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Land-use Change in the U.S.

Recent results, accuracy, and implications

Tyler J. Lark and Holly Gibbs

University of Wisconsin-Madison

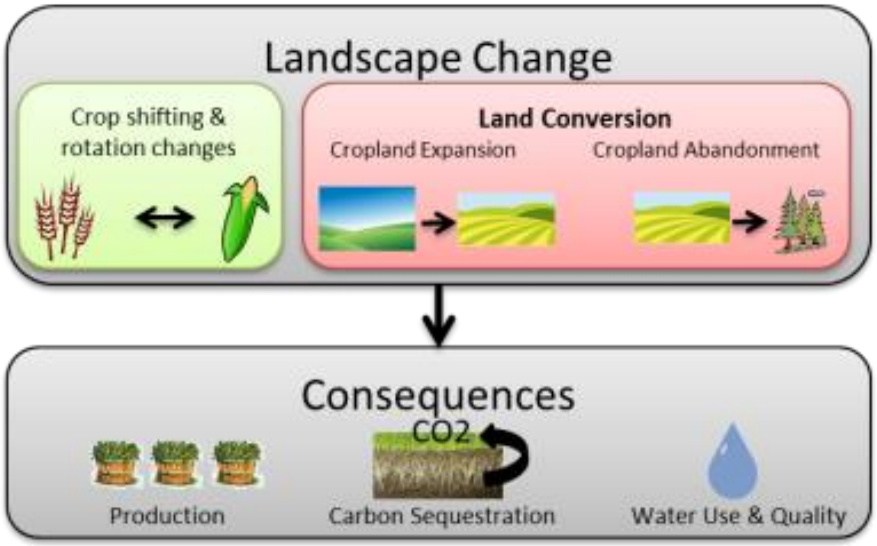
October 28th, 2015

Main results:

Lark, Salmon, and Gibbs. "**Cropland Expansion Outpaces Agricultural and Biofuel Policies in the United States**." *Environmental Research Letters.* (April 2, 2015)

Cropland conversions in the U.S. 2008-2012

- Where? What crops?
- What land sources?
- What impacts?



- Previous studies:
  - High levels of land conversion detected regionally
  - Cropland dynamics **yet to be comprehensively assessed at national level**

- We fill that data gap → insights to federal policies
  - 2014 Farm Bill (crop insurance, CRP)
  - Enforcement of Renewable Fuels Standard

Overview of Approach

- Satellite time coverage:
  - USDA – 2008-2012
  - MRLC – 1992-2011
  - USGS – back to 1970s

- Spatial-temporal processing
  - Include all crops and rotations
  - Track ***net*** and ***gross*** changes

- First nationwide assessment to be:
  - Field-level and crop-specific
  - Consistent with all available data from USDA

USDA Cropland Data Layer (CDL)

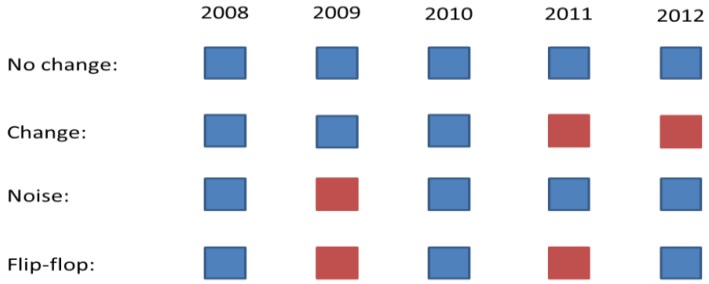
+

&

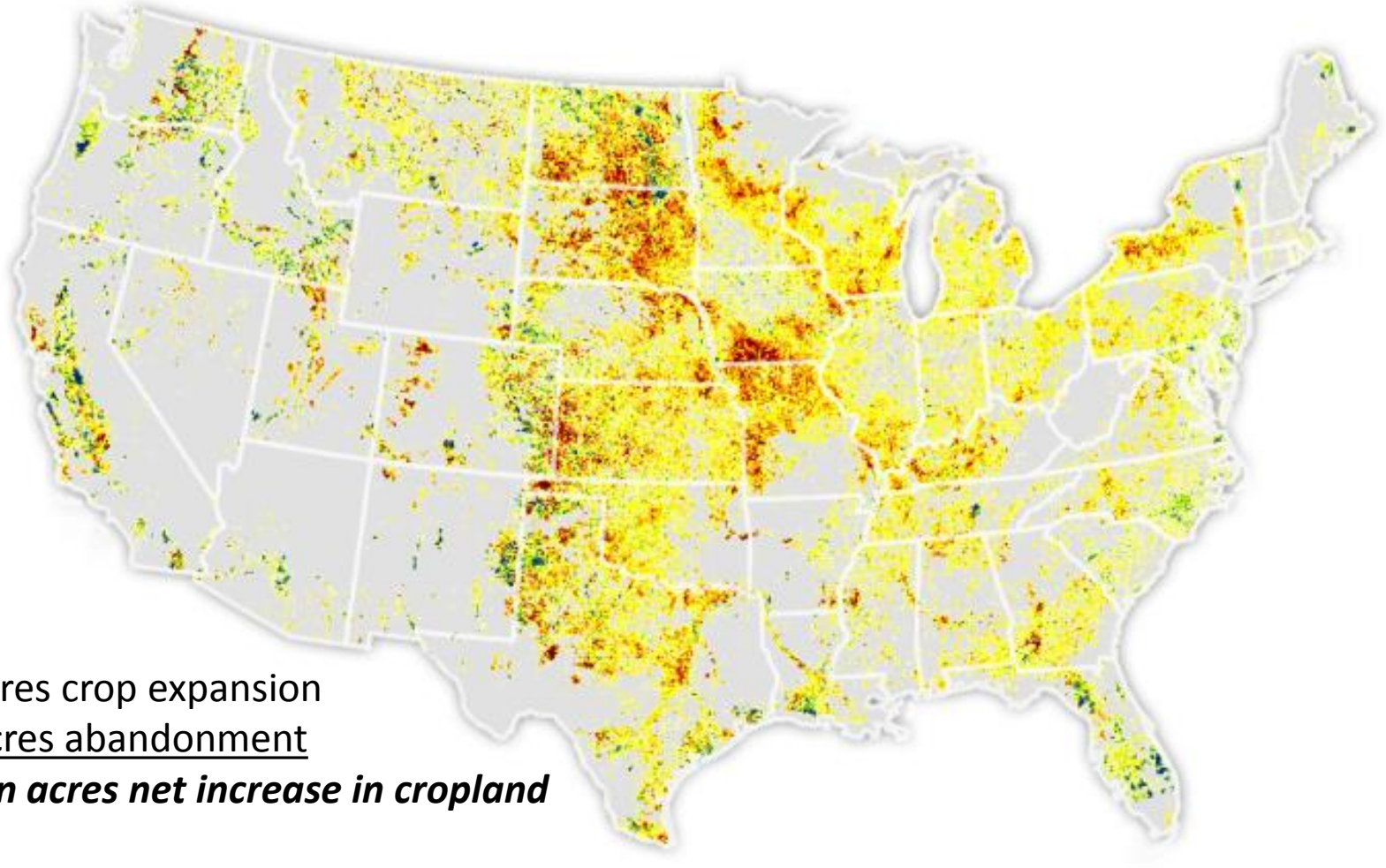
MRLC National Landcover Database

USGS Land Cover Trends Dataset

Trajectory-based Analysis

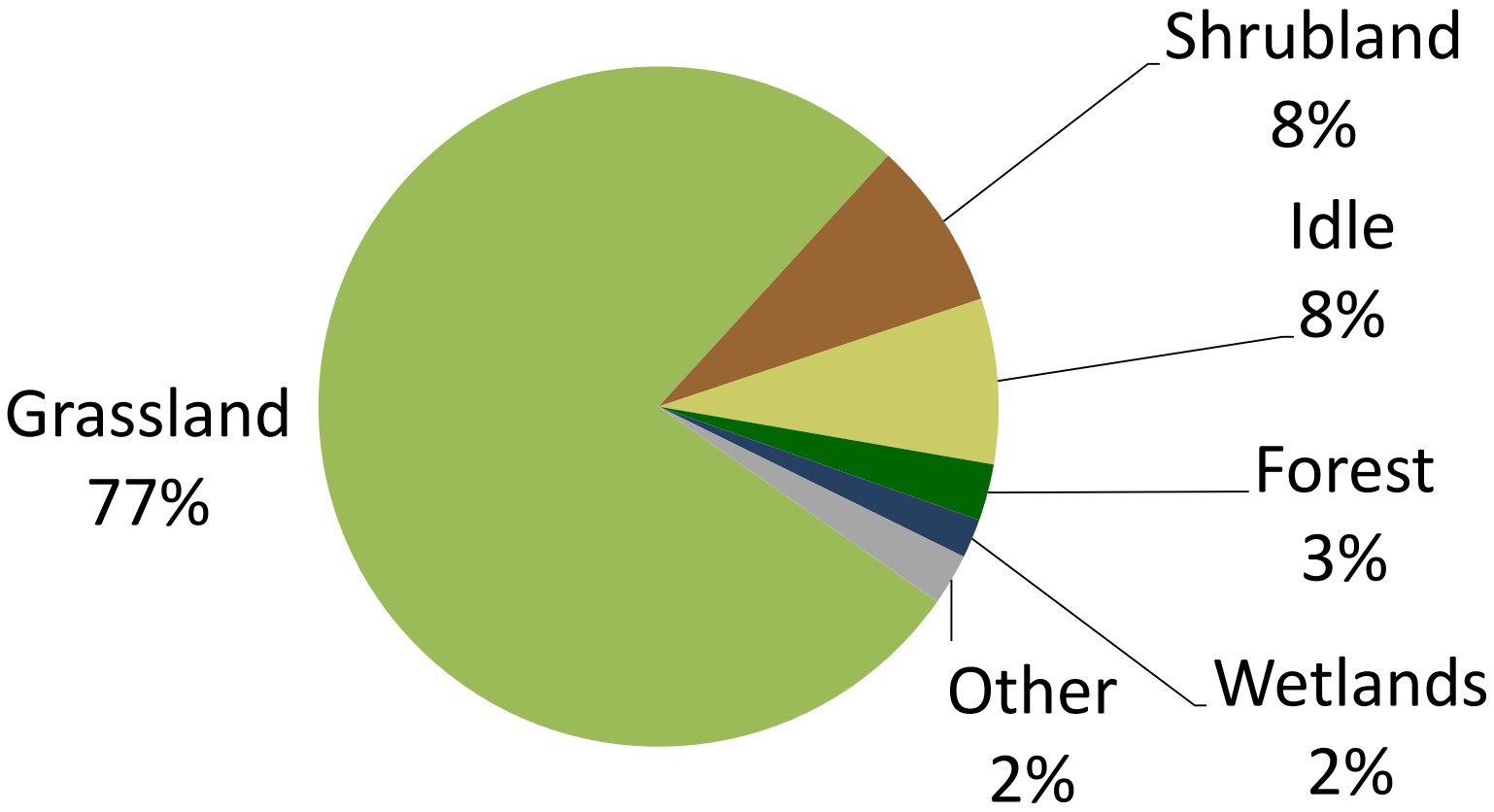


7 million acres of land converted to crop production 2008-2012

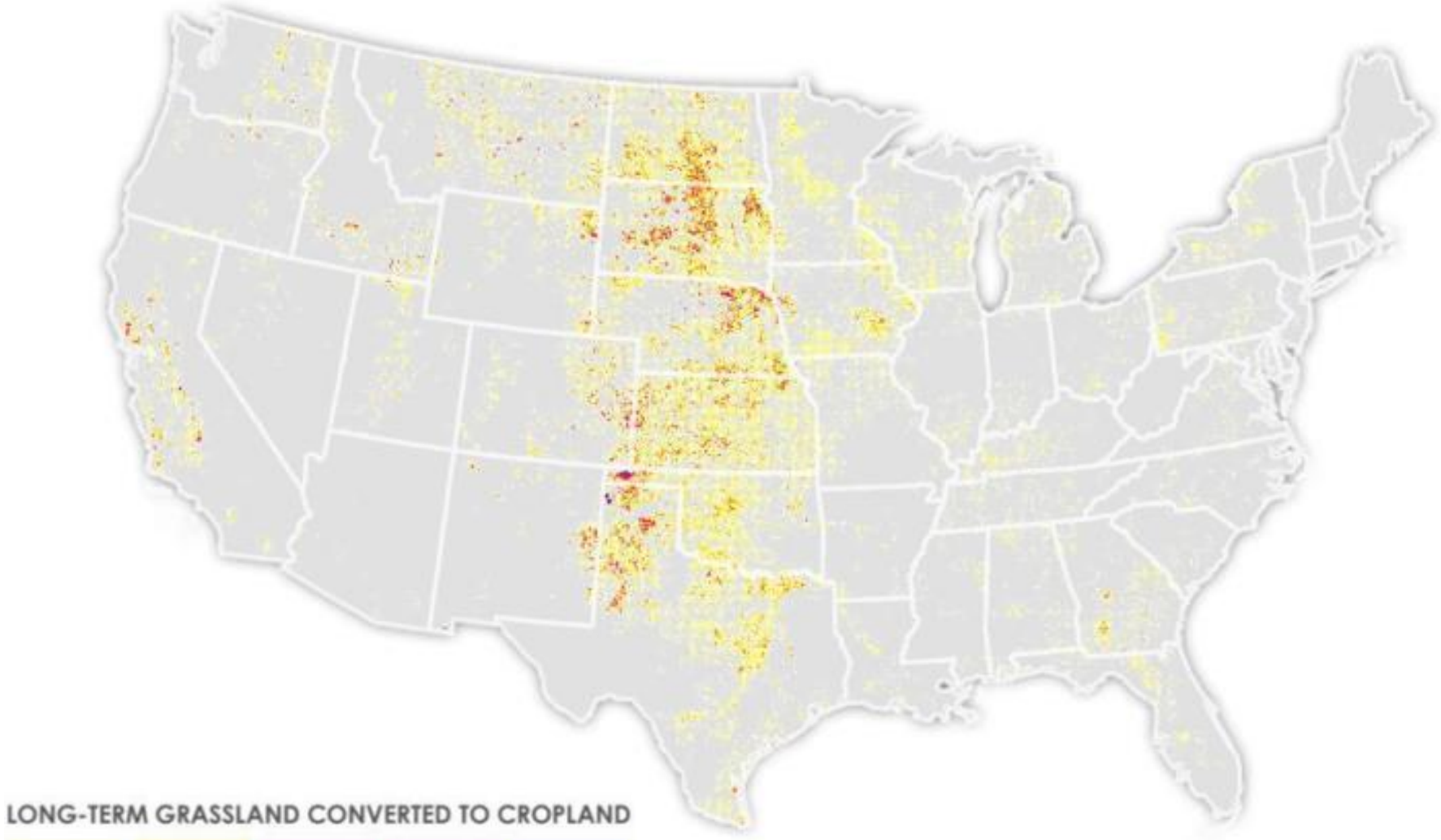


7.3 M acres crop expansion
- 4.3 M acres abandonment
3.0 million acres net increase in cropland

Grasslands were the primary source of new croplands 2008-2012

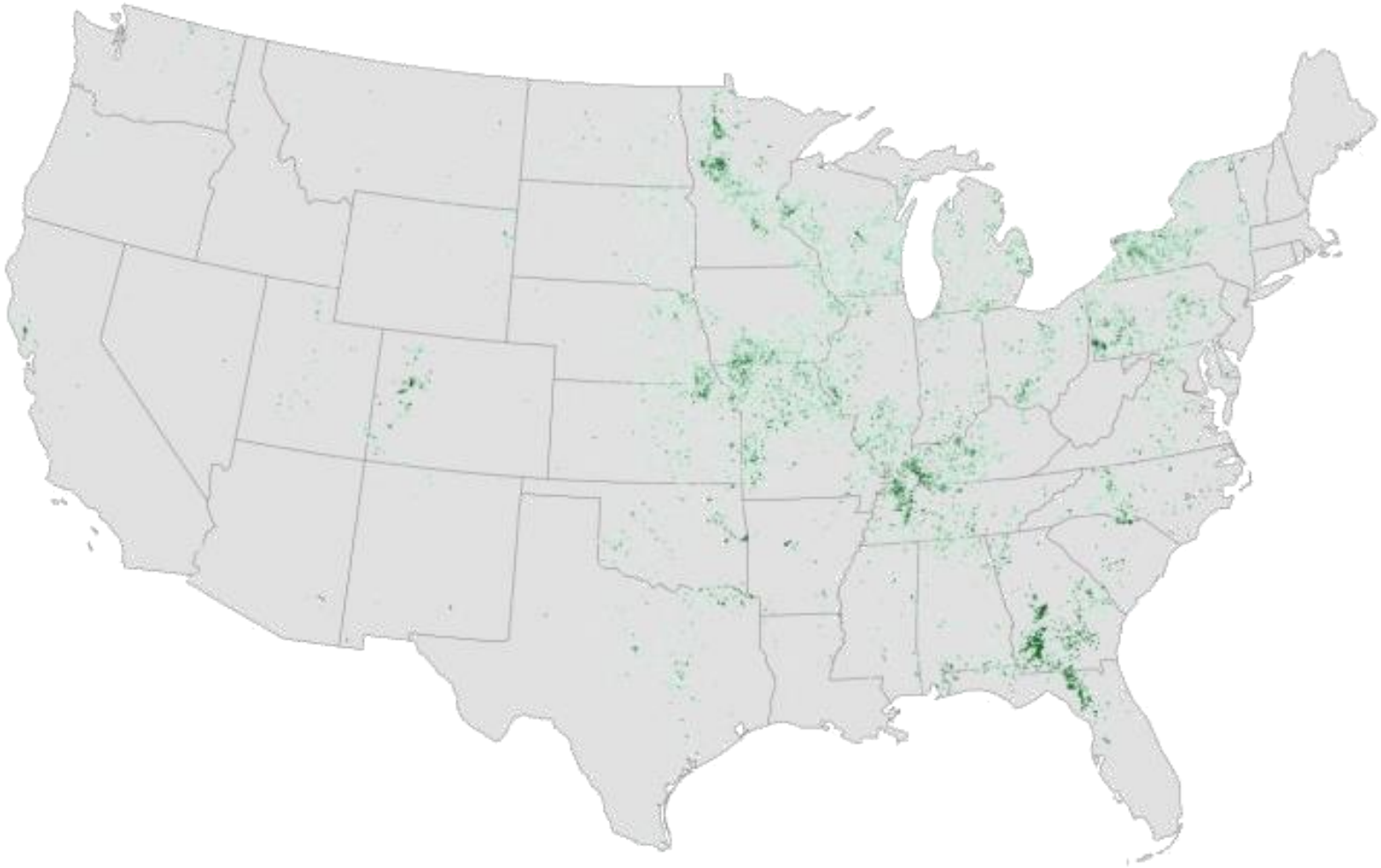


27% of converted grasslands were long-term (20+ yr) unimproved grasslands



Total unimproved grassland conversion: 1.6 M Acres

Conversion of forests was greatest in Georgia and the Eastern half of the U.S.



Total forest-to-cropland conversion: 198,000 acres

Forest to cropland conversion by state.

Ranking is amount of conversion relative to other states.

Forest to Cropland Conversion, 2008-2012

State	Acres	Rank	State	Acres	Rank
Alabama	3,589	18	Nebraska	3,381	19
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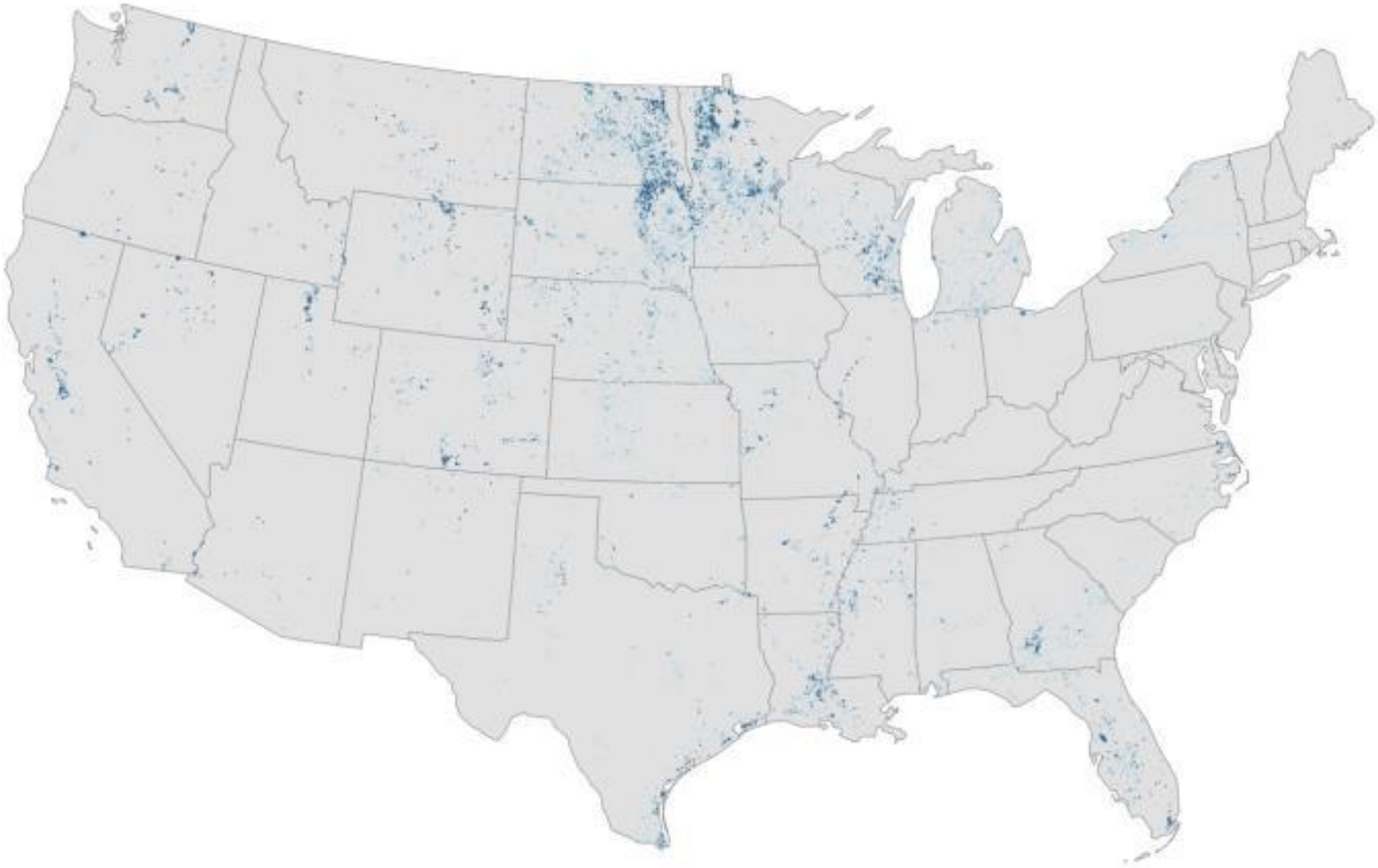
Missouri	13,134	3	Wisconsin	7,626	9
Montana	435	34	Wyoming	684	32

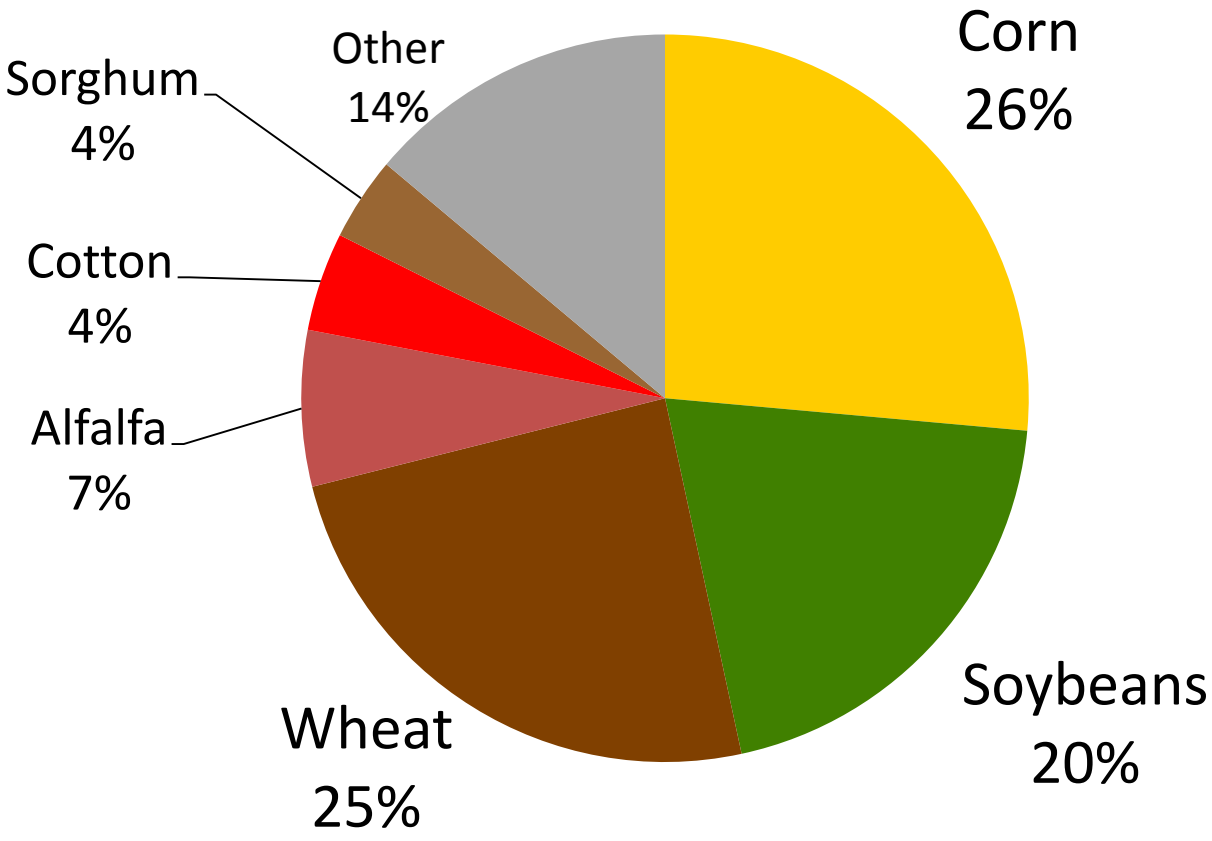
U.S. Total = 197,688 Acres

Wetland conversion was concentrated in Minnesota and the Dakotas



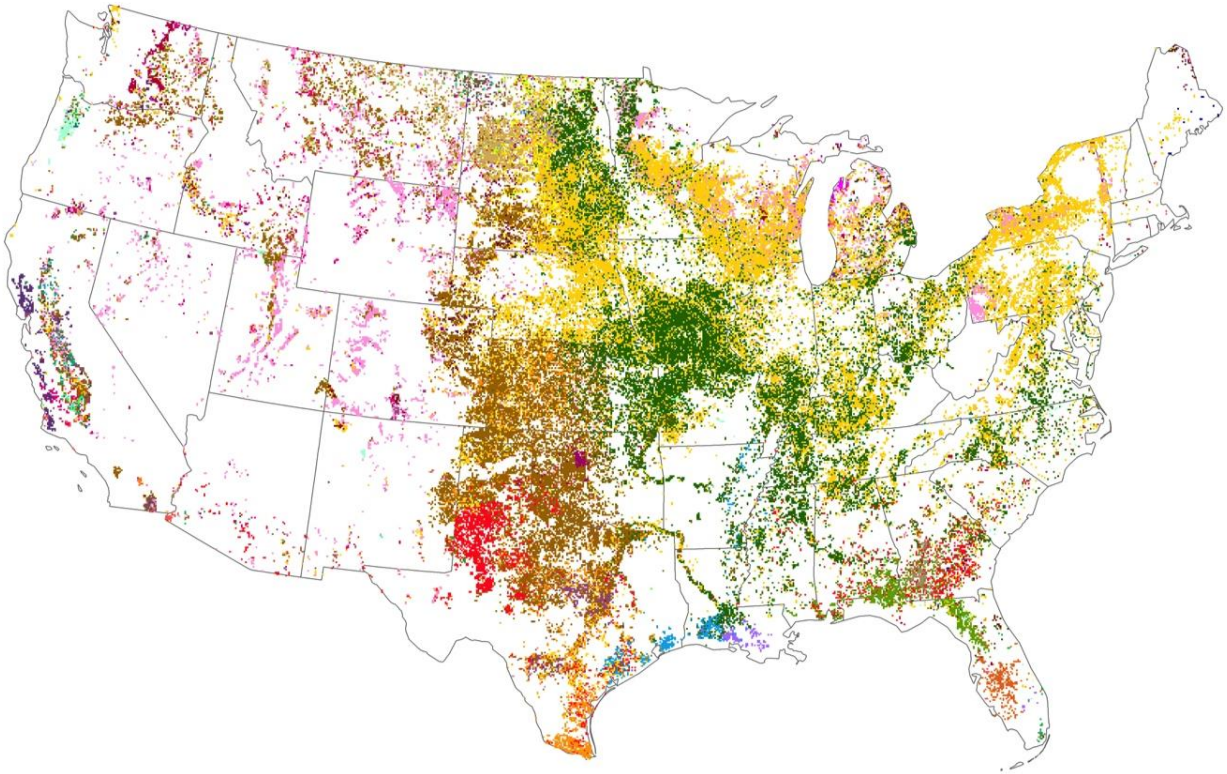
Total wetland-to-cropland conversion: 136,000 acres

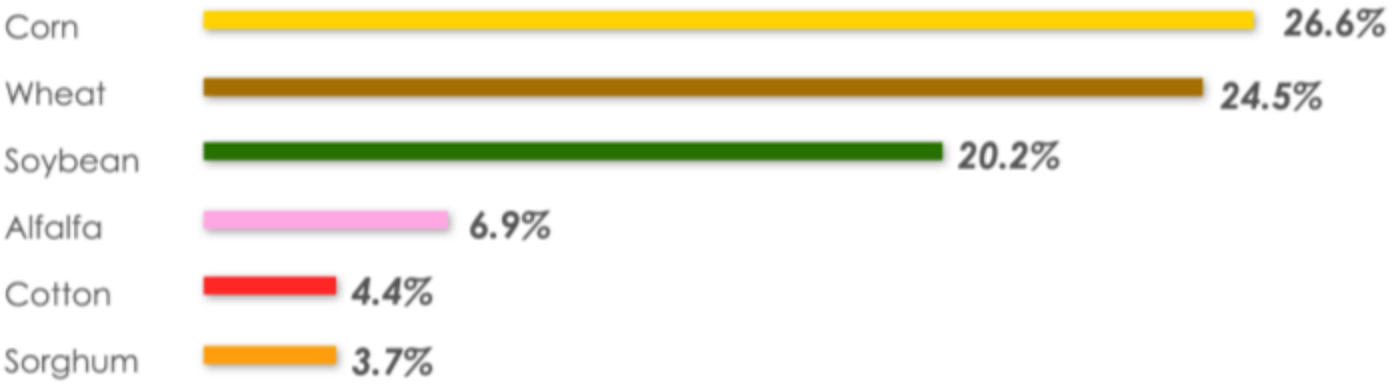
Corn was the most common “break-out” crop



First crop after new conversion, 2008-2012

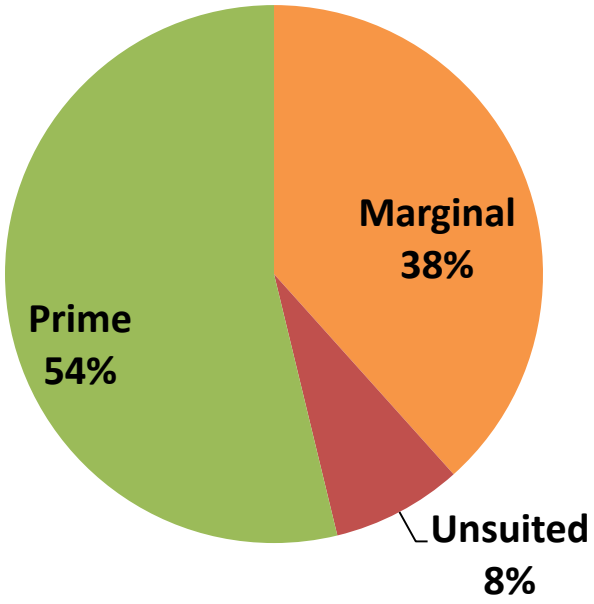
“Break-out” crops vary by region



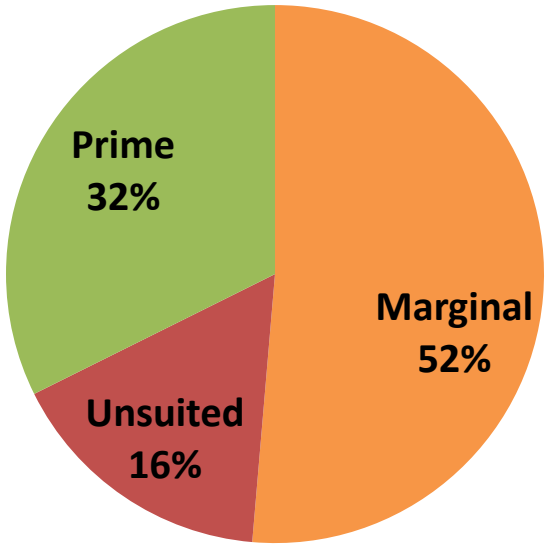


New croplands are less suitable

Pre-2008 Cropland



New Croplands 2008-2012



Lower Yields?

Agricultural quality of existing and new croplands
(by NRCS Land Capability Class)

Potential CO2 emissions from domestic LUC

- 3.4 M Acres of new corn and soy
- Emissions profile:
  - 42% from CRP
  - 22% from intact grasslands
  - 36% from intermediate value
- Cumulative emissions:

  131 MMT CO2e

- 34 coal-fired power plants
- 28 million cars on the road
  - >10% increase in U.S. vehicles

Comparison to Other Results

Data Source	Time Period	Years	Net Cropland Expansion (million acres)	Definition of Cropland
Census of Agriculture	2007-2012	5	7.8	Harvested + Failed + Fallow
NASS Acreage	2008 - 2012	4	2.6	Principle Crop Planted Area – non-alfalfa hay
CDL-based (this study)	2008 - 2012	4	3.0	Cultivated
National Resources Inventory (NRI)	2007 – 2012	5	4.3	Cultivated

ONGOING SUPPORTING WORK

Preliminary data & results

"Measuring land-use and land-cover change using the USDA Cropland Data Layer: Cautions and Recommendations."

TJ Lark, RM Mueller, DM Johnson, and HK Gibbs. *(Submitted)*

"Accuracy and validation of mapping crops and cropland conversions in the United States."

TJ Lark, IH Schelly, JM Salmon, and HK Gibbs. *(in preparation)*

ACCURACY OF CDL
Based on FSA reference data

State-level accuracies of 2012 CDL data

Accuracy	Range	North Dakota	South Dakota
All CDL Classes[1]	17-92%	55%	35%
USDA Farm Service Agency crops[1]	64-94%	80%	75%

[1]USDA Cropland data layer (2014), as reported by Dunn et al (2015)

Ongoing work / preliminary data

Highly Accurate Cropland vs. Noncropland discrimination

Accuracy	Range	North Dakota	South Dakota
All CDL Classes[1]	17-92%	55%	35%
USDA Farm Service Agency crops[1]	64-94%	80%	75%
Consolidated Classes[2]	92-99%	97%	98%

[1]USDA Cropland data layer (2014), as reported by Dunn et al (2015)

[2]Consolidated classes used in Lark et al (2015)

Ongoing work / preliminary data

Nationwide CDL Accuracy (2012)

Class Name	ID	Producer Accuracy	Omission Error	User Accuracy	Commission Error
Corn	1	95.2%	4.8%	94.8%	5.2%
Cotton	2	91.1%	8.9%	89.4%	10.6%
Soybeans	5	93.8%	6.2%	93.8%	6.2%
Spring Wheat	23	89.5%	10.5%	86.9%	13.1%
Winter Wheat	24	92.2%	7.8%	92.4%	7.6%
Alfalfa	36	75.4%	24.6%	79.8%	20.2%
Other Hay/Non Alfalfa	37	56.9%	43.1%	56.7%	43.3%
Fallow/Idle Cropland	61	69.3%	30.7%	79.0%	21.0%
Open Water	111	90.0%	10.0%	81.3%	18.7%
Developed/Open Space	121	88.9%	11.1%	60.8%	39.2%
Developed/Low Intensity	122	82.8%	17.2%	74.2%	25.8%
Developed/Med Intensity	123	83.6%	16.4%	80.6%	19.4%
Barren	131	73.6%	26.4%	75.5%	24.5%
Deciduous Forest	141	87.6%	12.4%	75.2%	24.8%
Evergreen Forest	142	86.7%	13.3%	73.2%	26.8%
Mixed Forest	143	44.4%	55.6%	51.2%	48.8%
Shrubland	152	87.2%	12.8%	71.2%	28.8%
Grassland/Pasture	176	79.0%	21.0%	49.8%	50.2%
Woody Wetlands	190	69.6%	30.4%	62.9%	37.1%
Herbaceous Wetlands	195	61.2%	38.8%	46.6%	53.4%
Consolidated Cropland	N/A	94.3%	5.7%	97.1%	2.9%
Consolidated Non-cropland	N/A	97.4%	2.6%	90.9%	9.1%

Ongoing work / preliminary data

Consolidated nationwide CDL inputs are accurate across time

	2008	2009	2010	2011	2012
Original CDL Overall Accuracy	49.1%	61.5%	76.2%	76.2%	78.4%
Consolidated CDL Overall Accuracy	95.7%	96.0%	96.3%	95.4%	95.9%

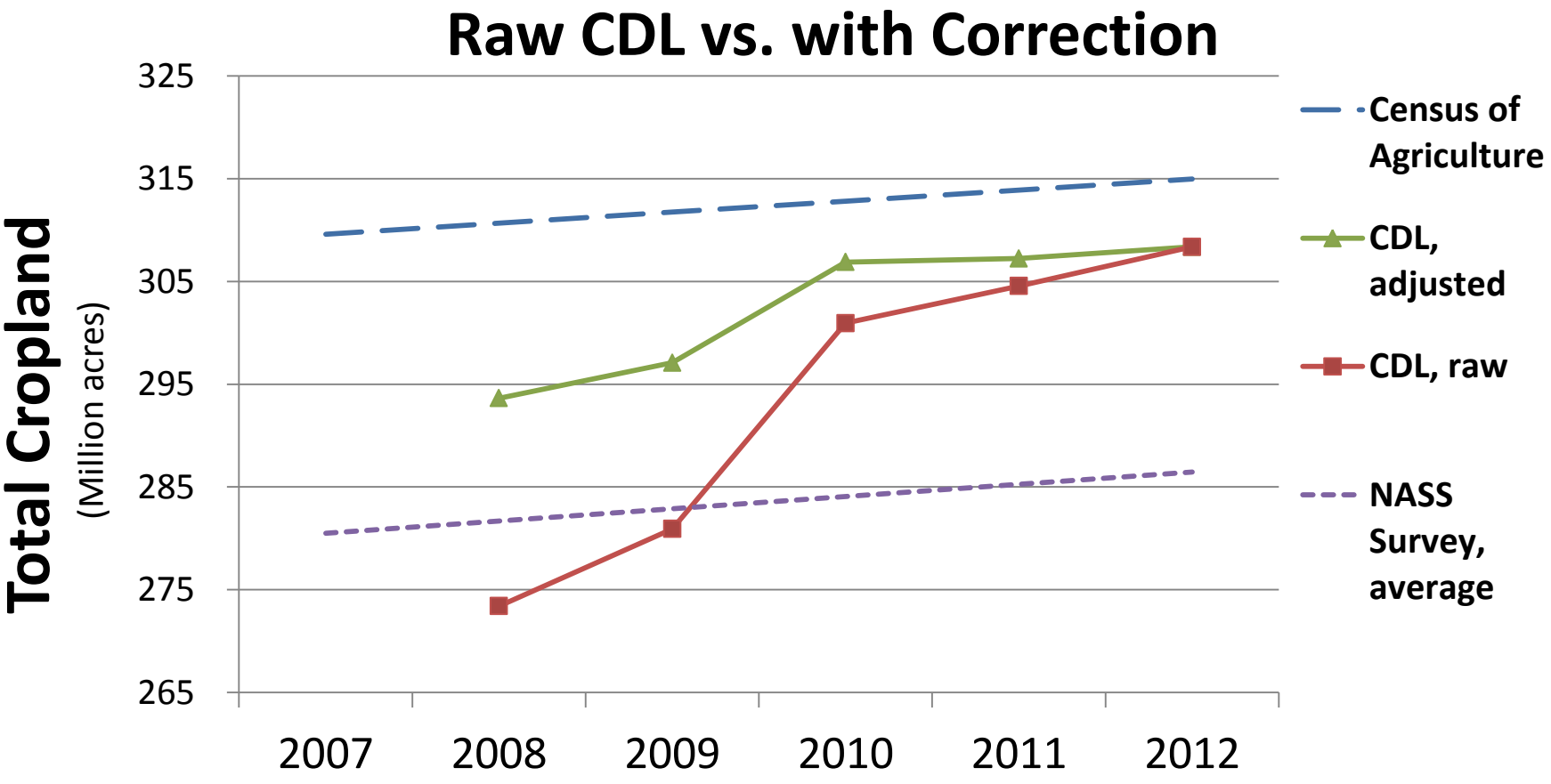
Ongoing work / preliminary data

Recommended practices for measuring LUC using the Cropland Data Layer

Recommendation	Details	Benefit	Example References Utilizing
Combine classes	Reclassify all grasslands, frequently rotated crops like corn/soy, or all crops into a single combined category where possible.	Reduces errors distinguishing among spectrally-similar land cover classes.	Johnson 2013[33] Wright & Wimberly 2013[8] Johnston 2013[20] Lark et al 2015[22]
Utilize all temporal data	When measuring changes over time all available data should be used, including intermediate years.	Allows temporal classification and temporal filtering of likely misclassifications. Aids field boundary identification.	Plourde et al 2013[19] Johnston 2014[21] Lark et al 2015[22] Sahajpal et al 2014[10]
Integrate multiple data sources	Use additional remote sensing and/or ground-based data sources in combination with the CDL.	Improves confidence of findings, enables correction of individual product biases.	Wright et al 2015[8] Lark et al 2015[22]
Establish Min/Max Unit of Change (MUC)	Match change detection size to expected range of plausible changes.	Reduces mapping of spurious change. Improved signal to noise ratio.	Cox and Rundquist, 2013[34]
Use post-classification processing	Use field segmentation, a Minimum Mapping Unit (MMU), or spatial filtering to remove likely misclassifications.	Improves consistency between map representation and reality (fields, etc.). Reduces speckle. Better alignment with CDL capabilities (when use MMU).	Sahajpal et al 2014[10] Wright & Wimberly 2013[8] Lark et al 2015[22]
Validate with independent data	Use published USDA statistics or other authoritative data to aid selection of processing and assessment methodology.	Improves selection of post-classification processing methods. Corroborates findings.	Johnson 2013[33] Plourde et al 2013[19] Sahajpal et al 2014[10] Lark et al 2015[22]
Adjust for areal bias	Use ancillary dataset or a regression estimator to correct for frequent crop underestimation bias.	Reduces false signals and exacerbated change areas due to CDL product improvement over time.	Lark et al 2015[22] Johnson 2013[33]

Ongoing work / preliminary data

Adjusting for CDL crop underestimation bias:

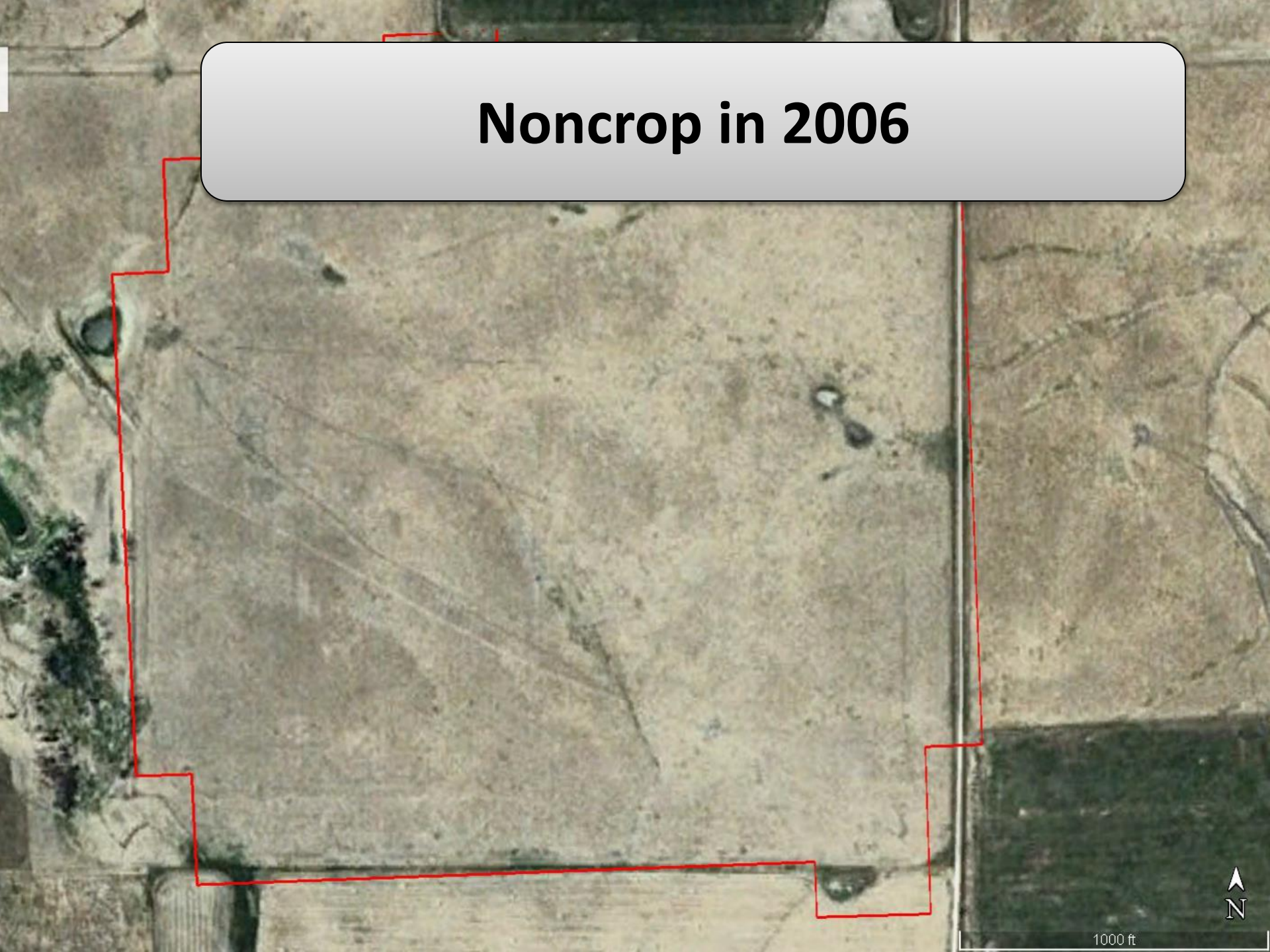


Crop Estimation Bias:	-5.6%	-4.4%	-4.1%	-3.3%	-2.9%

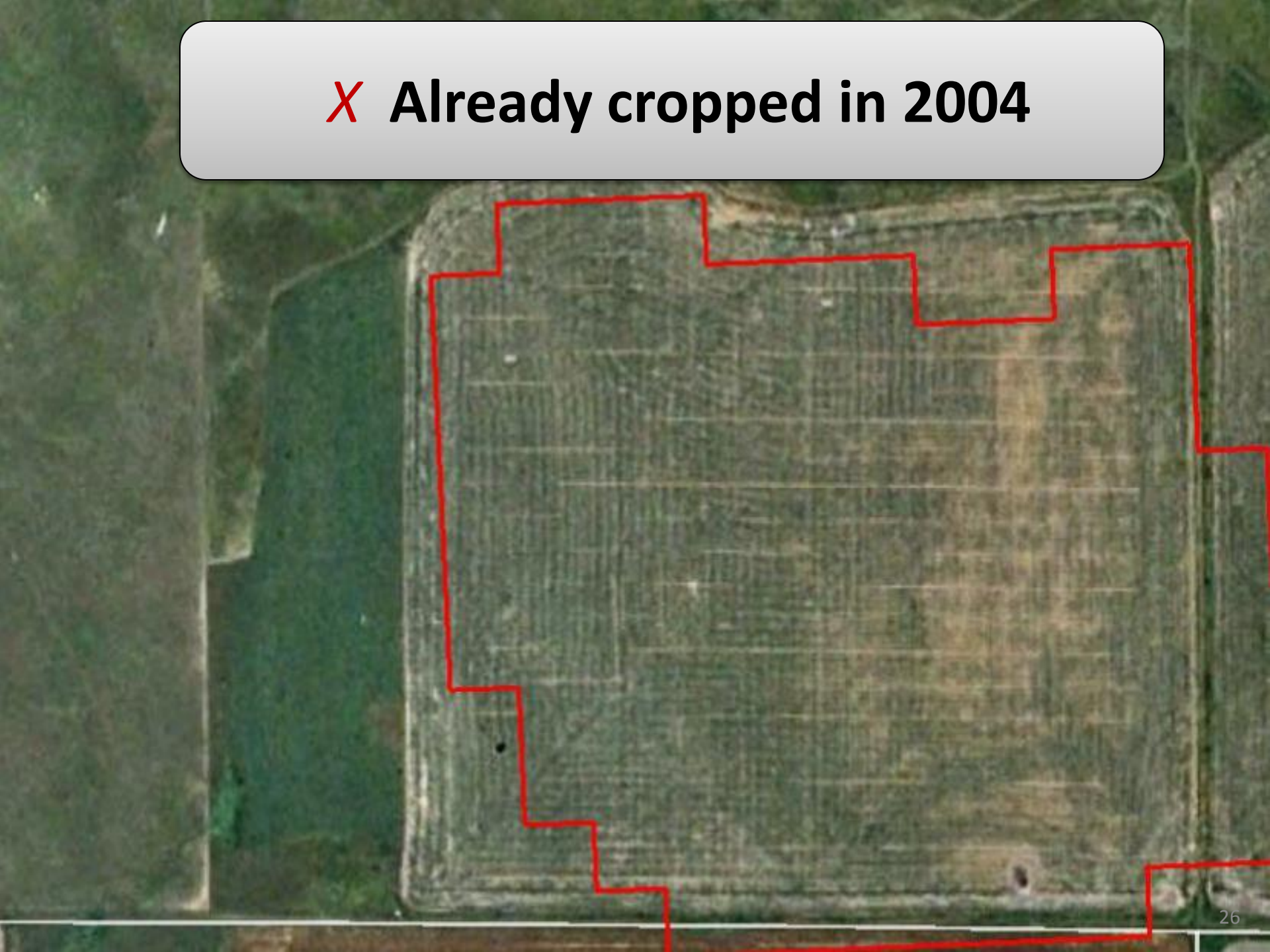
Ongoing work / preliminary data

ACCURACY OF U.S. LUC
Based on NAIP aerial photography

Noncrop in 2006




✓ Crop in 2012
N
1000 ft

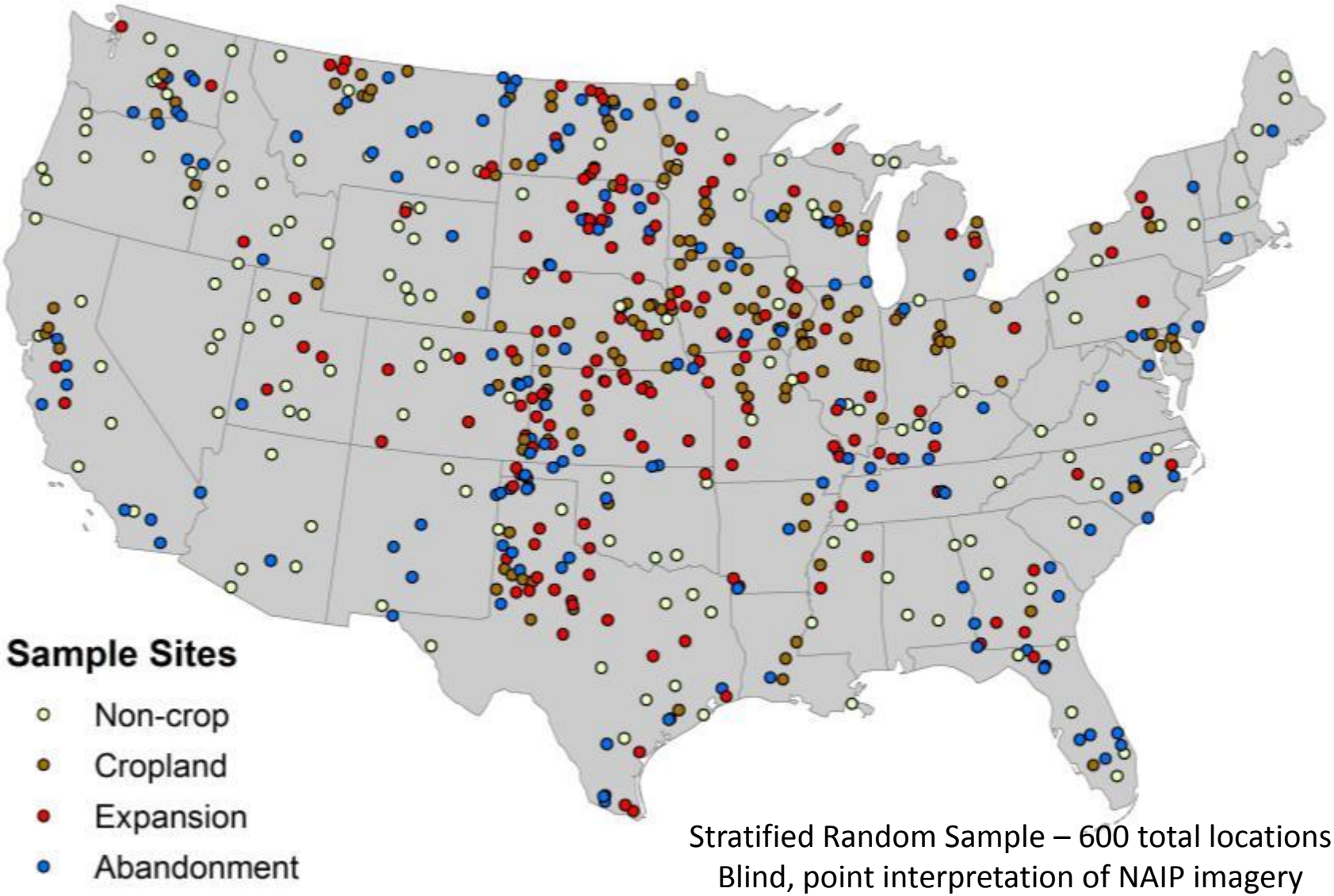

X Already cropped in 2004

Potter County, SD – Initial Accuracy Results

- # of fields correct: 33/50
- Total area correct: 3200/3779 acres **(85%)**

Ongoing work / preliminary data – do not cite

Formal Nationwide Accuracy Assessment – Reference Sites



Stratified Random Sample – 600 total locations
Blind, point interpretation of NAIP imagery
Must have images w/in 1-2 yr of study window

Formal Accuracy Results for Lark et al (2015):

Lark et al CDL Map	NAIP Image: Non-crop	Cropland	Expansion	Abandonment		Users Accuracy	SD	Bias
Non-crop	0.8255	0.0172	0.0000	0.0000	0.8427	**98.0%**	1.2%	2%
Cropland	0.0019	0.1435	0.0010	0.0000	0.1464	**98.0%**	1.1%	-10%
Expansion	0.0006	0.0005	0.0027	0.0000	0.0038	**70.4%**	3.7%	3%
Abandonment	0.0005	0.0007	0.0000	0.0010	0.0023	**43.2%**	4.1%	125%
	0.8285	0.1619	0.0037	0.0010				
Post-strat Producer's Accuracy:	**99.6%**	**88.6%**	**72.7%**	**97.5%**				

Overall **97.7%**

SD **1%**

Opportunities for future work…

Ready to partner & put data to use:

1. Expand accuracy assessment (validate other datasets?)

2. Carbon flux from domestic LUC

3. Modeling land availability

Summary Relevant Findings:

- **Aggregate** measures **do not capture** all changes
  - Contradicts RFS enforcement mechanism
- Over 1 M acres of previously uncultivated land converted
- CO2 emissions from domestic land-use change likely substantial

- ✓ **Promising result:** Improved methodologies can produce highly-accurate results while maintaining the spatial- and crop-specificity of the Cropland Data Layer

Thank you!

- Funded in part by:
  - Wisconsin Bioenergy Initiative
  - California Air Resources Board

- USDA NASS's Geospatial Research Analysis Section for crop statistic insights and clarifications

- Rudy Omri & Ian Schelly for mapping assistance

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Citation:

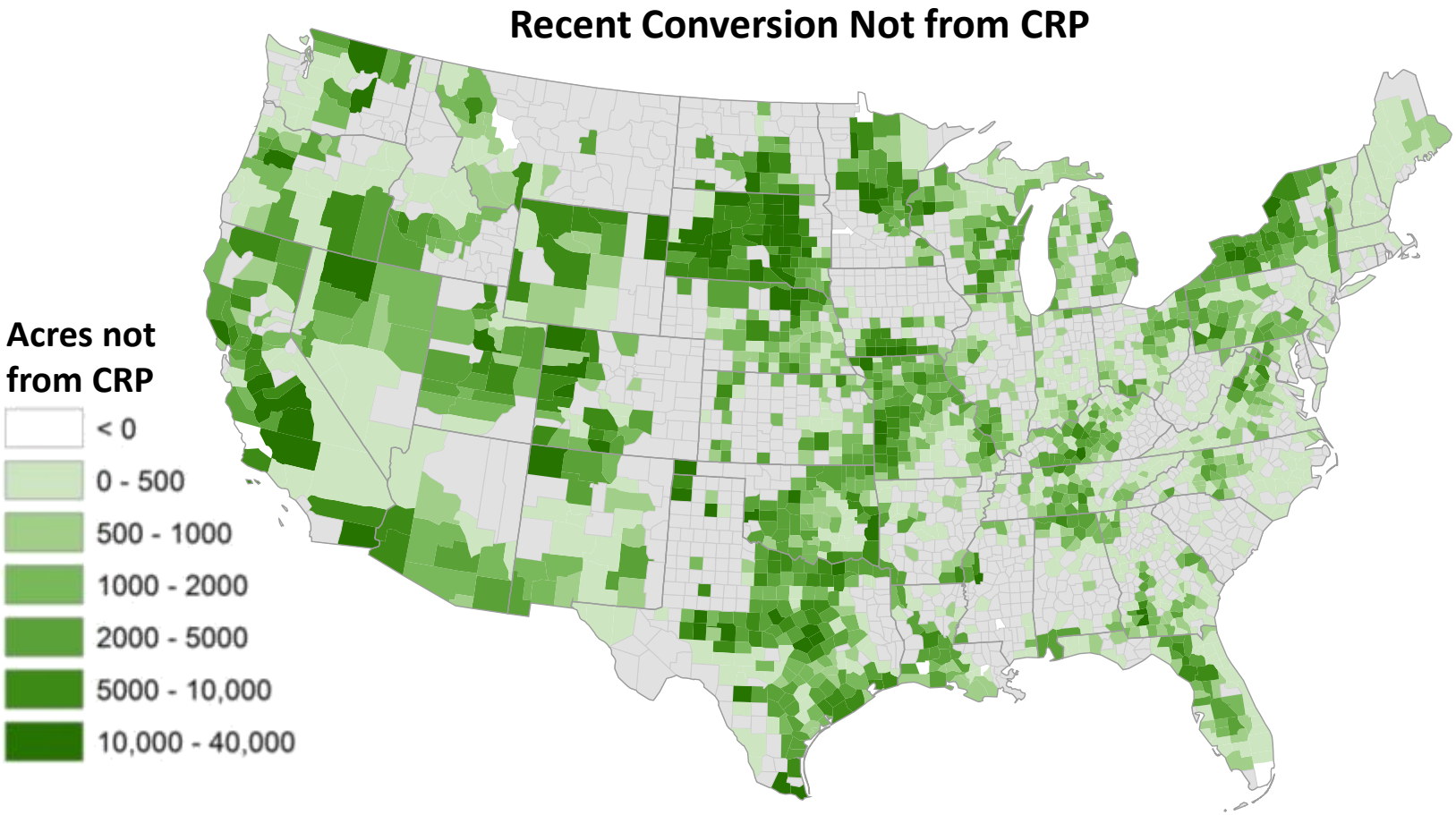
Lark, Salmon, and Gibbs. "**Cropland Expansion Outpaces Agricultural and Biofuel Policies in the United States**." *Environmental Research Letters.* (2015)

APPENDIX

Trajectory Analysis

- Reduces error by identifying noise and intermittent croplands
- Utilizes classifications from intermediate years

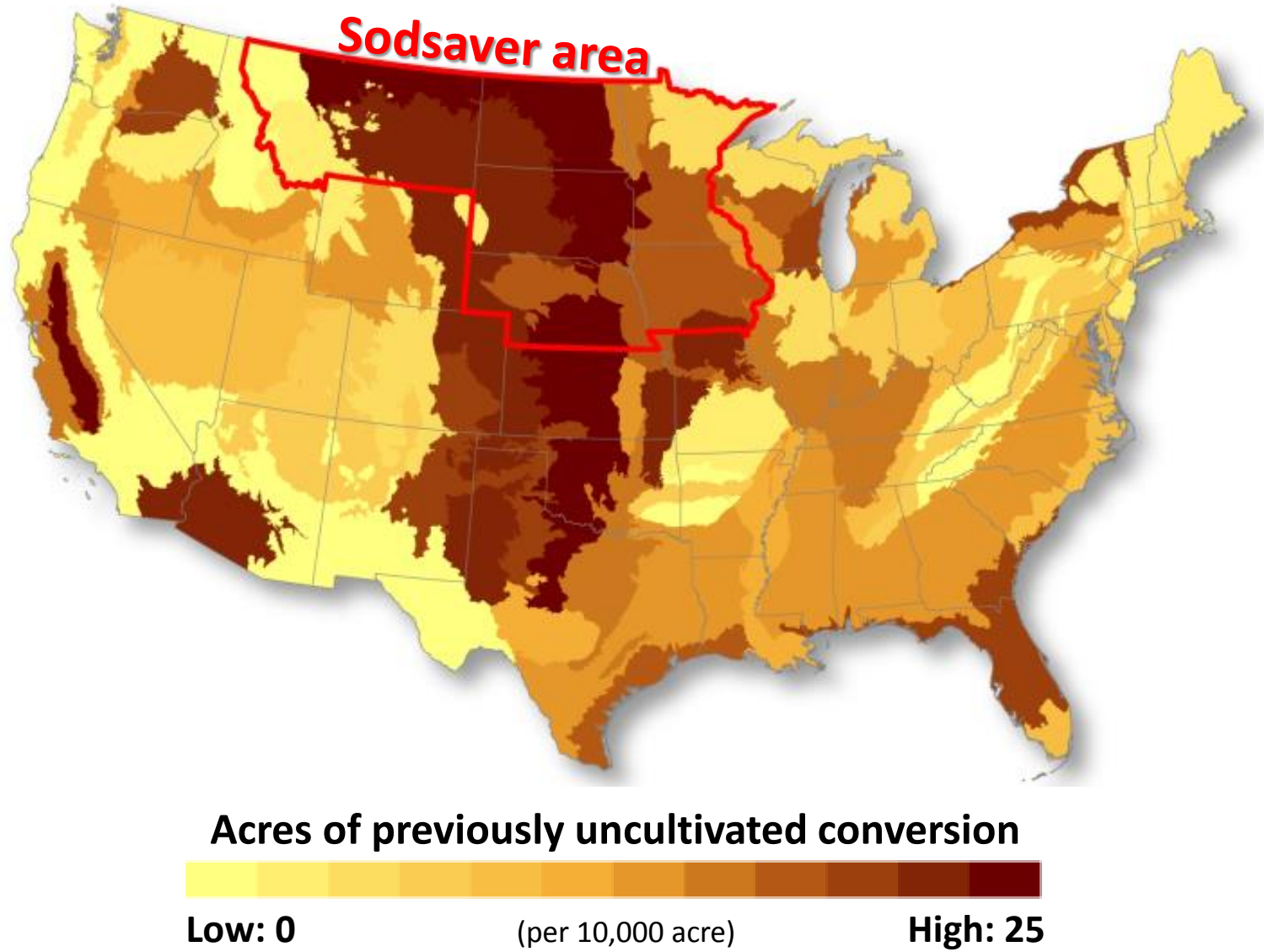
Only 42% of new cropland came from the Conservation Reserve Program (CRP)



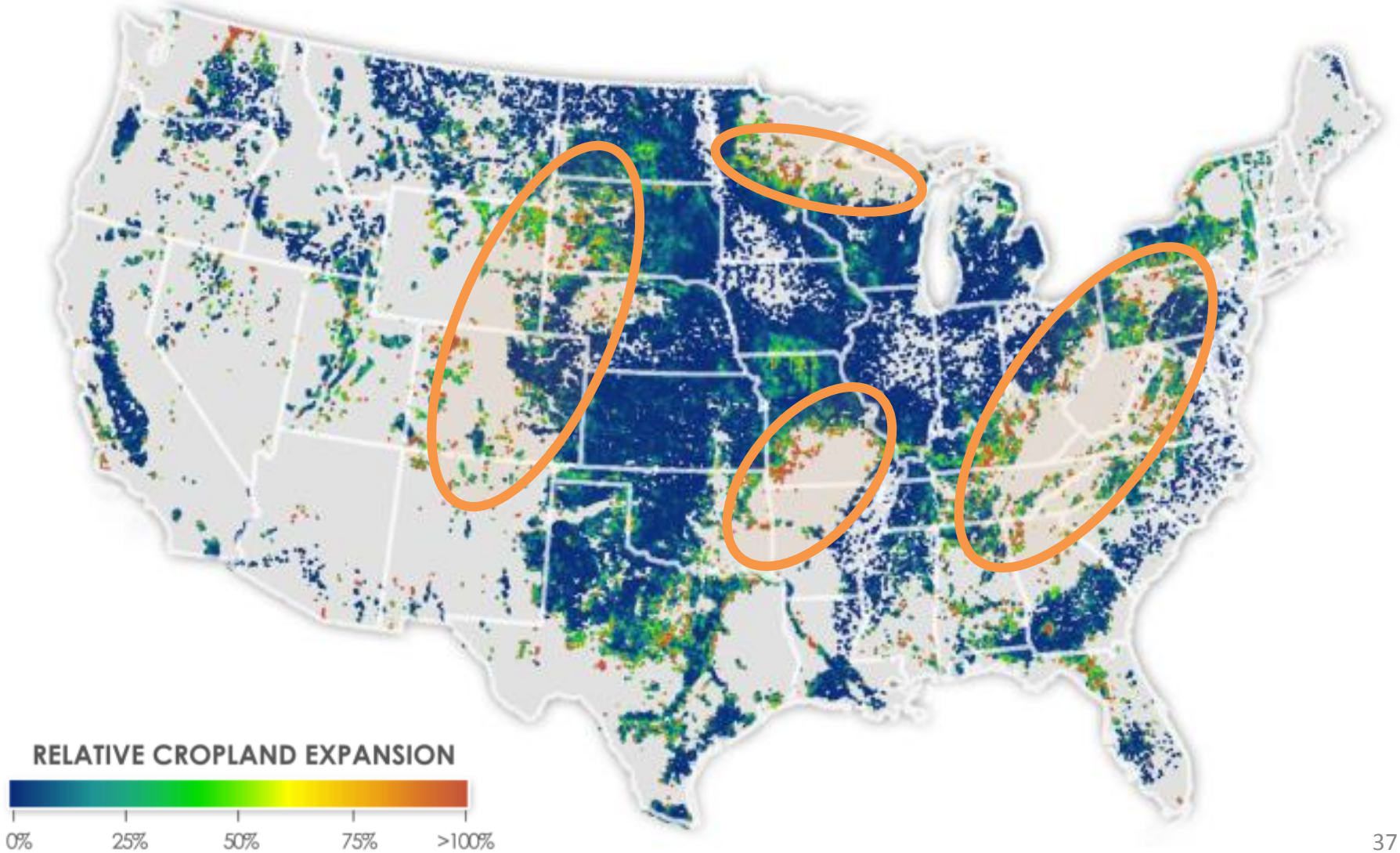
Total new cropland: 7.3 million acres

Maximum from CRP: 3.0 million acres

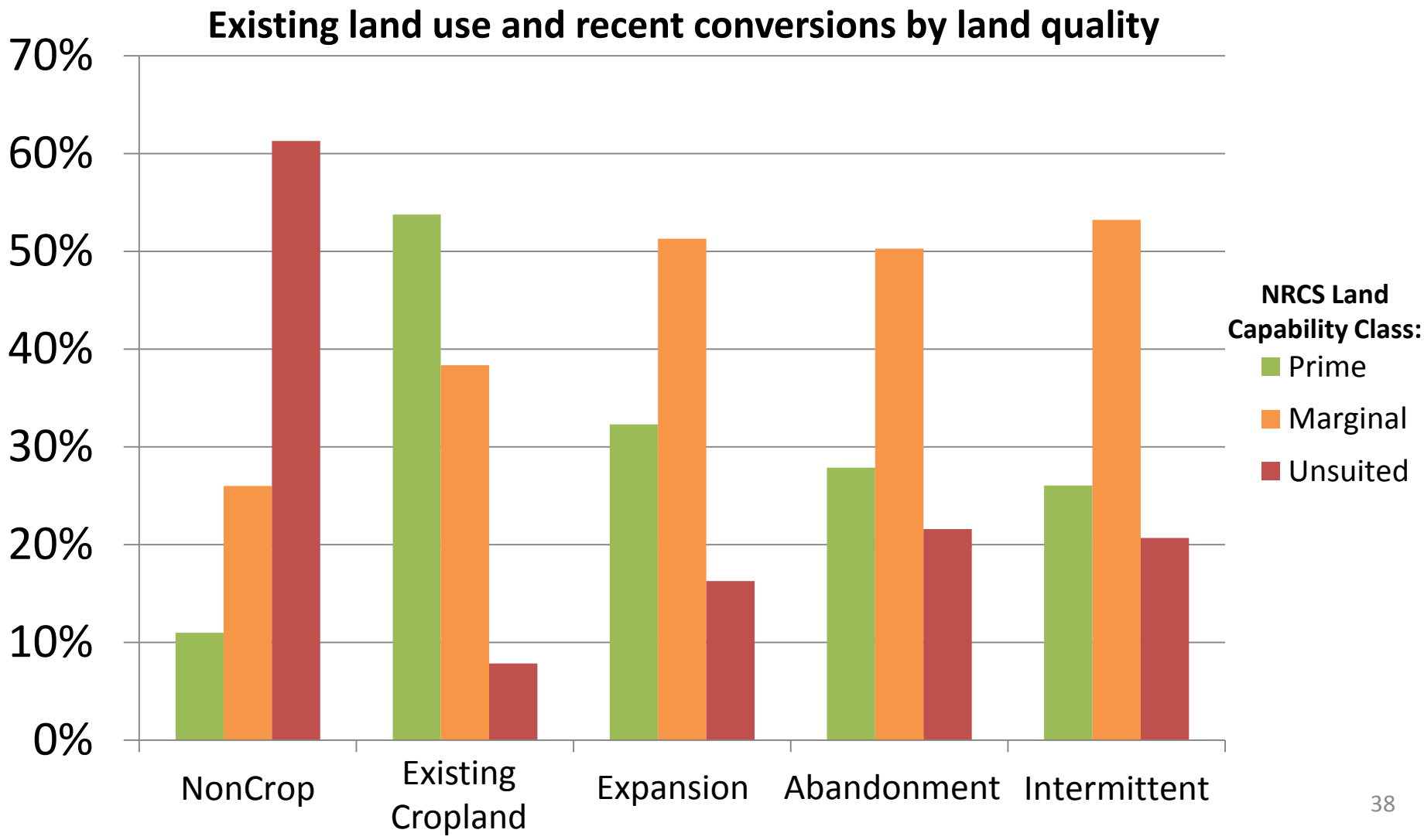
2/3 of new breakings occur outside a Sodsaver state



Croplands are also moving into “new frontiers” previously used for non-crop purposes



New croplands were more likely to be on marginal or poorly suited land



Total marginal cropland area expanded at 2x the rate of well-suited cropland

LCC	Cropland expansion	Cropland loss	Net expansion	Net expansion (aggregated classes)	
1	0.7%	0.5%	0.2%	0.77%	Well-suited
2	1.7%	0.8%	0.8%		
3	3.1%	1.7%	1.5%	1.5%	Marginal
4	4.4%	3.0%	1.4%		
5	3.8%	3.0%	0.8%	1.1%	Unsuited for cultivation
6	5.9%	3.8%	2.1%		
7	4.9%	5.5%	-0.6%		
8	7.9%	7.9%	-0.1%		

Cropland expansion on non-agricultural land by state.

Land uncultivated since pre-1970s converted to cropland 2008-2012

STATE	% of Conversion	Acres	STATE	% of Conversion	Acres
Alabama	12.0%	9,675	Nebraska	20.3%	65,323
Arizona	32.7%	29,608	Nevada	15.3%	10,525
Arkansas	9.8%	5,858	New Hampshire	6.3%	205
California	17.0%	43,663	New Jersey	7.1%	340
Colorado	19.0%	36,855	New Mexico	12.4%	29,355
Connecticut	12.4%	273	New York	7.8%	12,383
Delaware	29.1%	216	North Carolina	17.7%	7,154
Florida	56.8%	26,012	North Dakota	17.7%	81,641
Georgia	22.6%	15,099	Ohio	5.8%	4,140
Idaho	7.3%	7,370	Oklahoma	17.3%	55,932
Illinois	5.8%	8,850	Oregon	9.6%	10,449
Indiana	5.5%	5,212	Pennsylvania	6.2%	3,814
Iowa	8.1%	25,515	Rhode Island	13.7%	67
Kansas	18.2%	83,840	South Carolina	22.8%	6,226
Kentucky	6.8%	8,819	South Dakota	18.3%	81,627
Louisiana	17.7%	10,621	Tennessee	7.8%	8,023
Maine	5.7%	465	Texas	14.0%	105,945
Maryland	14.7%	1,137	Utah	10.1%	8,173
Massachusetts	10.3%	350	Vermont	5.8%	970
Michigan	5.6%	5,561	Virginia	11.9%	5,205
Minnesota	5.9%	22,636	Washington	6.4%	15,681
Mississippi	12.2%	9,500	West Virginia	4.7%	1,368
Missouri	5.5%	25,009	Wisconsin	5.3%	14,044
Montana	13.7%	93,879	Wyoming	16.9%	31,861

U.S. Total = 1,036,492 Acres

Forest to cropland conversion by state.

Ranking is amount of conversion relative to other states.

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Montana	435	34	Wyoming	684	32

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Wetland to Cropland Conversion by State, 2008-2012

STATE	Acres	Rank	STATE	Acres	Rank
Alabama	491	33	Nebraska	3,710	12
Arizona	1,620	21	Nevada	3,159	13
Arkansas	2,732	15	New Hampshire	3	46
California	5,944	6	New Jersey	73	41
Colorado	4,185	9	New Mexico	617	30
Connecticut	1	47	New York	1,381	22
Delaware	121	40	North Carolina	1,211	24
Florida	4,130	10	North Dakota	18,385	2
Georgia	2,450	18	Ohio	609	31
Idaho	1,224	23	Oklahoma	723	29
Illinois	1,041	26	Oregon	1,123	25
Indiana	429	34	Pennsylvania	53	43
Iowa	580	32	Rhode Island	-	48
Kansas	955	27	South Carolina	146	39
Kentucky	150	38	South Dakota	12,640	3
Louisiana	4,471	8	Tennessee	862	28
Maine	205	37	Texas	6,677	5
Maryland	250	36	Utah	2,713	16
Massachusetts	65	42	Vermont	24	44
Michigan	2,185	19	Virginia	308	35
Minnesota	25,659	1	Washington	3,727	11
Mississippi	1,880	20	West Virginia	12	45
Missouri	2,552	17	Wisconsin	7,055	4
Montana	2,743	14	Wyoming	5,180	7

U.S. Total = 136,453 Acres

Changes to enrollment in the Conservation Reserve Program (CRP) 2008-2012.

Could be cropped/abandoned for first time in year	Left CRP (non-renewal + attrition)	New CRP Enrollment
2009	1,269,643	378,415
2010	2,816,206	393,254
2011	2,248,034	2,074,171
2012	2,438,210	839,498
Total	**8,772,093**	**3,685,338**

Total enrollment in the CRP decreased by 5.1 million acres over the study period.

However, geospatial distribution of land exiting the program was such that it could account for a maximum of 3 million acres of recent crop expansion.