

Estimating the spatially heterogeneous elasticities of land supply to U.S. crop agriculture

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GTAP Conference (Online) June 17-19, 2020

Introduction

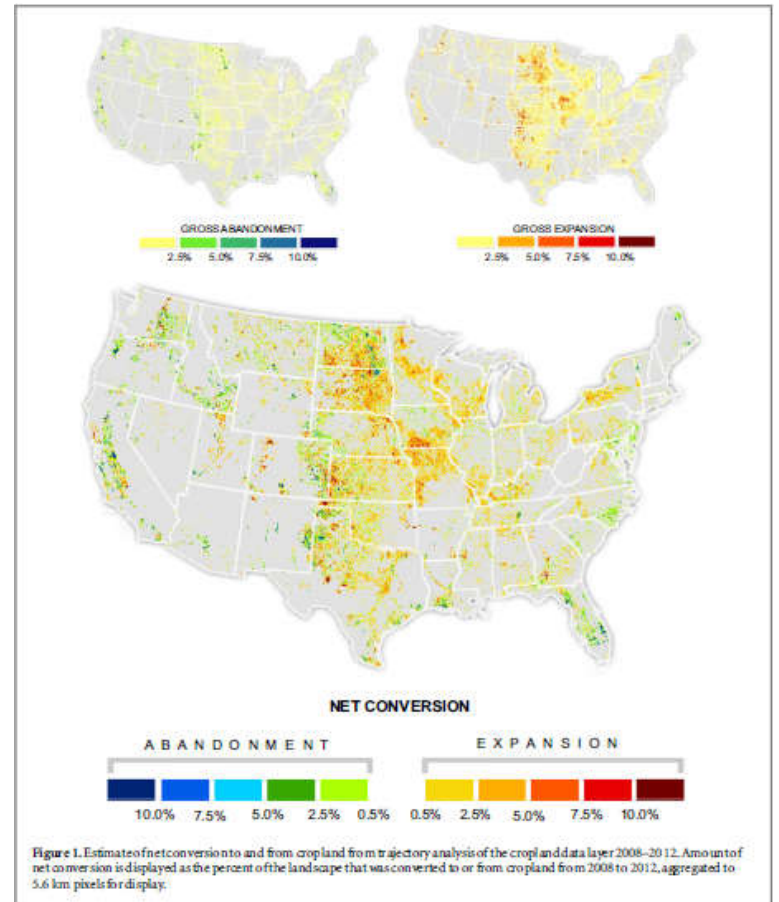
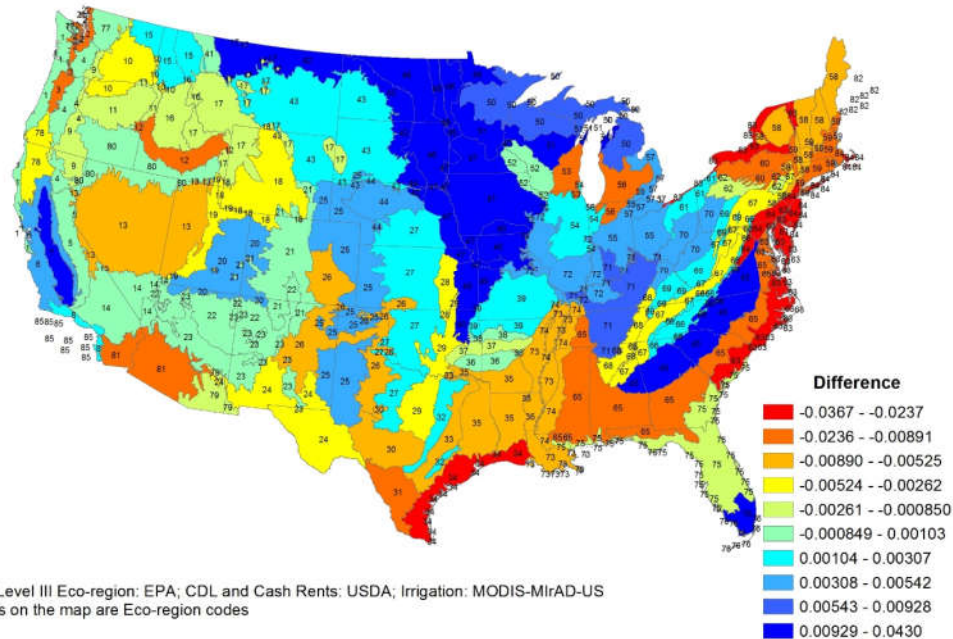
The primary objective of this component of the project is to estimate geographically explicit land supply elasticities to changes in agricultural cash rents.

Agenda:

- Land conversion - trends
- Cropland Data Layer and Agricultural Census comparison
- Cash Rents – trends
- Elasticity estimation
- Validity of results

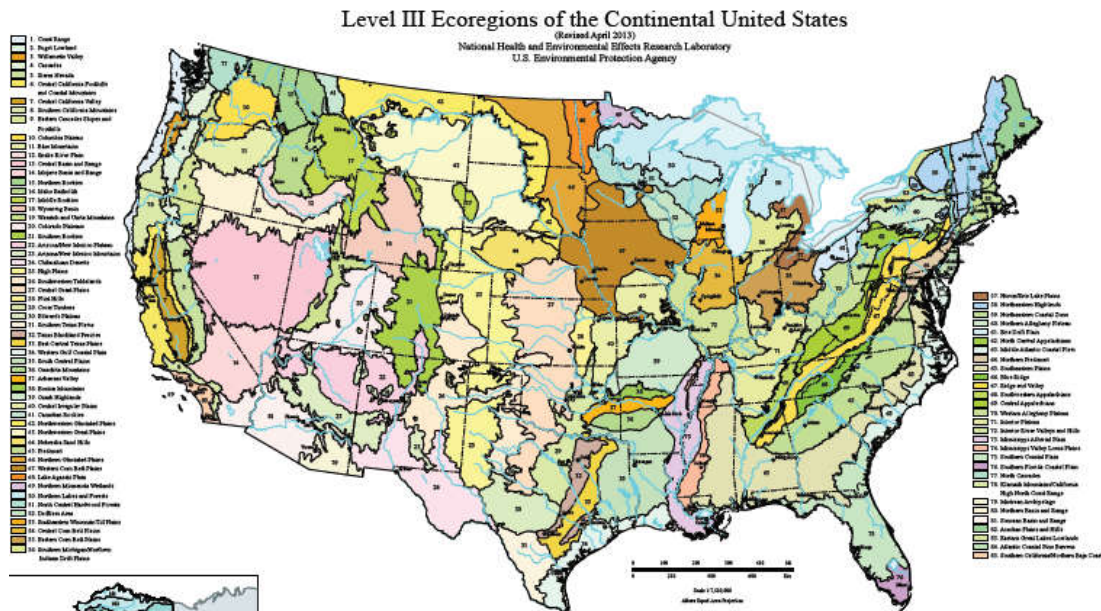
Land Conversion

Difference in average proportion cropland between 2012-14 and 2008-10



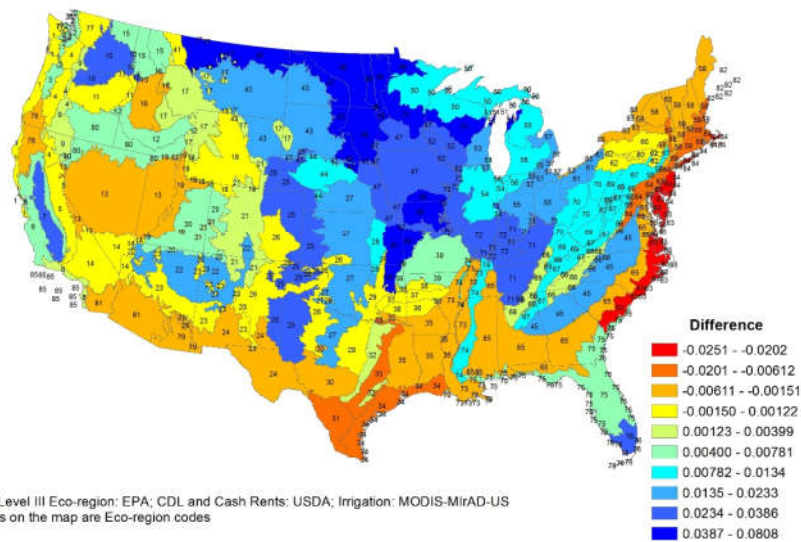
Lark et al., 2015

Land Conversion

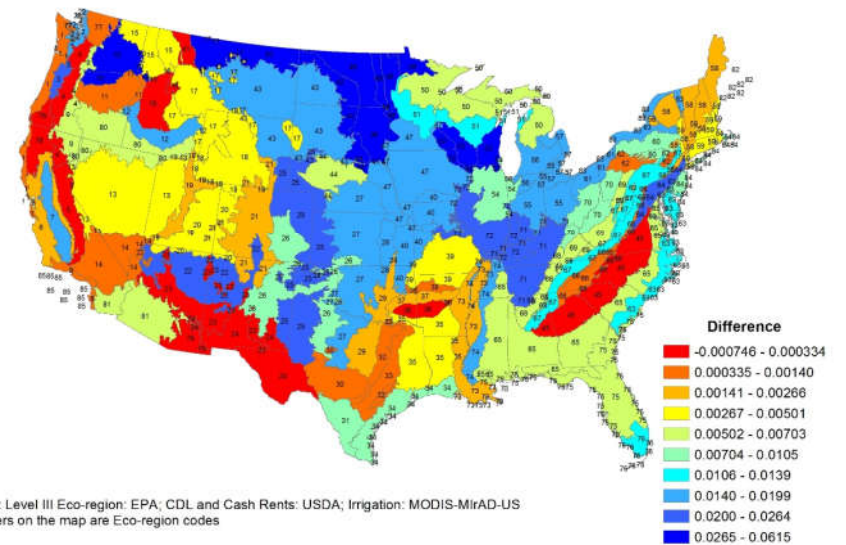


- We compare regions which saw land conversion as calculated from Cropland Data Layer to those estimated by Lark et al.(2015).
- Northern great plains and the high plains regions had amongst the highest proportions of land converted to agricultural land, for the period between 2008-10 and 2012-14.
- Regions that have higher agricultural land at the baseline saw higher expansion.

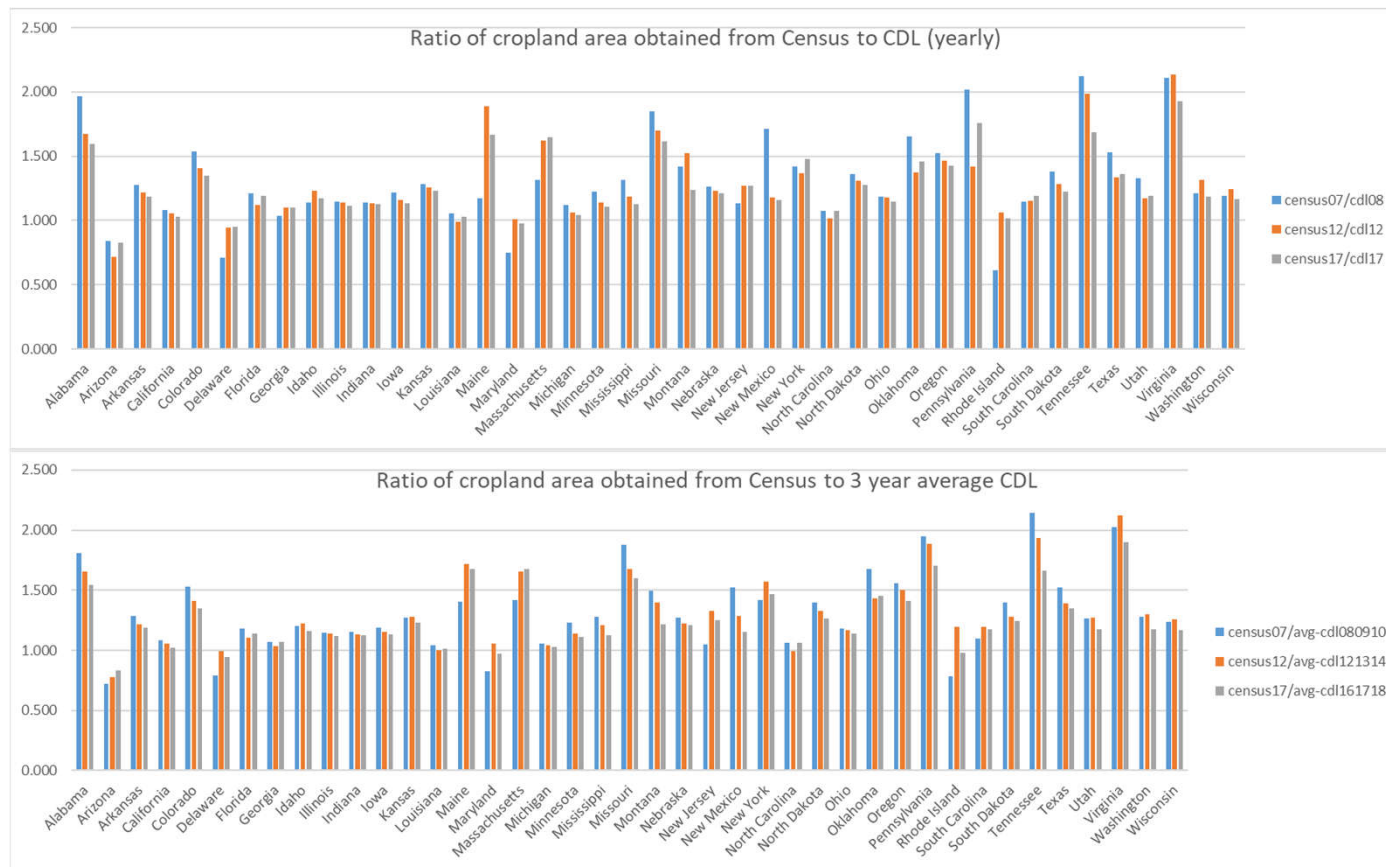
Difference in average proportion cropland between 2016-18 and 2008-10



Difference in average proportion cropland between 2016-18 and 2012-14

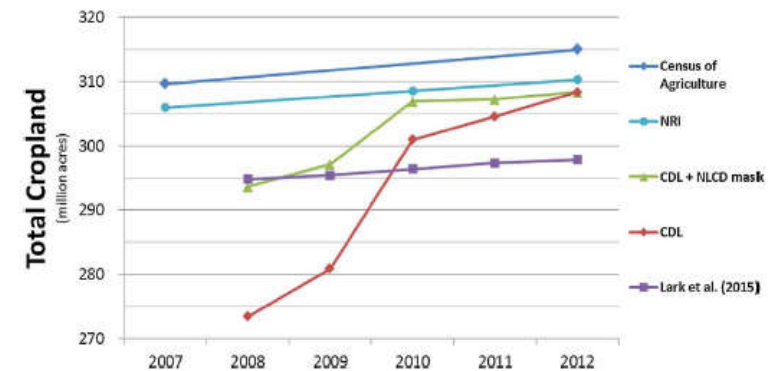


CDL and Census comparison



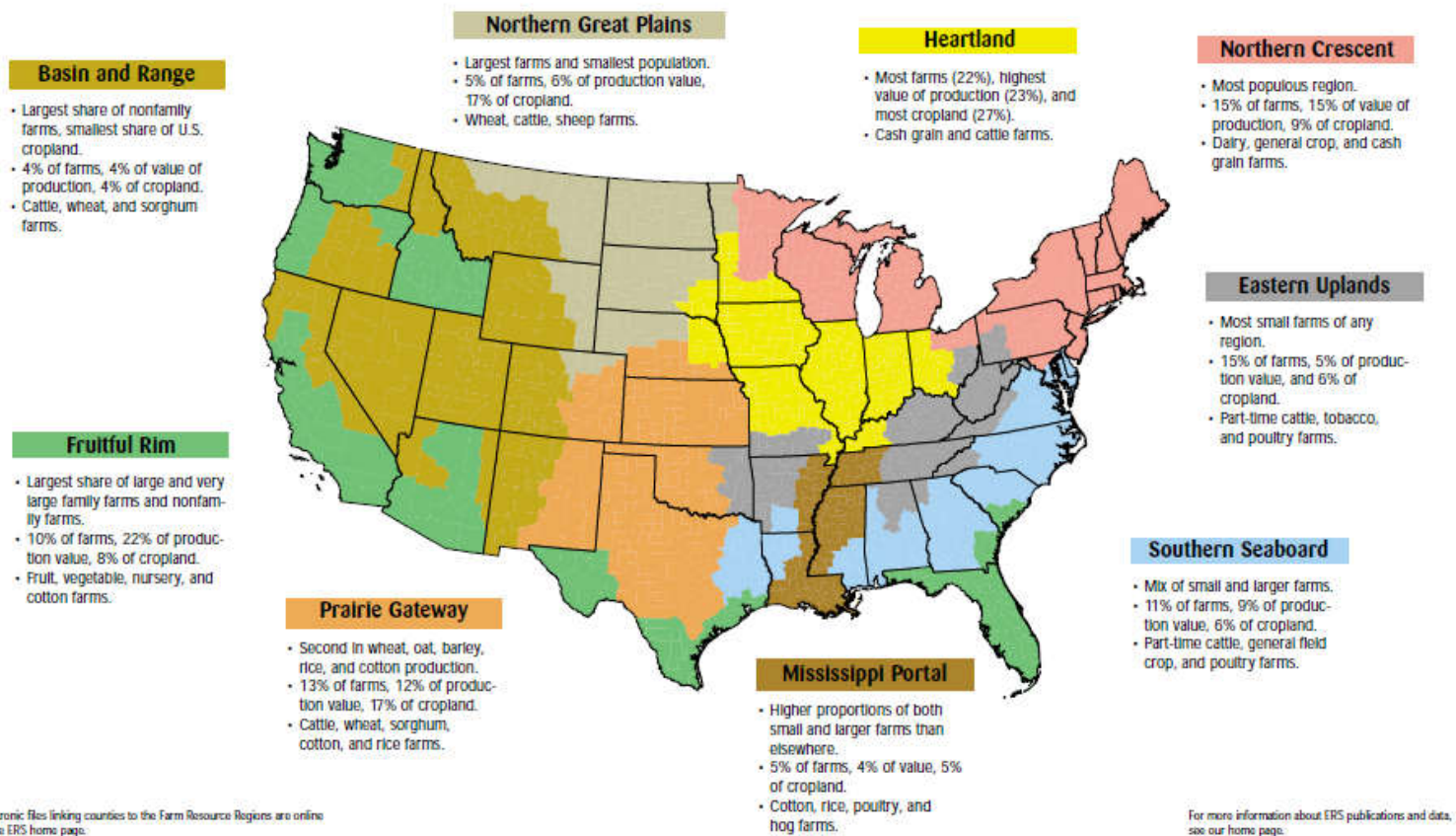
CDL and Census comparison

- Studies have found discrepancies between cropland-acres reported by Agricultural Census and the CDL (Lark et al., 2017).
- Lark recommends aggregating classes into broad categories, using average acreage of a few years instead of particular years, and checking with other sources of cropland data.
- We compare cropland data from CDL to Agri Census.
- For most of the states, total cropland from Agri Census is consistently 15% to 20% more than that from CDL. There are exceptions like New Hampshire, Vermont and West Virginia.
- The difference falls marginally over time.
- In our analysis, we have averaged cropland proportion over three years for each set of analysis. For example, we take the average of cropland proportion for 2008-10 as an approximate for the year 2009.



Lark et al., 2017

Farm Resource Regions - USDA



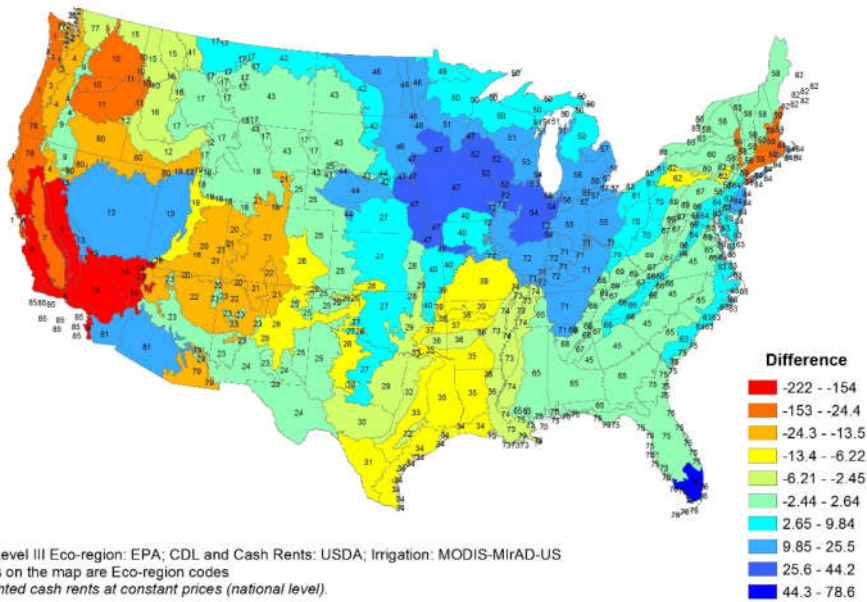
CDL and Census cropland by FRR

FRR code	Farm Resource Region	census07/cdl08	census12/cdl12	census17/cdl17	census07/avg-cdl080910	census12/avg-cdl121314	census17/avg-cdl161718
1	Heartland	1.2104	1.1754	1.1505	1.2059	1.1710	1.1507
2	Northern Crescent	1.2776	1.2484	1.2260	1.2816	1.2874	1.2195
3	Northern Great Plains	1.4398	1.3835	1.2979	1.4773	1.3684	1.2924
4	Prairie Gateway	1.3568	1.2501	1.2598	1.3540	1.2774	1.2559
5	Eastern Uplands	5.6154	3.8630	3.7196	5.2721	4.0492	3.6160
6	Southern Seaboard	1.3172	1.3146	1.3104	1.3287	1.2936	1.2867
7	Fruitful Rim	1.1421	1.1314	1.0931	1.1527	1.1401	1.0784
8	Basin and Range	1.5591	1.5060	1.3650	1.5730	1.4956	1.3586
9	Mississippi Portal	1.1029	1.0614	1.0253	1.0966	1.0646	1.0201

- Differences between CDL and Agri Census cropland area are consistent over time.
- CDL underestimates cropland in the Appalachia. However, the differences are lower in the agricultural regions.

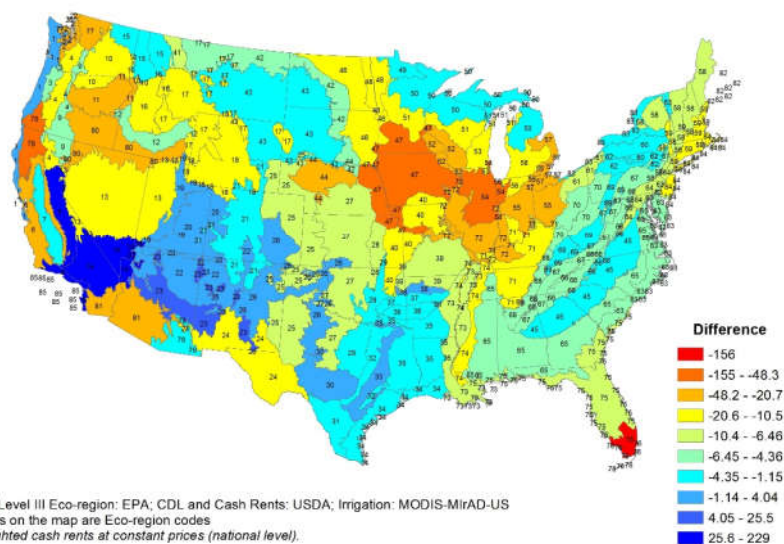
Cash rents

Difference in average land rent between 2013 and 2009

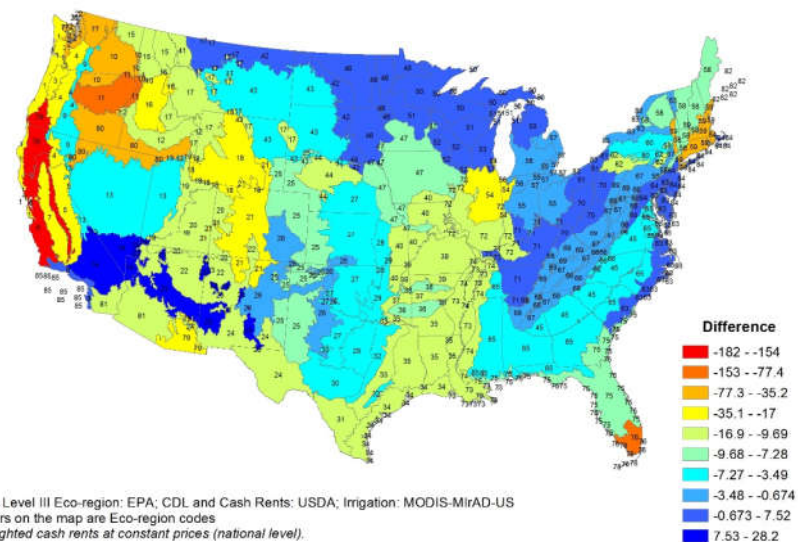


- County level cash rents data are obtained from NASS.
- Between 2009 and 2017, 70% of the counties had only non-irrigated cash rents, 25% had both irrigated and non-irrigated cash rents, and 4.5% had only irrigated cash rents available.
- In order to include counties irrespective of the irrigation status, we weigh cash rents by proportion of area that is irrigated for each grid cell in our analysis.
- We obtain grid cell level irrigation data from MODIS - MirAD-US.
- Land rents increased between 2009 and 2013 in the Mid-West, but fell substantially between 2013 and 2017.

Difference in average land rent between 2017 and 2013

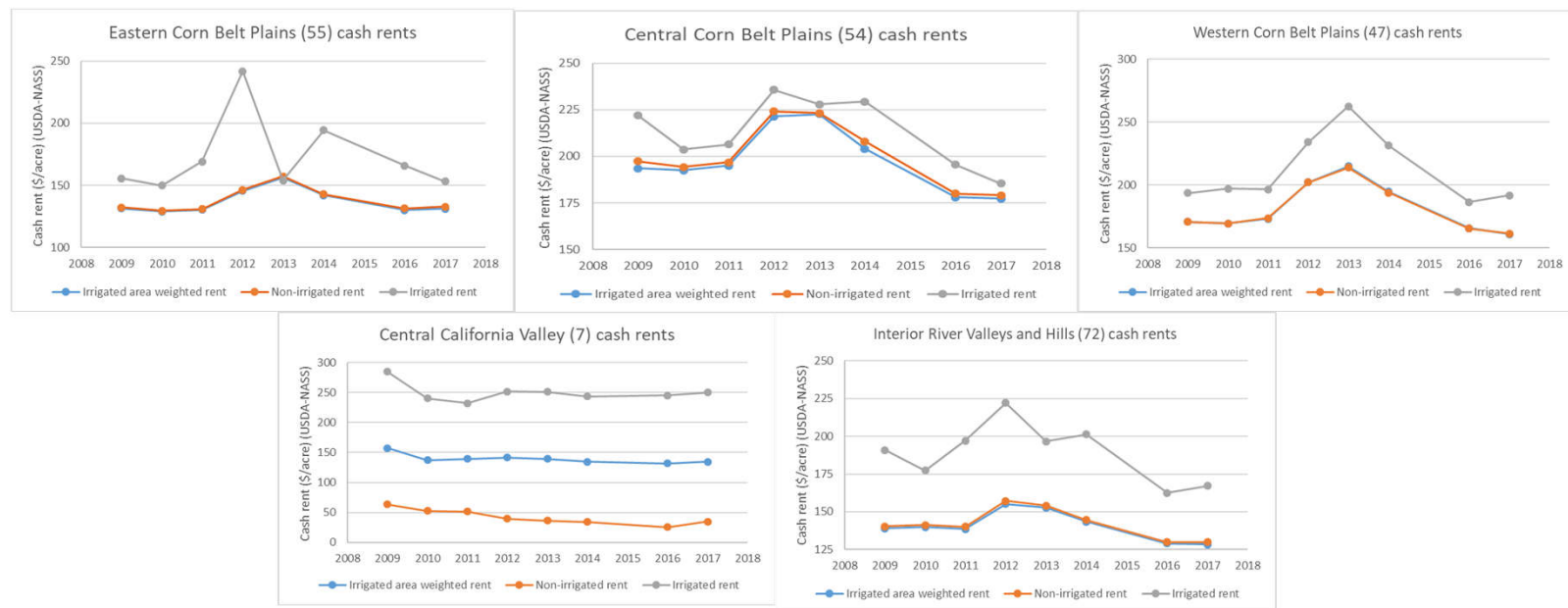


Difference in average land rent between 2017 and 2009

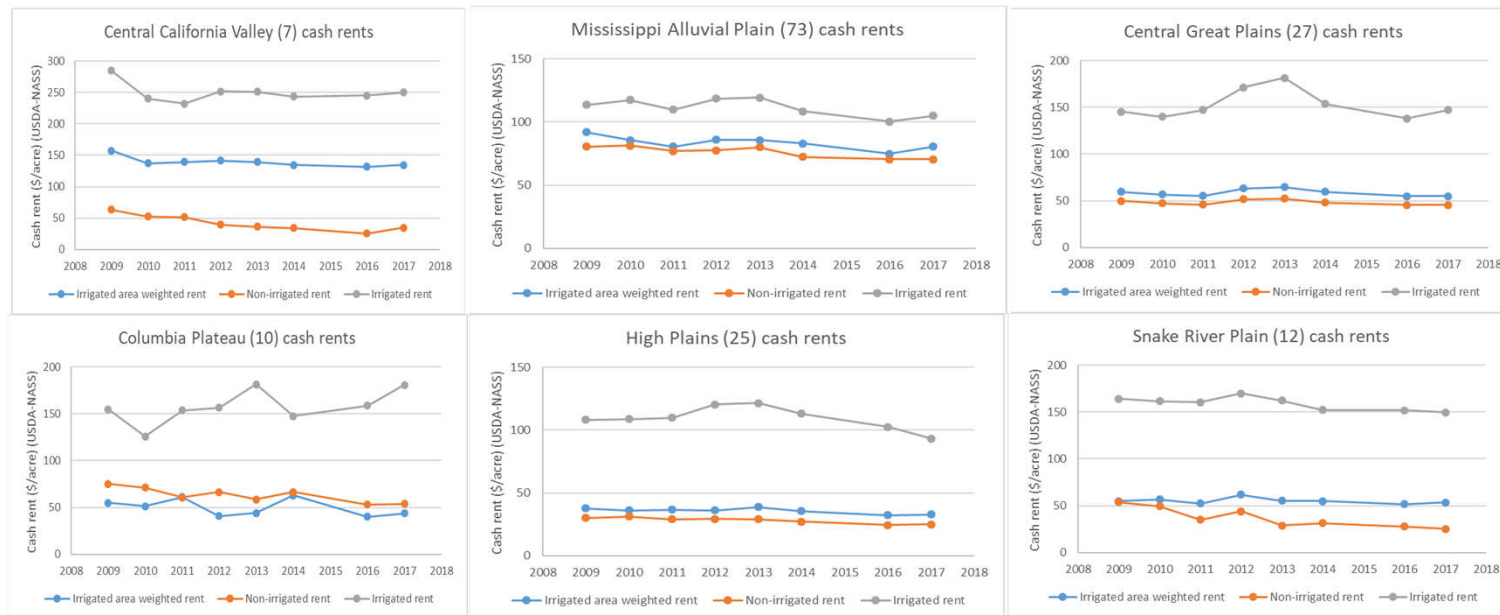


Trends in cash rents by Eco-region

Primarily agricultural Eco-regions



Primarily irrigated Eco-regions



Land conversion to Cropland by Farm Resource Region

Resource Region	Area in hectares	Proportion cropland 2017	Proportion of total cropland in 2017 that were of different LC type in 2009				
			Forests	G & P	Shrubland	Urban	Total
Heartland	59367818.25	0.5439	0.0026	0.0778	0.0000	0.0036	0.0840
Northern Crescent	71356782.33	0.1364	0.0094	0.1747	0.0011	0.0049	0.1901
Northern Great Plains	64955703.78	0.2916	0.0007	0.1478	0.0017	0.0037	0.1539
Prairie Gateway	79756293.33	0.2491	0.0009	0.0923	0.0123	0.0043	0.1099
Eastern Uplands	40039416.72	0.0326	0.0167	0.3670	0.0013	0.0089	0.3940
Southern Seaboard	47382866.82	0.0877	0.0137	0.1301	0.0095	0.0083	0.1617
Fruitful Rim	95113592.46	0.0895	0.0024	0.0890	0.0394	0.0072	0.1379
Basin and Range	131573676.5	0.0307	0.0023	0.1577	0.0600	0.0061	0.2261
Mississippi Portal	19260411.12	0.2635	0.0027	0.0494	0.0025	0.0061	0.0608
Total	608806561.32	0.1707	0.0032	0.1108	0.0088	0.0046	0.1274

- FRR's with high cropland proportions in 2017, except Mississippi Portal, had significant proportions of cropland coming from land that were grassland and pasture (G & P) in 2009.
- Conversions have been primarily from G & P.

Conversion of Cropland to other land cover/ use types by Farm Resource Region

Resource Region	Proportion cropland 2009	Proportion area under non-cropland LC in 2017					Proportion of each LC in 2017 that were Cropland in 2009				
		Forests	G & P	Shrubland	Urban	Total	Forests	G & P	Shrubland	Urban	Total
Heartland	0.5148	0.1769	0.1511	0.0015	0.0878	0.4172	0.0082	0.0855	0.0786	0.0160	0.0381
Northern Crescent	0.1295	0.4966	0.0742	0.0173	0.0963	0.6844	0.0083	0.1603	0.0344	0.0133	0.0262
Northern Great Plains	0.2624	0.0480	0.5040	0.0748	0.0253	0.6521	0.0029	0.0312	0.0089	0.0235	0.0262
Prairie Gateway	0.2409	0.0792	0.3790	0.2276	0.0494	0.7352	0.0037	0.0324	0.0228	0.0237	0.0258
Eastern Uplands	0.0268	0.6323	0.2139	0.0139	0.0826	0.9426	0.0013	0.0252	0.0162	0.0056	0.0073
Southern Seaboard	0.0977	0.4556	0.1175	0.0816	0.0918	0.7465	0.0100	0.0913	0.0508	0.0203	0.0286
Fruitful Rim	0.0925	0.2071	0.0890	0.4500	0.0643	0.8104	0.0017	0.0953	0.0106	0.0152	0.0180
Basin and Range	0.0290	0.2804	0.0886	0.5413	0.0131	0.9234	0.0002	0.0359	0.0031	0.0193	0.0056
Mississippi Portal	0.2650	0.2623	0.0856	0.0651	0.0630	0.4760	0.0044	0.1189	0.0191	0.0255	0.0298
Total	0.1634	0.2693	0.1858	0.2366	0.0565	0.7481	0.0044	0.0509	0.0098	0.0166	0.0186

- Among the LC types, cropland has primarily been converted to grassland and pastures, although the proportions are less than those for conversion to cropland.
- 16% of grassland and pastures in the Northern Crescent was converted from cropland.

Elasticities

Two types of models are used for estimating land supply elasticities:

- We use the Papke and Wooldridge (2008) fractional probit model for panel data to estimate the parameters from the following regression specification:

$$Z_{it} = \Phi(\beta_0 + \beta_1 R_{it} + \beta_2 A_i + \beta_3 Q_i + \varepsilon_{it})$$

- Here, where Z_{it} is the fraction of each grid cell under cropland and Φ denotes the standard normal cumulative distribution function (CDF). R_{it} refers to discounted irrigated area weighted grid-cell level land rents accruing to agriculture, A_i is grid cell level access index, and Q_i is grid cell level soil quality index. Both A_i and Q_i range from 0 to 1. Cash rents are obtained from USDA-NASS. Elasticities are obtained from the partial effects, fitted cropland proportion and cash rents.
- We also use a long difference estimator. For example:

$$\log Z_{it+4} - \log Z_{it} = \beta_0 + \beta_1 (\log R_{it+4} - \log R_{it})$$

- The estimated coefficient $\hat{\beta}_1$ is the land supply elasticity or percentage change in cropland proportion for a 1% increase in land rent between the years t and $t+4$.

Elasticities

Full Sample

FRR Code	Farm Resource Region	Panel Estimation Elasticities						Long Difference Elasticities					
		2009-13	n	2013-17	n	2009-17	n	2009-13	2013-17	2009-17	n	2 period	n
1	Heartland	-0.210***	46,850	0.175***	37,480	-0.00621***	74,960	-0.072***	-0.0207	-0.217***	10,339	0.0101	20,678
2	Northern Crescent	-0.0732***	31,330	0.341***	25,064	0.0559***	50,128	0.091***	0.0247**	0.288***	7,308	0.0272***	14,616
3	Northern Great Plains	0.0285***	36,170	0.0608***	28,936	0.0614***	57,872	0.0518***	-0.0099	0.044**	9,023	0.0182**	18,046
4	Prairie Gateway	0.0599***	40,015	-0.0383***	32,012	0.0150***	64,024	0.0455***	-0.0134	0.06***	9,841	0.00662	19,682
5	Eastern Uplands	0.135***	14,835	-0.0162	11,868	0.183***	23,736	0.393***	-0.377***	0.107**	4,249	0.0533	8,498
6	Southern Seaboard	-0.0630***	22,285	0.200***	17,828	-0.00572	35,656	0.166***	0.088***	0.123***	5,343	0.143***	10,686
7	Fruitful Rim	-0.145***	27,070	0.259***	21,656	-0.00514**	43,312	0.0068	-0.027***	-0.0165	6,998	-0.00756	13,996
8	Basin and Range	-0.127***	28,855	0.0982**	23,084	0.00475	46,168	-0.0013	0.009	0.0164	6,008	0.00128	12,016
9	Mississippi Portal	-0.0123	10,220	-0.0219	8,176	-0.00133	16,352	0.073*	0.0142	0.0385	2,654	0.0454**	5,308
	USA	-0.0699***	257,630	0.11***	206,104	0.0146***	412,208	0.0449***	-0.0087*	0.05***	61,763	0.0126***	123,526

- 2 period model refers to a 2 period panel model with 2009-13 and 2013-17 cropland and cash rents.
- We find significant heterogeneity in elasticities across the Farm Resource Regions.
- The full sample and 25% sample estimates are comparable and consistent across resource regions.

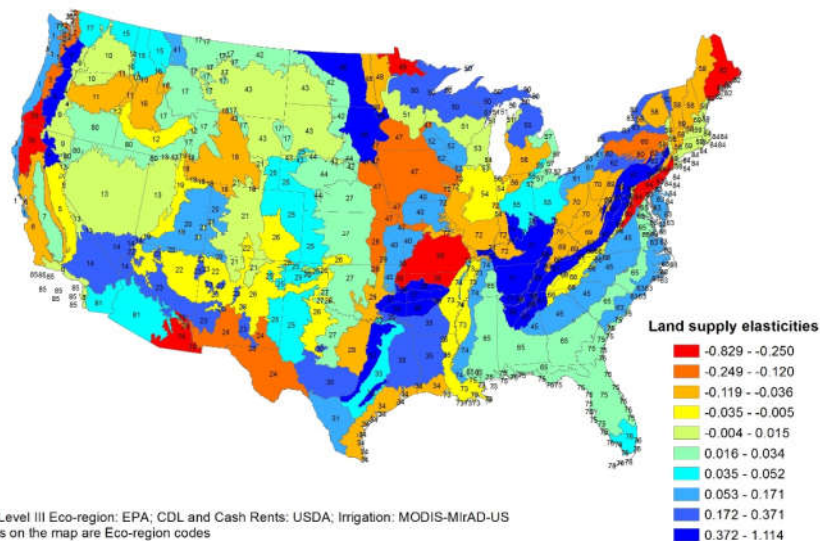
Elasticities

25% Sample elasticities

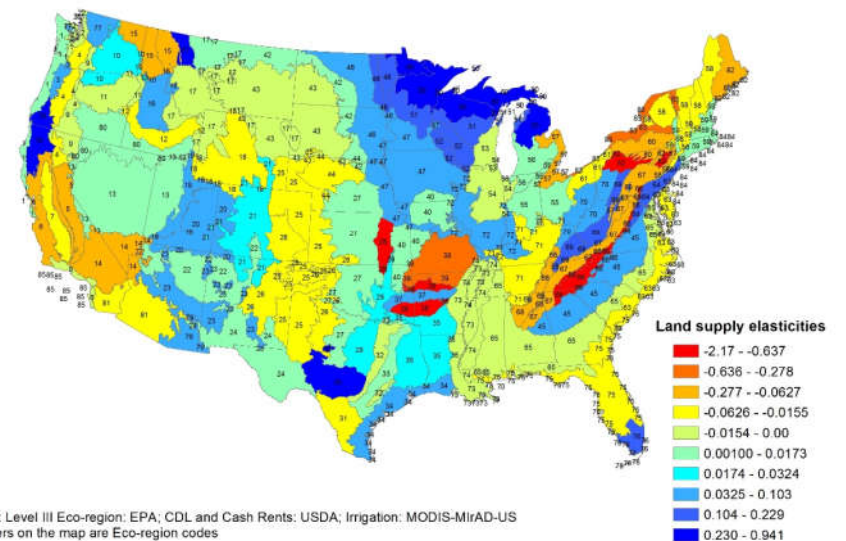
FRR Code	Farm Resource Region	Panel Estimation Elasticities						Long Difference Elasticities					
		2009-13	n	2013-17	n	2009-17	n	2009-13	2013-17	2009-17	n	2 period	n
1	Heartland	-0.228***	11,835	0.184***	9,468	-0.00717	18,936	-0.0322	-0.0265	-0.240***	2,620	0.0278	5,240
2	Northern Crescent	-0.0416***	7,885	0.317***	6,308	0.0449***	12,616	0.0958***	0.0147	0.291***	1,845	0.0269**	3,690
3	Northern Great Plains	0.0467***	8,740	0.0406*	6,992	0.0533***	13,984	0.0670***	-0.0318	0.0253	2,227	0.0214	4,454
4	Prairie Gateway	0.0627***	9,920	-0.0686***	7,936	0.0133***	15,872	0.0393*	-0.0591***	0.0275	2,455	-0.0165	4,910
5	Eastern Uplands	0.170***	3,515	-0.0323	2,812	0.212***	5,624	0.450***	-0.528***	0.235**	1,053	-0.0254	2,106
6	Southern Seaboard	-0.133***	5,455	0.246***	4,364	-0.014	8,728	0.200***	0.0953***	0.115**	1,324	0.174***	2,648
7	Fruitful Rim	-0.131***	5,670	0.197***	4,536	-0.00735	9,072	0.0224	-0.036	0.0371	1,768	-0.0138	3,536
8	Basin and Range	-0.0812*	5,195	0.0983	4,156	0.00237	8,312	-0.014	-0.0116	0.0155	1,472	-0.0183	2,944
9	Mississippi Portal	0.0693	2,655	-0.103**	2,124	-0.0112	4,248	0.0954	0.0165	0.0114	681	0.0649	1,362
	USA	-0.0643***	60,870	0.0752***	48,696	0.0107***	97,392	0.0458***	-0.026***	0.0619***	15,445	0.00127	30,890

Elasticities by Eco-Regions

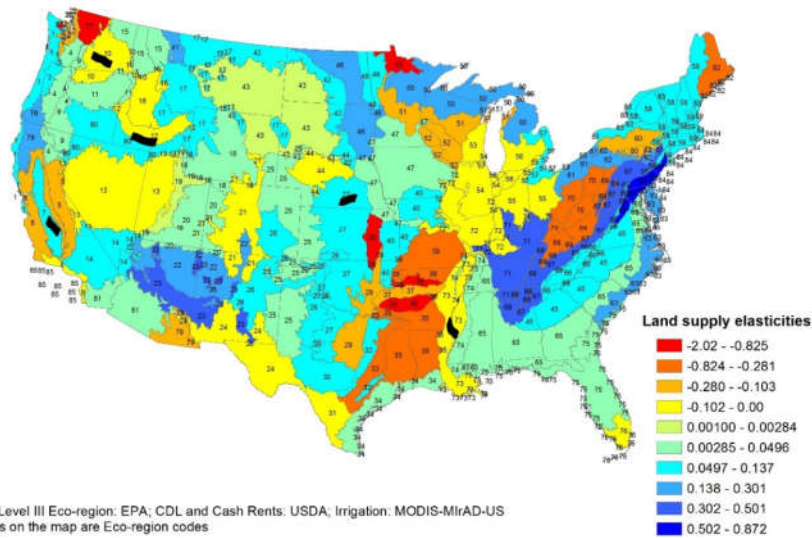
Land Supply Elasticities by Eco-regions
(long differences - 2013 and 2009)



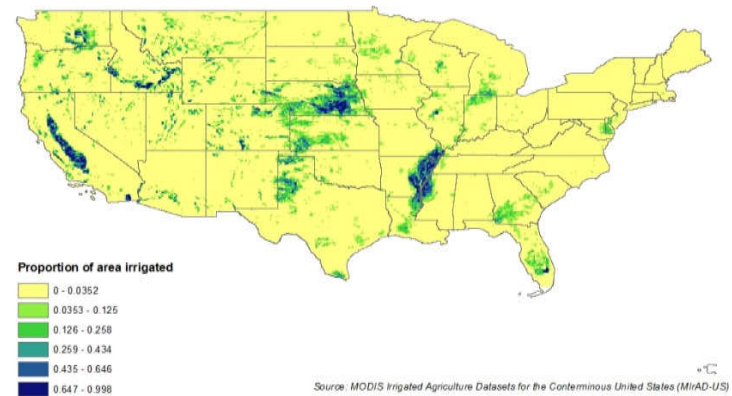
Land Supply Elasticities by Eco-regions
(long differences - 2017 and 2013)



Land Supply Elasticities by Eco-regions
(long differences - 2017 and 2009)



Irrigated agricultural areas in the US (2017)
Proportion of area irrigated for 5 arc minute gridcells



- Elasticities from the full sample long difference model shown.
- Heterogeneity in elasticities by Eco-regions.
- Signs and magnitudes change depending on the timeline. For example, the Western Corn Belt in Iowa.
- Traditionally irrigated areas (MIrAD data) do not have high elasticities.

Predictability

In-sample correlations between predicted and given proportion cropland. Full Sample long difference model.

FRR Code	Farm Resource Region	Spearman rank correlation coefficient						Pearson correlation coefficient					
		2009-13	2013-17	2009-17	n	2 period	n	2009-13	2013-17	2009-17	n	2 period	n
1	Heartland	0.0309*	-0.2031*	-0.0476*	10,339	0.2481*	20,678	0.0764*	0.0303*	0.1941*	10,339	0.0369*	20,678
2	Northern Crescent	0.1449*	0.1083*	0.1537*	7,308	0.3458*	14,616	0.0832*	0.0252*	0.1407*	7,308	0.1592*	14,616
3	Northern Great Plains	0.2818*	-0.09*	0.2267*	9,023	0.3507*	18,046	0.0687*	0.0199*	0.0424*	9,023	0.2257*	18,046
4	Prairie Gateway	0.1792*	-0.0265*	0.1587*	9,841	0.3168*	19,682	0.0521*	0.017*	0.0564*	9,841	0.1468*	19,682
5	Eastern Uplands	0.1761*	0.116*	0.1297*	4,249	0.2247*	8,498	0.1464*	0.1401*	0.0408*	4,249	0.2134*	8,498
6	Southern Seaboard	0.1542*	0.0654*	0.1301*	5,343	0.2709*	10,686	0.1146*	0.0655*	0.0808*	5,343	0.2110*	10,686
7	Fruitful Rim	0.0179	0.0008	0.0178	6,998	0.2515*	13,996	0.0086	0.0377*	0.0167	6,998	0.2005*	13,996
8	Basin and Range	0.0001	0.0261	-0.0068	6,008	0.2778*	12,016	0.0017	0.0135	0.0167	6,008	0.2534*	12,016
9	Mississippi Portal	0.1443*	0.0073	0.0957*	2,654	0.4196*	5,308	0.0803*	0.022	0.0342	2,654	0.2643*	5,308
	USA	0.2548*	0.1419*	0.2343*	61,763	0.2942*	123,526	0.2176*	0.0987*	0.1989*	61,763	0.1783*	123,526

- Corresponding elasticities are given in earlier slides.
- Correlations are relatively higher for 2009-13 and 2009-17 models.
- * corresponds to significance at 95% or higher confidence level

Predictability

In-sample correlations between predicted and given proportion cropland.

25% sample (stratified sample by Eco-regions) long difference model

FRR Code	Farm Resource Region	Spearman rank correlation coefficient						Pearson correlation coefficient					
		2009-13	2013-17	2009-17	n	2 period	n	2009-13	2013-17	2009-17	n	2 period	n
1	Heartland	0.0166*	-0.1773*	-0.0612*	2,620	0.2547*	5,240	0.0374*	0.039*	0.2043*	2,620	0.0006	5,240
2	Northern Crescent	0.1511*	0.0968*	0.1721*	1,845	0.3467*	3,690	0.095*	0.0157	0.1451*	1,845	0.1646*	3,690
3	Northern Great Plains	0.2998*	-0.0573*	0.1948*	2,227	0.3558*	4,454	0.0834*	0.058*	0.0218	2,227	0.2314*	4,454
4	Prairie Gateway	0.1705*	-0.01	0.1411*	2,455	0.2588*	4,910	0.0448*	0.0773*	0.0234	2,455	0.1495*	4,910
5	Eastern Uplands	0.2147*	0.1703*	0.1448*	1,053	0.1792*	2,106	0.1647*	0.1852*	0.0899*	1,053	0.1887*	2,106
6	Southern Seaboard	0.1756*	0.0621*	0.1158*	1,324	0.2747*	2,648	0.1282*	0.0741*	0.0741*	1,324	0.2396*	2,648
7	Fruitful Rim	0.0035	0.0548*	0.0104	1,768	0.2424*	3,536	0.0273	0.0467*	0.0367	1,768	0.1750*	3,536
8	Basin and Range	0.0204	0.008	-0.0019	1,472	0.2768*	2,944	0.019	0.0182	0.0159	1,472	0.2682*	2,944
9	Mississippi Portal	0.131*	0.0348	0.1035*	681	0.4044*	1,362	0.0986*	0.0306	0.0094	681	0.2859*	1,362
	USA	0.2444*	0.1396*	0.2245*	15,445	0.2847*	30,890	0.2153*	0.1144*	0.1932*	15,445	0.1753*	30,890

- Correlations are relatively higher for 2009-13 and 2009-17 models.
- Even though the correlations from the 2-period model are high, most of the coefficients from the long difference 2-period model are not significant.

Predictability

Out-of-sample correlations between predicted and given proportion cropland.

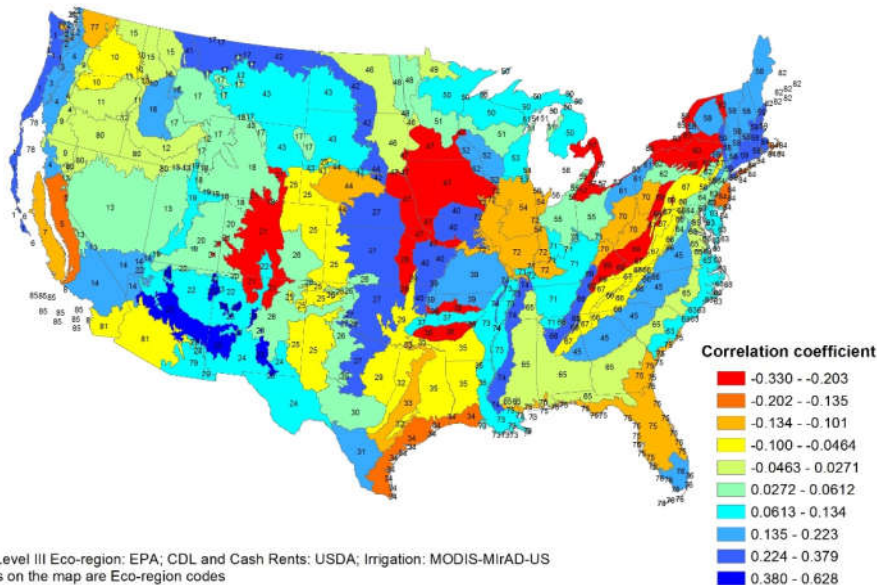
25% sample (stratified sample by Eco-regions) long difference model

FRR Code	Farm Resource Region	Spearman rank correlation coefficient				Pearson correlation coefficient			
		2009-13	2013-17	2009-17	n	2009-13	2013-17	2009-17	n
1	Heartland	0.0502*	-0.2123*	-0.0445*	2588	0.1216*	0.0024*	0.19*	2,588
2	Northern Crescent	0.1429*	0.1305*	0.1695*	1829	0.0921*	0.0371*	0.1623*	1,829
3	Northern Great Plains	0.2655*	0.1339*	0.2175*	2285	0.0418*	0.0531*	0.0726*	2,285
4	Prairie Gateway	0.1733*	0.033*	0.1543*	2405	0.0233*	0.0158*	0.0783*	2,405
5	Eastern Uplands	0.1452*	0.1349*	0.1289*	1073	0.1004*	0.1444*	0.0182*	1,073
6	Southern Seaboard	0.1575*	0.0442*	0.1322*	1343	0.0741*	0.0494*	0.083*	1,343
7	Fruitful Rim	-0.0099	0.0303*	0.0296*	1765	0.0235*	0.0808*	0.0124	1,765
8	Basin and Range	0.007	0.0643*	0.0337*	1505	0.019*	0.0182*	0.0081	1,505
9	Mississippi Portal	0.1876*	0.0315*	0.107*	647	0.1385*	0.0242*	0.0537	647
	USA	0.2701*	0.1509*	0.2385*	15,440	0.2268*	0.1171*	0.2051*	15,440

- Estimates from the long difference models using 25% sample are used to predict cropland proportions of another 25% sample of the data.
- Out-of-sample predictive power are relatively higher for 2009-13 and 2009-17 models.

In-sample correlations by Eco-regions

Pearson Correlations between In-sample
Predicted and Actual Cropland Proportion by Eco-regions
(long difference model - 2009 - 17)



- Correlations between predicted and actual cropland proportions vary by ecoregion.
- The long difference model for 2009-17 predicts cropland well for the Great Plains and the Glaciated Plains.
- However, the correlations are negative for the Western and Central Corn Belt Plains.
- We plan to test the predictive power of the remaining models (including both long difference and panel models), and also incorporate additional time varying covariates like precipitation and temperature that could impact cropland change.

Thank You