How to Estimate Crop Yield Densities of Counties with Missing Data

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NASS county-level corn yield data

Minnesota (57 out of 87 counties from 1955 to 2017)

Missouri (48 out of 114 counties from 1955 to 2017)

Maryland (13 out of 23 counties from 1955 to 2017)

Colorado (2 out of 64 counties from 1963 to 2017)

Montana (1 out of 56 counties from 1963 to 2017)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
ADAMS	116.5	113.5	115.5	112.5	119.5	126.5	140	140	141	130	138.5	119	131	113.5	124.5	89	110	84.5	122.5	82	74	117.5	126	47.5	138	138.5	167.5	76	94	NA	81.8	72.7	65	61.8	125.4	112.5	90.1	82
CHEYENNE	104.5	123.5	119	107.5	125	138.5	146	148	130	140	148.5	138	150.5	123	148.5	108	149	127	118.5	113	88.5	86	135	85.5	78.5	102.5	77	103.5	92	NA	127	92.2	75.5	101.8	102.6	101.3	81.8	110.7
DELTA	116.5	133.5	139.5	139	127.5	156	152	150.9	150	150	144.5	145	133.5	152.5	165	136.5	157.5	172.5	176.5	177	171.5	148.5	170	159	165	177	190.5	159	200	NA	NA	NA	NA	NA	NA	192.4	NA	NA
DOUGLAS	NA	NA	NA	NA	NA	NA	NA	130	120	120	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
ELBERT	51	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	150	140	NA	NA	NA	NA	60	55	38.5	66.5	20	36.5	72.5	49.5	42.5	60	44	NA	66.3	55.9	NA	NA	NA	75	40.4	71.4
FREMONT	75	NA	NA	NA	NA	NA	NA	NA	NA	NA	135	NA	NA	140	NA	NA	NA	NA	NA	0	NA	0	NA	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GARFIELD	115	115	85	NA	NA	NA	125	100	NA	NA	NA	NA	150	120	116.5	110	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
JEFFERSON	120	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
KIOWA	60	NA	NA	110	120	125	125	130	120	130	143.5	83	98.5	109	85.5	86	138	120	93	76	29	39	70	63	67.5	78.5	43.5	NA	60	NA	60.6	64.7	NA	59.6	NA	77.3	50.7	NA
LINCOLN	96	NA	NA	120	NA	NA	155	160	162	140	154	105	82.5	73.5	75	81.5	98	83.5	90	86.5	57	83.5	86.5	39	75	67	64	65.5	39	NA	59.8	46.6	27.5	32.6	62.8	73.8	64.2	NA
LOGAN	114	123.5	120.5	113.5	120.5	127	140	138.1	145.5	128.5	137	130.5	141.5	109	124.5	93.5	127	128	122	122	114.5	121.5	132	110.5	122	139.5	130	141	138	151	166	134.6	130.1	129.9	148.9	143.4	NA	NA
MORGAN	121	143	132.5	132.5	145	146	162	159.3	166	145	164	160	160	128	148.5	115	148.5	152	152	159	151.5	174.5	163	159	176	184	198	158	164	NA	NA	163.1	180.7	168.6	162.2	157.6	NA	184.8
OTERO	75.5	110	113	109	120	119	134	135	142	130	140	153	172.5	139.5	160.5	149	168	156	153.5	165.5	162.5	172	124.5	183.5	200	180.5	228.5	184.5	186	NA	190.2	174.8	148.1	NA	191.8	NA	187.7	171.7
PHILLIPS	125	127.5	132.5	111.5	129.5	129.5	135	156.5	158.5	139.5	151.5	143.5	127.5	94.5	144	100.5	115	127	126.5	127	111.5	130	142	124.5	127	144	141	141	152	NA	157.6	135	125.2	122.2	154.6	148.5	142.9	148.6
SAN MIGUEL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SEDGWICK	115.5	129	131	117.5	131	132.5	136	151.4	154	128	138.5	144.5	115.5	114.5	138.5	104	136.5	124	134	134.5	112.5	116	123	130.5	129.5	147	155	170.5	NA	NA	150.3	132	110.1	117.4	149.8	135	122.2	140.5
WASHINGTON	130.5	144	128	126.5	130	124.5	137.5	163.6	144.5	139.5	151.5	137	119.5	89.5	114	72	116.5	117.5	97.5	106.5	73.5	107.5	134.5	81.5	100.5	87.5	111	106.5	78	NA	104.5	79.8	66.6	NA	108.6	NA	NA	79.5
ARAPAHOE	110	NA	NA	105	120	112	120	NA	NA	NA	NA	166.5	145	81.5	78	30	100	140	84	72	54	112.5	60	83.5	NA	46.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
ARCHULETA	110	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BACA	92	95.5	115.5	102	120	116	124	140	165	160	130	155.5	169.5	164.5	147	134	192.5	143.5	184.5	179	151.5	154	147.5	131	172	130.5	136.5	112.5	108	NA	132.4	NA	138.2	NA	NA	NA	128.2	NA
BENT	74	98.5	120.5	106	109.5	105	114	120	115	120	125	115.5	134.5	127.5	125.5	111.5	134	139	174	203	127.5	120	90	0	152	133.5	190	167	149	NA	146.8	144	NA	NA	131.6	NA	155.4	164.3
BOULDER	120	117	127.5	114	124	129.5	131	146	144	135	148	144	129	147	141.5	97	153.5	149	148	140	130	115	124	140	164.5	163	147.5	149.5	NA	NA	155.2	173.3	NA	NA	NA	NA	153.1	160
CROWLEY	53	84.5	110	104	120	114	117	120	105	110	115	120	147.5	125	130	102.5	131.5	135	140	128	97	133.5	80	100	NA	NA	NA	NA	NA	119	NA	NA	NA	NA	NA	NA	NA	NA
DOLORES	115	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	140	116.5	NA	NA	NA	NA	0	0	NA	0	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EL PASO	40	68	90	80	86.5	70	120	75	110	120	NA	NA	NA	113.5	116.5	NA	NA	NA	NA	NA	160	NA	NA	NA	NA	NA	NA	NA	153	NA	NA	NA	NA	NA	NA	NA	NA	NA
HUERFANO	80	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	NA	NA	100	NA	NA	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
KIT CARSON	99.5	132	128	113.5	143	153	152	152.2	168	144	156.5	159	154.5	113.5	159.5	101.5	157.5	155	152.5	132.5	99.5	105	116.5	133	114	134	121	125	100	NA	136.7	110.8	89.3	95.7	102.6	121.7	116.7	133.7
LA PLATA	NA	112.5	130	80	100	105	105	130	125	130	NA	NA	115	130	100	NA	NA	NA	NA	NA	NA	NA	0	NA	NA	116.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
LARIMER	95.5	138.5	124	114	123	131	129	141	143	138	150	145.5	153	136.5	141.5	116.5	146.5	145	125.5	147	138.5	132.5	135.5	155	136.5	153	137.5	150	123	NA	184.3	NA	133	132	146.6	130	101.2	NA
LAS ANIMAS	80	99	95	94	98	100	108	100	100	136	126	100	120	117	160	112.5	140	130	140	140	114	120	NA	NA	NA	125	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MESA	113.5	125.5	135.5	133.5	135.5	131.5	135	140	135	142	146.5	143	129.5	137	120	134.5	137	141.5	148.5	152	145	147.5	133.5	138	148	159	189	149.5	128	NA	NA	NA	NA	NA	NA	NA	NA	NA
MONTEZUMA	110	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	170	140	125	175	173.5	200	180	153.5	160	150	NA	NA	NA	NA	168	0	NA	NA	NA	NA	NA	NA	NA	150	NA	NA
MONTROSE	117.5	113	129	118.5	135.5	131.5	136.5	137.5	140	136	151	138	160	148	148.5	137	166.5	169	170	159	162	162	154.5	154.5	171	166.5	180	165.5	179	NA	NA	NA	NA	NA	NA	NA	NA	NA
PROWERS	77	129	123.5	109	130	115	135	145	142	141	146.5	123	149	136.5	141.5	124.5	163.5	144.5	164	145	139.5	160	143.5	162.5	134.5	122	145	111.5	131	NA	152	128.4	158.5	NA	NA	NA	NA	NA
PUEBLO	106	106	130	117.5	119.5	115	147	145	165	140	170	167.5	167	152.5	172.5	120	171.5	175.5	186.5	201.5	168	208	116	125	187.5	160	204.5	194	214	NA	193	191.2	203.7	NA	NA	NA	NA	193.6
WELD	113	135.5	133	123.5	130.5	140.5	147	149.8	157	146.5	157.5	153.5	151.5	141	151.5	117	137.5	151	146.5	164.5	154	165.5	153.5	131.5	160.5	171.5	172.5	151.5	168	176	194.5	183.6	178.7	162.2	169.5	175.8	157.4	175.4

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
ADAMS	116.5	113.5	115.5	112.5	119.5	126.5	140	140	141	130	138.5	119	131	113.5	124.5	89	110	84.5
CHEYENNE	104.5	123.5	119	107.5	125	138.5	146	148	130	140	148.5	138	150.5	123	148.5	108	149	127
DELTA	116.5	133.5	139.5	139	127.5	156	152	150.9	150	150	144.5	145	133.5	152.5	165	136.5	157.5	172.5
DOUGLAS	NA	NA	NA	NA	NA	NA	NA	130	120	120	NA	NA	NA	NA	NA	NA	NA	NA
ELBERT	51	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	150	140	NA	NA	NA	NA
FREMONT	75	NA	NA	NA	NA	NA	NA	NA	NA	NA	135	NA	NA	140	NA	NA	NA	NA
GARFIELD	115	115	85	NA	NA	NA	125	100	NA	NA	NA	NA	150	120	116.5	110	NA	NA
JEFFERSON	120	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
KIOWA	60	NA	NA	110	120	125	125	130	120	130	143.5	83	98.5	109	85.5	86	138	120
LINCOLN	96	NA	NA	120	NA	NA	155	160	162	140	154	105	82.5	73.5	75	81.5	98	83.5
LOGAN	114	123.5	120.5	113.5	120.5	127	140	138.1	145.5	128.5	137	130.5	141.5	109	124.5	93.5	127	128
MORGAN	121	143	132.5	132.5	145	146	162	159.3	166	145	164	160	160	128	148.5	115	148.5	152
OTERO	75.5	110	113	109	120	119	134	135	142	130	140	153	172.5	139.5	160.5	149	168	156
PHILLIPS	125	127.5	132.5	111.5	129.5	129.5	135	156.5	158.5	139.5	151.5	143.5	127.5	94.5	144	100.5	115	127
SAN MIGUEL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SEDGWICK	115.5	129	131	117.5	131	132.5	136	151.4	154	128	138.5	144.5	115.5	114.5	138.5	104	136.5	124
WASHINGTON	130.5	144	128	126.5	130	124.5	137.5	163.6	144.5	139.5	151.5	137	119.5	89.5	114	72	116.5	117.5
ARAPAHOE	110	NA	NA	105	120	112	120	NA	NA	NA	NA	166.5	145	81.5	78	30	100	140
ARCHULETA	110	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BACA	92	95.5	115.5	102	120	116	124	140	165	160	130	155.5	169.5	164.5	147	134	192.5	143.5
BENT	74	98.5	120.5	106	109.5	105	114	120	115	120	125	115.5	134.5	127.5	125.5	111.5	134	139
BOULDER	120	117	127.5	114	124	129.5	131	146	144	135	148	144	129	147	141.5	97	153.5	149
CROWLEY	53	84.5	110	104	120	114	117	120	105	110	115	120	147.5	125	130	102.5	131.5	135
DOLORES	115	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	140	116.5	NA	NA	NA
EL PASO	40	68	90	80	86.5	70	120	75	110	120	NA	NA	NA	113.5	116.5	NA	NA	NA
HUERFANO	80	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
KIT CARSON	99.5	132	128	113.5	143	153	152	152.2	168	144	156.5	159	154.5	113.5	159.5	101.5	157.5	155
LA PLATA	NA	112.5	130	80	100	105	105	130	125	130	NA	NA	115	130	100	NA	NA	NA
LARIMER	95.5	138.5	124	114	123	131	129	141	143	138	150	145.5	153	136.5	141.5	116.5	146.5	145
LAS ANIMAS	80	99	95	94	98	100	108	100	100	136	126	100	120	117	160	112.5	140	130
MESA	113.5	125.5	135.5	133.5	135.5	131.5	135	140	135	142	146.5	143	129.5	137	120	134.5	137	141.5
MONTEZUMA	110	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	170	140	125	175	173.5	200
MONTROSE	117.5	113	129	118.5	135.5	131.5	136.5	137.5	140	136	151	138	160	148	148.5	137	166.5	169
PROWERS	77	129	123.5	109	130	115	135	145	142	141	146.5	123	149	136.5	141.5	124.5	163.5	144.5
PUEBLO	106	106	130	117.5	119.5	115	147	145	165	140	170	167.5	167	152.5	172.5	120	171.5	175.5
WELD	113	135.5	133	123.5	130.5	140.5	147	149.8	157	146.5	157.5	153.5	151.5	141	151.5	117	137.5	151

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
ADAMS	122.5	82	74	117.5	126	47.5	138	138.5	167.5	76	94	NA	81.8	72.7	65	61.8	125.4	112.5	90.1	82
CHEYENNE	118.5	113	88.5	86	135	85.5	78.5	102.5	77	103.5	92	NA	127	92.2	75.5	101.8	102.6	101.3	81.8	110.7
DELTA	176.5	177	171.5	148.5	170	159	165	177	190.5	159	200	NA	NA	NA	NA	NA	NA	192.4	NA	NA
DOUGLAS	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
ELBERT	60	55	38.5	66.5	20	36.5	72.5	49.5	42.5	60	44	NA	66.3	55.9	NA	NA	NA	75	40.4	71.4
FREMONT	NA	0	NA	0	NA	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GARFIELD	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
JEFFERSON	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
KIOWA	93	76	29	39	70	63	67.5	78.5	43.5	NA	60	NA	60.6	64.7	NA	59.6	NA	77.3	50.7	NA
LINCOLN	90	86.5	57	83.5	86.5	39	75	67	64	65.5	39	NA	59.8	46.6	27.5	32.6	62.8	73.8	64.2	NA
LOGAN	122	122	114.5	121.5	132	110.5	122	139.5	130	141	138	151	166	134.6	130.1	129.9	148.9	143.4	NA	NA
MORGAN	152	159	151.5	174.5	163	159	176	184	198	158	164	NA	NA	163.1	180.7	168.6	162.2	157.6	NA	184.8
OTERO	153.5	165.5	162.5	172	124.5	183.5	200	180.5	228.5	184.5	186	NA	190.2	174.8	148.1	NA	191.8	NA	187.7	171.7
PHILLIPS	126.5	127	111.5	130	142	124.5	127	144	141	141	152	NA	157.6	135	125.2	122.2	154.6	148.5	142.9	148.6
SAN MIGUEL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SEDGWICK	134	134.5	112.5	116	123	130.5	129.5	147	155	170.5	NA	NA	150.3	132	110.1	117.4	149.8	135	122.2	140.5
WASHINGTON	97.5	106.5	73.5	107.5	134.5	81.5	100.5	87.5	111	106.5	78	NA	104.5	79.8	66.6	NA	108.6	NA	NA	79.5
ARAPAHOE	84	72	54	112.5	60	83.5	NA	46.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
ARCHULETA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BACA	184.5	179	151.5	154	147.5	131	172	130.5	136.5	112.5	108	NA	132.4	NA	138.2	NA	NA	NA	128.2	NA
BENT	174	203	127.5	120	90	0	152	133.5	190	167	149	NA	146.8	144	NA	NA	131.6	NA	155.4	164.3
BOULDER	148	140	130	115	124	140	164.5	163	147.5	149.5	NA	NA	155.2	173.3	NA	NA	NA	NA	153.1	160
CROWLEY	140	128	97	133.5	80	100	NA	NA	NA	NA	NA	119	NA	NA	NA	NA	NA	NA	NA	NA
DOLORES	NA	0	0	NA	0	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EL PASO	NA	NA	160	NA	NA	NA	NA	NA	NA	NA	153	NA	NA	NA	NA	NA	NA	NA	NA	NA
HUERFANO	NA	0	NA	NA	NA	100	NA	NA	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
KIT CARSON	152.5	132.5	99.5	105	116.5	133	114	134	121	125	100	NA	136.7	110.8	89.3	95.7	102.6	121.7	116.7	133.7
LA PLATA	NA	NA	NA	NA	0	NA	NA	116.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
LARIMER	125.5	147	138.5	132.5	135.5	155	136.5	153	137.5	150	123	NA	184.3	NA	133	132	146.6	130	101.2	NA
LAS ANIMAS	140	140	114	120	NA	NA	NA	125	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MESA	148.5	152	145	147.5	133.5	138	148	159	189	149.5	128	NA	NA	NA	NA	NA	NA	NA	NA	NA
MONTEZUMA	180	153.5	160	150	NA	NA	NA	NA	168	0	NA	NA	NA	NA	NA	NA	NA	150	NA	NA
MONTROSE	170	159	162	162	154.5	154.5	171	166.5	180	165.5	179	NA	NA	NA	NA	NA	NA	NA	NA	NA
PROWERS	164	145	139.5	160	143.5	162.5	134.5	122	145	111.5	131	NA	152	128.4	158.5	NA	NA	NA	NA	NA
PUEBLO	186.5	201.5	168	208	116	125	187.5	160	204.5	194	214	NA	193	191.2	203.7	NA	NA	NA	NA	193.6
WELD	146.5	164.5	154	165.5	153.5	131.5	160.5	171.5	172.5	151.5	168	176	194.5	183.6	178.7	162.2	169.5	175.8	157.4	175.4

Data Omission

Quantity

- Level of data omission

Quality

- Recent data omission

Question

How to use a **spatial dependence** of crop yields to

estimate and **reproduce** the **crop yield distributions**

of counties with **missing values** or **no reports at all**?

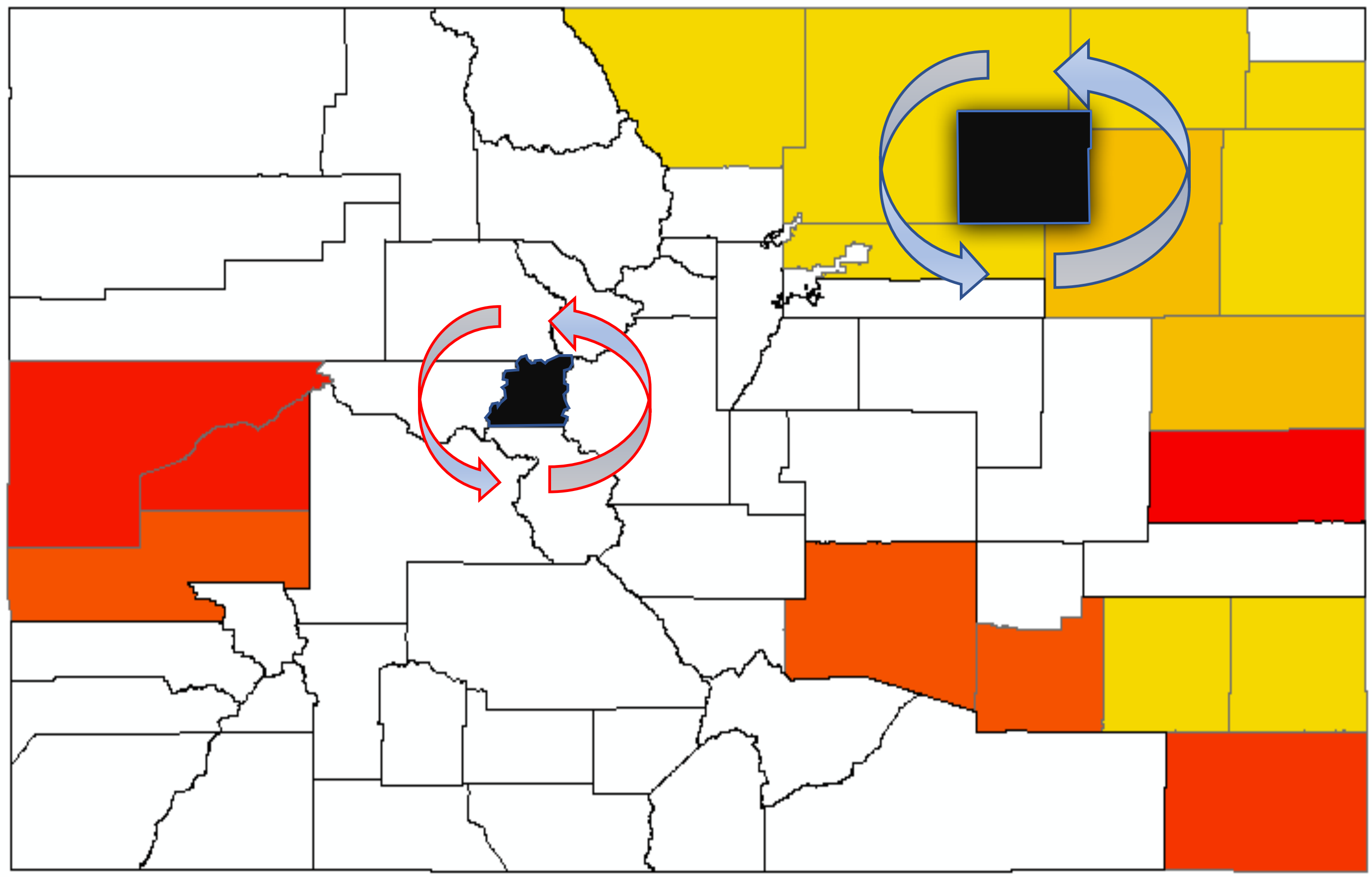
Possible options

1. Using neighboring counties yields

2. Bayesian Model Averaging **(Benchmark)**

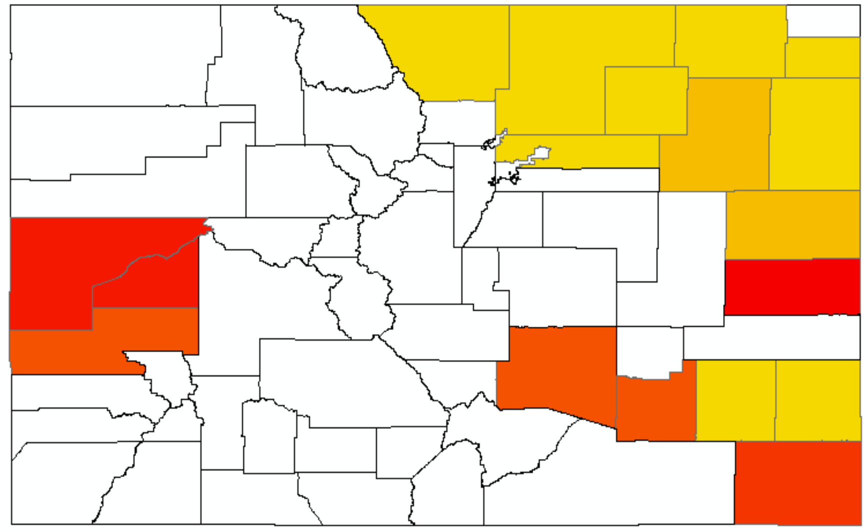
3. Bayesian Spatial Interpolation **(Proposed)**

Neighboring counties yields

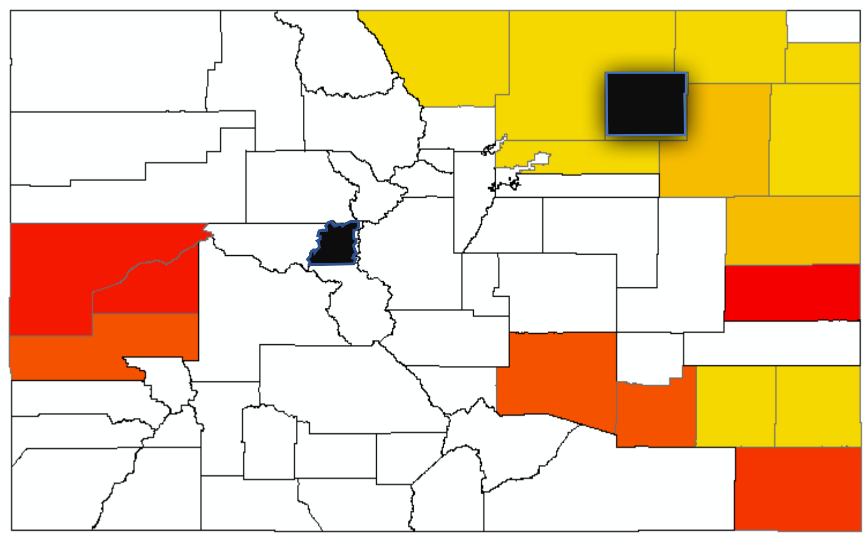


Bayesian Model Averaging (BMA)

Estimate each county's density (ϕ_i) indenpepedently by using its own yield records

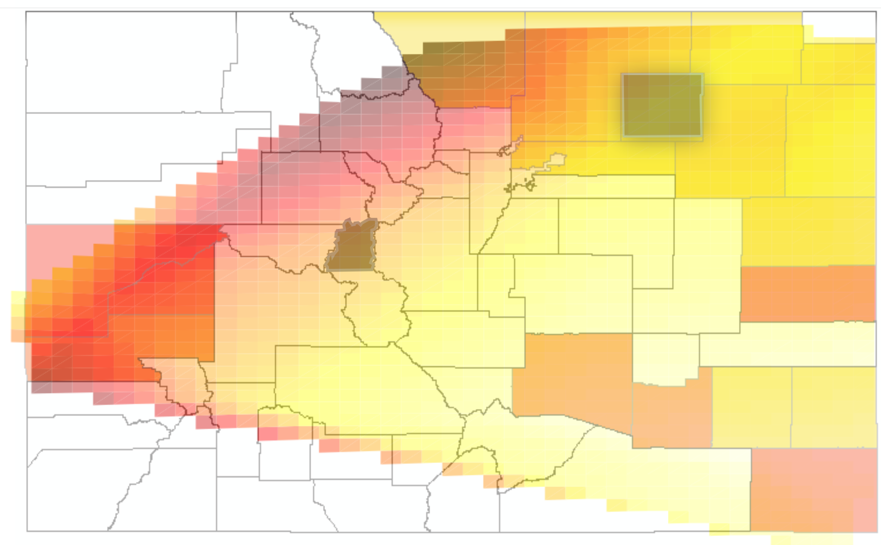


Final density (f_i) is an **weighted average** of **independently** estimated density ϕ_j, $f_i = \sum_{j=1}^{J} w_j^i \, \phi_j$



Bayesian Interpolation Model

Regard county level densities as a **variation from an integrated yield density structure across space**



Bayesian Spatiotemporal Models

- **Parameters** are stochastic and are spatially correlated by **distance** (Gaussian spatial process)

- Provides **site (county) specific density** estimates

- **Strong efficiency gain** even when # of obs is small

  (by updating spatial structures)

- Posterior predictive distribution **(time and space)**

  - Unbalanced panel data
  - Recover missing observations

Bayesian Spatiotemporal Models

- y_{it} be the crop yield of county i at year t, and be $y_{it} = \mu_{it} + \varepsilon_{it}$,
- Define a quantile function $Q_{it}(\pi)$ of county i at time t that satisfies the condition $P\{\mu_{it} < Q_{it}\} = \pi \in [0,1]$

$$Q_{it}(\pi) = \sum_{l=1}^{L} \{\beta_{0i} + \beta_{1i}t + [\gamma_{0il} + \gamma_{1il}t]B_l(\pi)\},$$

$$\mathrm{P}(y_{it}) = \sum_{l=1}^{L} I\{Q_{it}(h_l) \leq y_{it} < Q_{it}(h_{l+1})\}N(\beta_{0i} + \beta_{1i}t, (\gamma_{0il} + \gamma_{1il}t)^2),$$

where $B_l(\pi)$ is lth basis (quantile) function.

Bayesian Spatiotemporal Models

$$\mathrm{P}(y_{it}) = \sum_{l=1}^{L} I\{Q_{it}(h_l) \le y_{it} < Q_{it}(h_{l+1})\} N(\beta_{0i} + \beta_{1i}t, (\gamma_{0il} + \gamma_{1il}t)^2),$$

$$\mathrm{cov}(\beta_{0i}, \beta_{0j}) = \Sigma_{\beta_0} = \rho_{\beta_0} e^{-D_{ij}/\theta_{\beta_0}}$$

$$\mathrm{cov}(\beta_{1i}, \beta_{1j}) = \Sigma_{\beta_1} = \rho_{\beta_1} e^{-D_{ij}/\theta_{\beta_1}}$$

$$\mathrm{cov}(\gamma_{0il}, \gamma_{0jl}) = \Sigma_{\gamma_{0l}} = \rho_{\gamma_{0l}} e^{-D_{ij}/\theta_{\gamma_{0l}}}$$

$$\mathrm{cov}(\gamma_{1il}, \gamma_{1jl}) = \Sigma_{\gamma_{1l}} = \rho_{\gamma_{1l}} e^{-D_{ij}/\theta_{\gamma_{1l}}}$$

Empirical Application

Empirical application

- Iowa

  - **99** counties (1955-2017)

- Maryland

  - **23** counties (1955-2017) : **Small number of counties**

- Colorado

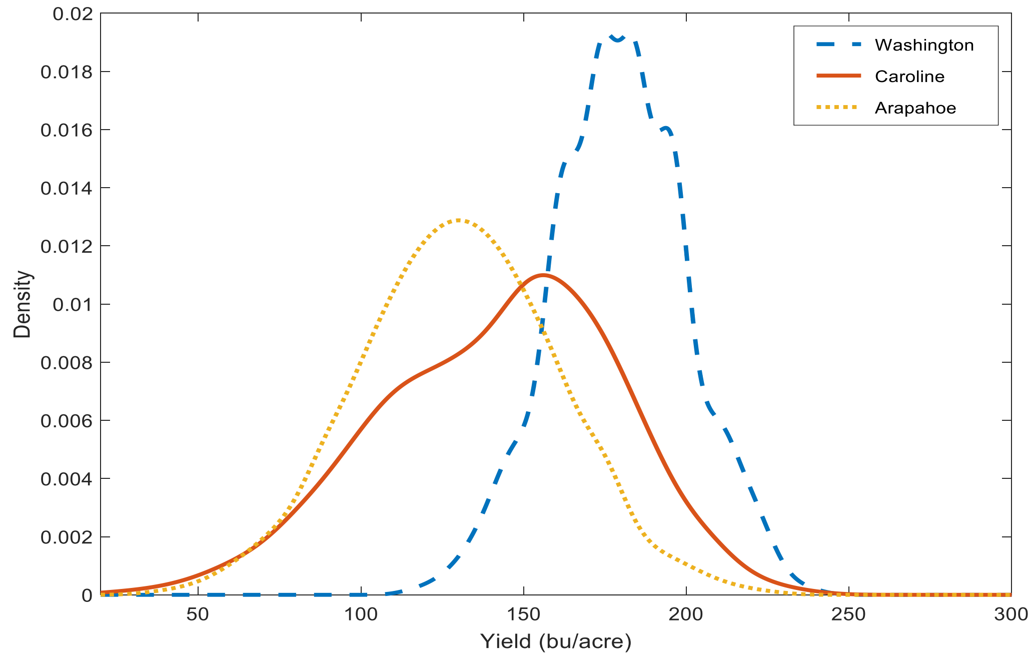
  - **53** counties (1963-2017)

Empirical application

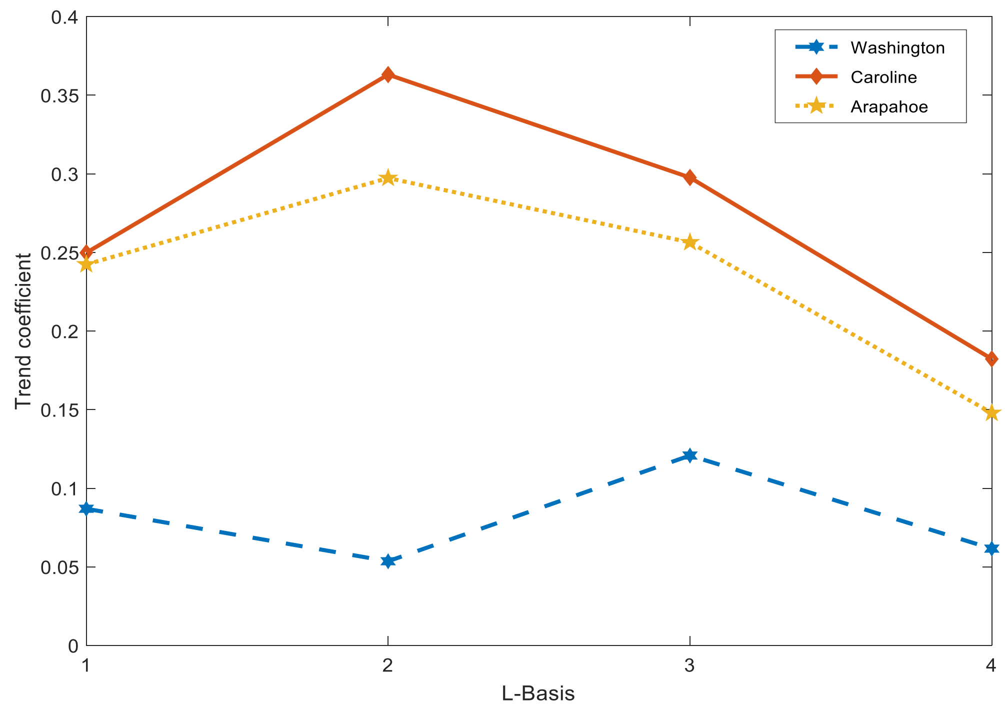
- Iowa
  - **Homogeneous geography**
- Maryland
  - **Heterogeneous geography**
- Colorado
  - **Heterogeneous geography**

Empirical application

- Iowa
  - **No significant data omission (0.1%)**
- Maryland
  - **No significant data omission (3%)**
- Colorado
  - **Significant data omission (47%)**



Washington
Caroline
Arapahoe
Density
Yield (bu/acre)
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
50
100
150
200
250
300

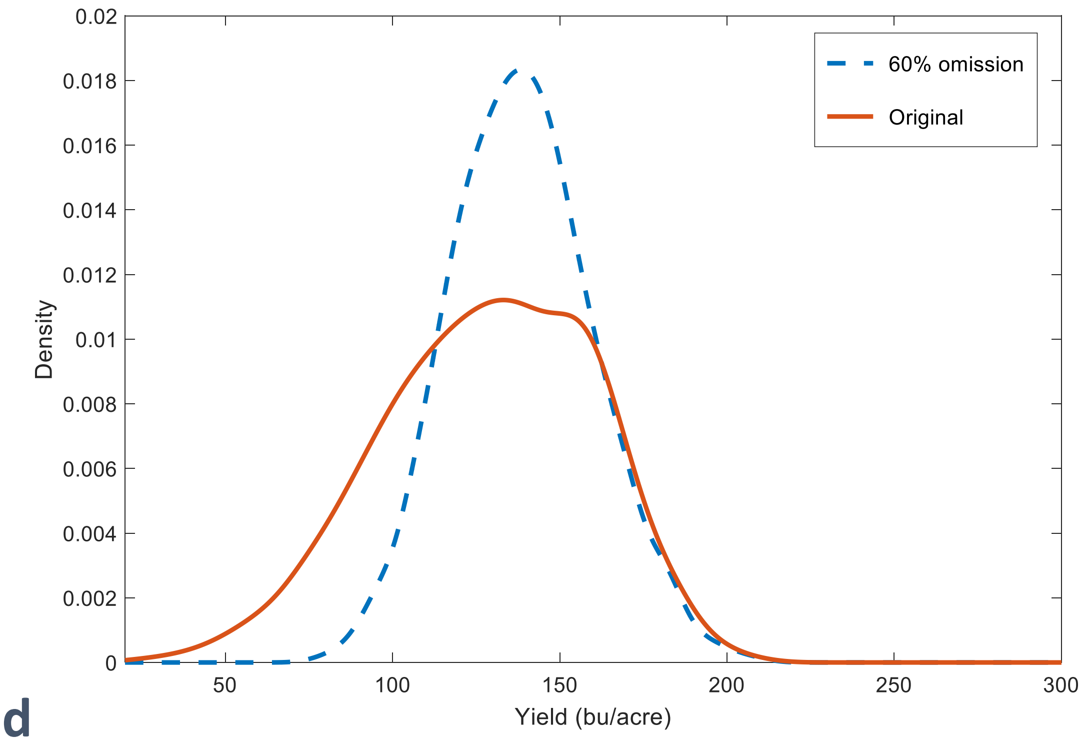


Washington
Caroline
Arapahoe
Trend coefficient
L-Basis
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4

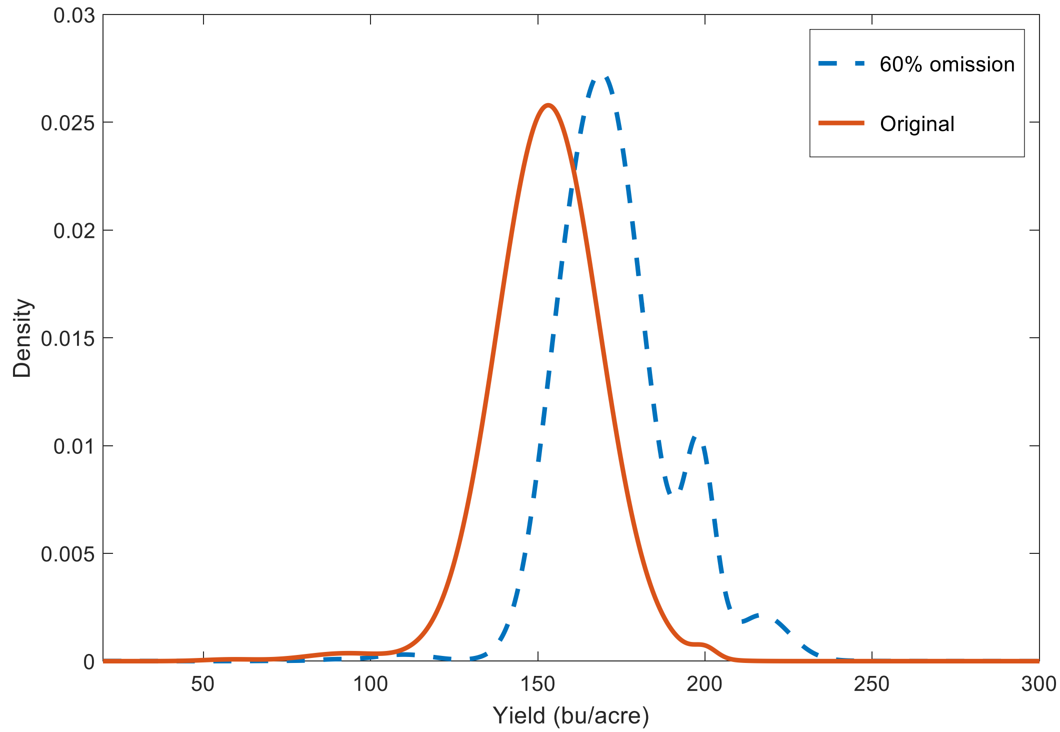
Loss ratio

20,000 posteriors and burn in first 10,000 obs

State / Data omission		60% omission		Original	
Model		BMA	Proposed	BMA	Proposed
Iowa	Mean	**4.43**	**1.42**	1.40	1.24
	RMSE	**7.02**	**2.99**	2.08	2.15
	Max	**21.02**	**4.49**	12.08	3.04
	Min	**0.23**	**0.00**	0.23	0.00
Maryland	Mean	**4.64**	**2.18**	1.47	0.75
	RMSE	**5.99**	**3.13**	1.72	1.12
	Max	**57.84**	**4.20**	2.85	1.69
	Min	**0.74**	**0.54**	0.54	0.15
Colorado	Mean	-	-	**7.23**	**4.17**
	RMSE	-	-	**7.80**	**4.64**
	Max	-	-	**26.50**	**9.38**
	Min	-	-	**0.00**	**0.00**



Allegany, Maryland



Out of sample premium game

- ***Between*** game : BMA vs Proposed model
- ***Within*** game : with vs without data omission

Between game (BMA vs Proposed)

State	Number of Counties	Dataset	*p*-value
Iowa	99	Original	0.593
		60% omission	0.084
Maryland	23	Original	**0.000**
		60% omission	**0.000**
Colorado	42	Original	**0.006**

Within game (original vs 60% omitted)

State	Model	*p*-value
Iowa	BMA	0.132
	Proposed	0.313
Maryland	BMA	**0.021**
	Proposed	0.191

Findings and Discussions

- The data omission problem, in general, **underrates insurance premiums** and results in **larger loss ratios**
- The estimation results remain consistently favorable to the proposed model compared to the BMA model in most of the states with/without data omission, except Iowa with the original dataset
- The proposed model is **superior** to the BMA model when there is a **considerable level** of data omission
- The proposed model tends to be less sensitive to the **quantity** (level)and **quality** (recent data) of the data omission

Findings and Discussions

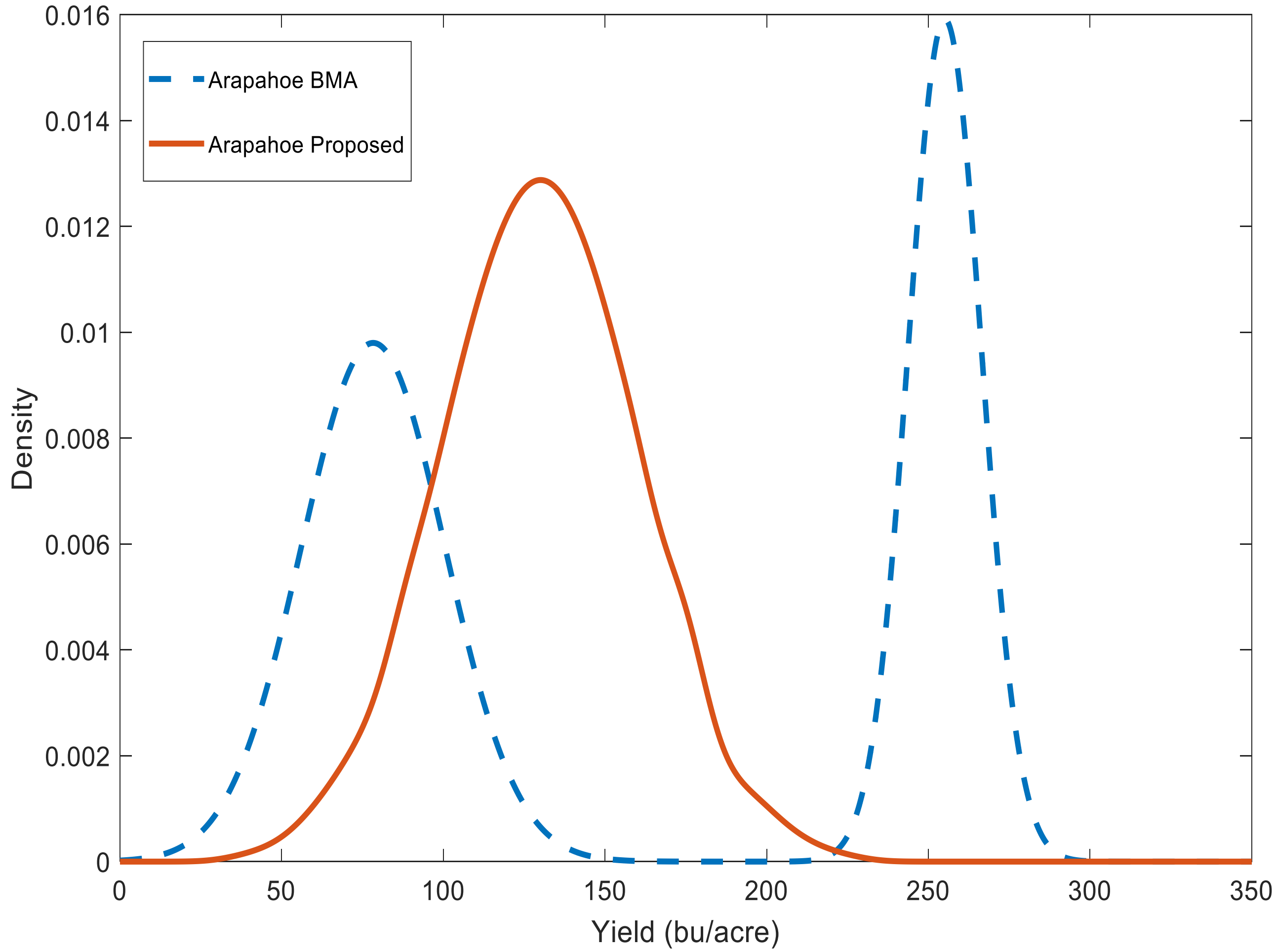
- **Identify changes** of multiple quantile levels of the crop yield distributions over **space** and **time**
  - Time varying skewness

- Apply the model for **identifying changes** in crop yield distribution over **time** and **space** in response to the changes of other principal factors, such as **climate**, **elevation**, and **soil types**

- Computational complexity

Thank you

Arapahoe, Colorado



- Total 35 years of yield data, but has no data since 2005