Development of a Multi-Model Ecosystem Simulator for Predicting the Effects of Multiple Stressors on Great Plains Ecosystems – A USEPA Region 7 Regional Applied Research Effort

Dr. Robert McKane, RARE Project Lead
Office of Research and Development, National Health and Environmental Effects Research Laboratory, Western Ecology Division, Corvallis, Oregon, mckane.bob@epa.gov, 541-754-4631

Project Description

The Regional Applied Research Efforts (RARE) Program promotes collaboration between EPA regions and the Office of Research and Development (ORD). ORD provides funding to each region to develop a current ORD research topic that can be enhanced to fit the region's top priorities. These funds are directed by each region's science liaison and science program to projects at ORD labs.

ORD's Western Ecology Division (WED) is collaborating with Region 7 on a RARE project to develop regional databases and modeling tools for conducting comprehensive environmental risk assessments for the Central Great Plains. This work focuses on the Flint Hills of eastern Kansas (Figure 1), an economically and ecologically important mosaic of rangeland, native tallgrass prairie, cropland and urban environments. Covering an area of 30,000 km^2, the Flint Hills ecosystem is considered to be its own unique ecoregion. Frequent wildfires were a principal force in the formation and maintenance of native tallgrass prairie. Today, prescribed fires are used extensively to enhance rangeland forage quality and productivity, and to prevent encroachment of woody species such as eastern redcedar. Unfortunately, grassland burning also releases harmful pollutants into the atmosphere and, under certain conditions, has caused air quality problems in Kansas City and other areas far downwind (Figure 2). Thus, policymakers are faced with a need to consider both the ecological benefits and human health effects of biomass burning.

The goal of this RARE project is to develop regional-scale geographic information system (GIS) databases and simulation models for spatially and temporally extrapolating the effects of multiple stressors on grassland ecosystems and regional air quality. Key stressors include fire, grazing, invasion of woody species, and climate change.

Because no single model can address all stressors and effects of interest, several models are being integrated for this work. While component models each serve a unique purpose, their integration allows a better understanding of how disparate processes interact within ecosystems and landscapes. For example, the GTHM-PSM model links the GT Hydrologic Model and the PSM biogeochemistry model to simulate processes that control the cycling and transport of water and nutrients within complex landscapes such as the Flint Hills. Thus, GTHM-PSM can simultaneously address how alternative fire management and climate scenarios affect grassland productivity, carbon sequestration, and stream water quality and quantity. In turn, GTHM-PSM's plant biomass and fuel load predictions will be used as input for BlueSky, a meteorologically-based fire management model that simulates smoke transport and consequent impacts on regional air quality, including distant urban areas like Kansas City.

The completed modeling framework will establish a decision support system for conducting comprehensive risk assessments that consider both the ecological and air quality impacts of biomass burning. It will track conditions of concern over timeframes (days to decades) that are relevant to understanding impacts on ecosystems and human health. The ultimate purpose of this research is to provide a decision support tool that policymakers and land managers can use to asses how alternative decisions will affect multiple endpoints of concern. For example, can burning strategies be identified that sustain rangeland productivity while minimizing impacts on air quality and human health?

Project Status (as of October 2008)

Flint Hills GIS Database: This project began in July 2006 with RARE funding ($50k annually for two years) to hire a GIS technician to develop the Flint Hills regional database. The GIS database was completed in July 2008 and includes the following spatial datasets at a scale of 30x30 meters: climate drivers, digital elevation models, vegetation characteristics, soil chemical and physical properties, geology, land use, and stream discharge and chemistry.

GTHM-PSM Ecohydrology Model: A fully functional version of GTHM-PSM has been completed that includes

software for visualizing simulated stressor effects on terrestrial ecosystem structure and function, and stream water quality and quantity. GTHM-PSM is being implemented in two phases: 1) model calibration and validation for the data-rich Konza Prairie Long Term Ecological Research (LTER) site, and 2) extrapolation to the Flint Hills region. For Phase 1, an initial calibration of GTHM-PSM was recently completed for the Konza Prairie. EPA, Georgia Tech and Kansas State University are collaborating to improve and ultimately validate Konza simulations describing the effects of burning, grazing and climate on grassland productivity, surface litter (fuel loads), soil carbon and nitrogen dynamics, and stream water quality and quantity. Phase 1 is expected to be completed in July 2009. Phase 2 extrapolation for the Flint Hills region is expected to be completed in late 2009.

BlueSky Smoke Transport Model: Collaborators at Kansas State University independently received a 3-year grant in 2008 to develop a grassland version of the BlueSky model for simulating smoke transport and pollutant loads for the Flint Hills airshed (http://www.oznet.ksu.edu/news/sty/2008/smoke_management022508.htm). KSU is also developing remote sensing methods for characterizing the spatial distribution of fuel loads in relation to various burning and grazing regimes. Algorithms based on this work will be incorporated into GTHM-PSM to improve dynamic fuel load predictions in relation to projected changes in land use, climate and other stressors. Testing of a web-based framework linking BlueSky and GTHM-PSM is expected to begin in 2010, with an initial focus on April 2003 prescribed burns that impacted regional air quality (Figure 2).

Final Outcome and Deliverables

- 2008 (complete): Flint Hills GIS database for supporting model-based risk assessments.
- 2008 (complete): fully functional beta version of GTHM-PSM ecohydrology model, with initial Konza Prairie simulations demonstrating capabilities for quantifying and visualizing the effects of long-term climatic variability on grassland productivity and stream water quality and quantity.
- 2010-2011: Peer-reviewed scientific publications describing GTHM-PSM validation tests and simulations for analyzing and predicting the effects of interacting stressors (fire, grazing, invasion of woody species, and climate change) on grassland productivity, carbon sequestration, and stream discharge and water quality.
- 2011: Web-based decision support system, including links to the Flint Hills GIS database, validated component models (GTHM-PSM and BlueSky), and stressor scenarios for assessing the ecological benefits and air quality effects of biomass burning in the Flint Hills. The website will serve as the primary technology transfer tool for delivering the models and simulation output to Region 7 and other clients. The website will provide instructions and examples that demonstrate the use of the simulator for conducting risk assessments in support of environmental decision making.

Collaborators and Responsibilities

EPA/ORD/NHEERL/WED, Corvallis, OR
- Dr. Robert McKane, Research Ecologist and RARE project lead, responsible for overall project coordination; co-lead for ecohydrology model validation and implementation.
- Adam Skibbe, GIS Technician (now with KSU), responsible for development of Flint Hills GIS database.

EPA Region 7, Kansas City, KS
- Brenda Groskinsky, Science Liaison, responsible for integration of science and Region 7 policy goals.

Georgia Institute of Technology, Atlanta, GA
- Dr. Marc Stieglitz, Hydrologist and lead developer of GTHM-PSM ecohydrology model; co-lead for ecohydrology model validation and implementation.
- Dr. Feifei Pan, Hydrologist, responsible for GTHM-PSM code development and calibration.

Kansas State University, Manhattan, KS
- Dr. John Blair, Director of Konza Prairie LTER project, and Dr. John Blair, Director of Konza Prairie Biological Station, providing expert advice and data for model calibration and validation.
- Dr. Doug Goodin, Landscape Ecologist, and Dr. Jay Ham, Environmental Physicist, leading parallel project to develop and implement grassland version of BlueSky smoke transport model for the Flint Hills airshed.

Figure 1. Flint Hills ecoregion and the Konza Prairie Long Term Ecological Research site

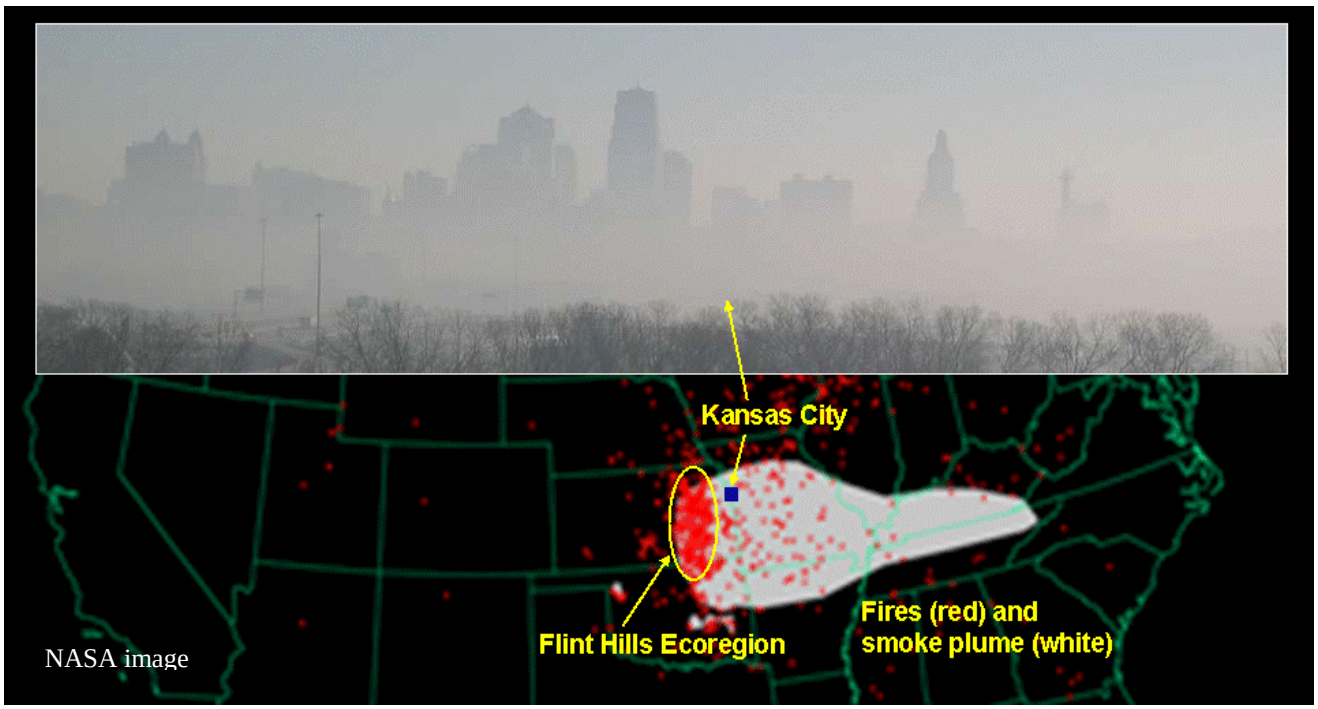

Figure 2. Because of spring-time weather conditions in 2003, most prescribed burning in Flint Hills grasslands occurred during a three-day time span in mid April, resulting in a smoke plume that drifted over a seven state area. During this episode, air quality in Kansas City did not meet acceptable standards for particulate matter and ozone. Monitoring since 2003 has shown that when grasslands are being burned, a significant increase in air particulate matter occurs in the Kansas City area.