Land Change Scenarios in the Northern Great Plains Arising from Extensive Cultivation of Biofuel Feedstocks

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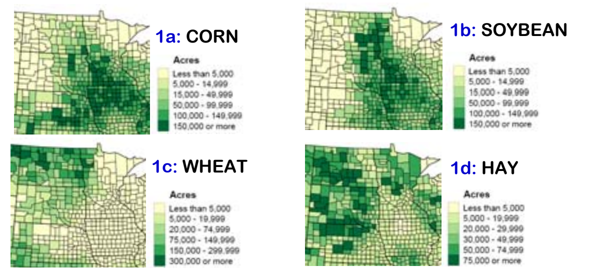
OVERVIEW

- DOE's "Billion Ton Study" explored the feasibility of redirecting plant biomass into production streams to alleviate national dependence on petroleum for transportation fuels. It has generated both support and skepticism, but the likelihood for land cover change in the Northern Great Plains is very high (Tables 1 & 2).
- The region is at the confluence of the western edge of the Corn Belt (Figure 1a, Table 2), the northern limit of soybean production (Figure 1b, Table 2), and the heart of spring wheat production (Figure 1c, Table 2), and historically encompassed the transition from tallgrass to mixed-grass prairies (Figure 2).
- Our project is exploring how changes in regional land cover may affect regional weather patterns during the growing season (due to changes in the timing and amount of evapotranspiration) and the risk of wildfire to feedstock crops (Figure 4). Understanding these potential effects of changes in agricultural land cover is critical for ensuring the sustainable production of biomass feedstocks and for developing strategies to mitigate potentially adverse environmental consequences.
- For the initial spatial distribution of crop area, we use the corn and soybean maps recently generated from MODIS data using a "vegetation continuous fields" approach to crop mapping (Chang et al., 2007; Figure 3). The products' higher spatial and temporal resolution offers as distinct advantage over traditional county level aggregates.
- A key challenge in this research is the spatial allocation of land cover change. The "draw area" of an ethanol plant is a complex and dynamic function of current weather, land productivity, production costs, fuel costs, commodity prices, the spatial configuration of neighboring plants, as well as state and federal policies, subsidies, and incentives.
- Although there are various econometric approaches to forecasting land change, their utility is limited by uncertain markets and governmental policies.
- We will turn instead to a standard approach in the modeling toolbox: Monte Carlo simulations. We will allocate land change in space stochastically by identifying key spatial constraints and linking them to a simple set of equations and rules. By running the change procedure many times, a distribution of potential future land cover patterns can be generated.
- As an initial step we have calculated the production density surfaces ($MGY^{-1}km^{-2}$) for current plants (Figure 5a) and plants under construction or in planning (Figure 5b). The change surface (Figure 5c) provides a spatial estimate of intensification due to new plants or expansion to existing capacity.

Table 1: Land Use Source: 2002 Census of Ag	Harvested Cropland (Mha)	Other Cropland (Mha)	Cropland Used for Pasture (Mha)	Enrolled in CRP or WRP (Mha)	Total Cropland Area (Mha)
Iowa	9.7	0.7	0.5	0.7	11.7
Minnesota	7.9	1.1	0.3	0.7	9.9
Nebraska	7.0	1.3	0.8	0.5	9.6
North Dakota	8.1	2.1	0.5	1.2	12.0
South Dakota	5.5	1.8	1.0	0.5	8.8
Regional Total	38.1	7.1	3.1	3.6	51.8
% of US in area	31%	25%	13%	27%	27%

Table 2: Crops Source: 2002 Census of Ag	Corn (Mha)	Soybean (Mha)	Wheat (Mha)	Hay (Mha)
Nebraska	2.97	1.85	0.62	1.15
North Dakota	0.40	1.06	3.20	1.15
South Dakota	1.28	1.65	0.65	1.48
"Core" Total	4.65	4.56	4.47	3.78
% of US in total area	17%	9%	24%	17%
% of US in production	15%	14%	20%	10%

Figure 1: Crop Area by County 2002 Source: Census of Ag



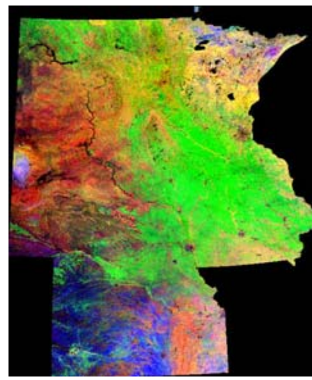


Figure 2: Land Surface Phenology
as revealed by the Wide Dynamic Range Vegetation Index (Gitelson *JPP* 2004; Viña et al. *GRL* 2004; Viña and Gitelson *GRL* 2005):

WDRVI = (α*NIR-red) * (α*NIR+red)$^{-1}$

calculated from USGS AVHRR NDVI biweekly composites for 2000.

Red = DOY 154-167 ➔ JUN02-JUN15
Green = DOY 196-209 ➔ JUL14-JUL27
Blue = DOY 70-83 ➔ MAR10-MAR23

Figure 3: Cropland Continuous Fields from MODIS imagery Chang et al. 2007

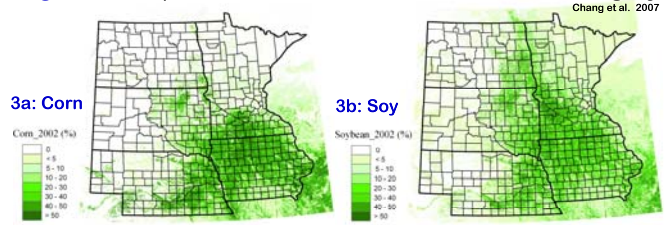


Figure 4: Total "hotspot" detections from MODIS sensors over 6 years. Notice the prevalence of fire occurrences across the region in agricultural areas as well as the larger forest fires in the west. Hotspots can arise from prescribed burning (to clear crop residues & control weeds), wildfires attributable to lightning strikes or accidental ignitions, or industrial activities. Native resolution of these points is $1km^2$ at nadir, but dot size was increased to $\sim35km^2$ to enhance visualization.
Source:http://activefiremaps.fs.fed.us/fireptdata.php

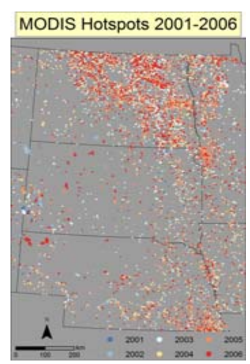


Figure 5a: Current Production Density

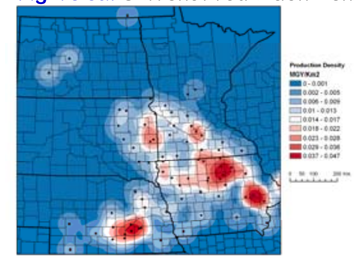


Figure 5b: Future Production Density

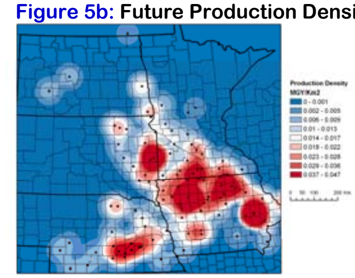


Figure 5c: Change Surface

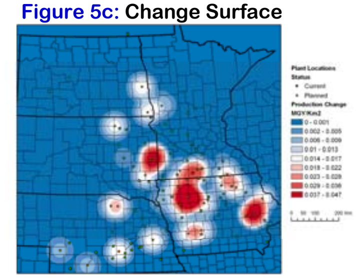


Figure 5: Ethanol production density surfaces ($MGY^{-1}km^{-2}$) calculated from plant location and capacity data using an 80km radius smoothed with a Gaussian kernel weighted by plant capacity.
Sources: Renewable Fuels Association; POET; Archer Daniels Midland; VeraSun Energy; US BioEnergy; Aventine Renewable Energy; Nebraska Energy Office.

References:

Chang, J, MC Hansen, K Pittman, M Carroll, and C Dimiceli. 2007. Corn and Soybean Mapping in the United States Using MODIS Time-Series Data Sets. *Agronomy Journal* 99:1654-1664.

Gitelson, AA. 2004. Wide Dynamic Range Vegetation Index for Remote Quantification of Crop Biophysical Characteristics. *Journal of Plant Physiology*, Vol. 161, 165-173, 2004.

Viña, A and AA Gitelson. 2005. New developments in the remote estimation of the fraction of absorbed photosynthetically active radiation in crops, *Geophysical Research Letters, 32, L17403.*

Viña, A, GM Henebry, and AA Gitelson. 2004. Satellite Monitoring of Vegetation Dynamics: Sensitivity Enhancement by the Wide Dynamic Range Vegetation Index, *Geophysical. Research Letters*, Vol. 31, L04503.

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