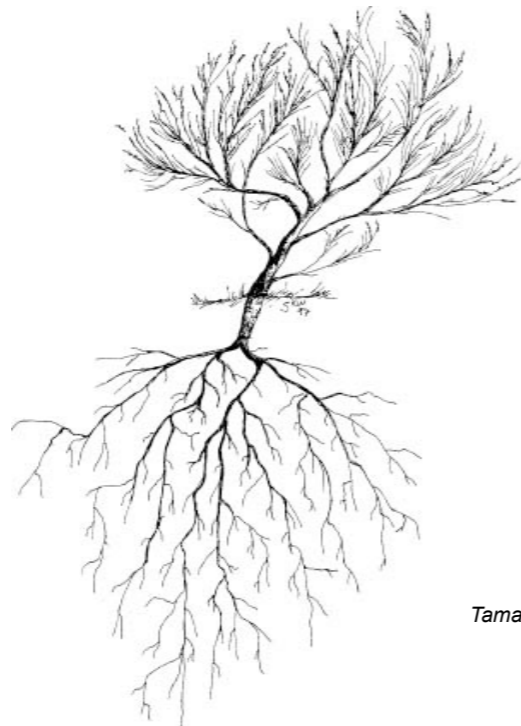




# The Invasive Species Forecasting System

*A NASA / USGS National Application Project*



*Tamarisk*

*John L. Schnase*

*Office of Computational and Information  
Science and Technology (CISTO / Code 606)*

*NASA Goddard Space Flight Center*

*Greenbelt, MD 20771*

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## Invasive Species

An "invasive species" is a species that is non-native to the ecosystem under consideration ...

... and whose introduction causes or is likely to cause economic or environmental harm or harm to human health.

- National Invasive Species Council



## Invasive Species

A Top Environmental Issue of the 21<sup>st</sup> Century ...

- Economic Costs:

- \$137+ Billion / Yr  
*(Pimentel, et al. 1999; NISC Management Plan, 2001)*

- Environmental Costs:

- Decreased biodiversity, ecological services, etc.

- Human-Health Costs:

- West Nile Virus, Malaria, etc.

- Agricultural Costs:

- Crop pathogens, hoof-and-mouth, mad cow disease

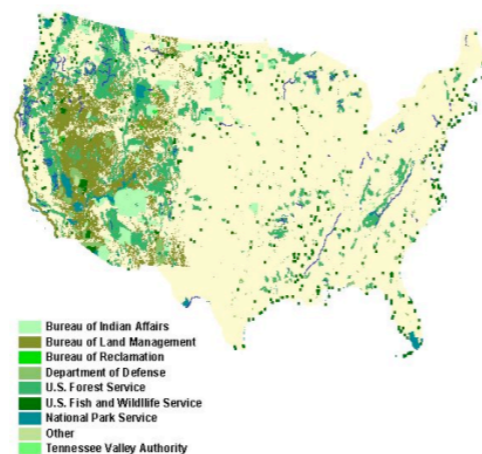
Notorious examples include:

*Dutch elm disease, chestnut blight, and purple loosestrife in the northeast; kudzu, Brazilian peppertree, water hyacinth, nutria, and fire ants in the southeast; zebra mussels, leafy spurge, and Asian long-horn beetles in the Midwest; salt cedar, Russian olive, and Africanized bees in the southwest; yellow star thistle, European wild oats, oak wilt disease, Asian clams, and white pine blister rust in California; cheatgrass, various knapweeds and thistles in the Great Basin; whirling disease of salmonids in the northwest; hundreds of invasive species from microbes to mammals in Hawaii; and the brown tree snake in Guam.*

*As many as 50,000 now, hundreds new each year ...*

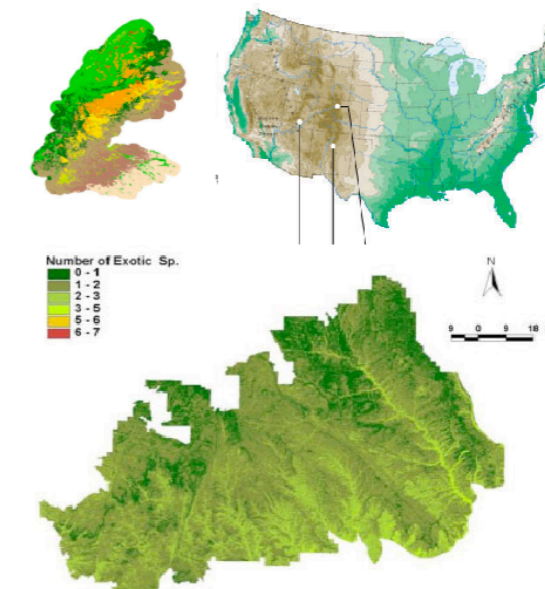
## Federal Government Response

- National Invasive Species Council (EO 13122 - 1999)
- Chaired by USDA, DOI, DOC
- USGS has a lead role in dealing with invasive species science in natural and semi-natural areas



## USGS Science / Client Needs

- On-demand, predictive landscape- and regional-scale models and maps for biological invasions
- Low-cost, high-performance computer modeling
- Integrated access to biological field data & NASA Earth Science data



## The ISFS Project ...

- Partnership between NASA and the US Geological Survey
- Goal to improve the invasive species management decision processes by improving efficiency, effectiveness, and access to tools tailored to the needs of the invasive species management communities.
- Based on USGS's early detection and monitoring protocols.
- Targets DOI operational agencies and DOI lands.

The screenshot shows the ISFS website with a navigation menu on the left containing links for Home, Science, Test Sites, Partners, People, and News. The main content area features a header with the NASA and USGS logos and the title 'Invasive Species Forecasting System'. Below this is a section titled 'The Invasive Species Forecasting System' which describes the partnership between NASA and the USGS. To the right, there is a 'General Information' section and a 'NASA Applications' section. A large satellite map of Amistad Reservoir is displayed in the center, with a caption below it: 'Landsat image of Amistad Reservoir located on the Rio Grande River near Del Rio, Texas (December 7, 2000). The water hyacinth is an aquatic weed native to South America. It has the capacity to grow and spread at astonishing rates, and in the wild it can clog the flow of rivers and waterways in days or weeks. The'.

## The National Invasive Species Forecasting System: A Strategic NASA/USGS Partnership to Manage Biological Invasions

By John L. Schnase, Thomas J. Stohlgren and James A. Smith

The diagram illustrates the process of the forecasting system. It starts with 'Landsat TM Data' and 'Vegetation Index' as inputs. These feed into 'Model Inputs', which then leads to 'Output'. The output is represented by several maps showing different aspects of the landscape, including 'Derived Slope', 'Elevation', 'Vegetation Cover Types', and 'Spatial Statistical Map'.

## Defending The Front

Invasive species are swift, prolific and headed our way. Scientists hope to stay one step ahead of them.

BY JENNIFER BOGO

The map shows the distribution of a weed species, with a legend indicating different levels of infestation. The legend ranges from 0-2 to 12-16. The map shows the weed spreading across a landscape, with a caption below it: 'GROWING LIKE A WEED Saltcedar or tamarisk, chokes the riverbeds of Rocky Mountain National Park, but land managers have limited resources to find and fight it. A predictive map of the park (left) shows where conditions are ripe for weeds to flourish; orange and brown areas would be the hardest hit.'

## Teaming with Life: Investing in Science to Understand and Use America's Living Capital

The cover features a photograph of a lush green landscape with a river and trees. The title is prominently displayed at the top.

## ECOLOGICAL FORECASTING

### AGENDA FOR THE FUTURE


Report of an NSF-USGS NASA Workshop on Biodiversity and Ecosystem Informatics held at NASA's Goddard Space Flight Center, June 22-23, 2000.

April 1, 2001



## Technology Accomplishments

### Scalable processing improvements with Cerro Grande Fire Site (CGFS) data


Re-engineered original S-plus code into a Fortran routine 

- **Reduced processing from 18 days to 61 mins**

Parallelized Fortran code 

- **Reduced processing from 61 mins to 2.47 mins**

18 days  2.5 min changes the science!

Performance of "Adaptive Kriging" for the CGFS study site exceeded goals 

- **1x Area: goal of 2.47 min, achieved 33 seconds. Exceeded goal by 4.5x**
- **10x Area: goal is 24.7 min, achieved 4 min 2 sec. Exceeded goal by 6x**

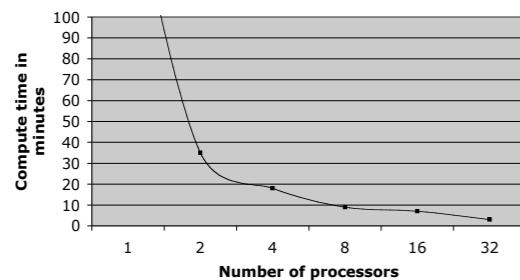
Dramatically improved both the quality and capacity of science results for our USGS clients through code optimization and cluster computing



"Constraints in computational time often forced us to substitute simple models for complex, more realistic and accurate models. We needed to greatly reduce computational time to allow us to evaluate larger areas more quickly."

- Dr. Tom Stohlgren, Director National Institute of Invasive Species Science, USGS

**Multiprocessor Scaling Curve**  
Cerro Grande Fire Site (nn-18)



## Science Accomplishments ...

- National habitat suitability map for tamarisk ...
- A function of MODIS Land Cover and vegetation seasonality.
- Model based on over 30,000 field data points compiled by the USGS.

### RESEARCH COMMUNICATIONS

## A tamarisk habitat suitability map for the continental United States

Jeffrey T. Morisette<sup>1\*</sup>, Catherine S. Jarnevich<sup>2</sup>, Asad Ullah<sup>3</sup>, Weijie Cai<sup>4</sup>, Jeffrey A. Pedelty<sup>1</sup>, James E. Gentle<sup>4</sup>, Thomas J. Stohlgren<sup>5</sup>, and John L. Schnase<sup>6</sup>

This paper presents a national-scale map of habitat suitability for tamarisk (*Tamarix* spp., salt cedar), a high-priority invasive species. We successfully integrate satellite data and tens of thousands of field sampling points through logistic regression modeling to create a habitat suitability map that is 90% accurate. This interagency effort uses field data collected and coordinated through the US Geological Survey and nationwide environmental data layers derived from NASA's MODerate Resolution Imaging Spectroradiometer (MODIS). We demonstrate the use of the map by ranking the 48 continental US states (and the District of Columbia) based on their absolute, as well as proportional, areas of "highly likely" and "moderately likely" habitat for *Tamarix*. The interagency effort and modeling approach presented here could be used to map other harmful species, in the US and globally.

Front Ecol Environ 2006; 4(1): 11-17

Tamarisk (*Tamarix* spp., salt cedar) is an Asian tree/shrub species which is invading riparian zones in the United States (Christensen 1962; Robinson 1965). It alters stream hydrology, increases soil salinity, and degrades habitats for native species. There are substantial costs associated with the eradication or control of tamarisk, with implications for water salvage, wildlife use, and riparian restoration (Shafiq et al. 2005). Furthermore, many organizations, from federal agencies to grassroots citizen coalitions, are concerned with tamarisk invasion. For example, the Secretaries of the Interior and Agriculture have called for a cooperative initiative to control invasive tamarisk (USDOL 2005), highlighting a national interest in setting priorities for tamarisk-related control and restoration efforts. These efforts, in turn, require geospatial information on tamarisk distribution, abundance, and suitable habitat at a national scale.

Here we present a map of tamarisk habitat suitability throughout the continental US. This work builds on recent analysis in the western US, showing the abundance of tamarisk in that region (Friedman et al. 2005). Our model, based on positive field locations and absence locations, shows that many low- and mid-elevation waterways in western and central US are vulnerable to tamarisk invasion. The potential habitat for tamarisk goes well beyond areas where it already occurs. Along with providing current distribution data, this habitat map can help guide containment boundaries, identify priority areas for early detection and rapid response, and monitor

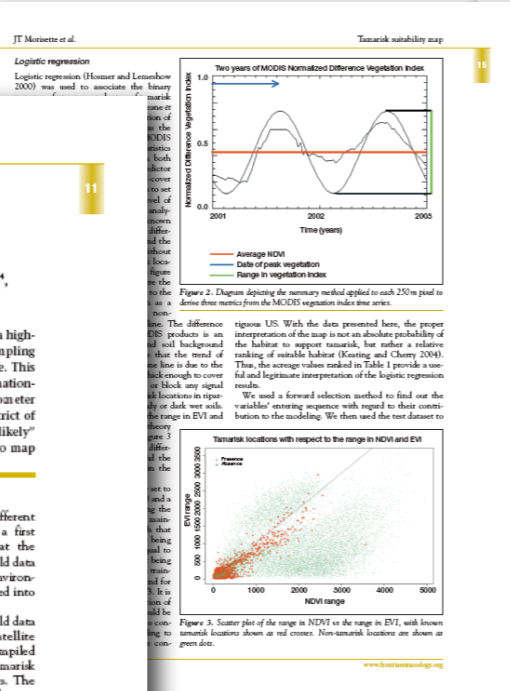
control strategies and cost-effectiveness in different states. We consider this mapping effort to be a first approximation for mapping tamarisk habitat at the national level. It will be improved upon as more field data become available, additional continental-scale environmental data layers are constructed and incorporated into the model, and users provide feedback.

The habitat map was constructed by coupling field data with geospatial information derived from satellite imagery. The US Geological Survey (USGS) compiled field data indicating the presence or absence of tamarisk from over 40 datasets and covering 32,148 points. The field data provided sufficient information to both construct and test the model. Two-thirds of the data were used to construct the model and one-third was used to test the results. These data were coupled to remote sensing data from the National Aeronautics and Space Administration's (NASA) Earth Observing System through a logistic regression.

Previous studies have also used remote sensing datasets to predict invasive species. For example, Peterson (2005) estimated cover of invasive grasses using a modeling approach similar to that described here, but for a smaller area with higher resolution data. Several studies have shown a relationship between a remotely-sensed spectral response and tamarisk habitat, but again, these are for smaller areas using higher resolution satellite or airborne data (Everitt et al. 1989; Everitt et al. 1996; Everitt and DeLoach 1990). The novel aspect of the work presented here is its national scale.

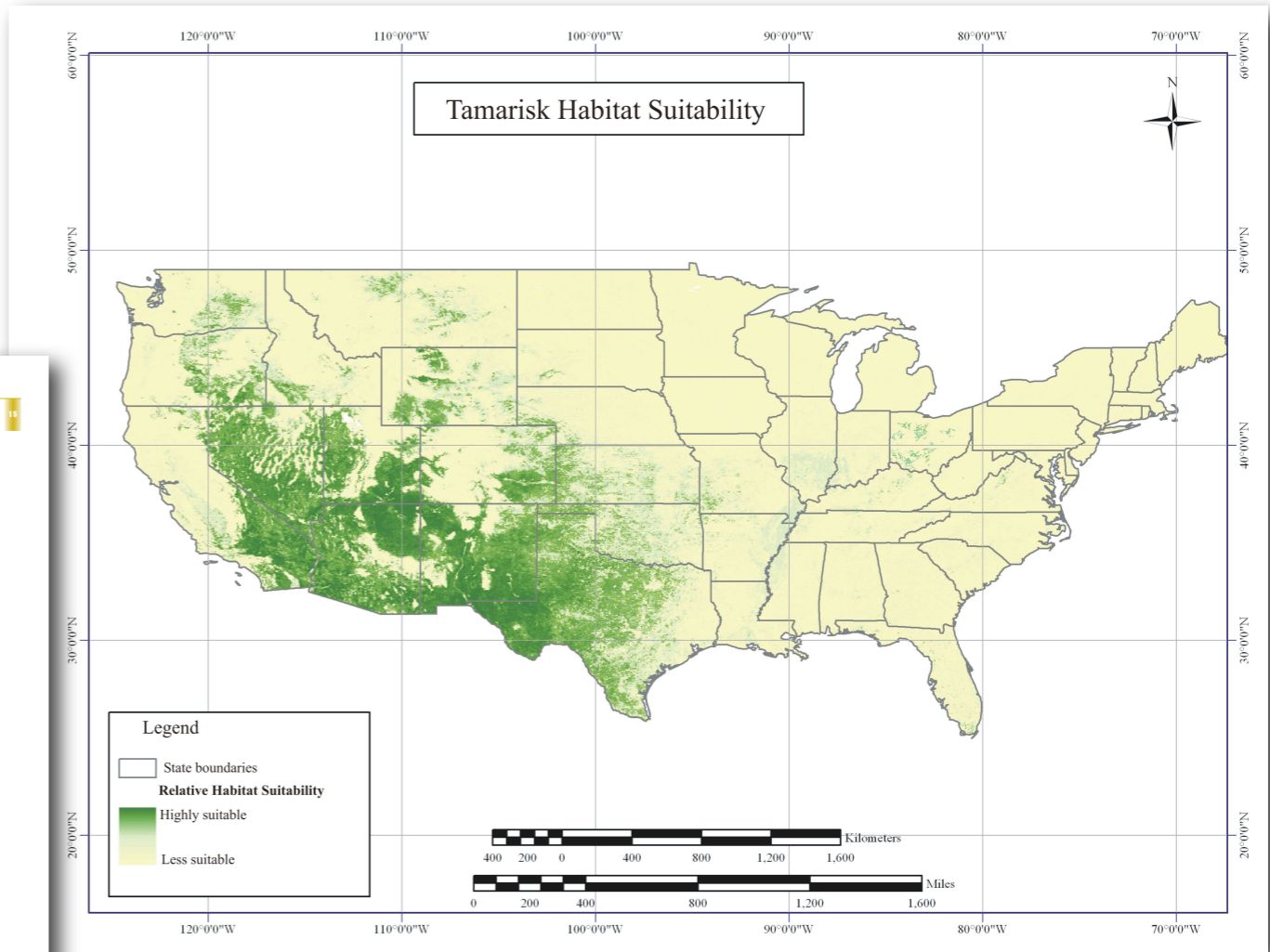
The stepwise logistic regression modeling procedure provided an empirical method to relate field data points to environmental layers derived from remote-sensing data covering the contiguous US. Previous work showing the spectral-temporal signature of tamarisk (Everitt and

<sup>1</sup>NASA Goddard Space Flight Center, Mail Code 614.5, Greenbelt, MD 20771 (\*jtmorisette@gsfc.nasa.gov); <sup>2</sup>Fort Collins Science Center, US Geological Survey, Fort Collins, CO; <sup>3</sup>Science Systems Application Inc., Greenbelt, MD; <sup>4</sup>George Mason University, Fairfax, VA

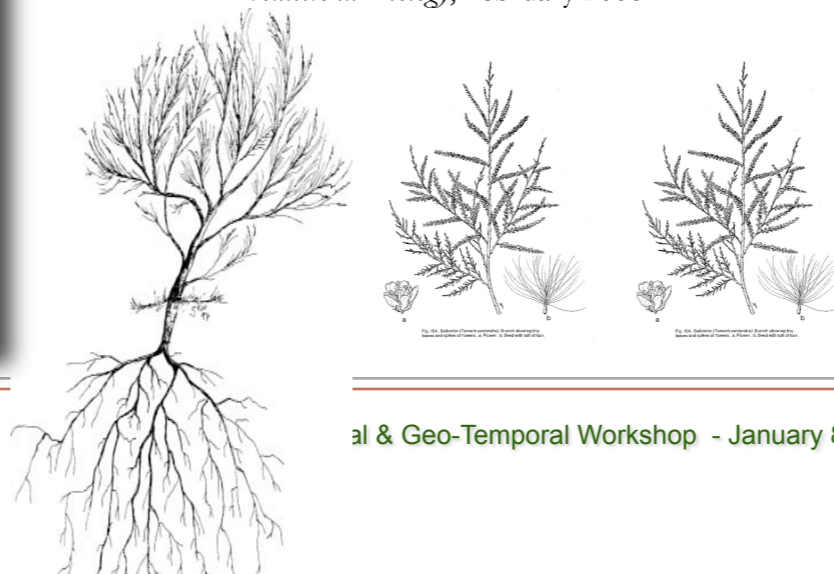
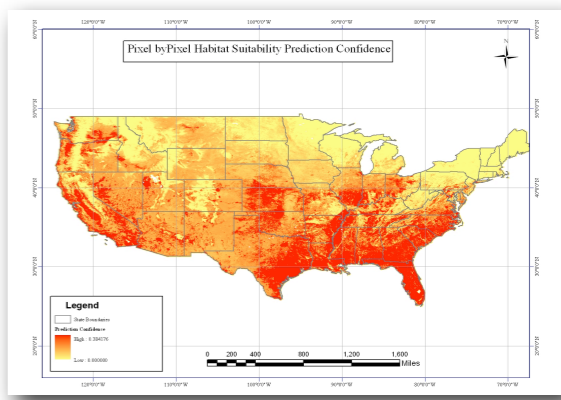


14	6.16	18
17	4.10	21
19	8.15	16
22	1.86	12
23	14.82	11
26	4.71	19
27	10.91	10
28	1.85	25
31	16.84	15
32	0.89	22
35	20.320	32
37	9.22	14
39	2.19	24
42	2.12	23
43	27.086	31
45	6.85	17
48	1.11	29
49	4.59	20
52	1.48	27
53	1.27	28
54	0.67	33
56	1.52	26
57	0.19	35
60	0.17	36
63	0.15	37
65	0.10	39
67	0.05	41
68	0.49	34
69	0.08	40
70	0.09	44
71	0.09	43
72	0.02	45
73	1.98	30
74	0.02	42
75	0.12	38
76	0.01	47
77	0.00	48
78	0.00	49
79	0.02	46

the practical constraints of pixel (1-500MB) from becoming too large by a wide range of potential. Changing work is directed at higher resolution, state-level maps and models. At the 1 km resolution, and with the methods employed here, the result is a map of



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.



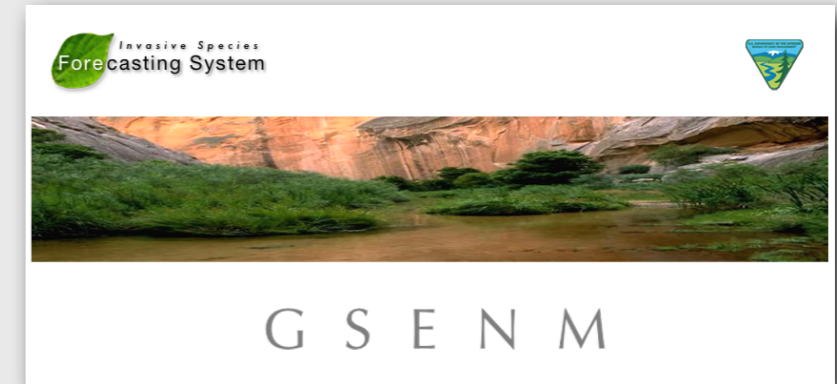
## Operational deployment ...

1. Classic Web Services / USGS Fort Collins Science Center
2. WebDAV-enabled Runtime Service / BLM Grand Staircase - Escalante National Monument ...

*Both based on a simple, adaptable, componentized "ISFS Framework" that implements our notion of a canonical modeling workflow ...*

*Option 2 - Turning out to be the winner*

*Light-weight application, assumes only intermittent / asynchronous internet connectivity, personalized / private data management, iTunes U / RSS / peer-to-peer sharing and communication ...*



- ISFS-G100-Console
- ISFS-G101-Moqui
- ISFS-G102-Coyote
- ISFS-G103-Peregrine
- ISFS-G104-Pareah
- ISFS-G105-Wolverine

# Invasive Species Forecasting System

xutm	yutm	pres_abs
422424	4159674	1
405105	4127066	1
404229	4127179	1
434927	4174629	0
423256	4161403	0
459478	4111353	1
430958	4112763	1
417839	4105218	1
421461	4109301	1
442243	4103983	1
436867	4141688	0
432029	4148220	0
433270	4147739	0
4175	4141782	0
4131352		1
4130866		0
4138089		0
4137960		0
4133851		1
4130477		0
4100189		1

Field Data Input



## Invasive Species Forecasting System

QuickMap • Sat 01 Sep 2007  
 Predicted Spatial Distribution of: **pres\_abs**  
 Grand Staircase - Escalante National Monument

**Results**  
 Response Variable: pres\_abs  
 Sample Points: 344

**Coverage Area**  
 Lower Left Corner: UTM - S12  
 03<sub>64</sub> 949 m E  
 05<sub>09</sub> 699 m N  
 Upper Right Corner: UTM - S12  
 40<sub>94</sub> 156 m E  
 42<sub>10</sub> 156 m N

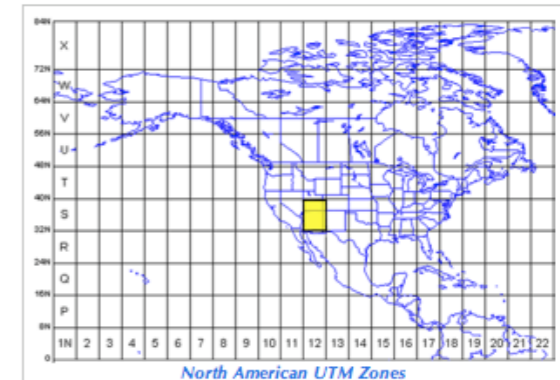
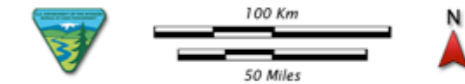
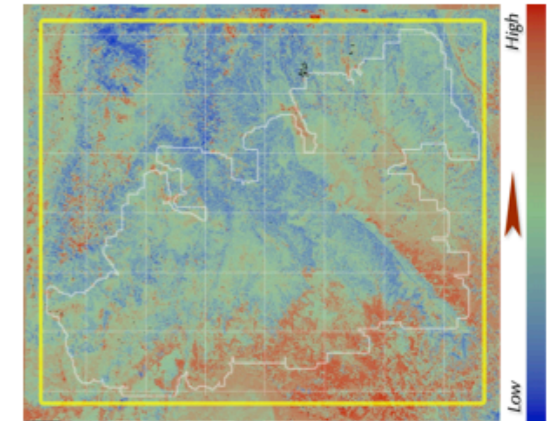
**Analysis Detail**  
 Method: Stepwise Logistic Regression (swlr v1.0 - Morissette / Li)

**Predictor Variables:**  
 - Label A - (Intercept)  
 - Label B - gsenm\_250m\_ndvi\_05peakdate\_ag01  
 - Label C - gsenm\_250m\_ndvi\_09brwdownrate\_ag02  
 - Label D - gsenm\_250m\_ned\_elev  
 - Label E - gsenm\_250m\_ned\_slope

Variable	Estimate	Std Err	z	pr
A	5.024	0.951	5.280	0.000
B	-0.090	0.023	-3.962	0.000
C	0.002	0.001	3.293	0.001
D	-0.002	0.000	-3.790	0.000
E	-0.027	0.011	-2.401	0.016

Null Deviance: 473.904  
 Residual Deviance: 423.792  
 Deviance Explained: 0.106  
 AIC: 433.792

**Output Products**  
 Model Run Bundle: GSENM\_cheat\_pres\_abs\_2001  
 250m GeoTIF Map: ./GSENM\_cheat\_pres\_abs\_2001.tif  
 Low-Res JPG Map: ./GSENM\_cheat\_pres\_abs\_2001.jpg  
 Field Data File: ./GSENM\_cheat\_pres\_abs\_2001.csv  
 Merged Data Set: ./GSENM\_cheat\_pres\_abs\_2001.mds  
 Raw Model Run Output: ./GSENM\_cheat\_pres\_abs\_2001.xml  
 Model Run Information: QM System Log  
 Statistics Information: Stat Tutorial



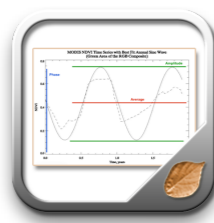
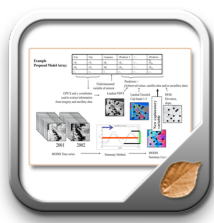
**Summary** • Lorem ipsum dolor sit amet, ligula suspendisse nulla pretium, rhoncus tempor placerat fermentum, enim integer ad vestibulum volutpat. Nisl rhoncus turpis est, vel elit, congue wisi enim sit, magna tincidunt. Maecenas aliquam maecenas ligula nostra, accumsan taciti. Sociis mauris in integer, a dolor netus non dui aliquet, sagittis felis sodales, dolor sociis mauris, vel eu libero cras. Interdum at. Enim eros in vel, volutpat nec pellentesque leo, scelerisque nec. Lorem ipsum dolor sit amet, ligula suspendisse nulla pretium, rhoncus tempor placerat fermentum, enim integer ad vestibulum volutpat. Nisl rhoncus turpis est, vel elit, congue wisi enim sit, magna tincidunt. Maecenas aliquam maecenas ligula nostra, accumsan taciti. Sociis mauris in integer, a dolor netus non dui aliquet, sagittis felis sodales, dolor sociis mauris, vel eu libero cras. Interdum at. Enim eros in vel, volutpat nec pellentesque leo, scelerisque nec.

DRAFT • For Review and Evaluation Only • Please Do Not Distribute

ISFS\_V1.0.1 / QM\_V1.0.1 (11.0s)

## Lessons learned ...

- Major successes**  
 Habitat-suitability modeling important to many people and many types of decision processes. And "pretty close" is often good enough ...
- Major failures**  
 Traditional, enterprise-scale, government-based information services difficult to implement these days. Points to expanded role for **private-sector infrastructures** and alternative deployment strategies ...
- What's missing**  
 A coherent approach to **regionalized data and application construction and delivery**. Problems, solutions, responses, budgets, and management scopes are regional. For example, the National Interagency Fire Center is very interested run-time ISFS (BAER Teams especially). Important implications for a globe-centric NASA ...
- What's next**  
 R&D that moves us toward **a generative ecology for Earth science modeling**: Lightweight (microkernel) modeling architectures, agile regionalized delivery, multi-appliance accommodative, data/model syndication, podcasting/catching, client-side tailorability, mashups, iconographic interfaces, private-sector infrastructures, etc. ...







GRAND STAIRCASE - ESCALANTE  
NATIONAL MONUMENT