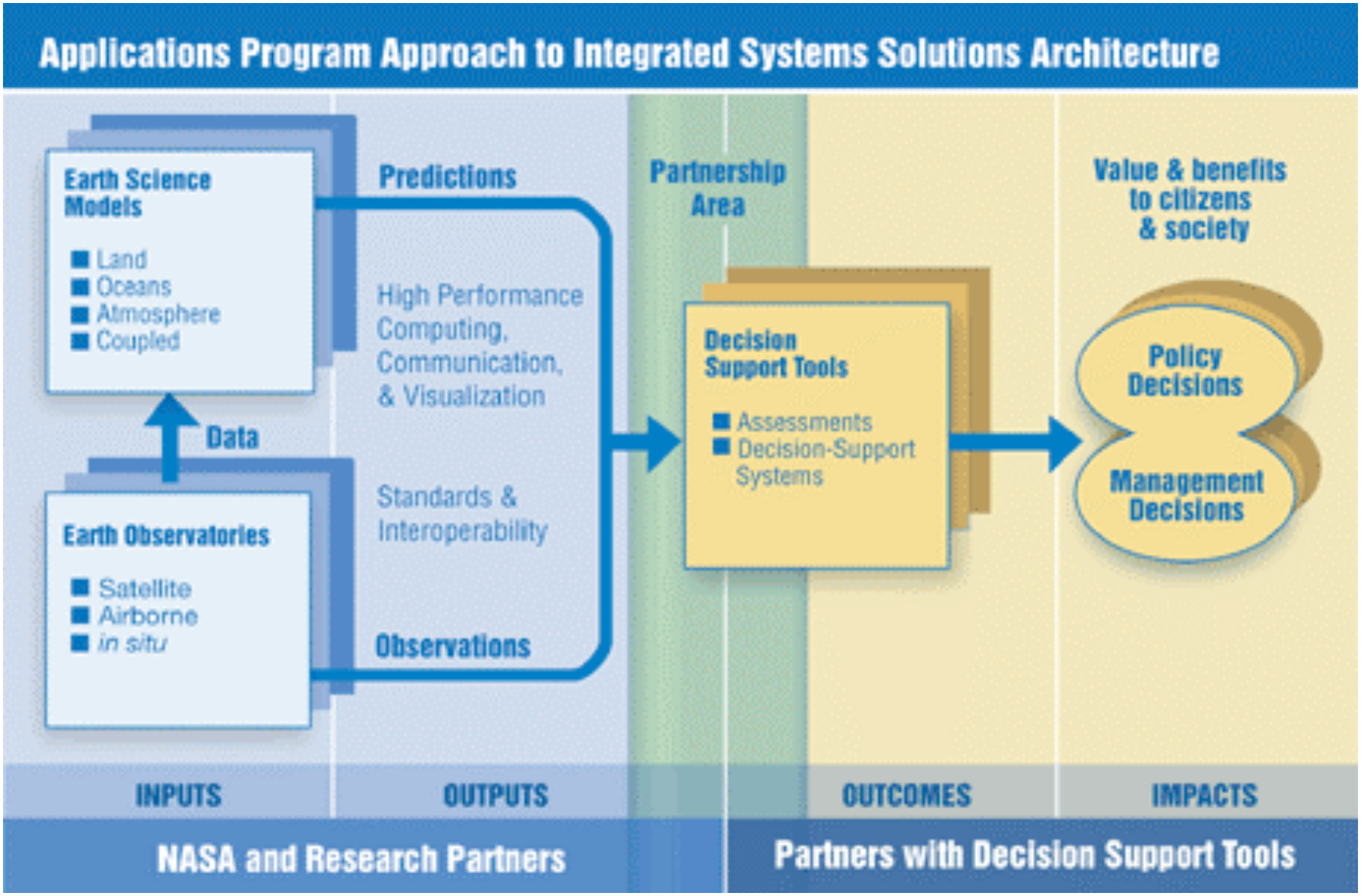
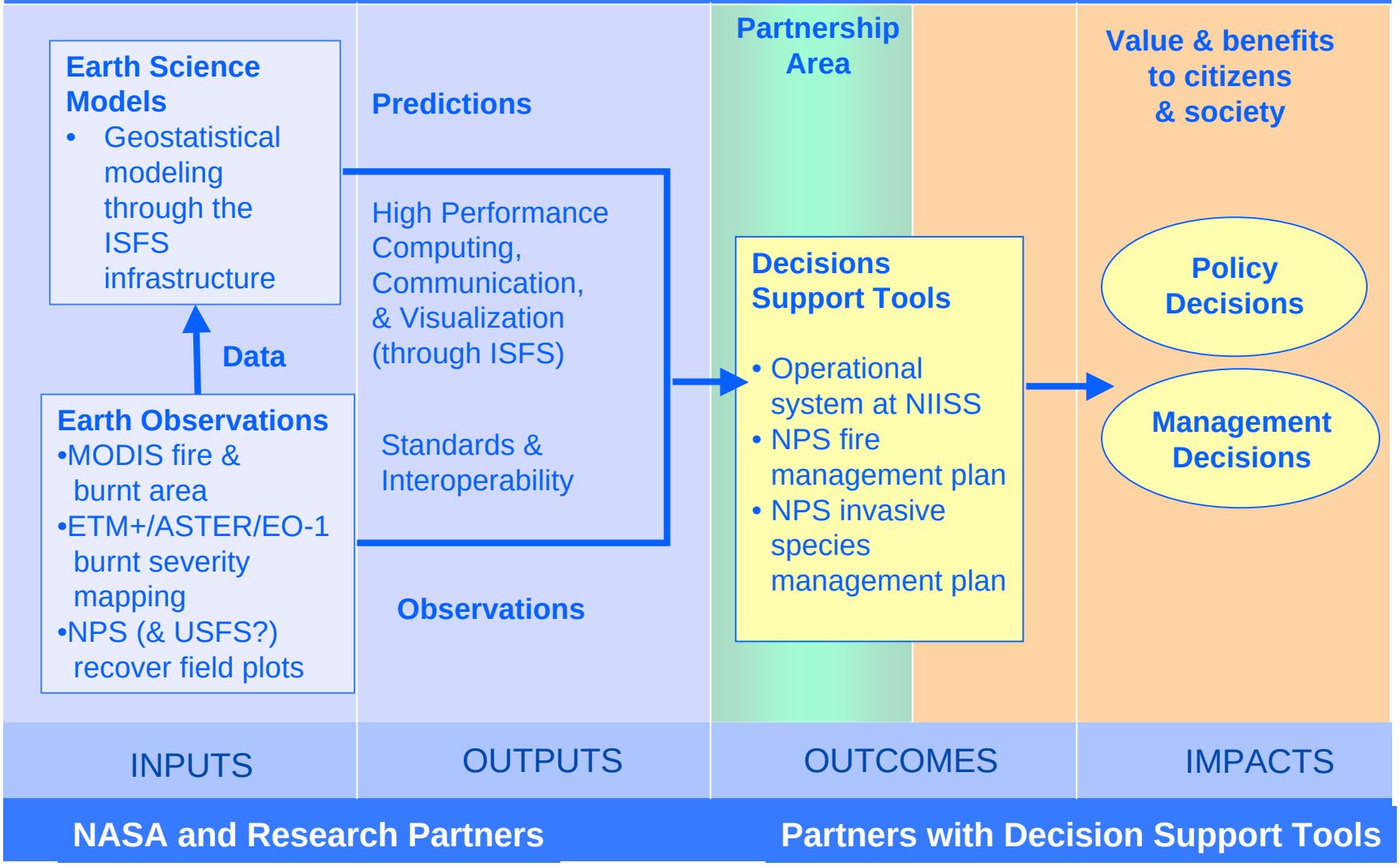
Using the Invasive Species Forecasting System to support National Park Service decisions on fire management activities and invasive plant species control

Jeff Morisette[1], with contributions from Nate Benson[2], Kara Paintner[2], Brad Welch, Joel Silverman[3], David Roy[4], Peter Ma[5], and Neal Most[5], Jeff Pedelty[1], John Schnase[1] and Thomas Stohlgren[6]

[1]NASA Goddard Space Flight Center, Greenbelt, Maryland
[2]National Park Service, Institute of Invasive Species Science, USGS, Fort Collins Colorado
[3]Colorado State University
[4]South Dakato State University
[5]Innovim
[6]USGS


Applications Program Approach to Integrated Systems Solutions Architecture
Earth Science Models
Land
Oceans
Atmosphere
Coupled
Data
Earth Observatories
Satellite
Airborne
in situ
Predictions
High Performance Computing, Communication, & Visualization
Standards & Interoperability
Observations
Partnership Area
Decision Support Tools
Assessments
Decision-Support Systems
Value & benefits to citizens & society
Policy Decisions
Management Decisions
INPUTS
OUTPUTS
OUTCOMES
IMPACTS
NASA and Research Partners
Partners with Decision Support Tools

Approach for Integrating NASA imagery and modeling with the National Park Service Fire Ecology and Invasive Species Programs



Outline

- NASA's ISFS
  (Invasive Species Forecasting System)

- Using the National Park Service as
  an "early adopter"

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  an "early adopter"

Environmental Costs…
Agricultural Costs…
Human-Health Costs…

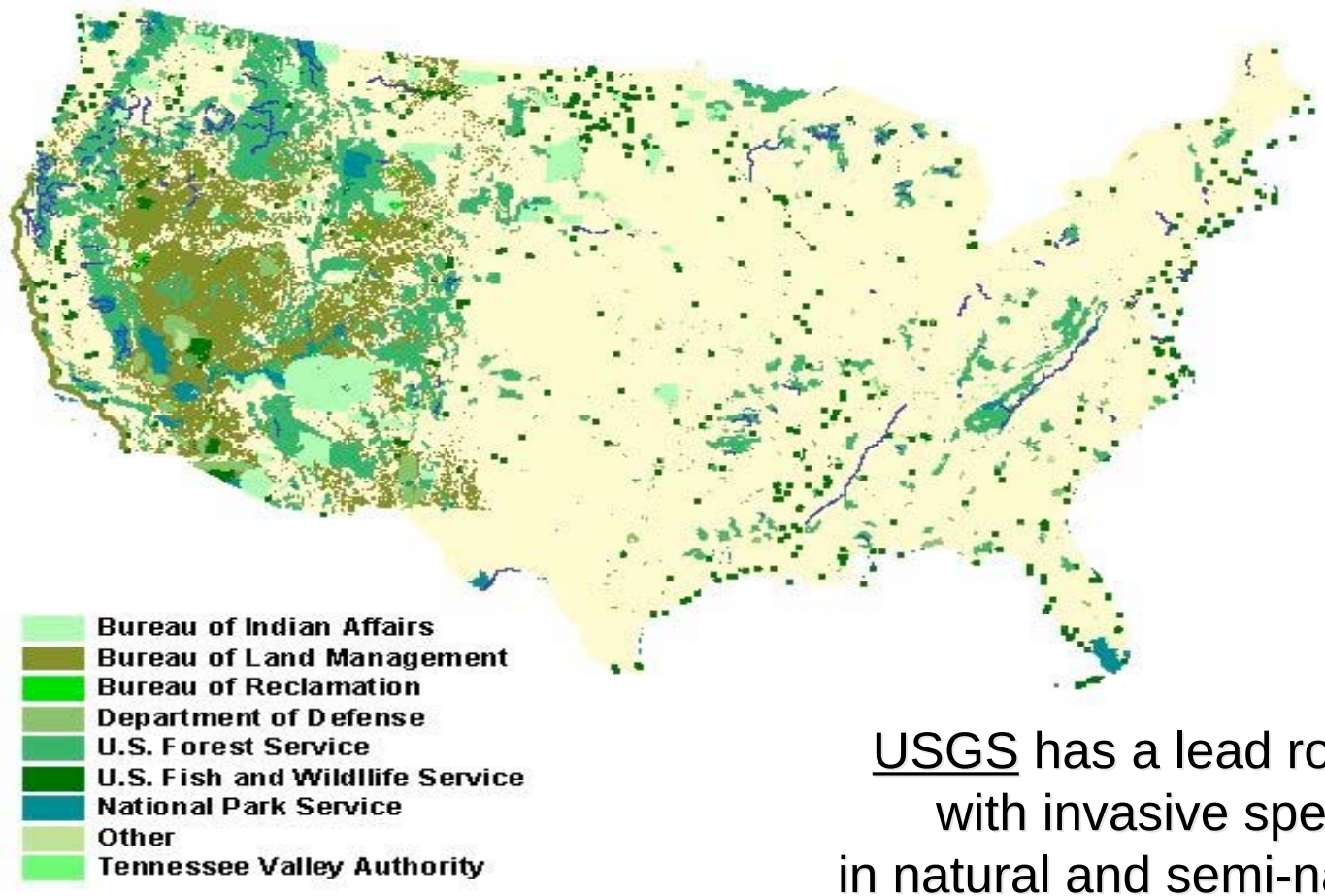
Invasive Species

… plus connections to
fire activity and climate change

"Update on the environmental and economic costs associated with alien-invasive species in the United States"

David Pimentel*, Rodolfo Zuniga, Doug Morrison,
in *Ecological Economics*

National Response:
National Invasive Species Council



USGS has a lead role in dealing with invasive species science in natural and semi-natural areas.

NEWS

U.S. Department of the Interior

Office of the Secretary
For Immediate Release: May 13, 2005
National Council Promotes Strategies for War
on Invasive Plants, Animals, Pathogens

Secretary Norton Commends Council's Team Tamarisk Initiative

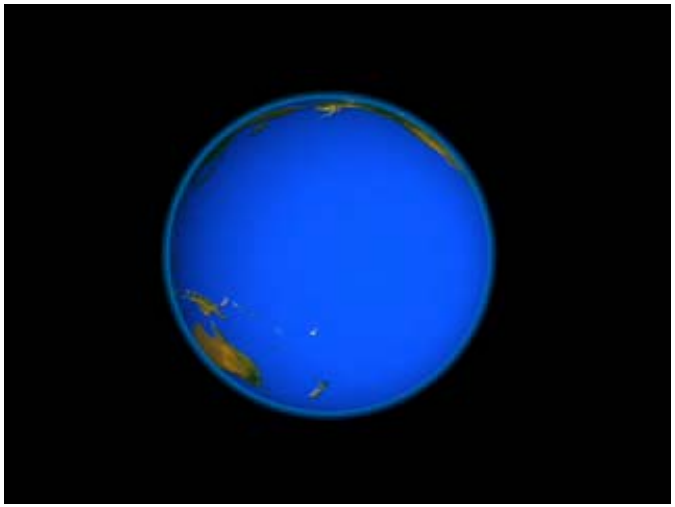
WASHINGTON - Secretary of the Interior Gale Norton today urged leaders of a cabinet-level council to increase their war-planning against an invasion of plant and animal species that costs the nation more than $120 billion annually in ecological and economic damage.

"No single agency, no one department can do it alone"

"The potential invaders are many. Their potential impacts are vast. By working together we can continue to win the small victories that mean much in the larger war."

http://www.doi.gov/news/05_News_Releases/050513b

NASA's Response



NASA / USGS
"Invasive Species
Forecasting System"

NASA brings expertise on:

- satellite data and derived products
- computation technologies
- modeling

Schnase, J.L., Stohlgren, T.J., & Smith, J.A. 2002. "The National Invasive Species Forecasting System: A strategic NASA/USGS partnership to manage biological invasions". *Earth Observing Magazine*, August, pp. 46-49.

Base-line Statistical Modeling Array

Example Existing Model Array:

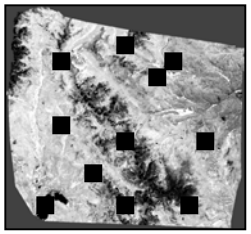
Lat	lon	response	Predictor 1	…	Predictor N
X_1	Y_1	R_1	X_{11}	…	X_{n1}
X_2	Y_2	R_2	X_{12}	…	X_{n2}
…	…	…	…	…	…

Field-measured variable of interest

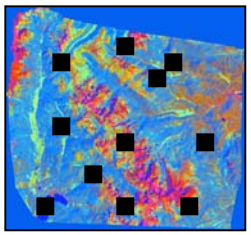
Predictors derived from satellite data and/or ancillary data)

GPS X and y coordinates

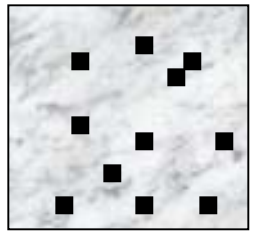
Vegetation Health



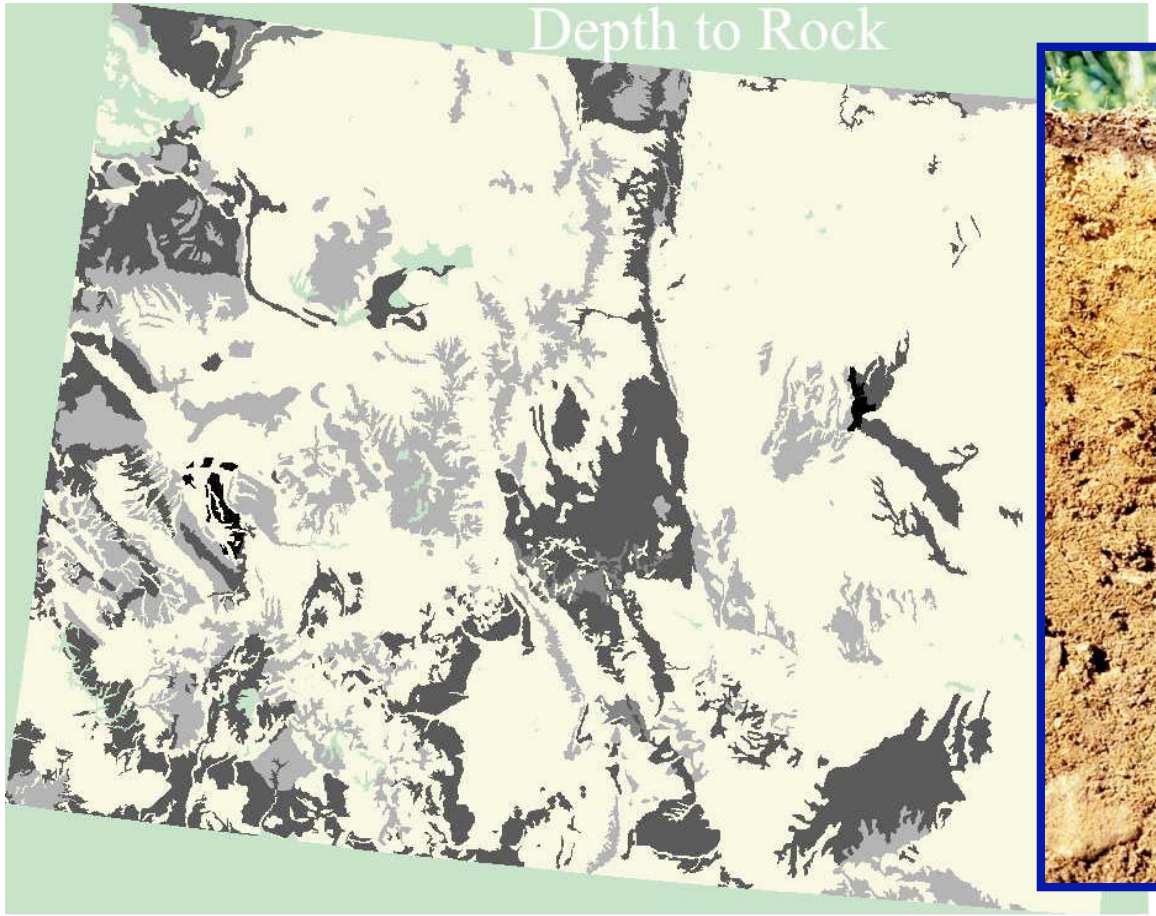
Brightness Greeness Moisture



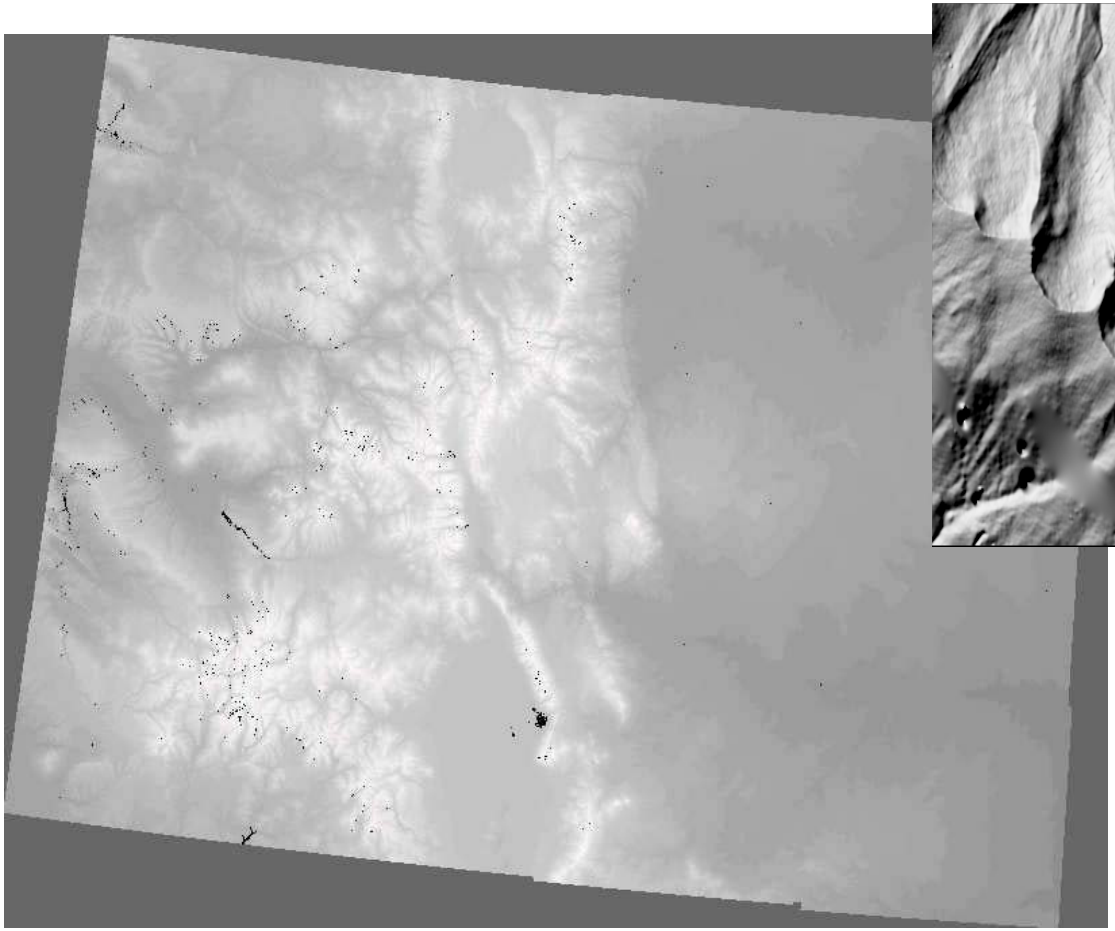
Elevation, slope, Aspect

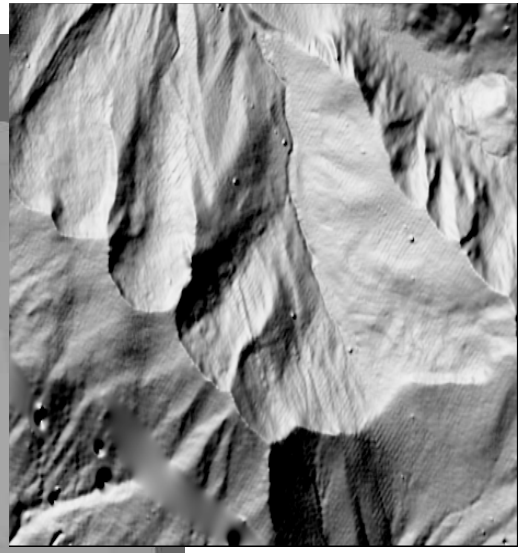


Environmental data layers: Soil properties



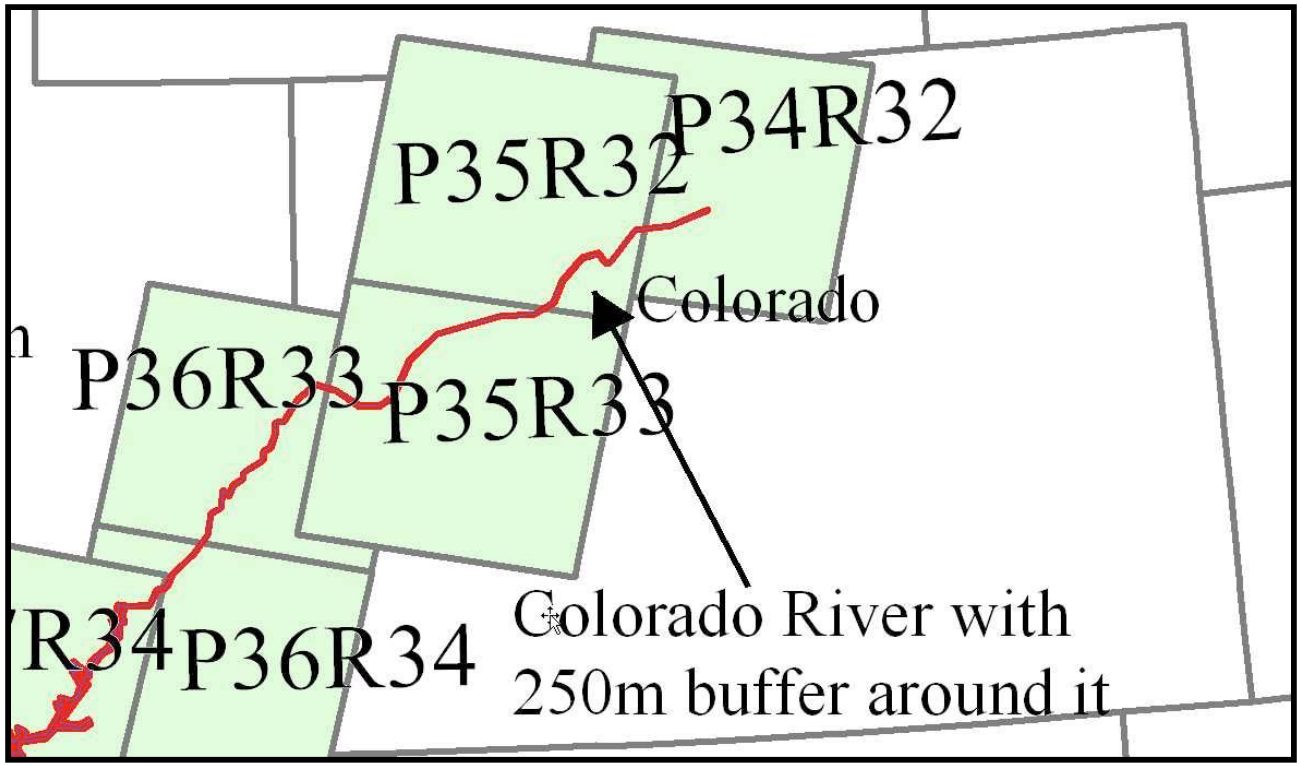
Environmental data layers: Elevation, slope and aspect



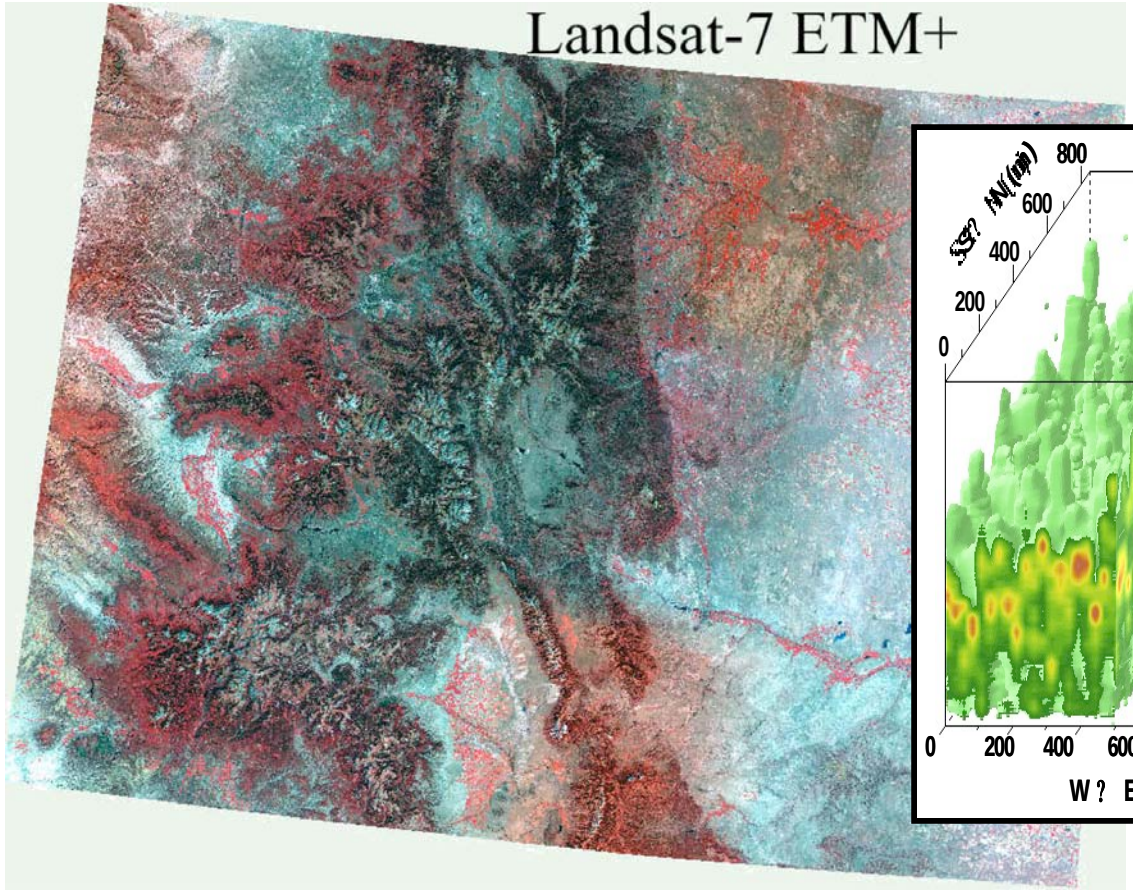


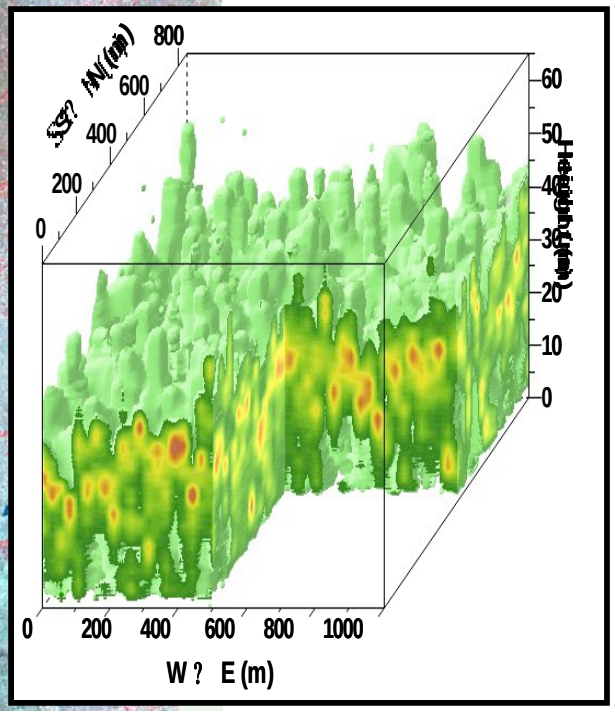
Input data: Distance to…

- Streams
- Roads



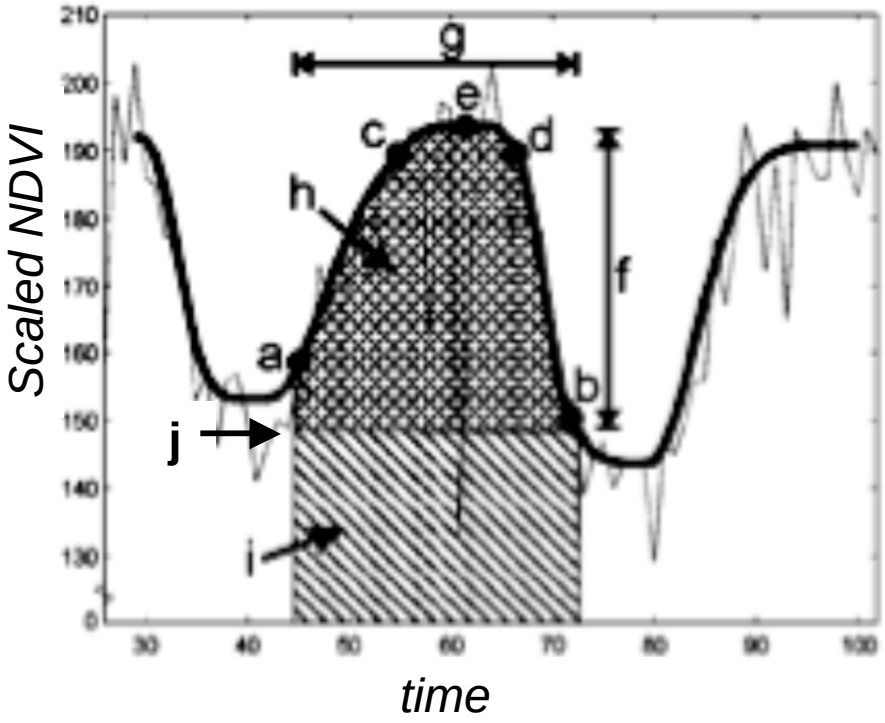
Environmental data layers: Vegetation signal





LIDAR

Phenology parameters “TIMESAT”



a) Beginning of season
b) End of season
c) Left derivative
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e) Peak (time and value)
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i) Integral over season - absolute
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TIMESAT - a program for analyzing time-series of satellite sensor data
Per Jonsson & Lars Eklund, Computers & Geosciences 30:833-845, 2004.

Tamarisk throughout the year

ISFS Tamarisk Modeling Array

Lat	lon	response	Predictor 1	…	Predictor N
X_1	Y_1	R_1	X_{11}	…	X_{n1}
X_2	Y_2	R_2	X_{12}	…	X_{n2}
…	…	…	…	…	…

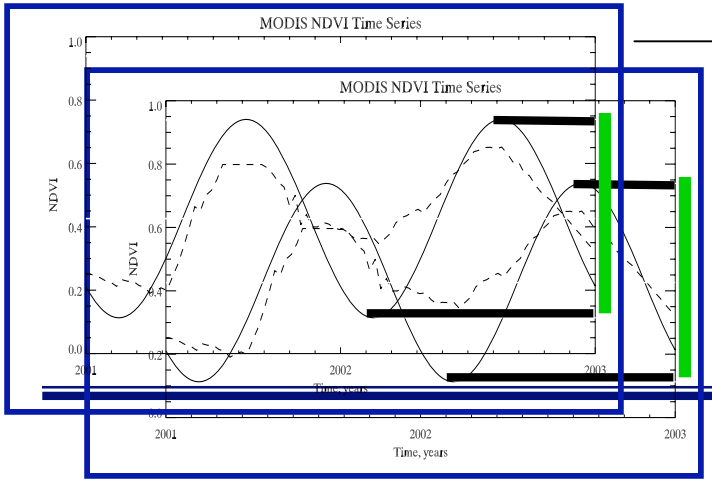
31,919 Field Observations

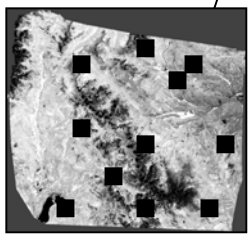
GPS X and y coordinates

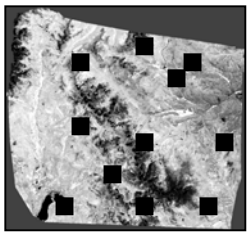
Range in Veg. Index

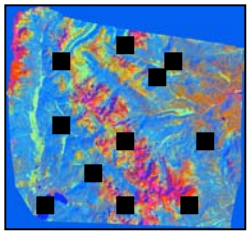
Range in Soil-adjusted vegetation index

MODIS land cover

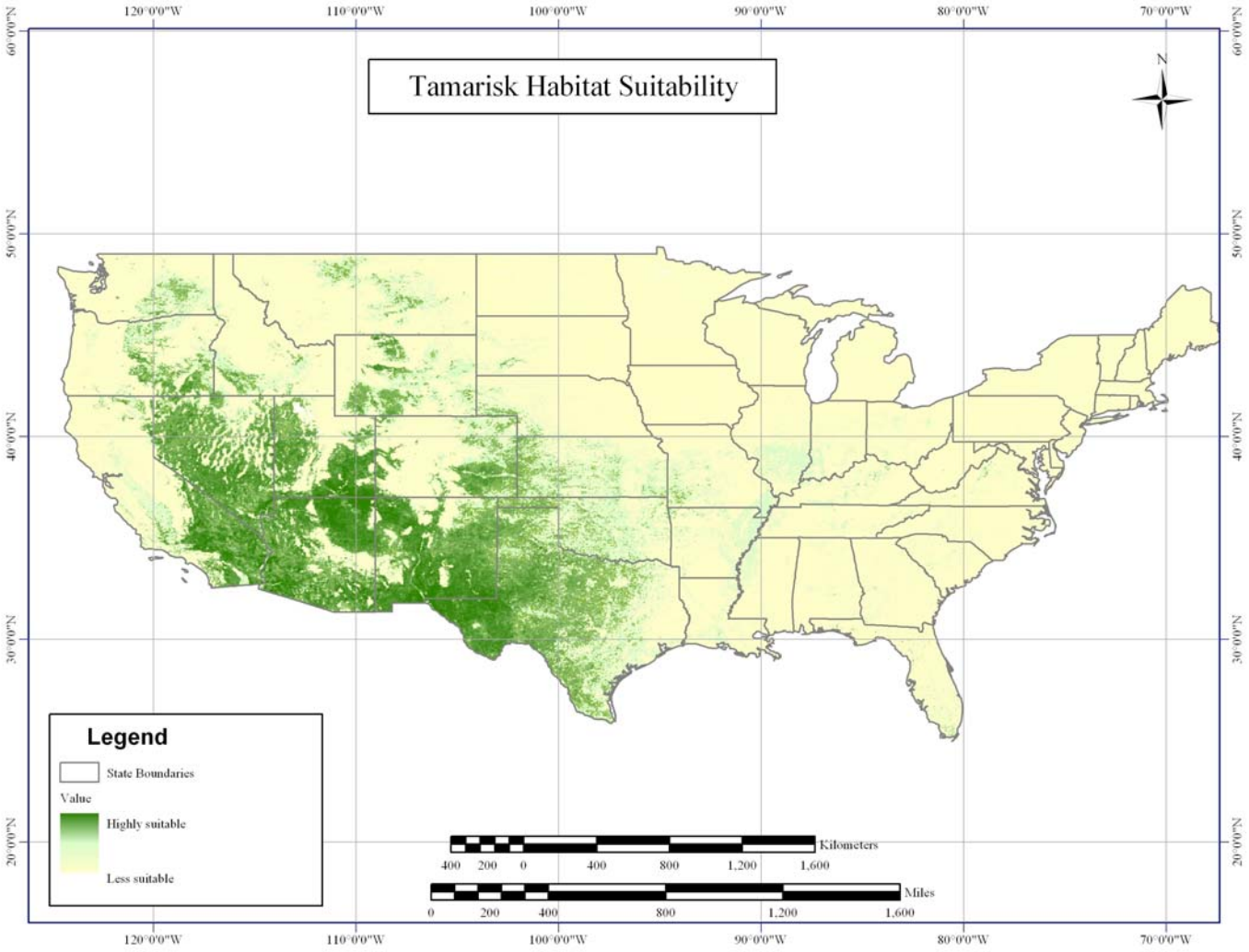








National map of habitat suitable for tamarisk



Habitat suitability = a function of Land Cover Class and Vegetation index from the MODIS sensor

Morisette, J.T., C. S. Jarnevich, A. Ullah, W. Cai, J.A. Pedelty, J. Gentle, T.J.Stohlgren, J.L. Schnase, A tamarisk habitat suitability map for the continental US., *Frontiers in Ecology*, February 2006.

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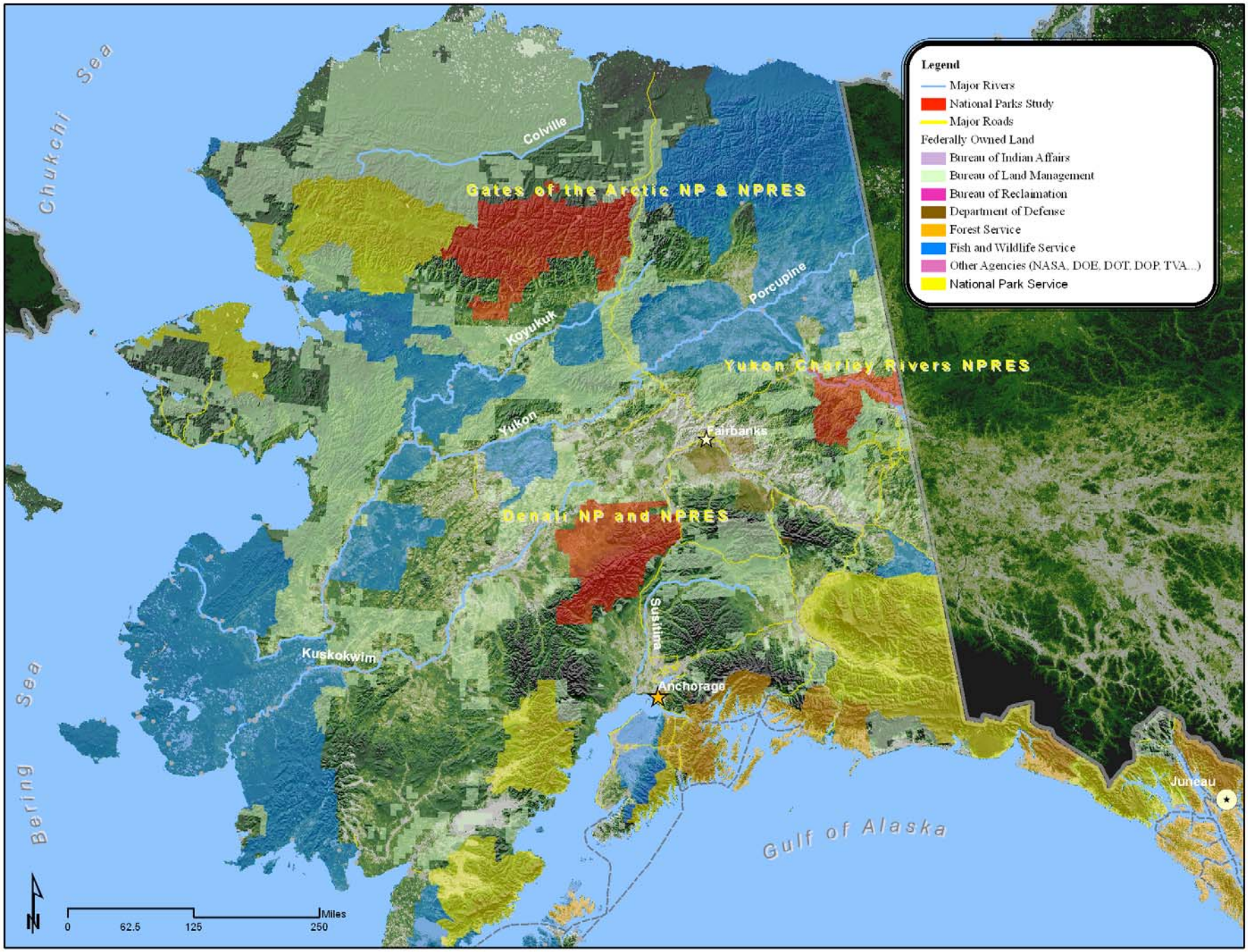
- Using the National Park Service as an "early adopter"


Legend
Major Rivers
National Parks Study
Major Roads
Federally Owned Land
Bureau of Indian Affairs
Bureau of Land Management
Bureau of Reclamation
Department of Defense
Forest Service
Fish and Wildlife Service
Other Agencies (NASA, DOE, DOT, DOP, TVA...)
National Park Service
Chukchi Sea
Bering Sea
Gulf of Alaska
Colville
Gates of the Arctic NP & NPRES
Koyukuk
Porcupine
Yukon Charley Rivers NPRES
Yukon
Fairbanks
Denali NP and NPRES
Susitna
Kuskokwim
Anchorage
Juneau
N
0
62.5
125
250
Miles

Species: White Sweet Clover
(*Melilotus alba*)

Alaska: DENA, GAAR, YUCH

Habitat / Issues:

- Bee Keepers (Agriculture)
- Clings to footwear (Recreation)
- Ride river currents down stream
- Recently disturbed areas
- Floodplain (certain rivers)
- Riverbeds where roads and rivers cross
- Calcareous soils / rich loams/ clay loams / highly alkaline soils > 6.5
- Recent **fires result in germination** of seeds

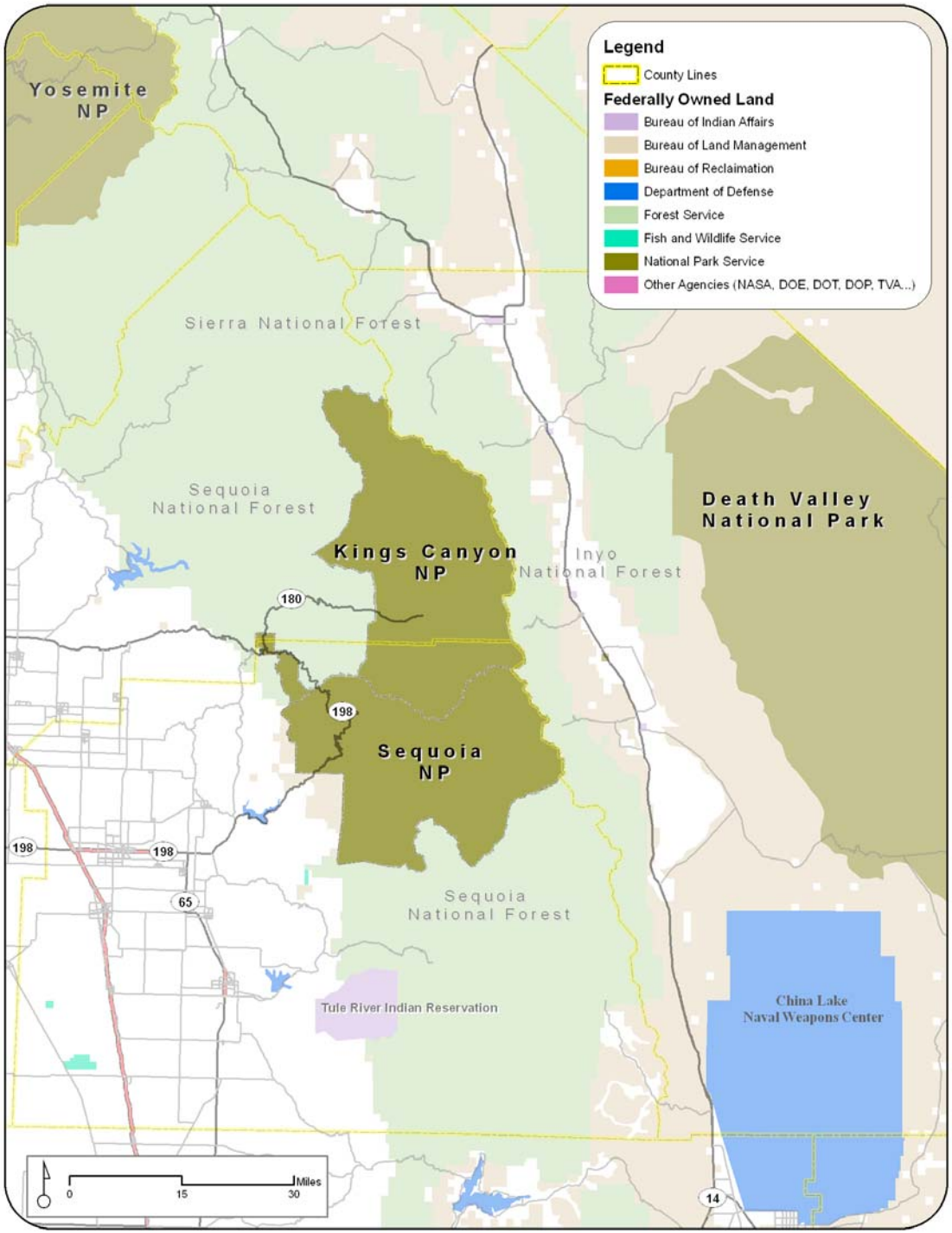
"Ecologists think it's one of the biggest threats to natural ecosystems in Alaska, a place unique when compared to the Lower 48 because of the small number of non-native plants introduced here by man."

Species: Bird vetch
(*Vicia cracca*)

Alaska: DENA, GAAR, YUCH

Habitat / Issues:
- Bird Vetch (Vicia cracca)
- Near Highways, (existing visual survey data)
- Well drained soil / sunny position
- Waste places
- **Disturbed soils**

“Extremely drought tolerant and cold hardy, vetch adapts to all soil textures. The vetches are extensively used as green manure for soil improvement, for hay, and in the South for winter pasture. Its tendrils cling to everything and proceed to climb up or pull down whatever is in reach.”


Legend
County Lines
Federally Owned Land
Bureau of Indian Affairs
Bureau of Land Management
Bureau of Reclaimation
Department of Defense
Forest Service
Fish and Wildlife Service
National Park Service
Other Agencies (NASA, DOE, DOT, DOP, TVA...)
Yosemite NP
Sierra National Forest
Sequoia National Forest
Kings Canyon NP
Inyo National Forest
Death Valley National Park
Sequoia NP
Sequoia National Forest
Tule River Indian Reservation
China Lake Naval Weapons Center
180
198
198
198
65
14
0
15
30
Miles

Species: Bull Thistle
(*Cirsium vulgare*)

SEQUOIA AND KINGS CANYON NATIONAL PARKS (SEKI)

Habitat / Issues:
- Foothills and Dry Meadows
- Riparian areas
- Clear-Cuts
- **Disturbed habitats**
- Seepage area / along a stream
- Timber harvest
- Edges of fresh and brackish marshes
- Pastures over grazed lands
- Gopher mounds
- Near existing stands
- Below 7,000 feet (2,120m)

"Now found on every continent except Antarctica, Bull Thistle is common throughout the Pacific States, and it is the most common and widespread of pasture and rangeland thistles in western North America."

Habitat / Issues:

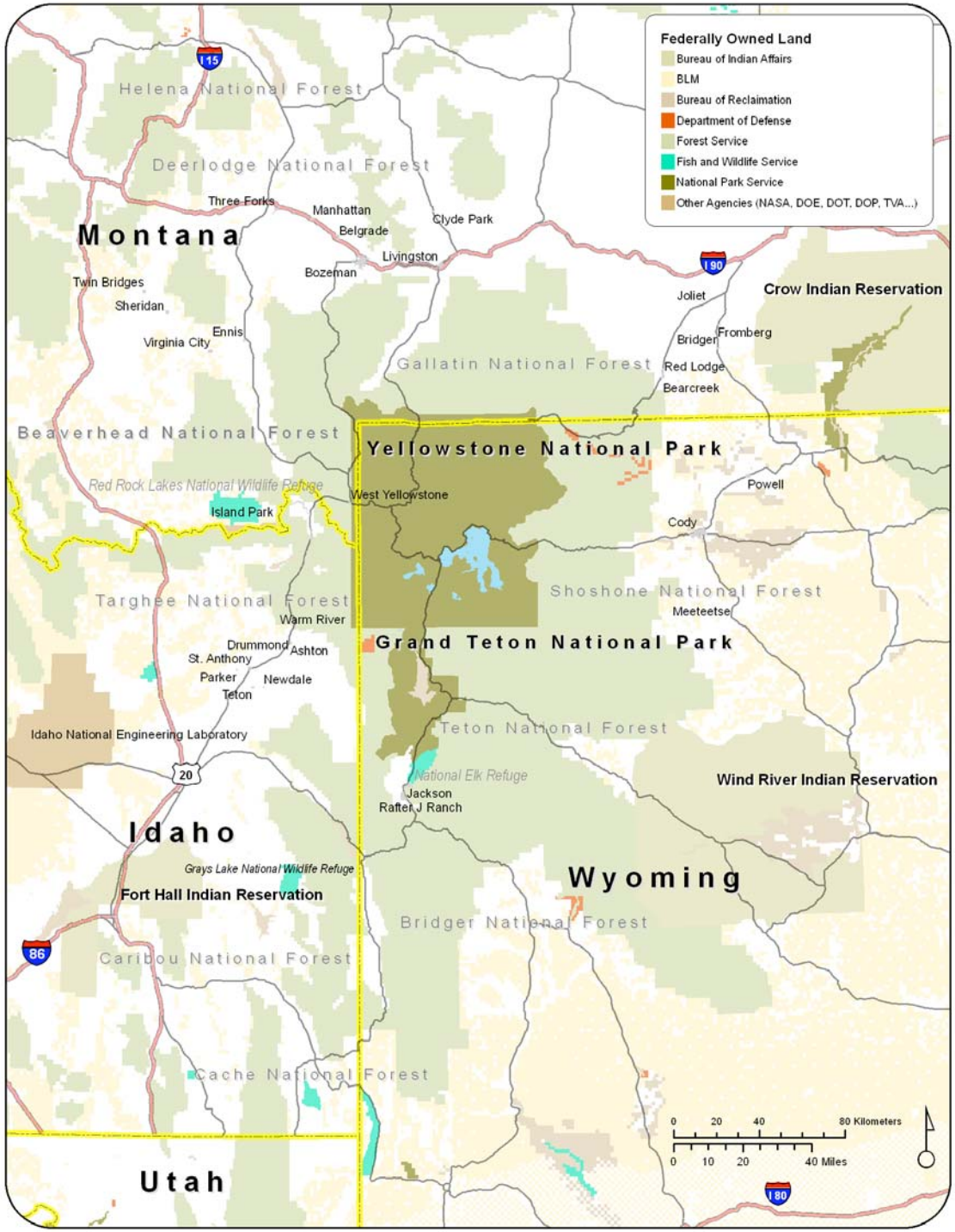
- **Recently burned** range / wild lands
- Eroded areas
- **Fire frequency** (3-5 year rate)
- High levels of potassium
- Does not flourish in areas of high canopy cover

Species: Cheatgrass

(Bromus tectorum)

SEQUOIA AND KINGS CANYON NATIONAL PARKS (SEKI)

"Although fire is a natural part of the sagebrush grassland ecosystem, those fires usually occurred at intervals between 60-100 years (Whisenant 1989). Cheatgrass infested areas burn at a much greater frequency, every 3-5 years (Whisenant 1989). At this frequency, native shrubs and perennial grasses cannot recover and after a few wildfire cycles a cheatgrass monoculture develops…Put simply, **fire begets cheatgrass and cheatgrass begets fire** (Devine 1998)."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Other Agencies (NASA, DOE, DOT, DOP, TVA...)
I 15
I 90
I 80
86
20
Helena National Forest
Deerlodge National Forest
Gallatin National Forest
Beaverhead National Forest
Targhee National Forest
Shoshone National Forest
Teton National Forest
Bridger National Forest
Caribou National Forest
Cache National Forest
Montana
Idaho
Wyoming
Utah
Three Forks
Manhattan
Belgrade
Clyde Park
Livingston
Bozeman
Twin Bridges
Sheridan
Ennis
Virginia City
Joliet
Bridger
Fromberg
Red Lodge
Bearcreek
Crow Indian Reservation
Yellowstone National Park
West Yellowstone
Red Rock Lakes National Wildlife Refuge
Island Park
Powell
Cody
Meeteetse
Grand Teton National Park
Warm River
Drummond
Ashton
St. Anthony
Parker
Newdale
Teton
Idaho National Engineering Laboratory
National Elk Refuge
Jackson
Rafter J Ranch
Wind River Indian Reservation
Grays Lake National Wildlife Refuge
Fort Hall Indian Reservation
0 20 40 80 Kilometers
0 10 20 40 Miles

Habitat / Issues:

- Roadsides
- Sandy / Gravely soils
- Cultivated fields
- Range lands / clear cuts
- Below 2,800 meters (9,2000 ft)
- **Recently burned areas**

Species: Dalmatian toadflax

(*Linaria genistifolia*)

YELLOWSTONE NATIONAL PARK (YELL)
GRAND TETON NATIONAL PARK (GRTE)

"Dalmatian toadflax reproduces by seed and vegetative propagation. Once established, high seed production and the ability for vegetative reproduction allow for rapid spread and high persistence (Saner *et al.* 1995)… The large, deep, root systems of both species protect them from burning. In fact, areas that have been recently disturbed by fire are susceptible to increased toadflax infestation. "

Species: Canada Thistle
(*Cirsium arvense*)

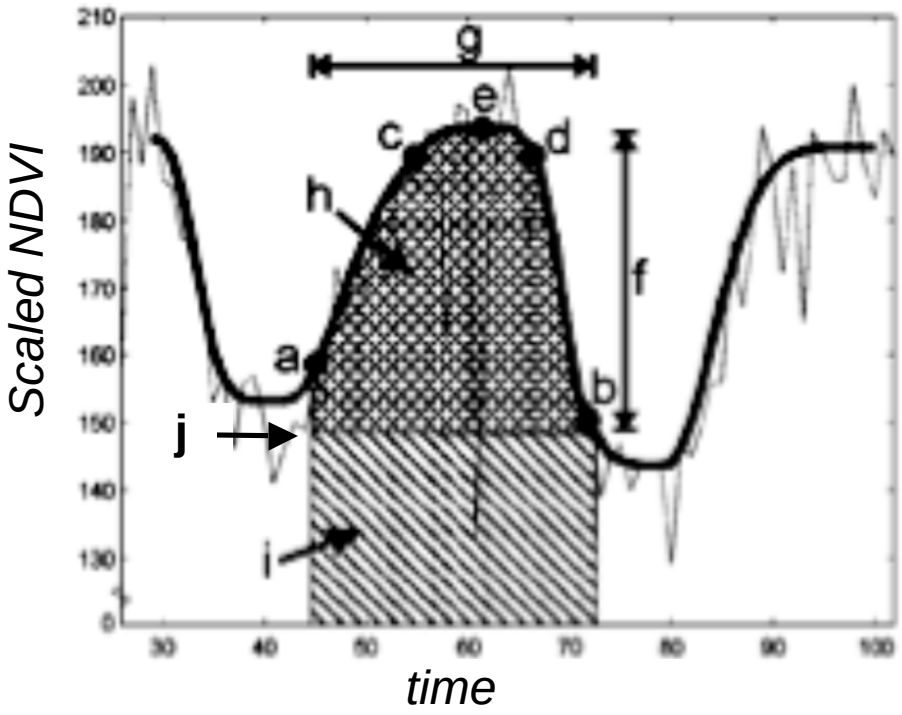
YELLOWSTONE NATIONAL PARK (YELL)
GRAND TETON NATIONAL PARK (GRTE)

Habitat / Issues:

- Prairies, grasslands, riparian areas
- Positively correlated with previous year precipitation
- Barrens, fields, **disturbed areas**
- Wet areas stream banks, sedge meadows

"Cirsium arvense is invasive in prairies and other grasslands in the midwest and Great Plains and in riparian areas in the intermountain west. It is particularly troublesome in the northwest and north-central states, and in southern Canada (Moore 1975)."

Phenology parameters “TIMESAT”



a) Beginning of season
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j) Base value

TIMESAT - a program for analyzing time-series of satellite sensor data
Per Jonsson & Lars Eklund, Computers & Geosciences 30:833-845, 2004.

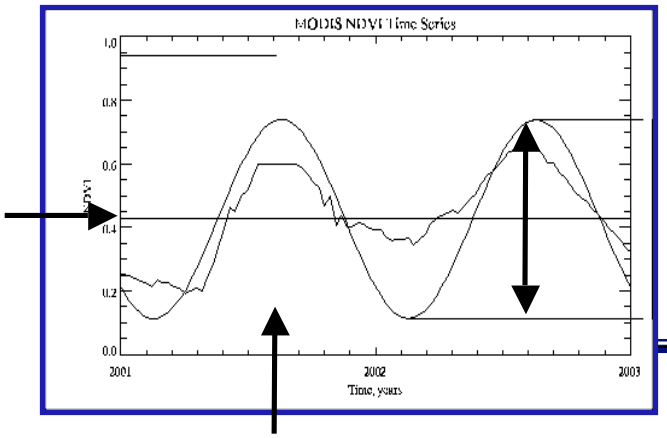
Placing Timesat metrics into model array

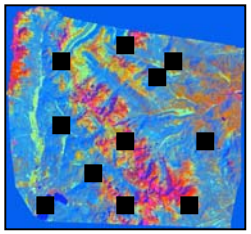
Lat	lon	response	Predictor 1	…	Predictor N
X_1	Y_1	R_1	X_{11}	…	X_{n1}
X_2	Y_2	R_2	X_{12}	…	X_{n2}
…	…	…	…	…	…

Field Observations

GPS X and y coordinates

Eleven landscape phenology metrics derived from timesat and included in modeling arrays.



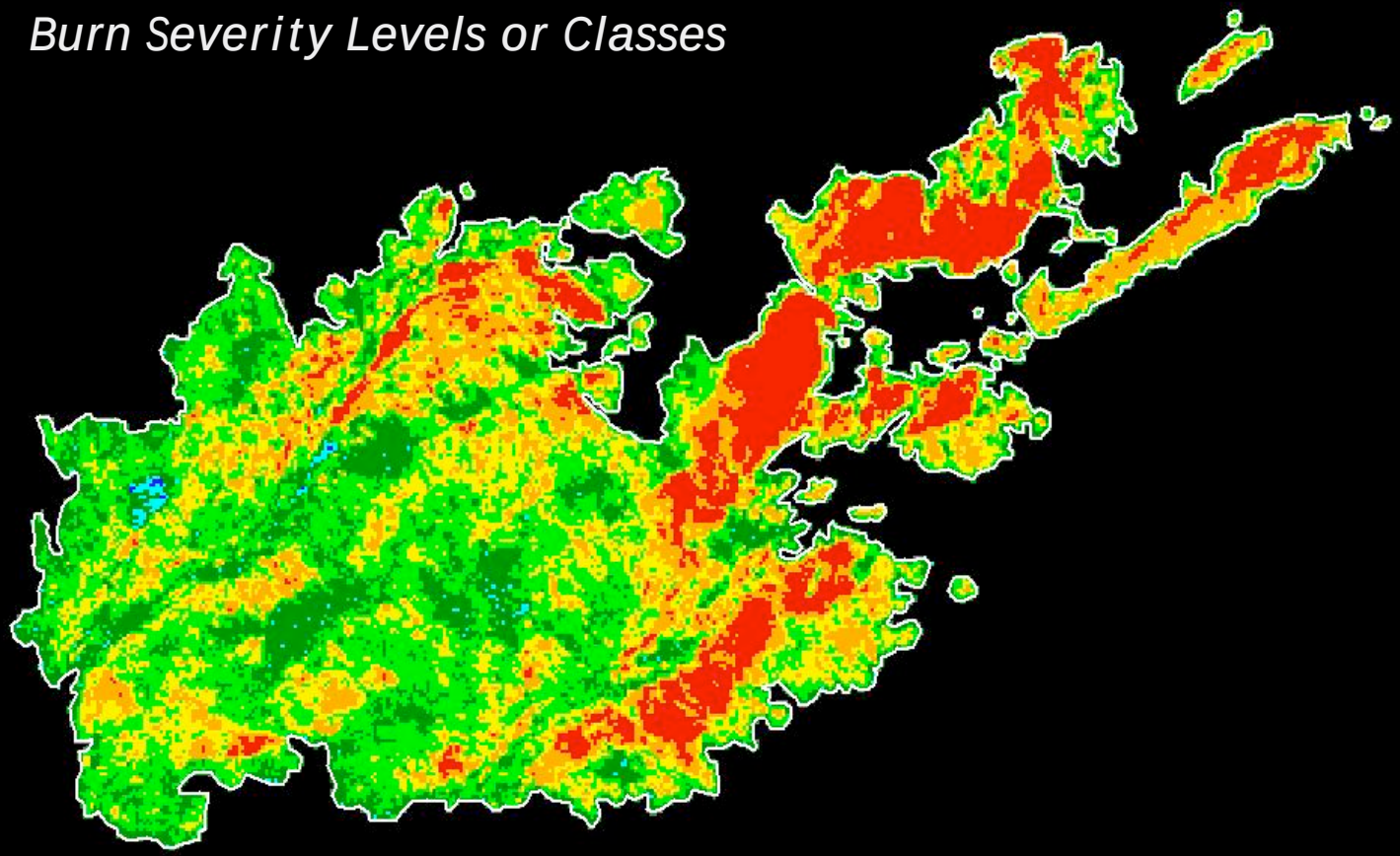


dNBR
07/10/99 - 06/25/00

Burn Perimeter Mapped

Burn Data Extracted by Perimeter

Burn Severity Levels or Classes



USGS
science for a changing world

Potential Modeling Array

Example
Existing Model Array:

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X_1	Y_1	R_1	X_{11}	…	X_{n1}
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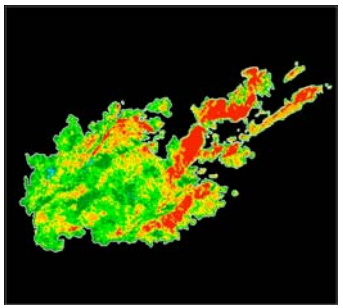
Field-measured variable of interest

Predictors derived from satellite data and/or ancillary data)

GPS X and y coordinates



Burnt area

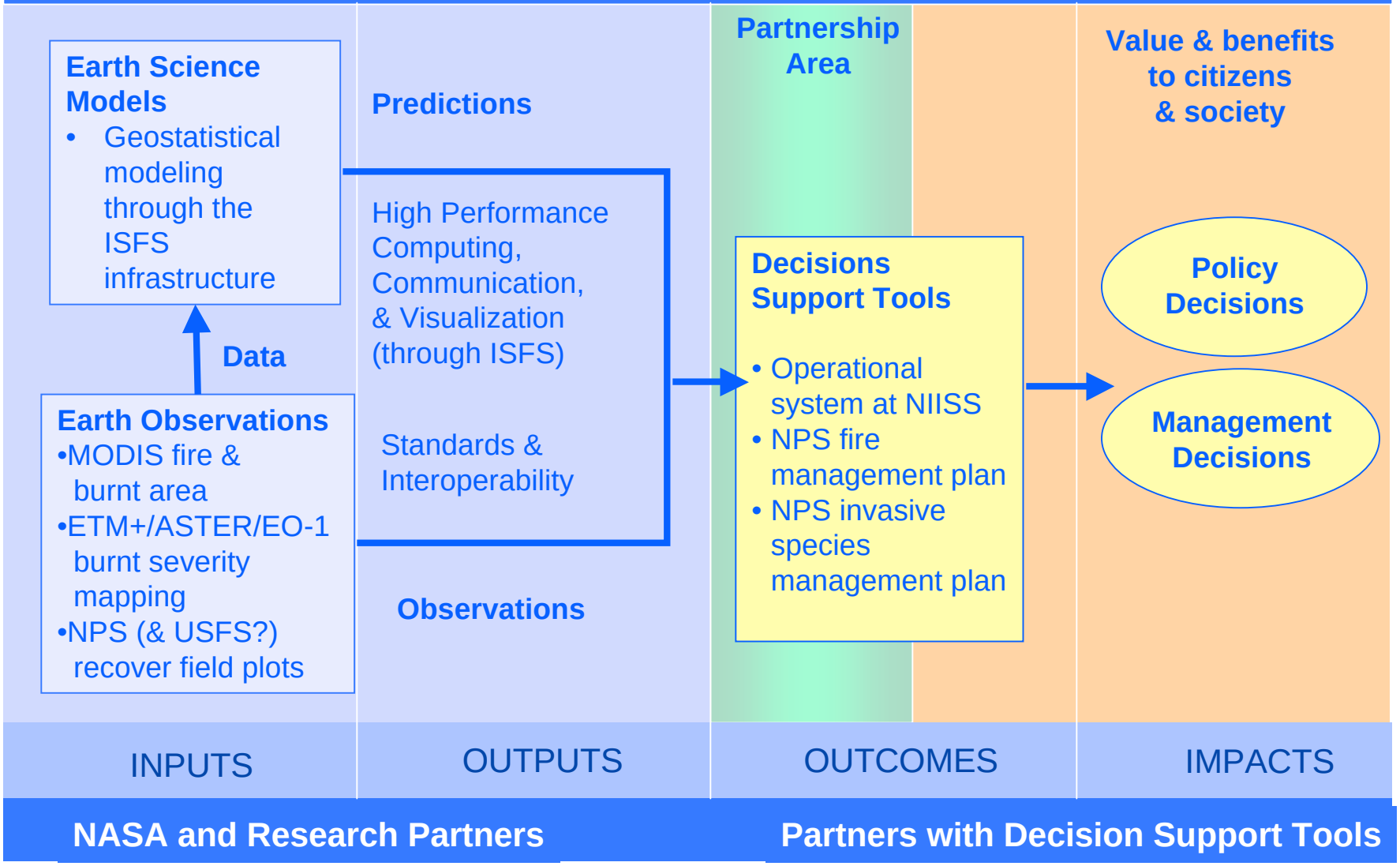
Potential burnt area environmental data layers:

- time since last burn

- severity of last burn

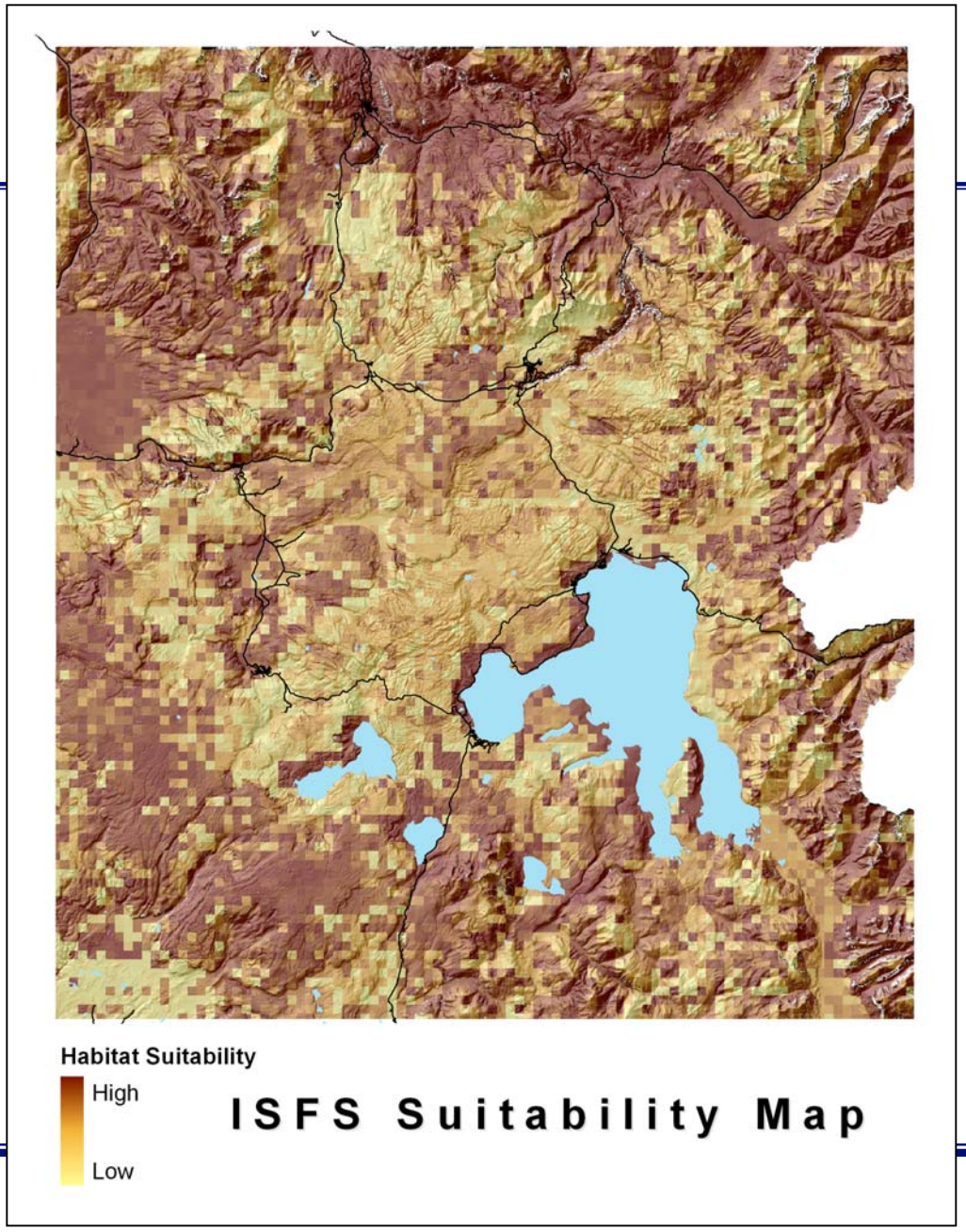
- total number of previous burns

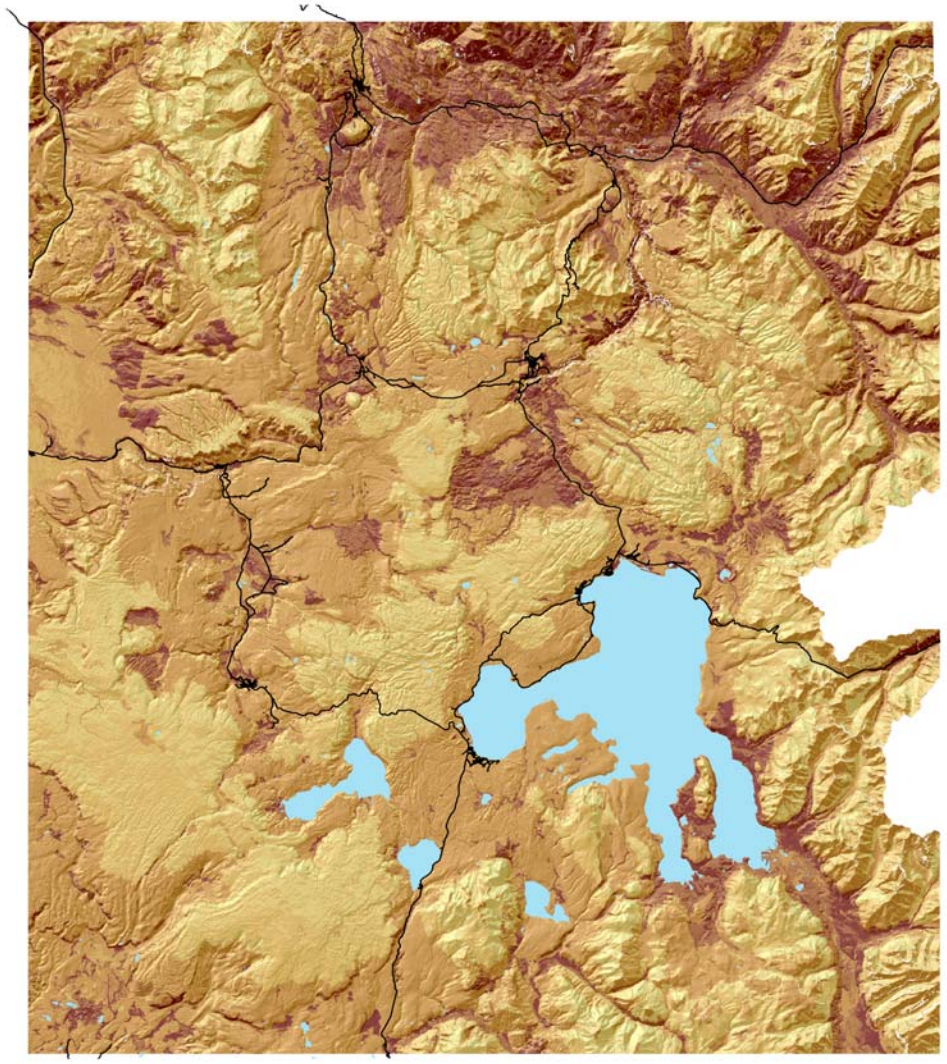
Approach for Integrating NASA imagery and modeling with the National Park Service Fire Ecology and Invasive Species Programs

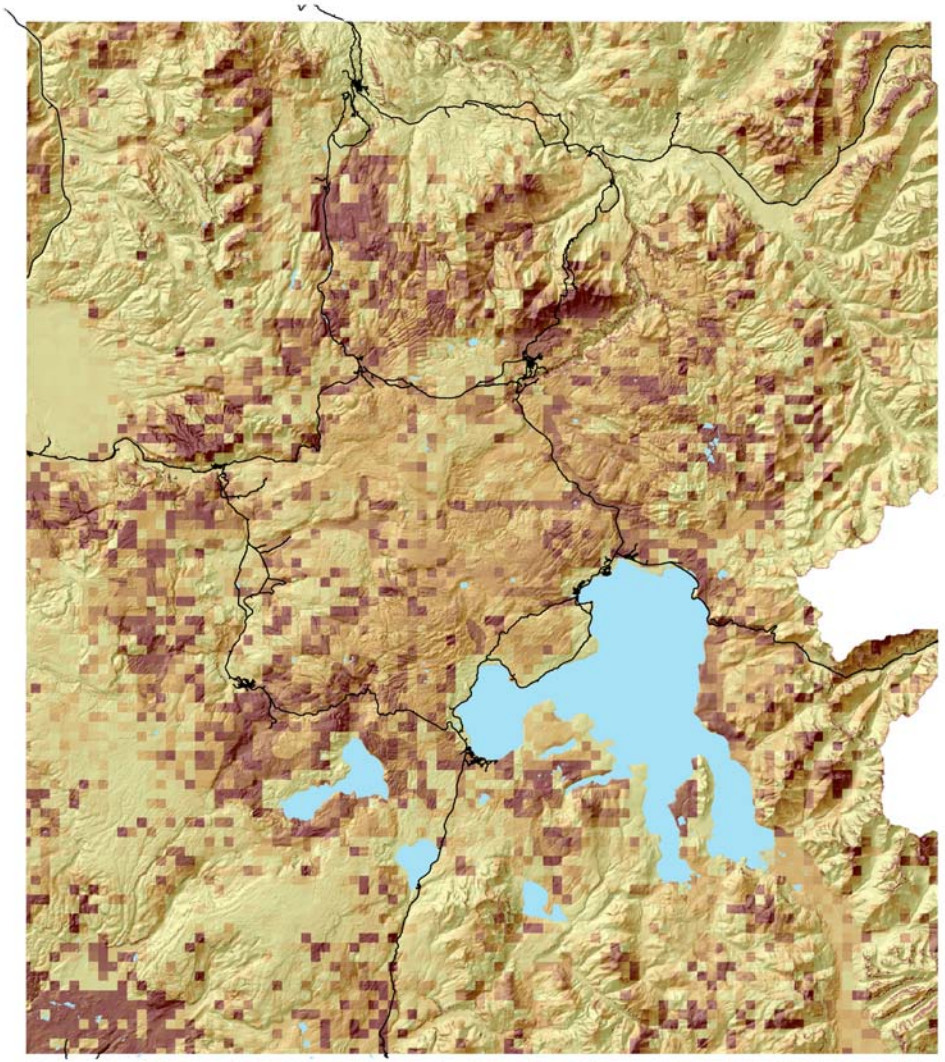


Initial visits to National Parks: implications for the decision support approach

- It is important for the partner to know what we can do as well as we can not do.
- We are building a relationship with the partner so that they help “invent” the tools to be used.
- Without an explicit decision support system we are trying to extract “expert opinion” habitat maps as a benchmarking activity.


Habitat Suitability
High
Low
ISFS Suitability Map


Habitat Suitability
High
Low
Expert Opinion



ISFS Suitability VS. Expert Opinion

We have found it critical and useful to work at the grass-roots level.

so…

Working at the Grass-roots level: implications for the applied science program

- Be strategic in partnerships
- Start small, use “rapid prototyping”
- Build multiple iterations into the schedule
- Benchmark the process
- Set goals to get you to the next level

- Looking for common characteristics of successful applied science program projects might help frame future research.

Thank you!

For more information

please contact:

Jeff Morisette

Jeff.morisette@nasa.gov

301-614-5498