

Donna Ormerod

From: Norm Klocke <nklocke@ksu.edu>
Sent: Wednesday, October 26, 2011 2:52 PM
To: nklocke@cox.net
Subject: FW: Deficit irrigation materials
Attachments: Procedures for Adjusting APH - final 4-15.doc; RMA Deficit Irrigation Template - Final 4-15.xlsx

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From: Raymond J Supalla [<mailto:rsupalla@unlnotes.unl.edu>]
Sent: Friday, April 15, 2011 4:21 PM
To: Davis, Rebecca; Bob Bettger; 'Stover, Susan'
Cc: Norman Klocke; Derrel L Martin; Gary W Hergert; cthompson2@unl.edu
Subject: Deficit irrigation materials

To: Rebecca Davis, Susan Stover and Bob Bettger:

Attached to this message are two files. A Microsoft Word file which explains the procedures for computing yield adjustments from water shortages, and an Excel file which contains an Excel Macro for producing yield adjustment tables, plus all of the data required for Colorado, Kansas and Nebraska. The data are still under review, but as far as I now know there are no errors or problems. If we propose any changes as a result of further review they will be sent to you before May 1, and will include only data inputs. We expect to make no changes in procedures that would impact your implementation arrangements.

Note that what we are recommending is slightly more complex than our last communication. We are suggesting three irrigation system types, furrow irrigation without reuse, furrow irrigation with reuse, and center pivots. Previously we were suggesting only one furrow irrigation option, but given the range of efficiencies that exist perhaps two furrow irrigation options would be better. The other change is that we provided county specific estimates of yield per inch of ET (b), whereas previously we had suggested using the same values at all locations primarily because of possible difficulties in estimating the value for all situations. It turned out that the methods we used worked well for producing county specific estimates.

If you have questions about the procedures or spot any data problems, please give me a call. In the meantime we will continue seeking additional review. We also plan to prepare a journal article describing this program for submittal in a peer reviewed publication.

Hope everything works as planned.

No. 126, Orig.
Ex. K101

Ray Supalla

Procedures for Adjusting APH when Implementing a Deficit Irrigation Insurance Practice

Implementation of a deficit irrigation insurance practice requires a procedure for adjusting expected yield for a change in water supply. Insurance procedures use historical yields, usually a 10 year average, to establish an expected yield (APH). When known water supplies for a prospective year are less than what they had been historically, then the producers established APH overstates yield expectations and must be adjusted downward to determine insurance coverage.

We have used a crop production function approach to represent the impact of water stress on crop yield. Our method builds on the procedures of Stewart and Hagan (1973) and Martin et al. (1984). We begin with a linear relationship of crop yield to seasonal evapotranspiration (ET):

$$Y = Y_n + b(ET - ET_n) \quad (1)$$

where Y is the marketable yield, Y_n is the yield without irrigation, b is the slope of the yield-ET relationship, ET is the crop evapotranspiration at a specified irrigation level and ET_n is the evapotranspiration for the rainfed crop. Numerous researchers have shown that a linear relationship exists between yield and ET for many irrigated crops grown in the Great Plains (Doorenbos and Kassam, 1979; Hergert et al., 1993; Klocke et al., 2004; Nielsen, 1995; Payero et al., 2006; Schneekloth et al., 1991; Stegman, 1982 and Stegman et al., 1990).

Martin et al. (1984) developed production functions from the linear yield-ET relationship based on parameters that can be readily defined. The function depends on three conditions:

- The rainfed yield and ET of the irrigated crop (Y_n , ET_n),
- The yield and ET when the crop is fully irrigated (Y_f , ET_f) along with the amount of gross irrigation required to produce the full yield (D_f), and
- The slope of the yield-ET relationship (b).

Martin et al. (1984) used the assumption suggested by Stewart and Hagan (1973) that the slope of the production function should equal the slope of the yield-ET relationship when the production function is evaluated at zero irrigation. This assumed that if a very small annual irrigation depth was applied that all of the irrigation would be used for ET. Given these assumptions, yield can be based on three physically defined parameters and represented in Cobb-Douglas form as:

$$Y = Y_n + (Y_f - Y_n) \left[1 - (1 - D/D_f)^{1/\beta} \right] \quad \text{where } \beta = (ET_f - ET_n)/D_f \quad (2)$$

The parameter β , which we call water use efficiency at full irrigation, is derived mathematically from physically defined parameters and represents the fraction of the irrigation application for full yield that is used for ET. Thus the complete production function is based on physical parameters that can be measured or estimated.

Equation 2 can also be written as

$$Y = Y_n + b(ET_f - ET_n) \left[1 - (1 - D/D_f)^{1/\beta} \right] \quad \text{where } b(ET_f - ET_n) = (Y_f - Y_n) \quad [3]$$

If we are interested in considering only the change in yield, Equation 3 reduces to

$$dY = bET_{inc} \left[(1 - D_a/D_f)^{1/\beta} - (1 - D_p/D_f)^{1/\beta} \right] \quad [4]$$

where: dY = change in expected yield, bushels per acre;

ET_{inc} = ET increase from full irrigation, previously written as $(ET_f - ET_n)$;

D_a = irrigation depth applied after reduction occurs;

D_p = irrigation depth applied prior to reduction; and

All other variables as defined earlier.

The data required by RMA to implement this procedure are the full irrigation requirement (D_f), yield per inch of ET (b), and water use efficiency at full irrigation (β), defined by crop and irrigation system type for each location. For ease of implementation we are recommending three generalized system types defined in terms of application efficiency (AE), which is the proportion of applied water which is available to the crop but not necessarily used or consumed as ET. The suggested system types are center pivot, AE = 0.85; gravity with reuse, AE = 0.70; and conventional gravity, AE = 0.60.

The full irrigation requirement D_f is defined as net irrigation (NI) divided by AE. The “b” value is defined for each crop and location as the difference between the fully irrigated and the non-irrigated yield divided by the ET increase from full irrigation. The NI and ET increase values were simulated for each crop for 121 weather stations in Colorado, Kansas and Nebraska using CROPSIM, a crop simulation model developed by Derrel Martin, University of Nebraska – Lincoln. A medium fine sandy loam soil with a water holding capacity of 1.5 inches per foot of rooting depth was assume for all simulations. The results for each weather station were then regressed as a function of latitude and longitude to get corresponding values for each county. The county level estimates for NI and ET increase are attached as a spreadsheet printout.

Estimating “b” required two other parameters, the relationship between the irrigated and non-irrigated yields, called Y_d/Y_m , and the fully watered yield. The Y_d/Y_m values were also simulated by weather station using CROPSIM, then regressed as a function of latitude and longitude to get county values. Fully irrigated yields, Y_m , were defined as the mean NASS yield (National Agricultural Statistics Service) for the highest eight of the last eleven years, plus two standard deviations. The “b” values were then computed as:

$$b = [Y_m - (Y_d/Y_m)Y_m]/ET_{inc} \quad [5]$$

The “b” values are the most critical parameter for accurately determining the impact of water reductions on expected yields. These values are also attached as a spreadsheet printout for ease of review.

The final parameter needed for calculating yield adjustments is water use efficiency at full irrigation, or β . This value is field specific and a direct function of AE and NI, because the irrigation rules used in the simulations inevitably result in water that is available to the plant but unused for ET, with the amount proportionately higher when NI is low and smaller when NI is relatively high. We accordingly specify that β vary by irrigation system type and NI such that:

$$\beta = AE \times (ET_{inc}/NI) \quad [6]$$

Excel Program for Producing APH Adjustment Tables

Transmitted with this document is an Excel file (Deficit Irrigation Data.xls). This file contains a macro for producing yield adjustment tables and three additional worksheets containing the required data for Colorado, Kansas and Nebraska, respectively. The macro allows you to select the state, county, crop and irrigation system type using drop down menus. It then computes yield adjustments for a range of historical water levels and water reduction amounts. This program can be used directly to produce the required tables, or simply used as a data base and a check on a corresponding program to be developed internally by RMA.

References

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Appendix i **Nebraska Data**

Nebraska

County Centroid	LAT	LONG	Corn Final Data				
			NIR	Etinc	YDYM	Ymax	Little B
Adams	40.523	-98.501	10.766	8.353	0.482	202.968	12.596
Antelope	42.178	-98.072	9.612	6.734	0.518	208.802	14.934
Arthur	41.572	-101.696	13.897	12.203	0.257	186.713	11.362
Banner	41.543	-103.715	16.236	15.157	0.113	172.253	10.078
Blaine	41.926	-99.983	11.816	9.541	0.381	176.484	11.449
Boone	41.705	-98.063	9.825	7.053	0.517	199.637	13.665
Box Butte	42.213	-103.082	15.188	13.764	0.161	182.262	11.111
Boyd	42.896	-98.772	9.993	7.133	0.471	202.107	14.988
Brown	42.445	-99.934	11.508	9.095	0.386	185.136	12.490
Buffalo	40.855	-99.074	11.270	8.958	0.442	204.178	12.721
Burt	41.854	-96.321	7.911	4.626	0.642	212.190	16.417
Butler	41.222	-97.133	9.039	6.112	0.582	212.024	14.507
Cass	40.913	-96.139	8.117	4.979	0.652	216.045	15.117
Cedar	42.598	-97.249	8.520	5.311	0.579	205.972	16.342
Chase	40.530	-101.698	14.307	12.818	0.253	203.931	11.877
Cherry	42.543	-101.119	12.778	10.686	0.302	195.096	12.739
Cheyenne	41.219	-102.987	15.525	14.292	0.164	184.126	10.771
Clay	40.524	-98.051	10.281	7.742	0.514	204.471	12.844
Colfax	41.576	-97.088	8.842	5.828	0.586	210.866	14.966
Cuming	41.916	-96.788	8.372	5.200	0.609	218.199	16.407
Custer	41.394	-99.727	11.770	9.538	0.397	191.944	12.129
Dakota	42.387	-96.563	7.906	4.561	0.627	213.194	17.444
Dawes	42.709	-103.136	14.994	13.464	0.159	176.970	11.055
Dawson	40.866	-99.815	12.078	9.976	0.389	198.687	12.167
Deuel	41.113	-102.332	14.814	13.404	0.210	187.568	11.050
Dixon	42.499	-96.869	8.169	4.880	0.605	218.167	17.640
Dodge	41.576	-96.645	8.376	5.240	0.618	213.109	15.538
Douglas	41.300	-96.147	7.972	4.760	0.652	212.786	15.537
Dundy	40.182	-101.688	14.410	12.979	0.253	200.573	11.546
Fillmore	40.525	-97.596	9.794	7.128	0.546	208.878	13.300
Franklin	40.183	-98.953	11.368	9.142	0.448	210.039	12.680
Frontier	40.527	-100.394	12.842	10.971	0.346	199.029	11.856
Furnas	40.173	-99.912	12.424	10.474	0.380	216.127	12.802
Gage	40.265	-96.693	8.924	6.055	0.610	190.397	12.275
Garden	41.622	-102.344	14.613	13.101	0.211	184.694	11.117

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KS000518

Garfield	41.894	-98.982	10.733	8.178	0.452	190.526	12.760
Gosper	40.504	-99.831	12.226	10.195	0.387	213.653	12.854
Grant	41.917	-101.743	13.794	12.037	0.255	0.000	0.000
Greeley	41.563	-98.515	10.375	7.762	0.484	202.933	13.480
Hall	40.866	-98.502	10.644	8.168	0.483	201.476	12.758
Hamilton	40.877	-98.021	10.121	7.508	0.517	208.905	13.434
Harlan	40.174	-99.405	11.865	9.769	0.416	208.893	12.492
Hayes	40.527	-101.062	13.589	11.913	0.299	203.706	11.990
Hitchcock	40.176	-101.042	13.683	12.062	0.299	206.015	11.975
Holt	42.460	-98.784	10.240	7.494	0.469	200.677	14.231
Hooker	41.888	-101.141	13.127	11.198	0.298	192.007	12.033
Howard	41.219	-98.518	10.523	7.982	0.483	201.485	13.052
Jefferson	40.168	-97.146	9.432	6.703	0.577	203.019	12.812
Johnson	40.396	-96.266	8.434	5.425	0.641	209.438	13.874
Kearney	40.506	-98.949	11.258	8.975	0.450	0.000	0.000
Keith	41.197	-101.662	14.016	12.390	0.258	190.597	11.407
Keya Paha	42.878	-99.719	11.039	8.454	0.403	208.731	14.730
Kimball	41.199	-103.711	16.375	15.366	0.112	154.500	8.926
Knox	42.634	-97.881	9.174	6.131	0.534	209.550	15.939
Lancaster	40.784	-96.689	8.740	5.777	0.612	207.018	13.908
Lincoln	41.052	-100.745	13.041	11.173	0.323	190.521	11.538
Logan	41.556	-100.476	12.532	10.481	0.344	192.036	12.011
Loup	41.933	-99.447	11.223	8.792	0.419	173.031	11.429
Madison	41.922	-97.600	9.229	6.279	0.551	208.280	14.889
McPherson	41.570	-101.060	13.179	11.296	0.303	200.684	12.385
Merrick	41.169	-98.030	10.017	7.349	0.518	193.386	12.694
Morrill	41.694	-103.013	15.352	14.026	0.164	179.809	10.719
Nance	41.394	-97.994	9.886	7.162	0.521	203.565	13.615
Nemaha	40.387	-95.847	8.001	4.881	0.670	216.303	14.603
Nuckolls	40.177	-98.047	10.391	7.911	0.513	207.233	12.766
Otoe	40.652	-96.136	8.209	5.120	0.651	216.665	14.774
Pawnee	40.130	-96.240	8.492	5.521	0.642	205.318	13.331
Perkins	40.842	-101.650	14.140	12.580	0.258	202.020	11.915
Phelps	40.509	-99.414	11.765	9.614	0.416	215.352	13.073
Pierce	42.271	-97.611	9.072	6.043	0.552	205.311	15.233
Platte	41.568	-97.525	9.310	6.418	0.555	210.035	14.559
Polk	41.188	-97.571	9.518	6.718	0.550	208.242	13.934
Red Willow	40.176	-100.477	13.050	11.263	0.339	214.085	12.559
Richardson	40.124	-95.718	7.952	4.842	0.679	228.090	15.136

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KS000519

Rock	42.418	-99.454	10.992	8.448	0.421	182.258	12.500
Saline	40.531	-97.142	9.309	6.516	0.579	204.854	13.248
Sarpy	41.114	-96.110	8.009	4.824	0.654	215.590	15.445
Saunders	41.226	-96.634	8.512	5.446	0.617	212.187	14.903
Scotts Bluff	41.850	-103.709	16.090	14.942	0.115	176.026	10.428
Seward	40.872	-97.140	9.184	6.328	0.580	210.726	13.987
Sheridan	42.497	-102.434	14.297	12.608	0.208	183.113	11.500
Sherman	41.222	-98.973	11.016	8.603	0.450	197.679	12.627
Sioux	42.481	-103.771	15.855	14.576	0.113	182.856	11.131
Stanton	41.922	-97.190	8.794	5.731	0.580	211.650	15.498
Thayer	40.176	-97.594	9.906	7.300	0.545	207.734	12.948
Thomas	41.918	-100.582	12.487	10.387	0.338	0.000	0.000
Thurston	42.157	-96.550	8.007	4.714	0.627	205.559	16.271
Valley	41.570	-98.977	10.874	8.389	0.451	196.122	12.824
Washington	41.527	-96.223	7.955	4.715	0.648	202.394	15.114
Wayne	42.214	-97.125	8.584	5.435	0.586	215.021	16.375
Webster	40.178	-98.500	10.878	8.525	0.480	203.588	12.409
Wheeler	41.918	-98.525	10.225	7.536	0.485	185.963	12.708
York	40.872	-97.597	9.669	6.939	0.547	210.256	13.714

County Centroid	LAT	LONG	Soybeans Final Data				
			NIR	Etinc	YDYM	Ymax	Little B
Adams	40.523	-98.501	9.044	6.130	0.648	64.958	3.727
Antelope	42.178	-98.072	8.094	5.166	0.685	62.475	3.808
Arthur	41.572	-101.696	0.000	0.000	0.000	0.000	0.000
Banner	41.543	-103.715	0.000	0.000	0.000	0.000	0.000
Blaine	41.926	-99.983	0.000	0.000	0.000	0.000	0.000
Boone	41.705	-98.063	8.240	5.331	0.681	62.078	3.718
Box Butte	42.213	-103.082	0.000	0.000	0.000	0.000	0.000
Boyd	42.896	-98.772	0.000	0.000	0.000	0.000	0.000
Brown	42.445	-99.934	9.542	6.669	0.602	56.745	3.385
Buffalo	40.855	-99.074	9.386	6.503	0.625	66.142	3.811
Burt	41.854	-96.321	6.698	3.816	0.762	58.922	3.671
Butler	41.222	-97.133	7.620	4.721	0.718	63.642	3.795
Cass	40.913	-96.139	6.873	4.005	0.761	65.373	3.901
Cedar	42.598	-97.249	7.272	4.317	0.727	59.003	3.727
Chase	40.530	-101.698	11.594	8.915	0.501	62.014	3.469
Cherry	42.543	-101.119	10.449	7.672	0.549	60.788	3.576
Cheyenne	41.219	-102.987	0.000	0.000	0.000	0.000	0.000

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KS000520

Clay	40.524	-98.051	8.667	5.746	0.669	67.504	3.888
Colfax	41.576	-97.088	7.456	4.556	0.724	60.620	3.670
Cuming	41.916	-96.788	7.084	4.181	0.741	62.901	3.889
Custer	41.394	-99.727	9.717	6.872	0.601	62.175	3.611
Dakota	42.387	-96.563	6.742	3.821	0.757	58.971	3.755
Dawes	42.709	-103.136	0.000	0.000	0.000	0.000	0.000
Dawson	40.866	-99.815	9.982	7.139	0.591	68.603	3.926
Deuel	41.113	-102.332	0.000	0.000	0.000	0.000	0.000
Dixon	42.499	-96.869	6.973	4.034	0.744	55.921	3.551
Dodge	41.576	-96.645	7.074	4.186	0.745	61.481	3.752
Douglas	41.300	-96.147	6.737	3.873	0.765	59.707	3.629
Dundy	40.182	-101.688	11.730	9.030	0.498	73.061	4.060
Fillmore	40.525	-97.596	8.283	5.361	0.690	66.055	3.820
Franklin	40.183	-98.953	9.557	6.637	0.624	64.189	3.636
Frontier	40.527	-100.394	10.579	7.765	0.561	62.763	3.546
Furnas	40.173	-99.912	10.340	7.470	0.580	66.746	3.754
Gage	40.265	-96.693	7.615	4.696	0.729	58.781	3.394
Garden	41.622	-102.344	0.000	0.000	0.000	0.000	0.000
Garfield	41.894	-98.982	0.000	0.000	0.000	0.000	0.000
Gosper	40.504	-99.831	10.138	7.282	0.587	65.972	3.742
Grant	41.917	-101.743	0.000	0.000	0.000	0.000	0.000
Greeley	41.563	-98.515	8.667	5.768	0.658	60.689	3.594
Hall	40.866	-98.502	8.910	6.008	0.652	63.951	3.706
Hamilton	40.877	-98.021	8.503	5.595	0.674	68.296	3.979
Harlan	40.174	-99.405	9.930	7.030	0.603	63.736	3.598
Hayes	40.527	-101.062	11.104	8.353	0.531	66.367	3.730
Hitchcock	40.176	-101.042	11.233	8.460	0.528	67.221	3.752
Holt	42.460	-98.784	8.602	5.670	0.655	59.846	3.639
Hooker	41.888	-101.141	0.000	0.000	0.000	0.000	0.000
Howard	41.219	-98.518	8.790	5.895	0.655	63.970	3.747
Jefferson	40.168	-97.146	8.046	5.108	0.707	60.027	3.443
Johnson	40.396	-96.266	7.188	4.294	0.750	60.901	3.548
Kearney	40.506	-98.949	9.420	6.519	0.628	64.850	3.705
Keith	41.197	-101.662	11.311	8.645	0.510	65.928	3.738
Keya Paha	42.878	-99.719	9.246	6.322	0.617	58.362	3.540
Kimball	41.199	-103.711	0.000	0.000	0.000	0.000	0.000
Knox	42.634	-97.881	7.797	4.836	0.699	63.418	3.952
Lancaster	40.784	-96.689	7.402	4.507	0.734	59.641	3.515
Lincoln	41.052	-100.745	10.652	7.886	0.551	60.160	3.429

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KS000521

Logan	41.556	-100.476	10.259	7.468	0.568	61.502	3.557
Loup	41.933	-99.447	0.000	0.000	0.000	0.000	0.000
Madison	41.922	-97.600	7.777	4.860	0.704	60.589	3.688
McPherson	41.570	-101.060	0.000	0.000	0.000	0.000	0.000
Merrick	41.169	-98.030	8.401	5.497	0.677	64.850	3.814
Morrill	41.694	-103.013	0.000	0.000	0.000	0.000	0.000
Nance	41.394	-97.994	8.290	5.386	0.681	63.621	3.773
Nemaha	40.387	-95.847	6.824	3.952	0.769	65.952	3.855
Nuckolls	40.177	-98.047	8.807	5.866	0.666	66.221	3.775
Otoe	40.652	-96.136	6.971	4.095	0.758	63.694	3.757
Pawnee	40.130	-96.240	0.000	0.000	0.000	0.000	0.000
Perkins	40.842	-101.650	11.434	8.761	0.507	63.737	3.588
Phelps	40.509	-99.414	9.799	6.919	0.606	67.087	3.818
Pierce	42.271	-97.611	7.676	4.741	0.707	59.828	3.693
Platte	41.568	-97.525	7.833	4.926	0.704	60.251	3.621
Polk	41.188	-97.571	8.006	5.102	0.698	64.859	3.840
Red Willow	40.176	-100.477	10.789	7.962	0.554	69.633	3.902
Richardson	40.124	-95.718	0.000	0.000	0.000	0.000	0.000
Rock	42.418	-99.454	9.162	6.262	0.624	53.328	3.202
Saline	40.531	-97.142	7.893	4.977	0.711	60.329	3.504
Sarpy	41.114	-96.110	6.772	3.909	0.764	61.562	3.711
Saunders	41.226	-96.634	7.188	4.303	0.741	65.485	3.935
Scotts Bluff	41.850	-103.709	0.000	0.000	0.000	0.000	0.000
Seward	40.872	-97.140	7.757	4.853	0.715	65.731	3.866
Sheridan	42.497	-102.434	0.000	0.000	0.000	0.000	0.000
Sherman	41.222	-98.973	9.165	6.284	0.634	63.493	3.700
Sioux	42.481	-103.771	0.000	0.000	0.000	0.000	0.000
Stanton	41.922	-97.190	7.428	4.516	0.723	60.114	3.687
Thayer	40.176	-97.594	8.425	5.483	0.686	64.480	3.687
Thomas	41.918	-100.582	0.000	0.000	0.000	0.000	0.000
Thurston	42.157	-96.550	6.801	3.895	0.755	61.041	3.841
Valley	41.570	-98.977	9.045	6.162	0.637	57.125	3.364
Washington	41.527	-96.223	6.723	3.853	0.763	59.063	3.626
Wayne	42.214	-97.125	7.279	4.354	0.729	60.489	3.764
Webster	40.178	-98.500	9.185	6.251	0.645	63.870	3.629
Wheeler	41.918	-98.525	8.556	5.648	0.662	56.574	3.390
York	40.872	-97.597	8.147	5.237	0.694	66.071	3.866

* The shaded cells are counties where there are very few if any irrigated soybeans.

Appendix ii **Kansas Data**

Kansas

County Centroid	LAT	LONG	Corn Final Data				
			NIR	Etinc	YDYM	Ymax	Little B
Barber	37.2300	-98.6852	11.622	9.659	0.456	202.439	11.397
Barton	38.4787	-98.7572	11.564	9.515	0.456	226.794	12.973
Cheyenne	39.7864	-101.7295	14.575	13.219	0.248	225.9	12.85
Clay	39.3499	-97.1661	9.681	7.082	0.573	195.808	11.820
Cloud	39.4809	-97.6488	10.162	7.678	0.539	212.535	12.774
Comanche	37.1921	-99.2710	12.263	10.468	0.414	185.1	11.59
Decatur	39.7856	-100.4604	13.147	11.418	0.339	192.528	11.145
Dickinson	38.8668	-97.1535	9.774	7.233	0.572	196.197	11.620
Edwards	37.8882	-99.3112	12.250	10.415	0.414	198.726	11.181
Finney	38.0433	-100.7374	13.810	12.375	0.313	219.675	12.200
Ford	37.6933	-99.8884	12.905	11.252	0.372	215.539	12.028
Gove	38.9163	-100.4822	13.382	11.778	0.334	185.919	10.509
Graham	39.3499	-99.8837	12.621	10.788	0.379	191.553	11.034
Grant	37.5626	-101.3074	14.501	13.273	0.270	213.592	11.743
Gray	37.7384	-100.4381	13.510	12.013	0.333	213.513	11.854
Greeley	38.4803	-101.8061	14.952	13.789	0.238	218.947	12.098
Hamilton	37.9992	-101.7906	15.004	13.883	0.237	237.967	13.071
Harvey	38.0434	-97.4276	10.198	7.820	0.549	176.038	10.152
Haskell	37.5625	-100.8708	14.010	12.653	0.301	221.719	12.240
Hodgeman	38.0876	-99.8975	12.871	11.187	0.373	212.844	11.932
Jewell	39.7852	-98.2181	10.691	8.321	0.499	197.750	11.905
Kearny	38.0001	-101.3194	14.470	13.209	0.271	204.467	11.283
Kingman	37.5600	-98.1371	11.008	8.867	0.497	198.560	11.273
Kiowa	37.5592	-99.2857	12.254	10.439	0.415	194.974	10.934
Lane	38.4805	-100.4666	13.444	11.886	0.334	209.827	11.762
Logan	38.9174	-101.1484	14.128	12.719	0.287	214.054	12.004
McPherson	39.7844	-96.5226	8.890	6.051	0.620	204.348	12.831
Meade	37.2372	-100.3653	13.468	11.986	0.336	244.208	13.522
Mitchell	39.3933	-98.2083	10.783	8.468	0.498	187.915	11.134
Morton	37.1909	-101.7996	15.084	14.026	0.234	169.733	9.272
Ness	38.4790	-99.9159	12.833	11.116	0.373	139.914	7.892
Norton	39.7850	-99.9036	12.530	10.639	0.379	209.733	12.247
Osborne	39.3506	-98.7685	11.399	9.248	0.458	196.961	11.541
Pawnee	38.1814	-99.2371	12.132	10.250	0.420	218.222	12.341
Phillips	39.7853	-99.3474	11.918	9.868	0.418	216.997	12.789
Pottawatomie	39.3787	-96.3424	8.807	5.978	0.631	201.076	12.397
Pratt	37.6487	-98.7403	11.652	9.675	0.454	207.009	11.686
Rawlins	39.7861	-101.0760	13.837	12.288	0.295	218.282	12.523
Reno	37.9534	-98.0859	10.913	8.726	0.502	201.045	11.480
Republic	39.8288	-97.6492	10.069	7.533	0.540	182.332	11.138
Rice	38.3470	-98.2017	10.984	8.793	0.495	201.740	11.589
Riley	39.2957	-96.7361	9.240	6.530	0.603	193.889	11.788
Rush	38.5225	-99.3090	12.158	10.262	0.417	195.494	11.116
Saline	38.7845	-97.6500	10.318	7.924	0.536	185.7	10.87
Scott	38.4827	-100.9064	13.936	12.506	0.302	206.430	11.516

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Sedgwick	37.6848	-97.4602	10.273	7.934	0.545	186.649	10.696
Seward	37.1933	-100.8512	14.013	12.675	0.302	223.586	12.321
Shawnee	39.0429	-95.7569	8.275	5.332	0.672	172.099	10.587
Sheridan	39.3504	-100.4420	13.240	11.569	0.339	225.047	12.864
Sherman	39.3512	-101.7190	14.677	13.381	0.248	219.244	12.329
Smith	39.7857	-98.7861	11.305	9.095	0.459	190.907	11.366
Stafford	38.0315	-98.7183	11.586	9.571	0.457	200.107	11.356
Stanton	37.5629	-101.7846	15.042	13.955	0.236	220.476	12.067
Stevens	37.1926	-101.3125	14.532	13.330	0.269	217.166	11.916
Sumner	37.2378	-97.4761	10.323	8.020	0.543	185.040	10.554
Thomas	39.3512	-101.0556	13.927	12.435	0.295	220.514	12.503
Wabaunsee	38.9539	-96.2050	8.759	5.949	0.640	152.488	9.237
Wallace	38.9164	-101.7642	14.824	13.599	0.243	201.481	11.220
Washington	39.7849	-97.0875	9.484	6.800	0.580	203.735	12.591
Wichita	38.4817	-101.3478	14.433	13.133	0.271	200.815	11.149

			Soybeans Final Data				
County Centroid	LAT	LONG	NIR	Etinc	YDYM	Ymax	Little B
Barber	37.2300	-98.6852	0.000	0.000	0.000	0.000	0.000
Barton	38.4787	-98.7572	10.195	7.062	0.615	74.611	4.062
Cheyenne	39.7864	-101.7295	0.000	0.000	0.000	0.000	0.000
Clay	39.3499	-97.1661	8.428	5.413	0.698	62.627	3.498
Cloud	39.4809	-97.6488	8.778	5.773	0.677	65.392	3.661
Comanche	37.1921	-99.2710	0.000	0.000	0.000	0.000	0.000
Decatur	39.7856	-100.4604	10.945	8.085	0.551	69.885	3.884
Dickinson	38.8668	-97.1535	8.649	5.569	0.693	64.276	3.540
Edwards	37.8882	-99.3112	10.964	7.740	0.584	66.550	3.578
Finney	38.0433	-100.7374	0.000	0.000	0.000	0.000	0.000
Ford	37.6933	-99.8884	0.000	0.000	0.000	0.000	0.000
Gove	38.9163	-100.4822	11.369	8.407	0.541	62.974	3.441
Graham	39.3499	-99.8837	10.684	7.734	0.573	65.314	3.609
Grant	37.5626	-101.3074	0.000	0.000	0.000	0.000	0.000
Gray	37.7384	-100.4381	0.000	0.000	0.000	0.000	0.000
Greeley	38.4803	-101.8061	0.000	0.000	0.000	0.000	0.000
Hamilton	37.9992	-101.7906	0.000	0.000	0.000	0.000	0.000
Harvey	38.0434	-97.4276	9.310	6.082	0.672	56.677	3.055
Haskell	37.5625	-100.8708	0.000	0.000	0.000	0.000	0.000
Hodgeman	38.0876	-99.8975	0.000	0.000	0.000	0.000	0.000
Jewell	39.7852	-98.2181	9.120	6.149	0.654	66.523	3.746
Kearny	38.0001	-101.3194	0.000	0.000	0.000	0.000	0.000
Kingman	37.5600	-98.1371	10.177	6.845	0.635	60.300	3.219
Kiowa	37.5592	-99.2857	11.127	7.829	0.582	65.523	3.501
Lane	38.4805	-100.4666	0.000	0.000	0.000	0.000	0.000
Logan	38.9174	-101.1484	0.000	0.000	0.000	0.000	0.000
McPherson	39.7844	-96.5226	7.674	4.723	0.732	60.155	3.417
Meade	37.2372	-100.3653	0.000	0.000	0.000	0.000	0.000
Mitchell	39.3933	-98.2083	9.290	6.278	0.650	64.672	3.604
Morton	37.1909	-101.7996	0.000	0.000	0.000	0.000	0.000
Ness	38.4790	-99.9159	0.000	0.000	0.000	0.000	0.000

Norton	39.7850	-99.9036	10.501	7.600	0.576	65.338	3.644
Osborne	39.3506	-98.7685	9.775	6.771	0.624	60.974	3.386
Pawnee	38.1814	-99.2371	10.745	7.577	0.590	62.943	3.403
Phillips	39.7853	-99.3474	10.052	7.117	0.602	69.675	3.898
Pottawatomie	39.3787	-96.3424	7.701	4.715	0.736	64.475	3.612
Pratt	37.6487	-98.7403	10.629	7.330	0.608	59.556	3.187
Rawlins	39.7861	-101.0760	11.428	8.627	0.522	67.228	3.723
Reno	37.9534	-98.0859	9.916	6.669	0.641	62.589	3.370
Republic	39.8288	-97.6492	8.622	5.652	0.680	62.584	3.540
Rice	38.3470	-98.2017	9.802	6.633	0.640	65.449	3.555
Riley	39.2957	-96.7361	8.082	5.072	0.717	68.881	3.845
Rush	38.5225	-99.3090	10.625	7.522	0.591	57.596	3.135
Saline	38.7845	-97.6500	9.114	6.016	0.670	60.436	3.320
Scott	38.4827	-100.9064	0.000	0.000	0.000	0.000	0.000
Sedgwick	37.6848	-97.4602	9.535	6.230	0.667	59.954	3.205
Seward	37.1933	-100.8512	0.000	0.000	0.000	0.000	0.000
Shawnee	39.0429	-95.7569	7.346	4.348	0.759	65.988	3.653
Sheridan	39.3504	-100.4420	11.129	8.222	0.547	69.798	3.846
Sherman	39.3512	-101.7190	0.000	0.000	0.000	0.000	0.000
Smith	39.7857	-98.7861	9.592	6.634	0.628	68.401	3.839
Stafford	38.0315	-98.7183	10.400	7.182	0.613	64.199	3.463
Stanton	37.5629	-101.7846	0.000	0.000	0.000	0.000	0.000
Stevens	37.1926	-101.3125	0.000	0.000	0.000	0.000	0.000
Sumner	37.2378	-97.4761	9.805	6.394	0.662	54.191	2.868
Thomas	39.3512	-101.0556	11.611	8.761	0.519	64.333	3.534
Wabaunsee	38.9539	-96.2050	7.784	4.749	0.738	64.238	3.547
Wallace	38.9164	-101.7642	0.000	0.000	0.000	0.000	0.000
Washington	39.7849	-97.0875	8.162	5.195	0.706	65.214	3.694
Wichita	38.4817	-101.3478	0.000	0.000	0.000	0.000	0.000

* The shaded cells are counties where there are very few if any irrigated soybeans.

Appendix iii
Colorado Data

Colorado

County Centroid	LAT	LONG	Corn Final Data				
			NIR	Etinc	YDYM	Ymax	Little B
Adams	39.87444	-104.346	17.579	17.004	0.062	185.394	10.227
Baca	37.31878	-102.56	15.946	15.108	0.180	201.806	10.953
Bent	37.95333	-103.071	16.478	15.746	0.146	210.841	11.437
Boulder	40.08959	-105.354	18.712	18.417	-0.009	163.755	8.972
Cheyenne	38.82687	-102.603	15.802	14.838	0.183	213.643	11.771
Kiowa	38.43139	-102.741	16.031	15.152	0.171	189.462	10.363
Kit Carson	39.30496	-102.601	15.696	14.671	0.184	213.713	11.881
Larimer	40.66749	-105.461	18.649	18.287	-0.015	190.795	10.586
Lincoln	38.98757	-103.513	16.822	16.115	0.118	184.545	10.098
Logan	40.72463	-103.11	15.857	14.757	0.153	205.541	11.792
Morgan	40.26243	-103.809	16.829	16.025	0.102	203.395	11.400
Otero	37.90266	-103.716	17.235	16.704	0.100	237.584	12.806
Phillips	40.59355	-102.356	15.036	13.732	0.207	211.261	12.204
Prowers	37.9542	-102.392	15.696	14.759	0.194	187.512	10.236
Pueblo	38.17149	-104.512	18.137	17.827	0.044	228.352	12.248
Sedgwick	40.87556	-102.351	14.928	13.570	0.208	214.473	12.516
Washington	39.96964	-103.2	16.211	15.269	0.144	192.689	10.801
Weld	40.55518	-104.393	17.418	16.743	0.061	203.870	11.431
Yuma	40.00299	-102.422	15.303	14.120	0.200	232.043	13.150

RMA Deficit Irrigation
Developed by University of Nebraska -

1) Select State

Nebraska

2) Select County

Red Willow

3) Select Irrigation System

Pivot System (AE = 0.85)

4) Select Crop

CORN

Historical Water Use, Inches	Reduction in h				
	1	2	3	4	5
1	-12.4	na	na	na	na
2	-12.1	-24.5	na	na	na
3	-11.8	-23.9	-36.3	na	na
4	-11.4	-23.2	-35.3	-47.7	na
5	-11.1	-22.5	-34.3	-46.4	-58.8
6	-10.7	-21.7	-33.2	-44.9	-57.0
7	-10.3	-21.0	-32.0	-43.4	-55.2
8	-9.8	-20.1	-30.8	-41.9	-53.3
9	-9.4	-19.2	-29.5	-40.1	-51.2
10	-8.8	-18.2	-28.0	-38.3	-49.0
11	-8.2	-17.1	-26.4	-36.3	-46.5
12	-7.6	-15.8	-24.7	-34.0	-43.9
13	-6.8	-14.4	-22.6	-31.5	-40.8
14	-5.8	-12.6	-20.2	-28.4	-37.2
15	-4.3	-10.1	-16.9	-24.5	-32.7
16	-0.8	-5.1	-10.9	-17.7	-25.3
17	0.0	-0.8	-5.1	-10.9	-17.7
18	0.0	0.0	-0.8	-5.1	-10.9
19	0.0	0.0	0.0	-0.8	-5.1

20	0.0	0.0	0.0	0.0	-0.8
21	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0

7 Insurance Template

Lincoln UNL - Water Optimizer Team

Historical Water Supply, Inches of Gross Irrigation

6	7	8	9	10	11	12	13	14	15
Reduction in Bushels per Acre									
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	na	na
na	na	na	na	na	na	na	na	na	na
-69.4	na	na	na	na	na	na	na	na	na
-67.3	-79.7	na	na	na	na	na	na	na	na
-65.1	-77.1	-89.6	na	na	na	na	na	na	na
-62.6	-74.4	-86.5	-98.9	na	na	na	na	na	na
-60.0	-71.5	-83.2	-95.3	-107.7	na	na	na	na	na
-57.2	-68.3	-79.7	-91.5	-103.6	-116.0	na	na	na	na
-54.1	-64.8	-75.9	-87.3	-99.1	-111.2	-123.6	na	na	na
-50.6	-60.9	-71.6	-82.7	-94.1	-105.9	-118.0	-130.4	na	na
-46.6	-56.4	-66.7	-77.4	-88.5	-99.9	-111.7	-123.8	-136.2	na
-41.6	-50.9	-60.8	-71.0	-81.7	-92.8	-104.2	-116.0	-128.1	-140.5
-33.5	-42.4	-51.7	-61.6	-71.8	-82.5	-93.6	-105.0	-116.8	-128.9
-25.3	-33.5	-42.4	-51.7	-61.6	-71.8	-82.5	-93.6	-105.0	-116.8
-17.7	-25.3	-33.5	-42.4	-51.7	-61.6	-71.8	-82.5	-93.6	-105.0
-10.9	-17.7	-25.3	-33.5	-42.4	-51.7	-61.6	-71.8	-82.5	-93.6

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-5.1	-10.9	-17.7	-25.3	-33.5	-42.4	-51.7	-61.6	-71.8	-82.5
-0.8	-5.1	-10.9	-17.7	-25.3	-33.5	-42.4	-51.7	-61.6	-71.8
0.0	-0.8	-5.1	-10.9	-17.7	-25.3	-33.5	-42.4	-51.7	-61.6
0.0	0.0	-0.8	-5.1	-10.9	-17.7	-25.3	-33.5	-42.4	-51.7
0.0	0.0	0.0	-0.8	-5.1	-10.9	-17.7	-25.3	-33.5	-42.4
0.0	0.0	0.0	0.0	-0.8	-5.1	-10.9	-17.7	-25.3	-33.5
0.0	0.0	0.0	0.0	0.0	-0.8	-5.1	-10.9	-17.7	-25.3
0.0	0.0	0.0	0.0	0.0	0.0	-0.8	-5.1	-10.9	-17.7
0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.8	-5.1	-10.9
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.8	-5.1
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.8

