

"SCALING UP THE ECOSYSTEM CONSEQUENCES OF FOREST EXPANSION IN THE GREAT PLAINS REGION: A RENEWAL PROPOSAL"

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INTRODUCTION

This is a renewal proposal to our earlier NASA LCLUC grant 'Land-Cover Change in the Great Plains: Predicting Impacts of Regional Forest Expansion on Biogeochemical Processes.' As highlighted recently, forest encroachment in the Great Plains is poorly known, difficult to quantify, but potentially important as a C sink. Indeed, land use is becoming recognized as an equally important factor, if not more important, in rates of C accumulation in biomass and soils, as compared to growth enhancement by elevated CO₂, N deposition and global change, in general. Woody encroachment is occurring rapidly in the Great Plains: Juniper, in particular, is spreading over more than 7 million ha in a five state area in the lower Midwest.

Our earlier LCLUC project filled a critical gap in understanding the role of land use and land cover change in the Great Plains. Our research group has quantified how woody encroachment in eastern Kansas grasslands has resulted in fundamental changes in ecosystem function as related to this life form shift C₄ prairie grasses to a C₃ evergreen junipers.

The goals of the earlier project were to:

- assess the current distribution of land cover, document the historical change in land cover (especially forest cover) using aerial photographs and satellite remotely sensed data (using both historical and present data), linked to a GIS data base that will have important information on the potential forcing factors (socioeconomic vs climatic, ecological),
- quantify the effects of forest expansion on biogeochemical processes controlling the quantity, quality, and distribution of soil organic matter and soil C, and nitrogen (N) cycling and availability,
- determine how these life-form shifts alter ecosystem C balance and fluxes of CO₂, H₂O, and energy, and
- incorporate a spatially-explicit model (GEM) that will link our *in situ* biogeochemical and ecosystem studies with spatial information on land cover change to predict ecosystem consequences of future forest expansion.

APPROACH

Our approach has been strongly multi-disciplinary: it has involved *in situ* biogeochemical approaches at the plot-level linked with multi-temporal Landsat images and historical aerial photos and biogeochemical modeling. Our research has been unique in that we have also quantified changes in C source/sink activity by using eddy flux towers in forest and grassland as a complement to direct measurements of carbon stocks in biomass and soils. From our 1.5 years of net C exchange measurements, of particular note is how conversion to forest changes the phenology of net CO₂ exchange and source/sink activity; the forest site (with trees utilizing C₃ photosynthetic pathway) is a C sink in the cool parts of the growing season while the C₄ grassland site is a strong, but short duration, C sink in mid-summer. We aim to continue these critical measurements of net C exchange, water and energy balance on an interannual basis to determine if the same phenological pattern continues and how year-to-year differences in temperature and precipitation, so characteristic for the Great Plains, affect source/sink activity in forest relative to grasslands.

In our renewal proposal, our overall objective will be to 'scale up' our extensive plot-scale data to the regional level of the Great Plains and to continue to calibrate our biogeochemical model (GEM) to allow us to predictive the ecosystem consequences if woody encroachment continues in the future. Because the use of remote sensing is so integral to quantifying the rate and extent of forest encroachment, our research group has teamed up with Dr. Kevin Price from the Kansas Applied Remote Sensing Center at the University of Kansas. Price brings to the project a special expertise in the analyses of multitemporal data and has rapidly moving into the realm of hyperspectral analysis. He brings to the research program over 19 years of experience using remotely sensed data to study land use and land cover patterns.

Detecting patterns of woody encroachment

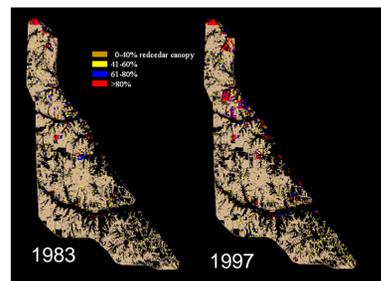


Fig. 1. Changes in Juniper cover classes in Riley County KS using a linear spectral mixing model with TM imagery. In the 60-80% Juniper cover class, Juniper increased by 55%, and the closed canopy cover class increased by 120%.

Fig. 2. Series of aerial photos from the Randolph study site. Junipers appear dark in color. Note the prominent fence-line.

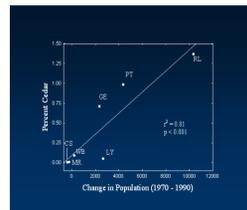
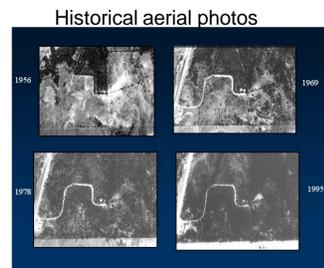
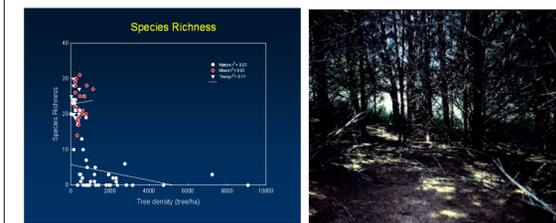


Fig. 3. Area of closed canopy cedar forest as a function of change in population size in several KS counties

Changes in species diversity with Juniper expansion

Fig. 4. Reduction in plant species richness (10m² plots) as Juniper density increases. Note that in forest-grassland mosaics, diversity is relatively high. In closed canopy forests, the number of species drops to <5 per plot.



RESULTS

Ecosystem consequences of forest expansion: Changing biomass allocations

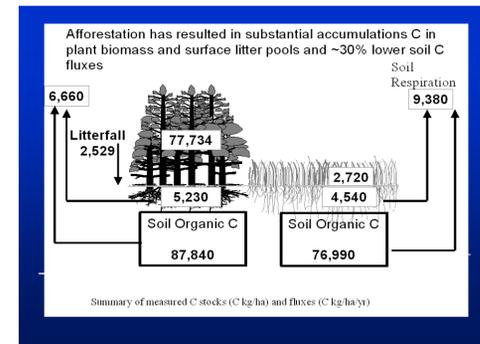


Fig. 5. Summary of measured stocks and fluxes in grassland and closed canopy Juniper forest. Note the dramatic shift in the distribution of C in biomass from belowground in prairie to aboveground in Juniper forest. Soil respiration in forest is reduced by ~30% compared to grassland.

Causes and consequences of woody encroachment: A conceptual model

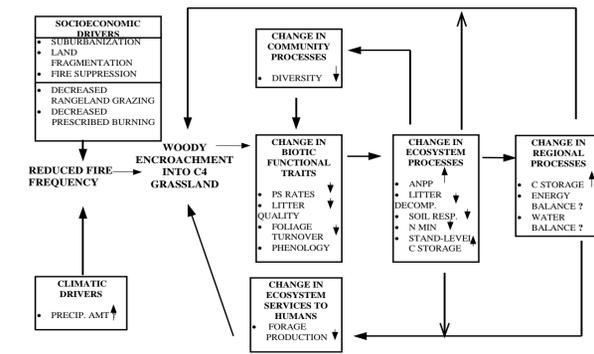
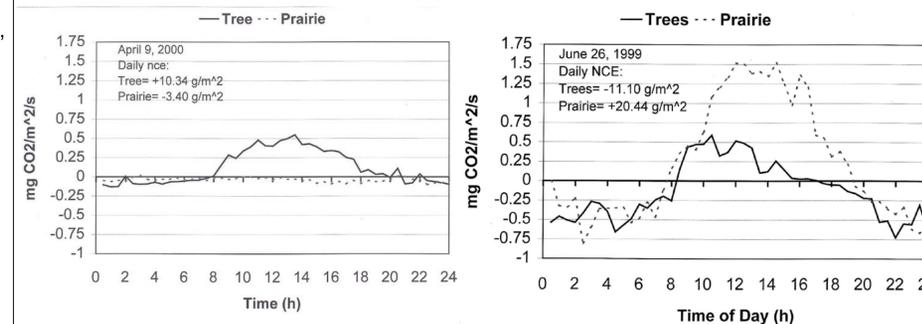


Fig. 6. Conceptual model illustrates reduced fire frequency facilitates the initiation of woody encroachment. Different biotic traits associated with the shift from grass to forest change ecosystem processes at the stand and regional level. These changes in ecosystem function can feedback to further enhance woody encroachment.

Fig. 7. Changes in net ecosystem fluxes of CO₂ between C₄ tallgrass prairie and C₃ Juniper forest. Note that Juniper forest is a net C sink in April, and prairie is a net C sink in June.



Soil organic C dynamics and belowground C cycling as forest invades grassland: A stable isotope approach

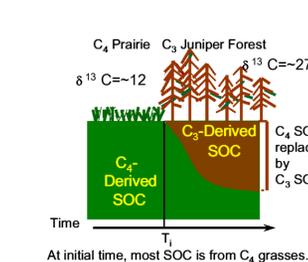


Fig. 8. Soil δ¹³C signatures reflect vegetation origin of soil organic matter.

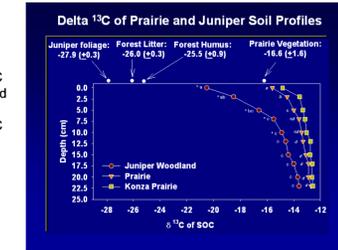
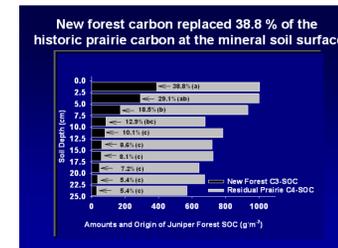


Fig. 9. Amounts and percentages of C₃ forest-derived and C₄ prairie-derived C in SOC profiles in Juniper forest. Dark bar=SOC derived from forest, gray bar=SOC derived from residual prairie carbon.



Spatial and temporal scaling of ecosystem processes using GEM (General Ecosystem Model)

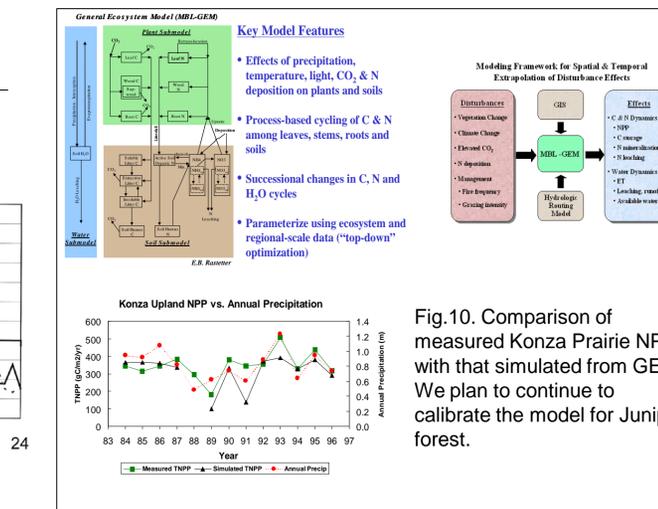


Fig. 10. Comparison of measured Konza Prairie NPP with that simulated from GEM. We plan to continue to calibrate the model for Juniper forest.

Future Research Plan: "Scaling Up the Ecosystem Consequences of Forest Expansion in the Great Plains Region: A renewal proposal"

Our overall goal is to determine rates and patterns of woody encroachment over space and time in the Great Plains, and concomitant rates of change in C and N stocks and fluxes, and to develop a predictive biogeochemical model to forecast future rates of woody encroachment

Our specific objectives are to:

- continue to develop the spectral mixing models necessary to capture the fine-scale dynamics of woody encroachment across the Great Plains region. This will allow us to determine the regional extent and to relate this to regional C storage.
- link our spectral mixing model cover classes to plot-level changes in C and N stocks and fluxes in the same cover classes to predict changes in rates of C and N accumulation in time and space as woody encroachment proceeds,
- continue to parameterize and calibrate our biogeochemical model (GEM) to develop spatially explicit prediction of the biogeochemical and ecosystem consequences of forest expansion in the Great Plains,
- develop a predictive model based on scenarios of future regional woody encroachment in order to generate hypotheses about future land use/land cover change and concomitant changes in C and N stocks and fluxes,
- explore how interannual variation in temperature/moisture affect C source/sink activity, water and energy balance in forest relative to grassland, and the role of phenological differences between the dominant C₄ prairie grasses and C₃ juniper forest, and
- explore the ecological tradeoffs that may occur as forest encroachment (primarily junipers in the Great Plains) drastically lowers biodiversity in these grasslands while providing a regionally important C sink.

Accomplishments and productivity

- 3 graduate students and 1 post-doc trained
- 4 publications, either accepted or in press, 2 submitted
- 12 research presentations at national meetings
- Co-organized ESA symposium on Land Use and Land Cover Change at the 2000 Annual Meeting