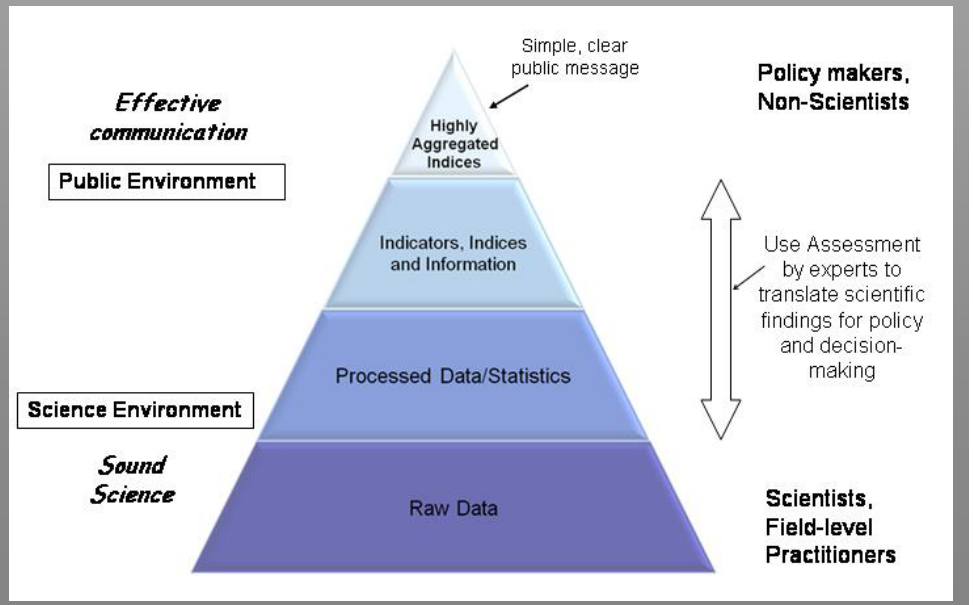
National Park Service Inventory and Monitoring Program

"The overall purpose of natural resource monitoring in parks is to develop scientifically sound information on the current status and long term trends in the composition, structure, and function of park ecosystems, and to determine how well current management practices are sustaining those ecosystems."

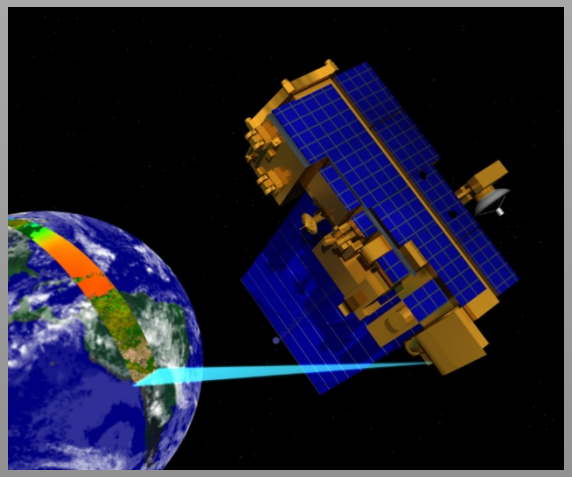


Fancy et al. 2008, Env. Mon. Ass.

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

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

NPS I&M Program

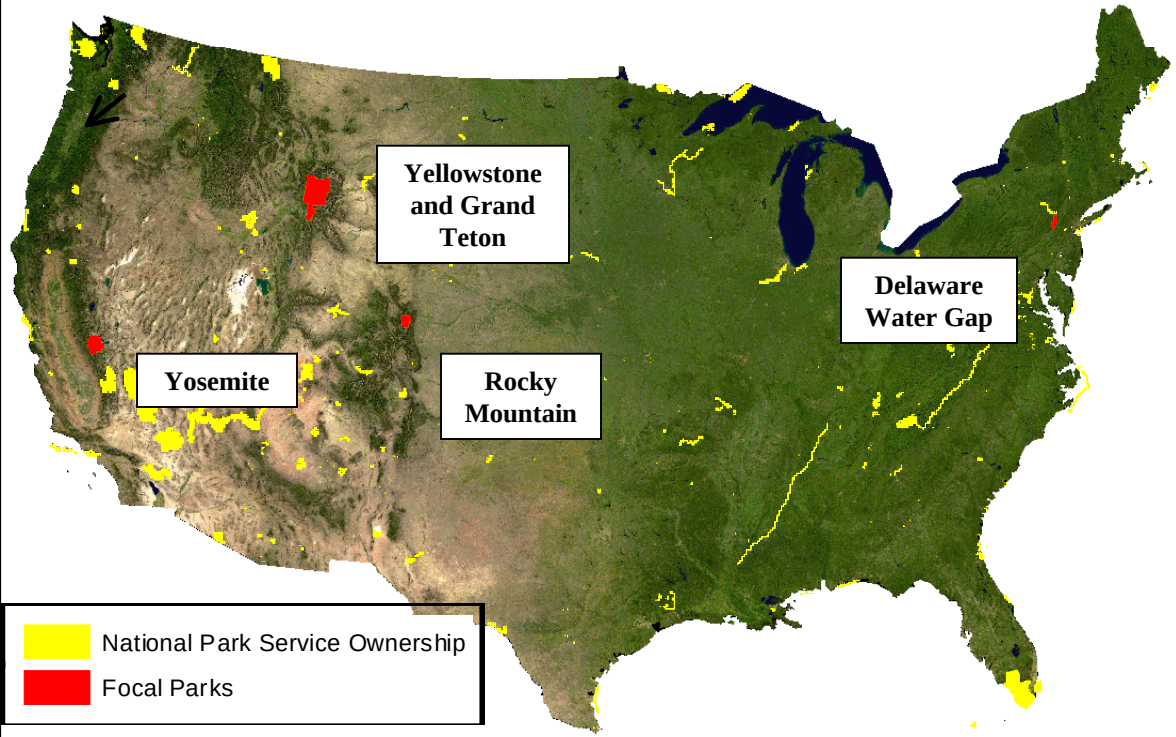


Objectives

- **Identify NASA and other products useful to park monitoring and identify the boundaries of the greater park ecosystems appropriate for monitoring.**
- **Add value to these data sets for understanding change through analysis and forecasting.**
- **Deliver these products and a means to integrate them into the NPS I&M decision support framework.**

John Gross
NPS I&M

Forrest Melton,
Rama Nemani,
NASA Aimes
Linda Mutch,
Bill Kuhn
NPS I&M



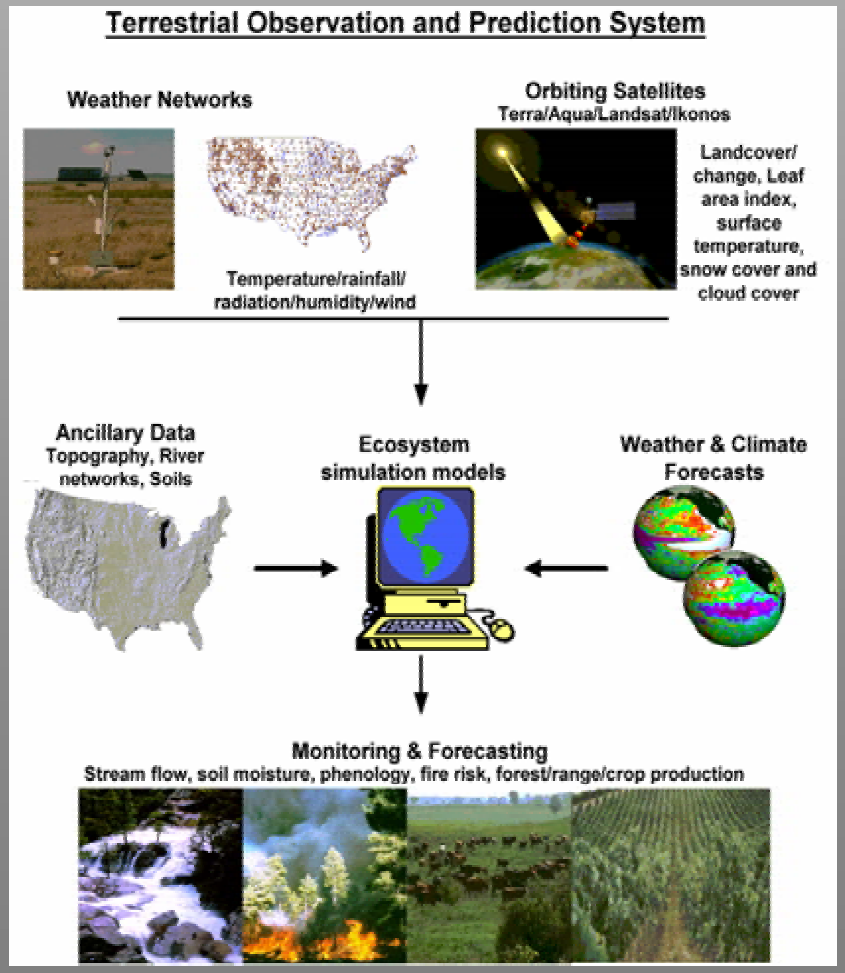
Dave Theobald
Colorado State Univ
Billy Schweiger, Brent Frakes
NPS I&M

Andy Hansen and
Nate Piekielek
Montana State University
Cathy Jean,
Rob Daily
NPS I&M

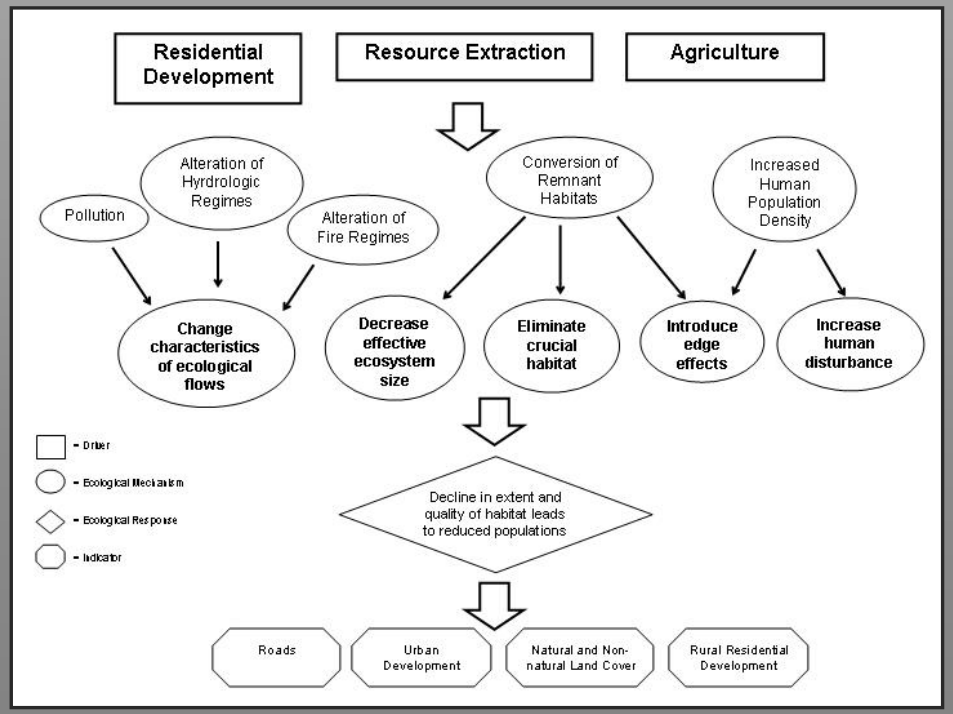
Scott Goetz
Woods Hole
Matthew Marshall,
NPS I&M

Objective 1: Indicators

1. Evaluate which TOPS and other products are most relevant to parks monitoring.
2. Select potential high priority indicators in context of NPS I&M conceptual models and I&M scientists. (24 identified)
3. Finalize indicators to demonstrate power of the approach (13 listed)



Nemani et al., 2003, EOM



Jones et al., 2008, RSE

Objective 1: Indicators

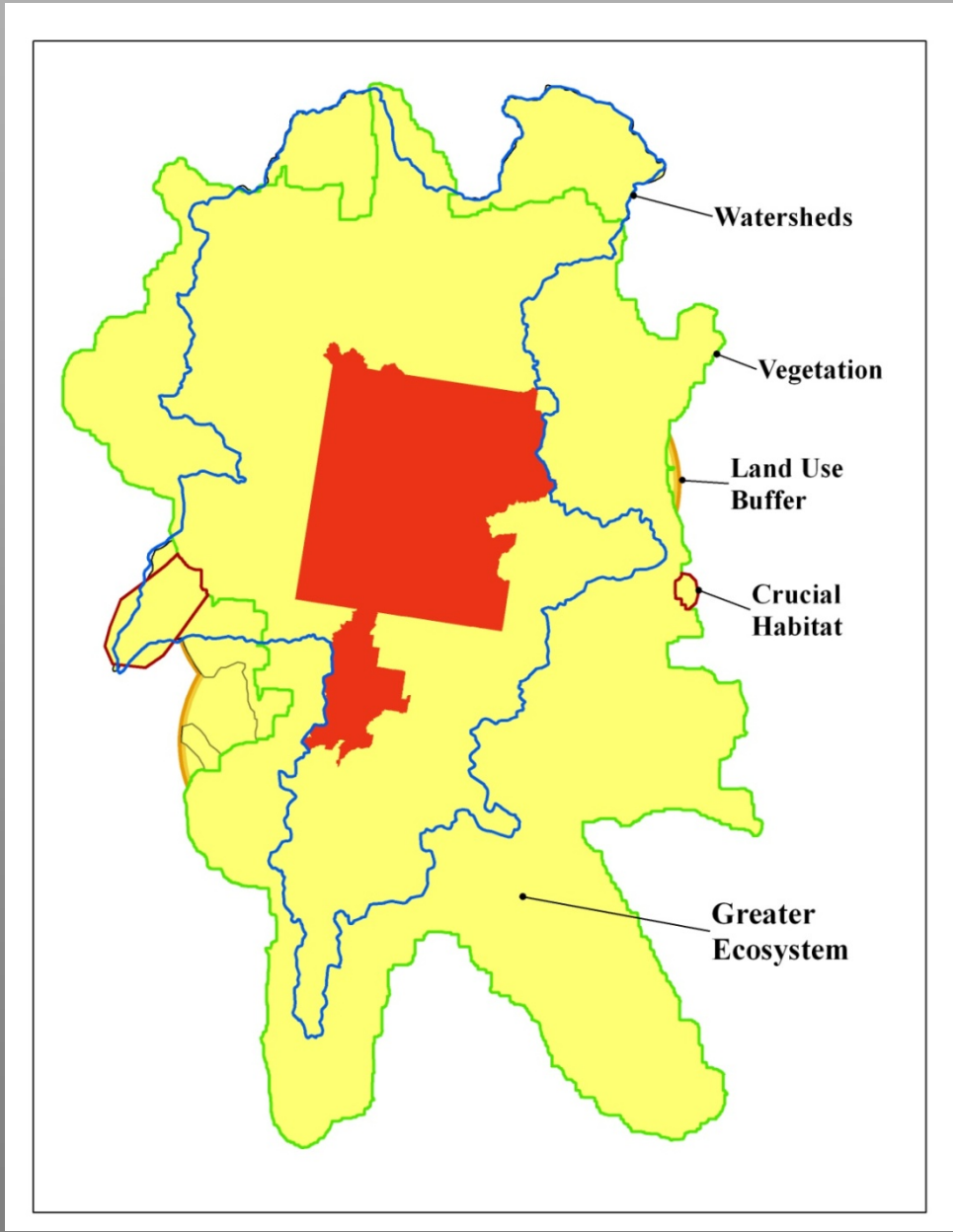
Level 1	Level 2	Level 3	Lead	Comments	Delivery
Air and Climate	Weather and Climate	Weather and Climate	FM, AH, RN	Phenology - NDVI, EVI, LAI Annual anomaly Date of min/max PAT, Leaf on /off	SOP with contract
Water Water	Hydrology	Ground-water Dynamics	FM, RN	Soil moisture Wetlands Monthly/annual trends/anomalies	SOP with contract
		Stream health	SG	Biotic indicators Sensitive taxa	Proof of concept
Landscape	Consumptive Use	Visitor Use	DT	Visitor shed demographics	SOP with transfer
	Landscape Dynamics	Land Cover and Use	DT, AH, SG	Ecosystem type composition Summary by spatial scale	SOP with transfer
			AH	Biodiversity and habitat indices Species, guild, community levels	SOP with transfer
			SG, DT	Impervious cover change	SOP with contract
			AH, DT	Housing density change Home density by section	SOP with transfer/ contract
			SG, AH, DT	Landscape fragmentation/ connectivity	SOP with transfer/ contract
		Extreme Disturbance Events	FM, AH	Fire effects via NDVI/EVI, FPAR/LAI, soil moisture, evapotranspiration, vegetation stress (leaf water potential)	SOP with transfer/ contract
		Primary Production	FM	GPP/NPP TOPS GPP Incorporate ground & existing plot based measurements	SOP with contract, Operational
		Monitoring area	NP, AH	Greater park ecosystem boundaries	SOP with transfer
		Land use	DT, AH	Land use – NLUD, Census, B of Econ.,	SOP with contract

Objective 1: Delineating Greater Ecosystems

Criteria	Mechanism	Ecological Process	Possible Implications
Contiguity of surrounding natural habitat	Effective size of ecosystem	•Species Area Effect •Trophic Structure	•Decreased species richness •Smaller population size •Trophic cascades
Watershed and airshed boundaries	Change in ecological flows	•Mass and energy balance, flows •Pollution effects	•Altered water quantity and quality •Degraded air quality/vegetation damage •Impacted viewshed
Disturbance	Altered disturbance regimes	Dynamic steady-state equilibrium	•Altered seral stage distribution •Loss of disturbance adapted, often rare species •Altered ecological flows
Edge effects of human activity	•Exotic species and disease •Poaching/hunting	•Demography •Competition •Organism movement and behavior	•Population decline •Altered community composition and structure
Crucial Habitat outside of park	Habitat disturbance or destruction	•Source-sink dynamics •Metapopulations •Organism movement	•Altered dispersal and seasonal migration •Population decline

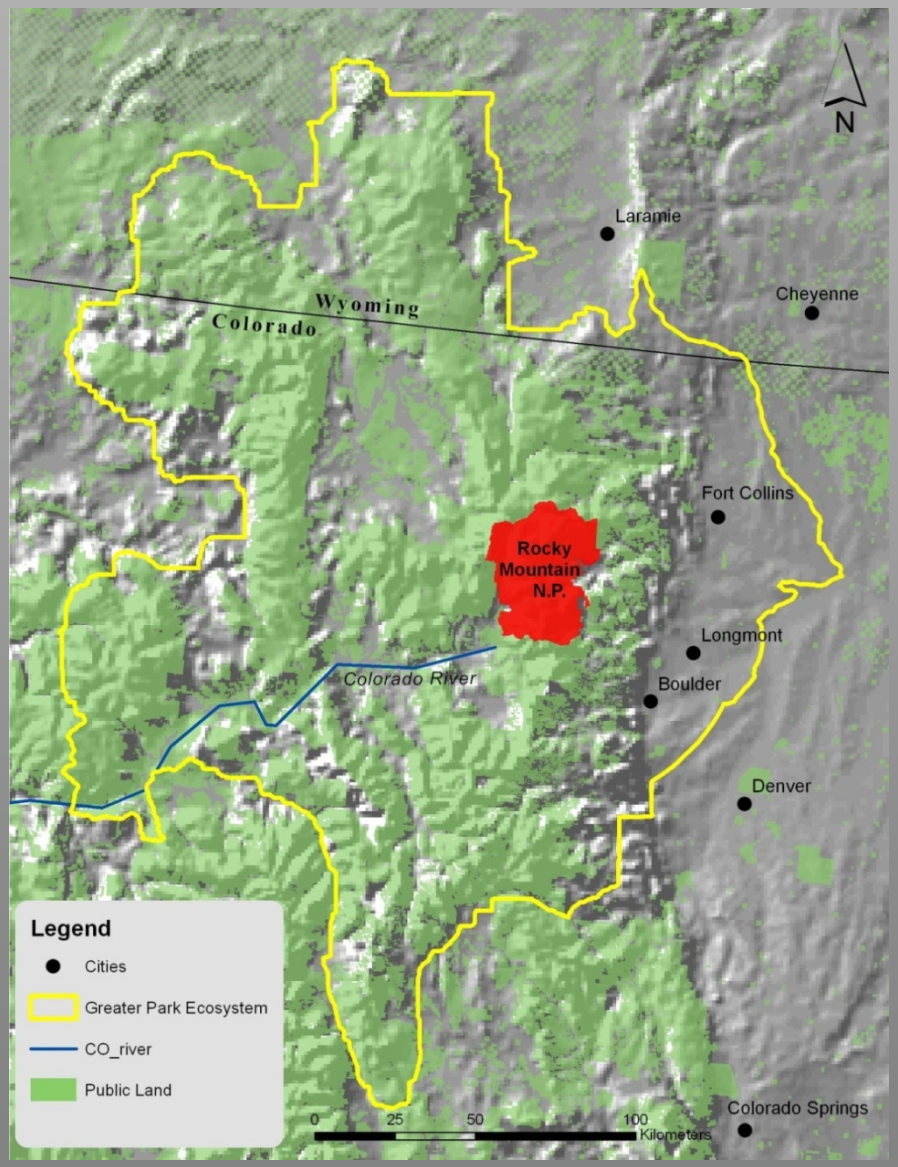
Hansen and Defries 2007, EA

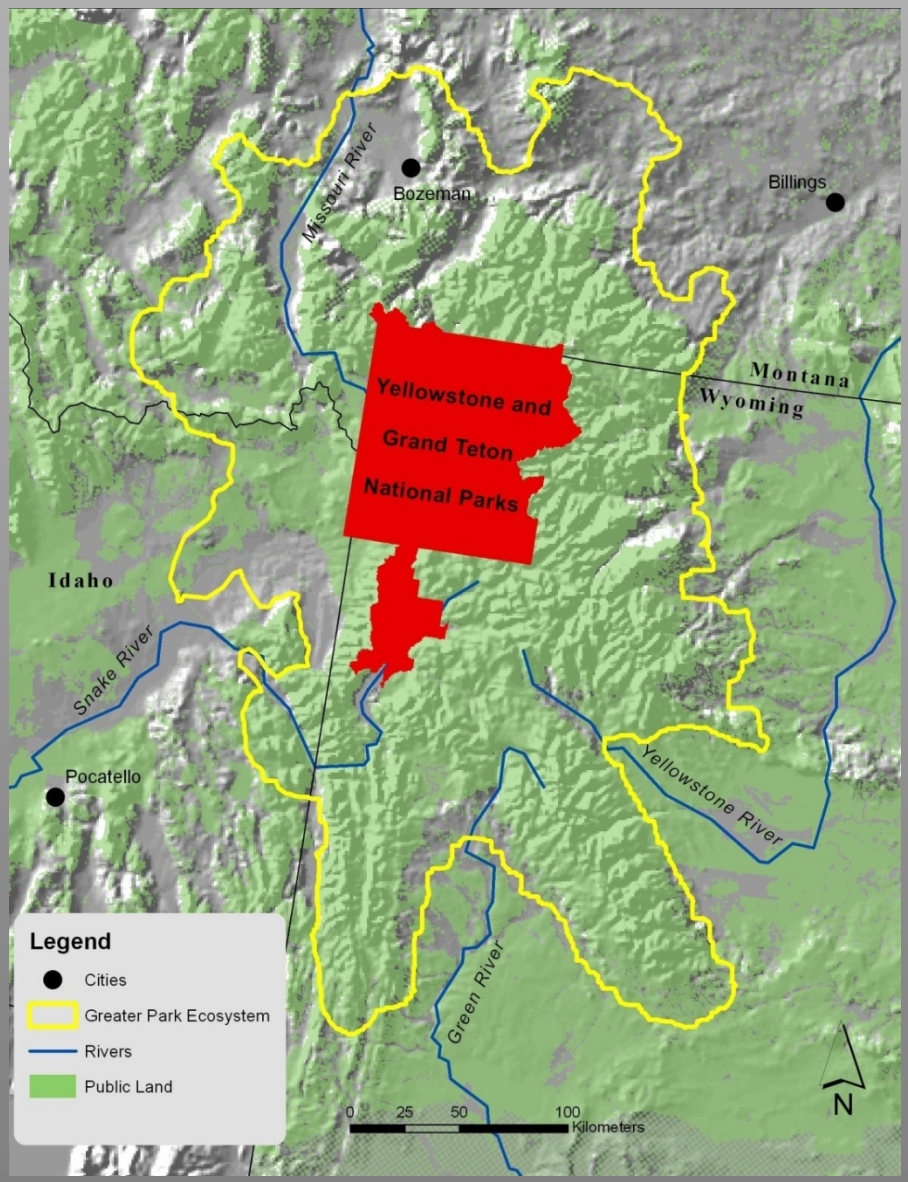
Objective 1: Delineating Greater Ecosystems



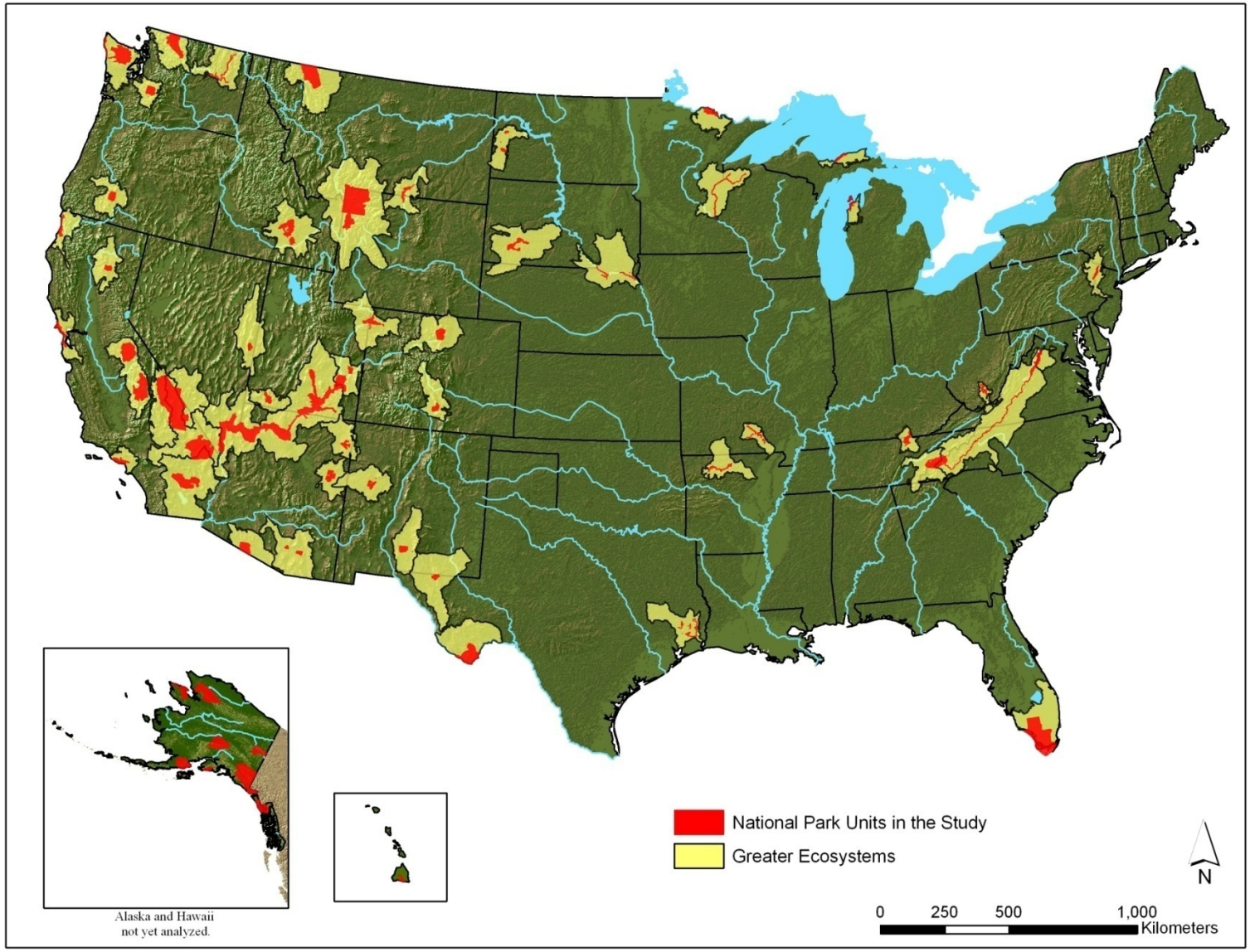
Greater Yellowstone Ecosystem

Objective 1: Delineating Greater Ecosystems





Objective 1: Delineating Greater Ecosystems



Hansen, A., S. Running, C. Davis, J. Haas. Vulnerability of US National Parks to Climate and Land Use Change

Objective 2: Add Value Through Analysis and Forecasting

Land use change metrics

Land cover

•Extent

•Spatial configuration

Land use

•Home density and area impacted

•Agriculture

•Road density and area impacted

•Development in Park

+

Natural resource metrics

Animal species distribution/habitat use

Ecosystem/habitat extent

Biodiversity indices

•Bird Hotspots

•Corridors

•High Priority Conservation Areas

→

Analyses

Habitat Suitability Models

Connectivity Models

Human Disturbance Models

Future Land Use Models

=

Output

Habitat Extent/Spatial Configuration

+

Connectivity

+

Human Disturbance

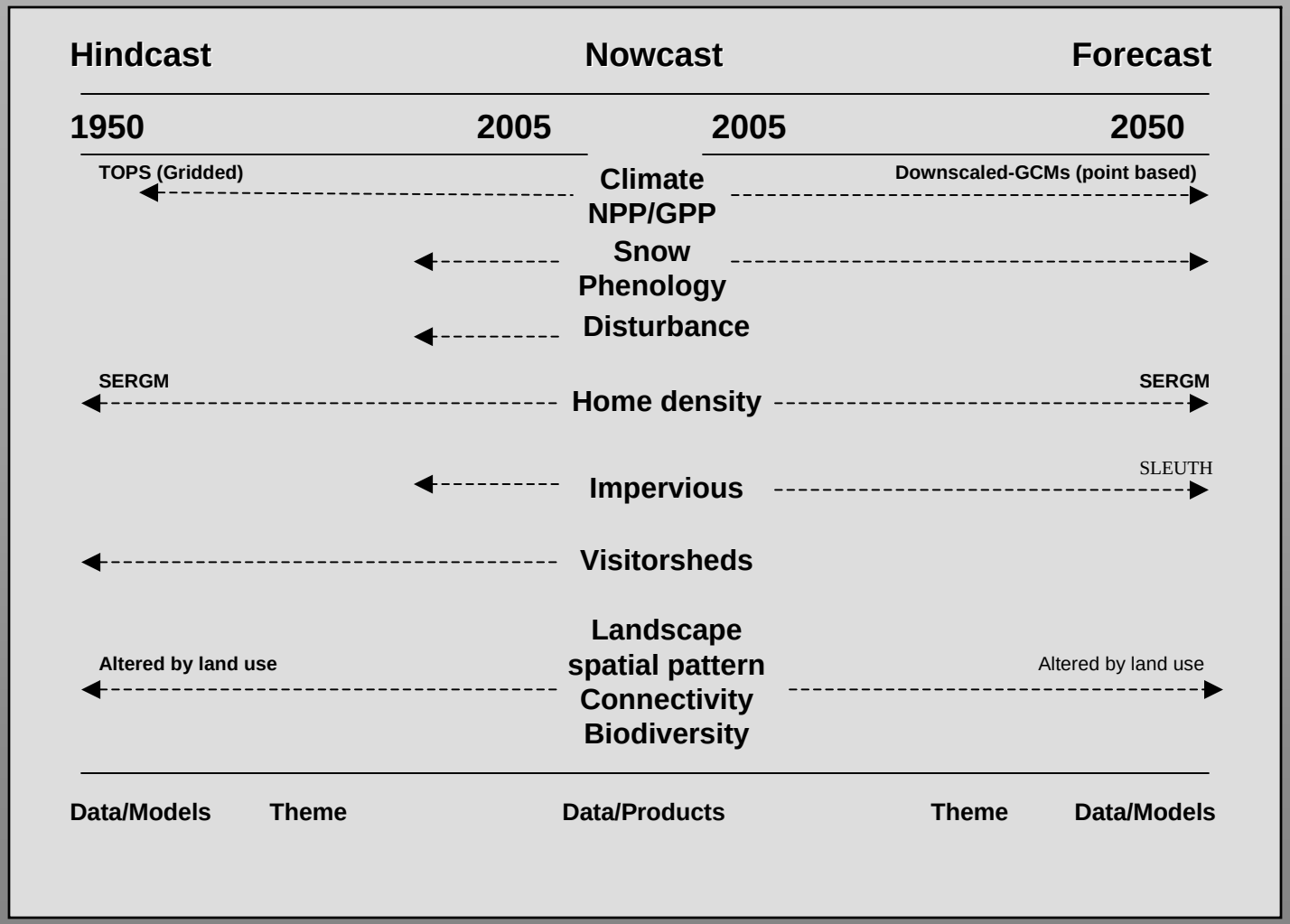
+

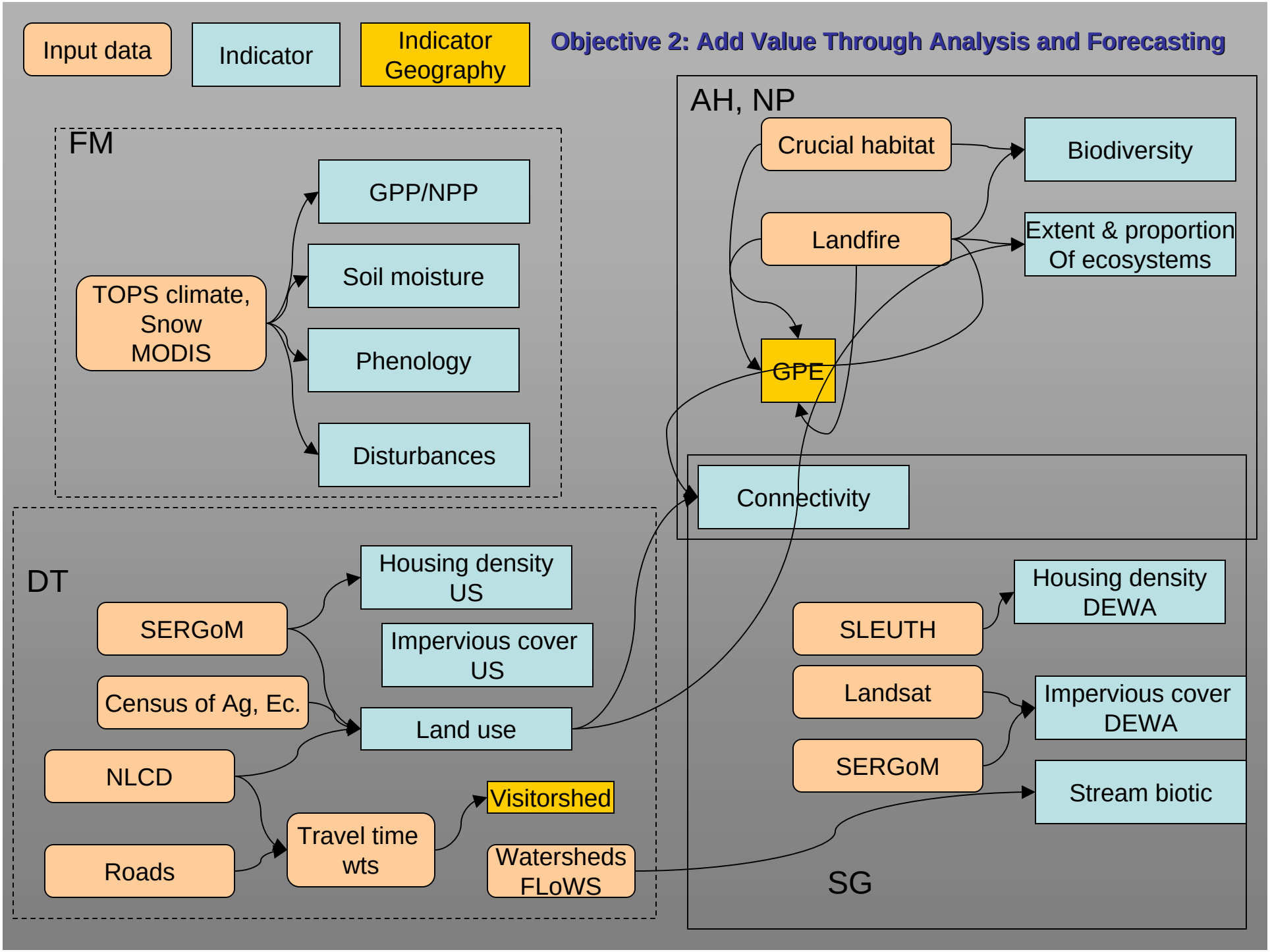
Habitat Vulnerability to Future Land Use

↓

Integrated Habitat Condition

Objective 2: Add Value Through Analysis and Forecasting



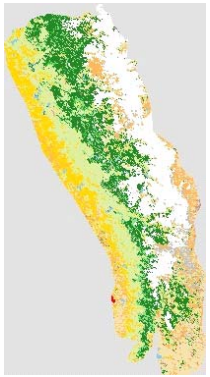

Input data
Indicator
Indicator Geography
Objective 2: Add Value Through Analysis and Forecasting
FM
TOPS climate, Snow MODIS
GPP/NPP
Soil moisture
Phenology
Disturbances
AH, NP
Crucial habitat
Landfire
GPE
Biodiversity
Extent & proportion Of ecosystems
Connectivity
DT
SERGoM
Census of Ag, Ec.
NLCD
Roads
Housing density US
Impervious cover US
Land use
Travel time wts
Visitorshed
Watersheds FLoWS
SG
SLEUTH
Landsat
SERGoM
Housing density DEWA
Impervious cover DEWA
Stream biotic

TOPS Products for Sierra Greater Park Ecosystems

Satellite

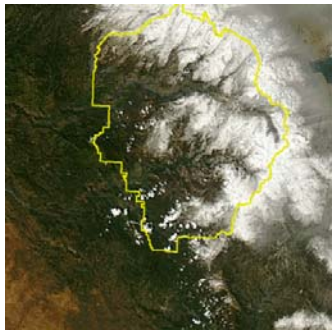
EVI
Sept. 14, 2007

Snow Cover
Oct. 15, 2007



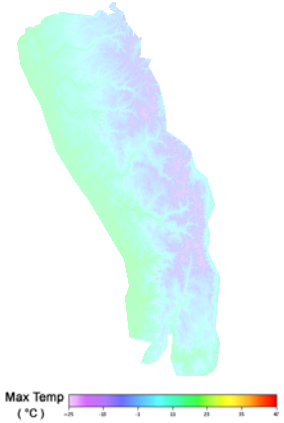
Leaf Area Index
Sept. 22, 2007

MODIS Direct Broadcast

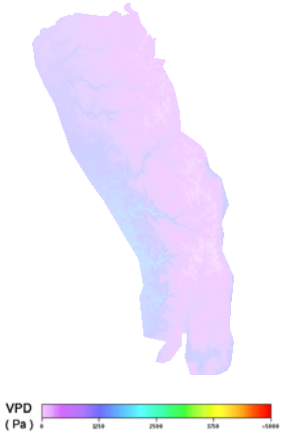


Climate

Maximum Temp.
Nov. 12, 2007

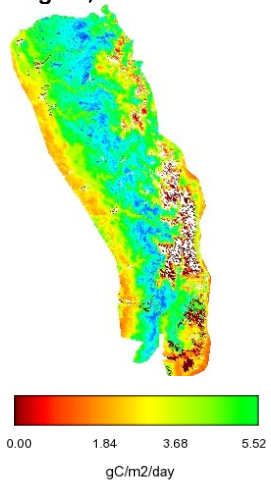


Vapor Pressure Def.
Nov. 12, 2007



Ecosystem Model

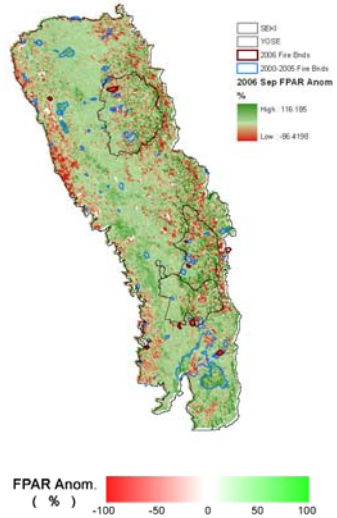
TOPS GPP
August, 2007



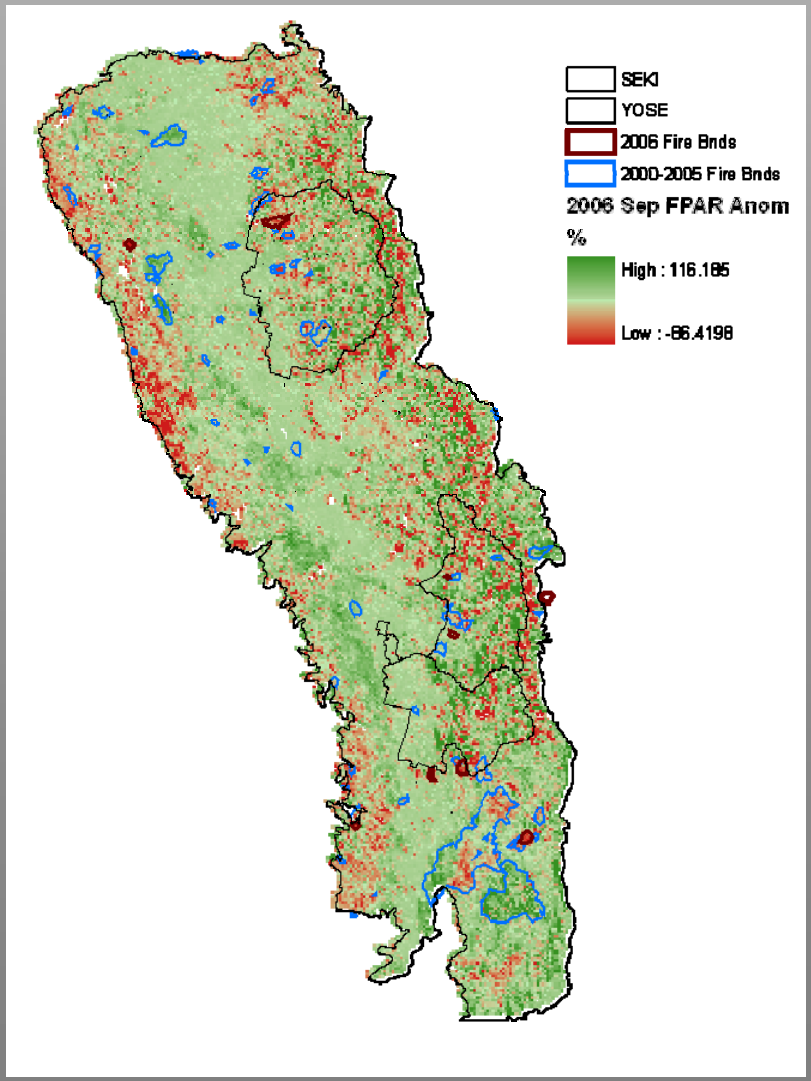
Soil Moisture
July 30, 2007

Trends & Anomalies

FPAR Anomaly
August, 2007



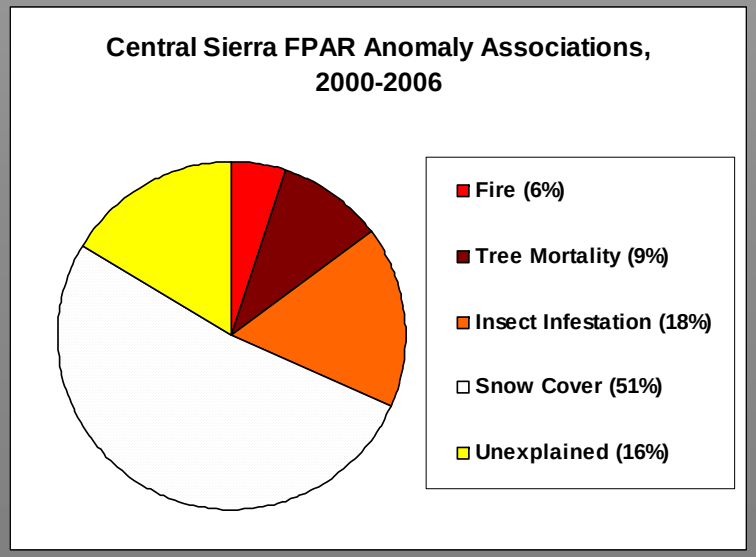
Objective 2: Add Value Through Analysis and Forecasting



Anomaly Detection for Monitoring of Disturbance Effects and Vegetation Condition

For central Sierra Nevada, from 2000-2006:

- **An anomaly threshold of -6% detected >350,000 negative anomaly events after QA filtering**
- **Detected 74% of fire events > 300 acres in size**
- **84% of FPAR anomalies explained through cross-referencing**
- **Next step is to examine unexplained anomalies using time series of Landsat data to verify**



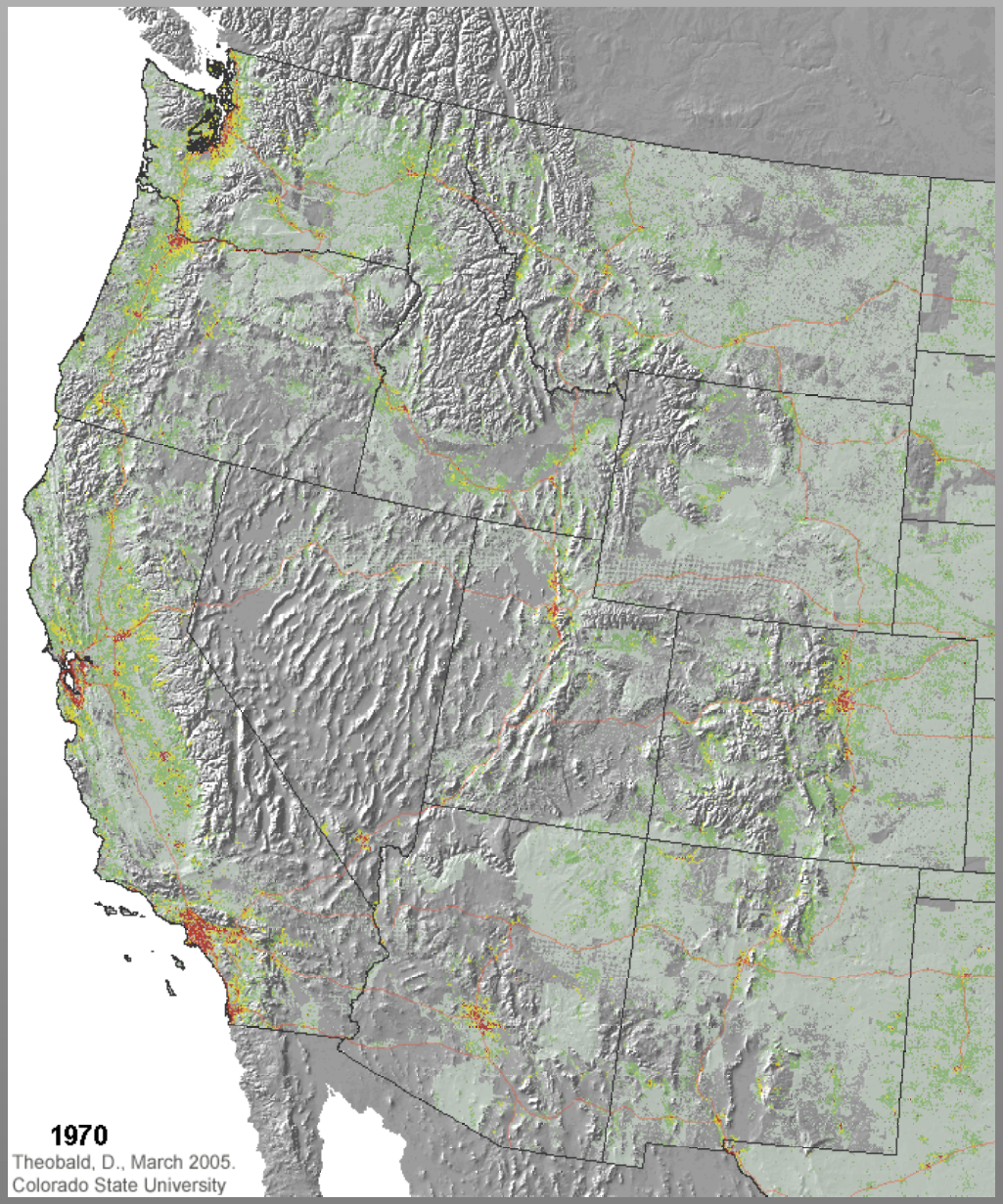
Objective 2: Add Value Through Analysis and Forecasting

SERGoM housing density:

- **1940-2000, 10**
- **2010-2030, 10**

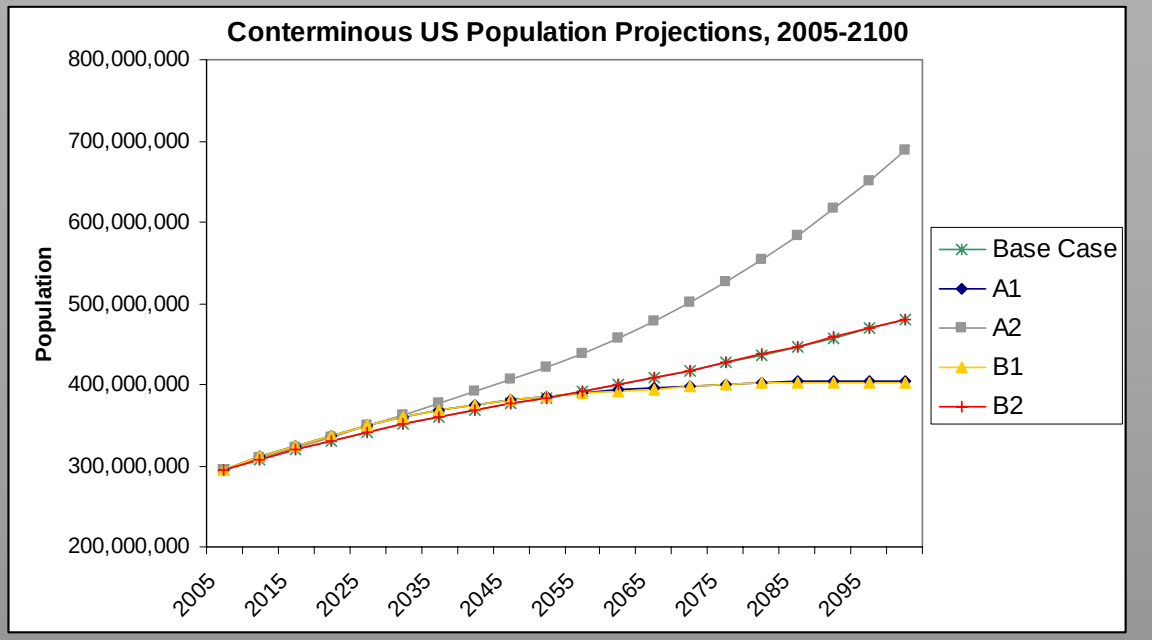
Revisions:

- **Dasymetric mapping**
  - **Groundwater wells (west)**
  - **NLCD2001**
  - **Roads + slope**
- **PAD v4.5plus**



Objective 2: Add Value Through Analysis and Forecasting

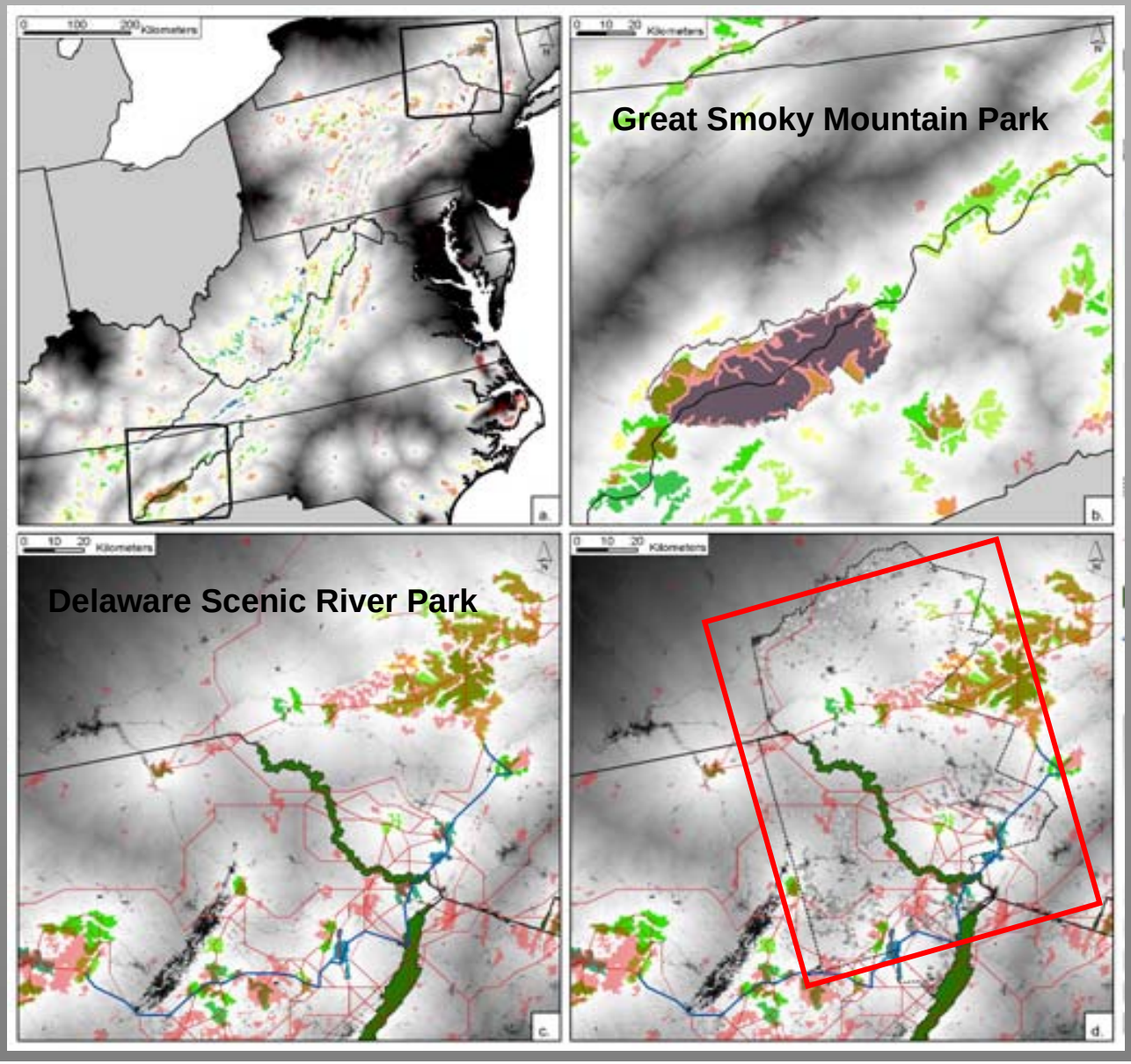
ICLUS SRES Housing Density



Summary of Adjustments to SERGoM v3 for SRES scenarios

Scenario	Storyline Description	SERGoM		
		Household size	*Form*	*Travel time (minutes)* *<5; 10; 20; 30; 45; >45*
A1	**Fast economic development, low population growth, high integration**	**Smaller (-15%)**	**No change**	**75; 75; 85; 90; 95; 100**
B1	**Similar to A1 but env. Sustainable economic growth**	**Smaller (-15%)**	**Slight compact**	**90; 95; 85; 90; 95; 100**
A2	**Like A1 but higher fertility & high domestic migration**	**Larger (+15%)**	**No change**	**75; 75; 85; 90; 95; 100**
B2	**Regionally oriented world, medium fertility rate**	**No change**	**Slight compact**	**90; 95; 85; 90; 95; 100**
Baseline		**No change**	**No change**	**75; 75; 85; 90; 95; 100**

Objective 2: Add Value Through Analysis and Forecasting



Connectivity of Core Habitat Areas

Graph Theoretic Approach

Example Loss of Habitat Connectivity Associated with Exurban Growth

Goetz et al, RSE

Objective 3: Integrate into NPS I&M Framework

- Summaries - by spatial and temporal scale
- Stories – interpretation of trends and interactions
- Delivery – Standard Operating Procedures, Model Builder tools, contracts
- Web-based interface – data organization, display, access

Indicator	Analysis Ecosystem model	Summaries (by spatial/temporal scale)	Stories
Phenology			
Soil moisture			
Stream IBI			
Major ecosystems			
Habitat types			
Impervious surface			
Housing density			
Landscape frag/connectivity			
Disturbance			
GPP/NPP			
Land use			

Objective 3: Integrate into NPS I&M Framework

ArcToolbox

Topographic Wetness Index+ (TWI+)

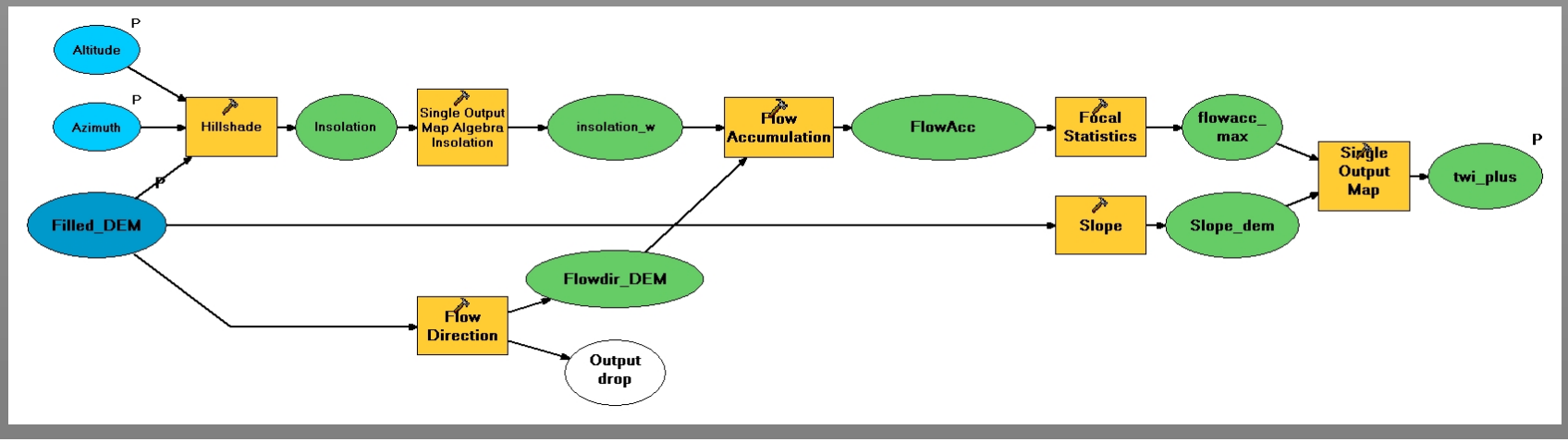
Computes the Topographic Wetness Index that incorporates solar insolation (TWI -- also known as Compound Topographic Index). This index is based on Beven and Kirkby's (1979) TOPMODEL, which is a physically based, distributed watershed model that simulates hydrologic flow of water, identifying where saturated land-surface areas develop that have the potential to produce overland flow. It is commonly used to general a surface of soil moisture and used for vegetation and hydrological modeling.

Rather assuming that all locations have the same amount of contributing moisture, this tool incorporates differences between south and north facing aspects. That is, rather than accumulating a value of 1.0 for all cells (as in TWI), this tool accumulates a weighted value ranging from 0.0 (xeric) to 1.0 (mesic) based on insolation. Here we use a simple approximation of solar insolation based on the HILLSHADE routine, using azimuth and altitude values that represent the location of the sun at the autumnal equinox at noon.

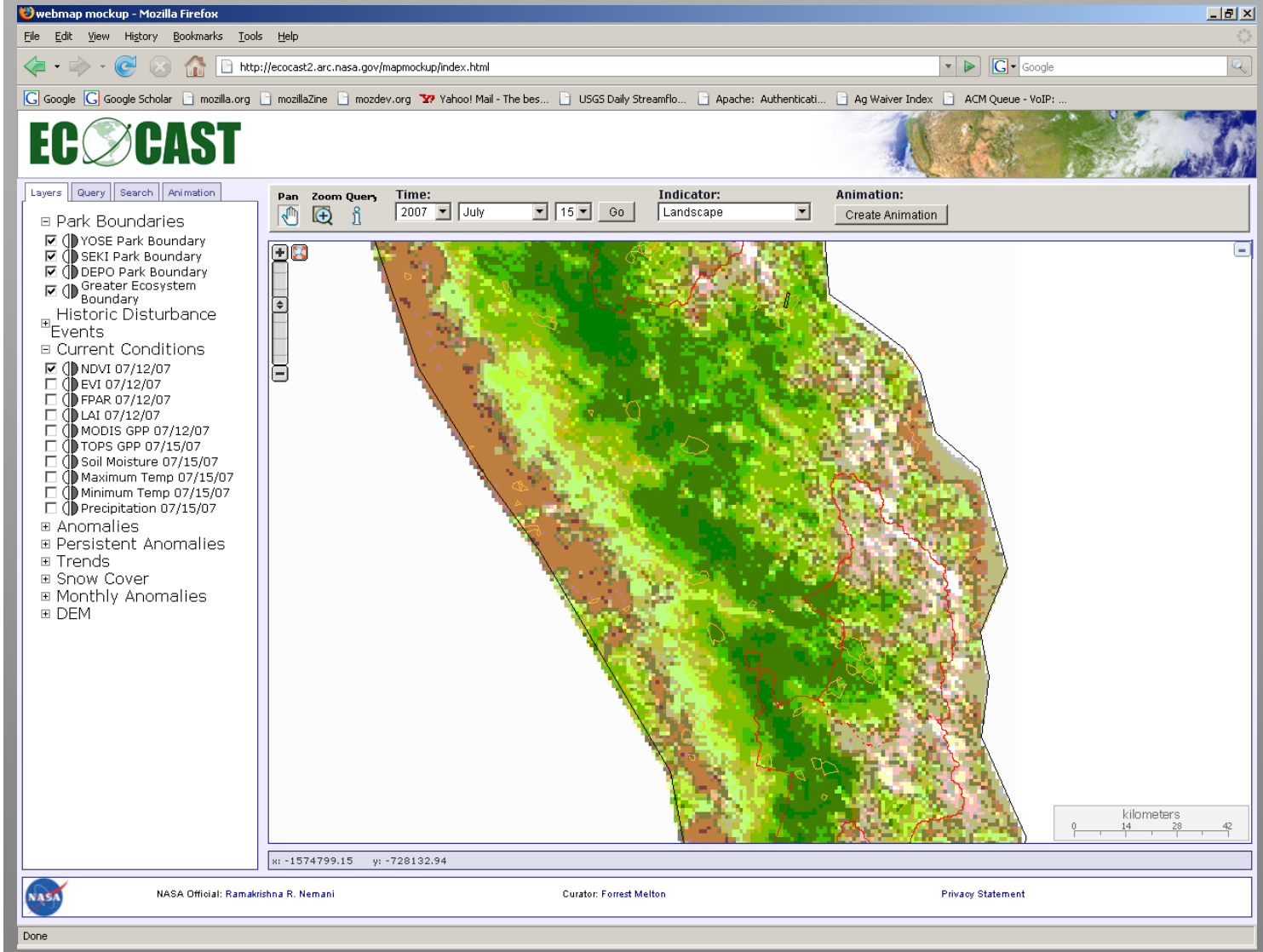
•TWI = ln (a / tan(b)), where a is the accumulated upslope area and b is the local slope in degrees.

Beven, K.J. and M.J. Kirkby. 1979. A physically based variable contributing area model of basin hydrology. Hydrologic Science Bulletin 24(1):43-69.

Note: This tool is part of the LCaP toolbox. Theobald, D.M. 2007. LCaP v1.0: Landscape Connectivity and Pattern tools for ArcGIS. Colorado State University, Fort Collins, CO.



Objective 3: Integrate into NPS I&M Framework



- Browser-based, open source (ka-Map / Mapserver) data access and visualization system
- Rapid data access, visualization, query, and analysis
- Supports timeseries plots, animations, data queries
- FTP & WMS data access

TOPS Data Gateway

Schedule

1. Identify NASA and other products useful to park monitoring and identify the boundaries of the greater park ecosystems appropriate for monitoring these indicators.

- **Establish collaborative team**
- **Complete survey of NPS I&M network scientists**
- **Identify and prioritize indicators**
- **Quantify boundaries of greater park ecosystems**
- **Complete evaluation report**

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

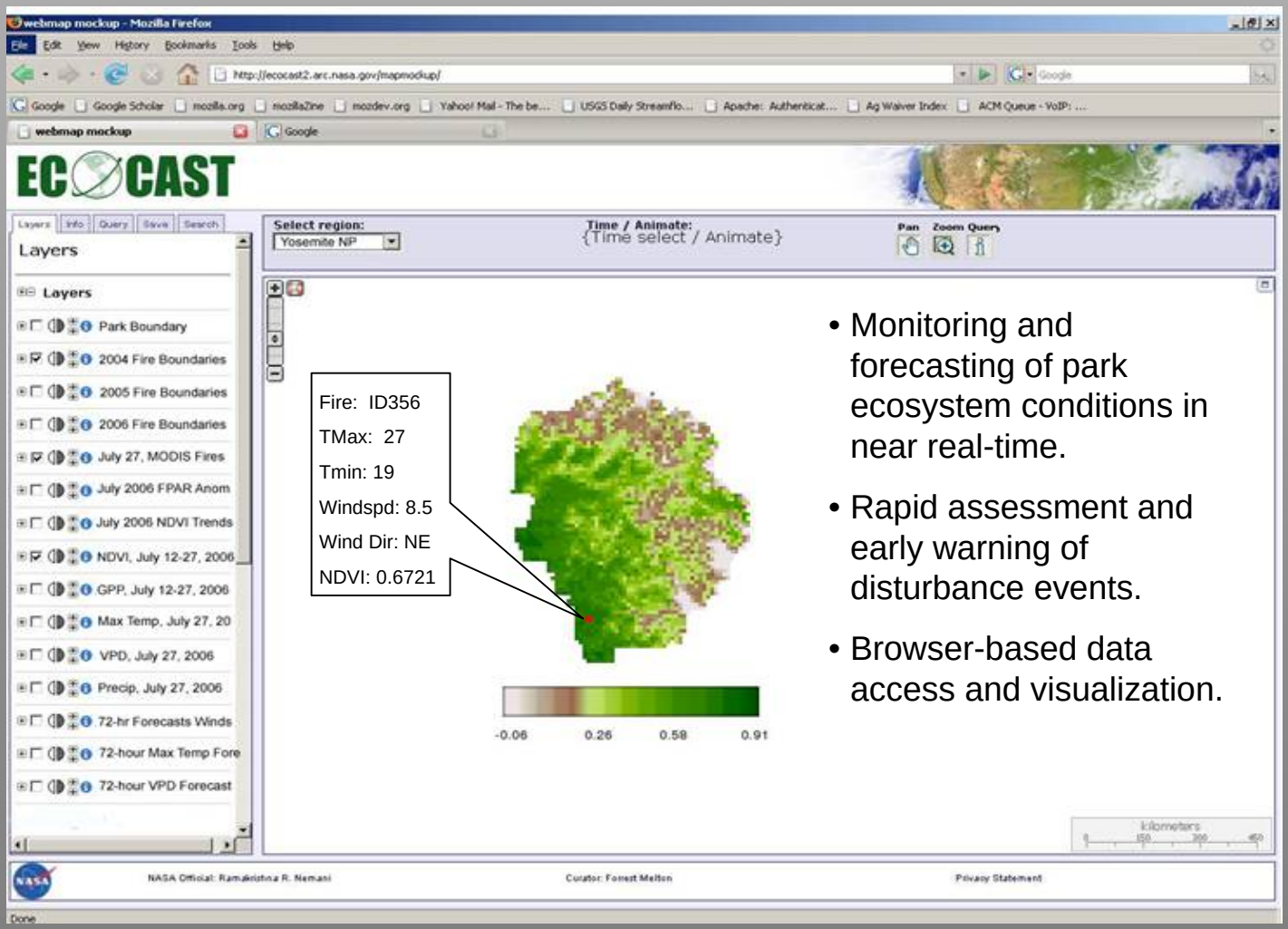
- **Complete assessement report**
- **Develop and apply functional prototype models**
- **Develop SOPs**
- **Synthesize results into “stories” useful to managers**

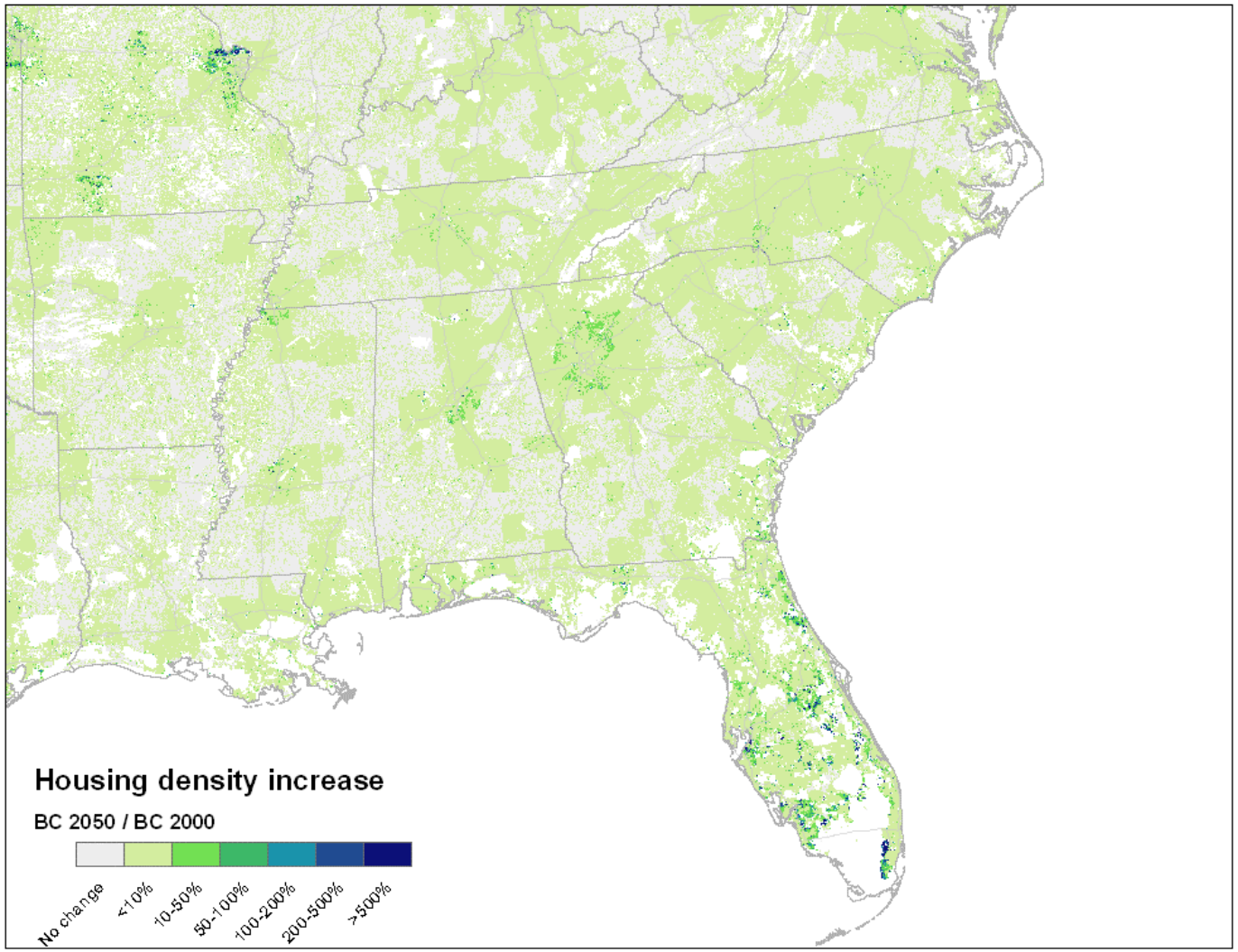
3. Deliver these products and a means to integrate them into the NPS I&M decision support framework.

- **Develop Model Builder tools**
- **Finalize web-based delivery system**
- **Conduct training sessions**
- **Complete final report**

Objective 3: Integrate into NPS I&M Framework

Ecocast Web Mapper



- Monitoring and forecasting of park ecosystem conditions in near real-time.
- Rapid assessment and early warning of disturbance events.
- Browser-based data access and visualization.

Objective 2: Add Value Through Analysis and Forecasting