Adapting the Kansas Crop Water Allocator (CWA) to Multi-year Use

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Introduction

Water supply for irrigation from the Ogallala in Kansas continues to become more limited, mostly due to loss of well capacity associated with declining aquifer thickness. Irrigation water use in Kansas is also constrained by an annual appropriation of water which includes, among other designations, the maximum total volume of water that can be diverted and the land area to which it can be applied. This annual appropriation of water to a user is through a permit system that once completed is referred to as a water right and can be maintained indefinitely if the terms of the water right are followed. The allowable volume of water as determined by the water right for most water rights in western Kansas is seldom the limiting factor today as most of the water rights were established before the occurrence of severe declines of the Ogallala and higher efficiency irrigation systems. However, whatever limits water availability, the irrigation producer must adjust the irrigation management strategy to the water availability. A tool to help in this decision making process for an annual allocation of water is the Crop Water Allocator (CWA). The original CWA was a planning tool that could help producers find the optimum combination of crop mix and irrigation amount for a given land area and fixed water volume in terms of net return per acre (Klocke et al., 2006).

Annual water allocations, as established by the 1945 Kansas Water Appropriation Act (K.S.A. 82a-701, et seq.), work reasonably well when allocations match long term water supply availability but impose little conservation incentive, especially as supplies become limited and irrigation practices use deficit irrigation management strategies. Institutional reductions of water allocation in areas where allocations are now known to exceed long term availability are problematic since the water allocation process results in an allocation that is defined as a real property right. In 1978, the Kansas legislature enacted the Groundwater Management District Act which contained provisions for the initiation of Intensive Groundwater Use Control Areas (IGUCA) (K.S.A. 8 82a – 1036-1038). IGUCAs allow for the implementation of additional corrective control provisions in areas of excessive deterioration of water supplies. While a number of localized IGUCAs have been established to address localized groundwater issues, the act, to date, has not been used to address the regional decline of the Ogallala. In several of the established IGUGAs , the total volume of water allocations were reduced but several new allocation concepts were allowed in lue of the annually based allocation to an authorized location, such as a multi-year water allocation and relocation of water allocations between points of diversions and/or authorized acreages.

Several other options have also been enacted by the Kansas Legislature that can be used to modify an individual water right at least temporarily, including the Localized Enhanced Management Area (LEMA)(S.B. 310) act and Water Conservation Area (WCA)(S.B. 275) act. LEMA's might be described as a voluntary IGUCA. The formation of an IGUCA involves a public hearing process in which the Chief Engineer (CE) from the Kansas Division of Water Resources takes input on water issues of a designated area and proposed control options. While producers have input to the process, the CE ultimately determines the final outcome of any new restrictions and management options available to water right holders in the IGUCA. IGUCAs do have periodic review and can be altered but the ultimate decision still lies with the CE. The process to form a LEMA, which can be formed within a Groundwater Management District, goes through the public hearing process with the CE to receive input on the LEMA management proposals and the CE can offer suggestions for changes but these changes must be acceptable to the LEMA originators. Once the CE accepts the LEMA, the proposal becomes the water policy for the region for the time period of the LEMA. A WCA is similar to a LEMA but has a streamlined process to allow any water right owner or group of owners an opportunity to develop a water management plan to allow for increased management flexibility with the ultimate goal of reducing withdrawals in an area in an effort to extend the useful life of the Ogallala aquifer. One LEMA and several WCAs have been formed and include as part of the water management scheme, a multi-year water allocation instead of an annual allocation.

Since multi-year water allocation is a potential option to irrigation water right owners, the question of what is the best allocation of the water resource relative to the crop and land resources available. Since management program discussed above are targeted to areas with declining water resources, the water allocation amounts must be reduced from current usage values, resulting in allocations that will be deficit as compared to full irrigation. Many of the current multi-year allocations use a 5 year base. The amount is dependent on the target area. The current LEMA set the new allocation to be an approximately 20 percent reduction of the 10 year average use in the area prior to LEMA establishment, in this case, the prior average annual use was 14 inches per acre, the LEMA allocation was set to 55 inches in 5 years (an average of 11 inches on an annual basis). To help producers and water managers consider impacts of multi-year allocations, and evaluate crop selection options, the CWA program was modified to accommodate multi-year allocations.

Description of CWA

The Multi-Yr CWA allows program operators to customize the inputs to their specific conditions but loads with default values that represent typical costs, yields, etc. in the same fashion as CWA. Figures 1 and 2 show the two pages of input for the program. Many input requirements contain default values. The program operator can customize the model by clicking on each input box and either selecting an input option from the dropdown menu or entering the desired value. Boxes with a question mark provide additional background information on the input as a help to the user. Crops of interest to a producer would be checked by clicking on the crop box next to the name. The land split selection determines how the acreage can be divided between crops or irrigation amount. A 50-50 selection means one half of the field can be of one crop that receives a certain irrigation amount and the one-half another crop or amount. The same crop could be selected but with different irrigation amounts. The total amount of irrigation application however cannot exceed the annual gross irrigation amount specified, although one split could receive the total amount and the other split(s), a reduced amount or none. The applied irrigation input limits the maximum amount of water that can be applied in a single year.

For each crop selected for consideration, the user should select current or projected crop price and the maximum yield that might be expected for each crop if grown under well watered conditions. Embedded into CWA are yield-water relationship curves (production functions) for each crop, an example curve is shown in figure 3. Crop yield are determined from the applied irrigation. The relationships used have been developed from irrigated field research conducted in the high plains region of western Kansas. The data from this research was then used as input to a crop simulation model that was executed to develop the applied irrigation and annual precipitation range. These curves are site specific to the annual rainfall, so the results are customized to the production conditions of western Kansas. All inputs including crop-specific production costs can also be customized by the operator of the program.

The original CWA calculates the net economic return from all possible combinations of crops and irrigation allocations among crops for each acreage allocation as determined by the land split and then ranks the net returns starting with the maximum. Net economic return is calculated by subtracting the production costs and irrigation costs from the total return, calculated by multiplying crop yield by the crop price. Net return does not include costs associated with land and equipment investments. The multi-year CWA uses a similar approach, however since the number of possible combinations become astronomically large quickly, statistical sorting of some options occurs.

The multi-year water allocation is set on the “Field and Irrigation” input page. The total number of inches of water for the allocation period is entered in the Total Water Allocation box and the number of years of the allocation, limited to 6 years, is entered into the Total Years box. The simulation run is started once the Calculate button is clicked at the bottom of either entry page. The top 100 crop selection combinations from the simulation are displayed for user’s review.

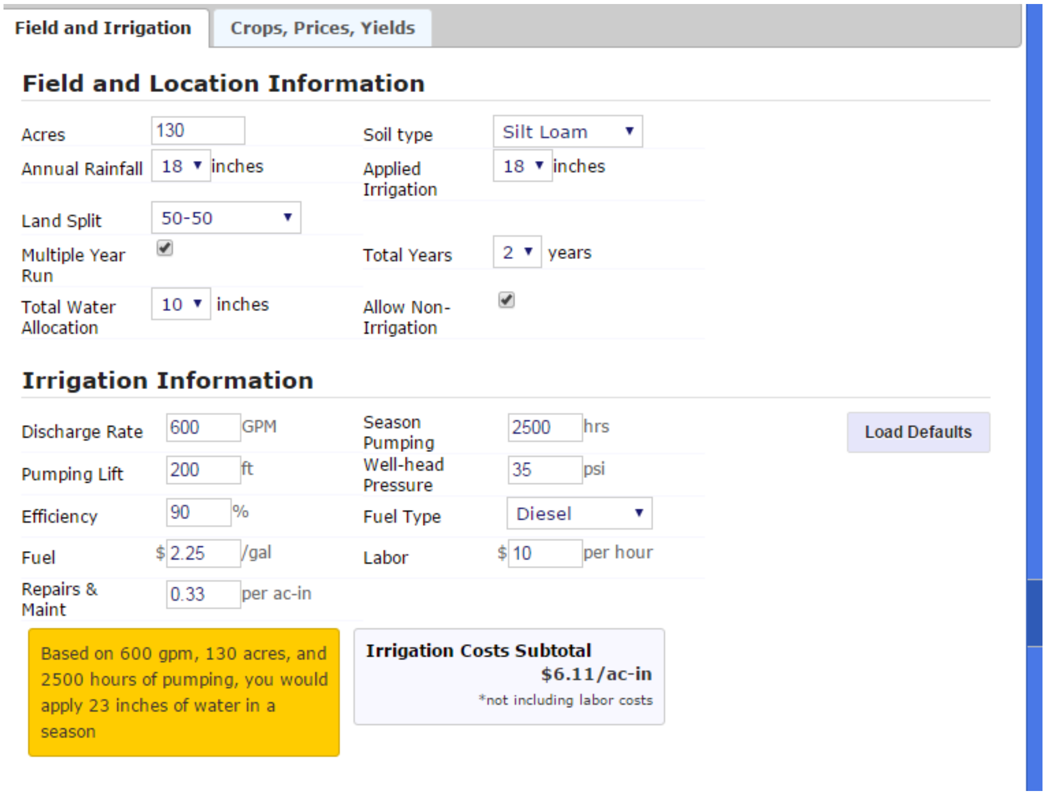

Figure 1: "Field and Irrigation" input page of the Multi-Yr CWA.

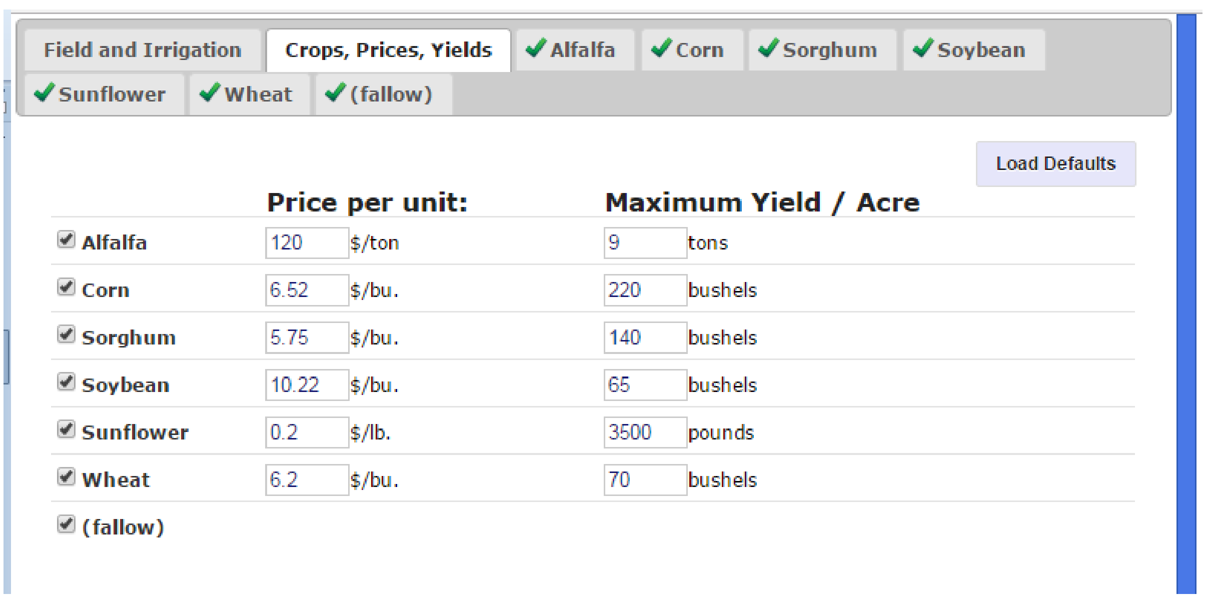

Figure 2: " Crops, Prices, Yields" input page of the Multi-Yr CWA. The illustration shows all of the available crop options as marked for consideration.

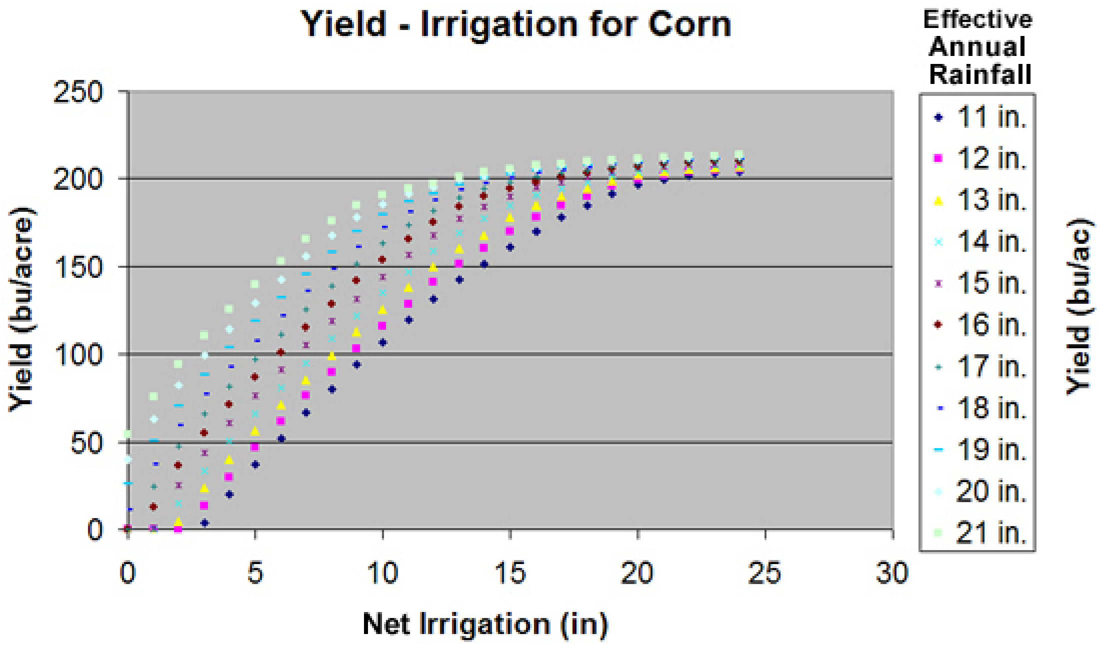

Figure 3: A Yield-irrigation relationship curve used in CWA. The example shown is for corn.

Results from Multi-Year CWA

Multi-year CWA begins evaluating the possible combination when the “Calculate” button is clicked. An example run is shown in Figure 4 (the two input pages) and Figure 5, which shows the first three options of the simulation run. For the input conditions in this example, corn was selected for both halves of the irrigated field and irrigated with the same amount of water. For years 2 and 3, sorghum was selected with equal irrigation amounts but at a lesser level than the corn of year 1, and finally sorghum years 4 and 5 at still a lesser amount than years 2 and 3. The final column shows the average return for this 5-year period was $252/acre. The next best option substituted soybean for sorghum in year 5 with a slight reduction in net return. Rank 3 option substituted corn for soybean in year 5. The ranking of other options are not shown. No time value of money, water or change in other costs or crop prices occur during the simulation period.

Sensitivity changes could be made by altering an input and generating new output. It is best to change only one input at a time. For example, figure 6 shows the results of changing the maximum yield potential of corn from 220 bu/ac to 240 bu/a for the yield-irrigation curve shown in Figure 3. The maximum yield potential can be altered by producer input based on their experience with the production capability of a particular field for non-water limited growing conditions. This single adjustment resulted in corn being selected as the first option (shown as rank 2 in Figure 6) for the entire five year period with the irrigation being divided equaled between the years. In the second option (rank 3), sorghum was a substitute for corn. In Figure 6, rank 1 is the first option selected from the figure 5 example; notice the pin on the righthand side of the chart has been activated. This saved the results from that simulation so that it could be easily compared to the change made in the next simulation.

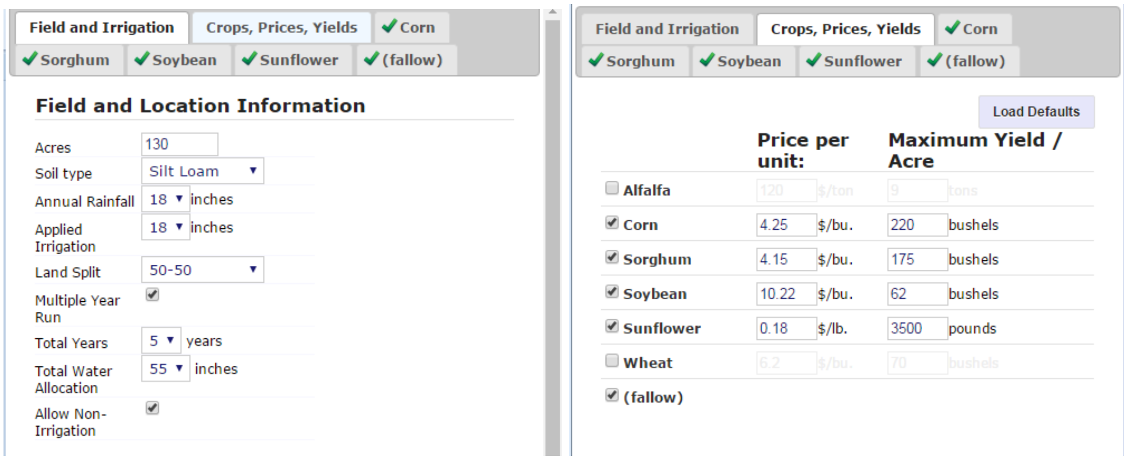

Figure 4: Input values for an example multi-year CWA simulation. The output chart for this example is shown in Figure 5.

Rank	Year	Acres	Crop	Yield /acre	Irrig. applied inches	Op. Costs $/acre	Returns $/acre	Annual Net RTN $/acre	Multi-year Ave. Net RTN $/ac
1	1	65.0	Corn	194.5 bu.	13.0	$561	$827	$266	$252/ac
		65.0	Corn	194.5 bu.	13.0	$561	$827		
	2	65.0	Sorghum	155.8 bu.	11.0	$394	$646	$253	
		65.0	Sorghum	155.8 bu.	11.0	$394	$646		
	3	65.0	Sorghum	155.8 bu.	11.0	$394	$646	$253	
		65.0	Sorghum	155.8 bu.	11.0	$394	$646		
	4	65.0	Sorghum	149.9 bu.	10.0	$380	$622	$243	
		65.0	Sorghum	149.9 bu.	10.0	$380	$622		
	5	65.0	Sorghum	149.9 bu.	10.0	$380	$622	$243	
		65.0	Sorghum	149.9 bu.	10.0	$380	$622		
2	1	65.0	Corn	194.5 bu.	13.0	$561	$827	$266	$251/ac
		65.0	Corn	194.5 bu.	13.0	$561	$827		
	2	65.0	Sorghum	155.8 bu.	11.0	$394	$646	$253	
		65.0	Sorghum	155.8 bu.	11.0	$394	$646		
	3	65.0	Sorghum	155.8 bu.	11.0	$394	$646	$253	
		65.0	Sorghum	155.8 bu.	11.0	$394	$646		
	4	65.0	Sorghum	149.9 bu.	10.0	$380	$622	$243	
		65.0	Sorghum	149.9 bu.	10.0	$380	$622		
	5	65.0	Sorghum	149.9 bu.	10.0	$380	$622	$238	
		65.0	Soybean	48.4 bu.	10.0	$263	$495		
3	1	65.0	Corn	194.5 bu.	13.0	$561	$827	$266	$250/ac
		65.0	Corn	194.5 bu.	13.0	$561	$827		
	2	65.0	Sorghum	155.8 bu.	11.0	$394	$646	$253	
		65.0	Sorghum	155.8 bu.	11.0	$394	$646		
	3	65.0	Sorghum	155.8 bu.	11.0	$394	$646	$253	
		65.0	Sorghum	155.8 bu.	11.0	$394	$646		
	4	65.0	Sorghum	149.9 bu.	10.0	$380	$622	$243	
		65.0	Sorghum	149.9 bu.	10.0	$380	$622		
	5	65.0	Corn	164.4 bu.	10.0	$476	$699	$233	
		65.0	Sorghum	149.9 bu.	10.0	$380	$622		

Figure 5: Top three example results from Multi-year CWA using the input pages of Figure 4

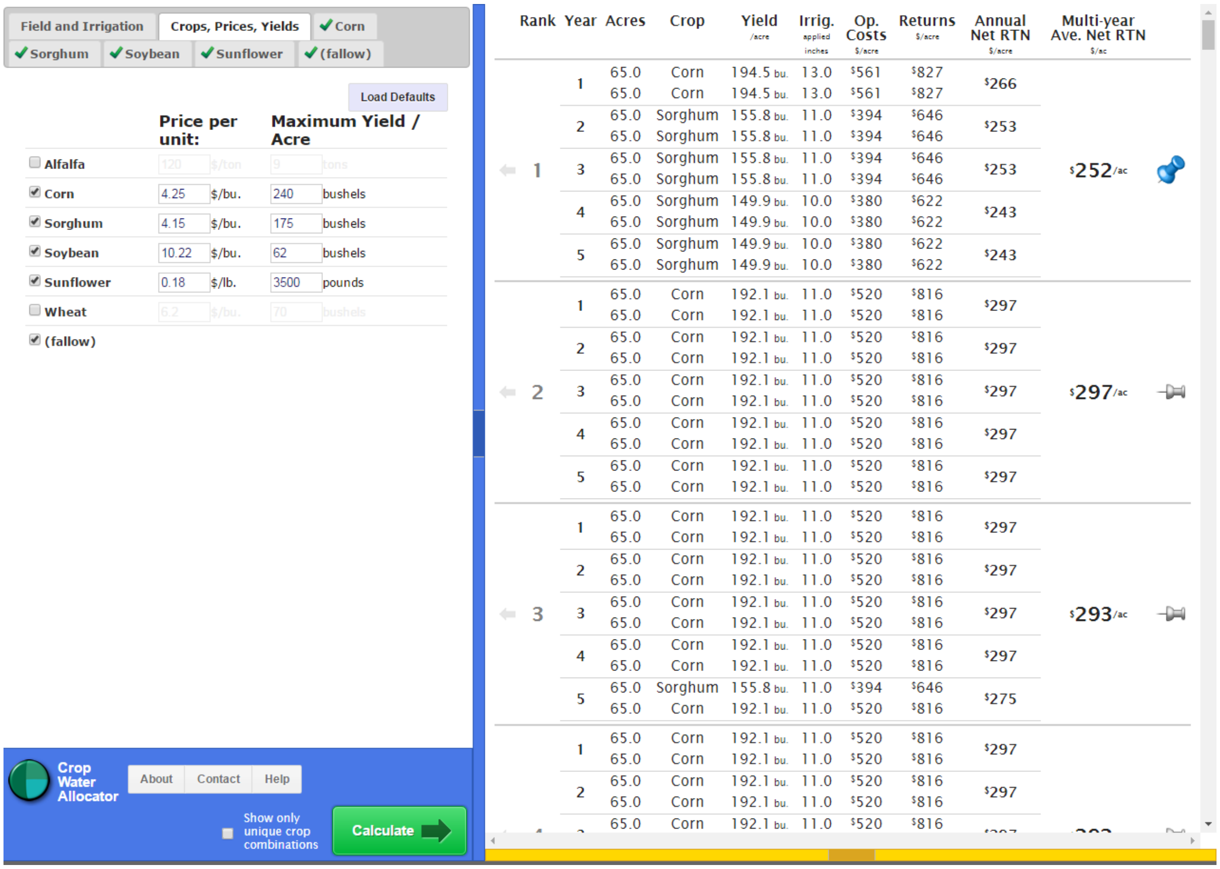

Figure 6: Results of Figure 4 example with the single change of input for corn maximum yield increase from 220 bu/ac to 240 bu/ac.

Figures 7 and 8 show the results of the last two combinations displayed; the only difference is figure 7 results show the 100 top ranking results based solely on the net return. Figure 8 display results show the top combination were sorted to display only the unique crop combinations. This latter display has a broader range of crop combinations, so less profitable crop options might be viewed.

The CWA is a long range planning tool, therefore the selected irrigation amount indicated is based on long term averages and the selected precipitation value. The irrigation amount applied during any given year should be based on growing conditions of that year, since large variations can occur (Rogers et al., 2015, Kisekka et al., 2015). Once the first growing season is completed, a new evaluation could be completed using updated crop prices, production costs, and remaining irrigation amount for the remainder of the years from the initial simulation.

Rank	Year	Acres	Crop	Yield /acre	Irrig. applied inches	Op. Costs $/acre	Returns $/acre	Annual Net RTN $/acre	Multi-year Ave. Net RTN $/ac
100	1	65.0	Corn	192.1 bu.	11.0	$520	$816	$297	$281 /ac
		65.0	Corn	192.1 bu.	11.0	$520	$816		
	2	65.0	Corn	192.1 bu.	11.0	$520	$816	$297	
		65.0	Corn	192.1 bu.	11.0	$520	$816		
	3	65.0	Corn	202.3 bu.	12.0	$565	$860	$294	
		65.0	Corn	202.3 bu.	12.0	$565	$860		
	4	65.0	Corn	179.3 bu.	10.0	$496	$762	$266	
		65.0	Corn	179.3 bu.	10.0	$496	$762		
	5	65.0	Soybean	51.1 bu.	11.0	$272	$522	$251	
		65.0	Soybean	51.1 bu.	11.0	$272	$522		
101	1	65.0	Corn	192.1 bu.	11.0	$520	$816	$297	$281 /ac
		65.0	Corn	192.1 bu.	11.0	$520	$816		
	2	65.0	Corn	192.1 bu.	11.0	$520	$816	$297	
		65.0	Corn	192.1 bu.	11.0	$520	$816		
	3	65.0	Corn	192.1 bu.	11.0	$520	$816	$297	
		65.0	Corn	192.1 bu.	11.0	$520	$816		
	4	65.0	Sorghum	155.8 bu.	11.0	$394	$646	$275	
		65.0	Corn	192.1 bu.	11.0	$520	$816		
	5	65.0	Corn	192.1 bu.	11.0	$520	$816	$239	
		65.0	Sunflower	2956.9 lb.	11.0	$352	$532		

Figure 7: Results of simulation for the top 100 results from the Figure 4 simulation run.

Rank	Year	Acres	Crop	Yield /acre	Irrig. applied inches	Op. Costs $/acre	Returns $/acre	Annual Net RTN $/acre	Multi-year Ave. Net RTN $/ac
100	1	65.0	Corn	220.5 bu.	14.0	$602	$937	$335	$257 /ac
		65.0	Corn	220.5 bu.	14.0	$602	$937		
	2	65.0	Corn	212.2 bu.	13.0	$585	$902	$317	
		65.0	Corn	212.2 bu.	13.0	$585	$902		
	3	65.0	Corn	192.1 bu.	11.0	$520	$816	$297	
		65.0	Corn	192.1 bu.	11.0	$520	$816		
	4	65.0	Corn	192.1 bu.	11.0	$520	$816	$239	
		65.0	Sunflower	2956.9 lb.	11.0	$352	$532		
	5	65.0	Sunflower	2258.4 lb.	6.0	$312	$407	$95	
		65.0	Sunflower	2258.4 lb.	6.0	$312	$407		
101	1	65.0	Corn	212.2 bu.	13.0	$585	$902	$317	$256 /ac
		65.0	Corn	212.2 bu.	13.0	$585	$902		
	2	65.0	Soybean	57.0 bu.	14.0	$310	$583	$304	
		65.0	Corn	220.5 bu.	14.0	$602	$937		
	3	65.0	Soybean	55.5 bu.	13.0	$303	$567	$291	
		65.0	Corn	212.2 bu.	13.0	$585	$902		
	4	65.0	Soybean	51.1 bu.	11.0	$272	$522	$274	
		65.0	Corn	192.1 bu.	11.0	$520	$816		
	5	65.0	Sorghum	53.2 bu.	0.0	$182	$221	$95	
		65.0	Corn	150.7 bu.	8.0	$489	$640		

Figure 8: Results of simulation for the top 100 results from the Figure 4 simulation run but sorted to only show unique crop combinations.

Conclusions

New irrigation water management options have become available to Kansas producers that face limited irrigation water supplies. One new management option is the allocation of water resources on a multi-year basis rather than the traditional annual water allocation. To help producers make decision on how to use the available land and irrigation water resources that result in the optimal economic returns, the planning tool, Crop Water Allocator, was modified to accommodate a multi-year water allocation. While many factors influence the outcome, the Multi-year CWA program may be a tool to help them determine the best crop acreage mix of the increasingly limited water resources.

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