Prescribed Burning and Smoke Management Planning Tools – Flint Hills Case Study

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EPA Tools & Resources Webinar

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Outline

1. Background: Flint Hills tallgrass prairie and prescribed burning
2. Multi-model framework for assessing impacts of prescribed fires
3. VELMA model & calibration for the 35 km^2 Konza Prairie Biological Station
4. Extrapolate VELMA Konza to estimate fuel loads for the 25,000 km^2 Flint Hills
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6. Conclusions
7. VELMA-BlueSky transferability & learning resources

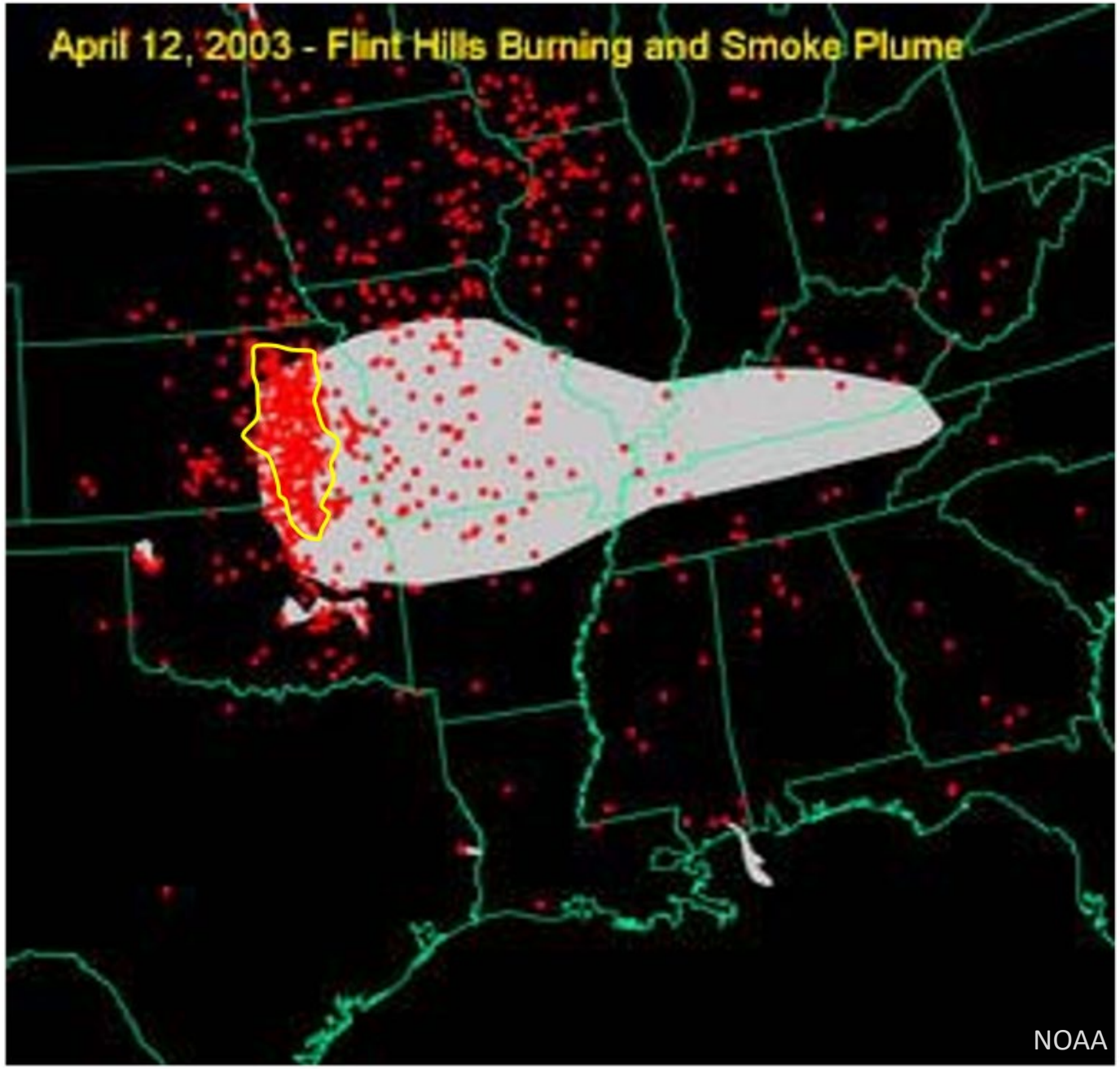
The Last Expanse of the Tall Grass Prairie

Composite Slide: Gina Grier

Prescribed fires in the Flint Hills Ecoregion of Kansas

Image source unknown

Flint Hills rangeland prescribed fires (red) and associated smoke plume (gray) over a 7-state area on April 12, 2003.
(NOAA-analyzed satellite image)



Prescribed Rangeland Fires:

What are the ecological and air quality tradeoffs?

Fires increase rangeland productivity…

prevent woody invasion…

and promote biodiversity

but, are a source of particulates and ozone

Composite: RB McKane

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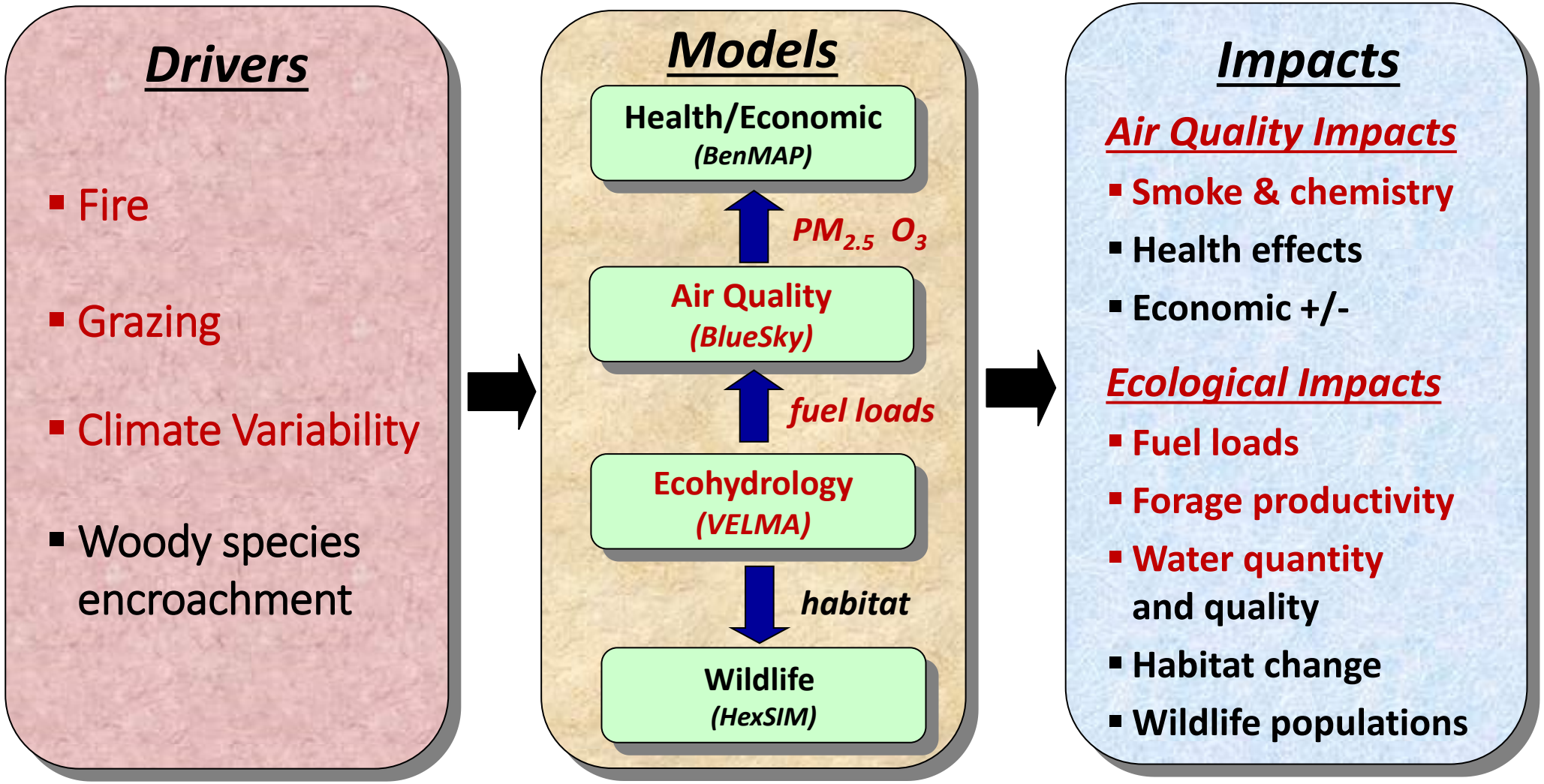
Multi-Model Framework for Assessing Impacts of Prescribed & Wildfires

Red type = Konza-Flint Hills project



Composite: RB McKane

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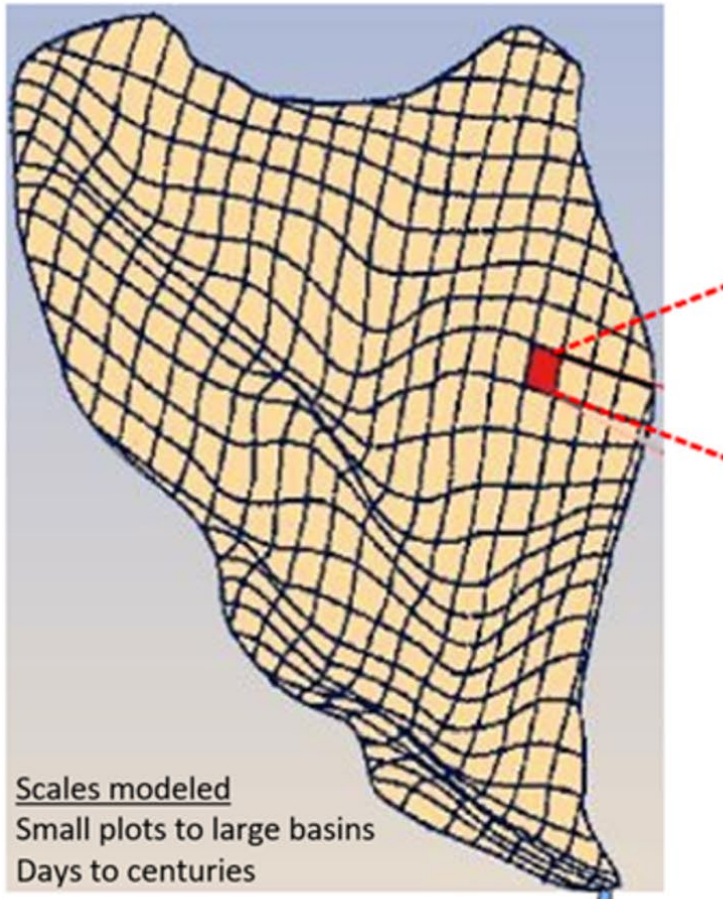
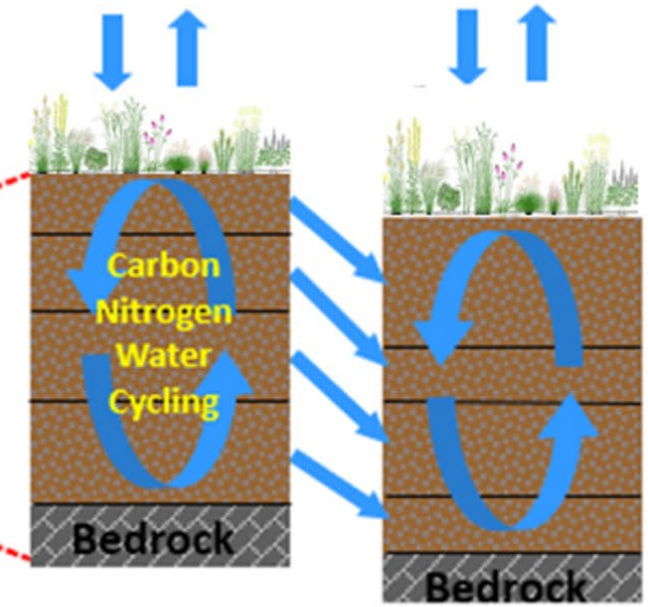
VELMA: **V**isualizing **E**cosystem **L**and **M**anagement **A**ssessments





Drivers of change

- Climate
- Land cover
- Land use (ag, forest, urban…)
- Nutrients & contaminants
- Fire

Modeled Ecosystem Goods & Services

- *Water quality regulation* *(nutrients, contaminants, temperature)*
- *Water quantity regulation* *(peak & low flows, landscape aridity)*
- *Habitat for fish and wildlife* *(salmon, prairie chickens…)*
- *Soil fertility & plant growth* *(biomass for food, fiber)*
- *Fuel load dynamics* *(fire risk, potential severity)*
- *Carbon sequestration* *(Greenhouse gas dynamics)*

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VELMA is transferable nationally to complex watersheds characterized by mixed land cover types and land uses

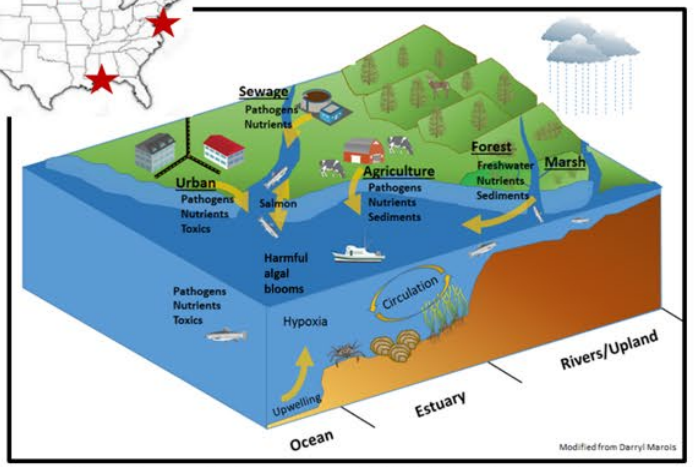
Salmon Recovery Planning
Puget Sound Basin, Oregon Coast

Urban Stormwater Green Infrastructure
Seattle, Duluth, Ohio

Agricultural Nutrient Runoff Remediation
Chesapeake Bay, MD

Wildland Fire Effects on Air & Water Quality
California, Oregon, Colorado

Smoke Management Planning
Central Plains Rangelands, KS



National Estuary WQ Restoration
Puget Sound, Tillamook Bay, Lower Columbia, Great Lakes, Mobile Bay, Chesapeake Bay

Slide: RB McKane

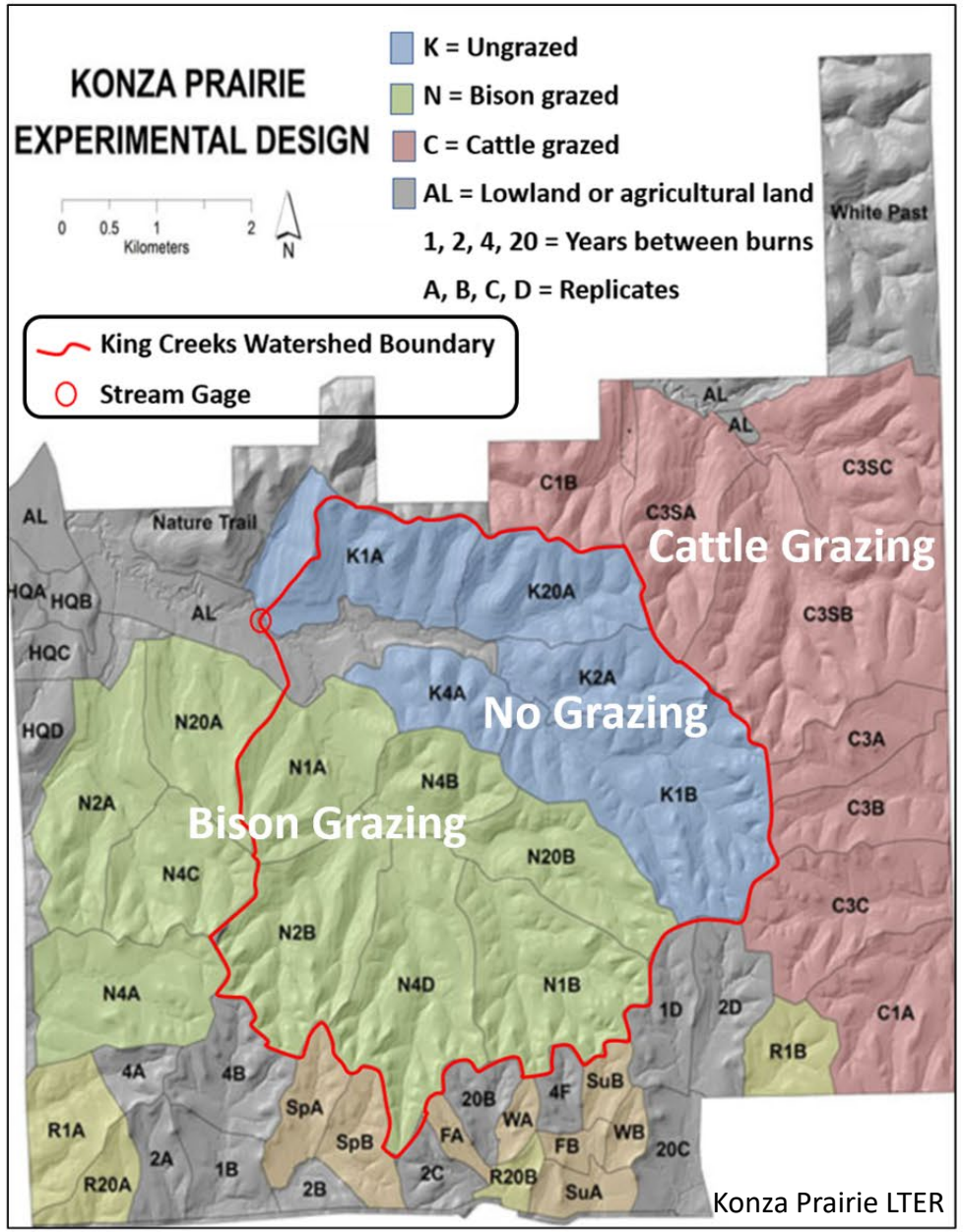
Calibration Approach –

We used VELMA to synthesize long-term experimental data collected over 4 decades at the 35 km^2 Konza Prairie Biological Station.

Together, those data describe the effects of climate, fire, grazing, topography, soil moisture, and plant-soil carbon and nitrogen dynamics on tallgrass prairie productivity and fuel loads.

VELMA's integration of these processes aimed to establish a virtual tallgrass prairie ecosystem that could be extrapolated from research plots to the 25,000 km^2 Flint Hills ecoregion.

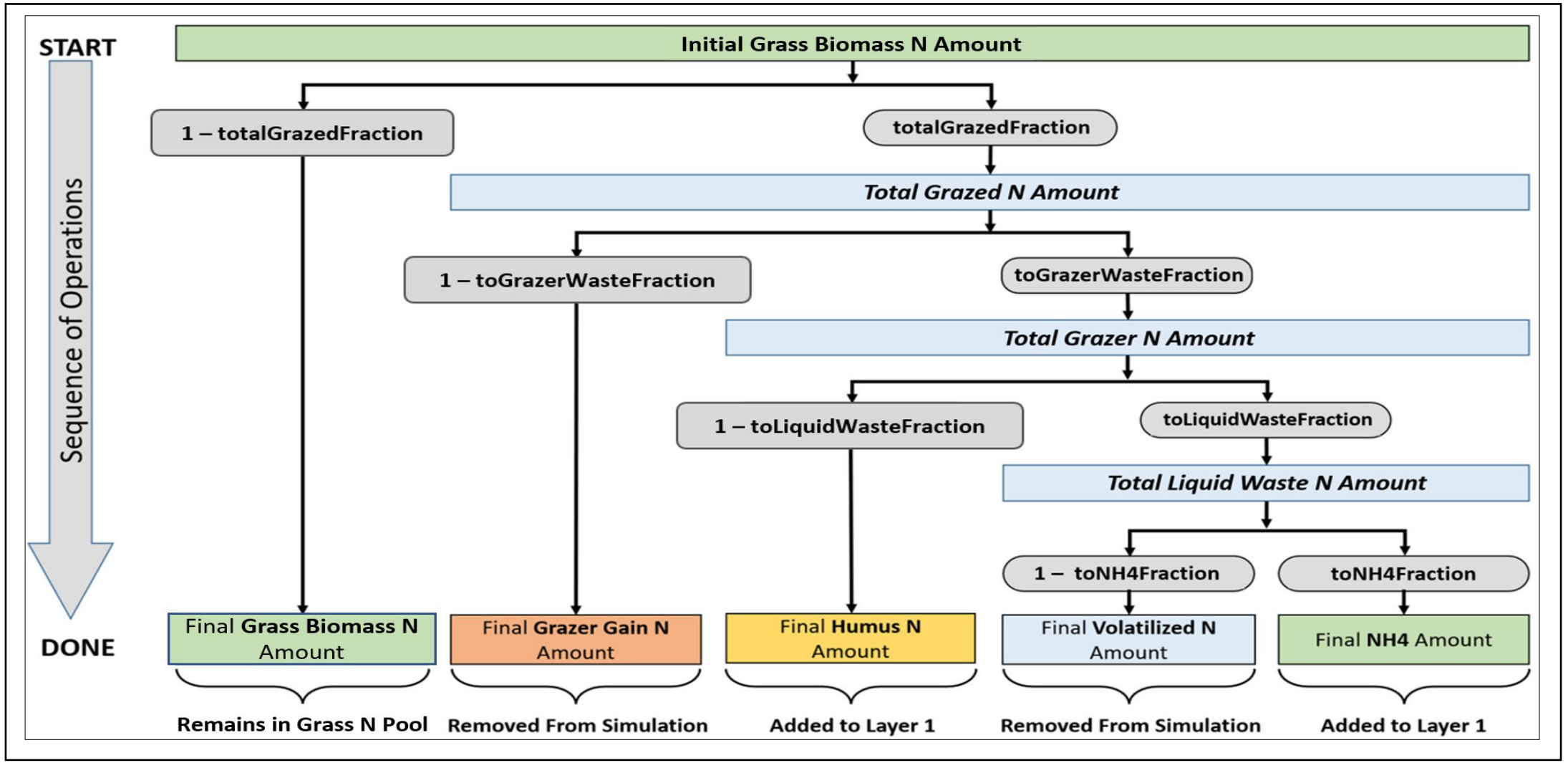
VELMA Calibration for Konza Prairie Biological Station Experiments



Calibration Step 1: VELMA grazer manure and urine nitrogen deposition submodel

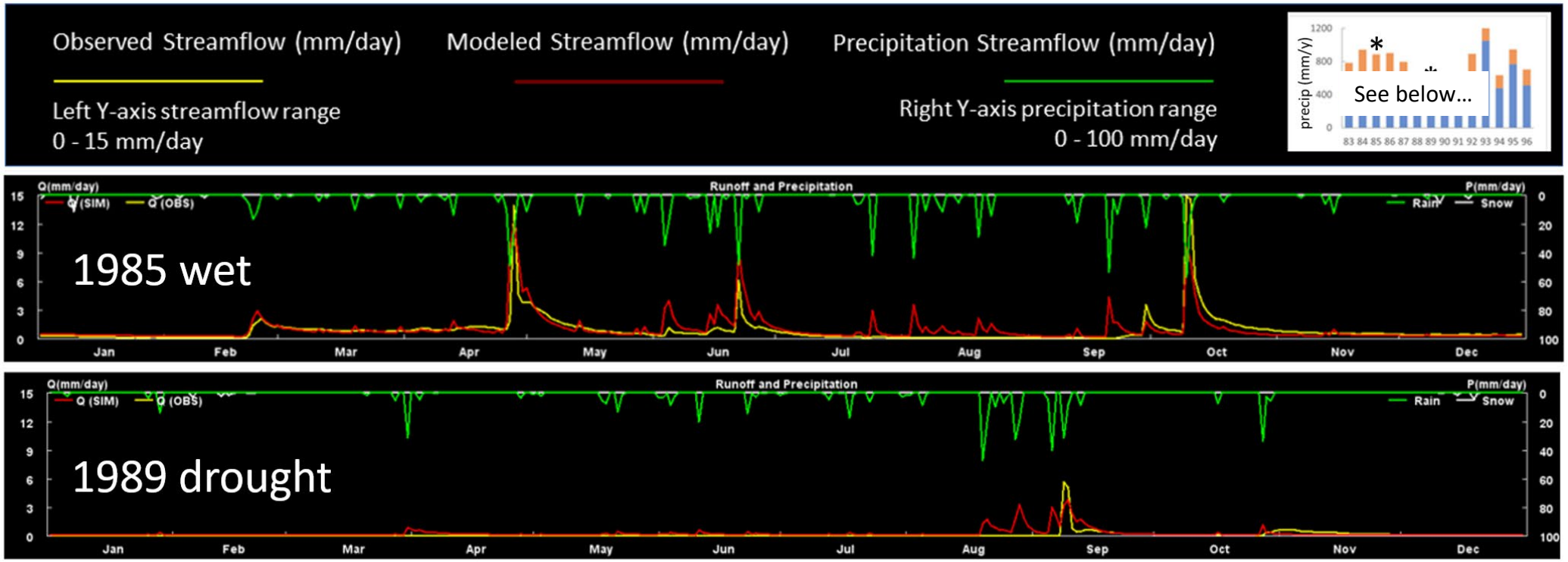
How: Published data for the grazed fraction of live plant biomass N is partitioned to cattle and bison weight gain, manure (humus N), urine N, volatilized N, and soil ammonium N.

Why: These grazer activities greatly influence the prairie nitrogen cycle and, therefore, grassland productivity.



Step 2: Calibrate VELMA streamflow to match Konza Kings Creek gage data

Why: Watershed runoff limits available soil moisture for grassland productivity



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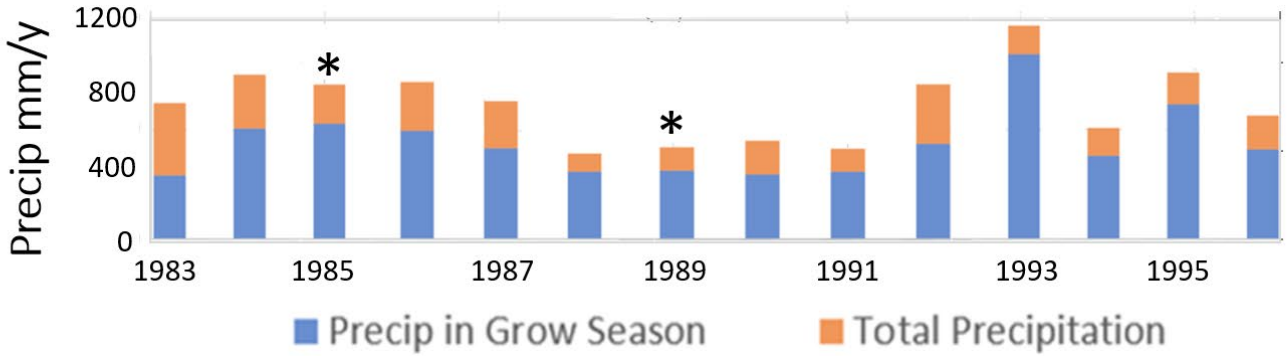


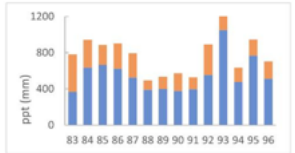
Step 3: Calibrate topographic control of hillslope soil moisture distribution

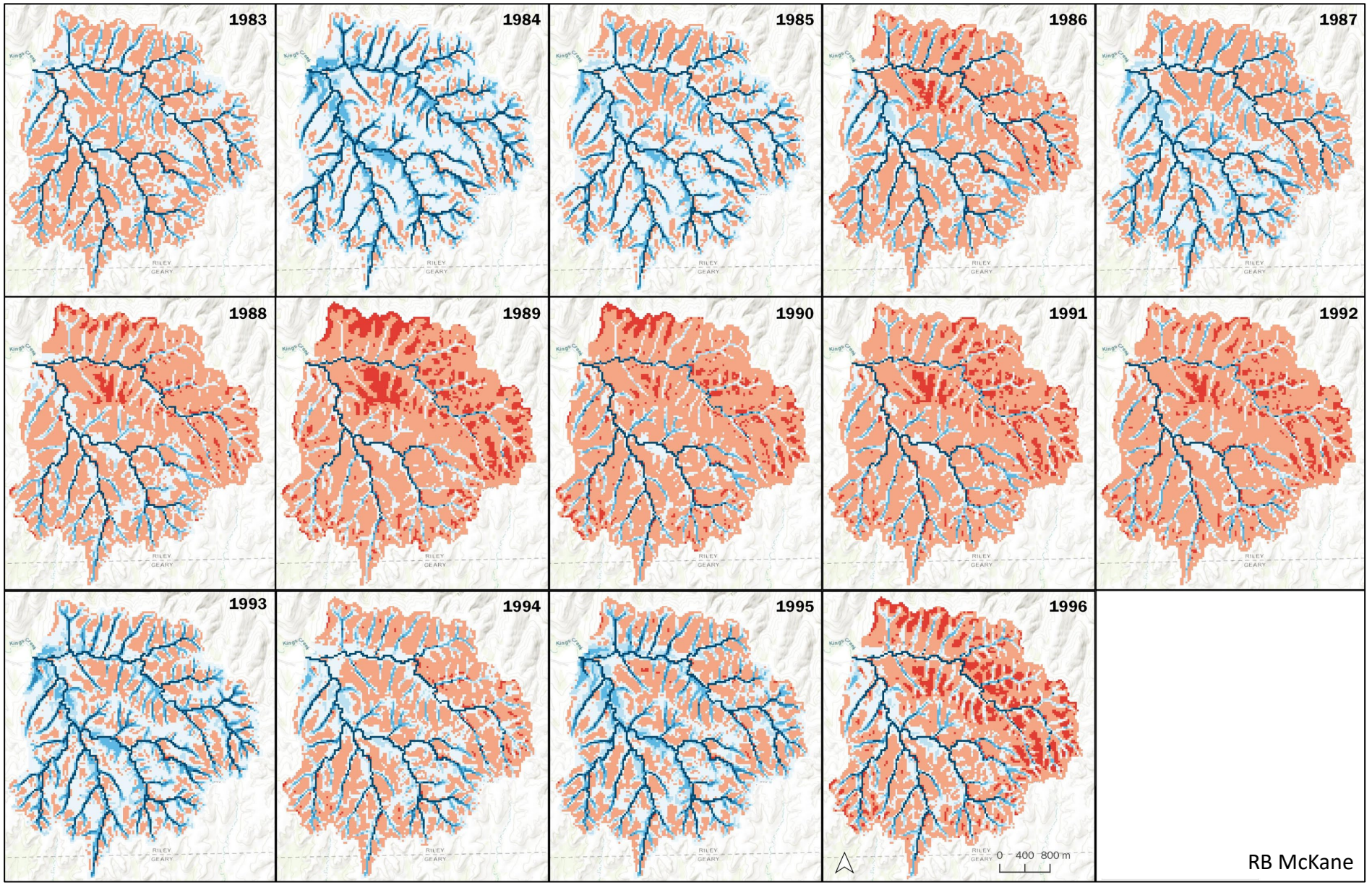
Why: Grassland productivity & fuel loads vary greatly with topographic position → dry uplands, wet drainages, wet lowlands

VELMA modeled soil water-filled pore space fraction (0-1) for Konza Kings Creek watershed on July 2nd of every year from 1983 to 1996.

Water-filled Soil Pore Space Fraction (0-1) on July 2nd

- <= 0.15
- 0.15 - 0.30 (near wilting point)
- 0.30 - 0.45
- 0.45 - 0.55
- 0.55 - 0.70 (field capacity)
- 0.70 - 0.85
- > 0.85 (saturation)

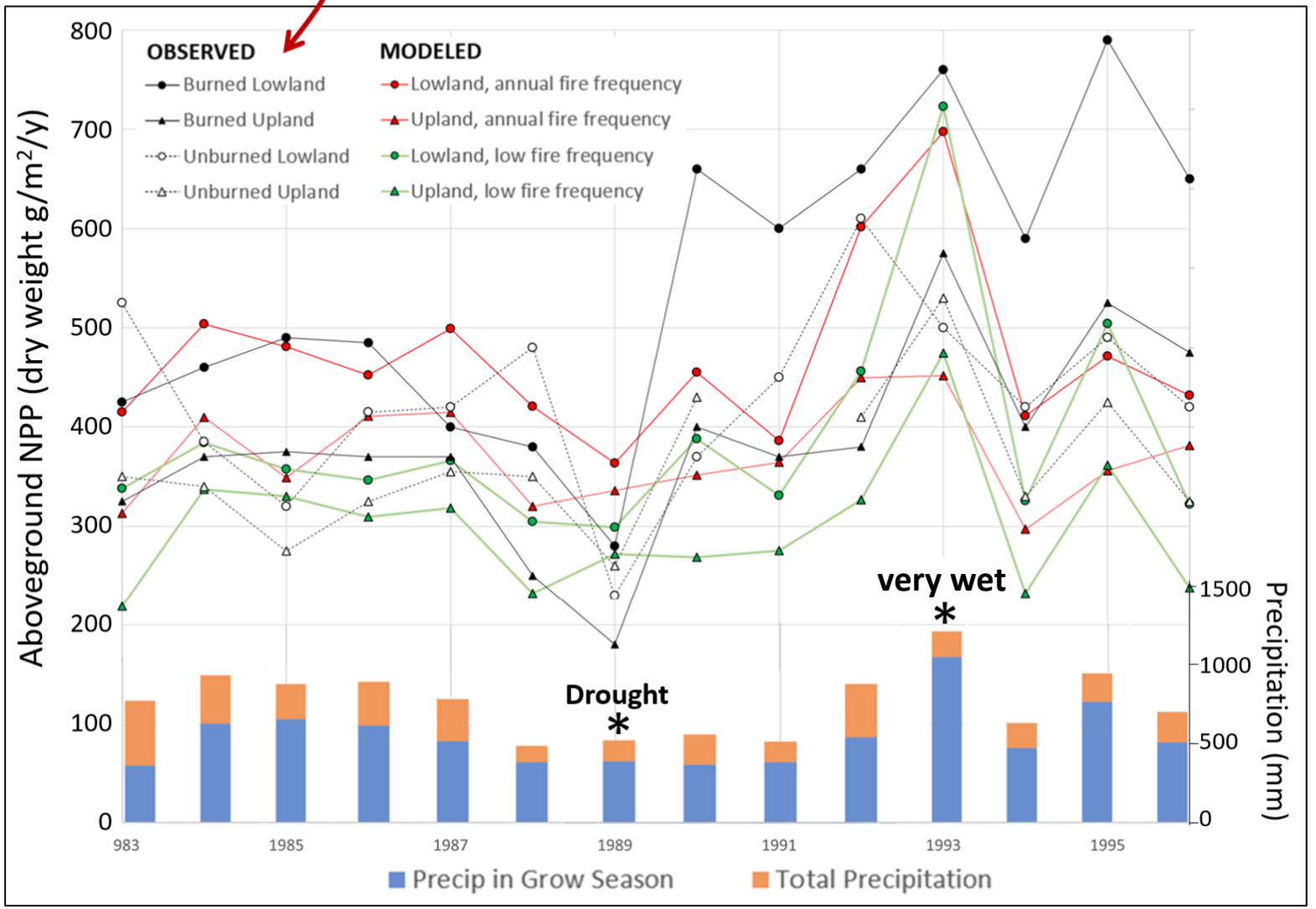




Step 4: Calibrate sensitivity of grassland productivity to moisture, nitrogen, and fire

Why: Limits to grassland productivity can rapidly switch from soil moisture to nitrogen during the growing season.

How: Calibrate VELMA responses to changing resource availabilities based on Briggs & Knapp (1995, 1998) observed productivity data



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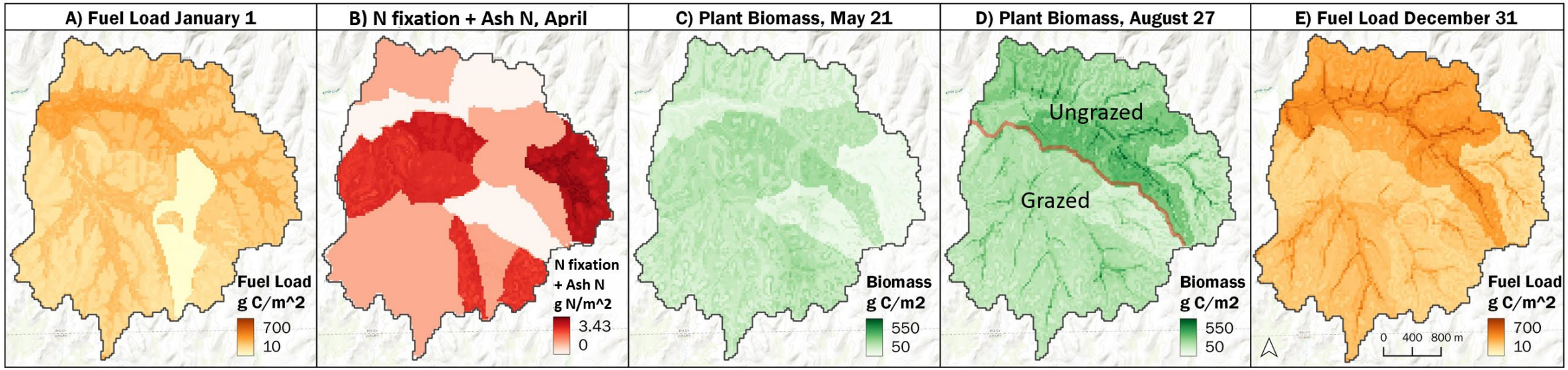
1993 time series: VELMA simulated Kings Creek Watershed grassland productivity & fuel loads

(A) January: initial fuel loads.
(B) April: post-burn non-symbiotic N fixation + ash N.
(C) May: aboveground plant biomass mid-May.
(D) August: peak-season aboveground NPP (bison graze 20-25% of grassland biomass production in southern zone)
(E) December: end-of-year dead plant fuel loads



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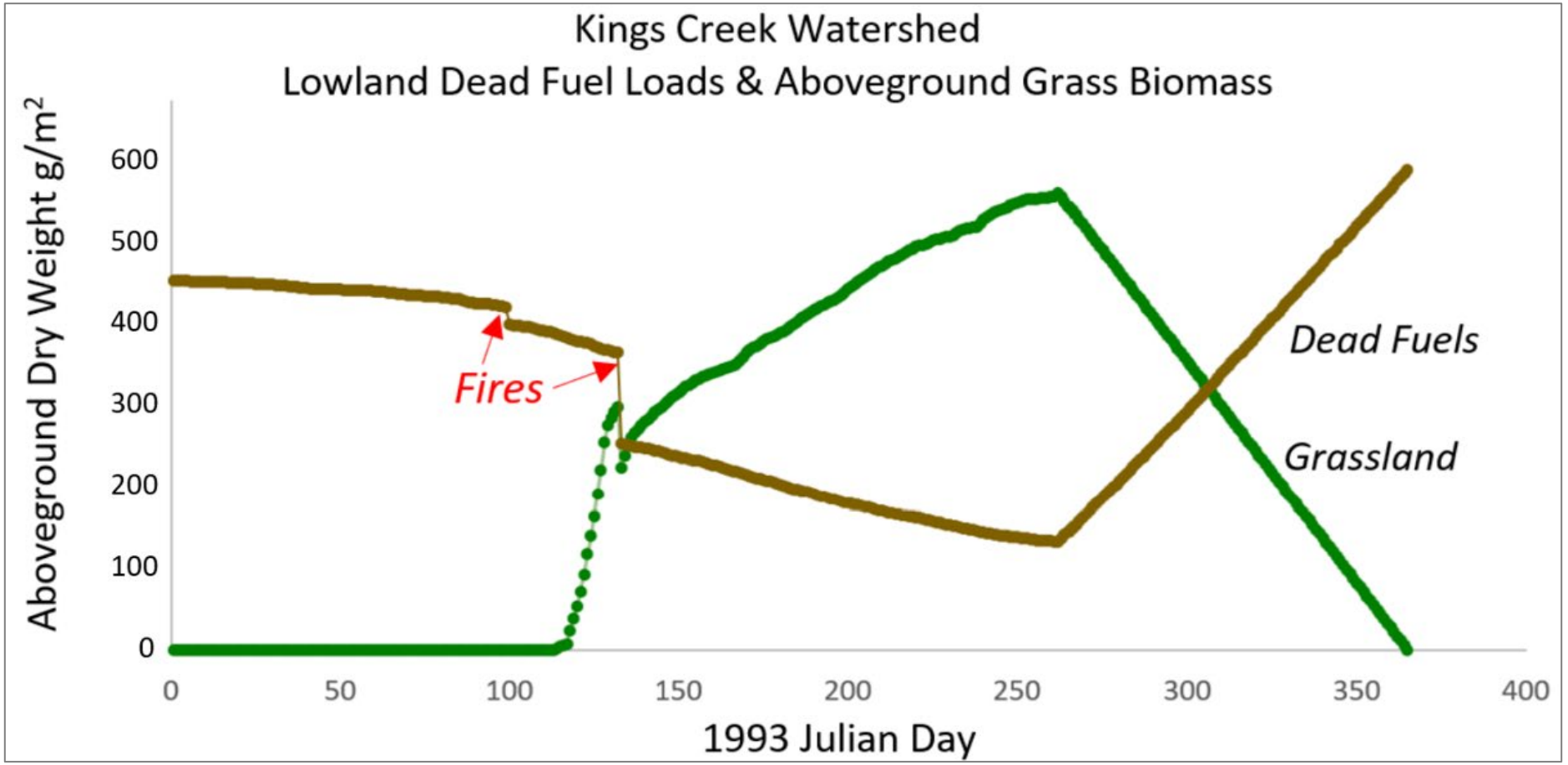
Graphical view of VELMA simulated 1993 grassland biomass & fuel loads

averaged across lowland habitats within the 11.4 km^2 Konza Kings Creek watershed



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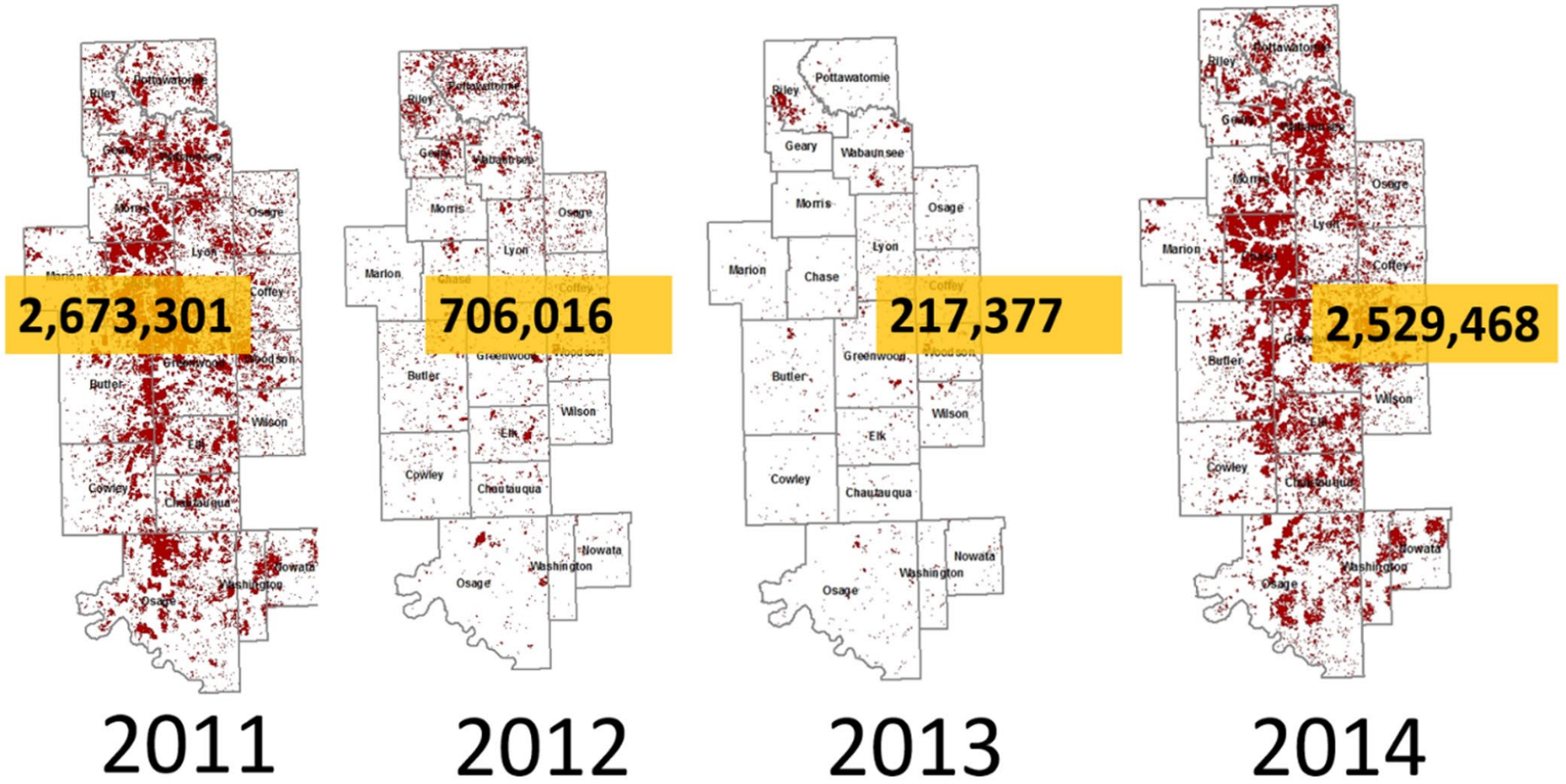
Extrapolate VELMA calibration for 35 km^2 Konza site to the 25,000 km^2 Flint Hills

How: Apply Konza calibrated VELMA to satellite-based Flint Hills burn scars, whereby modeled fuel loads for Dec 31st of the previous year are applied to Jan 1st of the current year.

Image: Flint Hills prescribed burn scars mapped for 2011-2014 (acres burned/y).

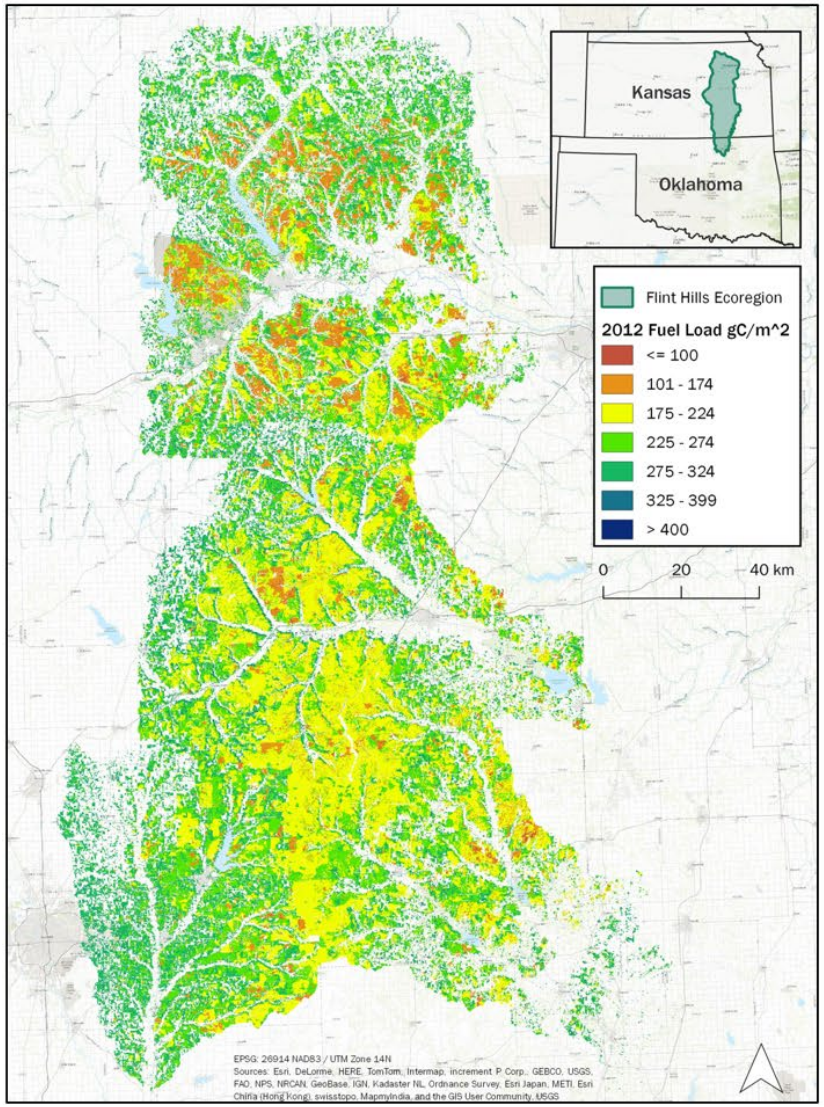
Climate, economics, and other factors can lead to high inter-annual variability in prescribed burning decisions (burn scars).

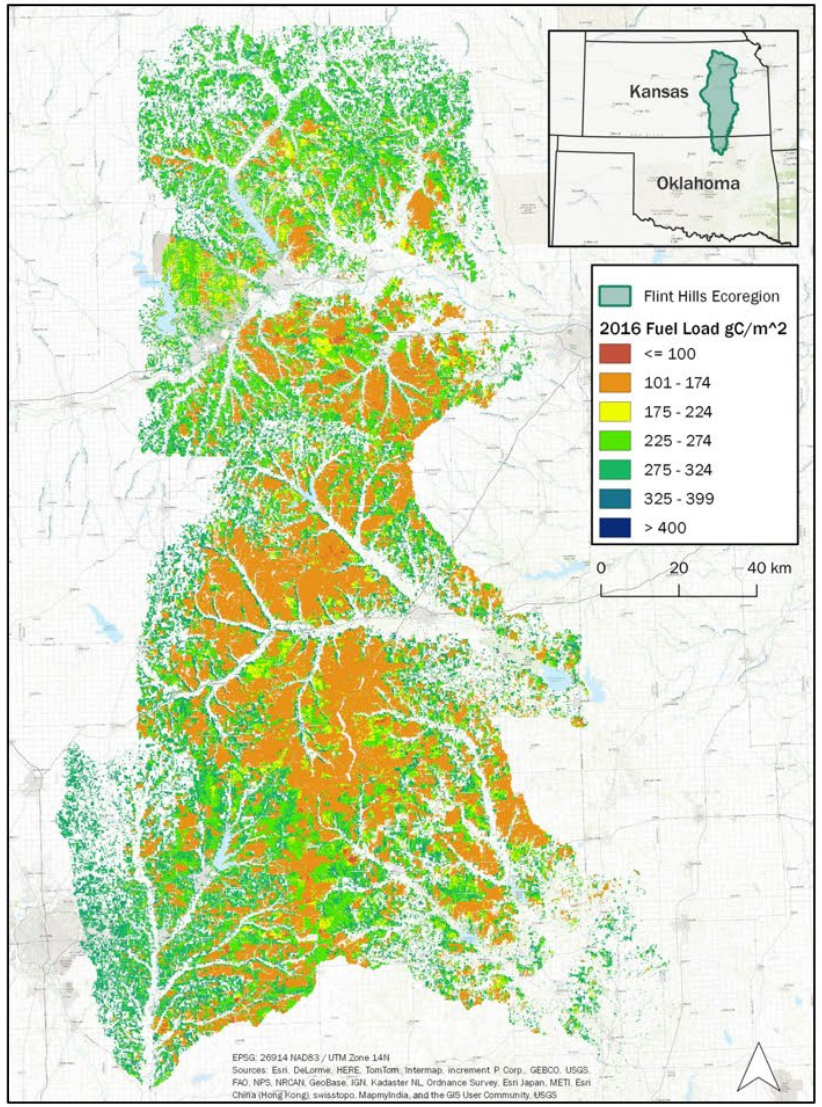


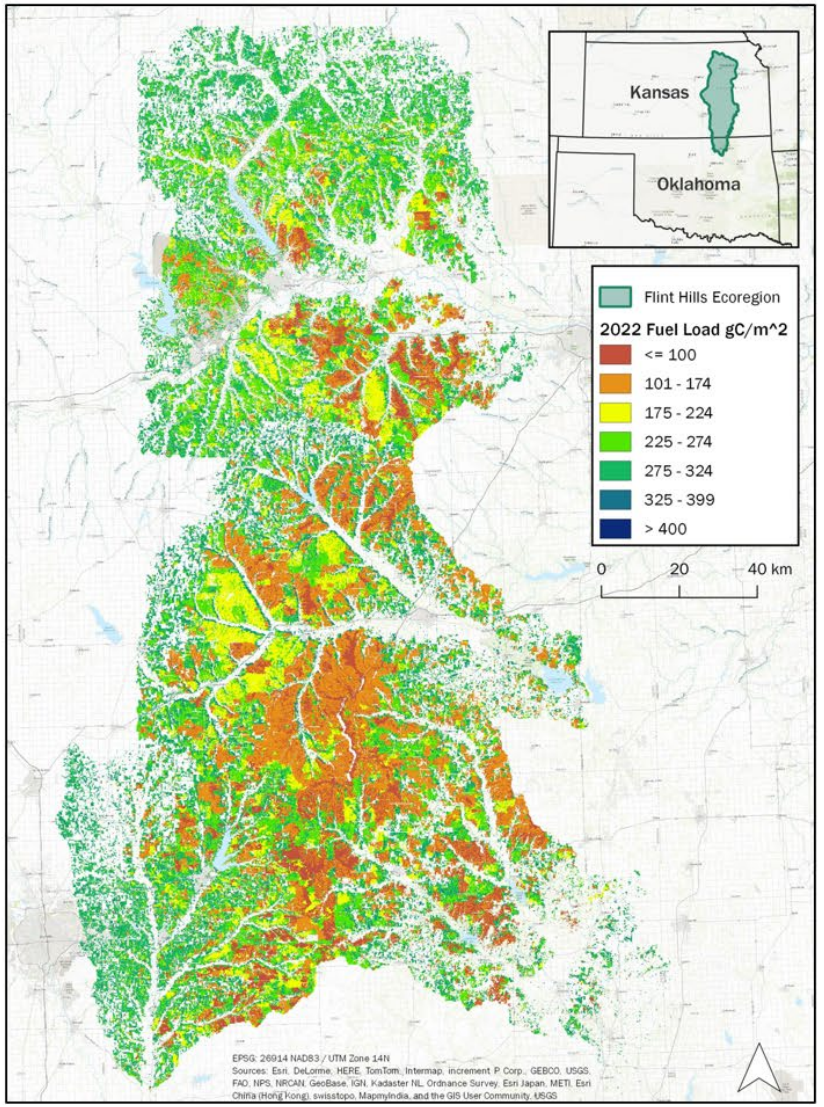
Doug Goodin, Jayson Prentice

VELMA modeled Flint Hills ecoregion fuel load maps (g carbon/m^2) for December 31 of 2012, 2016, 2022.

These 3 years were chosen from maps developed for 2000 to 2022 to illustrate fuel load interannual variability.







Sonali Chokshi

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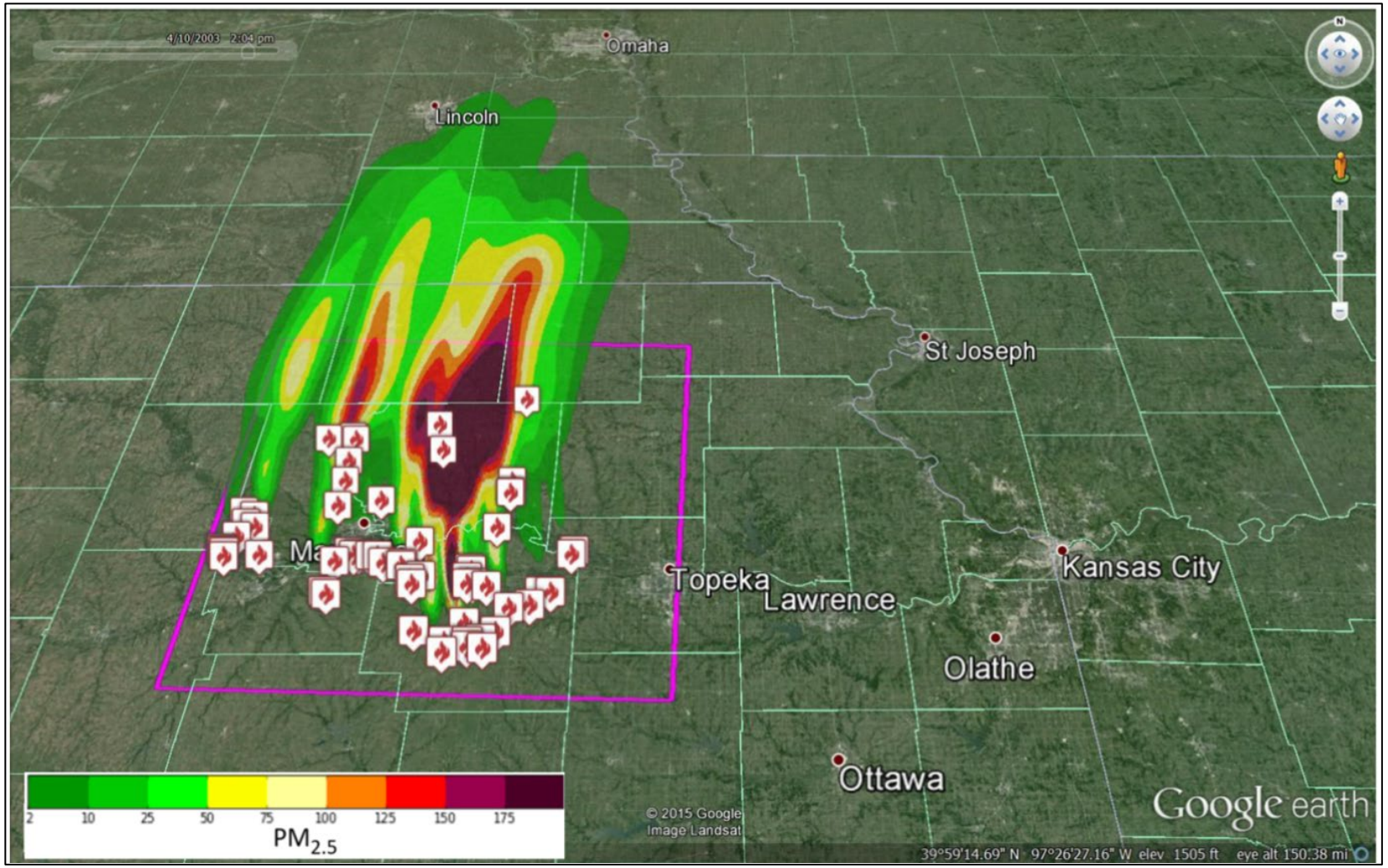
- Flint Hills BlueSky air quality modeling demonstration showing prescribed fire plume formation
- Air quality constituents included particulate matter (PM2.5, shown), volatile organic compounds (VOCs), nitrous oxides (NOx), and ozone (O3)



BL Barnhart

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Conclusions

- The preceding results demonstrate that VELMA provides a serviceably accurate synthesis of long-term Konza Prairie experimental data.
- Through its synthesis of diverse Konza data sets, VELMA extended those data by allowing behaviors of difficult to measure ecosystem components – soil moisture, streamflow, grassland productivity, and fuel loads – to be inferred and mapped across a wide range of spatial and temporal scales: days to decades, and watersheds to ecoregion.
- Importantly, these capabilities supported extrapolation of the experimental data in space and time to the 700 times larger Flint Hills tallgrass prairie ecoregion.
- Our multi-institution team is confident that the coupling of VELMA and BlueSky, via the State of Kansas www.ksfire.org website, opens new possibilities for improved rangeland management.
- A key goal for this toolset, yet unrealized, is to help decision makers identify tallgrass prairie management practices that better balance rangeland burning economic and ecosystem sustainability necessities against potential air quality and human health impacts. See slide #12.
- This VELMA-BlueSky framework is transferable to any ecosystem type where prescribed fires could help achieve multiple ecological and human health benefits. See slide #30…

VELMA-BlueSky implementation details are described in this manuscript, pending journal acceptance…

Manuscript in review at *Landscape Ecology* journal

Estimation of Flint Hills Tallgrass Prairie Productivity and Fuel Loads: A Model-Based Synthesis and Extrapolation of Experimental Data

Robert B. McKane[1*], Jonathan J. Halama[1], Bradley L. Barnhart[1], Allen F. Brookes[1], Kevin S. Djang[2], Sonali Chokshi[1], Paul P. Pettus[1], Brenda Groskinsky[3], Gina Grier[3], Andy Hawkins[3], Douglas Watson[4], Jayson Prentice[4], John M. Blair[5], Douglas G. Goodin[5], Loretta C. Johnson[5], Adam M. Skibbe[5], Marc Stieglitz[6], Feifei Pan[6], Alex Abdelnour[6]

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VELMA-BlueSky are highly transferable across ecosystem types, as for this EPA led multi-agency western forest prescribed fire & wildfire assessment

VELMA-FCCS	→	BlueSky	→	CMAQ	→	BenMap
Fuel loads, Mgmt impacts		Fire, Smoke		Atmospheric chemistry		Human Health, Economics

EPA United States Environmental Protection Agency

https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=352824

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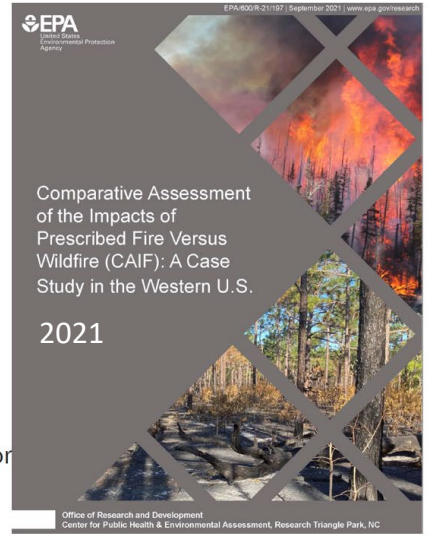
Comparative Assessment of the Impacts of Prescribed Fire Versus Wildfire (CAIF): A Case Study in the Western U.S.

Overview | Downloads



Notice

Press Release: EPA Releases Report Comparing Air Quality and Public Health Impacts from Prescribed Fire and Wildfire Smoke. [Released Sep 30, 2021]

Abstract

In January 2020, the Wildland Fire Leadership Council (WFLC) requested that EPA, in collaboration with scientific staff in the U.S. Forest Service (USFS), the Department of the Interior (DOI) and the National Institute of Standards and Technology (NIST), conduct an assessment of air quality and health impacts of prescribed fire compared to wildfire. This assessment is described in the final repor *Comparative Assessment of the Impacts of Prescribed Fire Versus Wildfire (CAIF): A Case Study in the Western U.S.*

VELMA learning resources website

https://www.epa.gov/water-research/visualizing-ecosystem-land-management-assessments-velma-model

or,

Just type “EPA VELMA” in your browser

- Download the executable VELMA model, supporting user manuals, publications, and other learning resources here
- VELMA is Java-based and Windows compatible
- Free!

★ Contact us about VELMA

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halama.jonathan@epa.gov

BlueSky learning resources website

AirFire Research Team

https://www.airfire.org/data/bluesky

WHAT IS BLUESKY?

BlueSky is a modeling framework. BlueSky modularly links a variety of independent models of fire information, fuel loading, fire consumption, fire emissions, and smoke dispersion.

WHAT CAN BLUESKY DO?

BlueSky connects models together and makes them easy to run in combination. Therefore BlueSky can enable:

- the lookup of fuels information from fuel maps
- the calculation of total and hourly fire consumption based on fuel loadings and weather information
- the calculation of speciated emissions (such as CO2 or PM2.5) from a fire
- the calculation of vertical plume profiles produced by a fire
- the calculation of likely trajectories of smoke parcels given off by a fire
- the calculation of downstream smoke concentrations.

Yes!

CAN I RUN BLUESKY ON MY COMPUTER?

You can operate BlueSky from your computer. You can do this through a web-based application (BlueSky Playground) we have developed.

Thank You!

mckane.bob@epa.gov

Extra Slide

EPA CAIF Timber Crater 6 case study in an Oregon forest (VELMA simulated fuel loads)

CAIF analysis of alternate prescribed burn scenarios

- Timber Crater 6 Fire – Modeled Prescribed Fire Emissions:
  - **1,071 tons of total PM2.5 emissions, ranging from 117 to 565 tons** across each of 4 prescribed fire scenarios
  - **$4 M (95% CI: $0 to $9 M)**

- In addition to estimating air quality and health impacts, CAIF study analyses demonstrate that household air filters and other interventions can provide public health benefits, with **potential human exposure reductions in $PM_{2.5}$ ranging from 14 to 31%.**

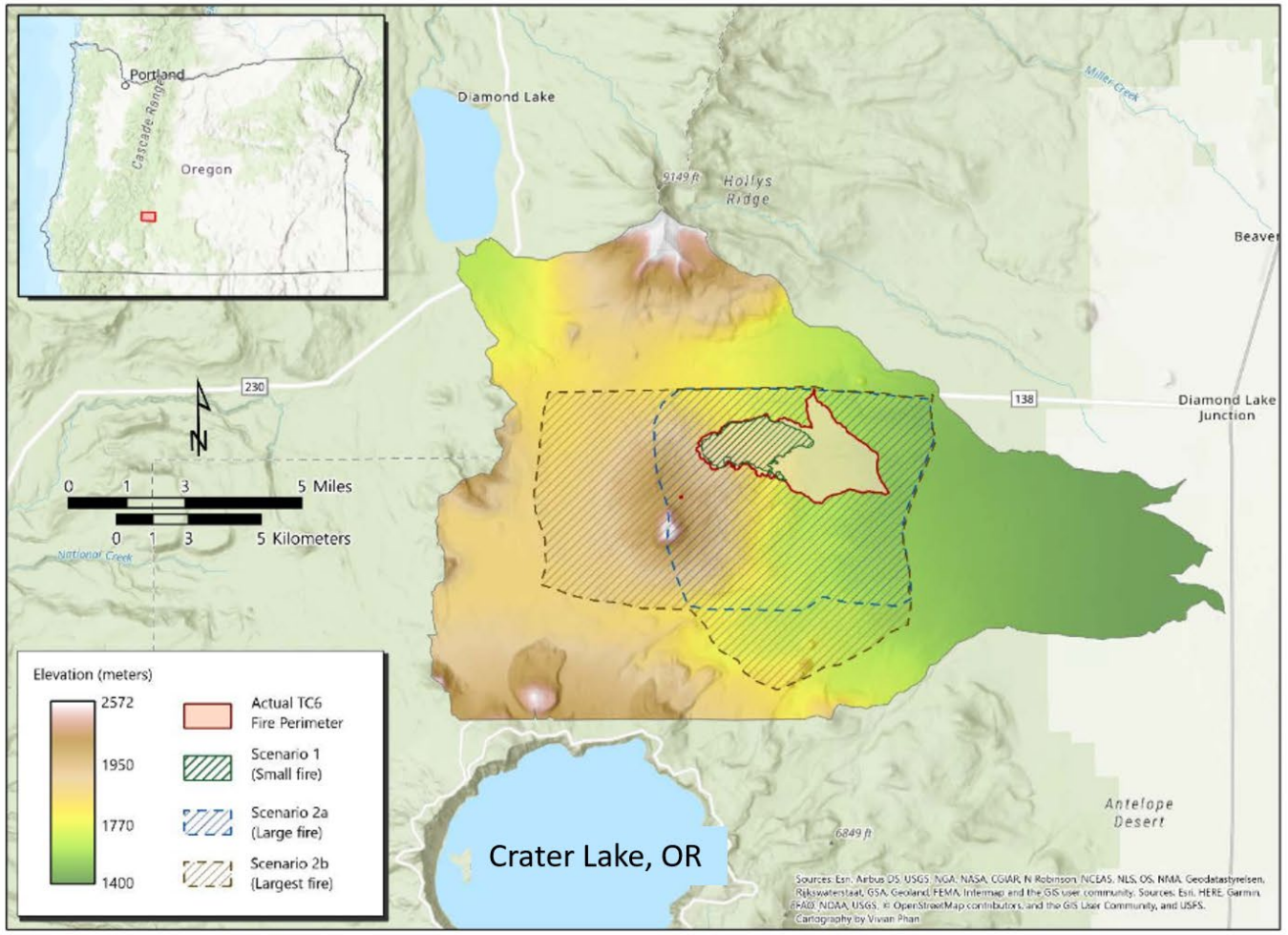

Figure 1-1 **Map of fire perimeters of hypothetical scenarios and actual fire for the Timber Crater 6 (TC6) Fire case study.**