Using Spatio-Temporal Analyses to Investigate Crop Migration and Change in the North Central US

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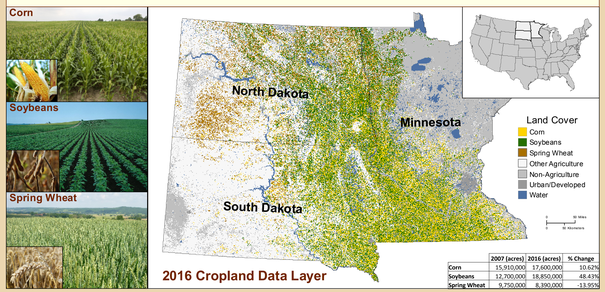
Crop Migration and Change Analysis, 2007 - 2016

Spatio-temporal analyses are utilized to investigate migration and change of three leading crops grown in the North Central region of the United States (Minnesota, and North & South Dakota) over a period of ten years (2007 - 2016). In 2007, the three largest crops in this region by area were corn, soybeans and spring wheat, according to official USDA estimates. By 2016, corn acres changed +10%, soybean acres +48% and spring wheat acres -14%.

To study migration & change, Cropland Data Layer (CDL) crop-specific 30m/56m land cover imagery is downloaded from the CropScape website (https://nassgeodata.gmu.edu/CropScape/) for years 2007 - 2016. 56m images are resampled to 30m for stacking multi-date imagery. Crop Frequency Layer 30m imagery of corn, soybeans & spring wheat for years 2008 - 2016 are also downloaded from CropScape.

The analyses entail creating single-crop images (corn, soybeans, & spring wheat masks) for each year. The crop masks are layered to produce 10-year time stacks for each of the three crops. Multi-temporal tabular and raster analyses are performed for each crop to examine: 1) crop acreage & directional migration trends of crop areas, 2) location and year a crop was first grown and last grown, 3) crop planting frequency, 4) land cover replaced by the crop and 5) 5-year averaged crop rotation patterns. Output results are in the form of maps, graphs & numeric tables.

The analytical results show a north-western expansion of corn and soybeans, and a western migration of spring wheat. Results also indicate these crops supplanted pasture/grassland, non-cropland and other crops, in addition to rotating with each other. Some factors contributing to crop migration/change are profitability of row crops over small grains, modified plant genetics, & farm management program changes. This study can assist to formulate agricultural best practices and monitor & forecast agricultural trends.

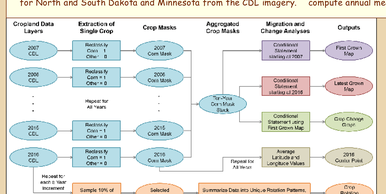


	2007 (acres)	2016 (acres)	% Change
Corn	15,910,000	17,600,000	10.62%
Soybeans	12,700,000	18,850,000	48.43%
Spring Wheat	9,750,000	8,390,000	-13.95%

Analysis Flow Model and Conditional Statements

A ten-year sequence of Cropland Data Layer raster imagery is used in the analysis. The first step is to create 10-year binary crop mask stacks of single crops (corn, soybeans, spring wheat) for North and South Dakota and Minnesota from the CDL imagery.

A series of conditional statements iterate through the ten crop masks to derive first & latest years a crop was grown, and percent and type of land cover initially replaced by a crop. Other analyses compute annual mean crop centers and crop rotation patterns.



First Grown

Conditional Statement	Output
If 2007 Corn Mask = 1	First Grown = 2007
Else if 2007 Corn Mask = 0 & 2008 Corn Mask = 1	First Grown = 2008
...	...
Else if 2008 – 2015	...
Else 2016	...

Latest Grown

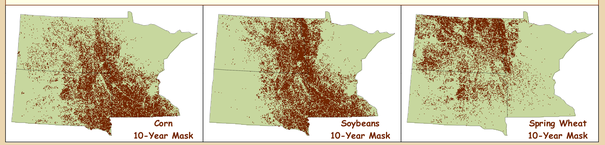
Conditional Statement	Output
If 2016 Corn Mask = 1	Laicst Grown = 2016
Else if 2016 Corn Mask = 0 & 2015 Corn Mask = 1	Latest Grown = 2015
...	...
Else if 2008 – 2015	...
Else 2007	...

Crop Change from Previous Year

Conditional Statement	Output
If First Grown = 2016	Crop Change = CDL 2015
Else if First Grown = 2015	Crop Change = CDL 2014
...	...
Else if First Grown = 2009	Crop Change = CDL 2008
Else if First Grown = 2008	Crop Change = CDL 2007

Multi-Year Raster Crop Mask Stacks for Individual Crops

To create 10-year raster crop mask stacks used in tabular & raster analyses: 1) extract CDL data for states MN, ND, SD & years 2007 - 2016 from CropScape portal, 2) create crop masks for each state & year by reclassifying pixels to 1 for a specific crop and to 0 for everything else, 3) stack each crop mask for all ten years to form a single dataset for each crop type (corn, soybeans, spring wheat).



Multi-Temporal Composites - First Year Crop Grown

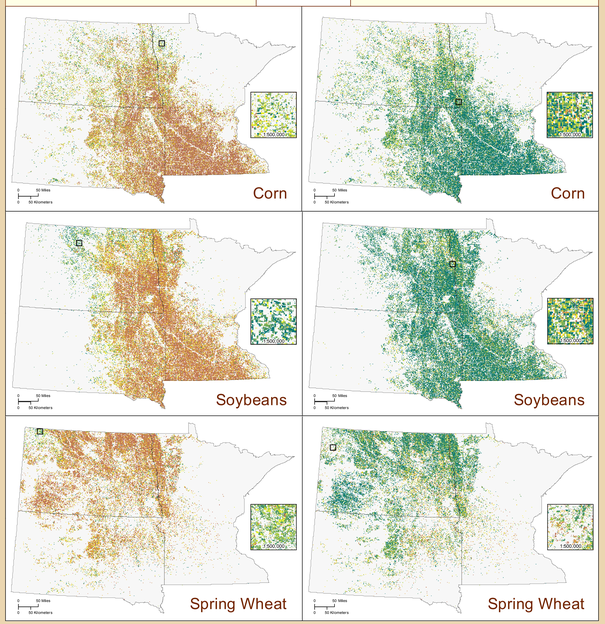
The multi-temporal composite maps show ten years (2007 - 2016) of raster crop data combined. The maps below, focus on - **Where and when was a crop first grown in the ten-year sequence?** In the analysis, a crop pixel is assigned to the year it is **first** present in the CDL. E.g., if the corn mask contains pixels in 2007, they are classified as first grown in 2007. If no corn pixels exist in 2007, but exist in 2008, they are classified as first grown in 2008, and so on to 2016. Corn/soybeans grew in areas more west/north after 2010.

Year Grown
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016

Multi-Temporal Composites - Latest Year Crop Grown

The maps below, reflect - **Where and when was a crop last grown in the ten-year period?** In the analysis, a crop pixel is assigned to the year it is **last** present in the CDL from 2007 - 2016. Corn/soybeans last grown in 2012 or earlier reside along the Minnesota-N. Dakota border and in central S. Dakota. In NW North Dakota, spring wheat at times replaces durum wheat.

A diverging color scheme depicts the year grown, using darker hues to emphasize early and recent years at the ends of the time period.

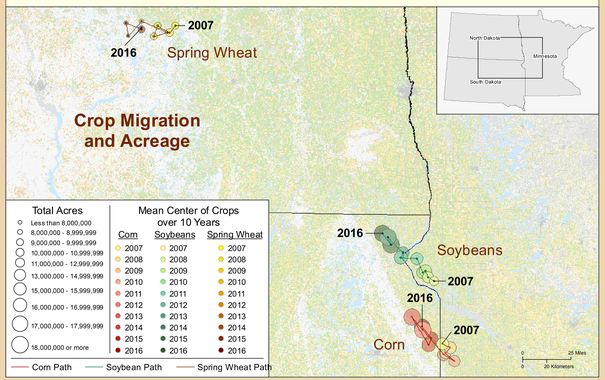


Crop Migration and Acreage, 2007 - 2016

The Crop Migration and Acreage map illustrates yearly mean centers and crop acreages for corn, soybeans and spring wheat, to answer - **Is there a directional trend to the overall migration of crop areas and has crop acreage changed from 2007 - 2016?**

To calculate the mean center, crop masks for the North Central region are generated to isolate pixels of a certain crop type (corn, soybeans, spring wheat). Latitude-longitude values are appended to the crop pixels. The global mean of all latitude and longitude coordinates are calculated and mapped as the mean center of the crop area, this is repeated for each year. A northwest migration pattern is evident for corn & soybeans, and a western migration trend for spring wheat.

Mean crop centroids summarize raster data to discreet points and are portrayed on the map as small, colored circles linked by thin, colored lines representing migration paths. Annual crop acreages are calculated and illustrated by colored, graduated circles.



Crop Change from Previous Year, 2007 - 2016

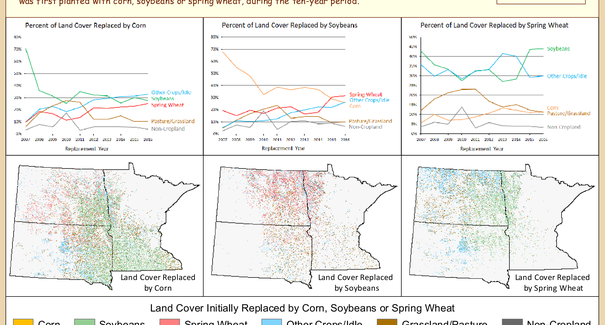
When examining crop change, it is important to know - **What land cover was replaced by the new crops grown?** Pixel-level analysis identifies what land cover type was replaced when corn, soybeans, and spring wheat were first grown. For example, if a corn pixel first appears in the 2016 CDL, the analysis looks at the corresponding pixel in the previous year's (2015) CDL and determines its land cover type. Land cover types are categorized into: corn, soybeans, spring wheat, other crops/idle, pasture/grassland, and non-cropland.

The graphs below, represent percentage and type of land cover a crop replaced when it was first grown in the ten-year sequence. Comparison of graphs shows evidence of follow-ing cropland and conversion from uncultivated to cultivated land. The Replaced Land Cover maps illustrate the type of land cover that was present the year **prior** to when the land was first planted with corn, soybeans or spring wheat, during the ten-year period.

10-Year Average of Land Cover Replaced by Soybeans
Corn: 40.88%
Spring Wheat: 21.15%
Pasture/Grassland: 13.87%
Other Crops/Idle: 15.82%
Non-Cropland: 8.32%

10-Year Average of Land Cover Replaced by Corn
Soybeans: 34.53%
Spring Wheat: 18.34%
Pasture/Grassland: 16.06%
Other Crops/Idle: 24.63%
Non-Cropland: 6.45%

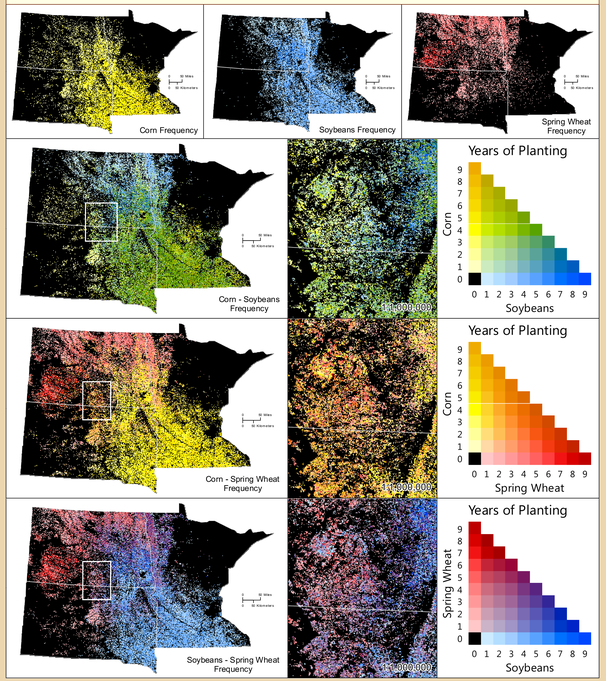
10-Year Average of Land Cover Replaced by Spring Wheat
Corn: 9.78%
Soybeans 34.83%
Pasture/Grassland: 16.71%
Other Crops/Idle: 33.36%
Non-Cropland: 5.32%



Planting Frequency of Crops, 2008 - 2016

Crop planting frequency maps address - **Where are the predominant crop growing regions for years 2008 – 2016?** The maps display the weighted number of years (frequency) that a crop was grown, though not necessarily consecutively. To create the data layers, the nine years of CDLs are recoded to represent only the crop of interest (corn, soybeans, spring wheat), then the individual years of crop-specific CDLs are added together to calculate a planting frequency count per pixel. Corn and soybeans grow in similar areas in North Dakota (ND), South Dakota (SD) and Minnesota (MN), while corn extends more west and soybeans more north. Spring wheat grows all over ND, and in parts of MN and SD.

On the single and bivariate maps, dark hues indicate crops grown more often, light hues depict crops grown less often. The bivariate maps show where two crops grew in the same area in 2008 - 2016.



Land Cover Rotation Patterns 2007-2016

Analyzing land cover for differences in crop rotations and substitutions answers - **What are the most common land cover rotation patterns?** In different years, farmers alternate planting corn, soybeans and spring wheat with each other, fallow land and crops, to preserve soil nutrients. The methodology to derive the most common rotation patterns for corn, soybeans and spring wheat is: 1) Sample 10% of cultivated land, 2) Group rotation patterns by rolling 5-year increments (2007-2011, 2008-2012, ... 2012-2016), and 3) Reduce dimensionality of data by summarizing results of patterns for like crops (see graph). Below are examples of unique rotation patterns summarized into a single Corn-Soybean pattern:

Corn – Soybean – Corn – Soybean – Corn
Soybean – Corn – Soybean – Corn – Soybean
Soybean – Corn – Soybean – Corn – Corn