An Examination of the Tradeoff between Net Return, Risk, and Water Quality for Crop Rotation in South Central Kansas

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Abstract

This paper determined the optimal crop rotation in South Central Kansas. The model incorporated net return, risk, and water quality. In general, water quality improved as tillage was reduced within a rotation type and by adding an alfalfa rotation. The optimal crop rotation mixes included wheat, grain sorghum, soybeans, and alfalfa.

Introduction

Water quality is an issue of growing concern in the Cheney Lake Watershed, which is located northwest of Wichita, Kansas. Controlling water quality typically involves switching to rotations that either have a lower net return, higher risk, or both. Because of the potential changes in net return and risk resulting from attempts to improve water quality, it is important to examine the tradeoffs between net return, risk, and water quality.

The objective of this study was to determine the optimal crop rotations in South Central Kansas. The modeling approach incorporates net return, risk, and water quality information for six common crop rotations utilized in the region.

Data and Methods

Crop rotations examined in this study included a continuous wheat rotation under conventional and reduced tillage production systems; a wheat/grain sorghum/soybean rotation under conventional tillage, reduced tillage, and no-till production systems; and an alfalfa/wheat rotation under a reduced tillage production system. Table 1 provides a list of the rotations as well as their abbreviations which are used in the discussion of the results.

Water quality variables examined included water yield, sediment yield, and total phosphorus. Water yield and sediment yield measure runoff, and total phosphorus measures transported organic, mineral, and soluble phosphorus. The tillage operations along with region specific data were incorporated into the SWAT and APEX models to obtain crop yields and water quality information for each crop rotation. Each simulation of the SWAT and APEX models generated data for 18 weather states. To facilitate comparisons among crop rotations and water quality parameters, the values of the three water quality variables (i.e., water yield, sediment yield, and total P) were assigned a value of 1.000 for the base rotation, continuous wheat production under a conventional tillage production system.

Simulation data for several soils common in the watershed were generated. This paper presents the results for the most common soil, Nalim loam with 0 to 1 percent slopes. Approximately 18 percent of the watershed is comprised of this soil.

The yield data from the SWAT and APEX models, cost estimates, and forecasted prices were used to develop a budget for each crop and crop rotation. These budgets provided the net return to land and management data used in the tradeoff analysis (i.e., modified Target MOTAD model) discussed below. Cost estimates included seed, fertilizer, herbicide and insecticide, tillage practices, non-machinery labor, interest, and miscellaneous costs. Seed, fertilizer, and forecasted harvest prices for 2010-2014 were obtained from Dhuyvetter et al. (2009). Herbicide and insecticide prices were obtained from Thompson et al. (2010). Interest rates, non-machinery labor, and miscellaneous costs for alfalfa were obtained from Dumler and Shoup (2009). Interest rates, non-machinery labor, and miscellaneous costs for grain sorghum, soybean, and wheat were obtained from Dumler et al. (2009, a-c). Custom rates for Kansas were used to estimate tillage costs (Kansas Agricultural Statistics, 2009).

The Target MOTAD model (Tauer, 1983; Watts et al., 1984) was modified in this study by adding water quality constraints. Specifically, a modified Target MOTAD model (Stucky, 2000; Stucky et al., 2000) was developed to examine the change in water quality resulting from a reduction in risk. With the Target MOTAD model, risk is measured as total deviations below a specified target. The average cash rent for south central Kansas was used as the target income (Kansas Agricultural Statistics, 2009).

Model solutions contained information pertaining to net return, risk, water quality, and crop rotation mix. Solutions presented include the profit maximizing or LP solution, and selected solutions with lower levels of risk. Separate solutions are presented for the WW and WGS rotations, and the WW, WGS, and AW rotations. Due to the fact that only 49.6 percent of the farms in the South Central Kansas Farm Management Association (KFMA) had hay and forage acres in 2008, it is important to examine a set of solutions that does not contain rotations with alfalfa or any other hay or forage crop. The solutions that included alfalfa restricted alfalfa production to 5.7 percent of crop acres. This percentage reflects the average alfalfa, other hay, and silage acres for KFMA farms in South Central Kansas in 2008.

Results

Before examining the optimal solutions under each water quality scenario, it is useful to compare net return to land and management, risk, and water quality information across rotations. Table 2 contains net return, risk, and water quality results for each crop rotation. A lower water quality index is preferred to a higher index. In other words, lowering one or more of the water quality indices represents an improvement in water quality. The only crop rotation with a water yield below that of the base rotation, WW-CT, was the AW rotation. The WW-RT and AW rotations have lower sediment yield and total phosphorus indices than the base rotation. In general, within a given rotation type (i.e., WW or WGS rotations), sediment yield and total phosphorus were improved by reducing tillage. Conversely, water yield was slightly higher for the reduced tillage rotations.

Risk was measured in Table 2 as the total amount of deviations below the target income of $45 over the 18-year period. Dividing the risk levels by 18 would yield an annual deviation measure. The AW rotation has the highest net return and lowest level of risk. The WW-RT rotation has the second highest net return and second lowest level of risk. The other rotations have considerably higher amounts of risk.

Table 3 presents the optimal solutions for the profit maximizing (LP) solution and four other risk levels. Solution D represents the most risk adverse preferences. The optimal crop rotation for the LP solution was the WW-RT rotation. Net return and risk for solution D were 7.9 and 40.9 percent lower, respectively, than net return and risk for the LP solution. The relatively large reduction in risk going from the LP solution to solution D is related to the negative correlation (-0.064) between the WW-RT and WGS-NT rotations. It is important to also note that the indices for water yield, sediment yield, and total phosphorus were higher for solution D. This result should not be particularly surprising. It is difficult to find a crop rotation that has high net returns, low risk, and good water quality characteristics.

The optimal solutions for the scenario that examined all of the crop rotations, including the rotation with alfalfa, AW, are presented in Table 4. The AW rotation was at the constraint level for each of the solutions in Table 4. Solution C represents the most risk adverse preferences. Net return and risk for solution C were 8.6 and 47.4 percent lower, respectively, than net return and risk for the LP solution. As in Table 3, the water quality indices increase, representing deterioration in water quality, as risk is reduced. The crop mix for solution D was 77.3 percent wheat, 8.5 percent grain sorghum, 8.5 percent soybeans, and 5.7 percent alfalfa. In comparison, the average percentages for KFMA farms in 2008 were 51.9 percent for wheat, 13.8 percent for grain sorghum, 10.5 percent for soybeans, 5.7 percent for hay and forage, and 18.1 percent for other crops.

Summary and Implications

The objective of this study was to determine the optimal crop rotations in South Central Kansas. Adding an alfalfa rotation to the crop rotation mix improved net return, lowered risk, and improved water quality. This result needs to be put in proper context. Given the difficulty and cost associated with hauling alfalfa long distances, it would not be practical for farms to substantially increase alfalfa acreage. Water yield increased slightly with reductions in tillage while sediment yield and total phosphorus decreased with reductions in tillage. In addition to alfalfa, the optimal crop rotation mixes included continuous wheat under a reduced tillage production system and a wheat/grain sorghum/soybean rotation under a no-till production system.

For numerous reasons, the results presented in this paper are preliminary. Future work will involve examining results for several soil types and include an analysis of the wheat/wheat/grain sorghum/grain sorghum rotation, CRP grass, and switchgrass.

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Table 1. Crop Rotations for South Central Kansas.

Abbreviation	Crop Rotation
WW-CT	Continuous Winter Wheat, Convential Tillage
WW-RT	Continuous Winter Wheat, Reduced Tillage
WGS-CT	Wheat/Grain Sorghum/Soybean, Conventional Tillage
WGS-RT	Wheat/Grain Sorghum/Soybean, Reduced Tillage
WGS-NT	Wheat/Grain Sorghum/Soybean, No-Till
AW	Alfalfa/Wheat

Table 2. Net Return, Risk, and Water Quality Information for Each Crop Rotation.

Crop Rotation	Net Return	Risk	Water Yield	Sediment Yield	Total P
WW-CT	45.55	274.16	1.000	1.000	1.000
WW-RT	77.88	76.18	1.034	0.305	0.381
WGS-CT	25.14	529.26	1.230	2.252	1.820
WGS-RT	45.56	301.08	1.259	1.636	1.538
WGS-NT	50.32	267.88	1.285	1.304	1.913
AW	123.41	0.00	0.627	0.260	0.357

Table 3. Selected Target MOTAD Solutions for WW and WGS Rotations.

Variable	LP	A	B	C	D
Average Net Return	77.88	77.68	75.98	74.28	71.74
Risk	76.18	75.00	65.00	55.00	45.00
Water Yield	1.034	1.036	1.051	1.067	1.090
Sediment Yield	0.305	0.312	0.374	0.435	0.527
Total P	0.381	0.392	0.487	0.581	0.722
WW-CT	0.000	0.000	0.000	0.000	0.000
WW-RT	1.000	0.993	0.931	0.869	0.777
WGS-CT	0.000	0.000	0.000	0.000	0.000
WGS-RT	0.000	0.000	0.000	0.000	0.000
WGS-NT	0.000	0.007	0.069	0.131	0.223

Table 4. Selected Target MOTAD Solutions for WW, WGS, and AW Rotations.

Variable	LP	A	B	C
Average Net Return	81.52	80.81	78.03	74.49
Risk	47.56	45.00	35.00	25.00
Water Yield	1.001	1.008	1.033	1.065
Sediment Yield	0.301	0.327	0.428	0.556
Total P	0.384	0.423	0.578	0.775
WW-CT	0.000	0.000	0.000	0.000
WW-RT	0.920	0.894	0.793	0.665
WGS-CT	0.000	0.000	0.000	0.000
WGS-RT	0.000	0.000	0.000	0.000
WGS-NT	0.000	0.026	0.127	0.255
AW	0.080	0.080	0.080	0.080