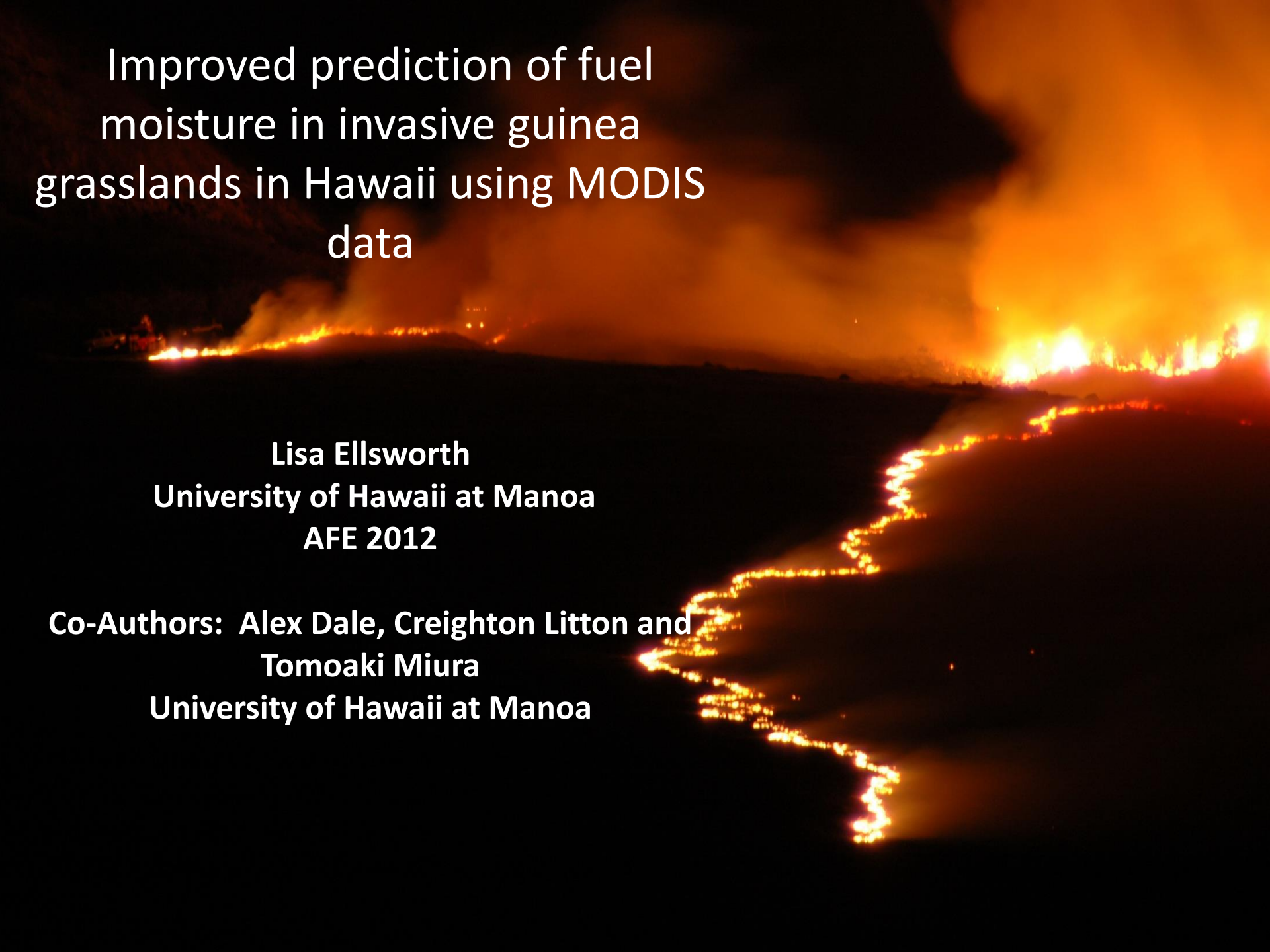
Improved prediction of fuel moisture in invasive guinea grasslands in Hawaii using MODIS data



Lisa Ellsworth
University of Hawaii at Manoa
AFE 2012

Co-Authors: Alex Dale, Creighton Litton and Tomoaki Miura
University of Hawaii at Manoa

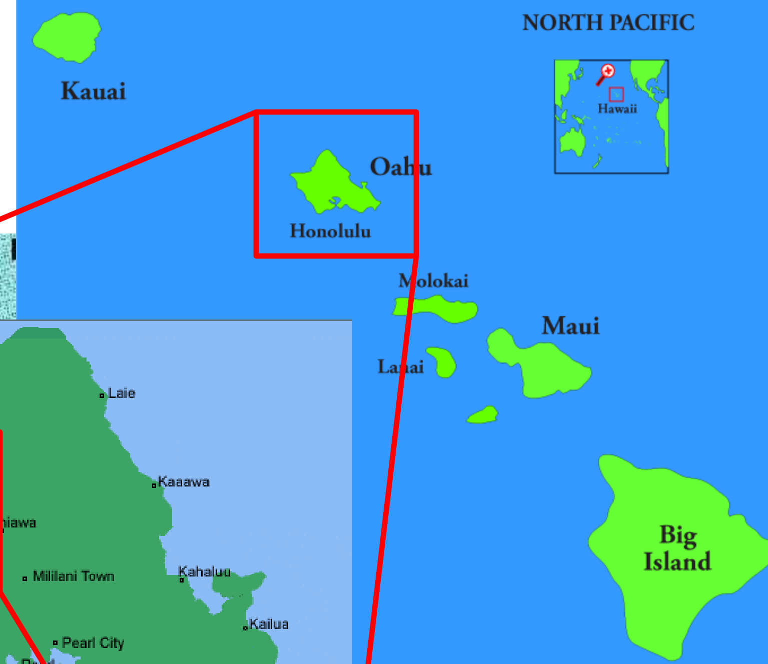
Background: Fire in Hawaii

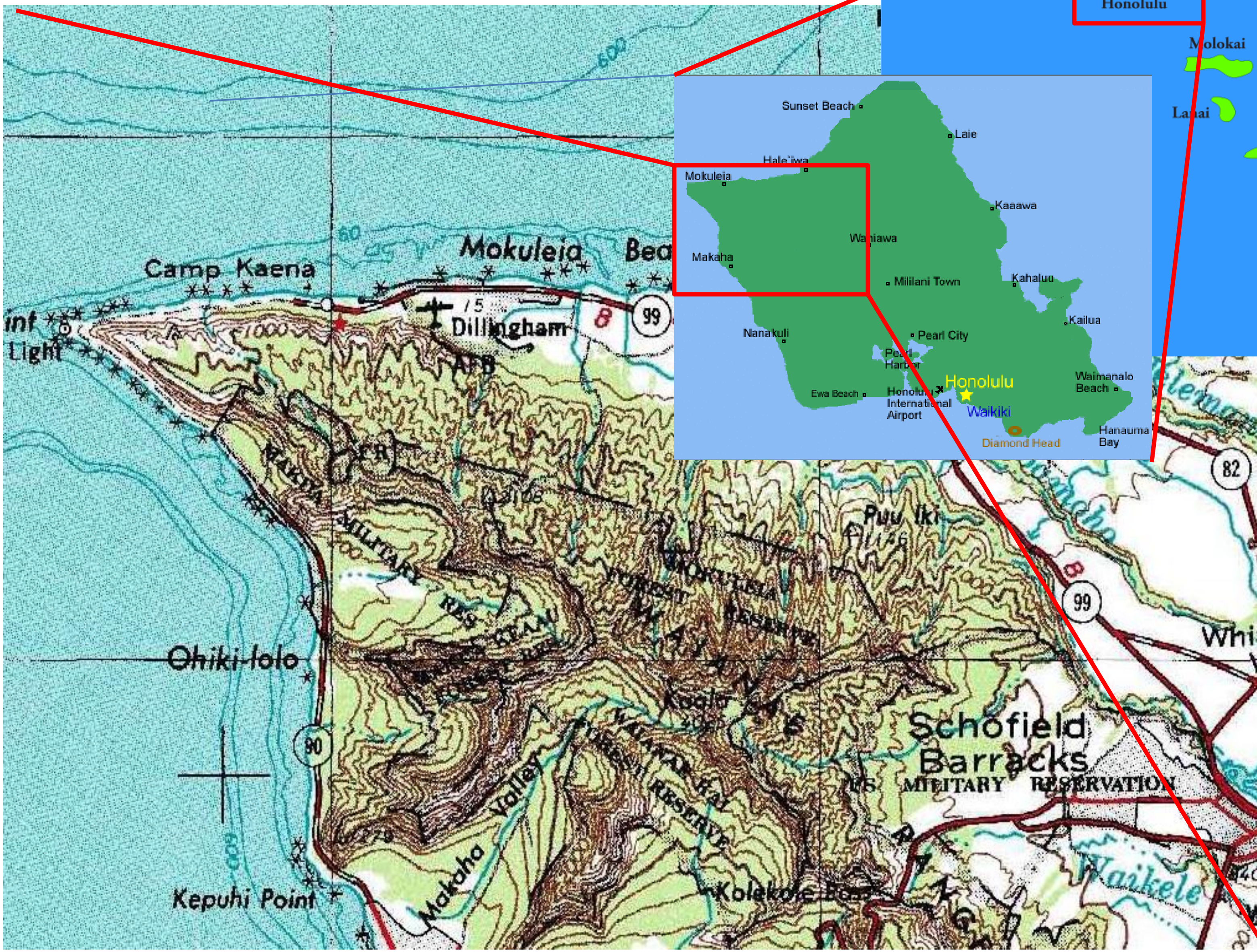
Background: Fire in Hawaii

- Native dry forests in Hawaii have largely been replaced by flammable, non-native invasive grasses

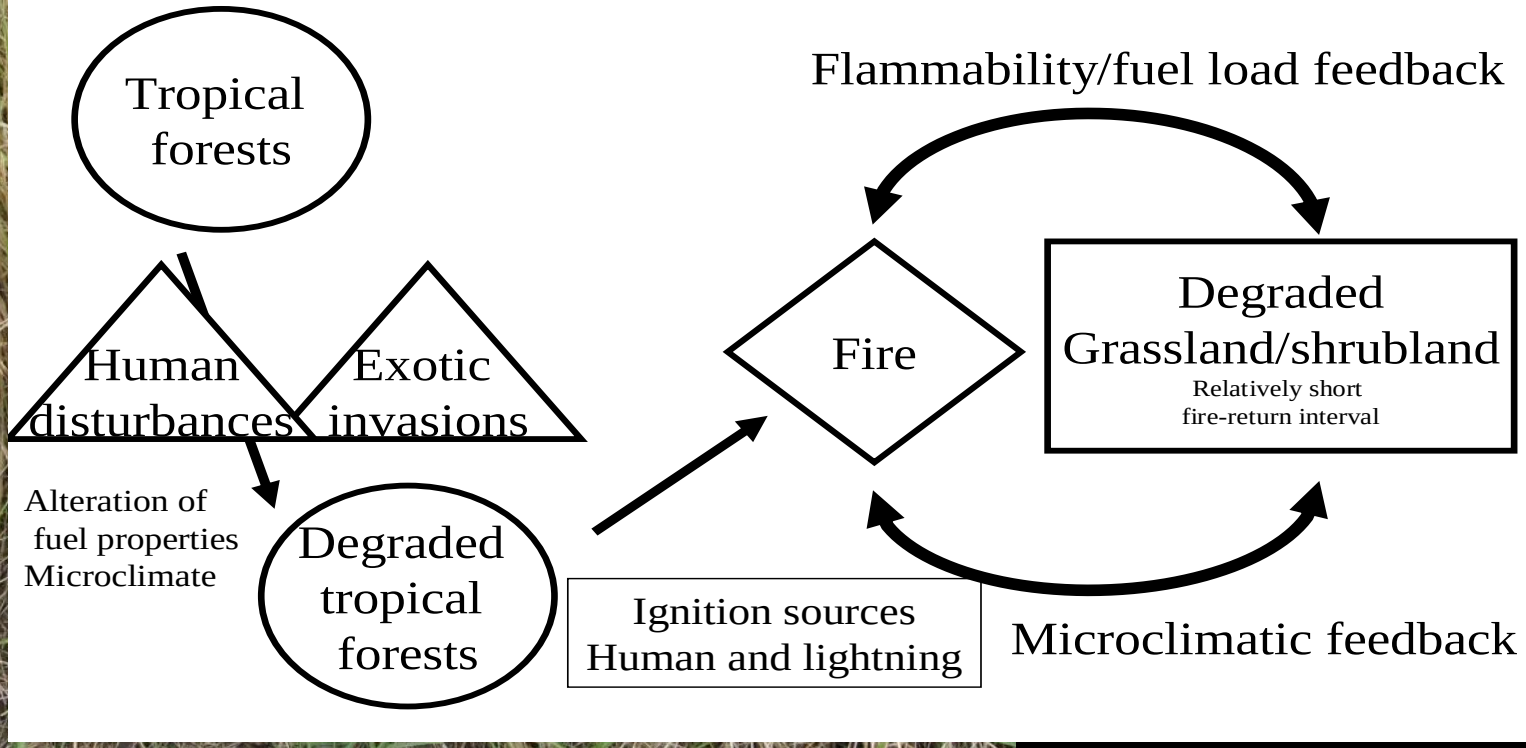
- Wildfires in Hawaii are primarily started by humans
  - Arson
  - Roadside
  - Military Training Activities
  - Escaped Prescribed Fires

NW Oahu


NORTH PACIFIC
Hawaii
Kauai
Oahu
Honolulu
Molokai
Maui
Lanai
Big Island


Sunset Beach
Laie
Hale`iwa
Mokuleia
Kaaawa
Wahiawa
Makaha
Mililani Town
Kahaluu
Kailua
Nanakuli
Pearl City
Pearl Harbor
Honolulu
Waimanalo Beach
Ewa Beach
Honolulu International Airport
Waikiki
Hanauma Bay
Diamond Head
Camp Kaena
Mokuleia
Dillingham
AFB
Light
Ohiki-lolo
Kepuhi Point
Makaha
Puu Iki
Schofield Barracks
US MILITARY RESERVATION
Kolekole Pass
Waikele
99
82
90

Background: Invasive Grass/Wildfire Cycle



D'Antonio and Vitousek 1992

Background: Fire in Hawaii

~2200 acres burned (June 2012)

Land Conversion

Makua Valley mid -1970's

Land Conversion

Makua Valley 2003 – following escaped Rx burn

Land Conversion

Background: Guinea Grass (*Megathyrsus maximus)*

- African in origin
- Occurs throughout the tropics and subtropics
- Nonnative and invasive in Hawaii
- Introduced for animal forage
- Naturalized in Hawaii by 1871
- High fire risk – location, fuel loads

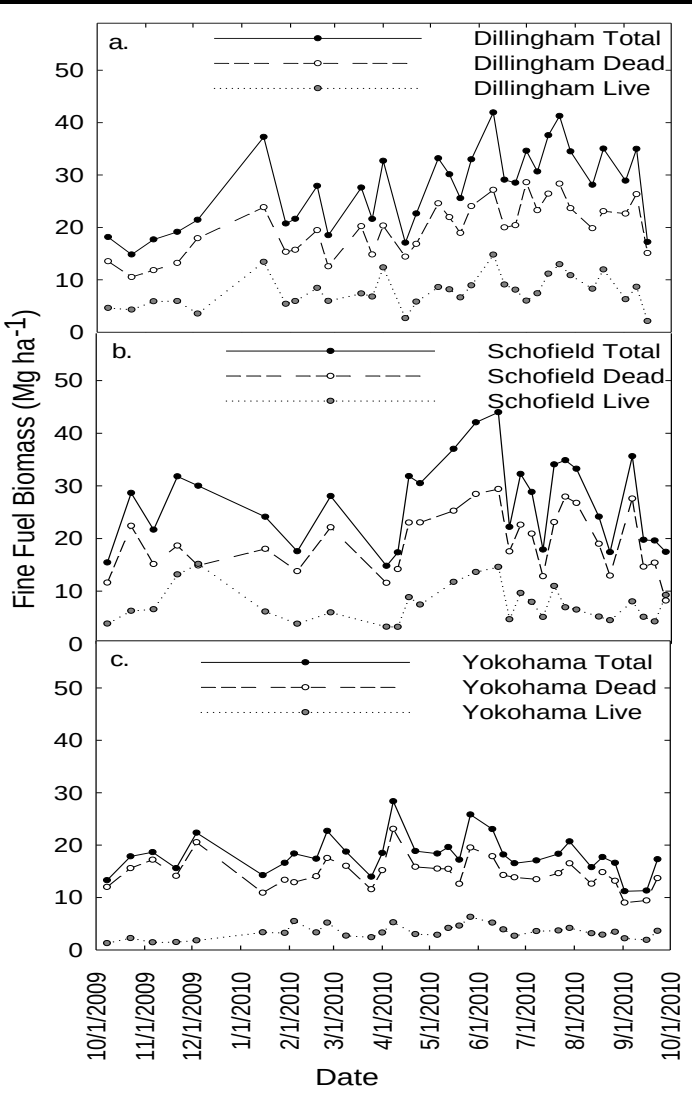
Spatial and Temporal Variability of Guinea Grass Fuels

Intraannual Variability in Fuel Loads

Dead Fuel > Live Fuel

Highest fuel loads in the late spring and early summer

Lots of variability between sampling dates



Ellsworth, L.M., C.M. Litton, A.D. Taylor and J.B. Kauffman. 2012. Spatial and temporal variability in *Megathyrsus maximus* grasslands on Oahu, Hawaii. *In review: International Journal of Wildland Fire.*

Spatial and Temporal Variability of Guinea Grass Fuels

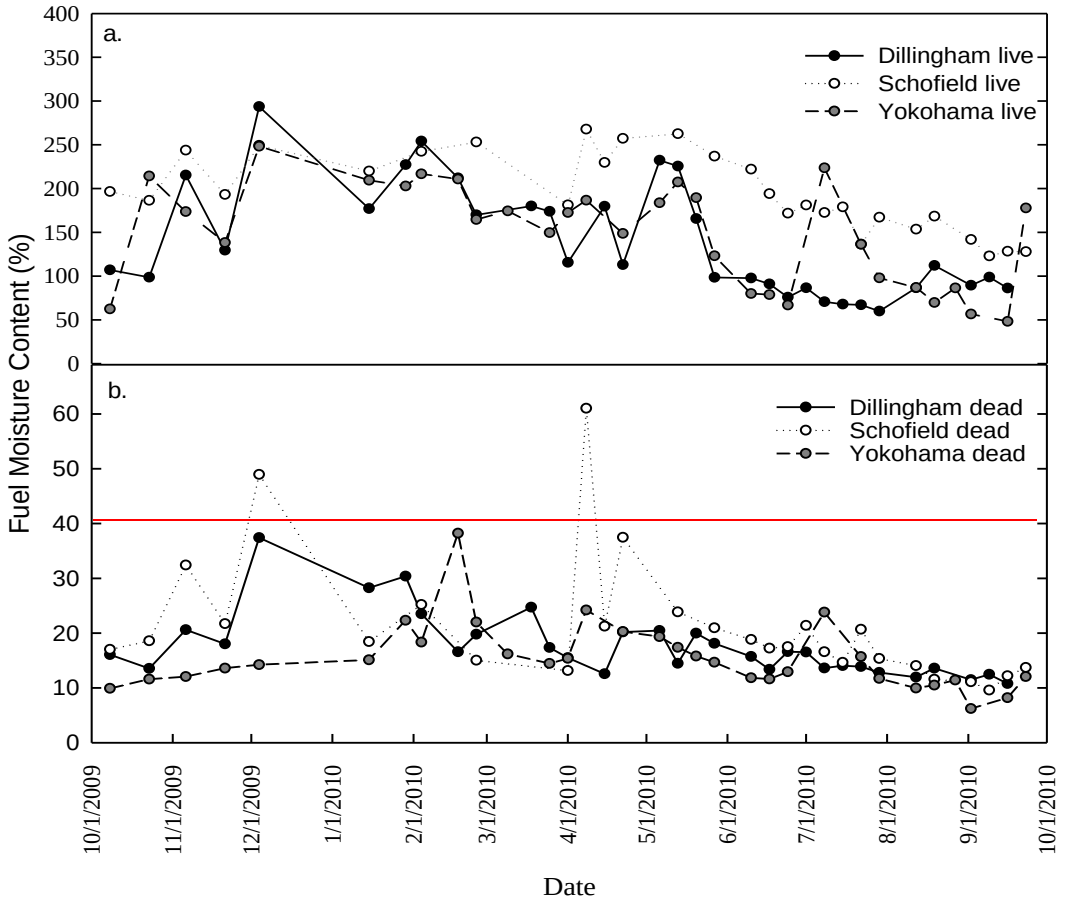
Intraannual Variability in Fine Fuel Moisture

Rapid changes between sampling dates

Lowest live and dead fuel moistures in summer and fall

Dead fuel moisture almost always below the moisture of extinction

Lots of variability - driven by weather?



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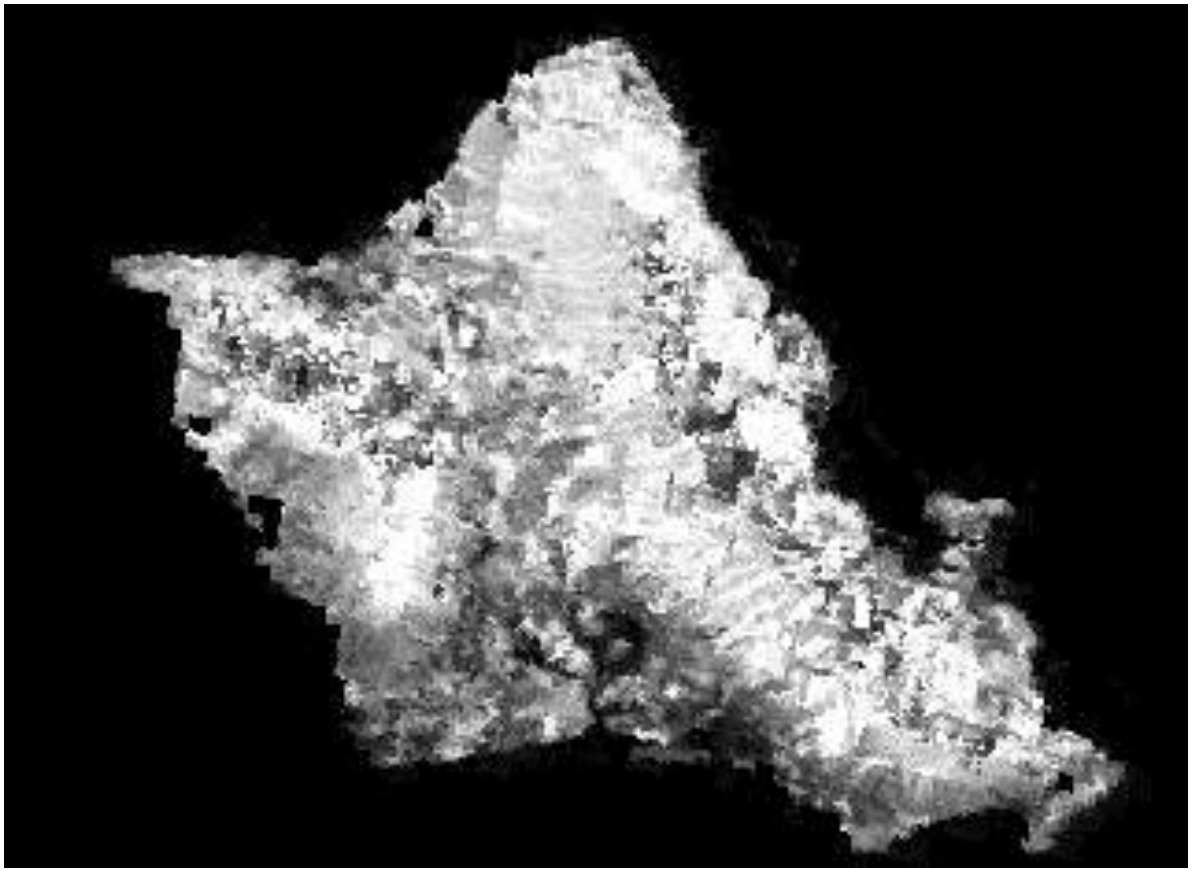
Fuel moisture modeling using (MODIS) data

Fuel Moisture

- Important driver of fire behavior
- Fuel moisture work and time intensive to measure *in situ*
- Weather station fuel moisture prediction system (intermediate in NFDRS) not always accurate in these grasslands
- May be useful for managers to be able to use remotely sensed data to estimate fuel moisture

Ellsworth, L.M., A.P. Dale, C.M. Litton, and T. Miura. 2012. Improved prediction of live and dead fuel moisture in invasive *Megathyrsus maximus* grasslands in Hawaii using Moderate Resolution Imaging Spectroradiometer (MODIS) data. *In prep for Remote Sensing of Environment*.

Fuel moisture modeling using (MODIS) data



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Fuel moisture modeling using (MODIS) data

Vegetation indices

- Derived from satellite data
- Good indices of canopy greenness
  - chlorophylls *a* and *b* in green vegetation strongly absorb light in the red regions of the electromagnetic spectrum,
  - plant cell walls strongly absorb light in the near infrared region

$$NDVI = \frac{\rho_{NIR} - \rho_{red}}{\rho_{NIR} + \rho_{red}}$$

$$EVI = G \frac{\rho_{NIR} - \rho_{red}}{\rho_{NIR} + C_1 \rho_{red} - C_2 \rho_{blue} + L}$$

$$EVI2 = G \frac{\rho_{NIR} - \rho_{red}}{\rho_{NIR} + 2.4 \rho_{red} + L}$$

Ellsworth, L.M., A.P. Dale, C.M. Litton, and T. Miura. 2012. Improved prediction of live and dead fuel moisture in invasive *Megathyrsus maximus* grasslands in Hawaii using Moderate Resolution Imaging Spectroradiometer (MODIS) data. *In prep for Remote Sensing of Environment*.

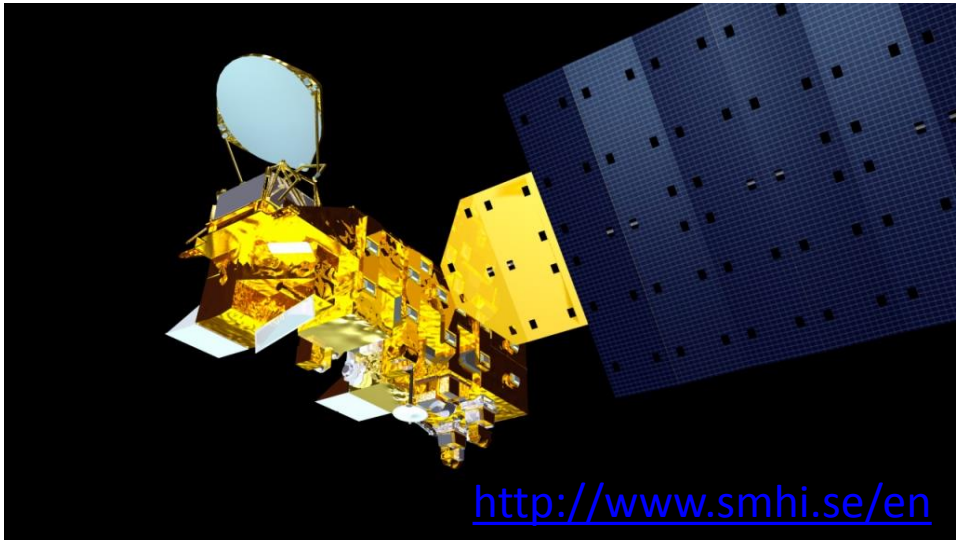
Fuel moisture modeling using (MODIS) data

Moderate Resolution Imaging Spectroradiometer (MODIS) data

Many satellites – tradeoffs between spatial and temporal resolution

MODIS: Daily Images
250 m pixel size

LANDSAT: 1 image every 16-18 days
30 m pixel size



Fuel moisture can change rapidly, and guinea grasslands cover large areas

MODIS data is free – Accessible for land managers

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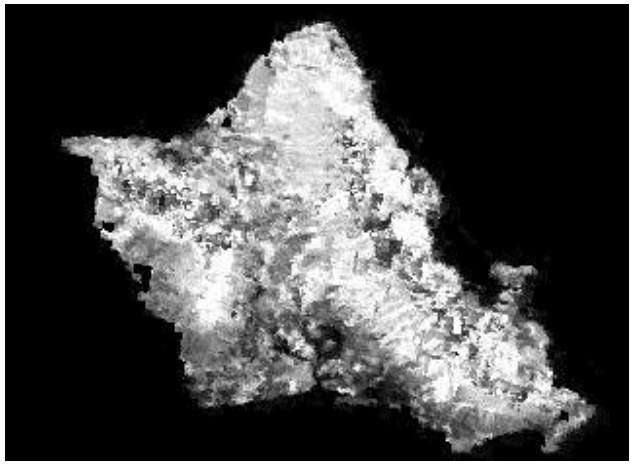
Fuel moisture modeling using (MODIS) data

Moderate Resolution Imaging Spectroradiometer (MODIS) data

Downloadable Products:

NASA Earth Observing System Data and Information System (http://reverb.echo.nasa.gov/reverb/)

1. Daily images
2. 8-day Composite Images – best pixel in an 8 day range
   - Loss of some temporal resolution
   - Potentially gain some accuracy – noise is filtered out
3. 16-day Vegetation Index products (EVI, NDVI, EVI2)
   1. Pre-processed data
   2. Greater loss of temporal Resolution



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Fuel moisture modeling using (MODIS) data

Objective:
Evaluate the use of vegetation indices derived from remotely sensed MODIS data to accurately predict live and dead fuel moistures in guinea grass dominated vegetation

Hypotheses:

- Because vegetation indices are a good indicator of vegetation greenness, there will be strong relationships between vegetation indices derived from MODIS imagery and *in situ* live fuel moisture content

- Since EVI performs well in areas of high biomass (Jensen 2007), it will be a stronger predictor of fuel moisture than other vegetation indices given the dense grass cover present at the study sites

- Daily MODIS data will show stronger predictive relationships with *in situ* fuel moisture than 8-day or 16-day composites

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Fuel moisture modeling using (MODIS) data

Methods:

- Used *in situ* live and dead fuel moisture measured at 4 sites biweekly for one year (October 2009-October 2010)
- Obtained corresponding Daily, 8-day composite, and 16-day vegetation index composite data
  - 8 different indices
- Obtained weather station fuel moisture predictions (WIMS data) and KDBI

Built empirical predictive models for live and dead fuel moisture based on the strongest predictors

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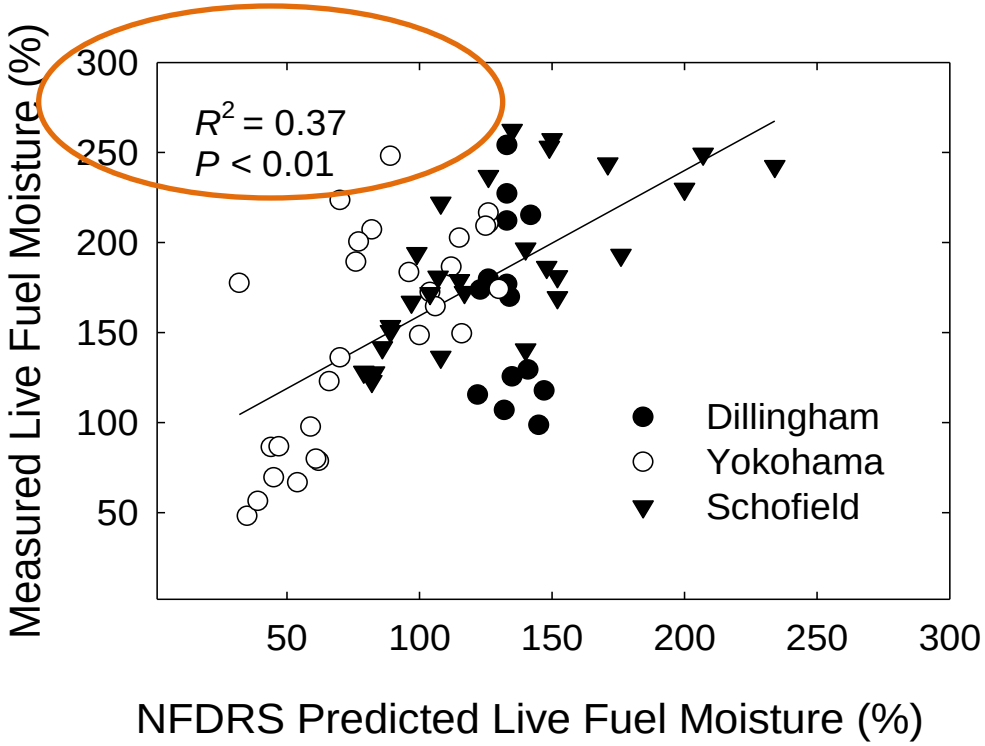
Fuel moisture modeling using (MODIS) data

Live Fuel Moisture –
Weather Station Predictions



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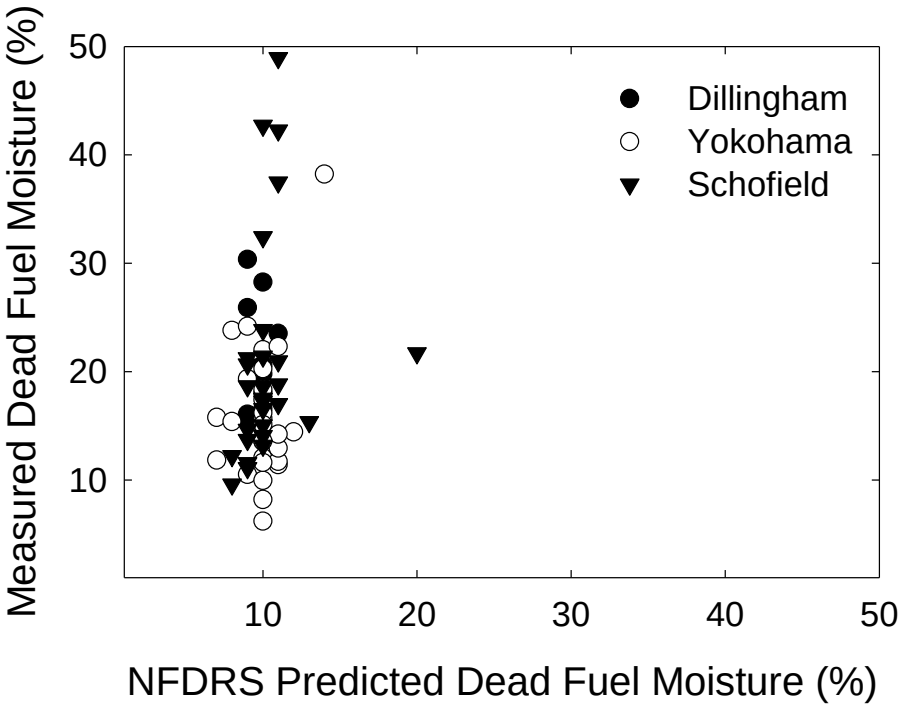
Fuel moisture modeling using (MODIS) data

Dead Fuel Moisture –
Weather Station Predictions



No Relationship with Dead Fuel Moisture!!!

BUT…….Dead fuel moisture changes on much more rapid temporal scales

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Fuel moisture modeling using (MODIS) data

	Live		Dead	
	r	P-value	r	P-value
Single day images				
EVI_1	**0.338**	**0.001**	0.170	0.093
NDVI_1	0.088	0.368	-0.015	0.875
EVI2_1	0.081	0.410	0.033	0.733
VARI_1	0.165	0.100	0.075	0.456
NDWI_1	-0.026	0.787	0.045	0.642
NDII_1	0.037	0.704	0.186	0.056
RGRE_1	0.055	0.576	0.045	0.643
Integral_1	0.105	0.282	0.142	0.144

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Fuel moisture modeling using (MODIS) data

	Live		Dead	
	r	P-value	r	P-value
8 day composites				
EVI_8	**0.399**	**0.000**	**0.333**	**0.000**
NDVI_8	**0.347**	**0.000**	**0.309**	**0.001**
EVI2_8	**0.328**	**0.000**	**0.379**	**0.000**
VARI_8	0.098	0.307	0.028	0.770
NDWI_8	0.020	0.837	0.120	0.211
NDII_8	0.139	0.144	**0.220**	**0.020**
RGRE_8	**0.274**	**0.003**	0.140	0.139
Integral_8	-0.101	0.287	-0.051	0.590

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Fuel moisture modeling using (MODIS) data

	Live		Dead	
	r	P-value	r	P-value
16 day MODIS products				
EVI_16	**0.364**	**0.001**	**0.423**	**0.000**
NDVI_16	**0.462**	**0.000**	**0.362**	**0.001**
EVI2_16	**0.449**	**0.000**	**0.450**	**0.000**
RGRE_16	**0.398**	**0.000**	0.049	0.663

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Fuel moisture modeling using (MODIS) data

Model Selection:

Used Vegetation Indices that significantly correlated with fuel moisture to build predictive model

- Daily
- 8-day
- 16-day

Looked at models created with weather station-derived predictors

- NFDRS Moisture Calculation
- KDBI – drought index

Hybrid Models – Using elements from remote sensing and weather stations

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Fuel moisture modeling using (MODIS) data

Live Fuel Moisture Predictive Models

	Model	R^2	Pred R^2	P
MODIS-based models				
1-day	LFM= 124 + 135 EVI_1	0.15	0.00	<0.001
8-day	LFM= 91.1 + 171 EVI_8 + 78.4 NDVI_8	0.20	0.15	<0.001
16-day	**LFM=2.1 + 402 EVI2_16 + 144 NDVI_16**	**0.46**	**0.40**	**<0.001**
WIMS-based models				
NFDRS	LFM = 78.7 + 0.807 NFDRS	0.37	0.33	<0.001
KBDI	LFM = 191 - 0.0624 KBDI	0.06	0.01	0.050
Hybrid models				
1-day	LFM = 101 + 67.6 EVI_1 + 0.654 NFDRS - 0.0652 KBDI	0.46	0.37	<0.001
8-day	**LFM = 91.2 + 7.77 EVI_8 + 0.735 NFDRS - 0.0524 KBDI**	**0.49**	**0.41**	**<0.001**

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Fuel moisture modeling using (MODIS) data

Dead Fuel Moisture Predictive Models

	Model	R^2	Pred R^2	*P*
MODIS-based models				
1-day	DFM = 16.0 + 8.61 EVI_1	0.00	0.00	0.082
8-day	DFM = 10.5 + 16.7 EVI_8 + NDVI_8	0.14	0.06	0.001
16-day	**DFM = 5.55 + 39.3 EVI2_16 + 10.9 NDVI_16**	**0.19**	**0.12**	**0.002**
WIMS-based models				
NFDRS	DFM = 7.62 + 1.12 NFDRS	0.05	0.00	0.066
KBDI	DFM = 19.9 - 0.00355 KBDI	0.01	0.00	0.477
Hybrid models				
1-day	DFM = 8.53 + 4.93 EVI_1 - 0.00807 KBDI + 1.11 NFDRS	0.13	0.00	0.116
8-day	DFM = 4.34 + 20.8 EVI_8 + 0.945 NFDRS	0.14	0.00	0.010
16-day	DFM = 0.79 + 56.2 EVI2_16 + 0.577 NFDRS	0.19	0.00	0.026

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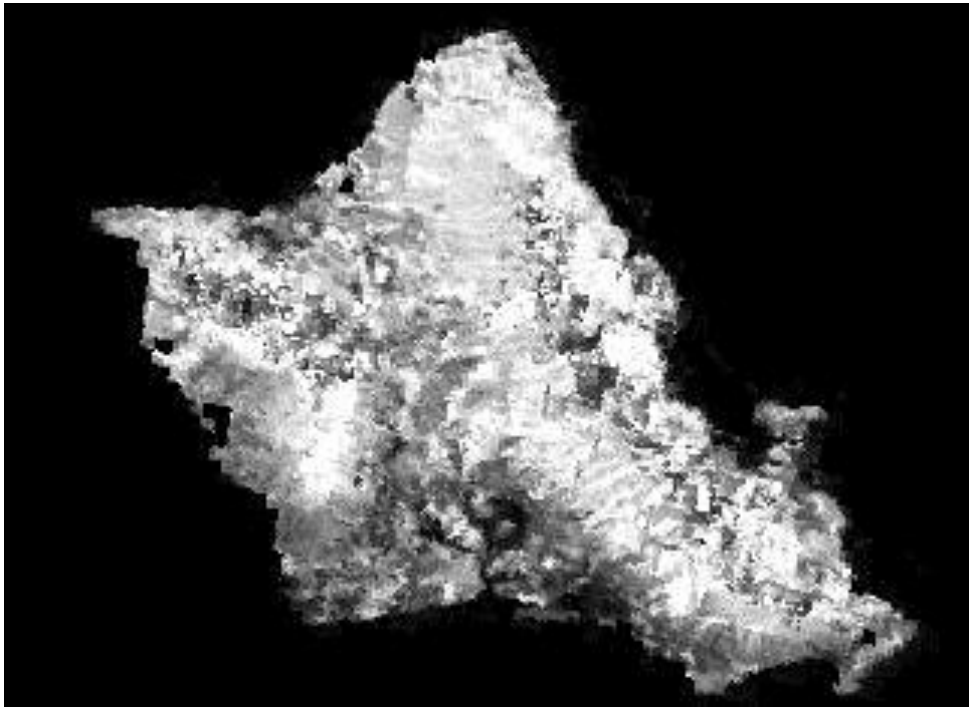
Fuel moisture modeling using (MODIS) data

Caveats:

Fuel moisture changes much faster than these methods predict!

- Moving average
- Not a substitute for on the ground fire expertise
  - ✓ Wind patterns
  - ✓ Precipitation (or lack thereof)



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Fuel moisture modeling using (MODIS) data

MODIS-based vegetation indices may improve prediction of *in situ* fuel moisture content as compared to the currently used WIMS-based models….which in turn may improve prediction of potential fire

Added benefits:

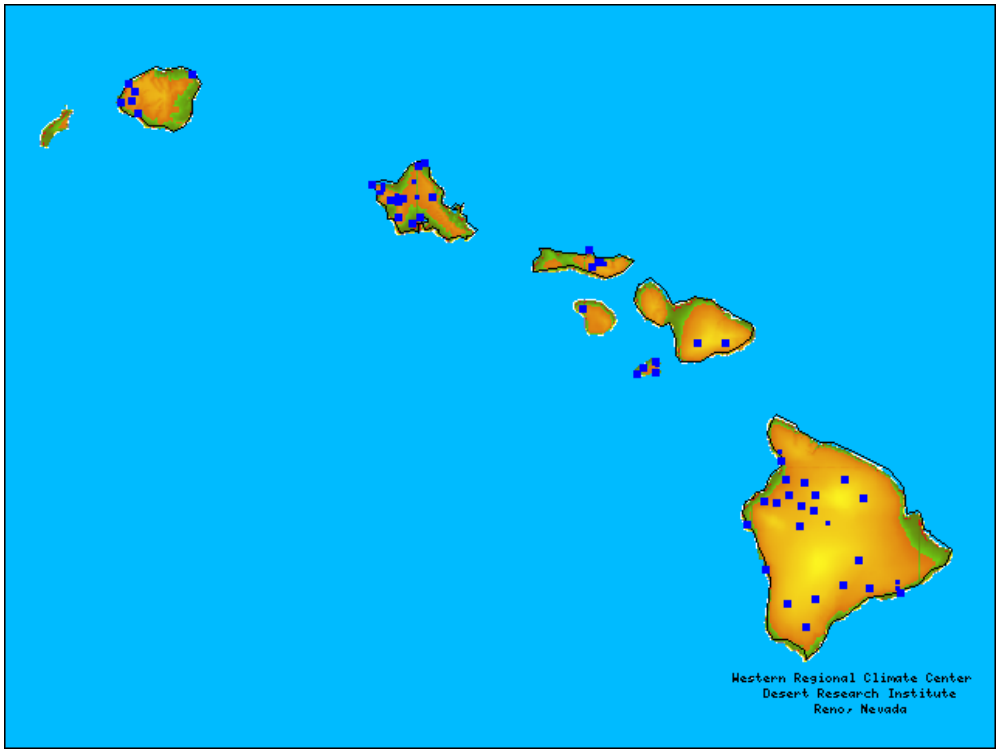
- Continuous spatial coverage
- Reliable data source

16 day products were in best models

- Pre-processed
- More accessible for managers

Next Steps

- Interface for manager access



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Thanks!

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Questions?

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