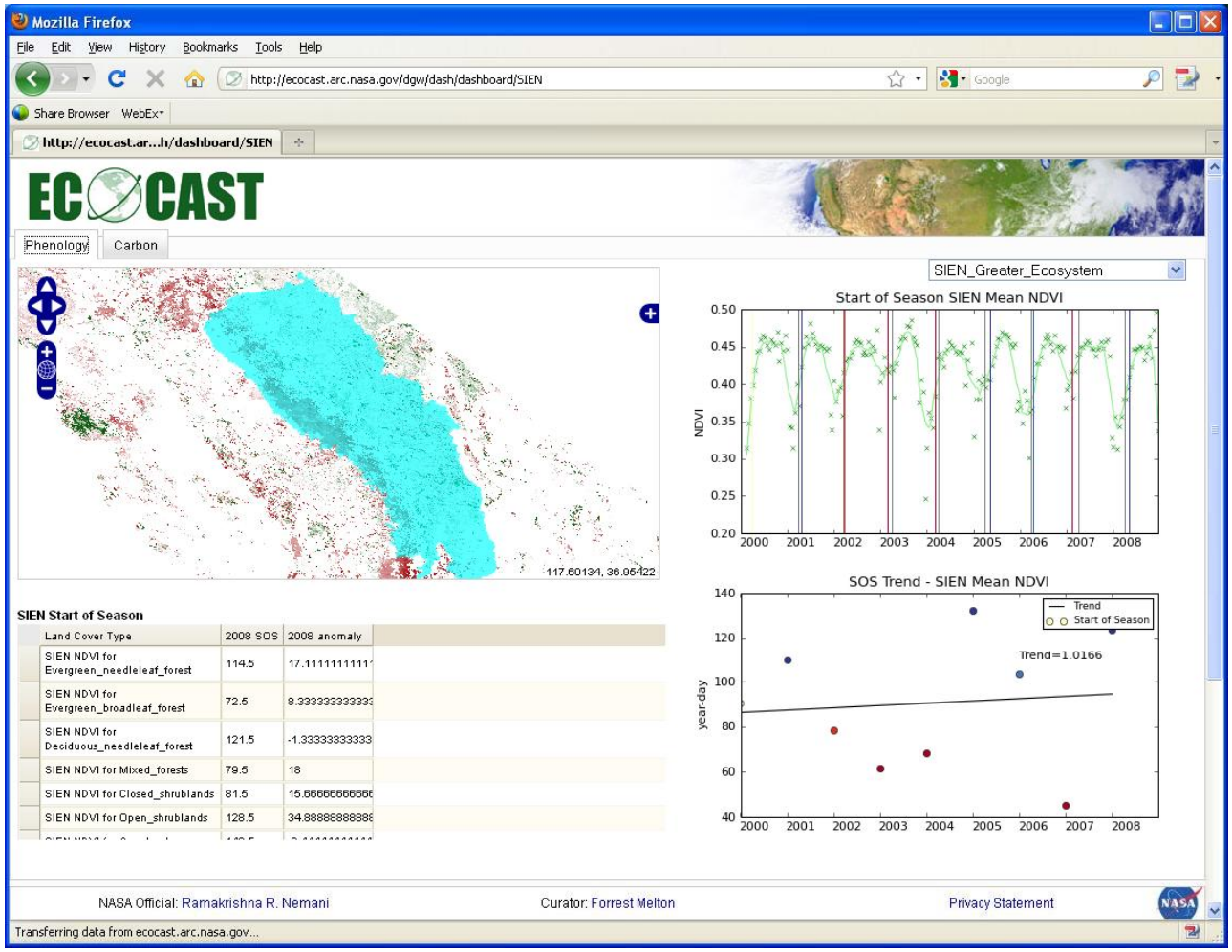
DEWA / UPDE and PACE
Trend in Peak NDVI from AVHRR (1982-2006)

Weather and Climate: Landscape Phenology

What: Measures trends and anomalies in phenological indicators including the 'start-of-season' (SOS) date, derived from satellite timeseries of vegetation index data

Why: Sustained shifts in vegetation phenology are a predicted consequence of climate change. Satellite-derived phenology indicators provide a useful supplement to surface measures, which may track only a subset of plant species.

Stressors: Climate change, land use change, drought



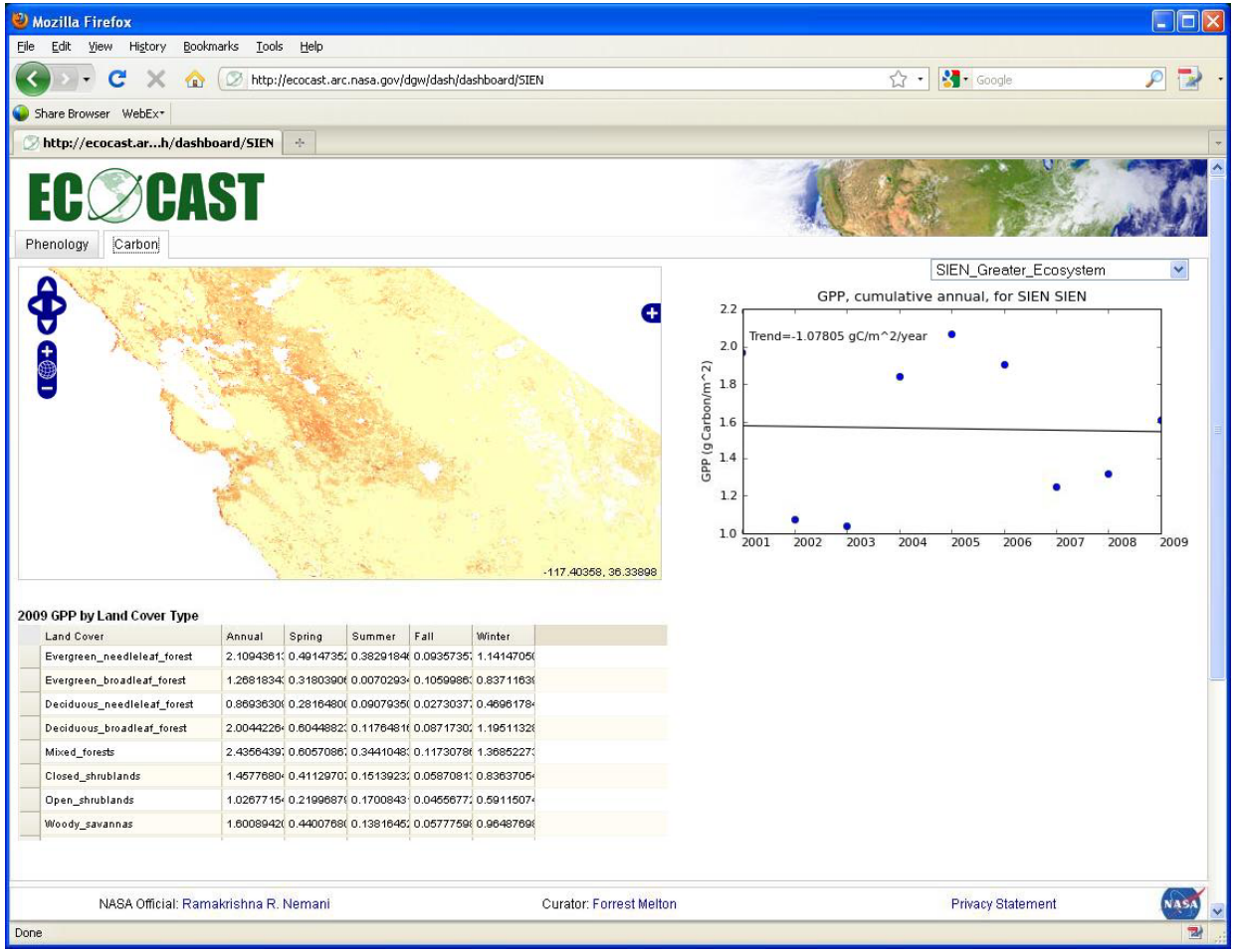
Summary: This indicator is currently being calculated for DEWA-UPDE, and will include measures of the annual Start-of-Season anomaly, and graphs and plots to summarize trends in SOS by land cover type, as shown in this example for the Sierra Nevada Network. The indicator is intended to provide a relative measure of landscape phenology for use in detecting temporary and sustained shifts in SOS dates, as opposed to an absolute measure for specific plant species.

Ecosystem Productivity: Gross Primary Production

What: Estimates gross primary production (GPP) and measures patterns and trends in GPP

Why: GPP provides an indicator of ecosystem condition that integrates interactions between climate, vegetation, soils and other aspects of the physical environment. Sustained trends in seasonal or annual GPP may provide a leading indicator of climate change impacts.

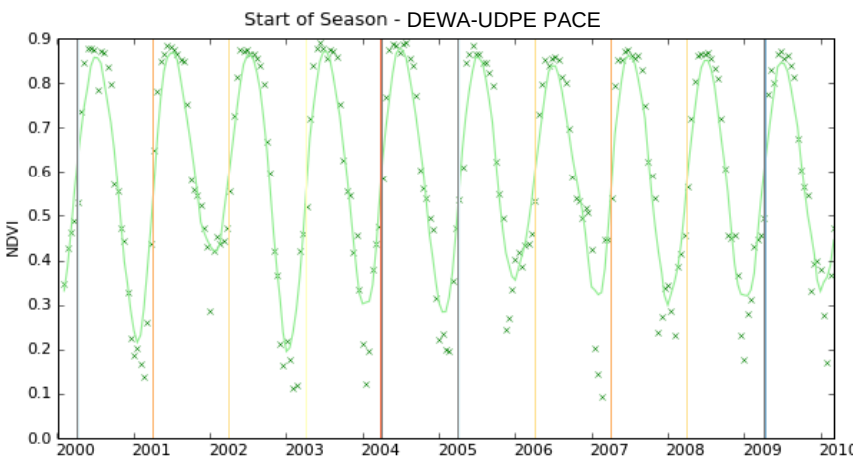
Stressors: Climate change, land use change, drought, wildfire, insect infestations

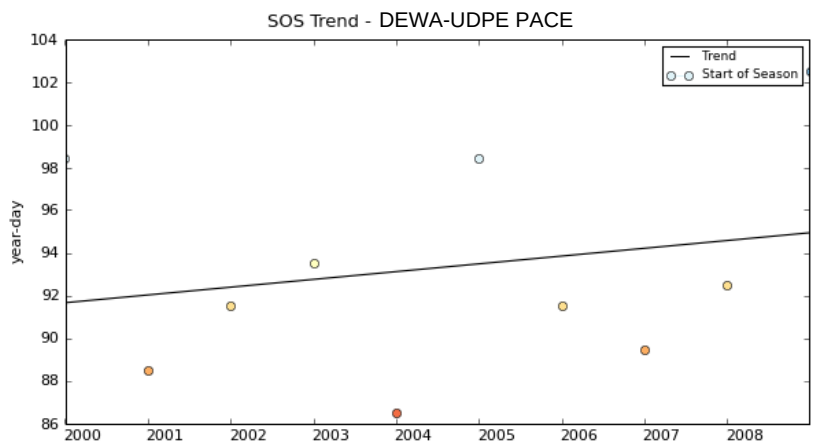


Summary: This indicator is currently being calculated for DEWA-UPDE, and will include measures of GPP trends and anomalies summarized by season and land cover type, as shown in this example for the Sierra Nevada Network. This indicator relies on the use of MODIS data, and the TOPS implementation of the Biome-BGC model. Production of the dataset will continue under the NASA Earth Exchange (NEX) project for the foreseeable future.

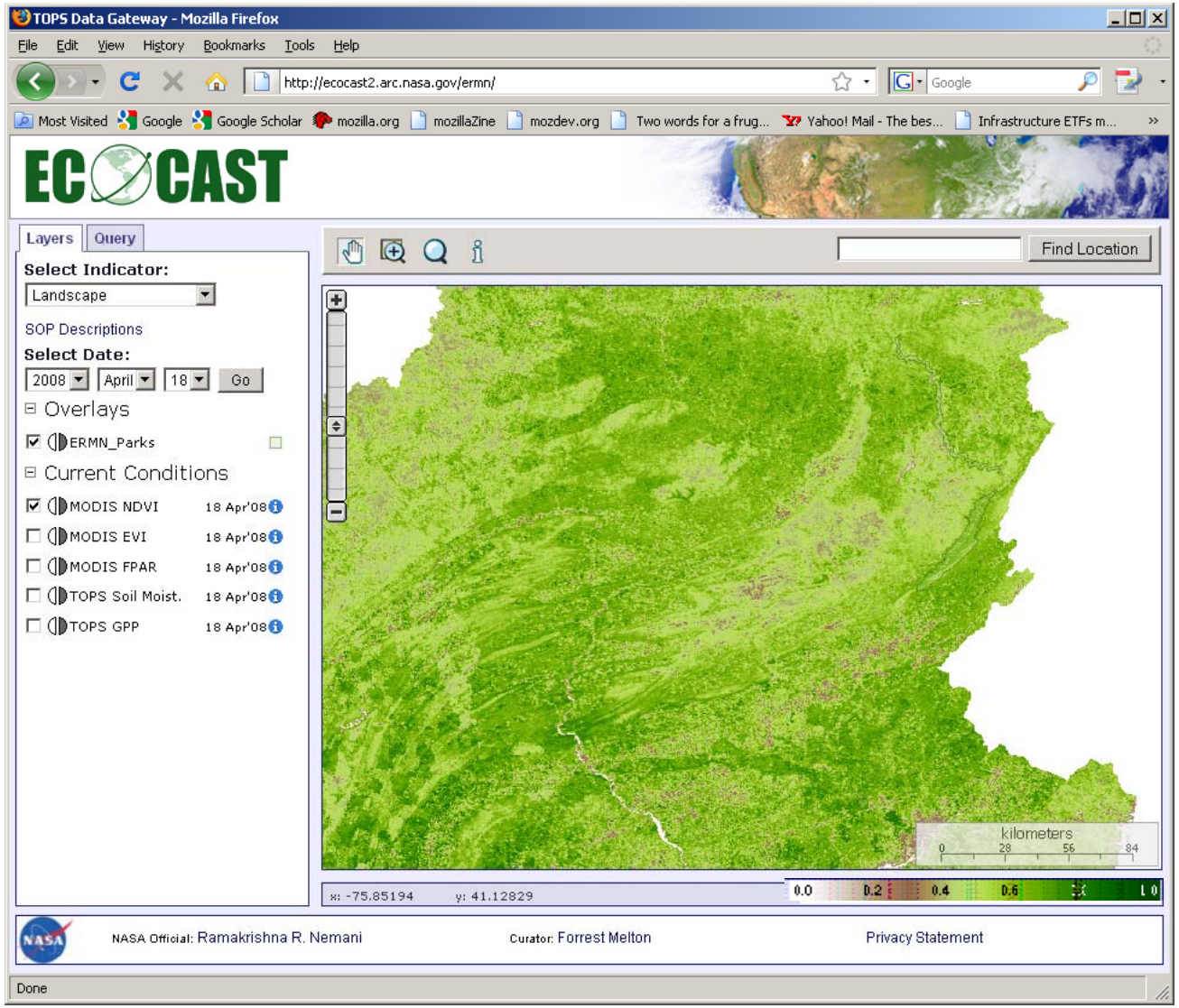
Weather and Climate: Landscape Phenology

Summary: Sample results for the Landscape Phenology indicator for the DEWA-UDPE PACE , showing the NDVI timeseries / SOS date for 2001-2009 (a), and the SOS date for recent years showing some interannual variability in SOS (e.g., 2004 versus 2005). The best-fit line is provided as a point of reference to assist in detecting emerging trends.





TOPS Data Gateway



- Data will be available via the TOPS Data Gateway for NPS where it can be can be browsed and queried
- Data used to calculate the indicators will also be retrievable via WMS, WCS, and OPeNDAP (an ArcServer implementation is also planned)

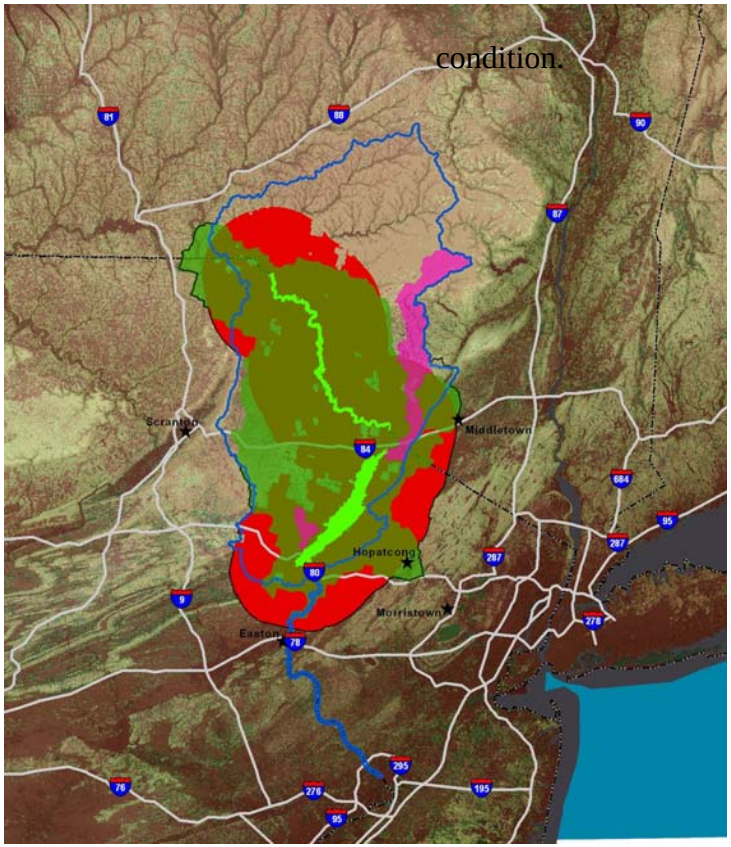
Delineating Protected Area Centered Ecosystems (PACE)

What: Area surrounding park with strong ecological connections to the park..

Why: This area may be important for monitoring, research, and cooperative management to maintain park condition.

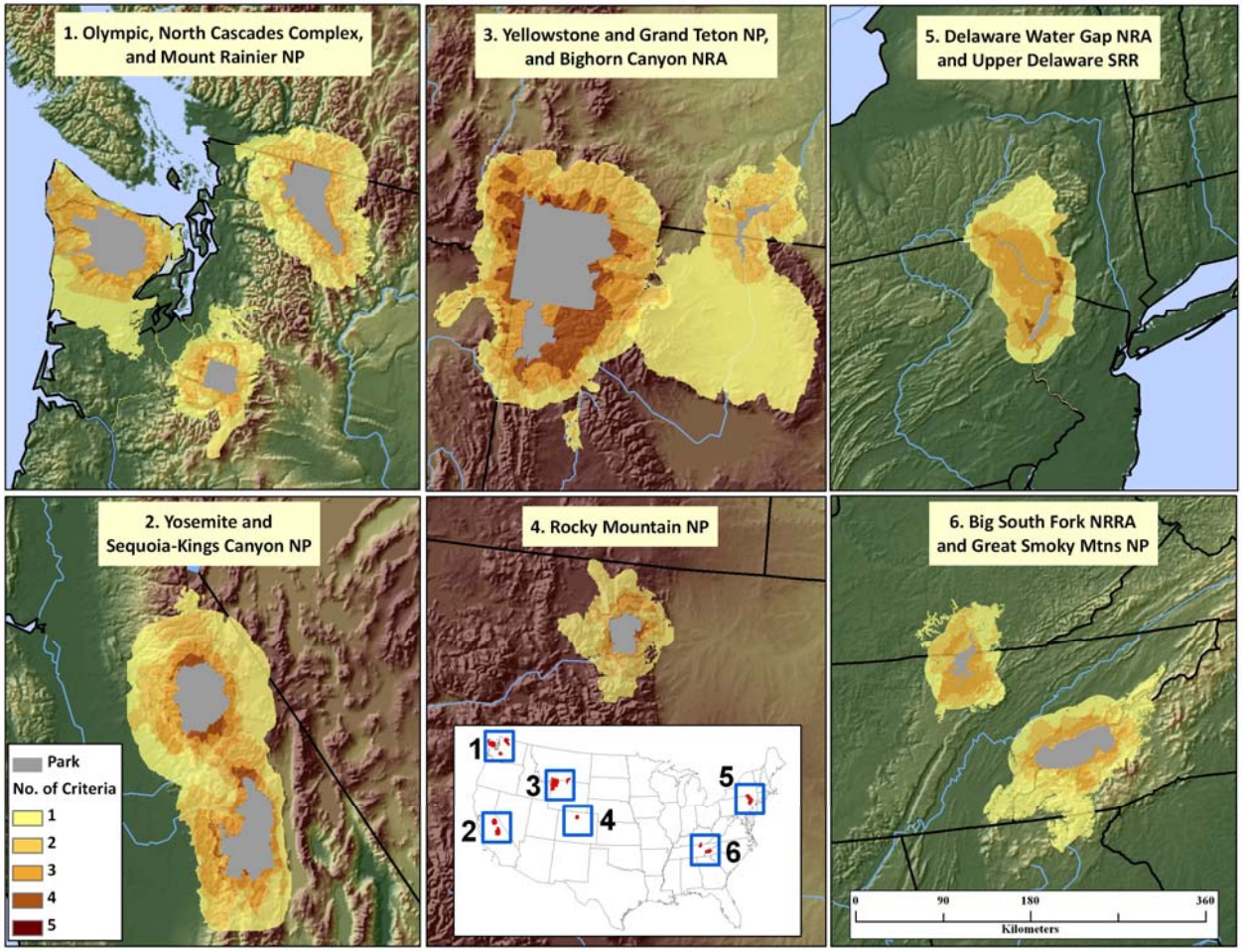
Stressors: Land use change, invasive species.

The DEWA/UPDE PACE outside the park was 32.5 times larger than the park area. The watershed layer covered the largest unique portion of the PACE, followed by the human edge effects layer. Some 63.2% of the PACE was covered by two or more criteria. .



Metric	Total	Criterion				
		Contiguous habitat	Water-shed	Disturbance	Crucial Habitats	Human Edge Effects
Area outside park (km^2	14046	7597	10826	---	725	9282
% of PACE uniquely covered		2.25	21.75	--	0.01	9.75

Criteria 1 watershed = thin blue line; Criteria 3 crucial habitat = solid purple; Criteria 4 cont. habitat = solid green; Criteria 5 edge effects = solid red; Draft PCE = bold black line



Maps of protected-area centered ecosystems for DEWA/UPDE and 12US National Park units. Gradations in color in the PACES outside of the parks indicate the number of overlapping classification criteria. Places with many overlapping criterion may be considered more important for monitoring and management.

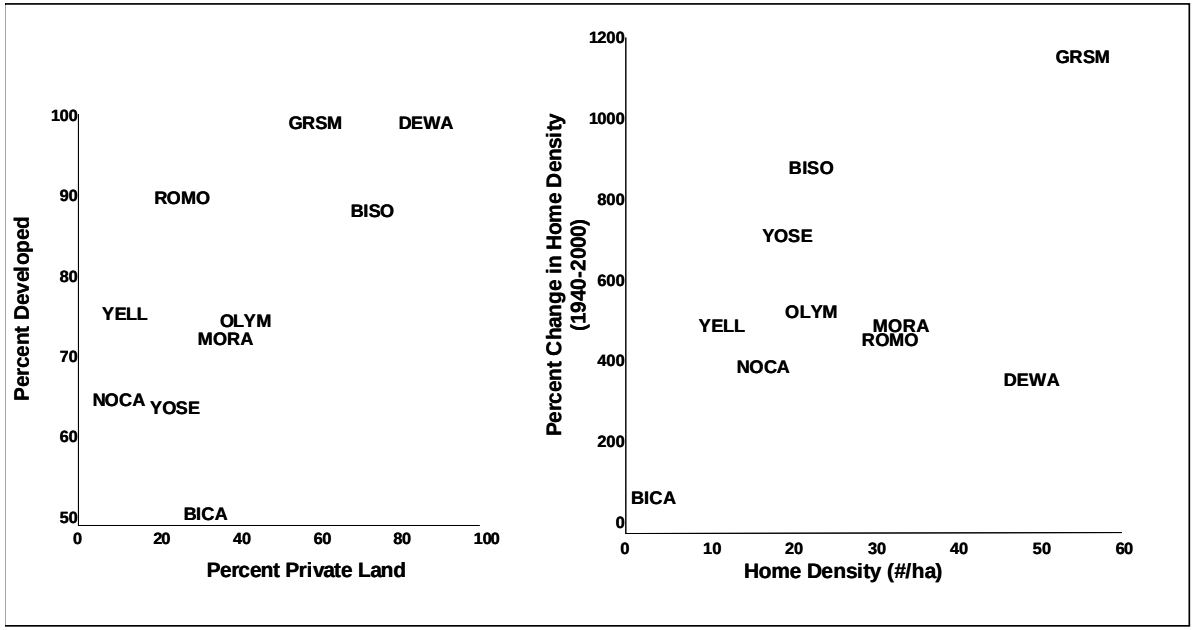
Landscape Dynamics: Land use within protected-area centered ecosystems (PACEs)

What: Metrics of land allocation and change in PACES outside of parks.

Why: These data provided indication of the challenges in maintaining park condition given the characteristics of the surrounding PACE.

Some 84% of the PACE outside of the park is private land, a larger amount than for other PACEs. Nearly 98% of those private lands are in agriculture, roads, homes or other land uses termed "developed" or are with designated buffers around development. Home density in these private lands is relatively high but growth in home density since 1940 is relatively low relative to the PACES examined thus far.

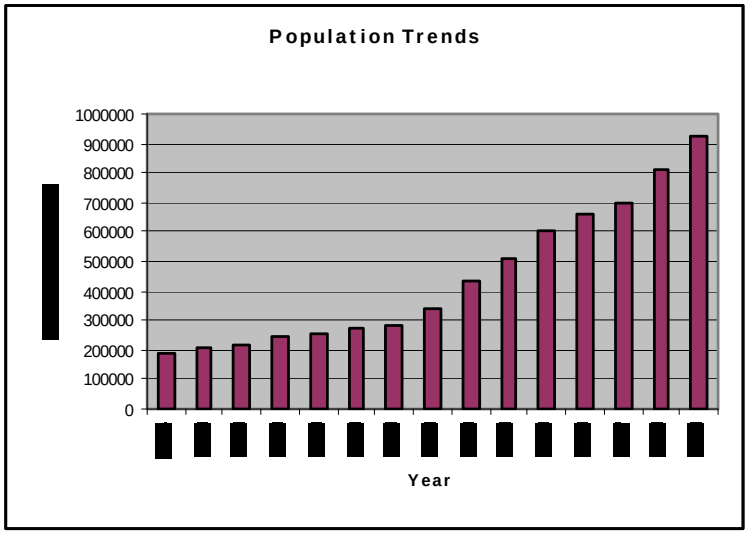
Percent of land that is private	Percent of private land developed in 2000	Home density on private lands in 2000 (#/km^2)	Change in home density on private lands during 1940-2000 (%)
84.0	98.3	0.477	345.6

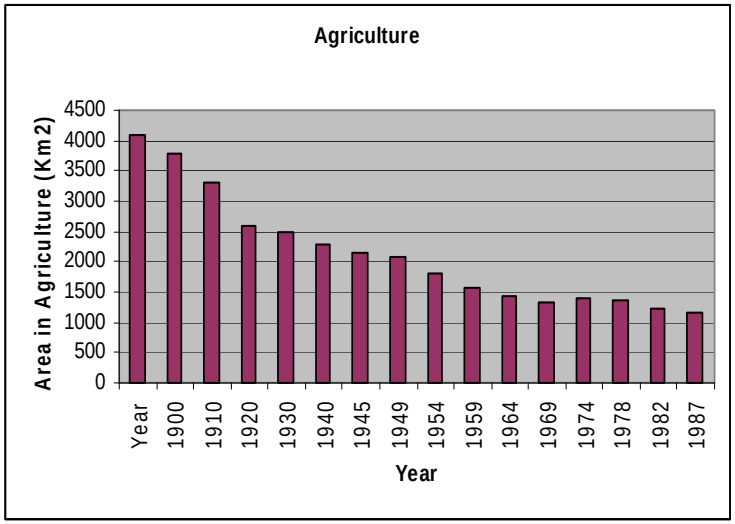


Location of the protected area centered ecosystems along gradients in land ownership and land development (home densities of >0.031 units/ha, roads, or agriculture lands) (left) and home density (units/ha) and percent change in home density from 1940 to 2000 (right).

Note: Developed lands included buffers of 1000 m adjacent agriculture or home densities>0.031 units/ha and 500 m of primary roads railroads and 100 m of secondary roads.

DEWA/UPDE PACE: 1900 - 2007



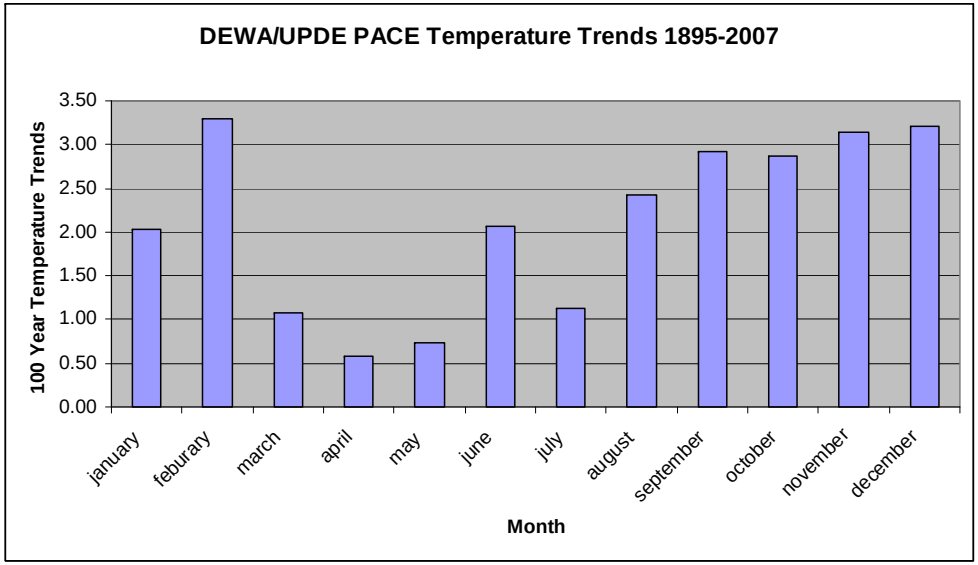


Pop distributed was distributed within PACE based on housing density. Ag data are for counties that cover >=10% of PACE or >=40% of the county is covered by the PACE.

Climate and Precipitation.

100-year climate trends for 6 National Parks (PACEs) by region based on PRISM data. Non-zero values are significant trends and represent the average annual increase or decrease across the time period of 1895 - 2007. Those highlighted in yellow are the three fastest changing in temperature of the 60 parks in the study. From Hass et al. in prep.

Region	National Park	Precip. (mm)	Temp. (C)
Desert Southwest	Organ Pipe Cactus	0	2.615
Northeast	Delaware Water Gap	0	2.031
Northern Rockies	Grand Teton	0	0.982
	Yellowstone	0	0.856
Pacific Southwest	Sequoia	0	0.585
	Yosemite	0	0.522
Southern Rockies/Colorado Plateau	Rocky Mountain	0	1.928



Note: Trends for all months but April are statistically significant. From Haas et al. in prep.

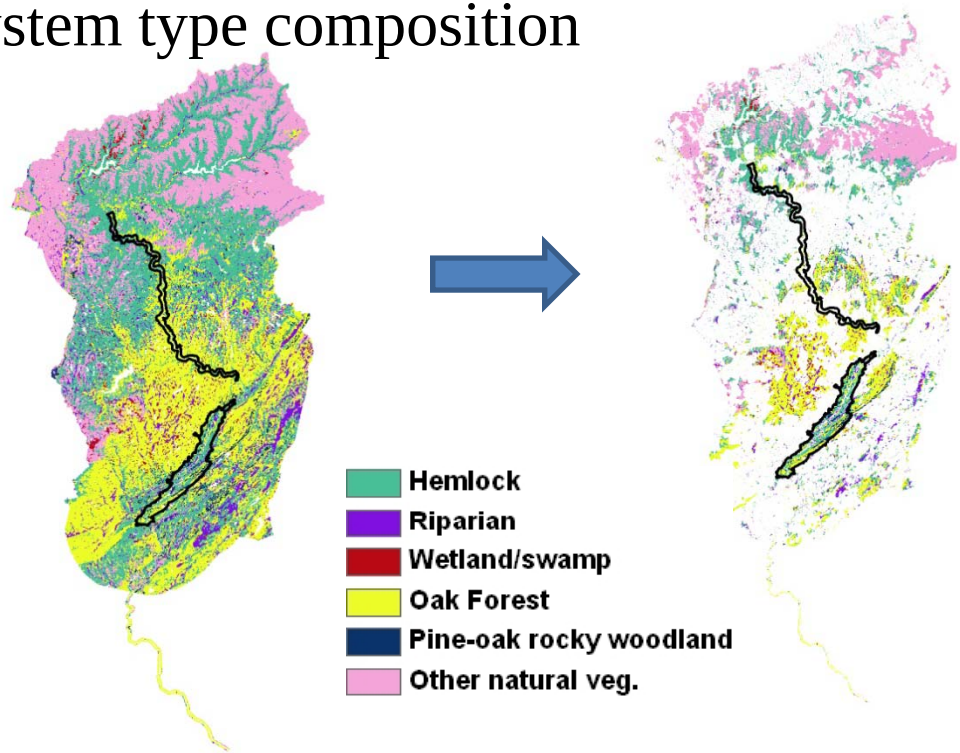
Landscape dynamics: Ecosystem type composition

What: Estimates reduction in area of potential pre-settlement ecosystem types due to current land use.

Why: Ecosystem types of greatest proportional loss are candidates for focused conservation, management and restoration.

Stressors: land use change.

All ecosystem types have undergone substantial loss of area due to on average 80% losses on private lands. Ecosystem types on public lands remain largely in tact with riparian and floodplain systems experiencing the greatest proportional losses followed by hemlock. Mean patch size has been dramatically reduced in each ecosystem type. Mean distance to the next nearest patch of the same ecosystem type decreases only as an artifact of there being more smaller patches on the landscape in the developed scenario.



Ecosystem Type	Hectares (thousands)	% Loss total	% Loss pvt land	% Loss Pub. land	% Mean patch size change	% Nearest neighbor change
Hemlock	467	74	80	14	-94	-42
Riparian – floodplain	95	68	79	18	-81	-45
Wetland – swamp	21	59	73	5	-60	-34
Oak Forest	420	71	86	10	-92	-49
Pine – oak rocky woodland	29	65	88	10	-66	-35
Other natural veg.	325	59	72	3	-91	-61
Mean		**66**	**80**	**10**	**-81**	**-44**

Note on methods: the distribution of pre-settlement ecosystem types were mapped by the LANDFIRE program based on biophysical factors and modeled disturbance conditions. This layer was validated within park boundaries using NPS Veg. Mapping program data with varying "accuracy". We evaluated the loss of ecosystem type area due to current land uses including residential and agricultural development and transportation networks.