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

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 park-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 submitted.

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 and ARC GIS geodata base
- Three conference calls
- Summary documents will use the results to communicate “stories” about condition and trends in the parks and surrounding areas.
- SOPS, the geodata base, 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.

General: Protected Area Centered Ecosystems (PACE)

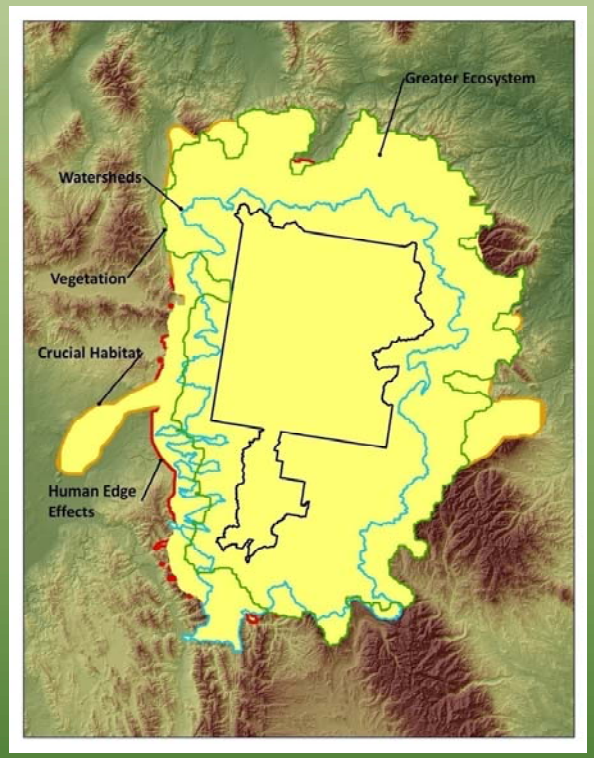
What: Area surrounding park with strong ecological connections to the park..

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

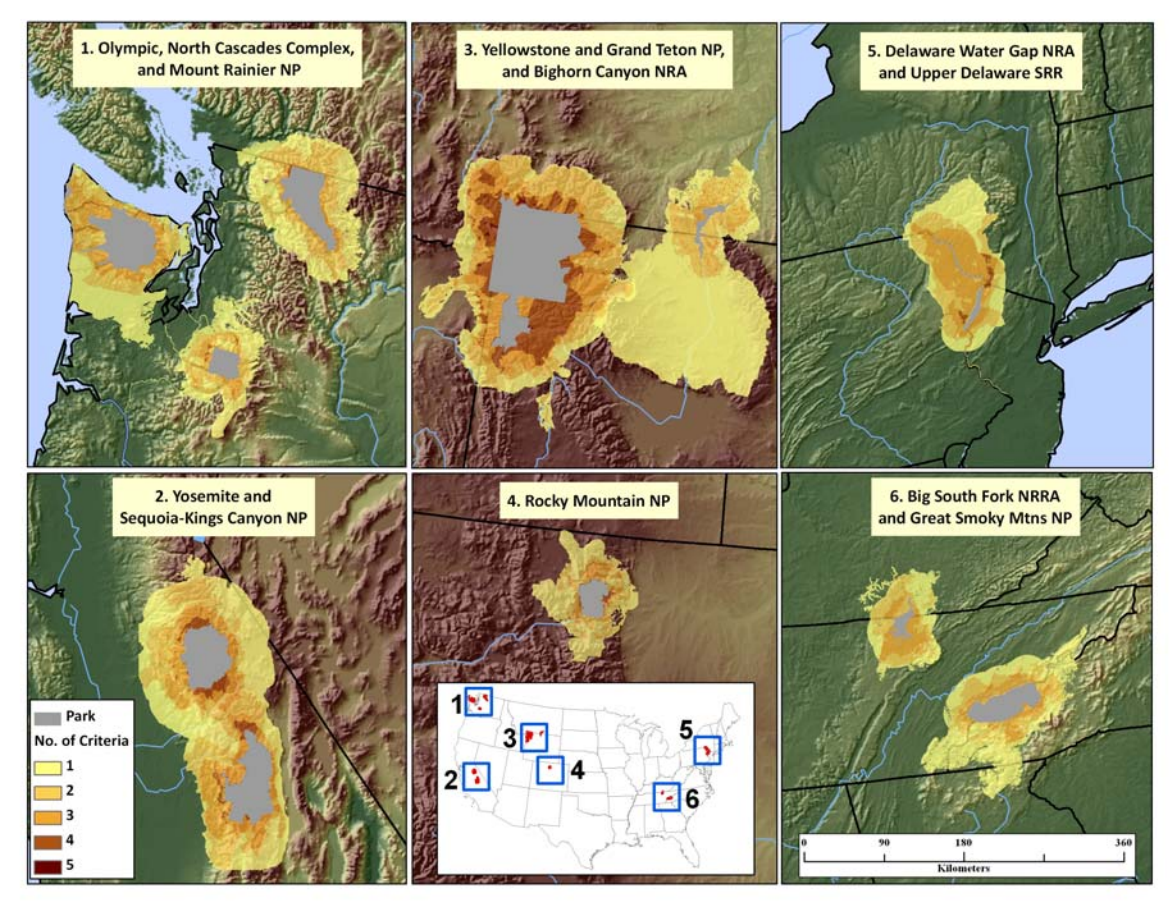
Stressors: Land use change, invasive species.

The YELL/GRTE PACE outside the park was 3.2 times larger than the park area. The areas mapped for each criteria overlapped substantially, with 78% of the PACE covered by two or more criteria. .

Metric	Total	Criterion				
		Contiguous habitat	Water-shed	Disturbance	Crucial Habitats	Human Edge Effects
Area outside park (km^2	32362	24876	12881	32158	13758	4730
% of PACE uniquely covered		0.25	0.5	11.5	3	3.25



Delineating Protected Area Centered Ecosystems (PACE)



Maps of protected-area centered ecosystems for YELL/GRTE and 12 US 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.

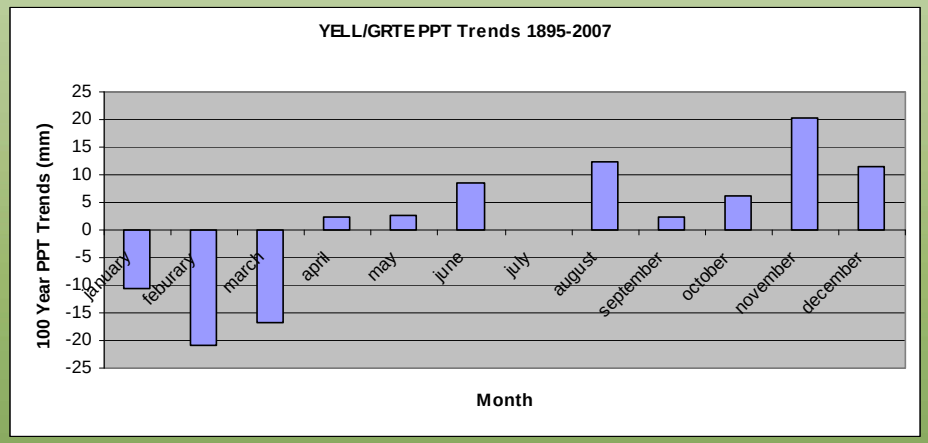
TOPS outputs

- Weather and climate
- Climate gridded daily 2000-20008
- Long term climate scenarios now -2100
- Phenology related indicators
- Extreme disturbance events
- Fire effects via changes in NDVI/EVI, FPAR/LAI
- Primary productivity GPP, NPP

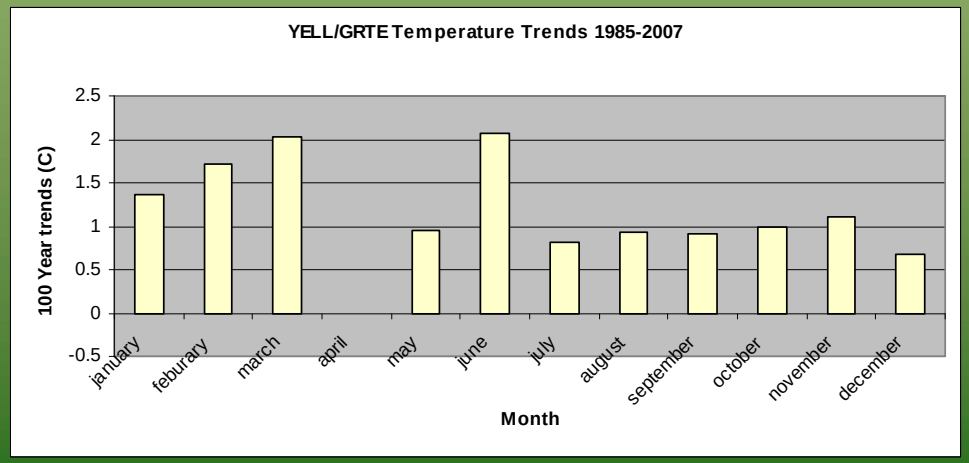
Temperature and Precipitation

100-year climate trends for YELL/GRTE PACEs 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. From Hass et al. in prep

Park	PPT (mm)	Temp (C)
YELL/GRTE	5.34 (NS)	1.21 (.01)



Significant change: Feb, Mar, Aug



Significant change: all but Apr, Sept, Dec

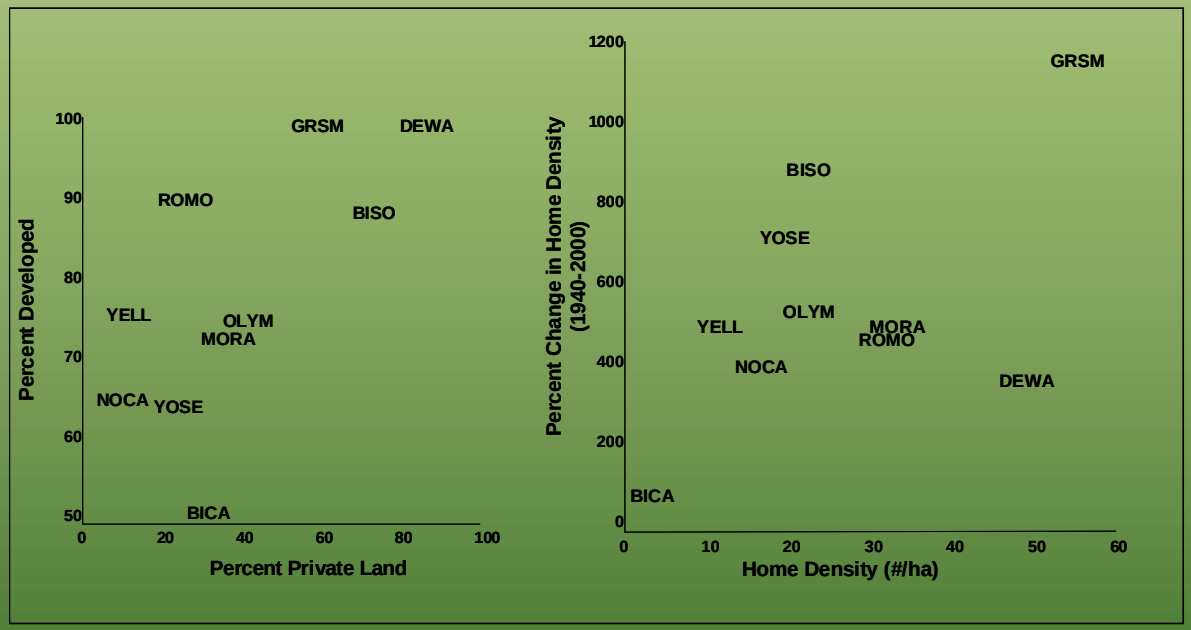
Landscape Dynamics: Land use within protected-area centered ecosystems (PACEs)

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 12% of the PACE outside of the park is private land, a smaller amount than for most other PACEs. Nearly 75% of those private lands are in agriculture, roads, homes or other land uses termed "developed" or are within designated buffers around development. Home density in these private lands is relatively low and growth in home density since 1940 is moderate 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 (%)
12.0	74.9	0.126	479.4



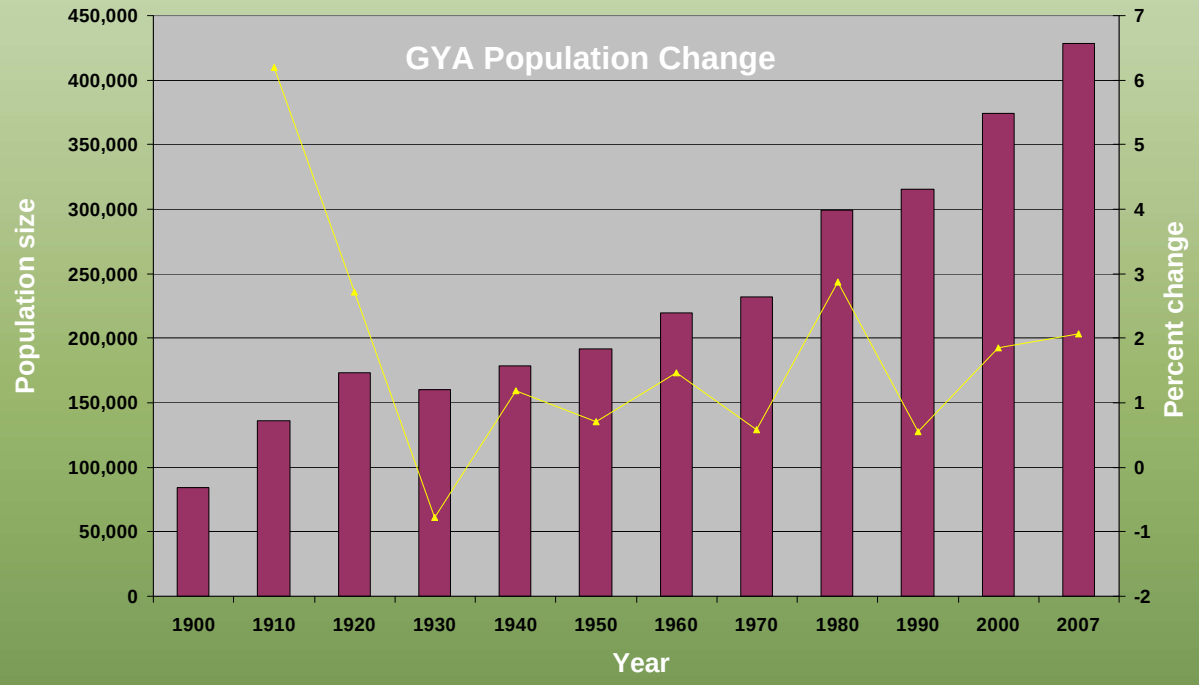
Location of the protected area centered ecosystems along gradients in land ownership and land development (home densities of >0.031 units/ha, roads, or agriculture lands) (left) and home density (units/ha) and percent change in home density from 1940 to 2000 (right).

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.

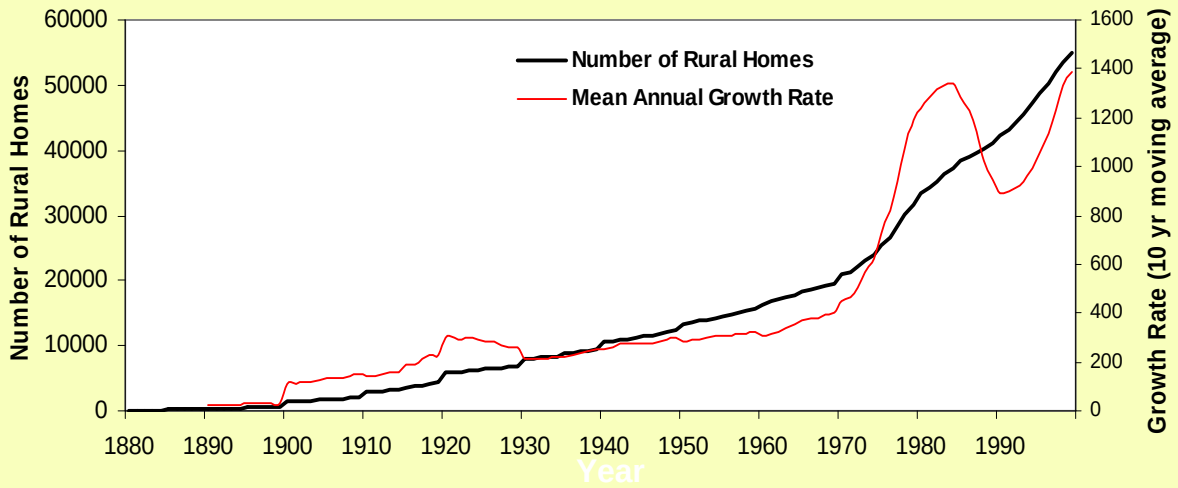
Landscape Dynamics: Population Density

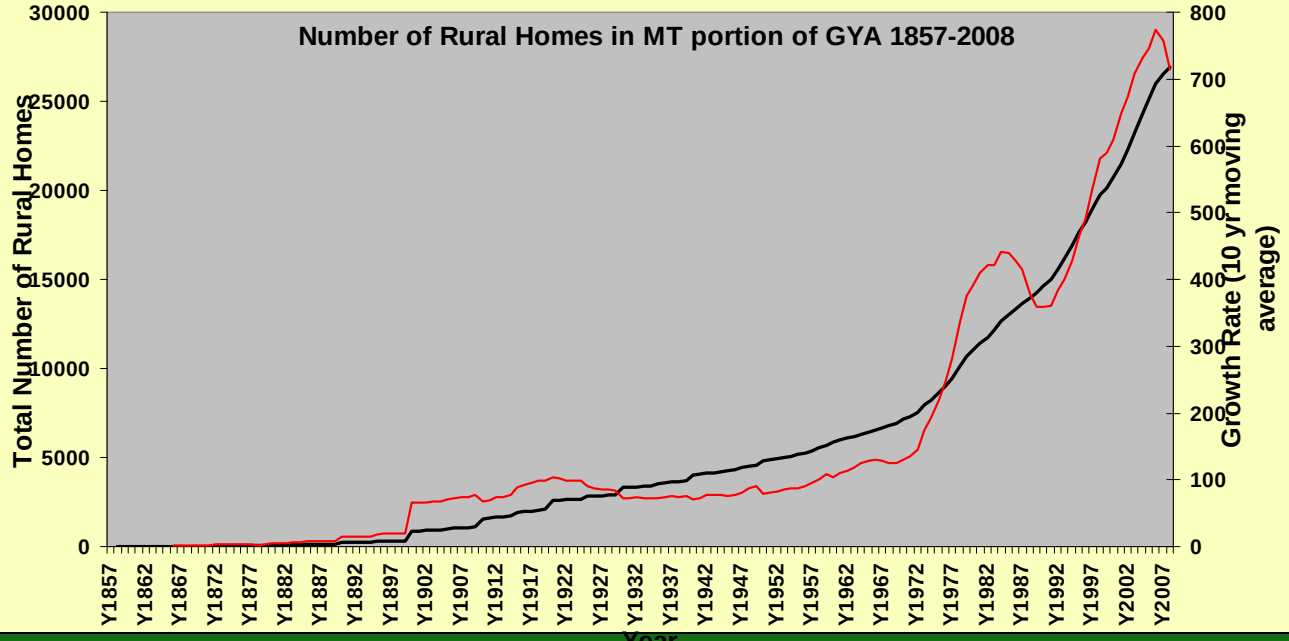
What: Metrics of land allocation and change in PACES outside of parks.

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



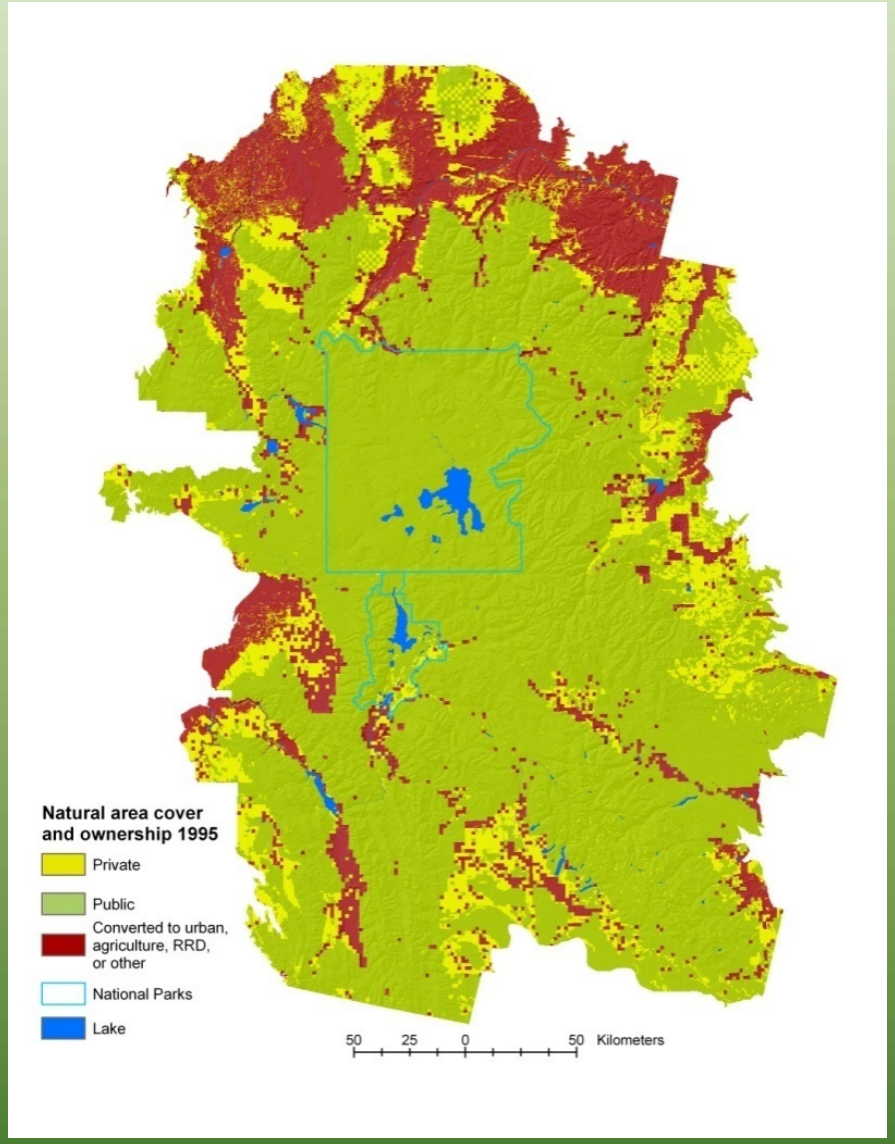
Landscape Dynamics: Exurban Development



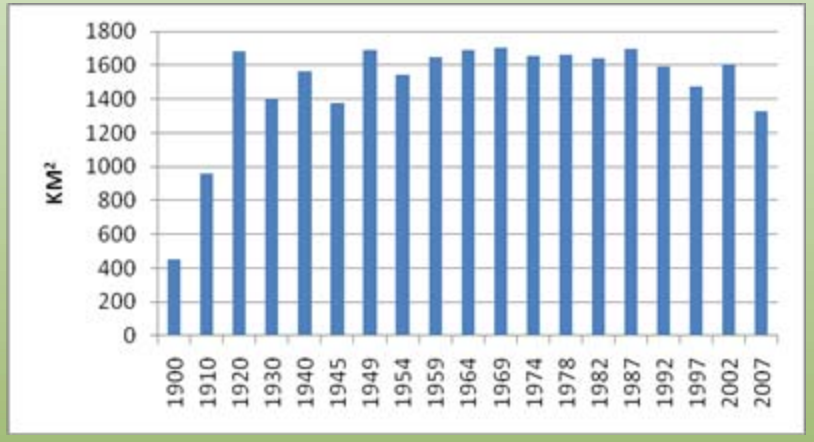


Hernandez et al. 2006, Piekielek in prep

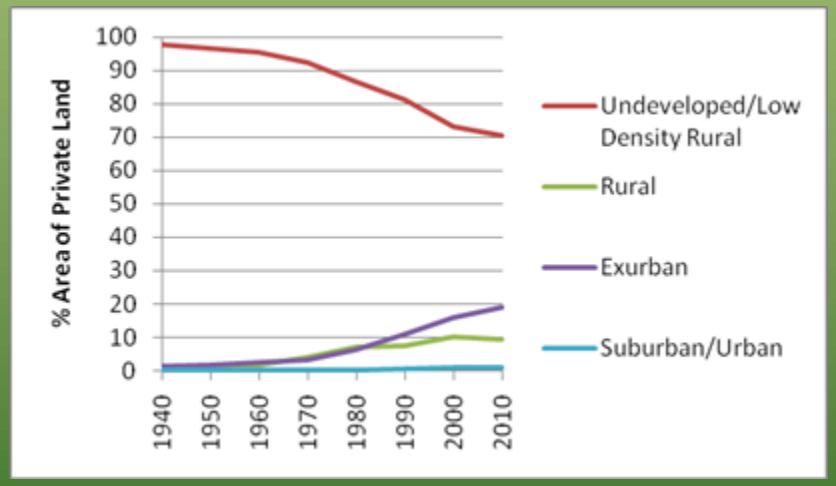
Landscape Dynamics: Agriculture and Home Density Class



Private Lands in Agriculture, Exurban, Urban Classes



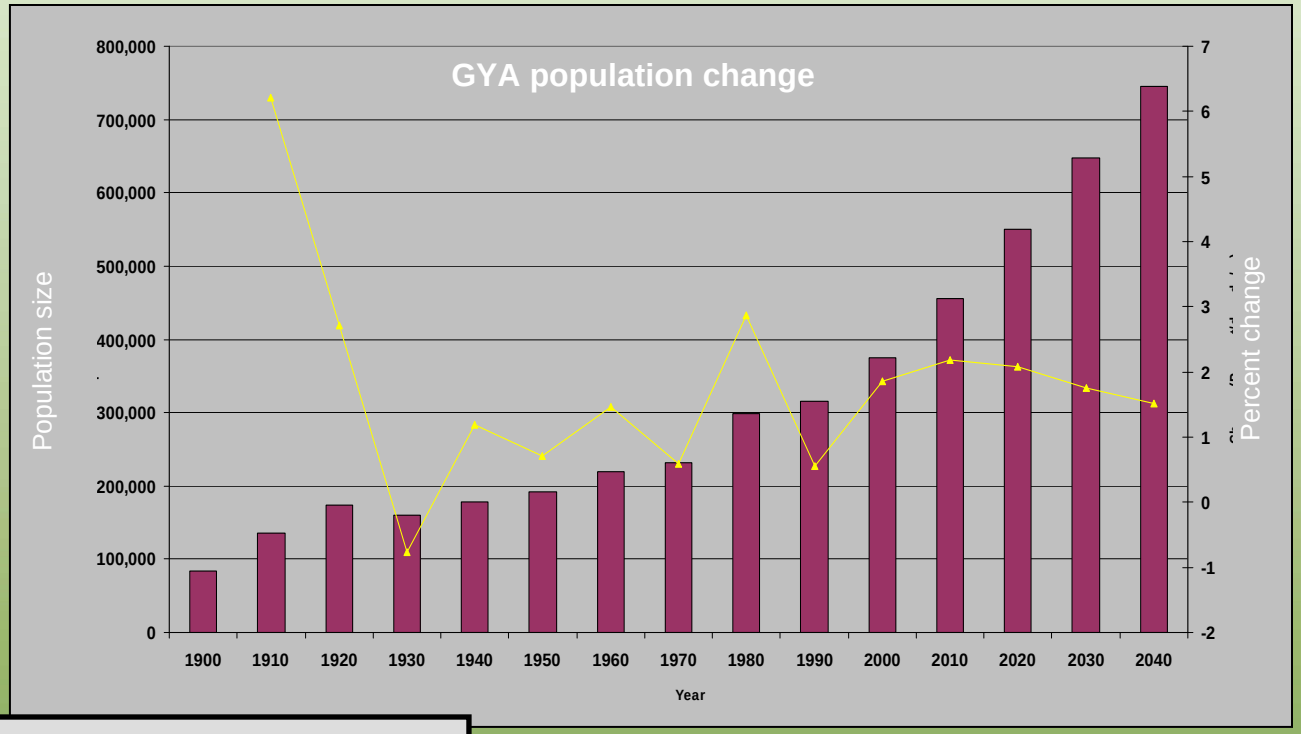
Area in Agriculture



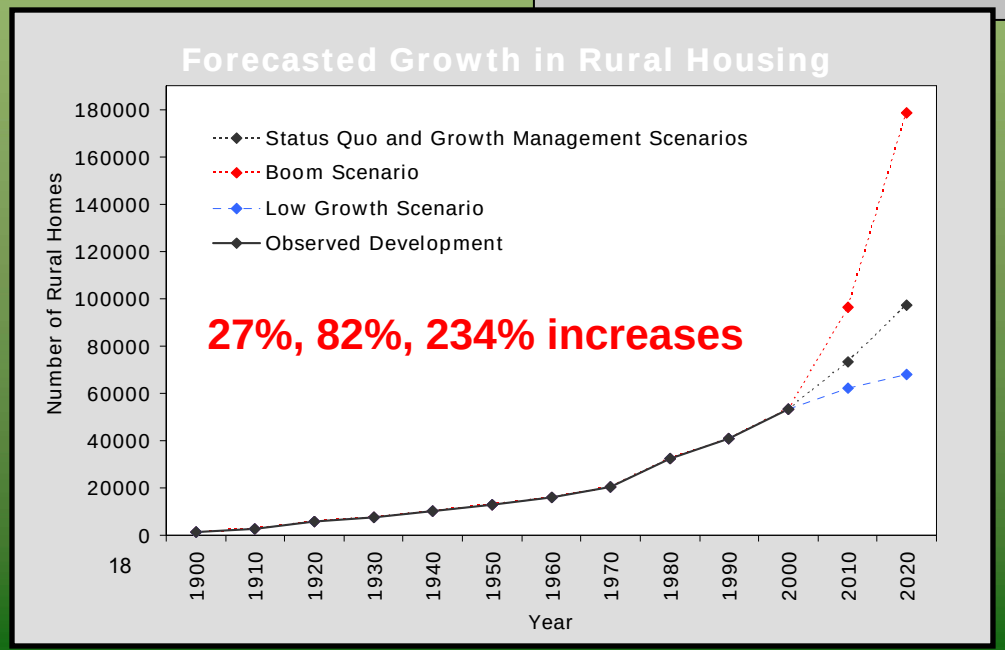
Land Use Type based on Housing Density

Davis et al. in prep.

Landscape Dynamics: Projected Future Population Size and Exurban Development



Davis et al. in prep.



Hernandez et al. 2006

Biodiversity: Reduction in Crucial Habitats

	Human Impacted Land		
	1980	1999	*2020
Pronghorn Range	2.00%	3.35%	5.83%
Moose Range	2.73%	5.49%	7.96%
Grasslands	2.99%	5.57%	8.36%
Grizzly Bear Range	3.13%	5.98%	8.52%
Douglas-fir	2.91%	6.01%	8.85%
Elk Winter Range	2.36%	6.26%	9.98%
Aspen	5.55%	13.92%	19.53%
Bird Hotspots	8.42%	16.91%	23.20%
Riparian Habitat	10.22%	17.30%	23.64%
Potential Corridors	8.89%	18.79%	24.43%
Irreplaceable Areas[1]	11.41%	23.15%	29.61%
Integrated Index[2]	11.80%	23.24%	29.93%
*projected impact under Status Quo scenario			

Gude et al. 2007

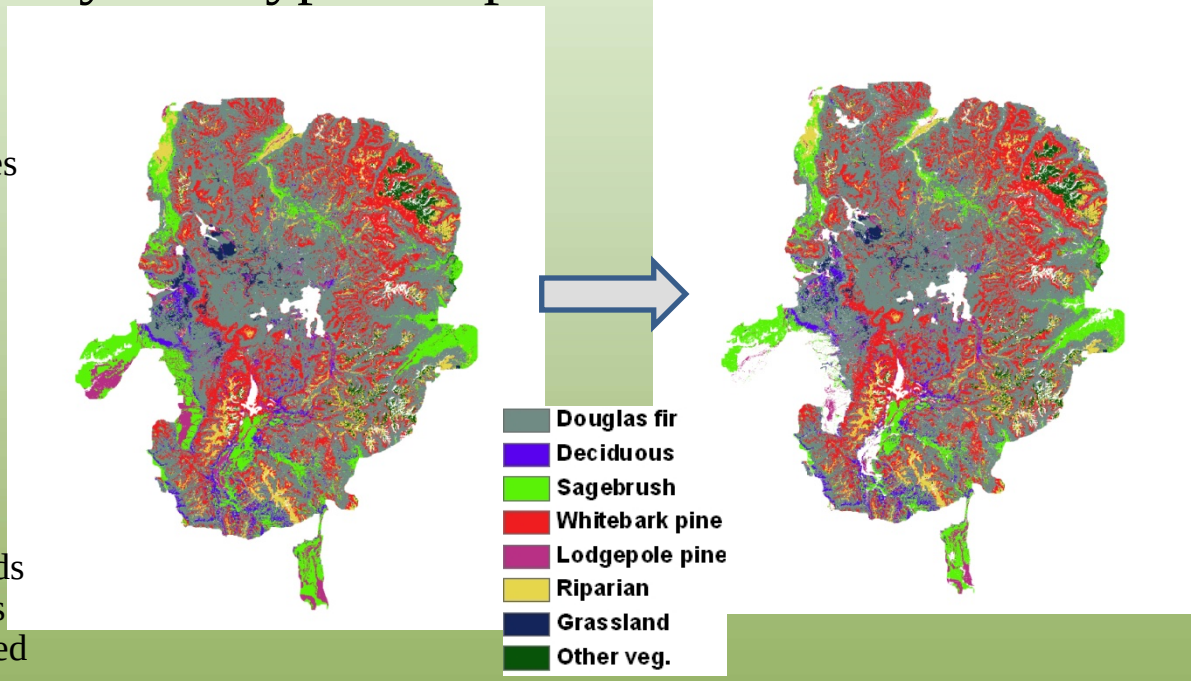
Landscape dynamics: Ecosystem type composition

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.

Lodgepole pine and sagebrush ecosystem types have experienced the greatest proportion losses. Losses on public lands have been minimal and on private lands moderate. Mean patch size has decreased substantially in more than half of the ecosystem types. Mean distance to the next nearest patch of the same ecosystem type has decreased only as an artifact of there being more smaller patches on the landscape.



Ecosystem Type	Hectares (thousands)	% Loss total	% Loss pvt land	% Loss Pub. land	% Mean patch size change	% Mean Nearest neighbor change
Douglas fir	1985	2	21	1	-40	-29
Deciduous	148	7	36	2	-30	-28
Sagebrush	459	19	33	3	-75	-59
Whitebark pine	911	1	25	0	-14	-14
Lodgepole pine	183	33	57	6	-74	-58
Riparian	245	4	22	0	-25	-25
Grassland	51	6	47	3	-44	-41
Other natural veg.	99	1	26	0	-9	-12
Mean		**9**	**33**	**2**	**-39**	**-33**

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.

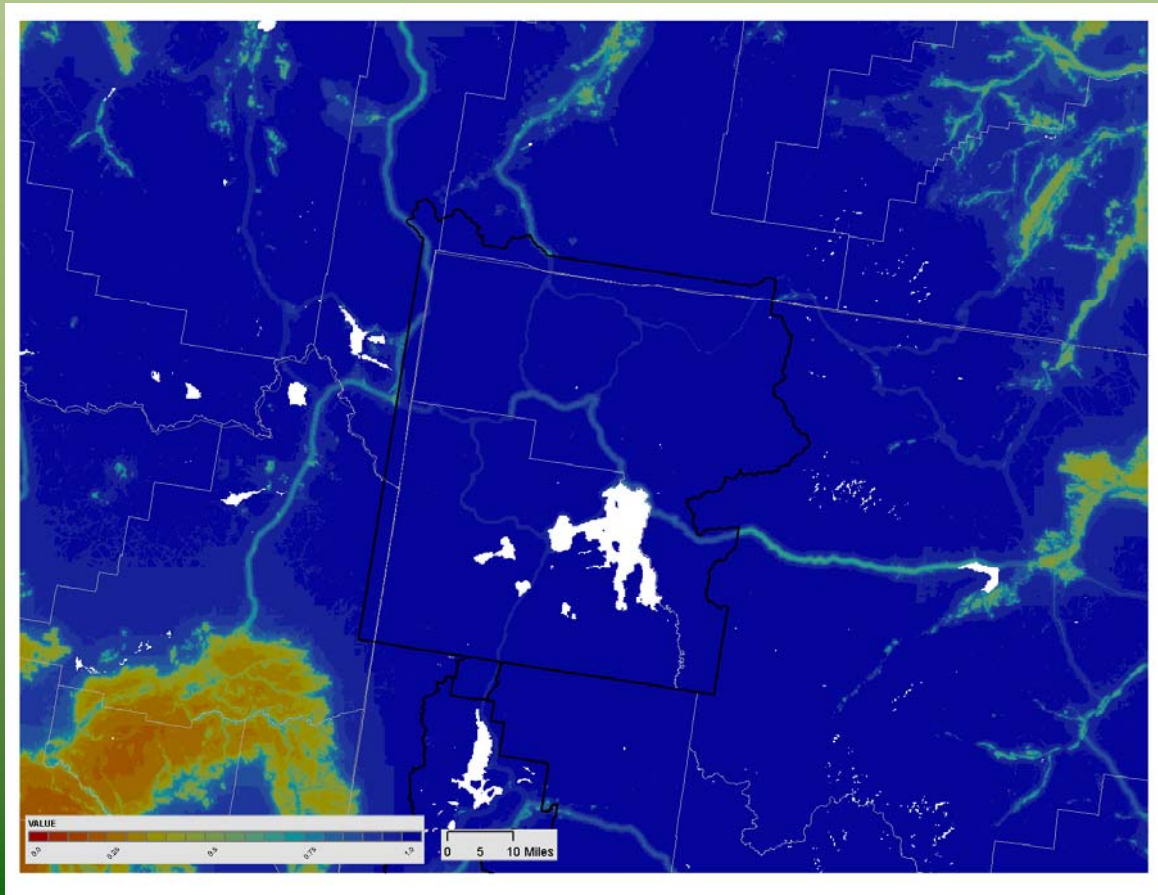
Landscape dynamics: Pattern of natural landscapes

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

YELL scores higher than its ecoregion and is declining very slowly from 0.9795 in 1992 to 0.9793 in 2001 to 0.9791 in 2030.



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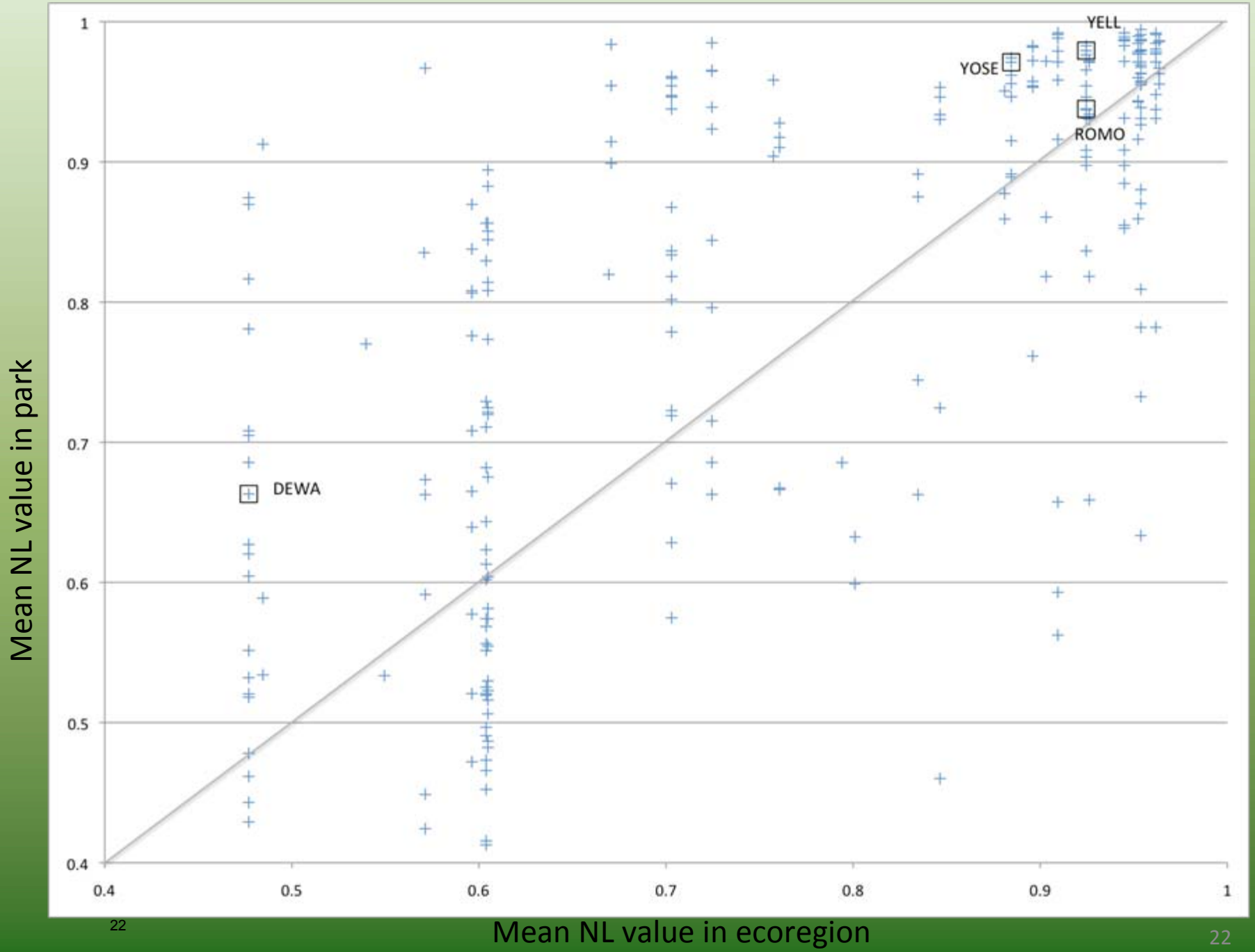
YELL
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0.7
0.8
0.9
1
Mean NL value in park
Mean NL value in ecoregion

22

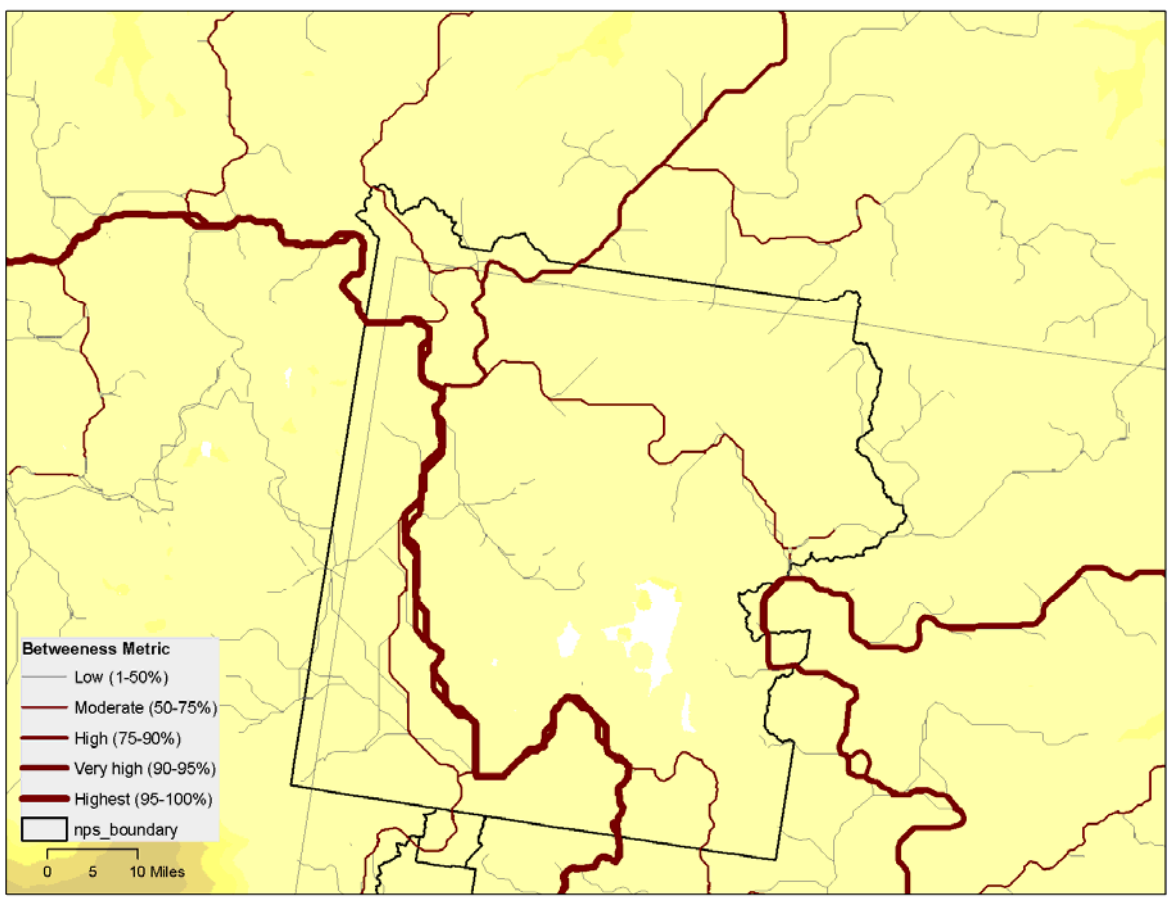
Landscape dynamics: Connectivity of natural landscapes

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

YELL is situated on a pathway that provides much greater than average connectivity (in the top 90-95% compared nationwide) and serves as a key location of connectivity in the Northern Rockies ecoregion.



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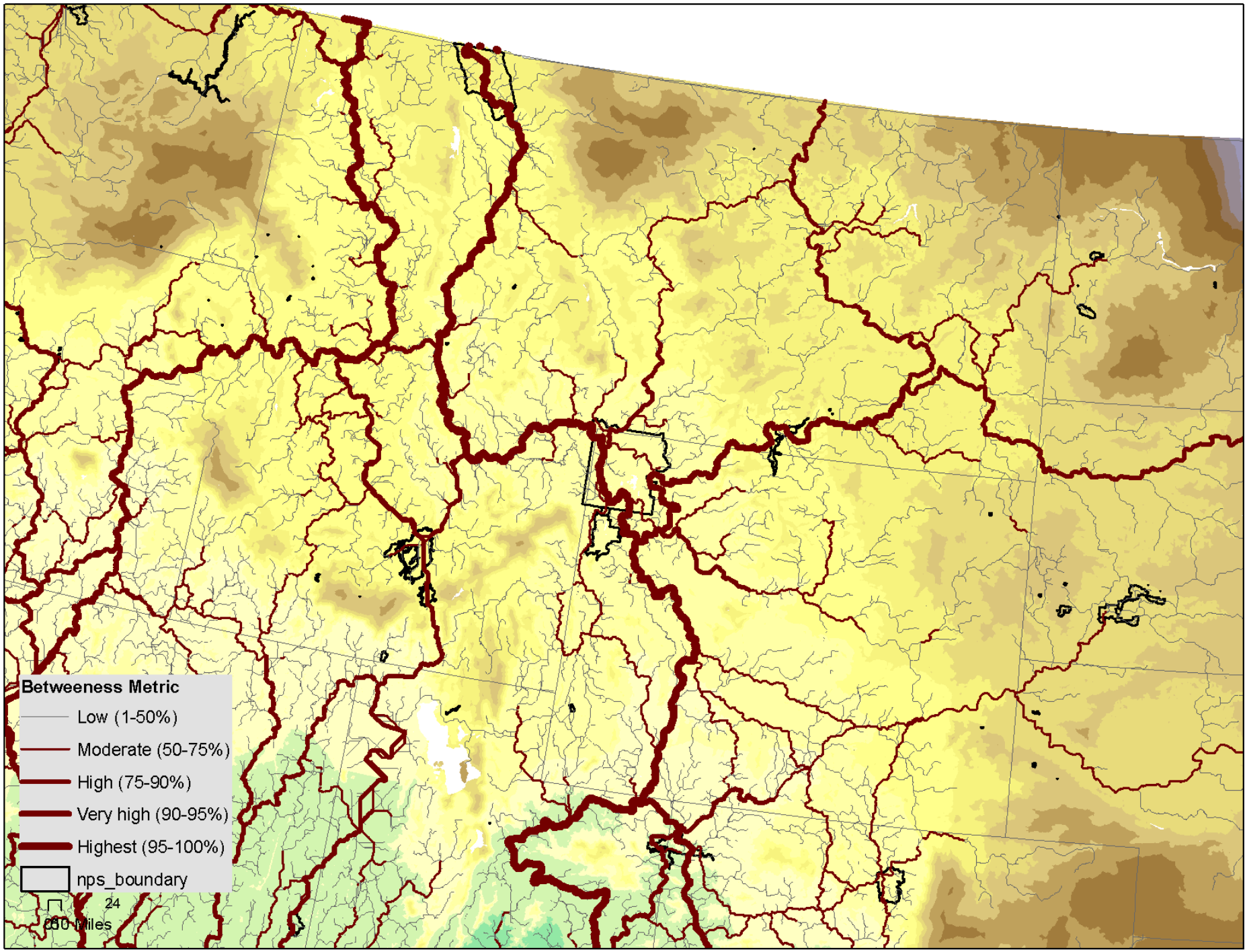
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Moderate (50-75%)
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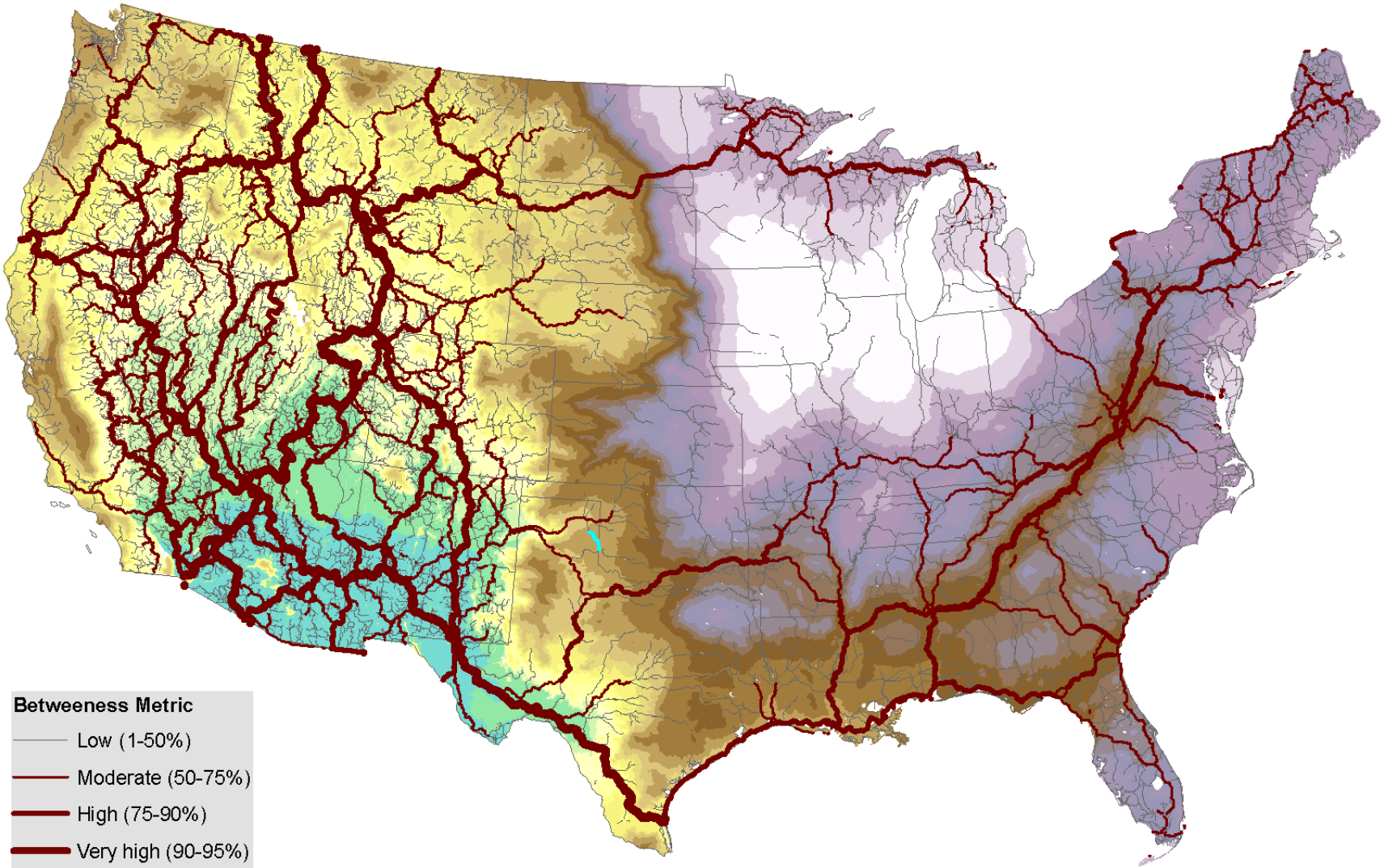
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High (75-90%)
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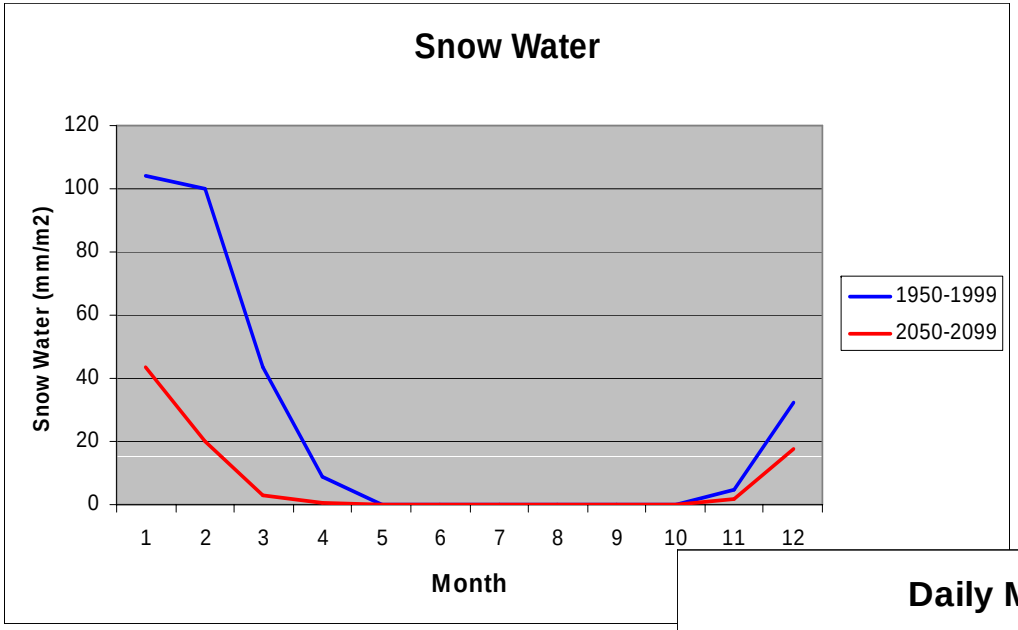
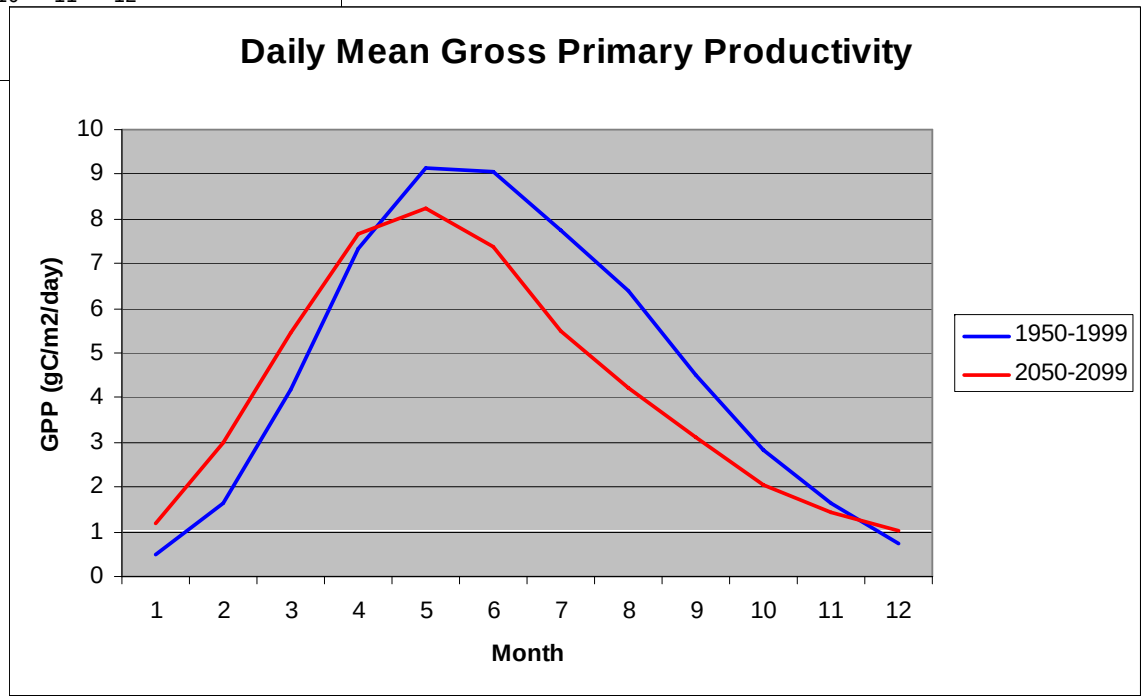
Forecasting Climate Impacts: TOPS Forecasted Changes in Snow Water and GPP for 2050-2099, Yosemite



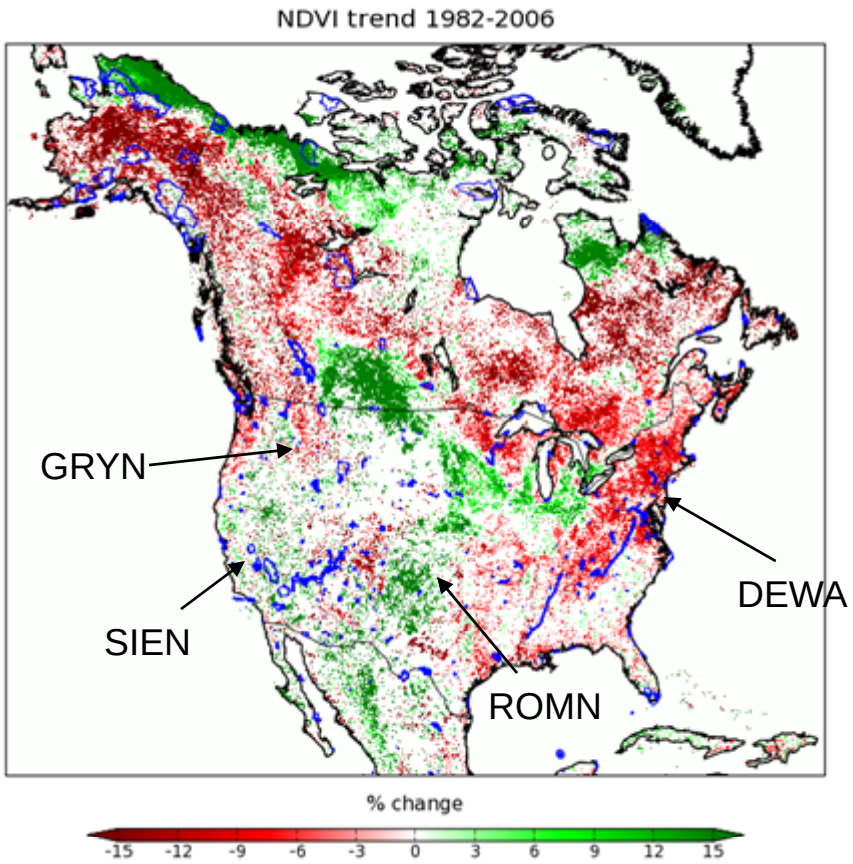


Landscape Dynamics: Trends in Vegetation Indices

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.

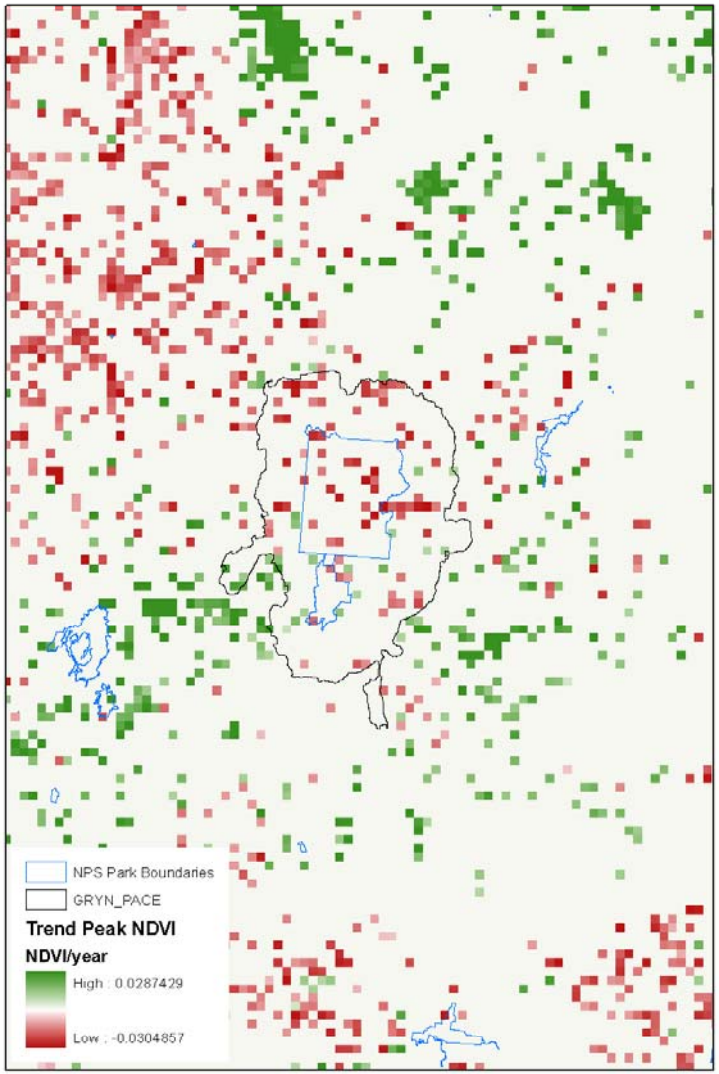
Stressors: Land use change, major wildfires, drought / climate, insect infestations and tree diseases



Trend in Peak NDVI

Landscape dynamics: Trends in Vegetation Indices

Summary: Disturbance and recovery associated with major wildfire events are likely primary drivers of observed patterns for GYRN. Sustained negative trends, or increase in area of pixels associated with negative trend may indicate need for further investigation.



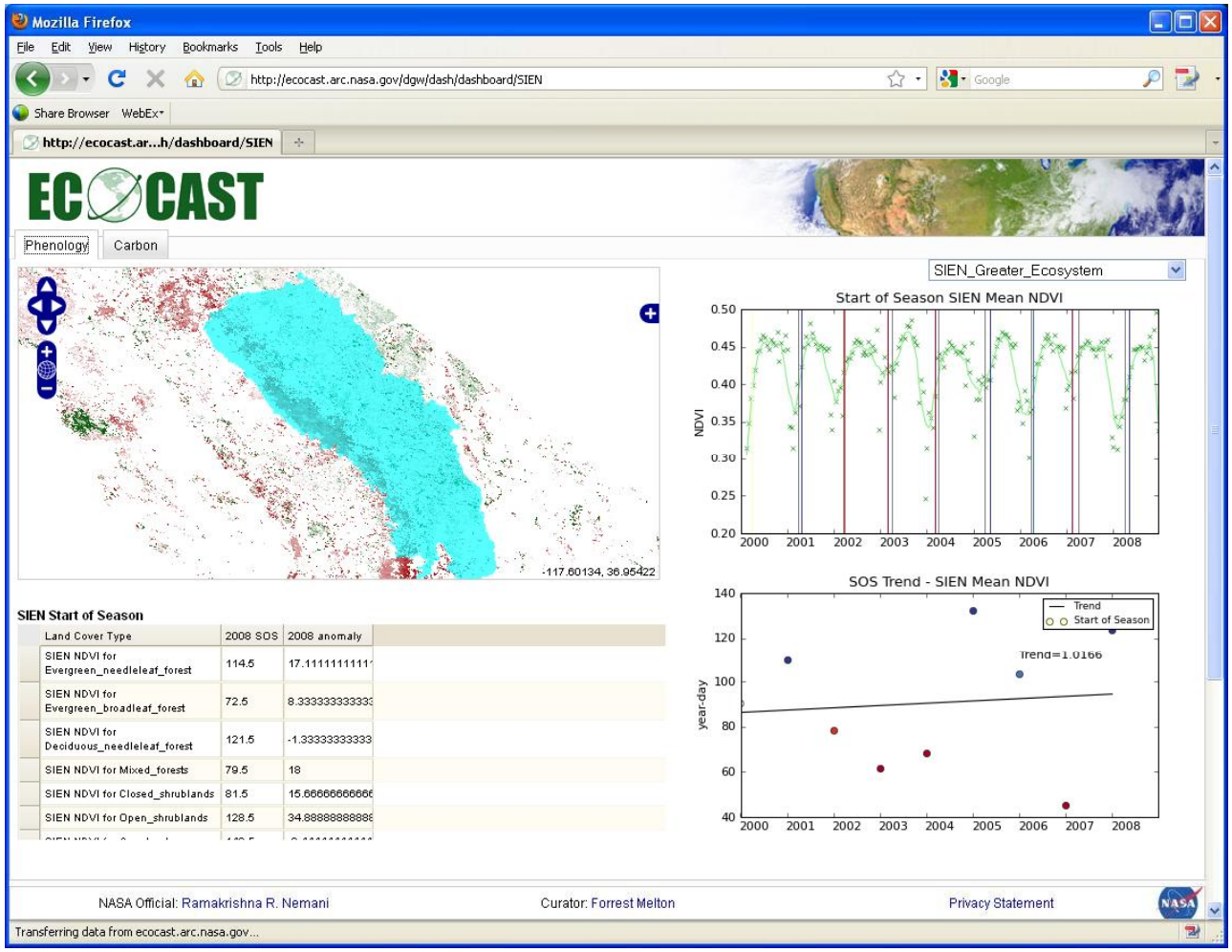
GRYN Parks and GRYN PACE
Trend in Peak NDVI from AVHRR (1982-2006)

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.

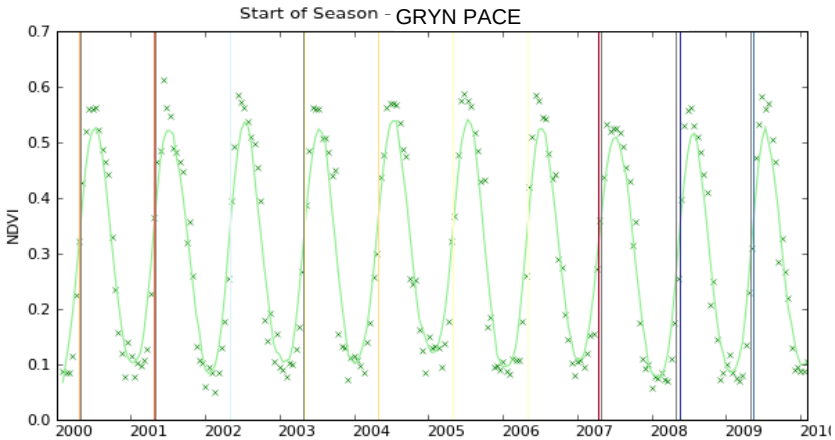
Stressors: Climate change, land use change, drought

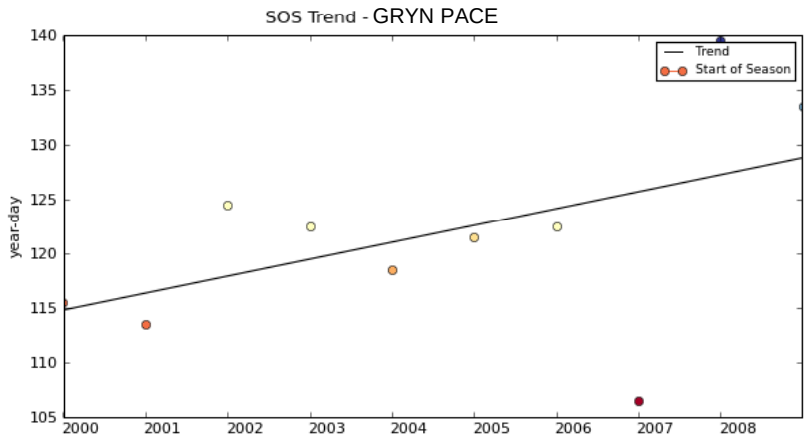


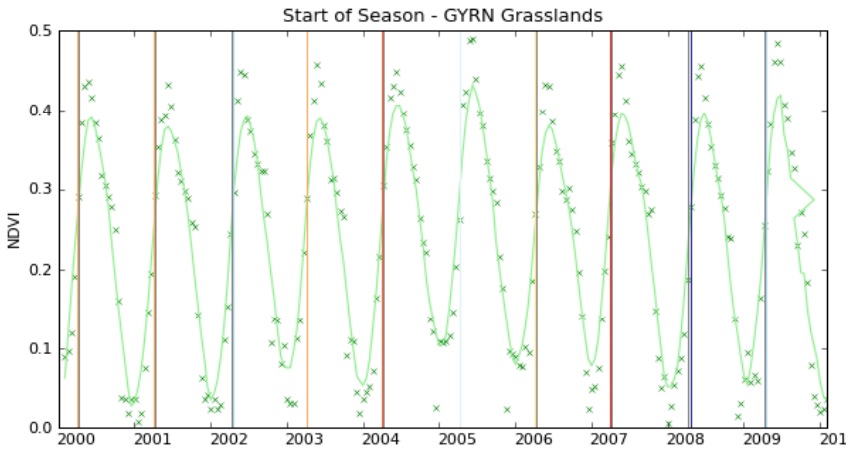
Summary: This indicator is currently being calculated for GYRN, and will include measures of the annual Start-of-Season anomaly, and graphs and plots to summarize trends in SOS by land cover type, as shown in this example for the Sierra Nevada Network. The indicator is intended to provide a relative 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.

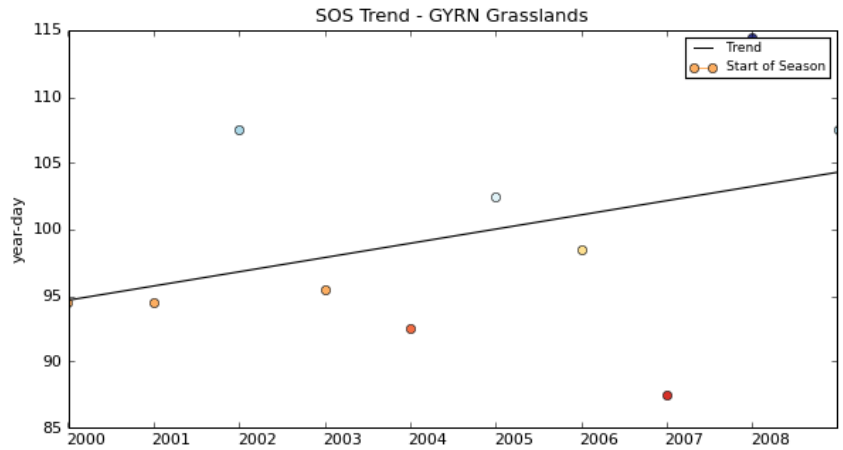
Weather and Climate: Landscape Phenology

Summary: Sample results for the Landscape Phenology indicator for the GRYN PACE and for grassland ecosystems within the GRYN PACE, showing the NDVI timeseries / SOS date for 2001-2009, and the SOS date for recent years showing significant interannual variability in SOS (e.g., 2007 versus 2008). The best-fit line is provided as a point of reference to assist in detecting emerging trends.







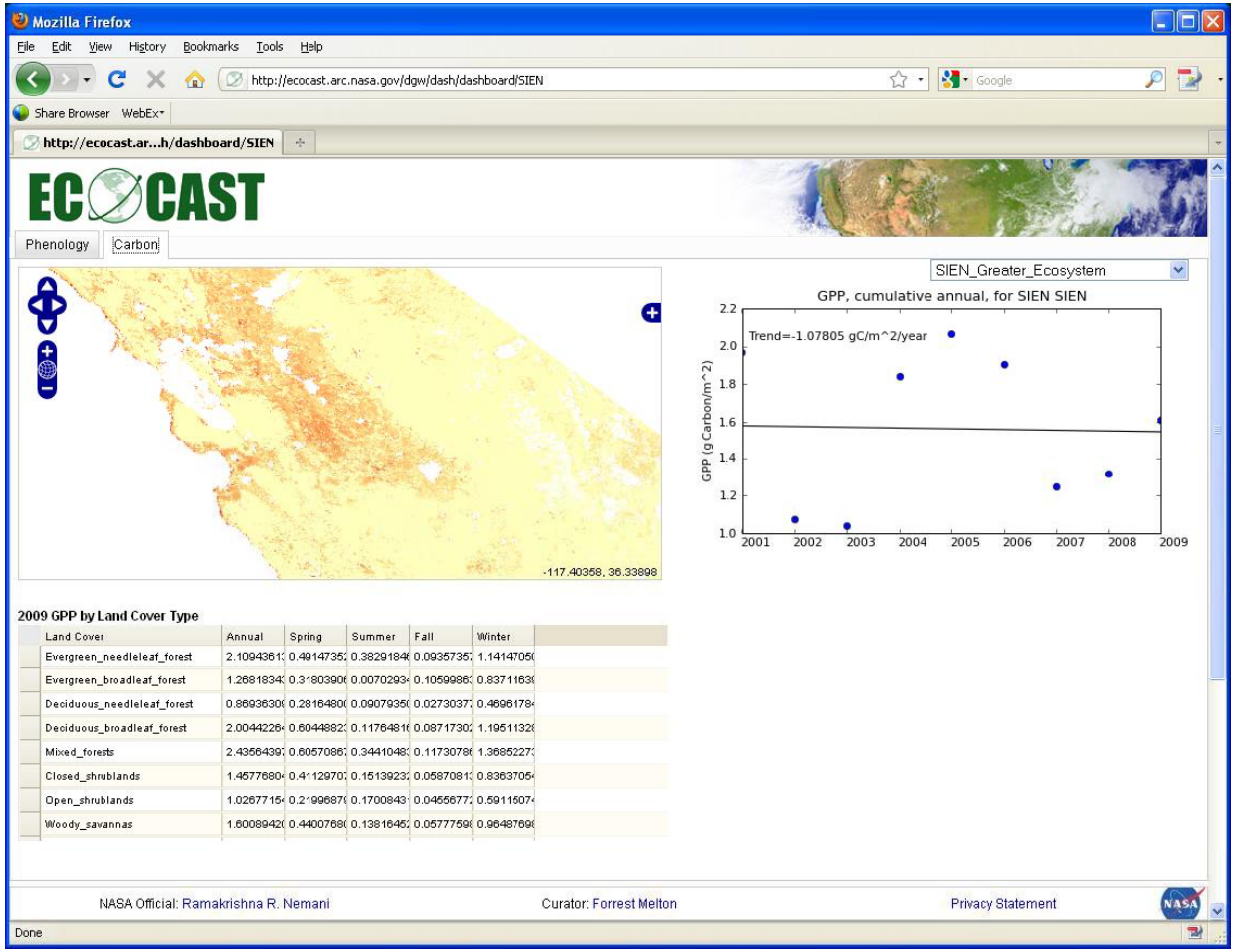


Ecosystem Productivity: Gross Primary Production

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.

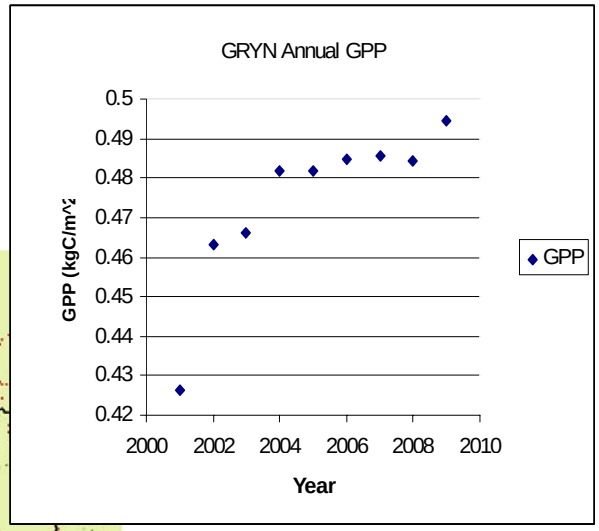
Stressors: Climate change, land use change, drought, wildfire, insect infestations



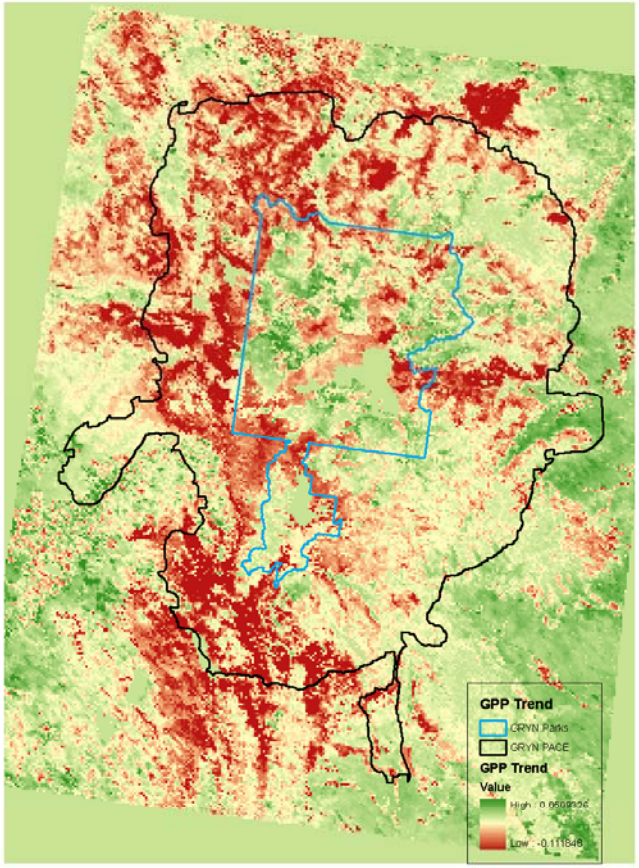
Summary: This indicator is currently being calculated for GYRN, and will include measures of GPP trends and anomalies summarized by season and land cover type, as shown in this example for the Sierra Nevada Network. This indicator relies on the use of MODIS data, and the TOPS implementation of the Biome-BGC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

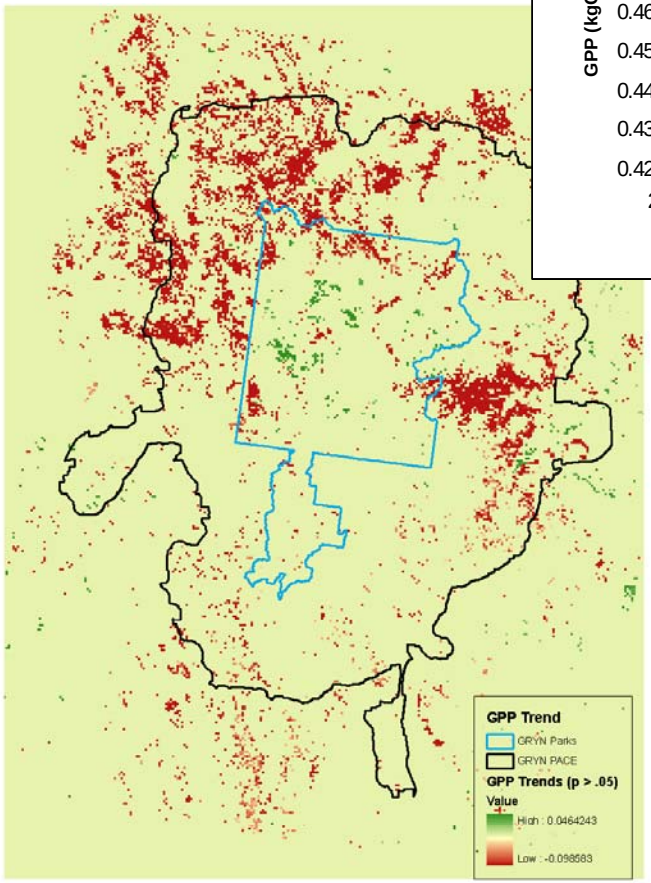
Ecosystem Productivity: Gross Primary Production

Preliminary results: Emerging negative trends in GPP to NW and E of park, but overall slight positive trend in total annual GPP in park, likely due in part to continuing post-fire recovery and succession.



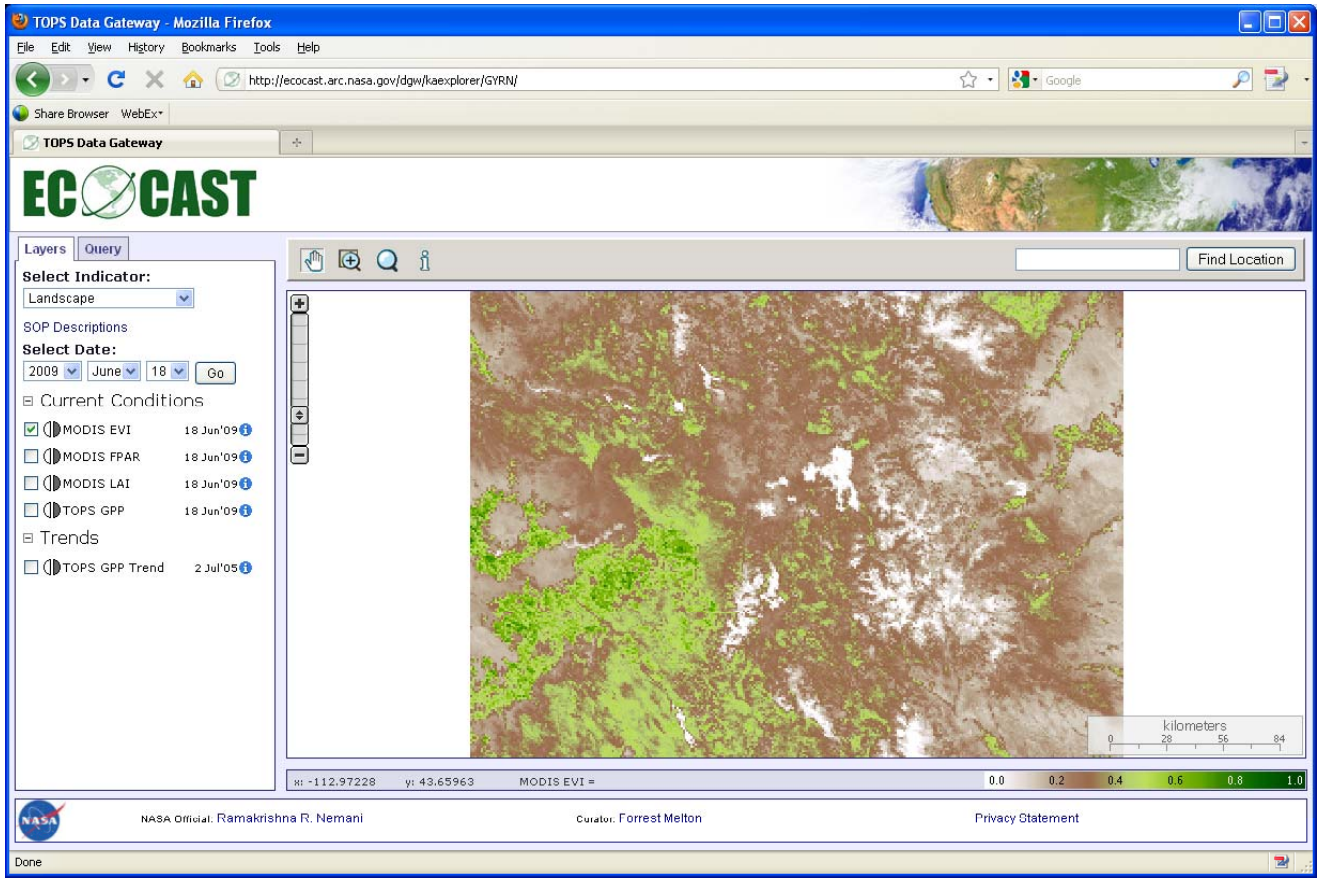
Annual average GPP for 2001-2009 for all GRYN parks.





Patterns in annual cumulative GPP from 2001-2009 within GRYN and GYRN PACE boundary. Figure on right is screened for significance of trend.

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)