Kansas v Nebraska & Colorado
No. 126, Orig., U.S. Supreme Court

Rebuttal Report

Prepared
By

Dr. Norman L. Klocke, P.E.

NLK Engineering

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Dr. David Sunding, Professor of Natural Resources Economics at the University of California-Berkley, submitted an expert report: "Assessment of Kansas Damages and Nebraska Unjust Enrichment Resulting from Nebraska's Overuse of Republican River Water in 2005 and 2006" on March 15, 2012. Dr. Sunding was also deposed as an expert in Denver, Colorado on April 13, 2012.

I am responding to Dr. Sunding's report and deposition as an expert.

1. Dr. Sunding's Qualifications

Dr. Sunding stated that his qualifications included agricultural and natural resources economics. He did not mention any more specific qualifications in the area of Great Plains agricultural crop production, process simulation modeling for irrigated agriculture, soil-water balance simulations, or the nature and occurrence of rainfall in north central Kansas.

He stated that he had worked with scientists in other water related disciplines but he did not mention in his deposition that he had any training or expertise in the principles of soil science, agronomy, agricultural meteorology, irrigation engineering, crop physiology, crop interactions with the atmosphere and soils. Expertise in all of these areas is necessary to develop crop simulation models based on physical processes. Dr. Derrel Martin (Professor of Irrigation Engineering, University of Nebraska), the developer of CROPSIM has used mathematical descriptions of physical processes that occur with irrigation based on his field research, my field research, and research from many other scientists in the scientific fields listed above. I have been trained similarly as Dr. Martin as an irrigation engineer. As irrigation engineers, we are trained in these scientific fields, which makes it possible to integrate atmosphere, soil, plant, and water processes into a simulation model.

Without expertise in these scientific disciplines, Dr. Sunding is not in a position to assess whether CROPSIM's results are appropriate for developing crop production functions.

2. Kansas Use of Crop Production Functions to Calculate Yield Differences

Throughout his expert report and deposition Dr. Sunding demonstrated that he did not understand the two-step process that we used to determine crop yields from irrigation amounts that range from non-irrigated to fully irrigated crops with production functions. On page 71 of Dr. Sunding's deposition he stated that: "I think the CROPSIM was used to infer the level of yields that would have been realized in the absence of Nebraska overuse". In fact, the simulation model, CROPSIM (Martin et al., 2010), generated physically based numerical parameters with input data from each county in Nebraska, eastern Colorado, and western and central Kansas (Table 1 of Klocke expert report November 18, 2011). These county-by-county-derived parameters were used in the Cobb-Douglas (C-D) mathematical function to calculate yield differences between crops receiving different amounts of irrigation. The C-D production function was developed in the economics field to describe the diminishing marginal returns from an input. Dr. Sunding did not mention the C-D function in his report or deposition, which was the mathematical form of the crop production function.

Because he lacked the understanding of the crop production function analysis that Kansas used to calculate yield losses, Dr. Sunding cannot speak to the validity of Kansas' analysis of yield losses due to changes in water supply during 2005 and 2006.

3. Applications of CROPSIM/Cobb-Douglas Crop Production Function

I collaborated with Dr. Martin under contract with the USDA's Risk Management Agency (RMA) and through that project we jointly proposed that the federal government use the same procedures to calculate yield losses for crop insurance claims (Supalla, 2011 included in my expert report). The same CROPSIM generated parameters for the same counties across Nebraska, Kansas, and Colorado were used in the C-D production functions to calculate yield changes when irrigation water supplies change. I tested Dr. Martin's C-D crop production function results with my field research data where I measured actual yields from six different amounts of irrigation over five years (Klocke et al., 2011). The results coincided with one another (Figure 4 of Klocke expert report November 18, 2011). Furthermore, we recommended that the same parameters be used every year for yield loss calculations. I used the same procedures in this case. I disagree with Dr. Sunding when he states that these procedures are not applicable for calculating yield differences in the KBID when irrigation water supply changes.

In pages 67-71 of Dr. Sunding's deposition, he discusses the Nebraska Water Optimizer, developed by Dr. Martin as a day-to-day decision management tool. The Optimizer actually is a tool for irrigators to make an annual decision about what crop(s) to plant and how much irrigation should be applied to each crop from a fixed supply. It is not for day-to-day irrigation management decisions. The Nebraska Water Optimizer uses C-D crop production functions for its optimization routine.

Contrary to Dr. Sunding's assertions, the C-D crop production function based on CROPSIM parameters is a method accepted by experts in Nebraska and Kansas for use in decision management tools and by the RMA for yield expectations for changes in water supplies for irrigaiton.

4. Historical Improvements in Crop Yields

Dr. Sunding has tried to equate yields reported by KBID with maximum yields predicted with the C-D production function, which was based on CROPSIM results from 30 years of actual field data. Figure 4 in Dr. Sunding's expert report shows that irrigated yields have increased steadily over the last 40 years. I would expect the 30-year average maximum yield from CROPSIM would be different from possible maximum yields from current years. However, as Dr. Sunding agreed in his deposition, calculating marginal returns does not depend on the maximum value. Dr. Sunding's figure 4 in his expert report is not relevant in the process of determining yield differences because KBID does not report non-irrigated yields and the reported irrigated yields may not come from full irrigation with no water shortages to the crop. The National Agricultural Statistical Service (NASS) <u>does</u> report non-irrigated yields:

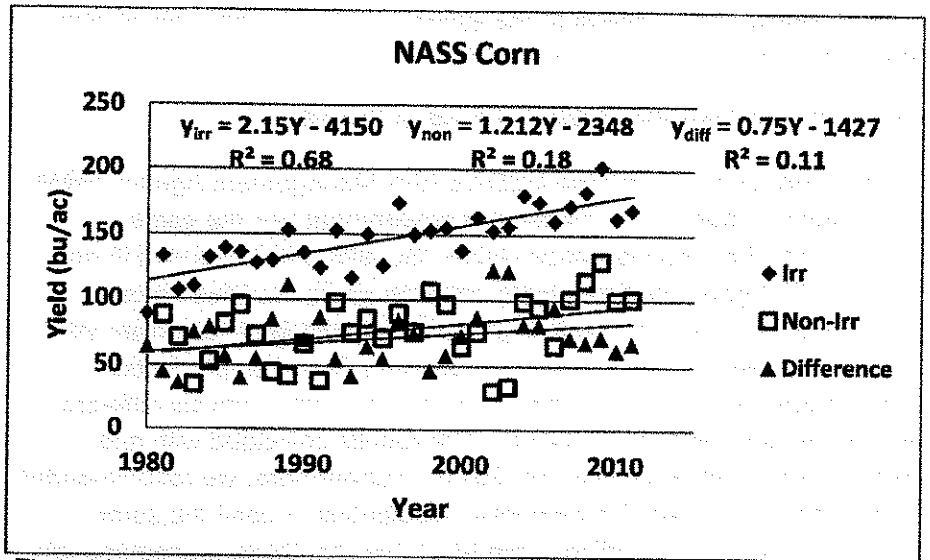

Figure 1. Irrigated and non-irrigated NASS corn yields for north central Kansas for 1980-2010.

The NASS corn yields for North Central Kansas from 1980 through 2010 show that yields increased at a rate of 2.15 bushels/acre/year (figure 1). The value for R^2 (0.68) indicates a relationship between yield and years, but there is year-to-year variability. Non-irrigated yields are highly variable with respect to years, as indicated by the small value of R^2 (0.18). Yield differences between irrigated and non-irrigated corn also are highly variable with no dependence on years. Irrigation reduces year-to-year variability in yields, but partially irrigated crops have more variability in yield than fully irrigated crops (Klocke et al., 2011). We still need the C-D production functions to calculate yield differences that were between full irrigation and no irrigation.

Thus, Dr. Sunding's criticisms based on historical improvements in irrigated crop yields without assessment of non-irrigated yields are irrelevant in this case.

5. Relationships of Crop Yields and Precipitation

Dr. Sunding stated we did not account for the precipitation amounts in 2005 and 2006 that produced very favorable growing conditions especially in 2005, yet annual precipitation does not correlate with yields. NASS corn yields from north central Kansas for 1985-2010 were highly variable with respect to annual precipitation from Scandia, Kansas (figure 2). There was no statistical correlation between annual precipitation and irrigated or non-irrigated crop yields.

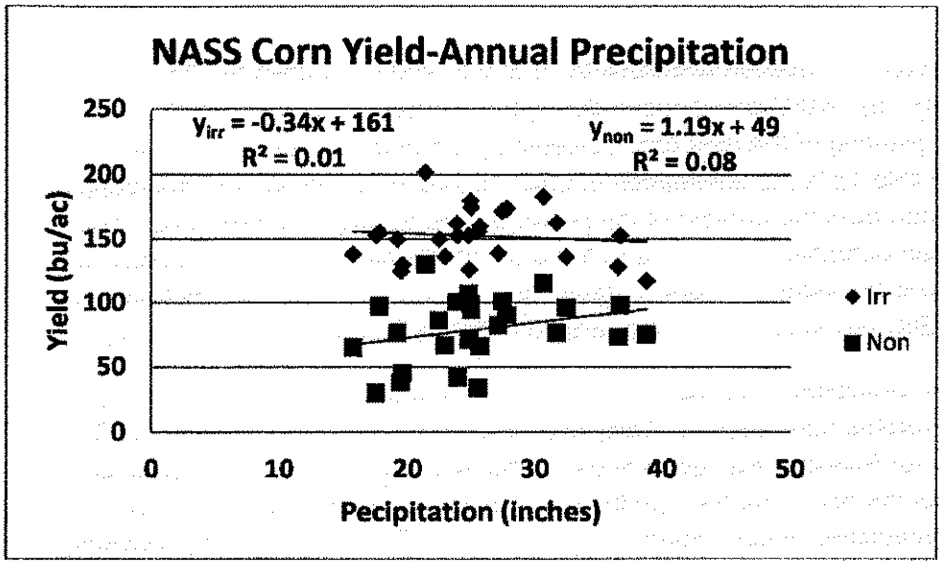

Figure 2. Irrigated and non-irrigated NASS corn yields for North Central Kansas versus annual precipitation for Scandia, Kansas for 1985-2010.

Not all precipitation benefits the crop to improve yield. Dr. Sunding did not recognize the principle effective precipitation in his expert report or deposition. The portion of precipitation that becomes effective for crop production is the water that contributes to evapotranspiration (used consumptively by the crop). The effectiveness of daily rainfall events is strongly dependent on the antecedent conditions of the soil surface and soil water content. Land slope, surface wetness, crop residue coverage, and soil type influence the infiltration of water into the soil. Soil water content in the active root zone influences the amount of precipitation that can be stored. If the surface is wet and bare, infiltration will be slow and runoff will occur. If the soil water content is more than its capacity to hold water, additional water percolates through the root zone and is not used by the crop. The timing of precipitation events with respect to irrigation greatly influences precipitation effectiveness because wet or dry soil surfaces influence infiltration.

There is no statistical relationship between crop yield and precipitation, so Dr. Sunding's assertions that Kansas should treat 2005 differently from 2006 is unfounded.

6. Variability of Precipitation

Dr. Sunding stated that 2005 had very favorable growing conditions and little irrigation would have been necessary that year (page 64 of his deposition). It is difficult to characterize whether or not a particular year was a favorable or unfavorable year for crop production based on precipitation. Precipitation varies both spatially and temporally across watersheds and across years (table 1). Summer precipitation in north central Kansas is dominated by thunder shower events, often with short duration with high intensity. These storms vary spatially which is demonstrated in table 1. KBID annual precipitation deviated by -0.6, 3.5 and 0.3 inches from the average among locations for 2004, 2005, 2006, respectively (table 1a). The deviation extremes for the three years were +7.5 and -5.7 inches. During the growing seasons KBID precipitation deviated from the location averages by -1.5, 2.5, and 0.4 inches for 2004, 2005, 2006 respectively (table 1b). KBID precipitation during the dormant seasons from the harvest of the prior crop until the planting of the next crop deviated by 0.6 and 0.5 inches from the location averages (table 1c). Table 1d is the summation of table 1b and 1c, which covers the cropping season or the time period from the harvest of the previous crop through the next crop. This is the precipitation that can potentially contribute to the crop. In this case KBID precipitation was 3.1 and 0.9 inches above the location average (table 1d). During quarterly periods from July through September, KBID deviated by -1.1, 0.6, and -0.5 inches from the location average.

Day-to-day variability in precipitation further complicates the characterization of one cropping season being more favorable than another. Daily precipitation for the 2004-2005 and 2005-2006 cropping season for Scandia, Kansas is shown in figures 3 & 4. Cropping season covers the time after harvest of the prior crop through the growing season of the next crop, which is the time framework when precipitation can impact crop production. The sequence of precipitation events influences their effectiveness for crop growth. For example, in July 2005 there was a storm that generated 2.5 inches of precipitation in one day and it was preceded by a day with 1.4 inches. It is unlikely that the 2.5 inches were effective in contributing to crop yield. Similarly in 2006 there was a 3.0 inch event preceded by a 1.2 inch event (back-to-back days). In addition, the timing and amounts of precipitation with respect to the timing of irrigation events led to large differences in the effectiveness of precipitation from event to event.

Table 1. Precipitation amounts in and around KBID.

a. Annual precipitation (inches)

Year	Hardy	Superior	Scandia	Jewell	Lovewell	KBID*	Average
2004	25.2	25.5	31.3	30.0	30.6	27.8	28.4
Dev.**	**-3.2**	**-2.9**	**2.9**	**1.6**	**2.2**	**-0.6**	
2005	26.3	23.3	34.5	26.5	28.1	32.0	28.4
Dev.	**-2.1**	**-5.1**	**6.0**	**-1.9**	**-0.4**	**3.5**	
2006	20.1	27.2	33.3	24.4	23.9	26.2	25.8
Dev.	**-5.7**	**1.3**	**7.5**	**-1.4**	**-2.0**	**0.3**	

b. May-September precipitation (inches).

Year	Hardy	Superior	Scandia	Jewell	Lovewell	KBID	Average
2004	18.7	17.7	21.3	20.6	21.7	18.3	19.7
Dev.	**-1.0**	**-2.0**	**1.5**	**0.9**	**2.0**	**-1.5**	
2005	16.0	12.8	21.1	16.0	18.1	19.8	17.3
Dev.	**-1.3**	**-4.5**	**3.8**	**-1.3**	**0.8**	**2.5**	
2006	13.4	18.2	22.1	15.3	15.7	17.4	17.0
Dev.	**-3.6**	**1.2**	**5.1**	**-1.8**	**-1.3**	**0.4**	

c. October-April dormant season precipitation (inches)

Year	Hardy	Superior	Scandia	Jewell	Lovewell	KBID	Average
2004-05	8.7	8.8	10.9	9.3	9.4	10.2	9.5
Dev.	**-0.8**	**-0.7**	**1.4**	**-0.3**	**-0.2**	**0.6**	
2005-06	6.0	7.1	9.8	8.9	6.3	8.2	7.7
Dev.	**-1.7**	**-0.6**	**2.0**	**1.2**	**-1.4**	**0.5**	

d. Preceding October-April dormant season + May-September growing season

Year	Hardy	Superior	Scandia	Jewell	Lovewell	KBID	Average
2004-05	24.7	21.6	32.0	25.3	27.4	29.9	26.8
Dev.	**-2.2**	**-5.2**	**5.2**	**-1.5**	**0.6**	**3.1**	
2005-06	19.4	25.3	31.8	24.2	22.1	25.6	24.7
Dev.	**-5.4**	**0.6**	**7.1**	**-0.5**	**-2.7**	**0.9**	

e. July-September precipitation (inches)

Year	Hardy	Superior	Scandia	Jewell	Lovewell	KBID	Average
2004	8.0	8.6	8.5	14.0	12.2	8.9	10.0
Dev.	**-2.0**	**-1.4**	**-1.5**	**4.0**	**2.1**	**-1.1**	
2005	11.9	9.4	14.1	10.1	13.5	12.6	11.9
Dev.	**0.0**	**-2.6**	**2.2**	**-1.9**	**1.6**	**0.6**	
2006	9.9	13.2	16.7	10.1	10.9	11.6	12.1
Dev.	**-2.2**	**1.1**	**4.6**	**-1.9**	**-1.2**	**-0.5**	

*Courtland station precipitation, from KBID Annual Reports

** Average across all locations by year.

***Deviation from average for all locations by year

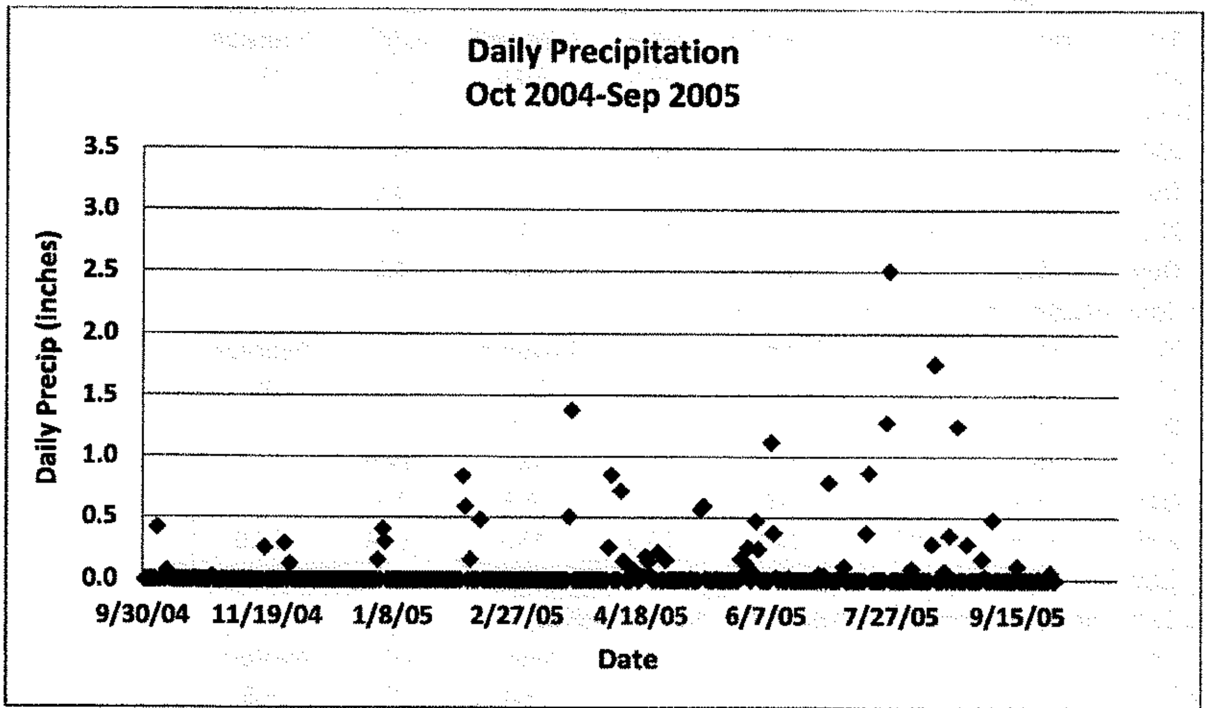

Figure 3. Daily precipitation for Scandia, Kansas for the cropping season October 1, 2004 through September 30, 2005.

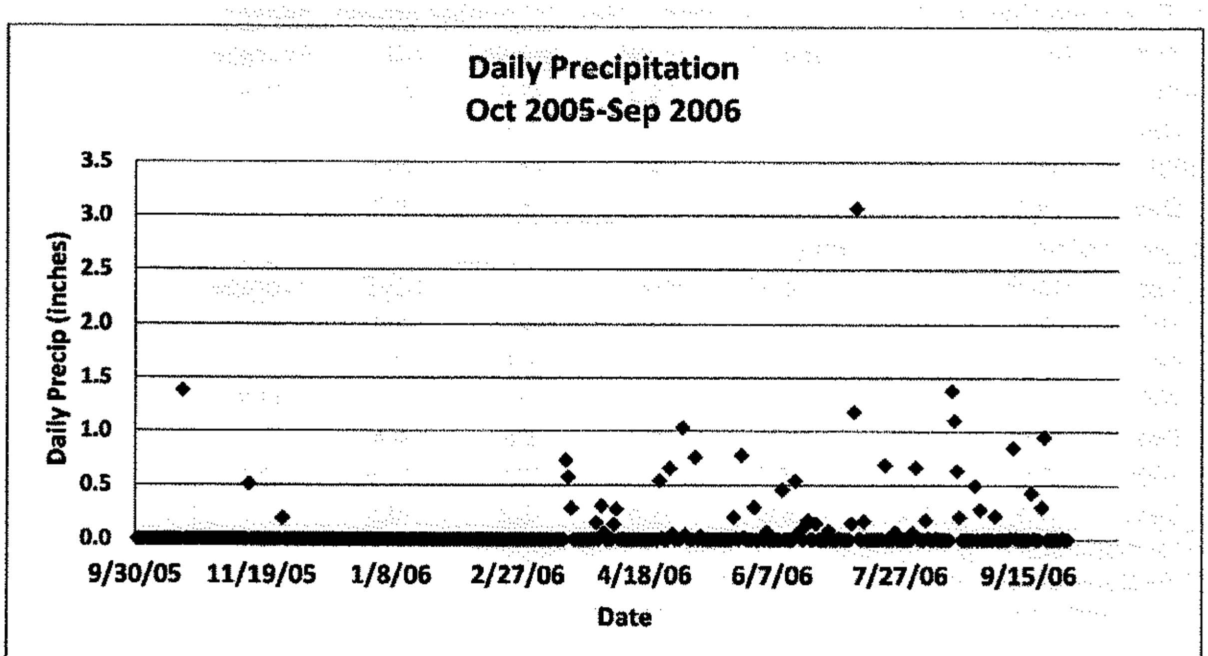

Figure 4. Daily precipitation for Scandia, Kansas for the cropping season October 1, 2005 through September 30, 2006.

Dr. Sunding did not evaluate the variability of precipitation due to the climate of north central Kansas. He did not account for the spatial, temporal, and daily variability of precipitation. This variability exceeded the differences in precipitation for 2005 and 2006 as reported by KBID. Therefore, his criticism of not treating 2005 and 2006 differently is without basis.

7. Non-Irrigated Crop Yield Response to Growing Conditions

Dr. Sunding did not examine non-irrigated crop yields to determine how 2005 and 2006 affected growing conditions. Non-irrigated crops do respond more directly to growing conditions of a particular season than irrigated crops because irrigation dampens the adverse effects of water shortages. Since KBID does not report non-irrigated yields, table 2 has comparisons using NASS yield data. CROPSIM predicted similar non-irrigated yields in 2005. From these data I conclude that 2005 had average growing conditions and 2006 had less than average growing conditions.

Table 2. NASS corn yields for north central Kansas for 2005 and 2006 and results from CROPSIM

	Irrigated	Non-Irrigated	Difference
Year	bu/ac	bu/ac	bu/ac
2005	175	94	81
2006	160	66	94
CROPSIM	182	98	84

NASS reported irrigated and non-irrigated soybean and sorghum together for north-central Kansas in 2005 and 2006 (table 3). These data also indicated that 2005 was an average year with respect to CROPSIM and 2006 was below average.

Table 3.

	Soybean	Sorghum
Year	bu/ac	bu/ac
NASS		
2005	42	96
2006	34	76
CROPSIM	43	102

Dr. Sunding did not appropriately characterize the growing conditions of 2005 and 2006 because he did not evaluate non-irrigated yields. CROPSIM predicted average conditions in 2005 that were consistent with NASS reported non-irrigated yields.

References

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Martin, D.L., R.J. Supalla, C.L. Thompson, B.P. McMullen, G.W. Hergert, and P.A. Burgener. 2010. Advances in deficit irrigation management. 5th National Decennial Irrigation Conference. American Society of Agricultural and Biological Engineers. Publication No. 711P0810cd. Phoenix, AZ. Dec. 5-8, 2010.

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