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Identifying Land Suitable for Biofuel Feedstocks: Dynamic Modeling of Ecosystem Performance

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U.S. Department of the Interior
U.S. Geological Survey

Overview

We identify land potentially suitable for biofuel feedstock development using an approach for dynamic monitoring of ecosystem performance.

The new monitoring and modeling approach can help land managers and decision makers make optimal land use decisions for biofuel feedstock development and sustainability.

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Objectives (long-term)

- Identify land in the Great Plains that may be suitable for future biofuel feedstock development
- Project future (e.g., 2040) biomass productivity based on the downscaled WCRP CMIP3 climate projections and ecosystem performance models to identify future productive lands
- Develop future net ecosystem exchange (NEE) maps to evaluate future NEE trends for the biofuel feedstock sites
- Assess the environmental and climate impacts (e.g., carbon sequestration and land cover changes) caused by biofuel development

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Objectives (current)

- Develop methods for identifying land suitable for biofuel feedstock development
- Implement dynamic monitoring of the ecosystem performance method for grasslands and marginal croplands within the Greater Platte River Basin (GPRB)
- Identify productive grasslands that are potentially suitable for cellulosic feedstock production (e.g., switchgrass, miscanthus)
- Identify marginal croplands that may be suitable for conversion to cellulosic feedstock production
- Validate current approaches (e.g., validate Growing Season Integrated NDVI as a proxy for ecosystem performance)

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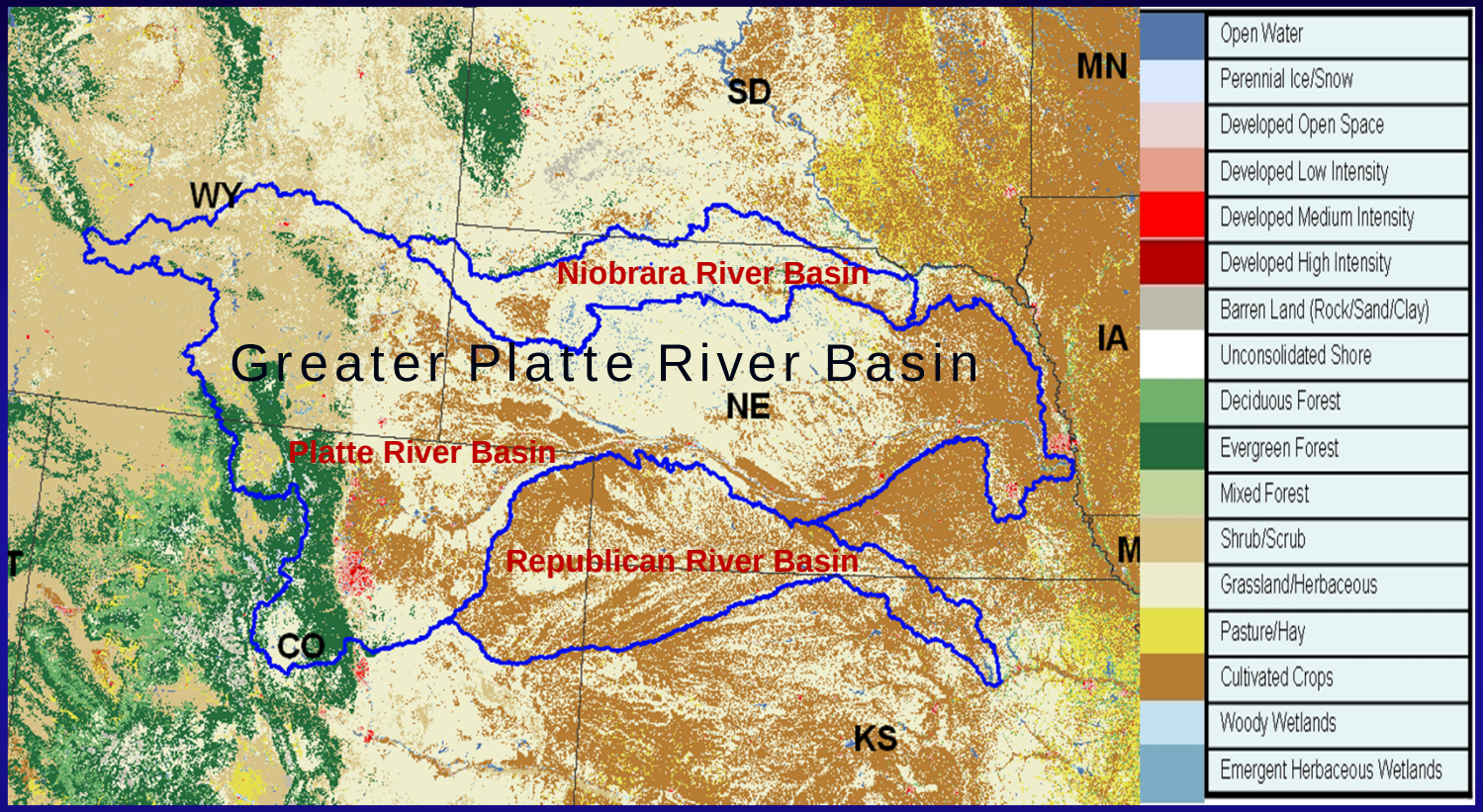
Study area



- **The main vegetation cover types: grassland (~50%) and cultivated crops (~30%). More than 60% of grasslands are warm season (C_4) grass.**
- **Other vegetation cover types: shrubland, evergreen and deciduous forests, and pasture/hay.**

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Approach or Methodology

Grasslands potentially suitable for cellulosic feedstocks (e.g., switchgrass, miscanthus):

- High ecosystem site potential (i.e., high grassland productivity)
- Fair to good range condition (i.e., lack of severe ecological disturbance)
- Excluding areas that are vulnerable to disturbance

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Ecosystem performance concepts

Site Potential = f(land cover, climate, elevation, slope, aspect, drainage, soil conditions, surface geology). Represents long-term ecosystem productivity.

Ecosystem Performance (EP) = growing season integrated NDVI (GSN). GSN is used as a proxy for vegetation productivity.

Expected Ecosystem Performance (EEP) = f(site potential, land cover, seasonal weather). Represents the expected GSN in a particular year (i.e., given the weather conditions of that year and in the absence of disturbance).

Ecosystem Performance Anomaly (EPA) = EP minus EEP, is categorized as normal performance, underperformance (e.g., wildfires, insects, and heavy grazing) and overperformance (e.g., irrigation and fertilization).

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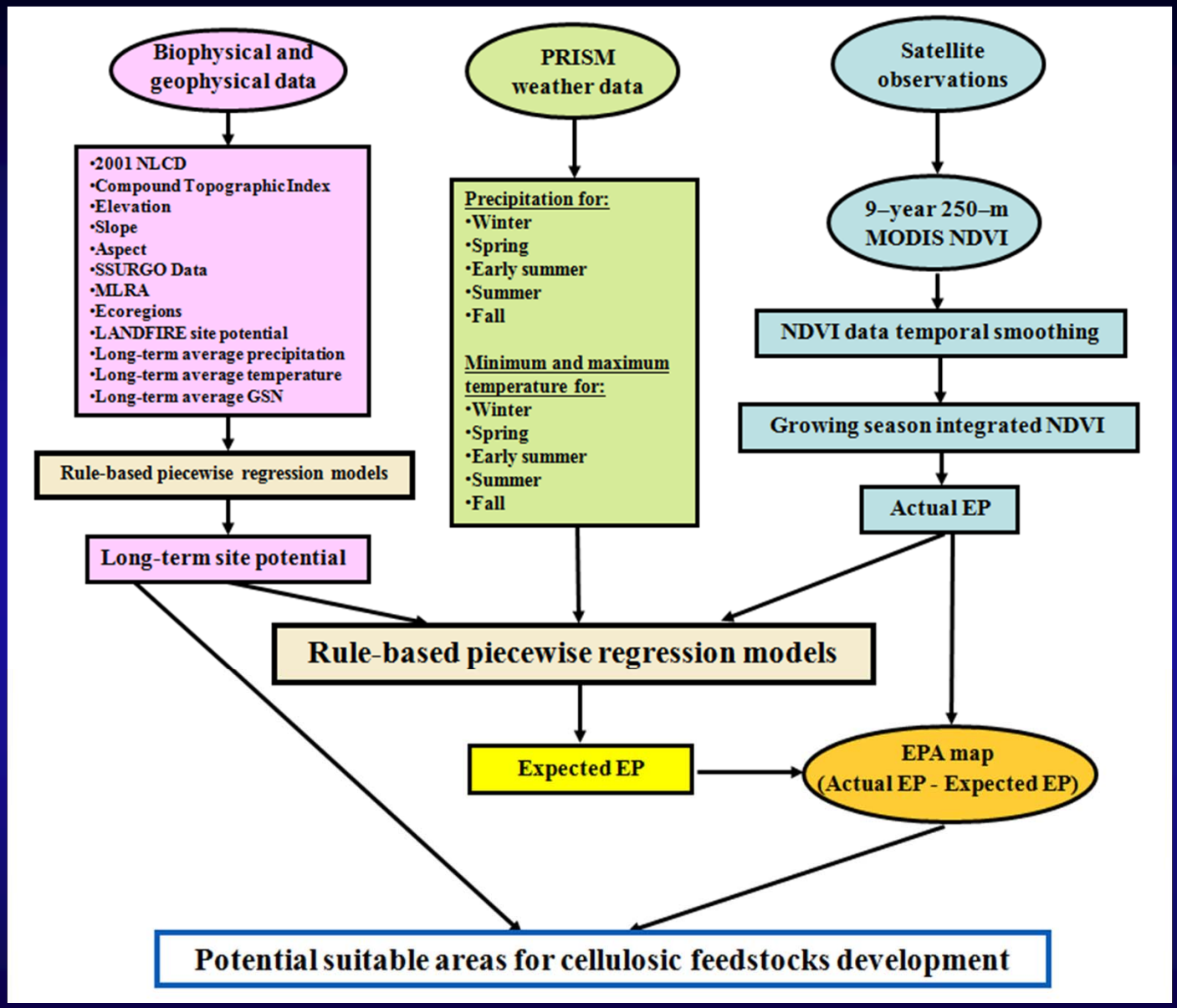
Biophysical and geophysical data
PRISM weather data
Satellite observations
•2001 NLCD
•Compound Topographic Index
•Elevation
•Slope
•Aspect
•SSURGO Data
•MLRA
•Ecoregions
•LANDFIRE site potential
•Long-term average precipitation
•Long-term average temperature
•Long-term average GSN
Precipitation for:
•Winter
•Spring
•Early summer
•Summer
•Fall
Minimum and maximum temperature for:
•Winter
•Spring
•Early summer
•Summer
•Fall
9–year 250–m MODIS NDVI
NDVI data temporal smoothing
Growing season integrated NDVI
Actual EP
Rule-based piecewise regression models
Long-term site potential
Rule-based piecewise regression models
Expected EP
EPA map (Actual EP - Expected EP)
Potential suitable areas for cellulosic feedstocks development

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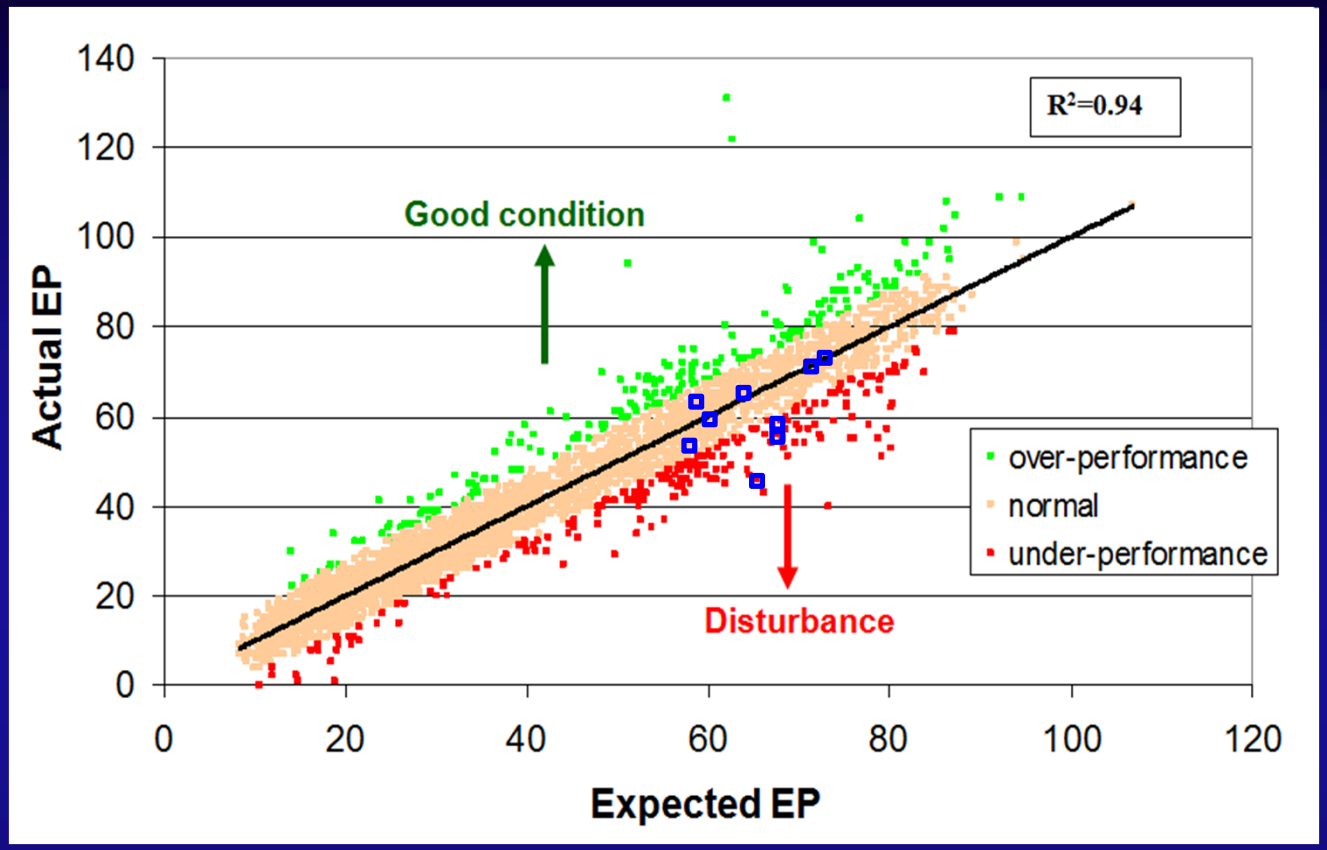
Comparing actual measured EP and model predicted EP



- 5,000 random pixels were selected from different years and locations
- Vertical axis displays management effects and disturbances
- Horizontal axis shows variation in weather

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Data Inputs

- Soil organic carbon and total biomass productivity derived from USDA Soil Survey Geographic (SSURGO) Database
- USGS 30-m Multi-Resolution Land Characteristics (MRLC) land cover data
- USGS 30-m compound topographic index (CTI) and digital elevation model (DEM)
- North and south aspect and slope maps derived from the USGS DEM data
- USGS LANDFIRE environmental site potential data
- USDA NRCS Major Land Resource Areas (MLRA) data
- Olson's Ecoregions map
- PRISM Long-term (1971–2000) averaged precipitation and temperature
- 2000–2008 PRISM precipitation and temperature data
- 9-year (2000–2008) eMODIS NDVI data

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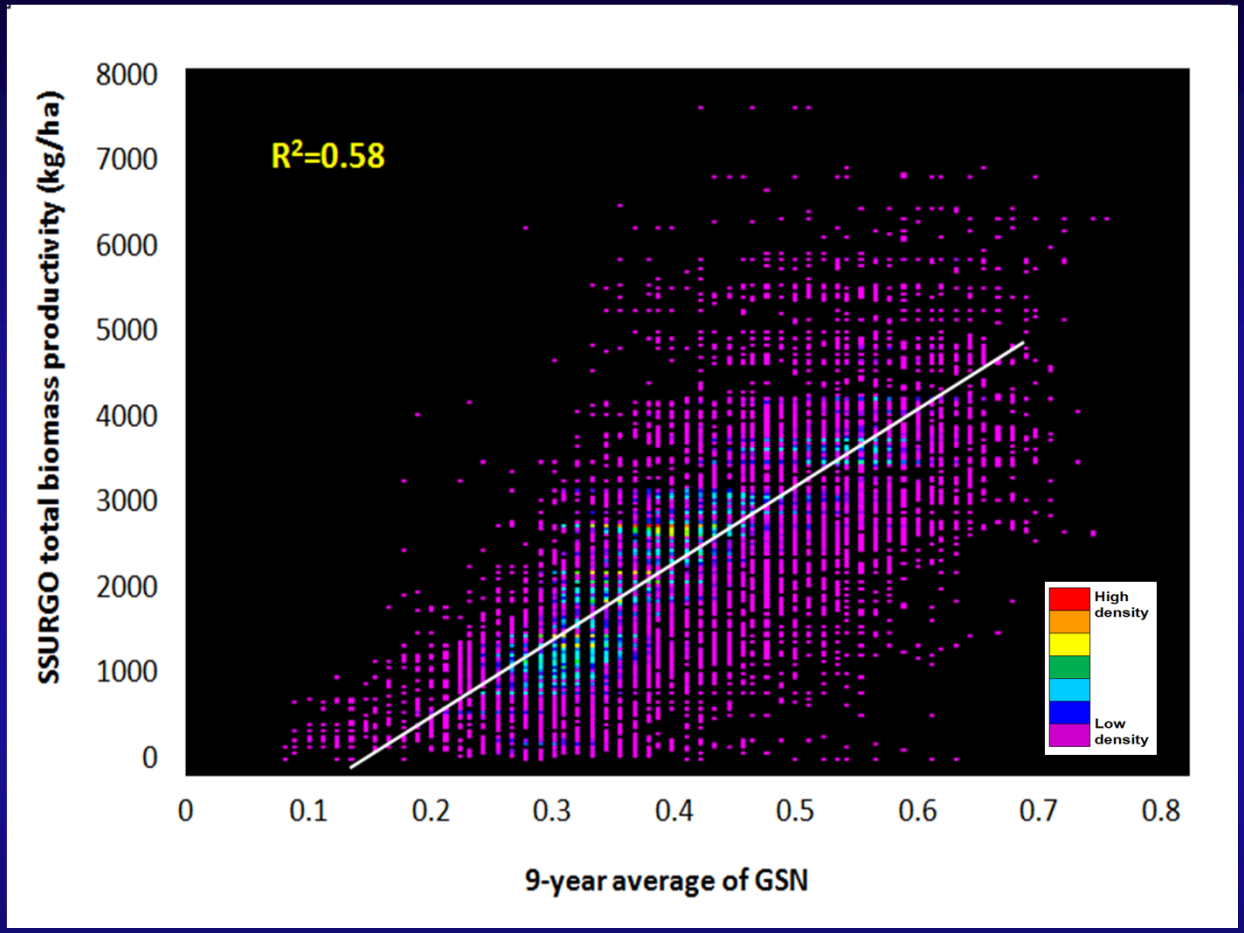
Verification of GSN as a proxy for ecosystem productivity



The correlation between eMODIS GSN and SSURGO total biomass productivity for grassland is statistically significant (R^2=0.58, ~20,000 random samples) in the GPRB.

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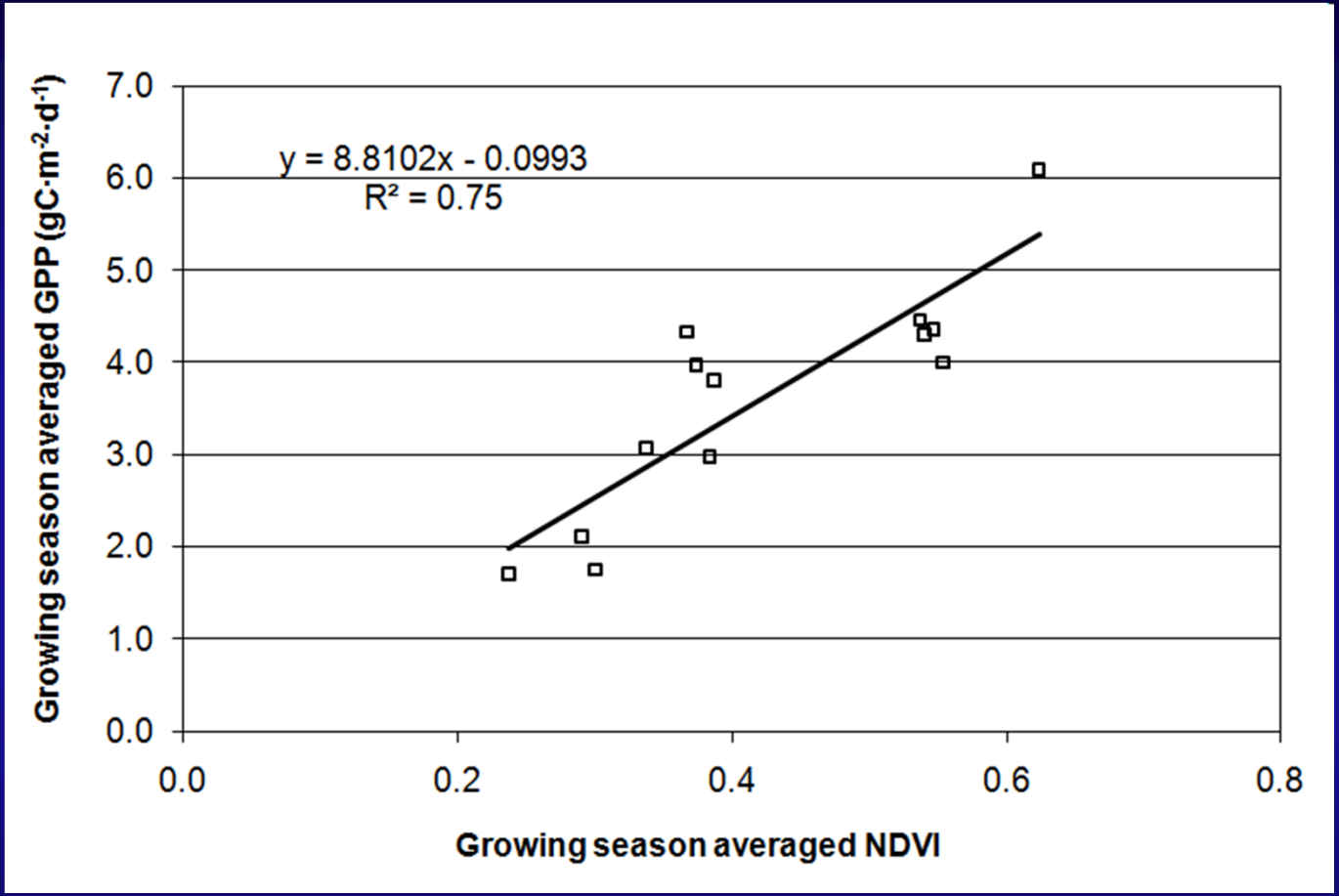
Verification of GSN as a proxy for ecosystem productivity



Strong correlation between GSN and flux tower Gross Primary Productivity (GPP) in the GPRB

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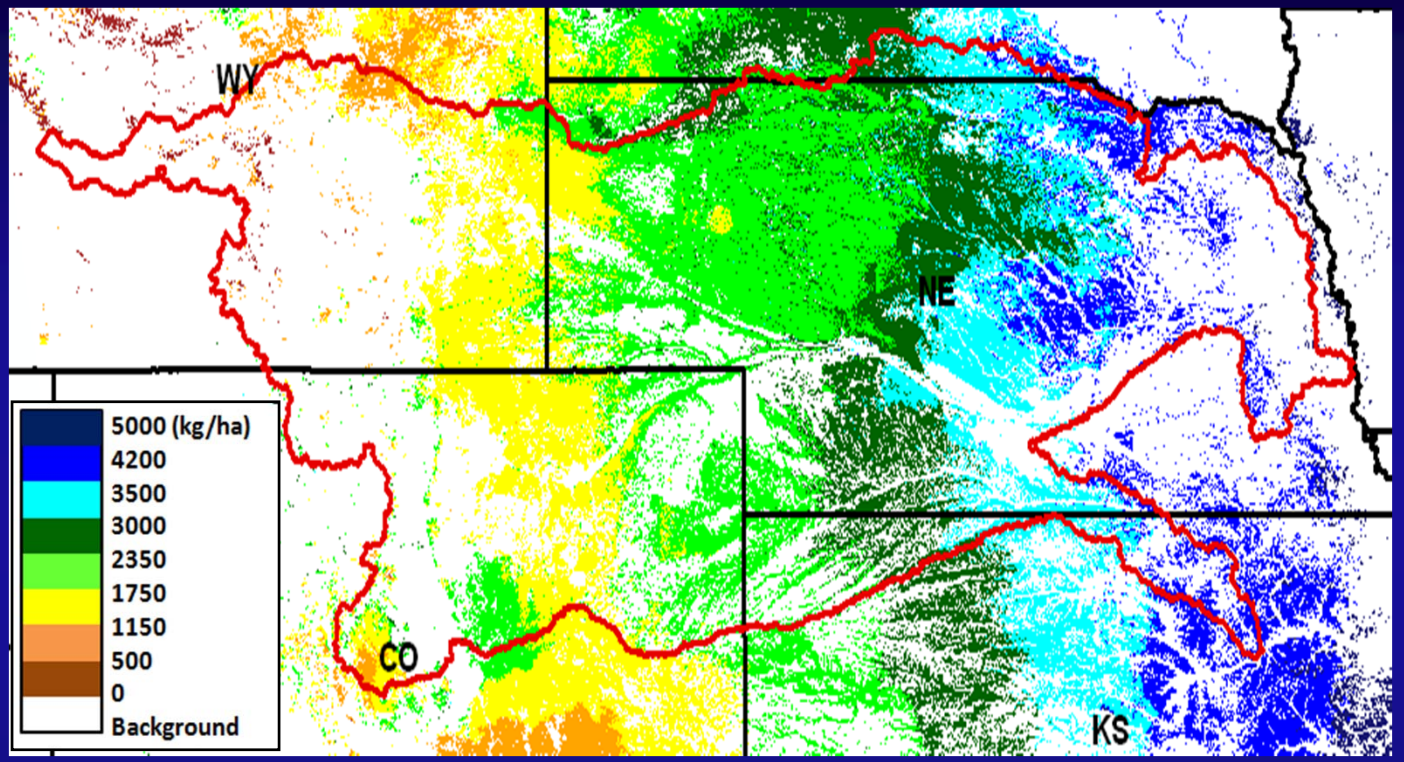
Results: grassland ecosystem site potential map



•The western part of the GPRB has very low grassland productivity: unfavorable vegetation growth conditions (e.g., shallow or rocky soils, high elevation, and less precipitation).

•The eastern part of the GPRB has high grassland productivity: potentially suitable for biofuel feedstock development .

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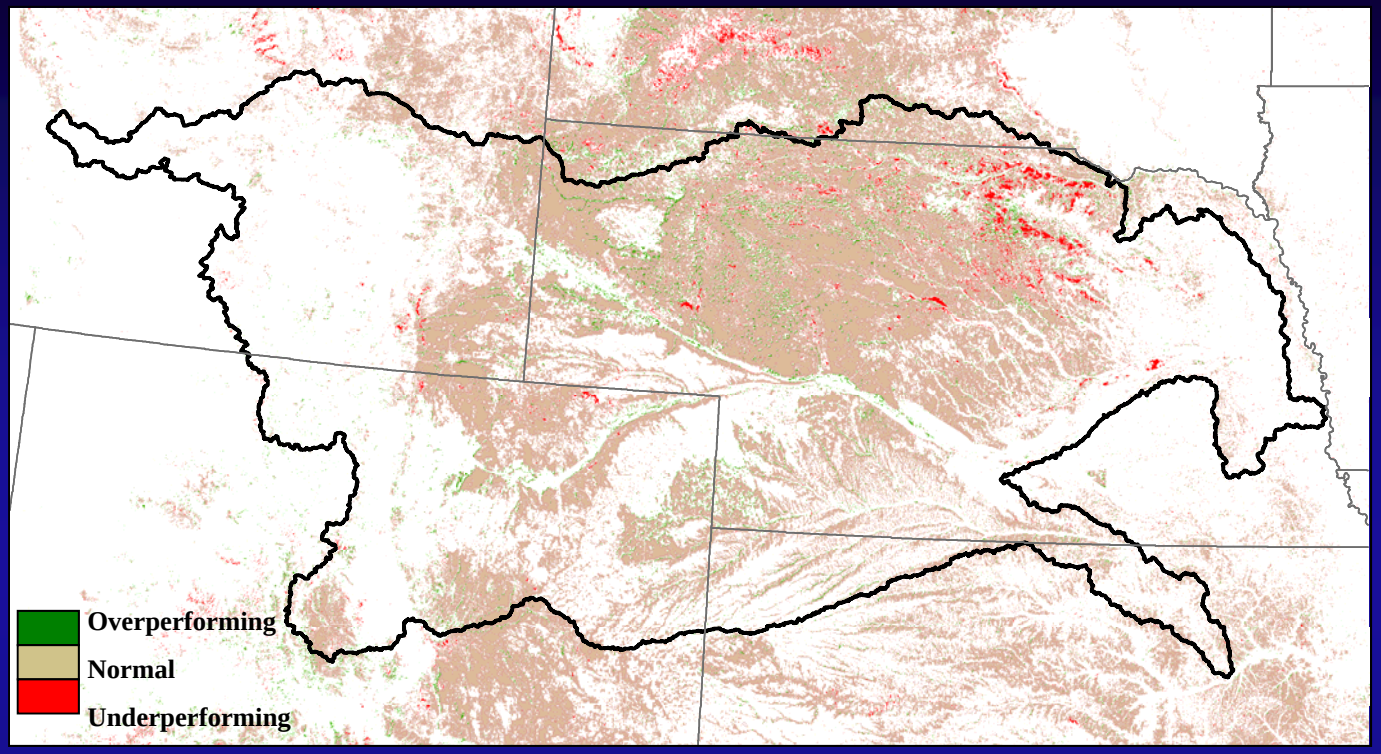
Results: multi-year persistent EPA map for grasslands



- Multiyear (i.e., more than 7 years) persistent EPA map for 2000–2008 in the GPRB.
- Areas identified as underperforming for multiple years (i.e., degraded lands) will not be suitable for biofuel feedstock development.
- Areas identified as overperforming and normal performing (i.e., fair or good range conditions) for multiple years will be potential regions for biofuel feedstock development.

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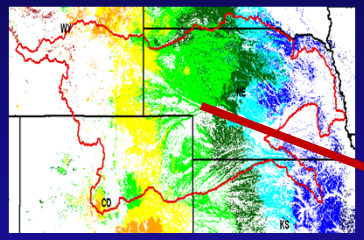
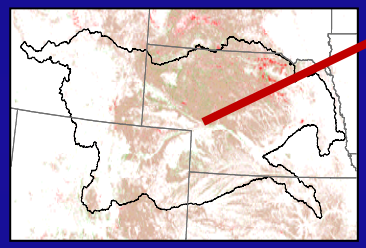
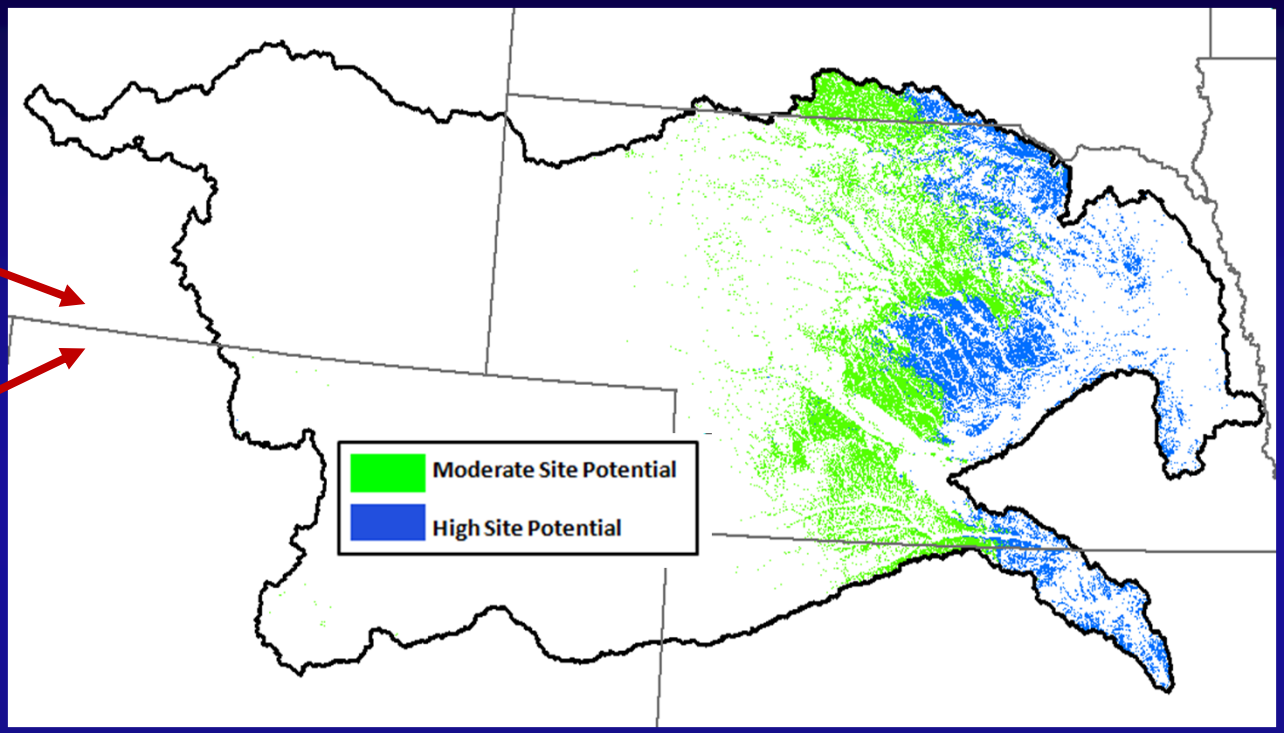
Results for grasslands

Site potential





Multi-year EPA



- Pixels that either overperformed or normally performed and have moderate or high site potential are identified.
- Areas identified as suitable places for biofuel feedstock development are mainly located in the eastern section of the GPRB.

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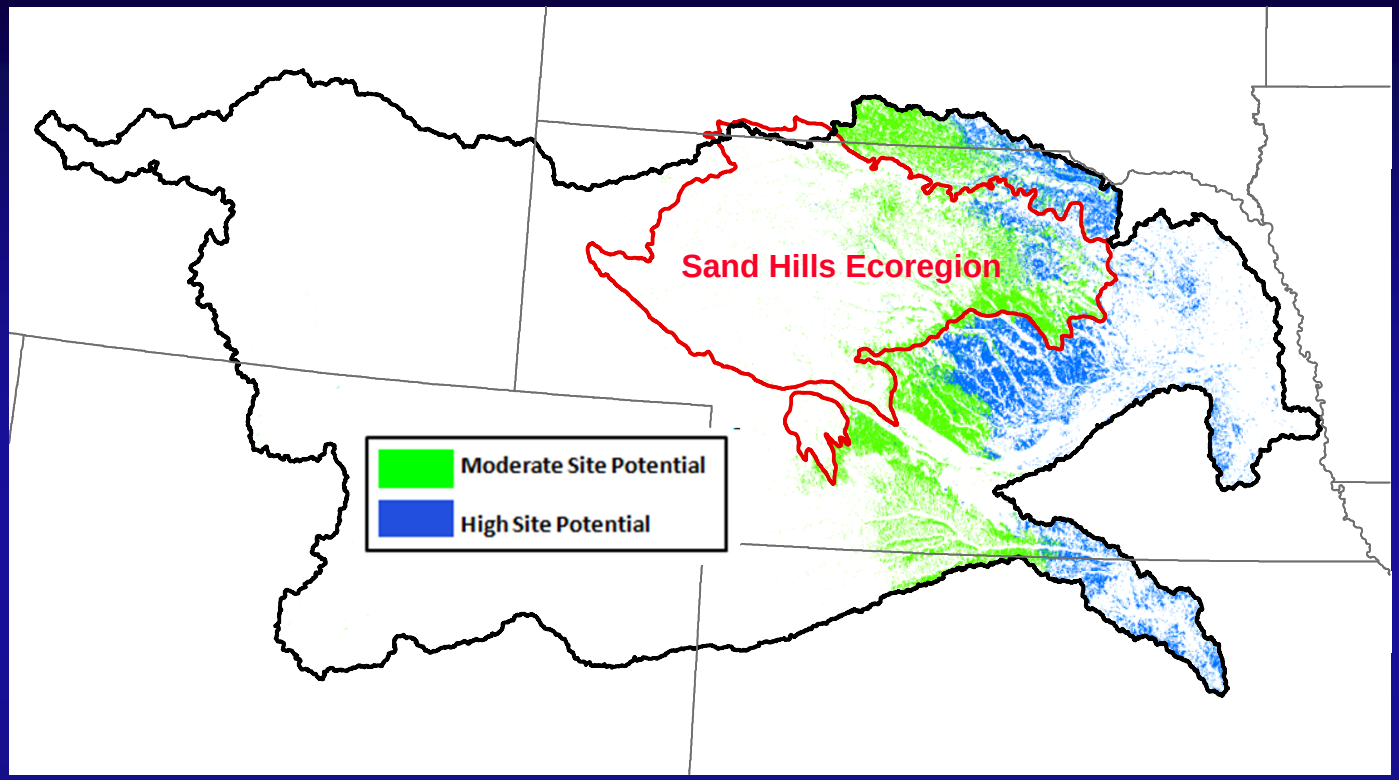
Results for grasslands



- Some areas identified as suitable for biofuel feedstock development are located within the Sand Hills Ecoregion: sand dune systems, sandy soil, native grassland.

- To avoid any undesirable land use and land cover changes (e.g., sand dune activation and erosion), we exclude some Sand Hills areas (i.e., SSURGO available water capacity < 10 cm) from the suitable area for biofuels development.

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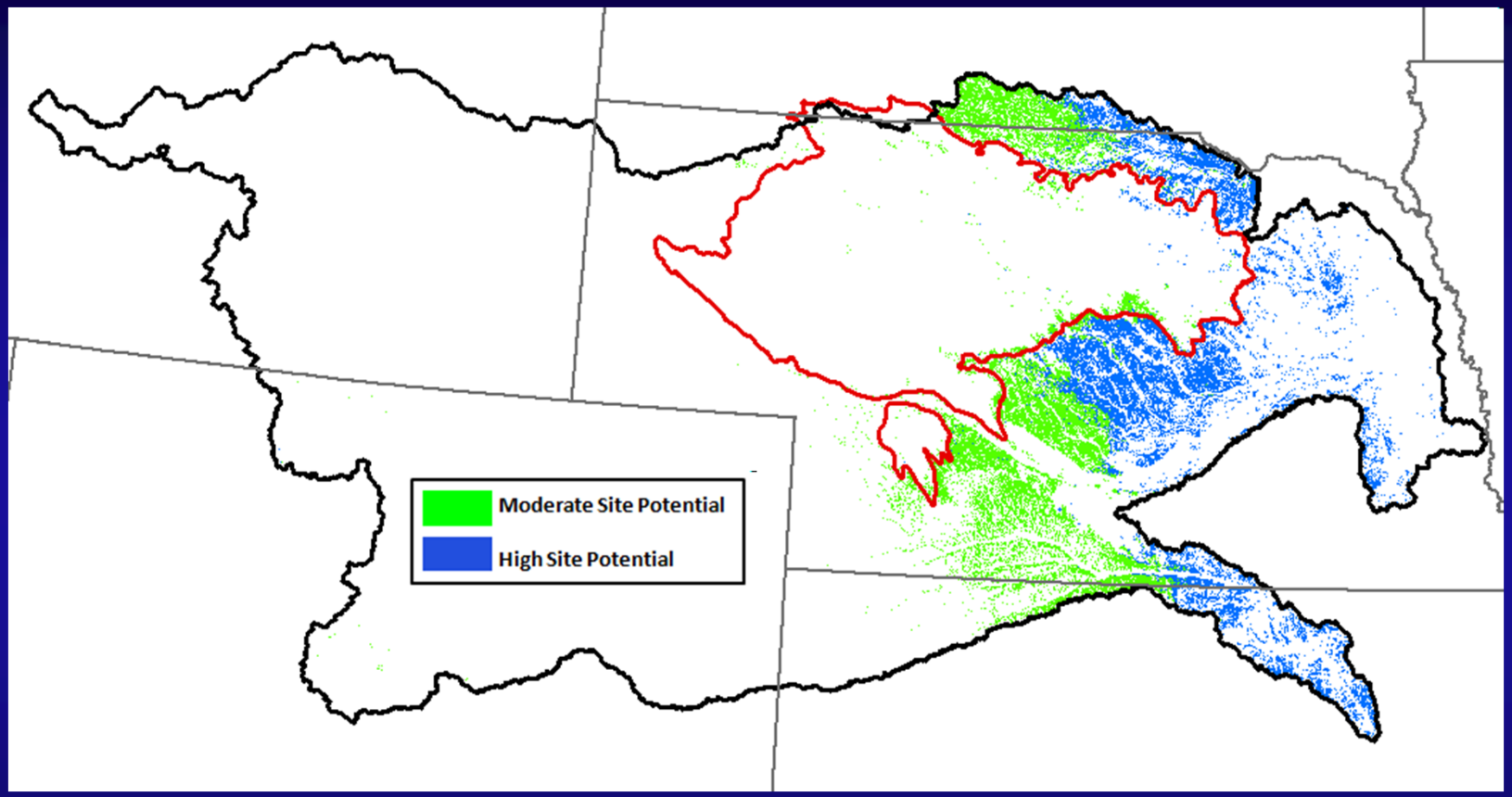
Results for grasslands



Map delineating potentially suitable areas for biofuel feedstocks within the GPRB

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Preliminary results: croplands study

Marginal croplands suitable for conversion to cellulosic feedstocks (e.g., switchgrass):

- **High site potential for grass**
- **Low site potential for crops**

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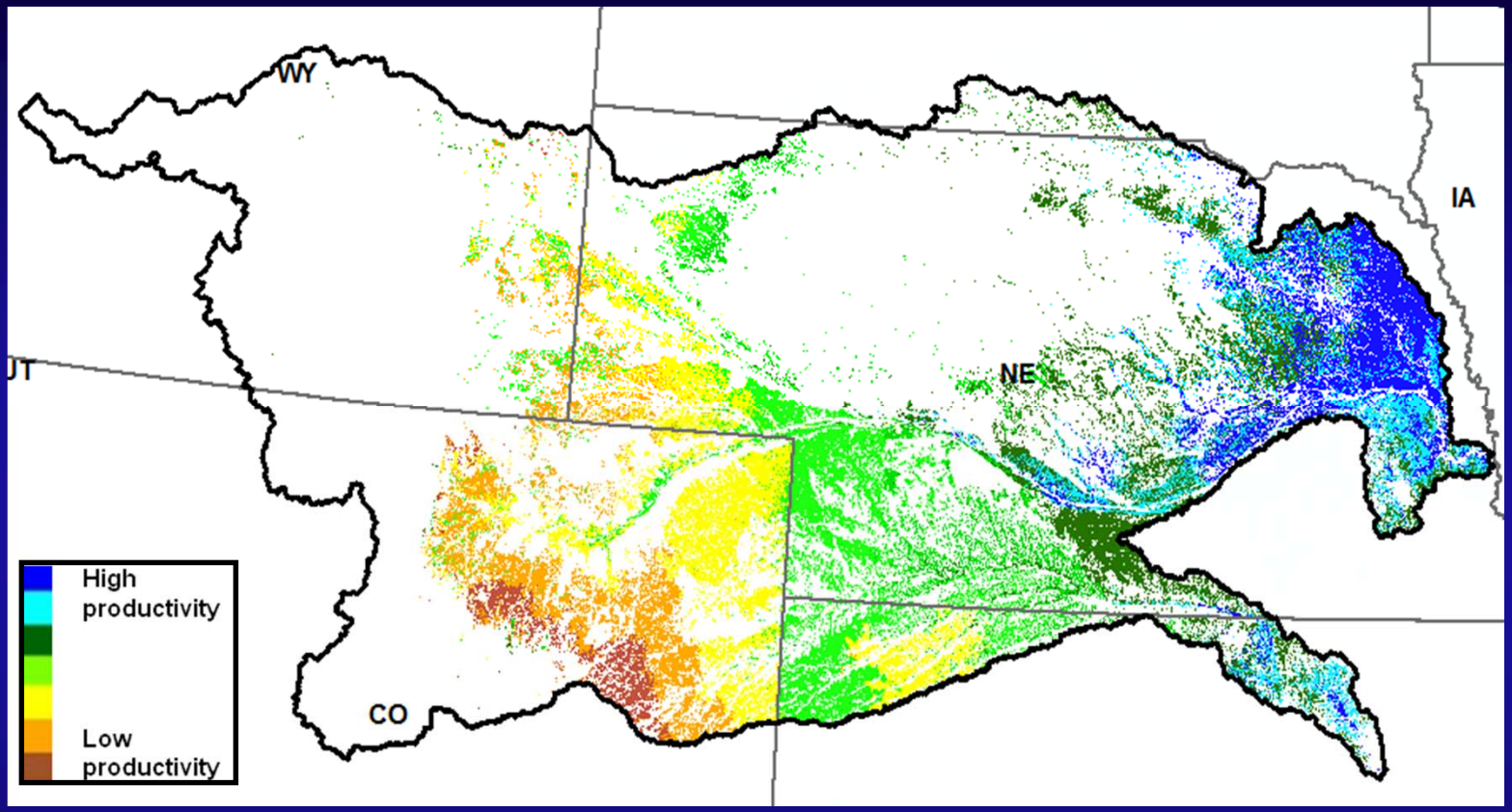
Preliminary results: croplands study



• Ecosystem site potential map for croplands (based on corn model)

•The western part of the GPRB has low site potential: unfavorable vegetation growth conditions

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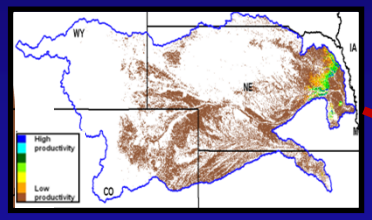
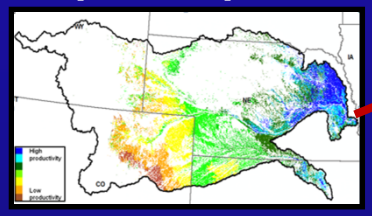
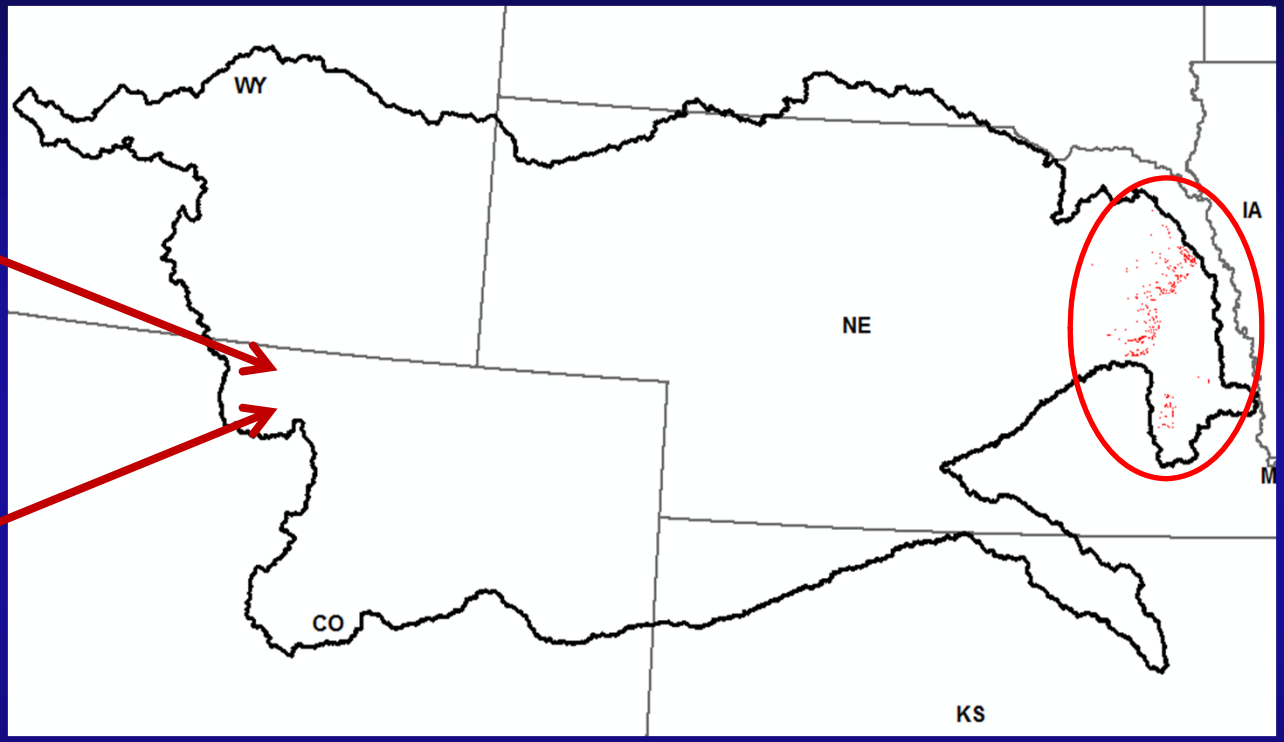
Preliminary results: croplands study

Grass site potential



Crops site potential





Marginal croplands with high (low) site potential for grass (crops) will be potentially suitable for biofuel feedstock development.

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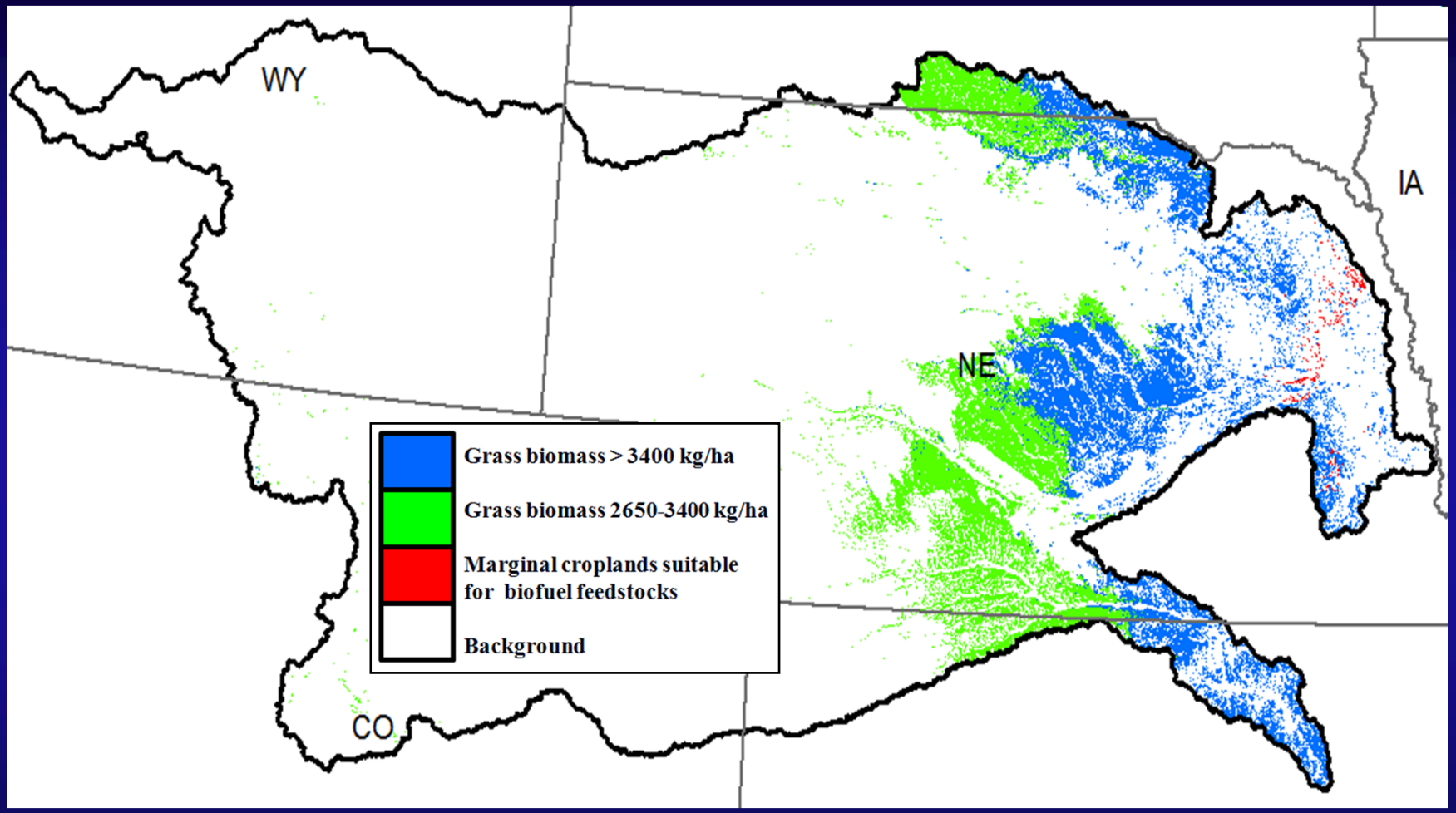
Grasslands and croplands potentially suitable for biofuel feedstocks



Total biomass productivity (for green and blue areas) is ~23 million metric tons

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Conclusions

- This study identified areas potentially suitable for biofuel feedstock development within the GPRB using satellite observations, weather data, and ecosystem performance models.
- Areas with high and moderate ecosystem site potential and persistent ecosystem overperformance or normal performance for grasslands are identified.
- Marginal croplands potentially suitable for conversion to biofuel feedstocks (e.g., switchgrass) are identified.
- The resulting map will be useful to land managers to make optimal land use decisions for biofuel feedstock development and sustainability within the GPRB.

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Future plans

- Predict future (e.g., 2020-2090) grassland and cropland productivity for the Greater Platte River Basin
- Develop NEE (net ecosystem exchange), GPP (gross primary productivity), and Re (respiration) models at a monthly time step, allowing for application to future climates
- Generate future NEE maps for the GPRB
- Evaluate the environmental and climate impacts (e.g., carbon sequestration and land cover changes) caused by biofuel feedstock expansion within the GPRB
- Extend the study area to the Great Plains

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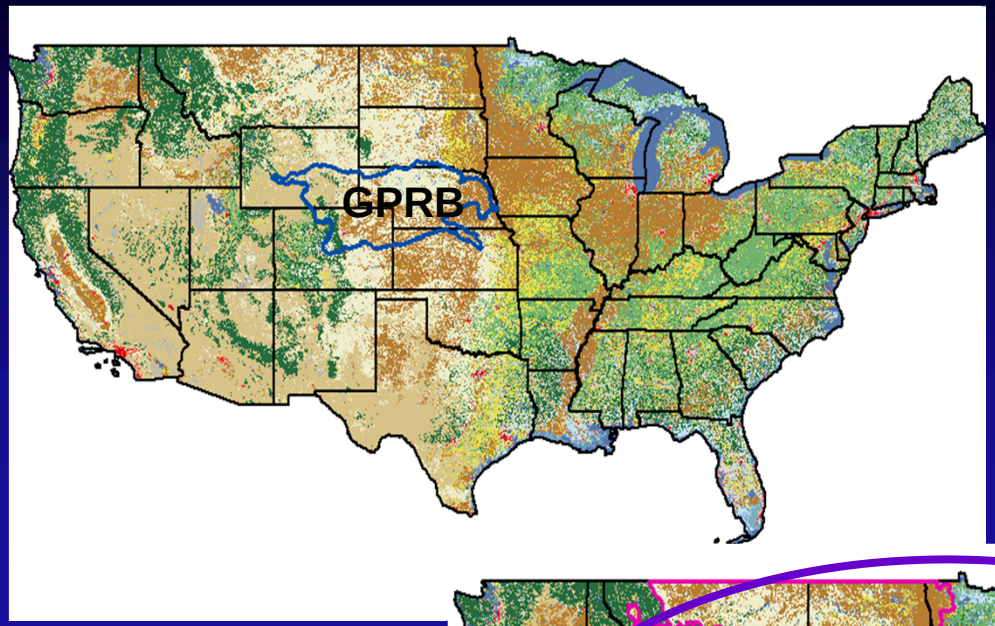
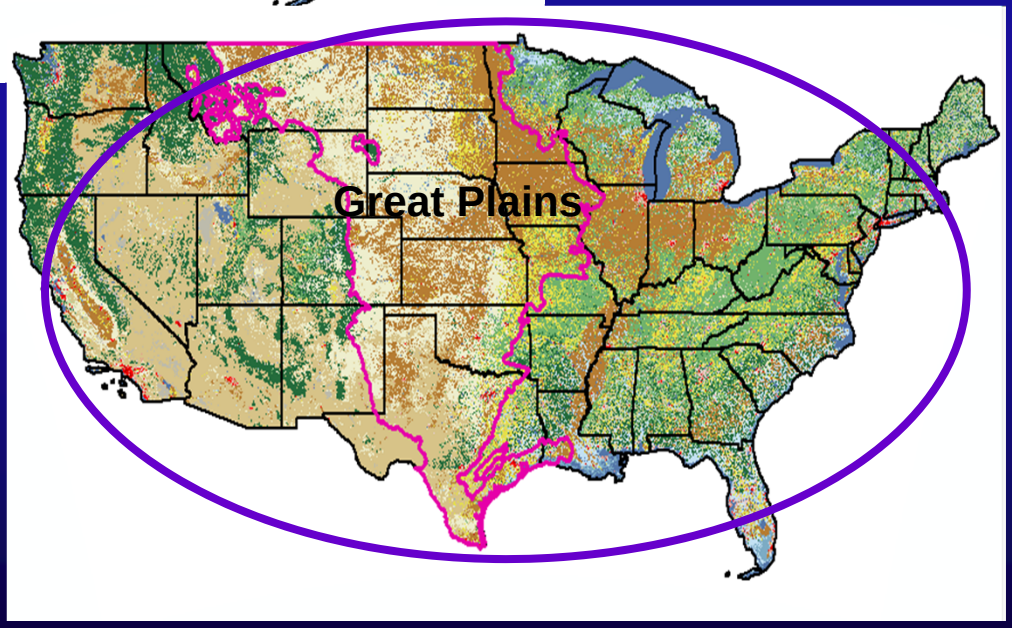


Working



Future

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Publications and Presentations

Publications

- Gu, Y., Boyte, S. P., Wylie, B. K., Tieszen, L. L., 2011. Dynamic Modeling of Ecosystem Performance with 250-m MODIS data: Identifying land suitable for cellulosic feedstocks in the Greater Platte River Basin. Submitted to ***GCB Bioenergy*** and under review.

- Gu, Y., Wylie, B. K., 2010. Detecting ecosystem performance anomalies for land management in the Upper Colorado River Basin using satellite observations, climate data, and ecosystem models, ***Remote Sens.,*** 2010, ***2***(8), 1880-1891.

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Publications and Presentations

Future manuscripts:

- **Gu, Y., Wylie, B. K., Gilmanov, T. G., Bliss, N. B., 2011. The relations between satellite-derived growing season integrated NDVI and grassland biomass productivity over the Greater Platte River Basin: connecting satellite observation to biomass productivity. In preparation to submit to *Remote Sensing of Environment***

- **Mapping marginal croplands for cellulosic feedstocks in the Greater Platte River Basin**

- **Identifying degraded lands over the Greater Platte River Basin and the Upper Colorado River Basin using dynamic modeling of ecosystem performance, 2000-2009**

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Publications and Presentations

Conference Presentations

- Gu, Y., Boyte, S. P., Wylie, B. K., Tieszen, L. L., 2010. Dynamic Modeling of Ecosystem Performance: Identifying land suitable for cellulosic feedstock in the Greater Platte River Basin, 2010 ACES (A Community on Ecosystem Services) conference, Phoenix, AZ. December 6-9, 2010.

- Gu, Y., Boyte, S. P., Wylie, B. K., Tieszen, L. L., 2010. Ecosystem performance assessment for grasslands in the Greater Platte River Basin: Implications for cellulosic biofuel development, 2010 AGU fall meeting, San Franscico, CA, December 13-17, 2010.

- Gu, Y. and Wylie, B. K., 2011. The relationship between satellite-derived growing season NDVI and grassland productivity over the Greater Platte River Basin: connecting satellite observation to biomass productivity, 2011 AAG annual meeting, Seattle, WA, April 12-16, 2011.

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Acknowledgments

•This work was funded by the USGS Geographic Analysis and Monitoring Program in support of Renewable Energy-Biofuels.

•The authors thank Norman Bliss for providing SSURGO soil organic carbon and available water capacity data.

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Thanks!

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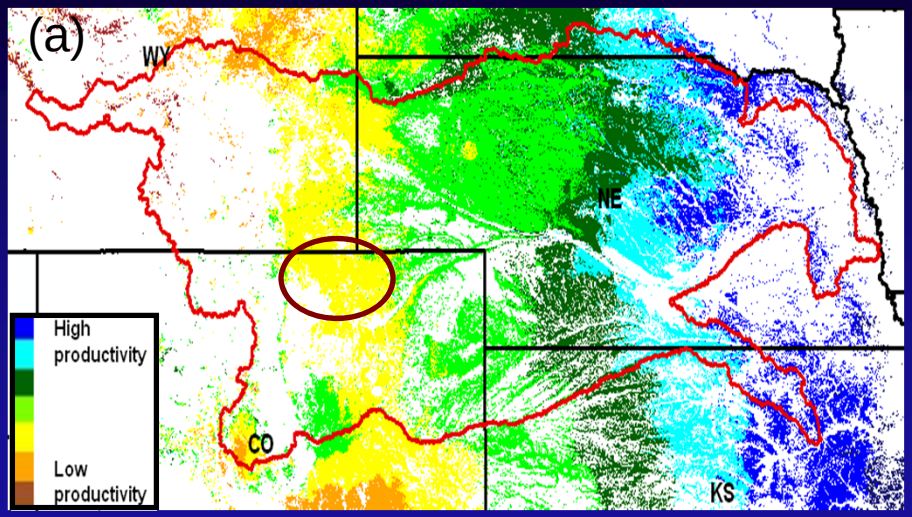
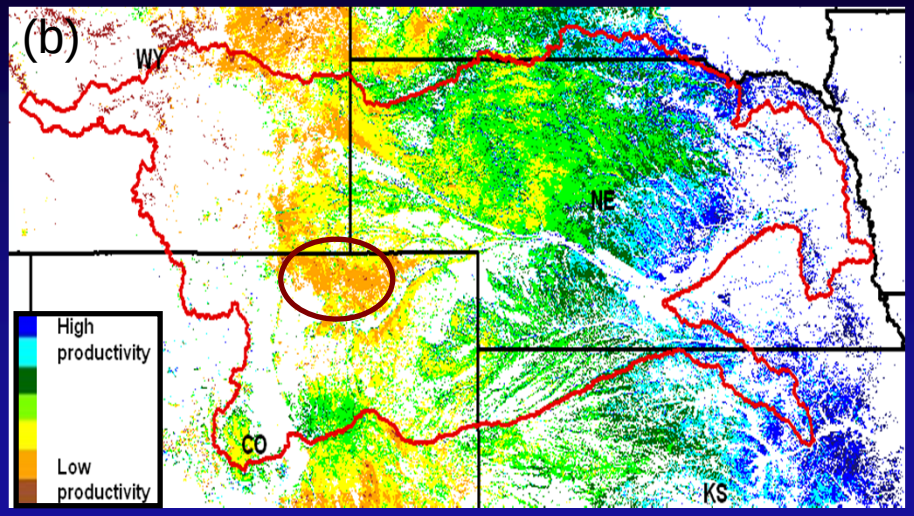
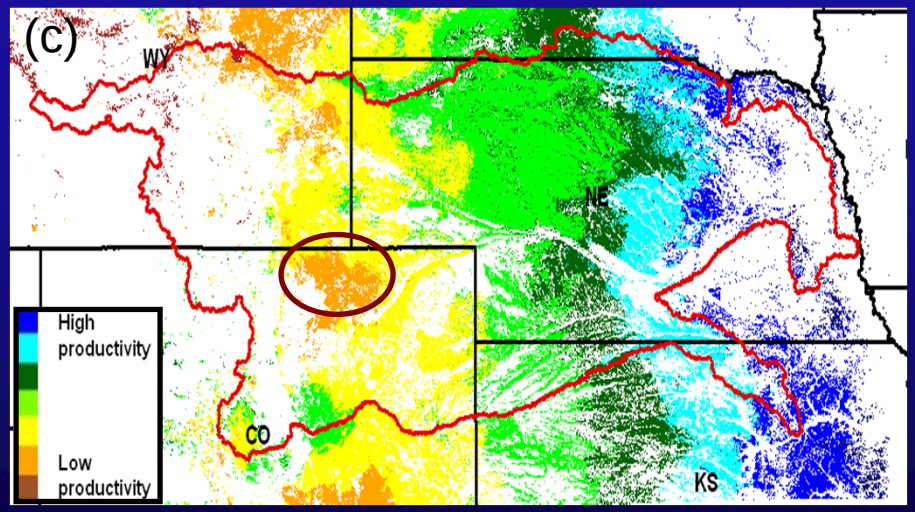
Grassland site potential map



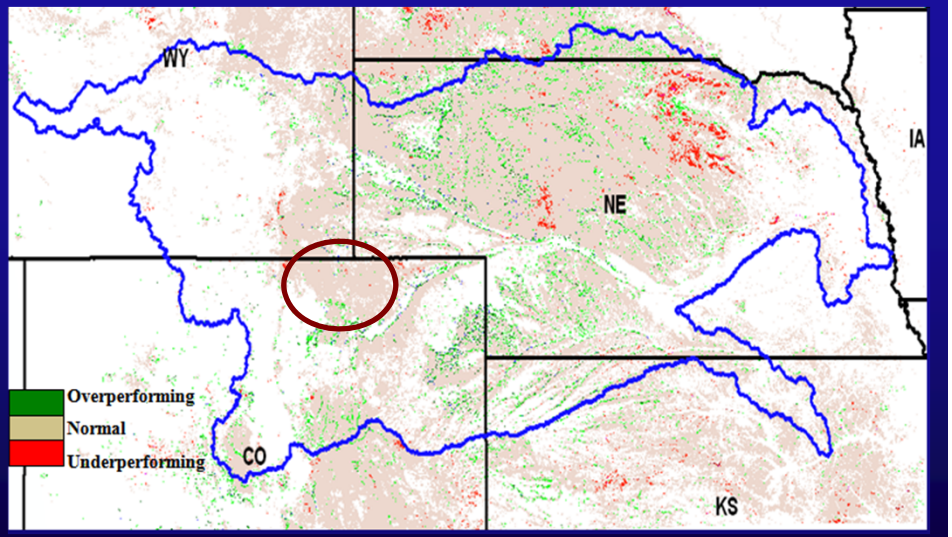
2006 actual EP map



2006 expected EP map



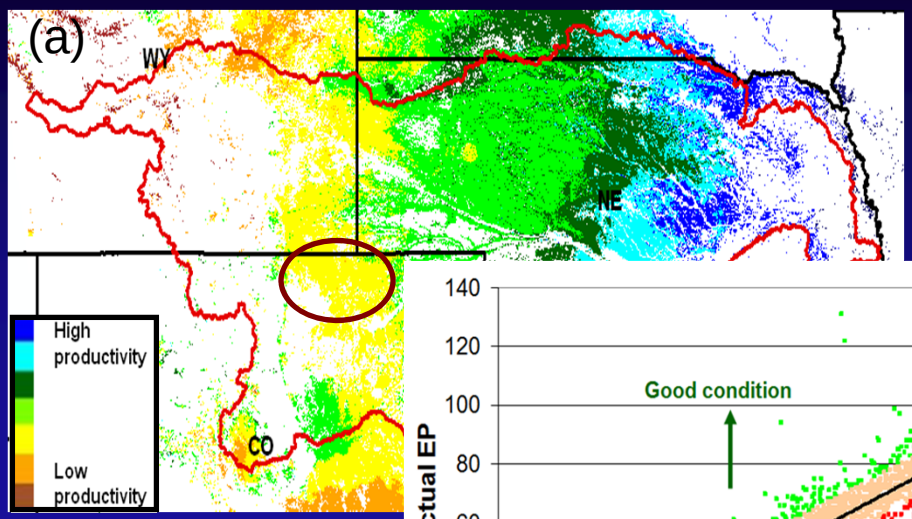
2006 EPA map

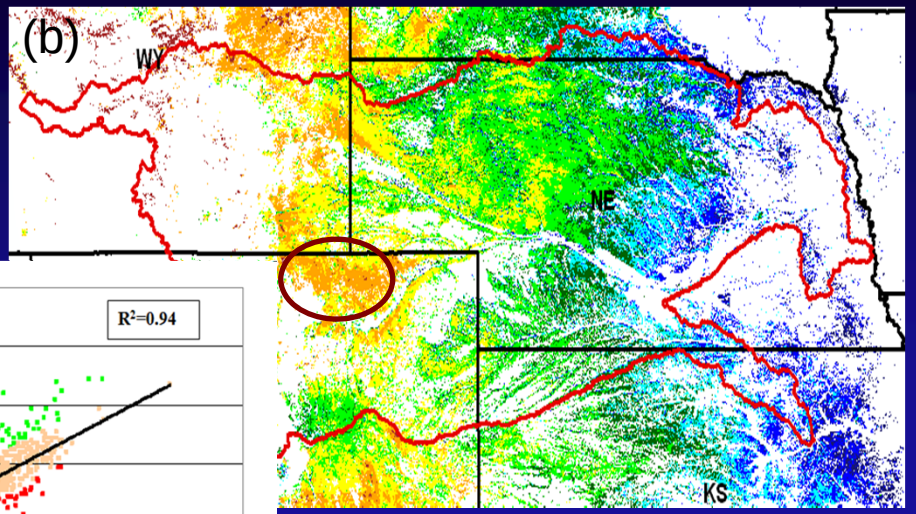


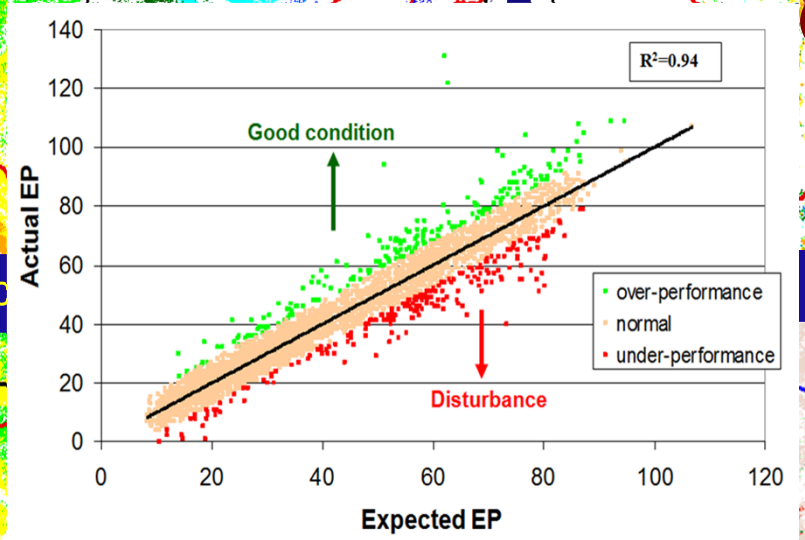
- The general spatial patterns are similar (e.g., productivities increase from west to east).
- Many differences exist because of ecological disturbances and different weather conditions.

Grassland site potential map

2006 actual EP map







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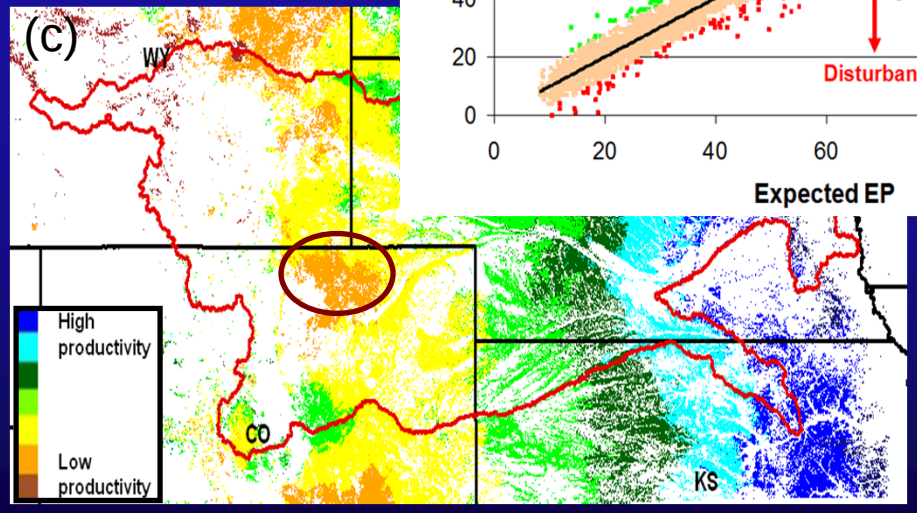

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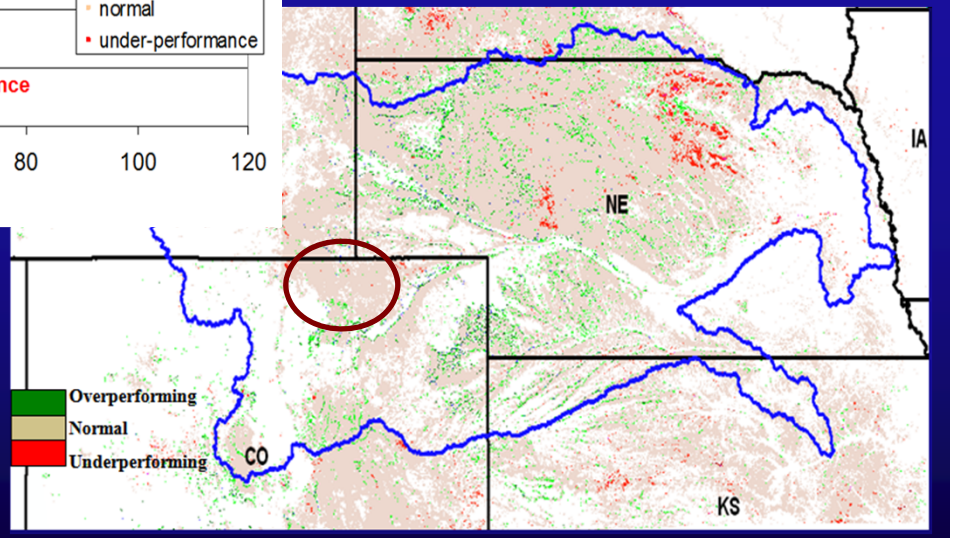

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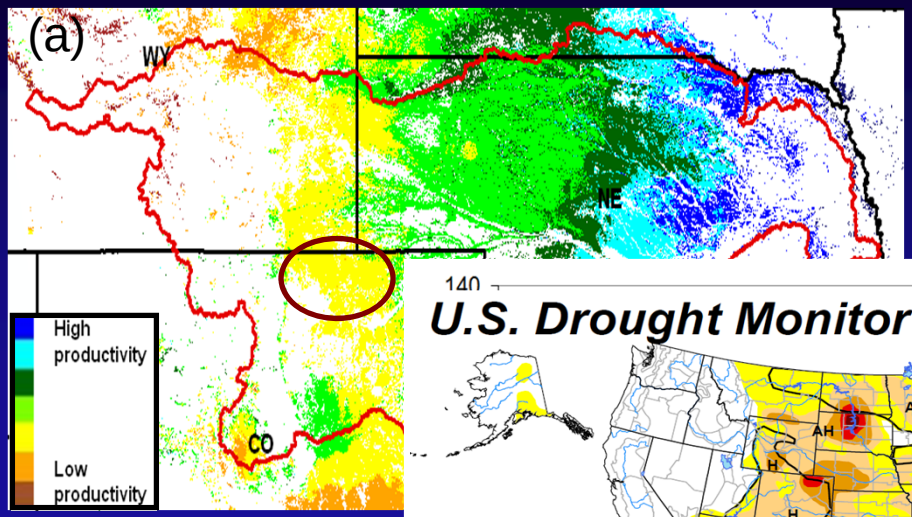

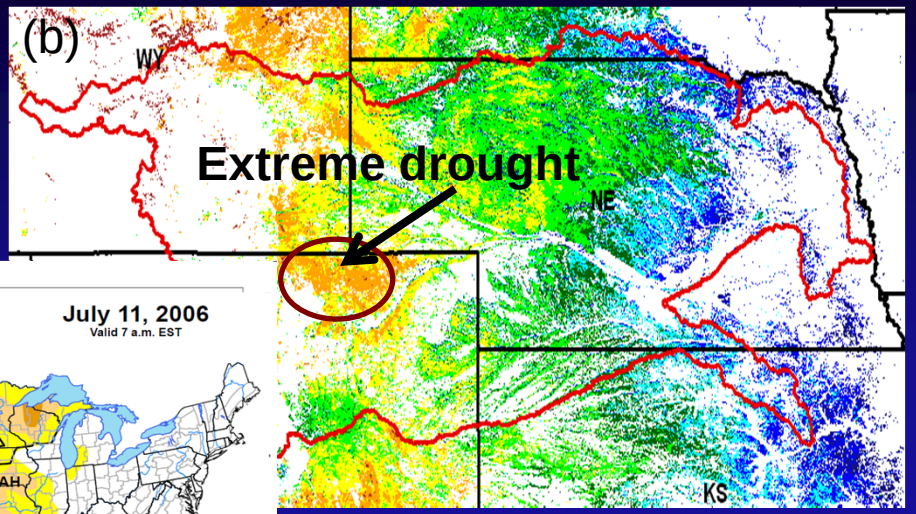

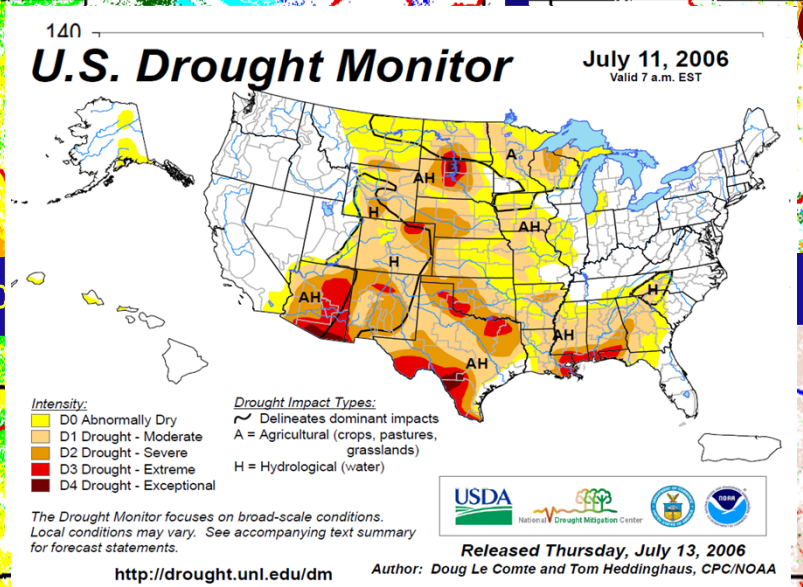

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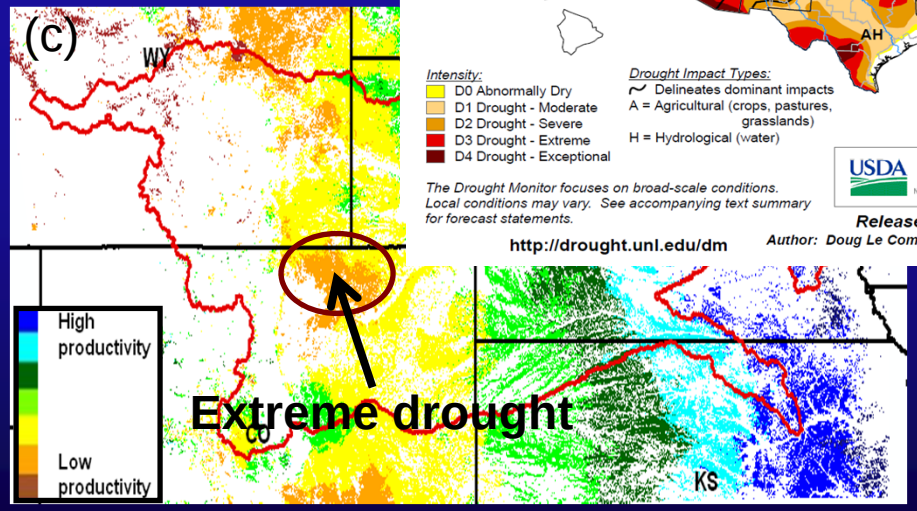

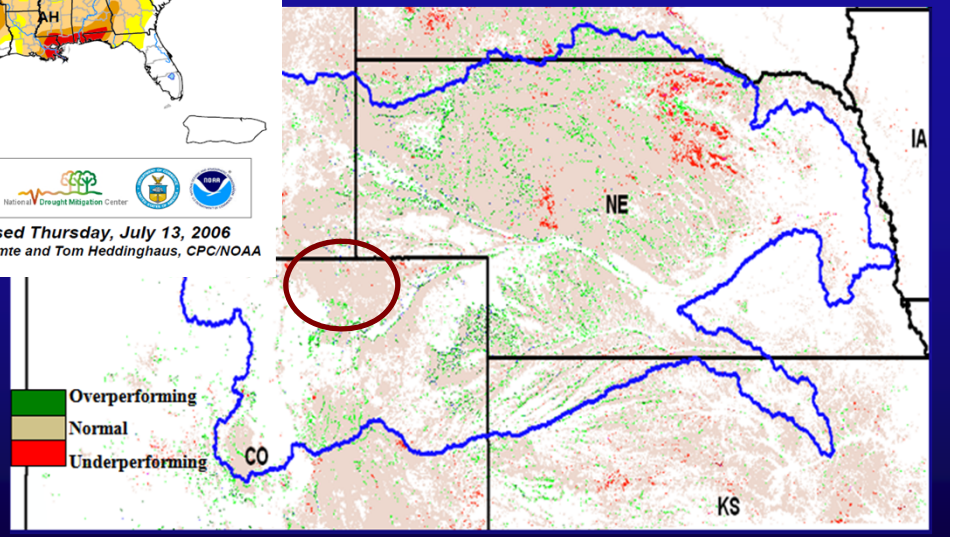

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