Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Applying Remote Sensing Metrics to Quantify Invasive Annual Plant Distributions and Map Potential Fire Hazard Across Mojave Landscapes

JANELLE DOWNS, JERRY TAGESTAD, VALERIE CULLINAN, KYLE LARSON

Pacific NW National Laboratory, Richland Washington

Fire Science Management for the Mojave Ecoregion—Barstow, CA, June 11, 2014

Invasive Species Detection and Fire Hazard: Objectives

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

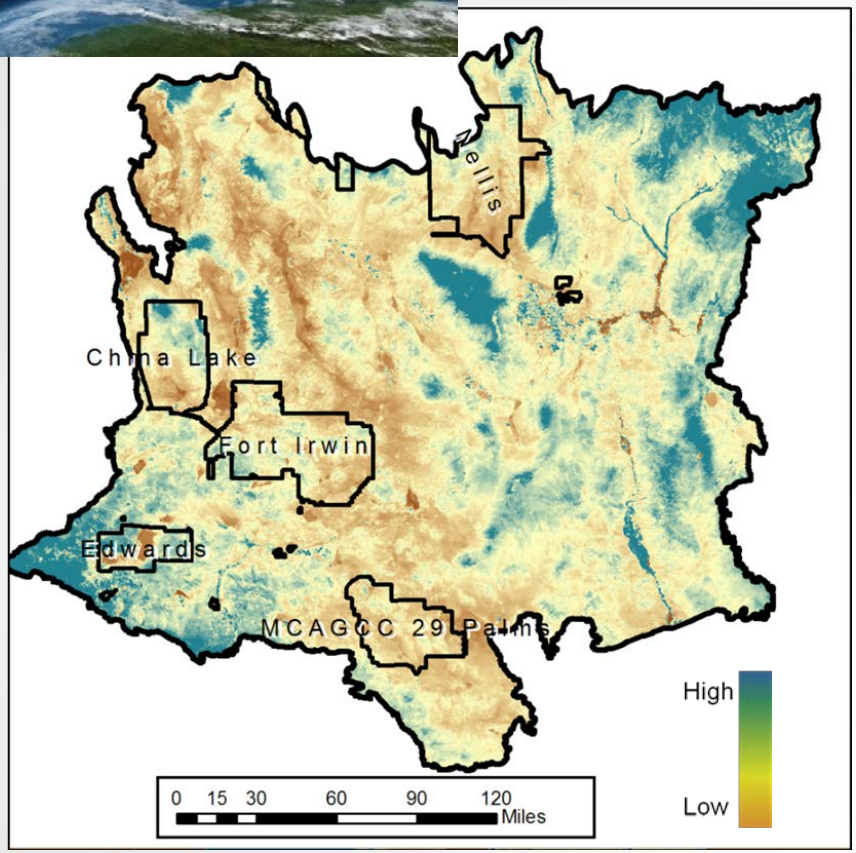
- Develop and evaluate models to predict relative abundance of nonnative annuals using environmental attributes and remotely sensed data
- Construct relationship between measured cover and biomass that could be related to potential fire risk
- Provide model and tools to evaluate and compare relative fire hazard for Mojave

Bromus rubens &
B. tectorum

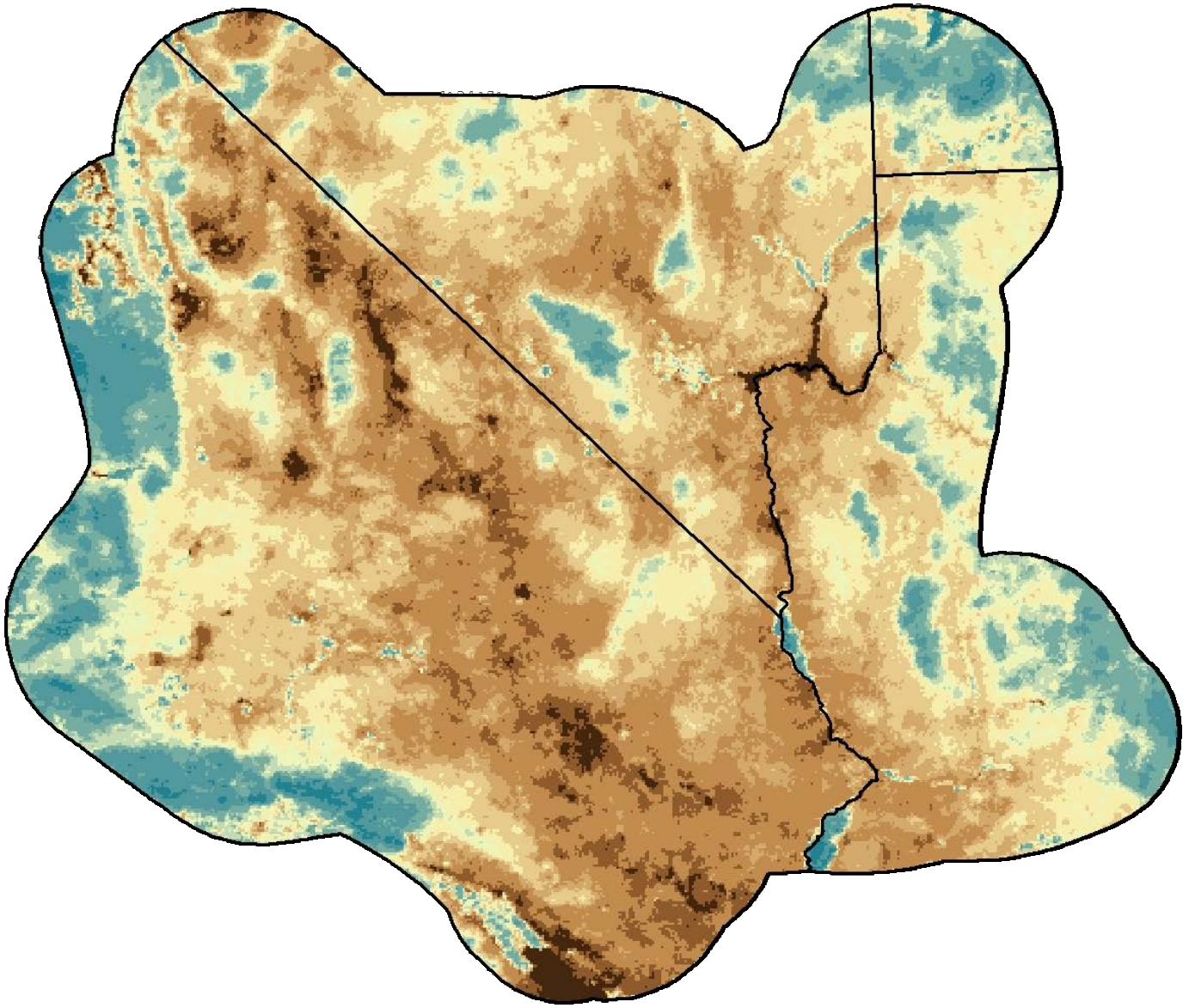
Schismus arabicus & S. barbatus)

Erodium cicutarium

Invasive Species Detection and Fire Hazard Analysis



- MODIS weekly NDVI composite images
  - From 2000-2014
  - USGS eMODIS product
  - 250 m pixel
- Utilize weekly MODIS NDVI data to describe phenology and relative productivity; develop models for current and past distribution of nonnative annuals.
- Develop landscape models to assess relative annual fire hazard



NDVI

High

Low

December

August

Data > Field Plot Measurements

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- 600 plot locations
- Collected during 2 campaigns (2009 & 2011)
- 50-meter plot size
- Cover measured for all species in subplots
- Biomass collected in a subset of the 2011 plots

Plotcode	X	Y	AlnannfbTotal	AlnAnnfb+erocic	broarv	brorub	brotec	hordsp	schara	schbar	SchismusTotal	vulbro	Alnanngr Total	erocic	Alnbiefb Total	AlnperfbTotal	AlnpergrTotal	baresoil	litter
66SER11	667150	3902163	0.0	2.3	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.3	2.3	0.0	0.0	75.3	1.7

Phenological signatures or "Phenometrics"

Calculated for the hydrologic year between beginning of October and end of following September

Peak NDVI —

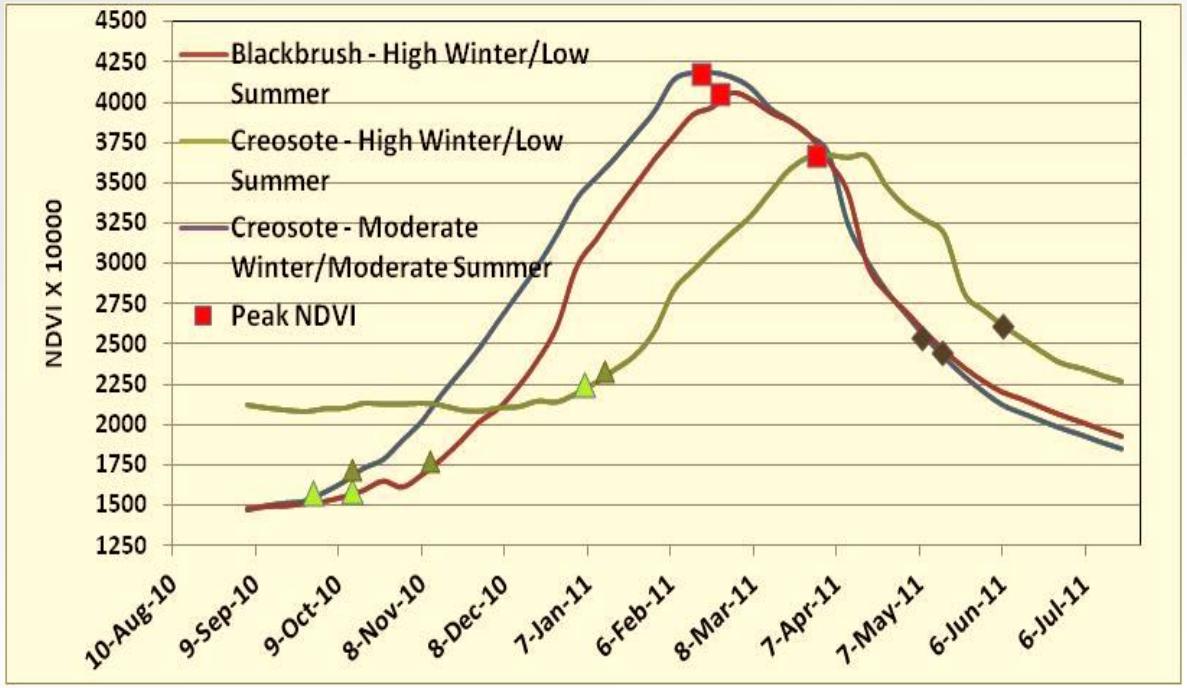
Maximum weekly NDVI during the growing season.

Start of Season (SOS) —

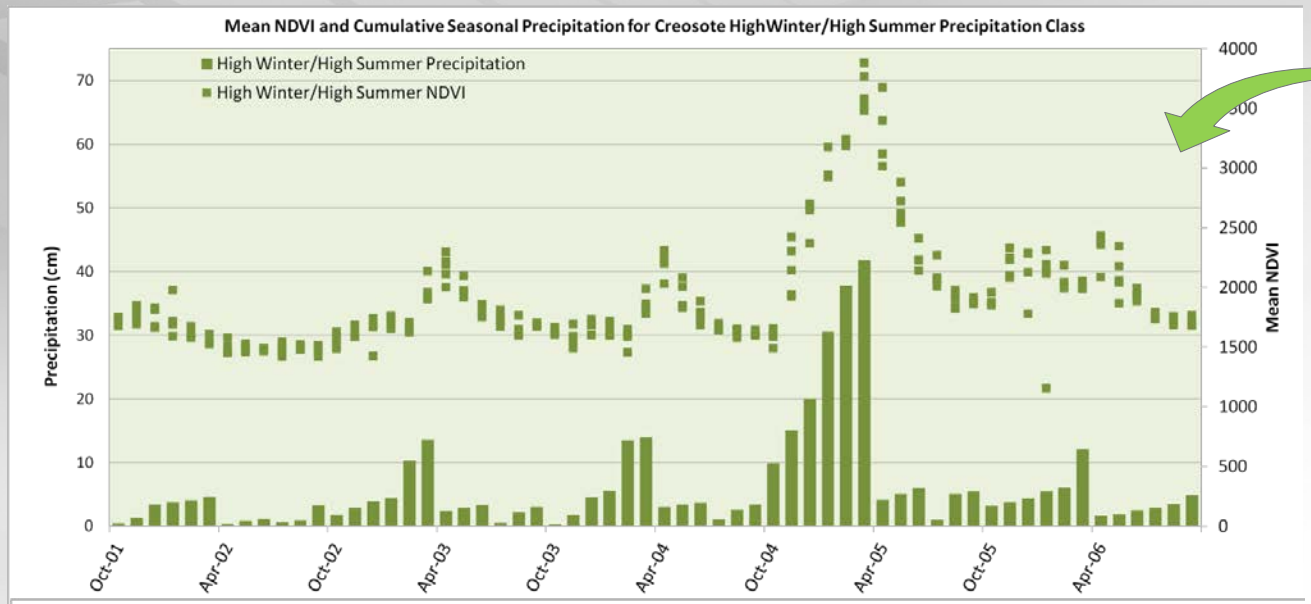
Weeks during which green-up is detected

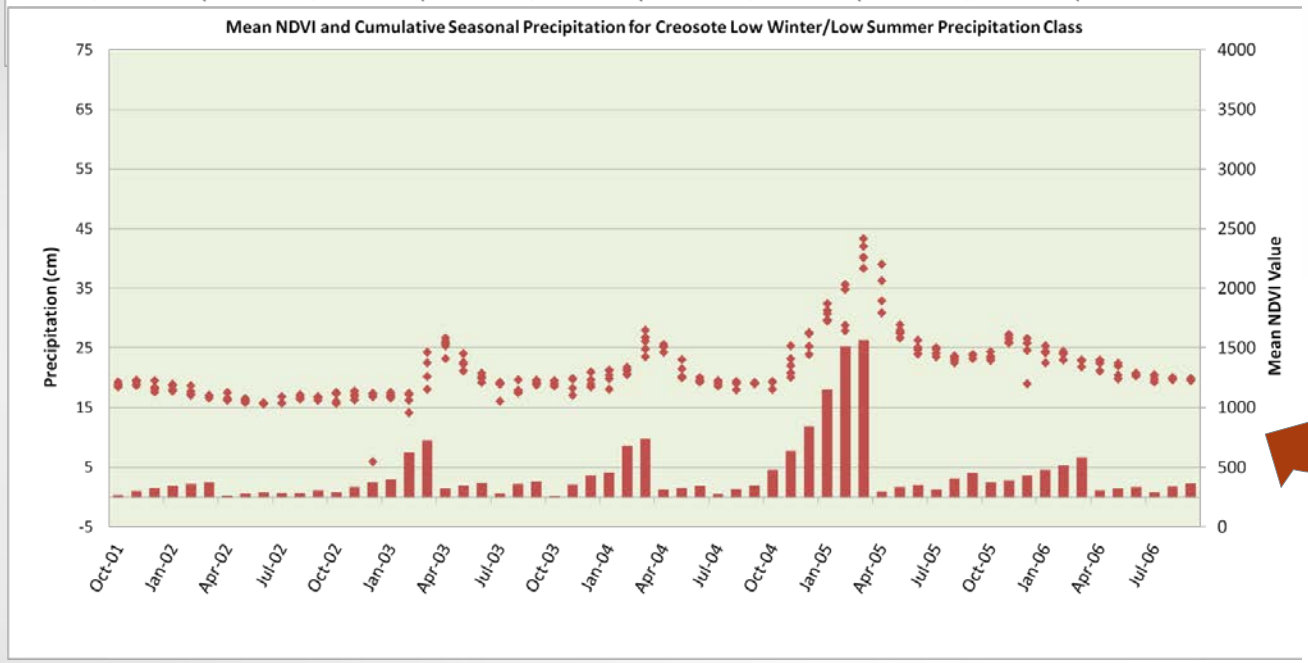
End of Season (EOS)–

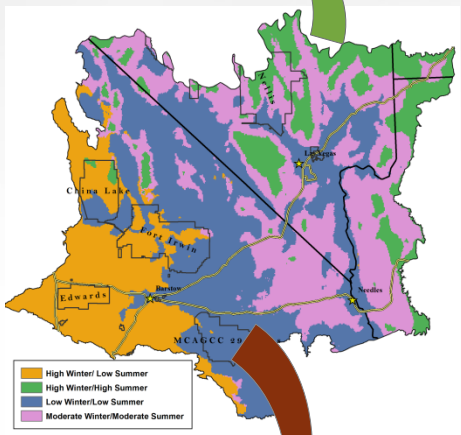
Week or month where senescence is nearly complete



Vegetation response to rainfall differs by zone







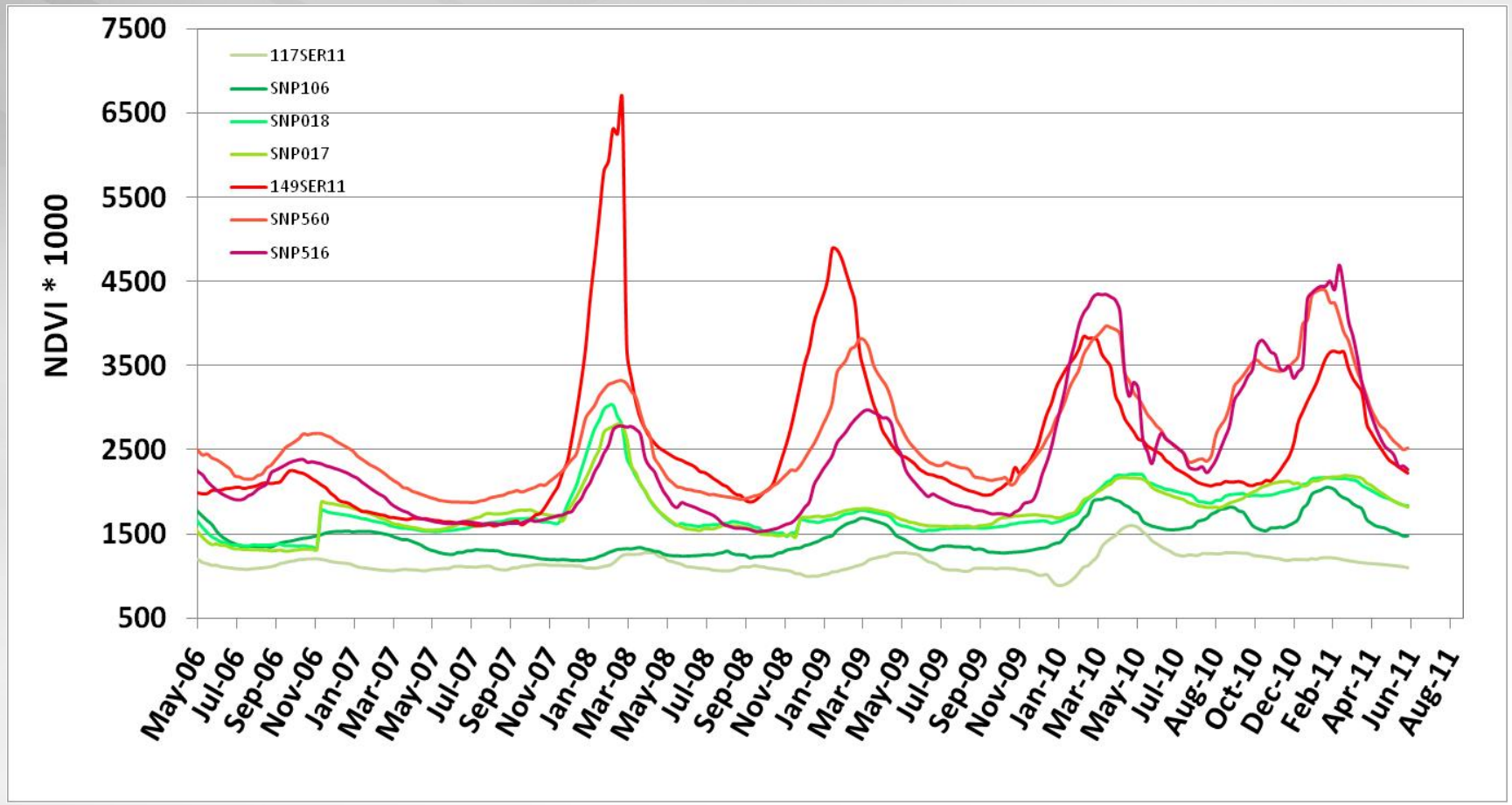
Data > Field Plot Measurements

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- More than 600 plot locations
- Collected during 2 campaigns (2009 & 2011)
- 50-meter plot size
- Cover measured for all species in subplots
- Biomass collected in a subset of the 2011 plots

Plotcode	X	Y	AlnannfbTotal	AlnAnnfb+erocic	broarv	brorub	brotec	hordsp	schara	schbar	SchismusTotal	vulbro	Alnanngr Total	erocic	Alnbiefb Total	AlnperfbTotal	AlnpergrTotal	baresoil	litter
66SER11	667150	3902163	0.0	2.3	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.3	2.3	0.0	0.0	75.3	1.7

Data—NDVI Signatures For Field Locations with >25% Cover NIA and <5% Cover NIA

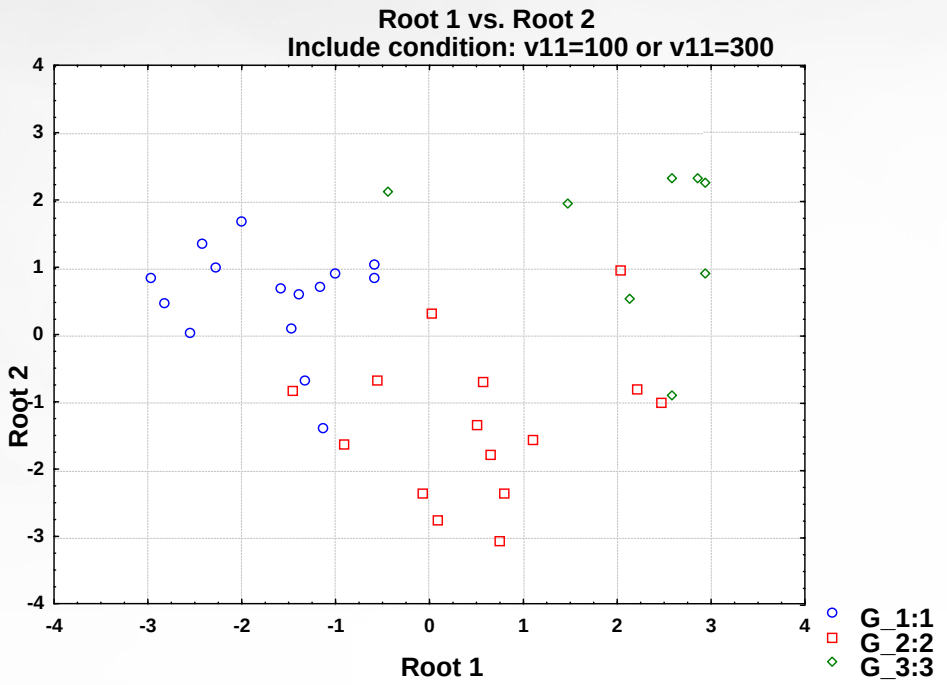


NDVI signatures for plots in Blackbrush in the Moderate Winter/Moderate Summer Precipitation Class
Noisy data smoothed via Savitsky-Gorlay filtering

Detecting and Mapping Nonnative Annual Species

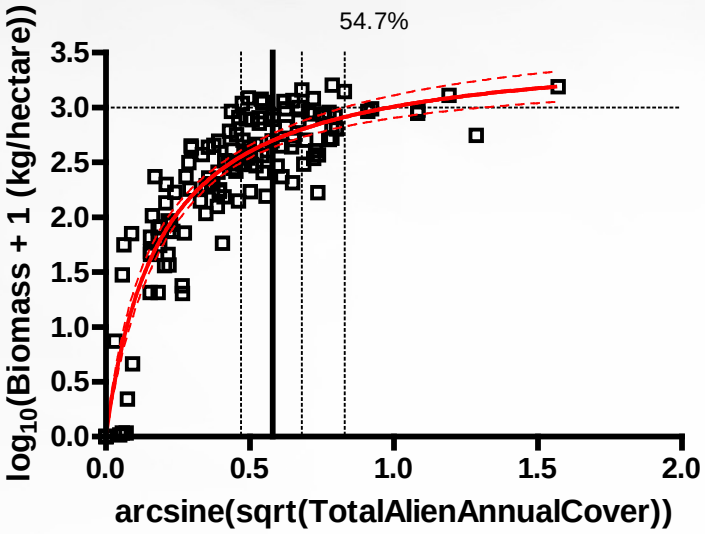
Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- Vegetation data from 515 field locations assigned categories relevant for predicting fire risk
  - Low nonnative annual cover (≤ 10%)
  - Intermediate (10% to 40%)
  - High (> 40%)
- 25% of dataset withheld for validation
- Discriminant models
  - standardized variables
  - by precipitation regimes and precipitation regime x vegetation association.
- Predictor variables:
  - Cumulative winter precipitation, monthly precipitation
  - Start of season (SOS) NDVI
  - Peak NDVI
  - Slope between SOS and Peak NDVI



Detecting and Mapping Nonnative Annual Species

- Relate measured nonnative annual cover to biomass measures
- N=128, R^2 = 0.82



$y = (b_{max} \bullet X)/(Kd + X)$

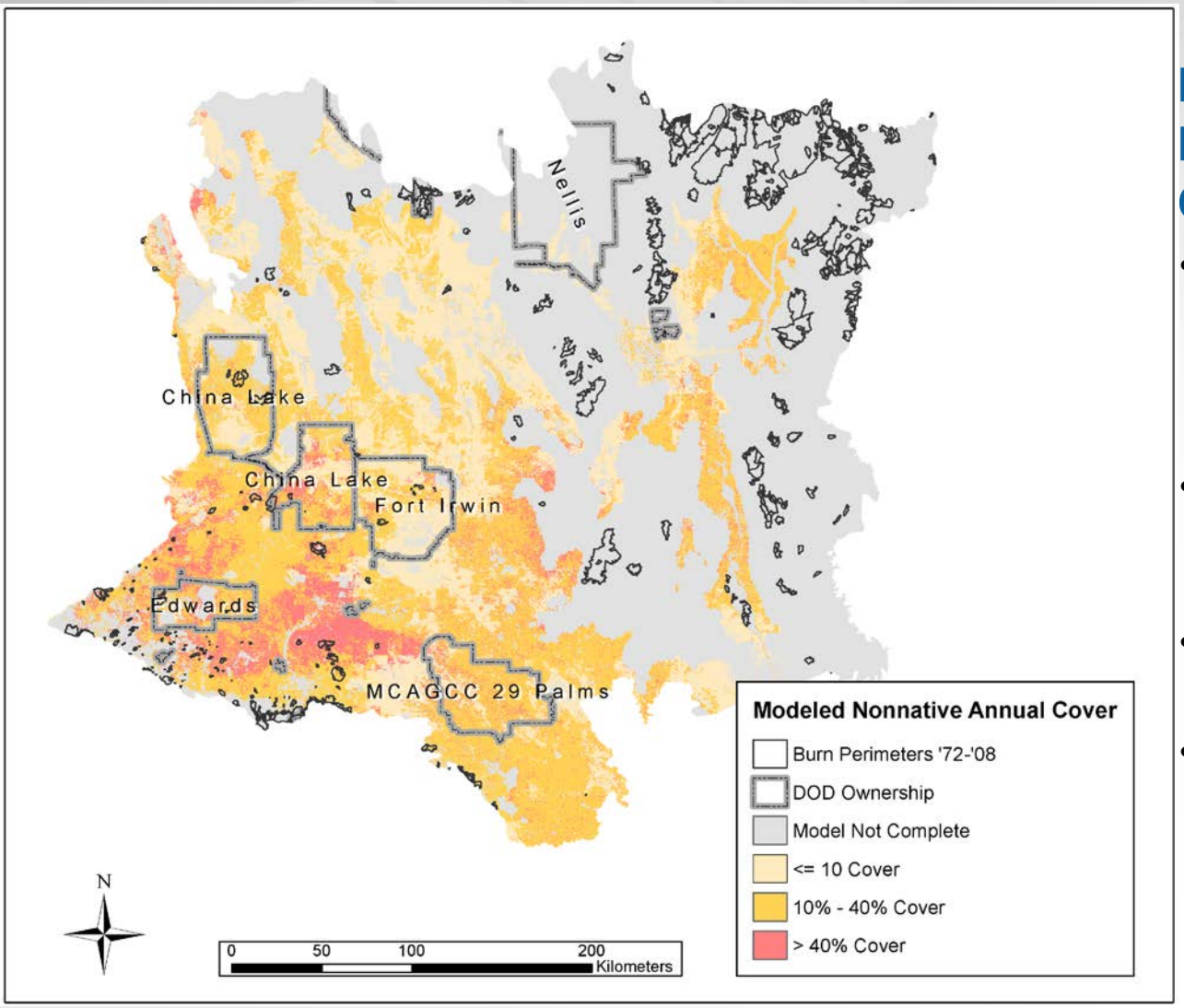
Fine Fuel Thresholds[(a)]	Log10 (biomass+1)	Cover = 0.0474*biomass
200 kg/h	2.30103	9.48
1000 kg/h	3	47.4

(a) based on values from Rao et al. (2010), Brooks et al. (2007), Brooks (1999), and Brooks (2002).

Model Testing and Validation

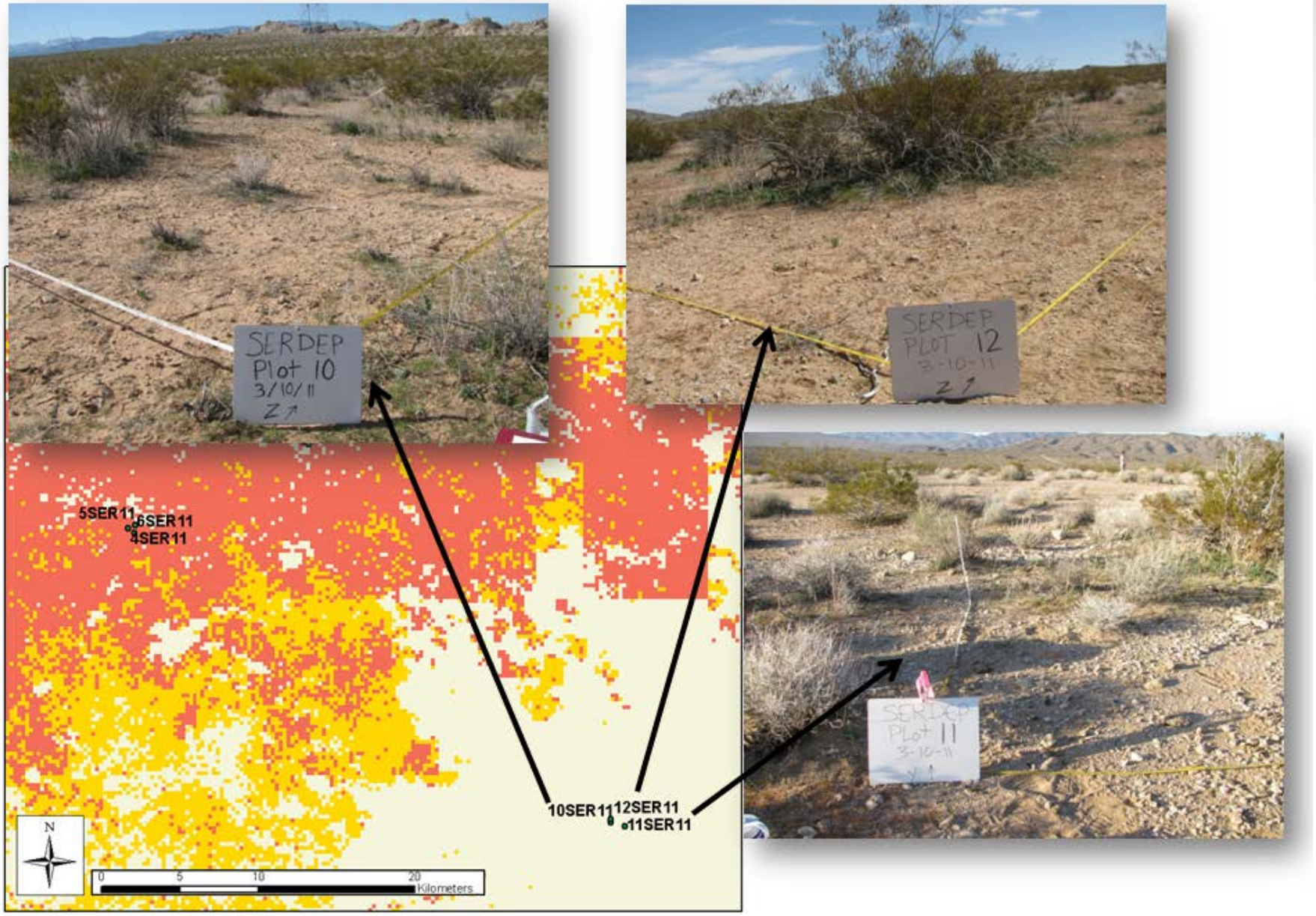
Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Model	Veg+Precip Classes	Modeled Sample Size	Validation Sample Size	Modeled Correct Classification	Modeled Maximum Error Size	Modeled Percent errors > 5	Validation Maximum Error Size	Validation Percent Errors > 10	1-Percent Errors > 10
M1	100, 300, 412 < 1720 m	38 +10(412)	22	86.8 (50% for 412)	9.96 (13.8 for 412)	8% (30% for 412)	4.7	0%	100%
M2	202, 205, 208, 210, 211	25	11	96	7.4	4%	37.4	27%	73%
M3	204 < 896 m	39	17	76.9	25.2	8%	47.1	24%	76%
M4	204 >= 896 m	44	8	77. 3	10.7	7%	7.1	0%	100%
M5	403, 404, 406, 407, 410, 411	36	12	75.0	14.8	17%	35.6	17%	83%
M6	401, 405	57	23	82.5	30.2	12%	11.3	9%	91%
M7	412 >= 1720 m	33	8	75. 8	11.9	9%	8.1	0%	100%
M8	402 >= 1200 m	62	15	75.8	36.6	8%	32	13%	87%
M9	402 < 1200 m	40	11	82.5	22.5	13%	31.8	27%	73%



Example of Model Results for 2010-2011 Growing Season

- Represents two precipitation regions
  - High Winter/Low Summer
  - Low Winter/Low Summer
- 88% correct classification based on limited validation dataset
- Represents 57% of the study area
- Weighted mean classification accuracy = 75% for initial discriminant models

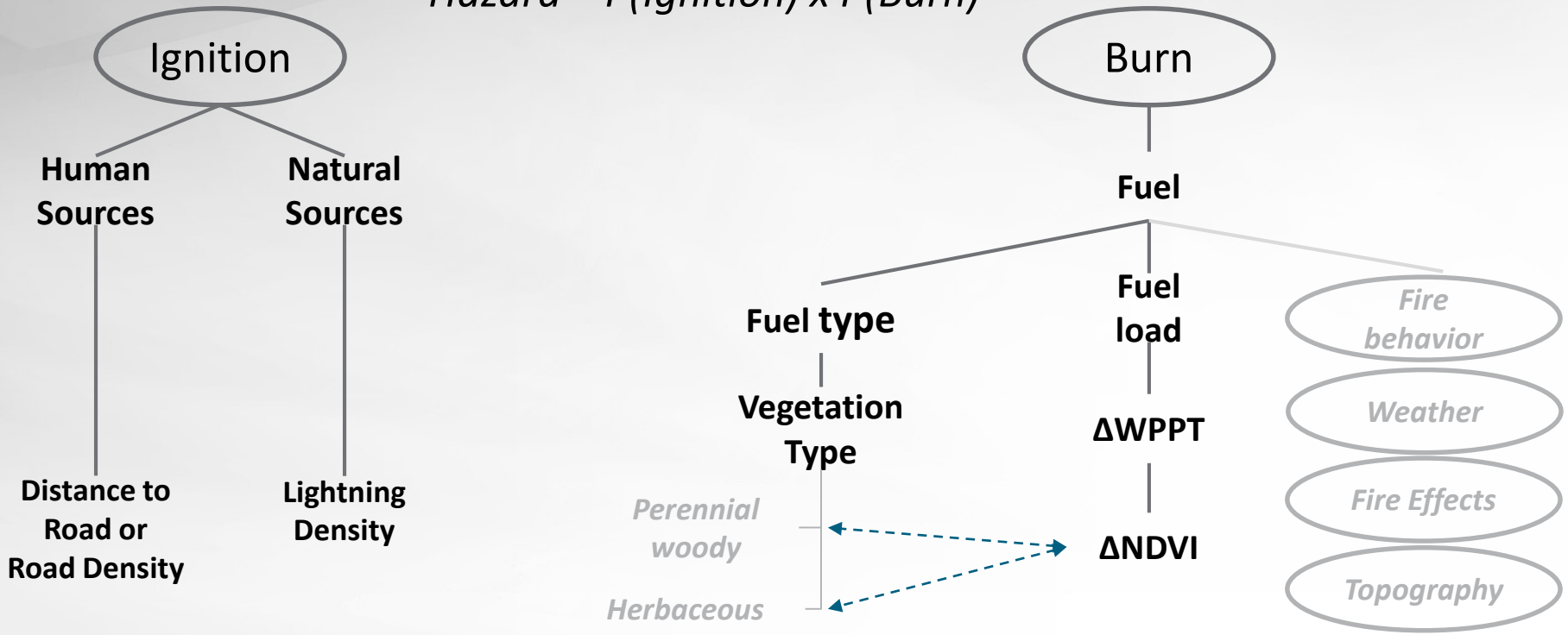

SERDEP
Plot 10
3/10/11
Z↗
SERDEP
PLOT 12
3-10-11
Z↗
SERDEP
Plot 11
3-10-11
5SER11
6SER11
4SER11
10SER11
12SER11
11SER11
N
0
5
10
20
Kilometers

Model Development

- Model based primarily on 2009 and 2011 field data
- Further data collection occurred during 2012 and 2013 for development and validation
  - Dry years – little growth of invasive annuals
- Existing models not robust
- Step back to drawing board
  - More complex models?
  - More data?
  - Logistics for incorporating current data and complex models into accessible information in timely manner
- What other metrics or modeling approaches can we use to evaluate potential fire hazard

Conceptual Model for Preseason Assessment of Fire Hazard

Hazard = P(Ignition) x P(Burn)

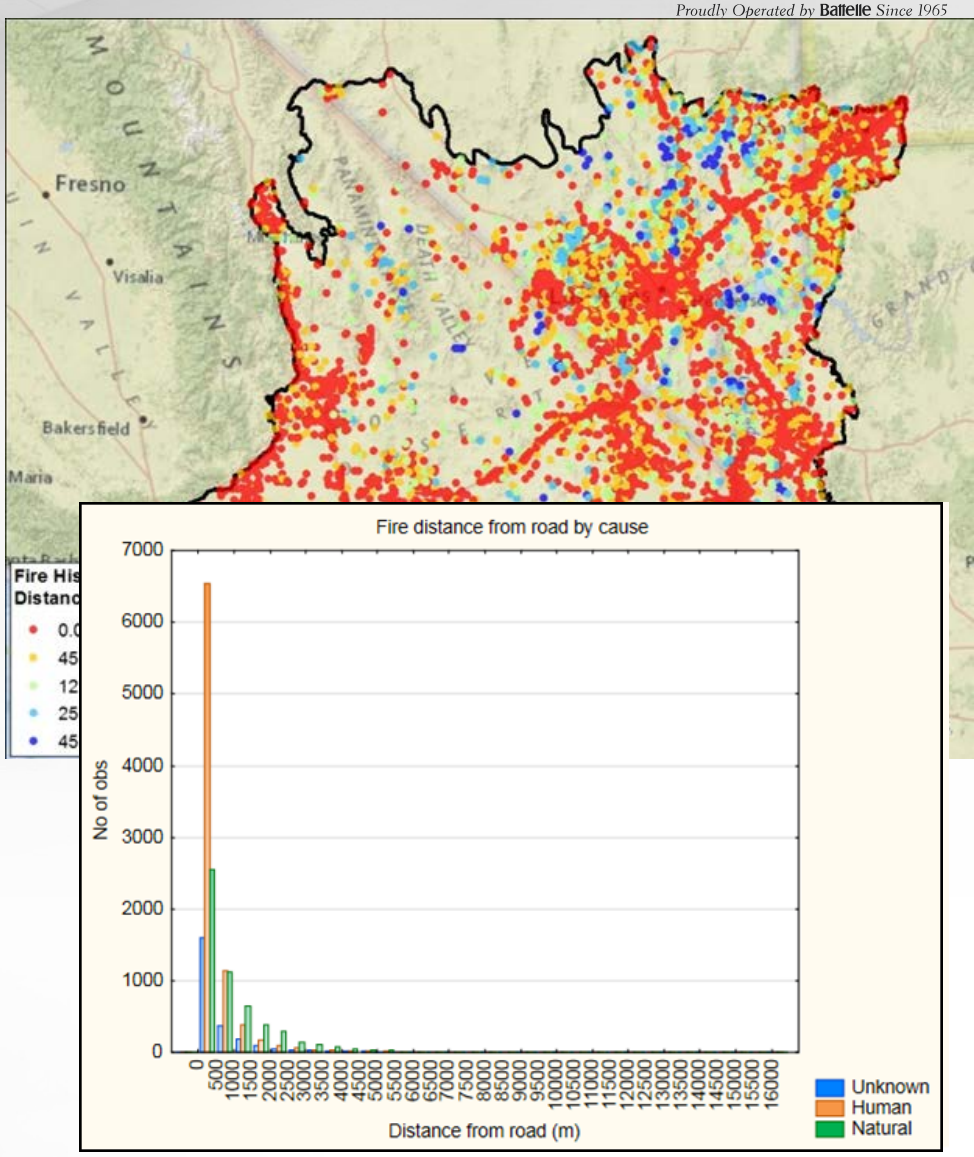


ΔNDVI = peak NDVI in current year (i) –median of peak $NDVI_{2000\text{-}2010}$

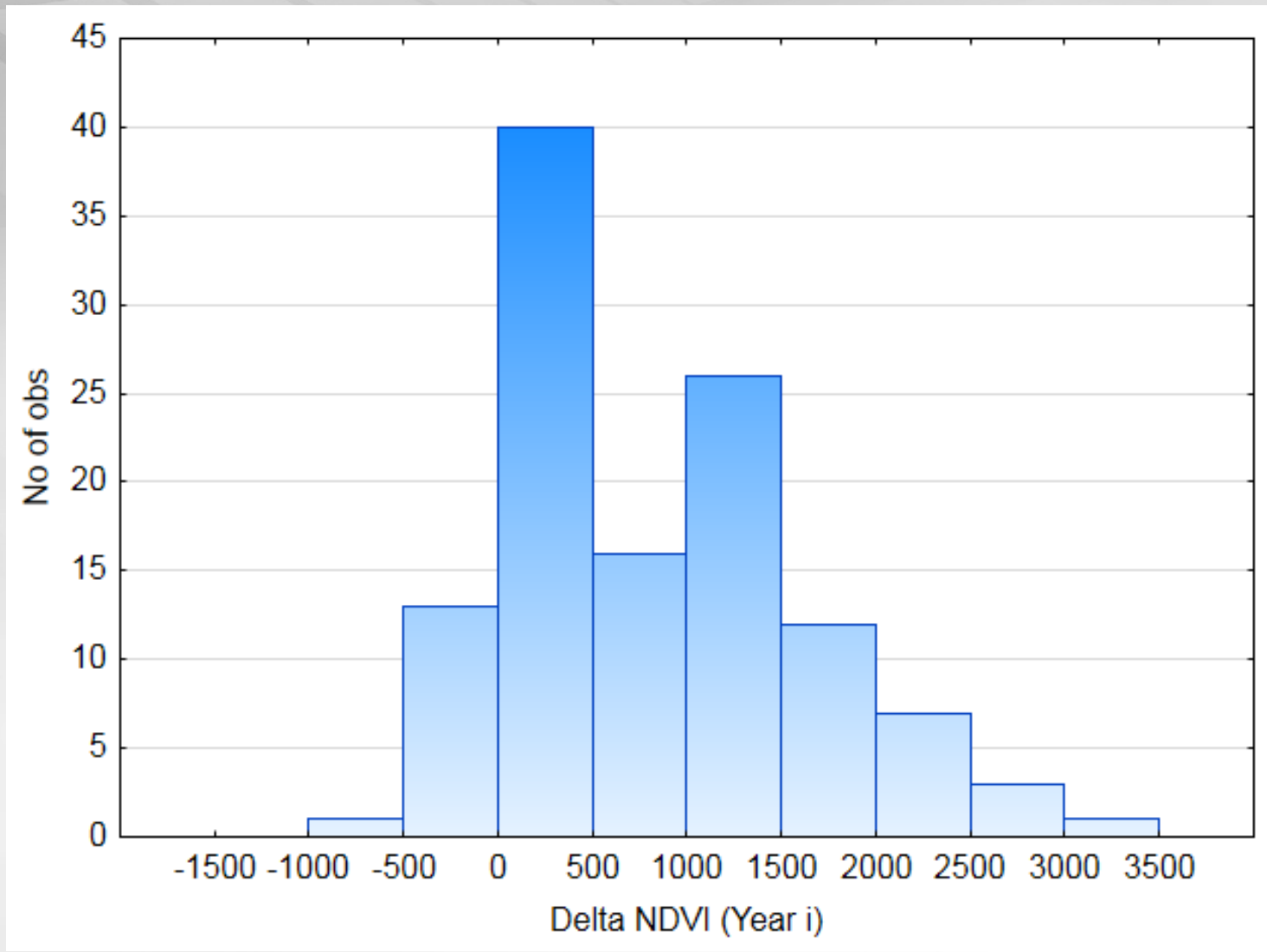
Mean ΔWPPT = Winter precipitation for current year –
median winter $precipitation_{1971\text{-}2010}$

Preseason Fire Hazard Assessment

- Use the database of fire starts for 1980 to 2012
- 81% of fire **starts** occur <1000 m from a road
- 52% human-caused, 33% natural, 15% unknown caus
- Inverse relationship between all fire types and distance from road is function of road density in Mojave.
- Relationship for human-caused fires.

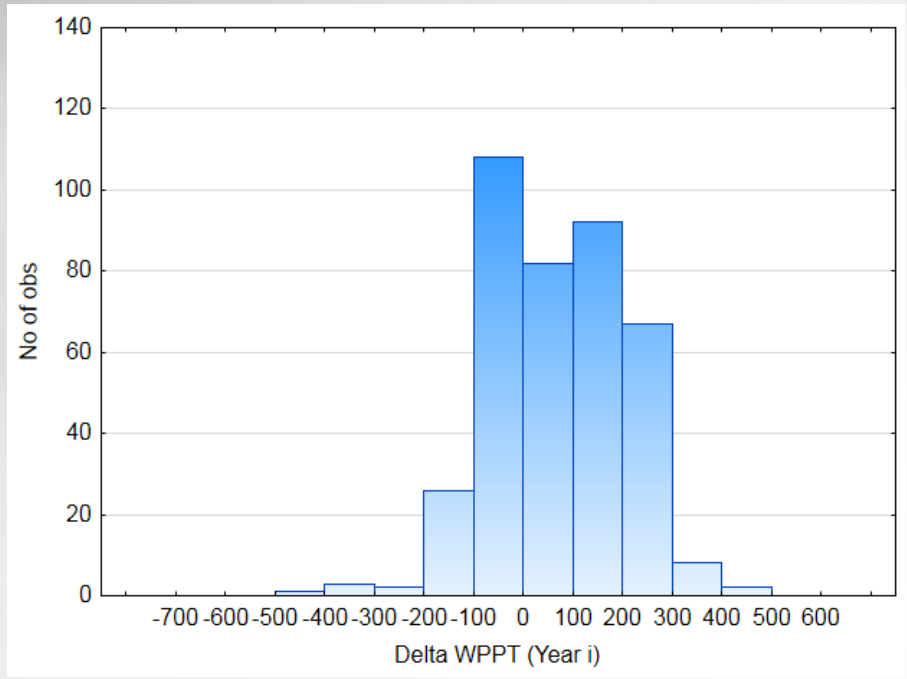


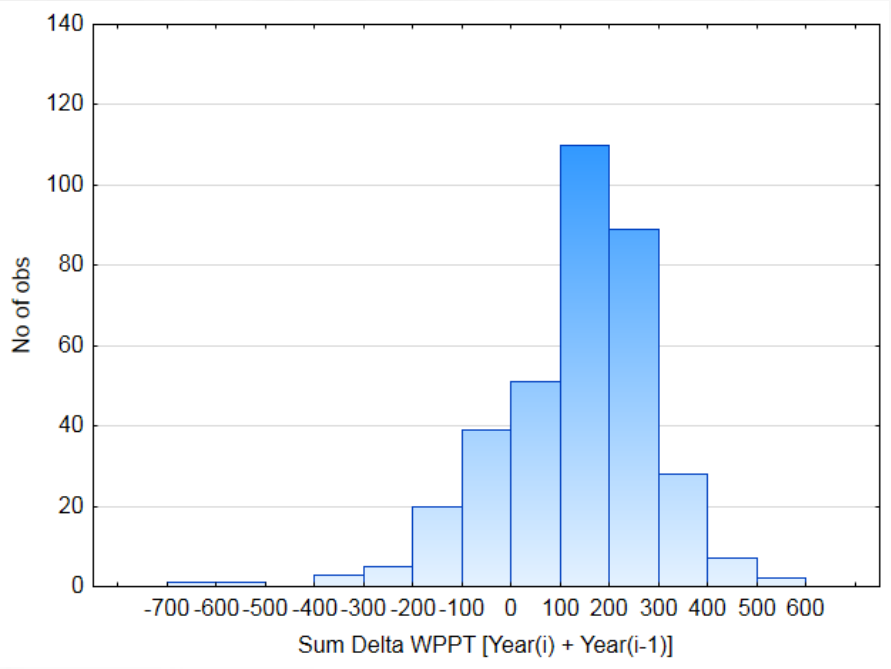
Mean ΔNDVI for Burned Areas 2000-2010



ΔNDVI = peak NDVI in current year (i) –median of peak $NDVI_{2000\text{-}2010}$

Mean ΔWPPT for Burned Areas (2000 – 2010)

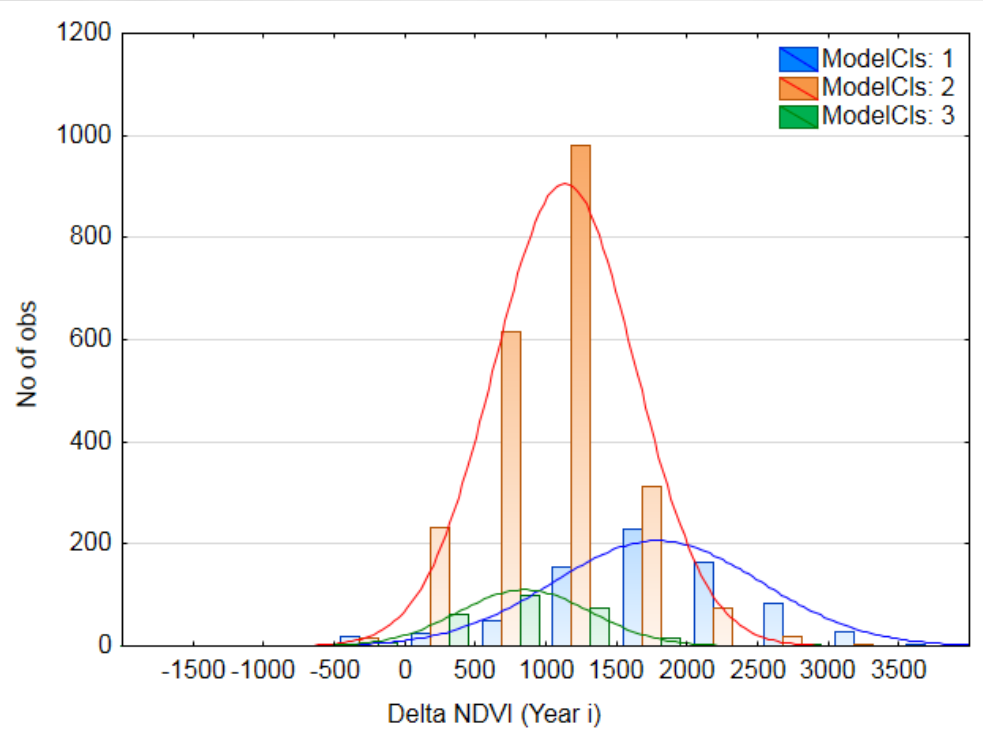




Mean ΔWPPT = Winter precipitation for current year – median winter precipitation$_{1971\text{-}2010}$

Subsampling by Vegetation Type within Burns

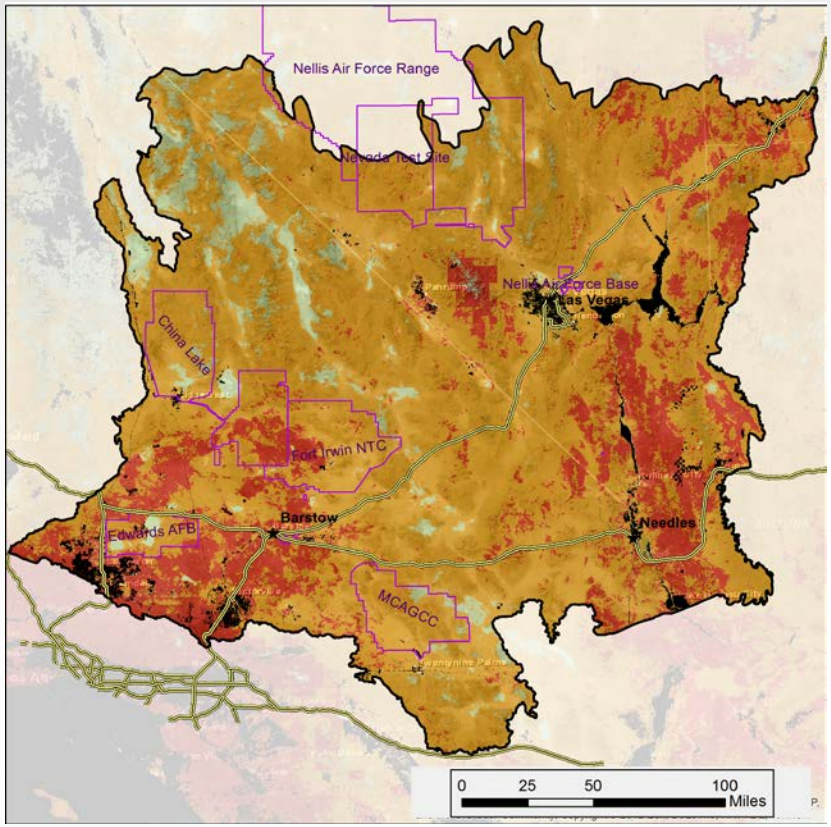
- Class 1 –low elevation
  - Creosote, Salt Desert Shrub and Mojave Scrub Shrub
- Class 2—mid elevation
  - Blackbrush, Sagebrush
- Class 3—higher elevation
  - Juniper, Pinyon Pine, Chapparal



65% of fires occurred in Blackbrush and Creosote vegetation types for the entire fire record

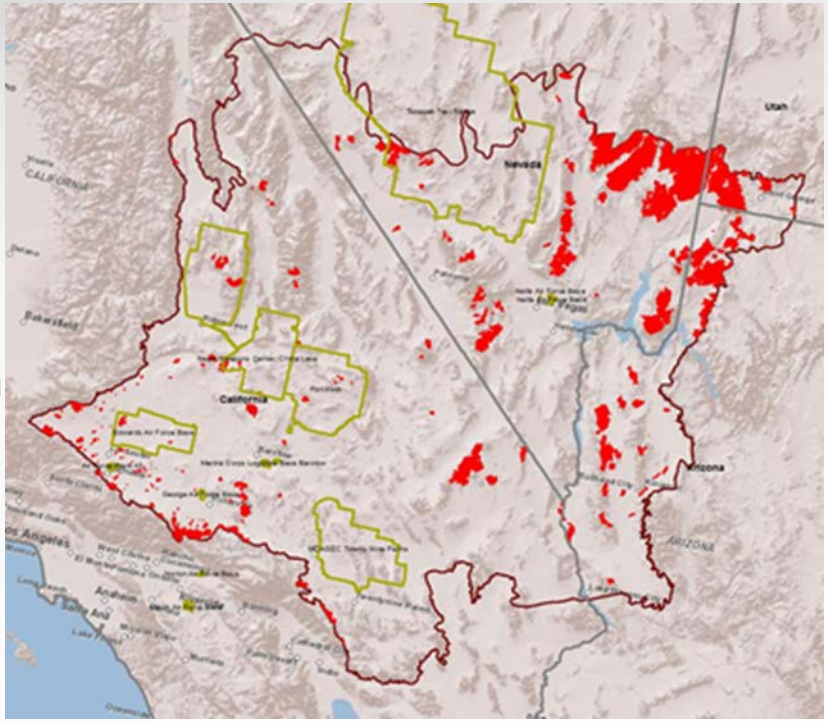
Preseason Fire Hazard

- Use precipitation zones as strata to divide region into sampling areas
- Using 10-year record of data:
  - Fire history (Burned/Unburned)
  - ΔNDVI
  - ΔWPPT
  - Ignition variables
  - Vegetation Type
- Apply logistic regression to derive parameter estimates to predict probability of fire hazard in that season



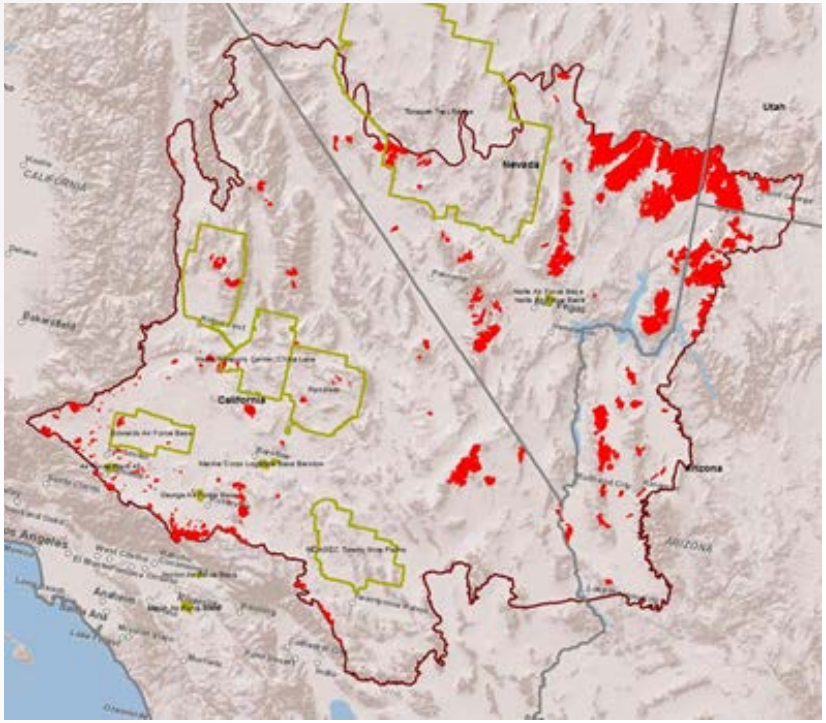
Preseason Fire Hazard: Logistic Regression Model

- Sampling Strategy
  - Stratified by
    - Precipitation Zone
    - Vegetation Type
    - Year
  - Sampled 1,000 fires and 1,000 non-fires from each Precipitation Zone – Vegetation Type combination
- Final Model
  - Logistic Regression
  - Variables included:
    - Distance to Road
    - Lightning Density
    - Delta winter precipitation
    - Delta NDVI
    - Dwppt^2
    - Lightning Density^2
  - Parameters estimated using 20X cross-validation.



Preseason Fire Hazard: Logistic Regression Model

- Model generates predicted probability of fire for each pixel (for each year or future year)
- More complicated models considered with little to no improvement in classification accuracy
- Classification Accuracy
  - Accuracy = 77.8%
  - False Positives = 6.3%
  - False Negatives = 15.8%



2001

2002

2003

2004

2005

2006

2007

2008

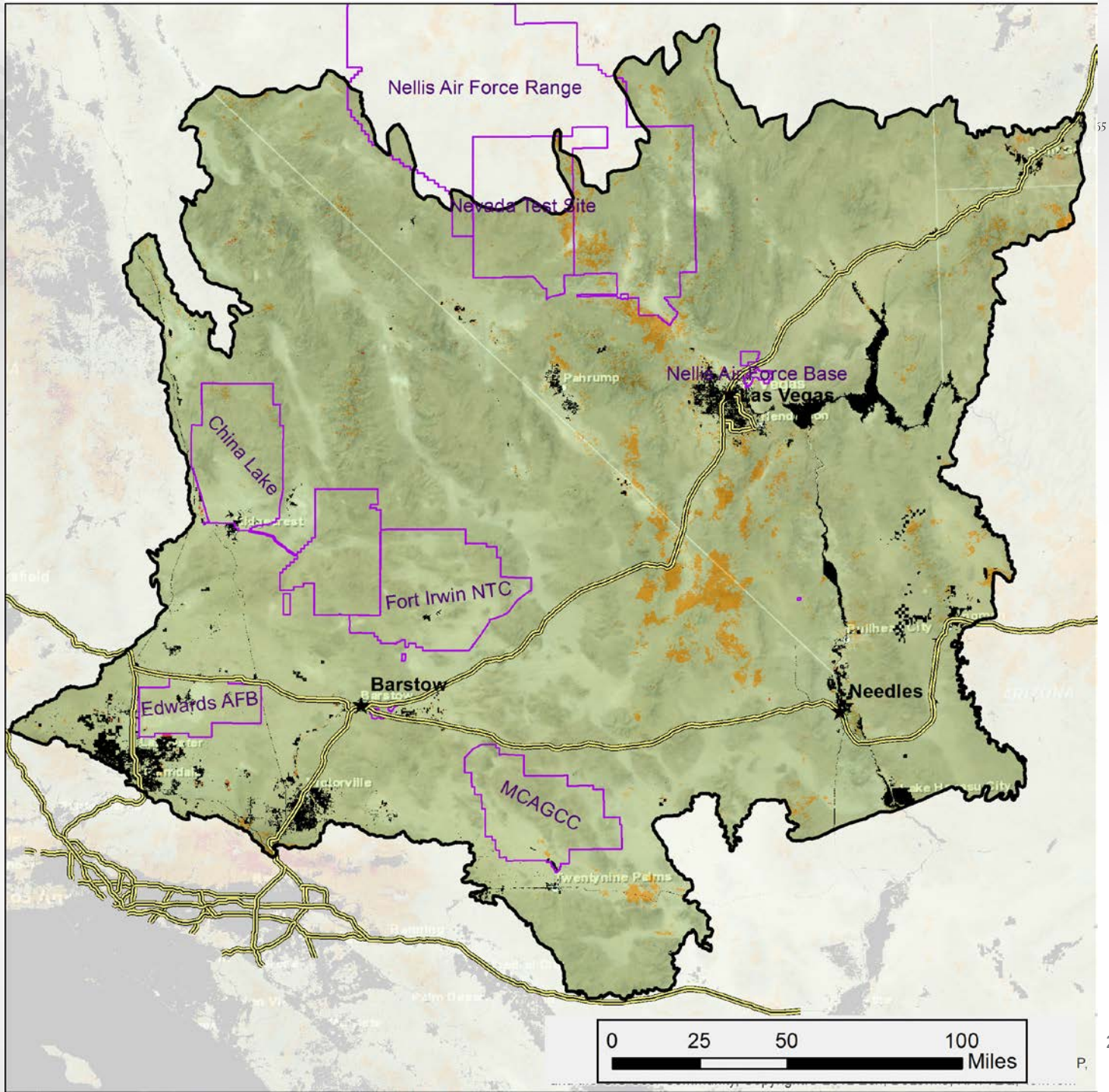
2009

2010

2011

2012

2013



Mojave Fire Management Portal linked through California Fire Science Consortium

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Information
(Handbook & Publications)

Web Portal

Project Products/ Information

Data Access
Collaboration
Customization
Visualization
Prediction

Web GIS

Dynamic Data and Maps

Dynamic Satellite Data

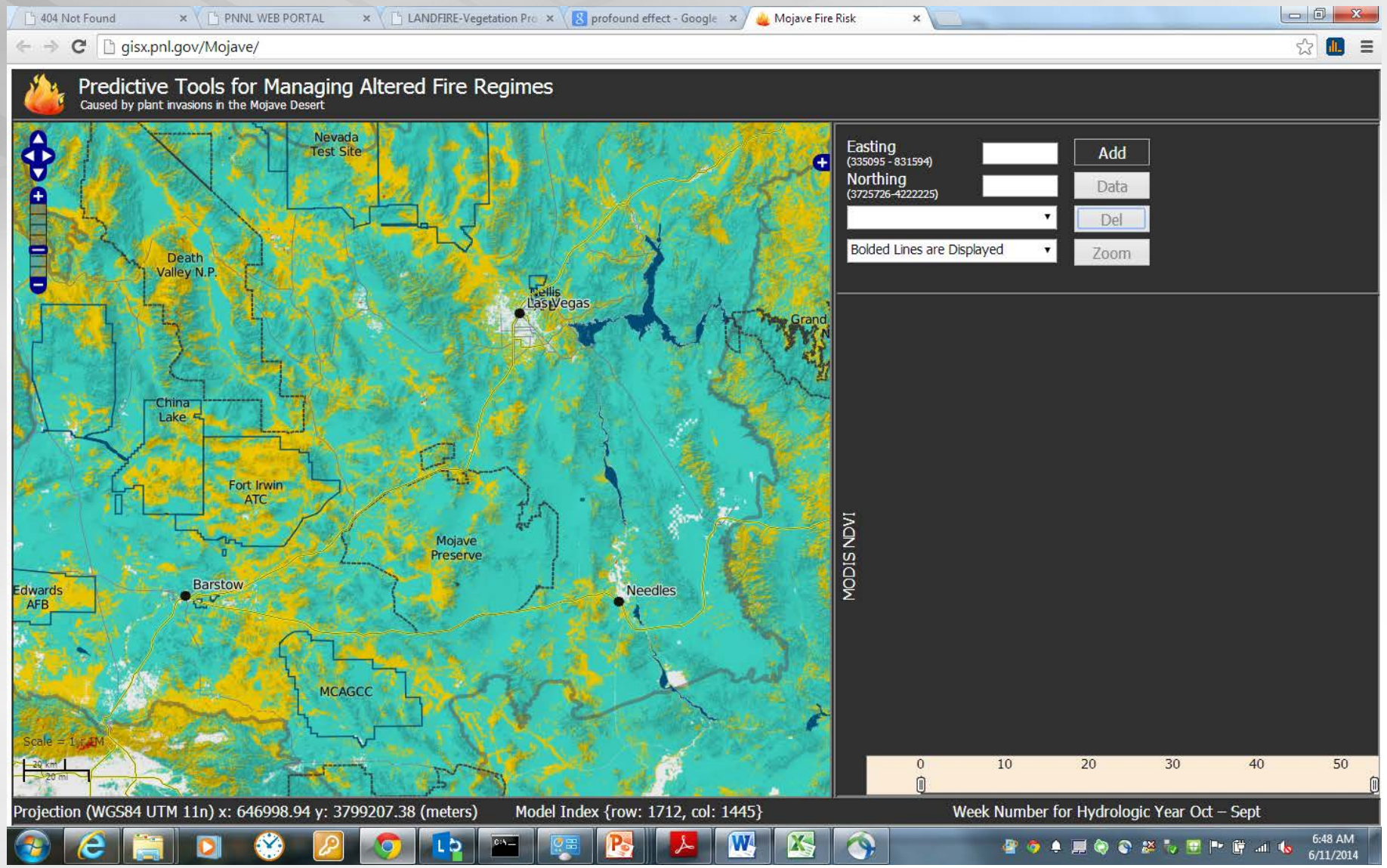
Models

Hazard Maps

Phenology

Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by Battelle *Since 1965*

http://gisx.pnl.gov/Mojave

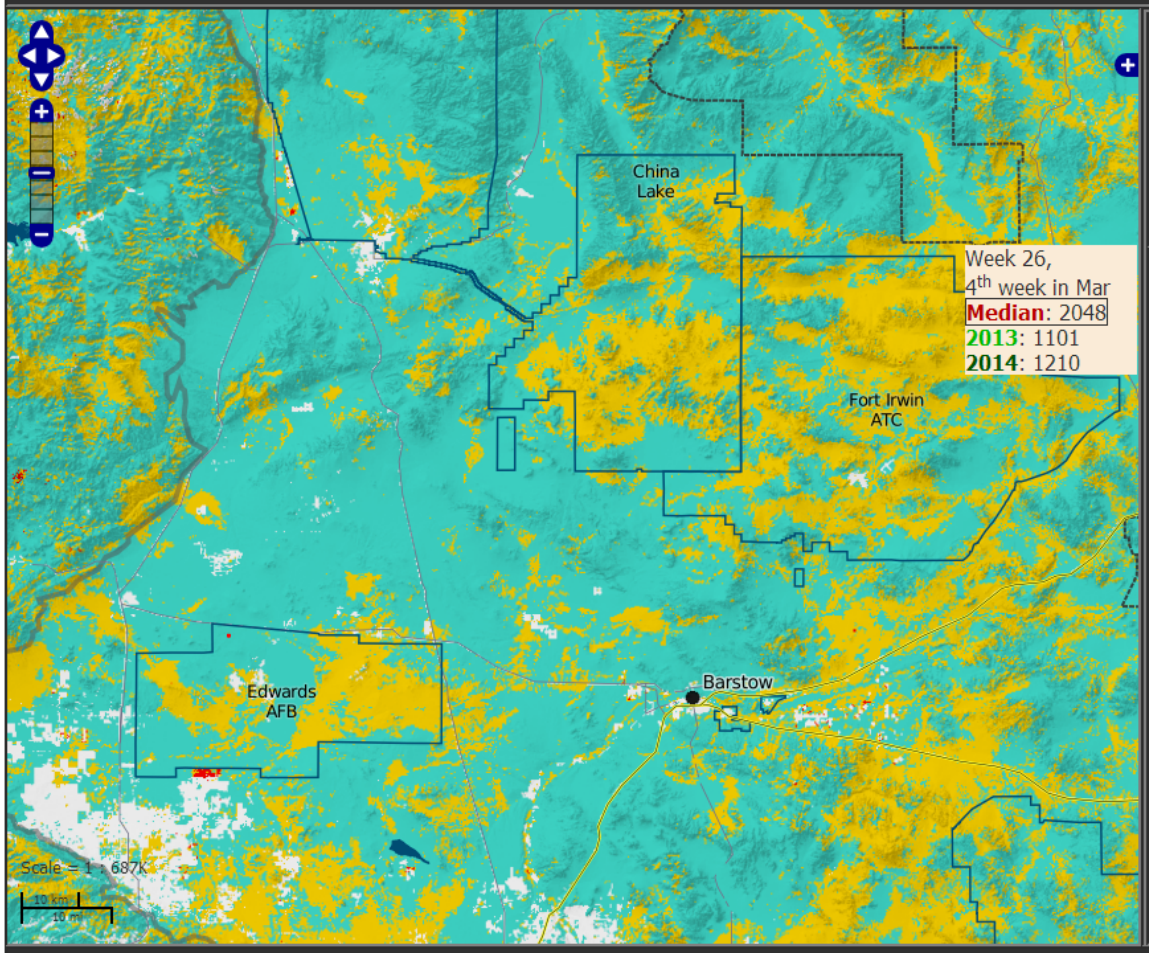


404 Not Found | PNNL WEB PORTAL | LANDFIRE-Vegetation Pro | profound effect - Google | Mojave Fire Risk

gisx.pnl.gov/Mojave/

Predictive Tools for Managing Altered Fire Regimes

Caused by plant invasions in the Mojave Desert



Easting (335095 - 831594)

Northing (3725726-4222225)

Add

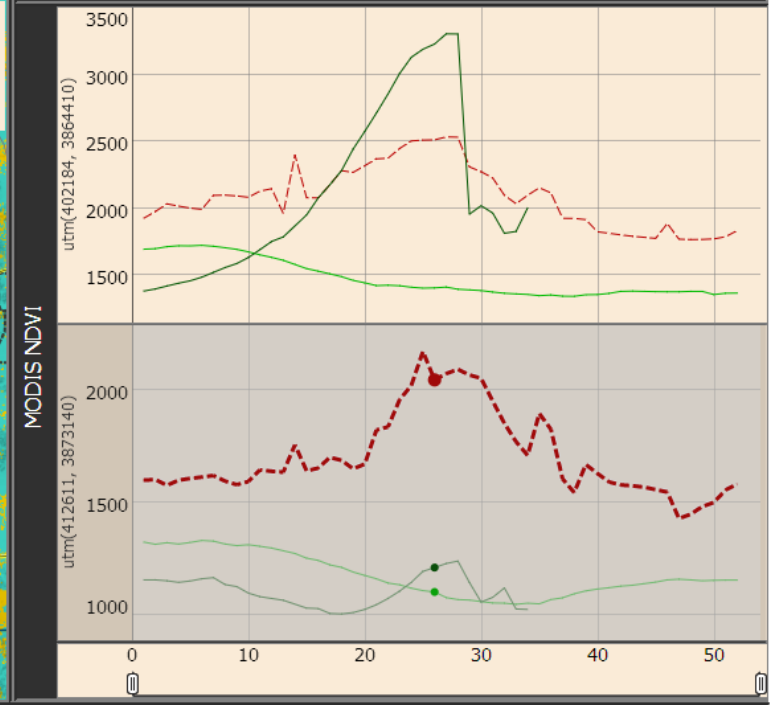
Data

Del

Zoom

utm(412611, 3873140)

Bolded Lines are Displayed



Projection (WGS84 UTM 11n) x: 411883.82 y: 3859559.56 (meters)

Model Index {row: 1470, col: 505}

Week Number for Hydrologic Year Oct – Sept

6:49 AM
6/11/2014