Wheat Stubble
To Burn or Not to Burn: An Economic Analysis

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Introduction

Wheat producers' options for managing wheat stubble in central Kansas after harvest include using a no-till system that leaves the residue in place, tilling the ground to incorporate some or all residue into the soil, and/or burning the stubble. According to Shroyer, Hargrove and Al-Khatib (2006), wheat producers burn stubble fields before fall planting in order to remove residue for easier planting, while at the same time providing control of some disease organisms and weed species. Burning of wheat stubble also has some disadvantages. These include long-run reduction in soil organic matter, loss of nutrients, hardening of the seedbed and reduced water infiltration capacity. These disadvantages are issues that the farm manager must weigh in the decision to burn or not.

One disadvantage from society's point of view that is receiving increased attention is air quality concerns due to smoke from rangeland and cropland burning. There has been increasing scrutiny of open burning, including agricultural burning, in recent years in some states such as Washington, Oregon, and Idaho. This is also occurring in Midwestern states, notably Kansas. The Kansas Department of Health and Environment (KDHE) has developed the Smoke Management Initiative, a comprehensive plan to address the negative impacts of open burning in the state. While the KDHE recognizes the importance of fire as a range and crop management tool, the goal is for landowners to manage burning in a way that reduces the impact of smoke (KDHE, 2008). Oklahoma is in the process of developing a smoke management plan (Blocksome, 2011).

Cropland comprises 27.5% of the land area burned in Kansas while rangeland is 71.7% according to a study conducted by Sonoma Technology (2004). The cropland burned consists of 76.1% wheat acreage, 13.6% is in hay production and the remaining acreage spread among other crops. This report also indicated that Kansas burned 5,205,313 acres of private rangeland and crop residue while Iowa burned 2,247 acres, Missouri 290,978 acres, Nebraska 215,526 acres, Oklahoma 2,303,359 acres, and Texas 3,798,581 acres.

Heavy rangeland burning occurs primarily in eastern Kansas in the Flint Hills region, where as much as 80% of the total acreage of rangeland is burned in several counties. Crop residue burning in continuous wheat is primarily an issue in central Kansas (KDHE, 2008). Recent information regarding the amount of wheat stubble burning is not available. The EPA (1992) reported that 600,000 acres of agricultural crop residue were burned annually in Kansas, with the primary crop being wheat.

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The current smoke management plan is voluntary and focuses on counties that traditionally burn significant areas of rangeland or pasture. Burning of materials such as land-clearing debris, crop residues, construction debris, firefighter training burns, and yard waste is prohibited during the month of April in 16 Kansas counties in the Flint Hills region (KDHE, 2010). Pasture burning is allowed. However, landowners are encouraged to use a website to obtain information from an environmental model to avoid burning on days when the model shows smoke is likely to impact urban areas. KDHE will address crop residue burning and will work with the agricultural community to reduce the acreage of croplands burned each year and to develop alternatives to burning (KDHE, 2008).

The goal of this analysis is to examine distributions of net returns to land and management to determine which tillage system or burning of winter wheat stubble is preferred under various cost scenarios and levels of risk aversion. There currently is no restriction or penalty for burning crop residue other than the prohibition in the month of April. Wheat stubble would not typically be burned in April, as the wheat is still growing, but would generally be burned soon after wheat harvest in the summer. Crop residue burning may be more restricted in the future. The U.S. Environmental Protection Agency (EPA) will weigh the air quality concerns against the agronomic justifications in deciding whether to limit cropland burning in the future (Shroyer, Hargrove and Al-Khatib, 2006). Although there is potential for future restrictions on burning wheat stubble other than in the month of April, there are currently none. Therefore, we focus on the manager's production risk using net returns of burning or not burning wheat stubble. The following systems were examined in the analysis; burn continuous wheat - BWW, reduced-till continuous wheat - RTWW, and no-till continuous wheat - NTWW.

Data and Methods Overview

Net returns from enterprise budgets were developed for the three systems. Yield and input data for the budgets were collected from the Harvey County Experiment Station in south-central Kansas from 1997 to 2006. Yield characteristics are reported in Table 1. Net returns to land and management were calculated using yields and prices based on actual historical yields, historical monthly price series, and several input cost scenarios.

Table 1. Crop Yield and Price Summary Statistics for South-central Kansas from 1997 to 2006.

	Systems[1]		
Yields	BWW	RTWW	NTWW
Mean (bu./acre)	48.8	46.5	49.7
Std. Dev.	15.4	18.6	13.2
C.V.[2]	0.32	0.40	0.27
Min	29.7	14.3	29.3
Max	74.2	76.9	71.3
Prices	Wheat 2006-2010	Wheat 2001-2005	Glyphosate 2001-2010
Mean	$5.67	$3.30	$41.52
Std. Dev.	$1.60	$0.38	$8.62
C.V.[2]	0.28	0.11	0.21
Minimum	$3.53	$2.94	$25.65
Maximum	$10.60	$4.58	$50.06

[1]RT = Reduced-till, NT = No-till, B = Burn, WW = Continuous Wheat

[2]C.V. = Coefficient of Variation (Std. Dev./Mean)

Study Area

The Harvey County Experiment Field is located near Hesston, Kansas. Harvey County is in the Central Great Plains Winter Wheat and Range Land Resource Region. The area landscape is nearly level to gently sloping (USDA-NRCS, 2006). Annual precipitation for the experiment field area averages 35 inches per year (USDA – NASS, 2008).

Field Operations and Input Costs

Winter wheat was drilled in rows spaced at eight inches. For the reduced tillage system (RTWW), weeds were controlled using a combination of disk, chisel, roller harrow, field cultivator, sweep treader and mulch treader. Herbicides were applied, if needed, in October/November or in April. In the BWW system, the stubble was burned soon after harvest in a manner similar to that used by growers of continuous wheat in the region. Stubble was ignited on the downwind side of each plot, forcing the burn front to move upwind across the plot when wind and moisture conditions were conducive for producing high burn temperatures and thorough combustion of stubble and weed seeds on the soil surface. Remaining weeds were controlled with some of the same tillage operations used in the RTWW system during the summer and fall as needed. A single fall or spring application of herbicide was used in the BWW system, as needed for additional weed control. In the no-till system (NTWW), weed control was accomplished solely with herbicides, which were applied three or four times per year. Costs were calculated using the average annual frequency of the field operations used during the experiment.

All field operation costs, with the exception of burning costs, were 2011 projected custom rates for Kansas (Dhuyvetter, 2011). The cost of burning an acre of wheat stubble was initially set at $7.00/acre, near the midpoint of the range reported by Gee and Biermacher (2007) for rangeland burning of $3.98/acre for a large burn of 833 acres and $9.87/acre for a smaller burn of 172 acres.

Nitrogen and phosphorus sources and rates were the same in each system. Fertilizer costs are for 107 lbs of N from urea before planting in the fall and 72 lbs of di-ammonium phosphate (DAP) at planting.

Glyphosate is the predominant herbicide used in the no-tillage system. It comprises 60% of the total cost of all chemicals used in the NTWW system. The initial analysis used a price of $25.65 per gallon with 4.5 lbs of active ingredient per gallon, the average price reported by USDA (2010) for spring of 2010. Glyphosate prices have been quite variable over the last ten years, ranging from $25.65 to $50.06/gallon in the last 10 years for April prices (USDA, 2010). This variability was considered in further analysis of yield, output price, and glyphosate cost variability.

Simulated Net Returns

Simulation and Econometrics to Analyze Risk (SIMETAR©) developed by Richardson, Schumann and Feldman (2004) was used to simulate yield, output price and glyphosate cost distributions and calculate distributions of net returns to land and management with 2011 costs. Net return distributions were constructed using equation 1.

$$NR_{ik} = Y_{ik} \times EP_i - C_k - G_{ik} - HC_{ik} \qquad (1)$$

where

NR_{ik}	=	net return to land & management ($/acre) for observation i for crop production system k,
i	=	observation, i = 1 to 1000,
k	=	crop production system k, k = 1-3,
Y_{ik}	=	simulated yield (bu/acre) for observation i for crop production system k,
EP_i	=	simulated price ($/bu) for observation i,
C_k	=	preharvest production costs ($/acre) in production system k, excluding glyphosate,
G_{ik}	=	simulated glyphosate cost ($/acre) for observation i in production system k, and
HC_{ik}	=	harvest cost ($/acre) for yield observation i in production system k.

Crop yields, wheat prices and glyphosate costs are stochastic, while all other costs are pre-determined. Observations from a simulated correlated multivariate empirical yield distribution derived from actual historical yields was multiplied by observations from a simulated empirical wheat price distribution derived from actual historical prices to calculate gross returns for each production system. Simulated empirical glyphosate costs, other current-year production costs, and harvest costs were then subtracted from gross returns to obtain the net return.

The yield, price and glyphosate cost distributions were generated in the following manner: a cumulative probability distribution function (CDF) using the 10 years of yield data with the probability ranging from 0.0 to 1.0 was formed by ordering the data and assigning a cumulative probability for each observation. Ten years of annual average glyphosate prices were used for the glyphosate cost distribution. The same process was repeated using monthly prices from January 2006 through December 2010. This 60-month empirical price data was used to capture the variability and the general increase in wheat prices after 2005. Irwin and Good (2011) contend that there has been a structural shift upward in prices beginning in 2007.

A monthly price series beginning in 2006 was used because monthly wheat prices in south-central Kansas for 2006 were higher in every corresponding month than for the years 2001 through 2005 with the exception of January 2004 and 2005. Further, in 8 of the 12 months of 2006, the monthly prices were $1.00/bu. or higher than those in 2005. The analysis was also performed using a 2001 to 2005 monthly wheat price distribution. A summary of the price distribution characteristics is reported in Table 1. Wheat prices were not allowed to fall below the 2011 commodity program loan rate. Commodity program payments were not considered because they do not impact the manager's production method decision.

The following explains the SIMETAR procedure used to generate the yield distributions. The empirical distribution shape is specified by the historical data used because too few observations exist to estimate parameters for another distribution (e.g., normal distribution). A cumulative probability distribution function (CDF) using the 10 years of yield data with probability ranging from 0.0 to 1.0 is constructed by ordering the data and assigning a cumulative probability for each observation (data point). Each observation is assumed to have an equal probability of occurring, so the additional probability for each sequential observation is equivalent. A simulated distribution of 1000 observations is generated by drawing 1000 values from a uniform standard deviate ranging in value from 0.0 to 1.0, similar to using the rand() function in a spreadsheet. The corresponding price or yield assigned to the distribution is from the cumulative probability represented by the uniform standard deviate value. If the value is 0.615, the price drawn would correspond to the 0.615 or 61.5% level of the cumulative distribution. If the value from the uniform standard deviate falls between the cumulative probabilities assigned the original data values, the yield is found by interpolation (Pendell et al., 2007). The same procedure is used to generate the wheat price and glyphosate price distributions. A multivariate distribution has been shown to correlate random yields appropriately, based on their historical correlation (Richardson, Klose and Gray, 2000). The multivariate distribution is a closed-form distribution, which eliminates the possibility of simulated values exceeding values observed in history (Ribera, Hons and Richardson, 2004).

Correlation between yields was included in the simulated net returns. Yield correlations range from 0.74 to 0.94. T-tests and F-tests were used to test for significant differences between the simulated data and the actual data. The statistical tests indicate that there were no statistically significant differences between the mean and variances of the experimental yield data, historical prices and costs and the simulated yields, prices and costs.

Risk Analysis Methods

Stochastic efficiency with respect to a function (SERF) was used to determine the preferred strategy when risk is considered. SERF orders a set of risky alternatives in terms of certainty equivalents (CEs) and risk premiums (RPs) derived from the difference in CEs for a specified risk preference (Hardaker et al., 2004). The CE value is the amount of certain payoff an individual would require to be indifferent between that payoff and the payoff of the risky alternative. The difference between CE values at a specific risk aversion level is known as the risk premium and represents the minimum certain amount that would have to be paid to an individual in order for the individual to be willing to switch from the less risky alternative to the more risky alternative (Hardaker et al., 2004).

The calculation of the CE depends on the utility function specified. A negative exponential utility function used in the SERF analysis conforms to the hypothesis that managers prefer less risk to more given the same expected return. With a negative exponential utility function, an absolute risk aversion coefficient (RAC) defined by Pratt (1964) as, $r_a(w) = -u''(w)/u'(w)$ is used. This ratio of the derivatives of the decision-maker's utility function, $u(w)$, was used to derive the CEs. This functional form assumes managers have constant absolute risk aversion. Under this assumption, managers view a risky strategy for a specific level of risk aversion the same without regard for their level of wealth. Babcock, Choi, and Feinerman (1993) note this functional form is often used to analyze farmers' decisions under risk. For additional justification for this functional form, refer to Schumann et al. (2004), who demonstrate the negative exponential function can be used as a reasonable approximation of risk averting behavior.

The simulated net return data outcomes from each crop production system were sorted into cumulative distribution functions (CDFs) which were used in the SERF analysis. Once the strategies were ranked using the CE results, a utility-weighted risk premium (RP) was calculated (Hardaker et al. 2004). This was accomplished by subtracting the CE of a less preferred strategy from the preferred strategy. The risk premiums and the resulting rankings are reported in the analysis in graphical form for a range of RACs from risk-neutral to extremely risk-averse. Decision-makers with RACs equal to zero are considered risk-neutral while managers with RACs greater than zero exhibit risk-averse behavior. Anderson and Dillon (1992) proposed a relative risk aversion coefficient (RRAC) definition of 0.0 as risk neutral and 4.0 as extremely risk averse. Thus, as suggested by Hardaker et al., 2004 the upper range of absolute RAC for use with a negative exponential utility function was calculated by dividing 4.0 by an appropriate level of wealth. In this case, the measure of wealth is the average per acre net worth of farms in south-central Kansas in 2009 of $507/acre (KFMA, 2010). Ribera, et al. (2004) and Pendell et al. (2007) provide other applications of the methodology.

Results

An initial static analysis was performed without simulation using 2011 costs, average yields and the average monthly price for the period 2006-2010. Net returns were highest for NTWW and were $8.35/acre larger than BWW (Table 2). Total costs were lower for NTWW and gross returns were higher. Under this initial analysis that used average yields and prices, lower glyphosate prices will further increase the NTWW system net return advantage over the BWW system. On the other hand, the glyphosate price would need to rise to $44.28 per gallon or higher for BWW to have equivalent or higher net returns than NTWW. According to USDA (2010), this has happened six times in the last 10 years, though recent prices have been significantly lower.

Table 2. Cost and Net Returns in $/acre.

	Systems[1]		
	BWW	RTWW	NTWW
Planting	$15.56	$15.56	$15.56
Seeds	$19.88	$19.88	$19.88
Fertilizer Application	$4.99	$4.99	$4.99
Fertilizer	$71.05	$71.05	$71.05
Fertilizer (applic.+ inputs)	$76.04	$76.04	$76.04
Burn	$7.00	$0.00	$0.00
Tillage	$34.80	$40.88	$0.00
Chemicals application	$1.28	$2.57	$16.67
Chemicals	$2.55	$5.93	$25.51
Chemicals (applic.+ inputs)	$3.83	$8.50	$42.18
Harvest[2]	$28.61	$28.10	$28.80
Interest	$6.50	$6.61	$6.39
Total cost	$192.21	$195.56	$188.84
Gross Returns	$276.76	$263.69	$281.74
Net Returns[3]	$84.55	$68.12	$92.90

[1] RT = Reduced-till, NT = No-till, B = Burn, WW = Continuous Wheat

[2] Based on 10-year average crop yield, 2006-2010 average wheat price and 2011 costs.

[3] Net Return to Land and Management

The simulated net returns analysis reported in Table 3 shows that NTWW had slightly higher net returns than BWW and a lower standard deviation and coefficient of variation. When the price series from 2001-2005 was used to calculate the average net returns, they were negative (Table 3). In that case, the BWW system was less negative than the other systems.

Table 3. Simulated Net Return Characteristics.

	2006-2010 Wheat Prices			2001-2005 Wheat Prices		
	Systems[1]			Systems[1]		
	BWW	RTWW	NTWW	BWW	RTWW	NTWW
Mean	$84.18	$69.37	$85.40	$-32.50	$-43.84	$-38.86
Std.Dev.	$116.85	$127.09	$108.66	$47.22	$54.87	$40.05
C.V. [2]	1.39	1.83	1.27	NA	NA	NA
Min	-$82.18	-$134.30	-$78.71	$-100.43	$-148.00	$-108.46
Max	$562.63	$585.57	$535.53	$121.41	$143.59	$123.54

[1] RT = Reduced-till, NT = No-till, B = Burn, WW = Continuous Wheat

[2] C.V. = Coefficient of Variation (Std. Dev./Mean)

In the future, some of the wheat straw left on the soil surface in a no-tillage system may have value as a biomass feedstock for alternative energy production. Nelson et al. (2010) estimated that wheat straw harvest would average 0.30 tons/acre in this region. This residue removal level is the largest harvest that would allow the rate of soil erosion from both rainfall and wind to be less than the NRCS-prescribed tolerable soil loss limit, T, and the level of soil organic matter to be unchanged or positive. Further, additional carbon sequestered in the soil with no-tillage may have value if carbon markets for agricultural offsets develop in the future.

Risk Analysis

The SERF analysis under the 2006-2010 monthly wheat price series indicates that NTWW was preferred to BWW at all levels of risk aversion. Although NTWW was preferred to BWW, the risk premiums were always less than $5.00 per acre up to an RAC of 0.0079 (Figure 1). Figure 2 reports the probability of net return for each of the three strategies being less than $0.00/acre, between $0.00 and $100/acre and more than $100/acre. The figure shows NTWW system had a higher probability of returns above $0.00 (78%) and $100/acre (38%) than the other strategies. The RTWW system had the greatest probability of having a net return below $0.00/acre (33%).

Figure 1. Risk premiums relative to burning wheat stubble 2006-2010 crop prices ($/acre).

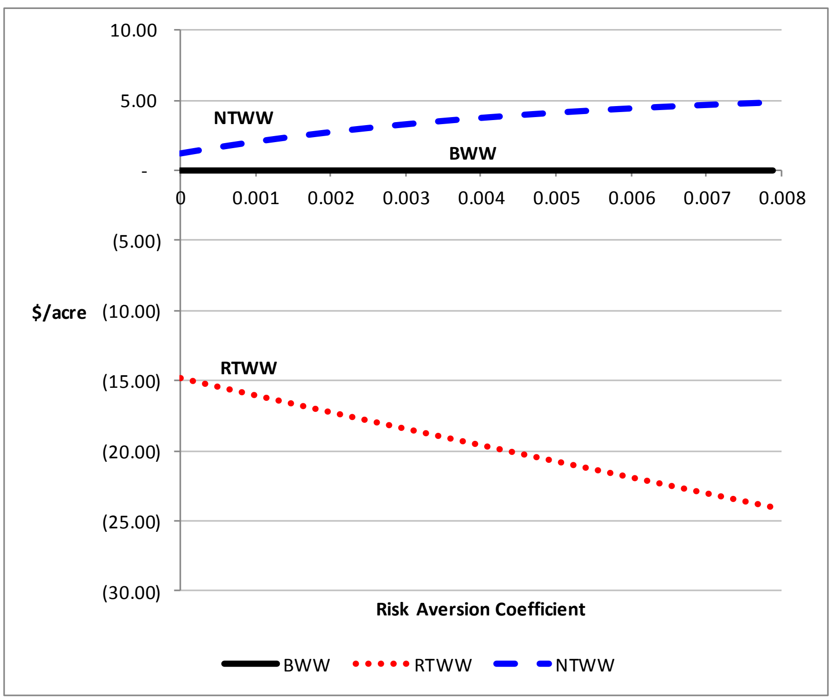
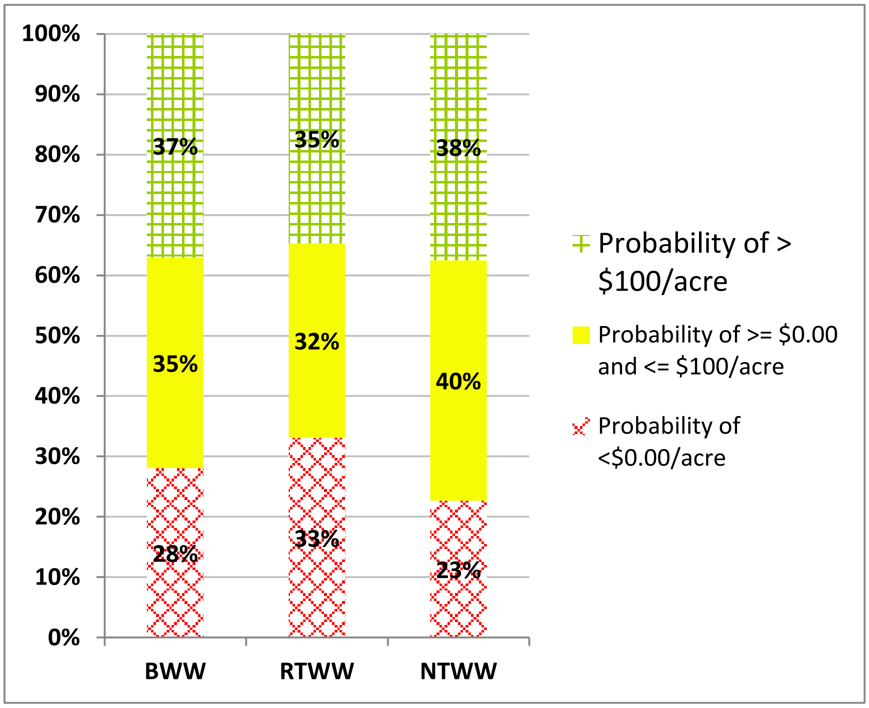


Figure 2. Probability of Net Returns with 2006-2010 Wheat Prices.

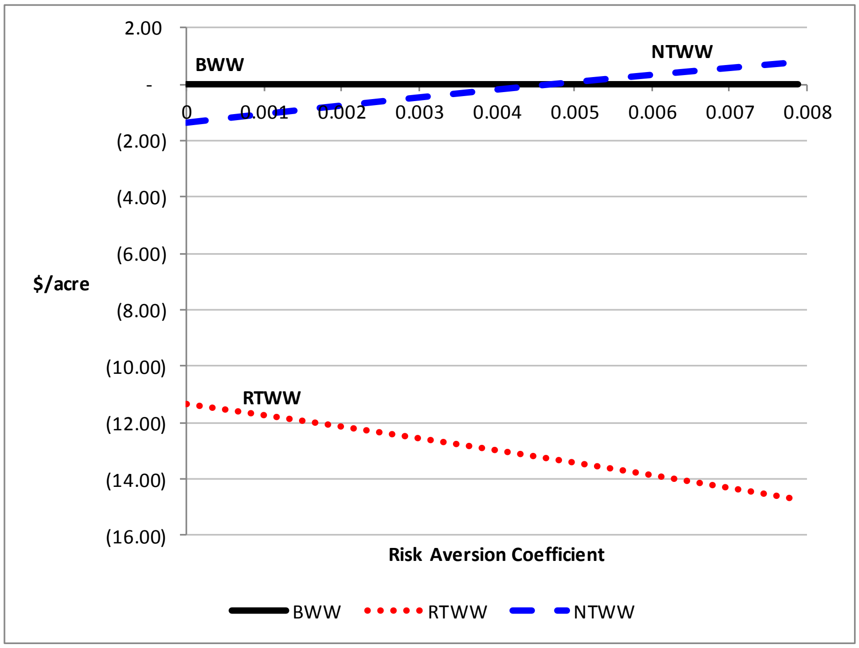


Under the 2001-2005 monthly price series, SERF analysis indicates the BWW strategy was preferred to the NTWW strategy up to an RAC of 0.0047 (Figure 3). According to Anderson and Dillon (1992), this RAC would correspond to moderate risk-averse behavior.[2]

SERF analysis with the 2006 through 2010 wheat price series was performed using the lowest and highest glyphosate price during the last 10 years of $25.65 and $50.06/gallon respectively. NTWW was preferred to BWW at all levels of risk aversion. Under the highest price of glyphosate, NTWW was preferred up to a RAC of 0.004. Under this scenario, the largest risk premium or the incentive needed to use NTWW instead of BWW was $3.16/acre. A price of $50.63/gallon was needed to make the NTWW system less preferred at all levels of risk aversion to BWW.

[2] Similar results were obtained with a power utility function for both wheat price series.

Figure 3. Risk premiums relative to burning wheat stubble 2001-2005 crop prices ($/acre).



<u>Conclusions</u>

The NTWW system generally has higher net returns and less risk than BWW. However, the differences are small, indicating that relatively small incentives to use NT rather than burning may be useful. The BWW and NTWW systems have greater net returns than RTWW. Therefore, in situations where weed problems develop in continuous no-till wheat, the system that burns wheat residue is a better alternative than reduced tillage. Although NTWW looks economically superior to the BWW system, factors including tradition, higher glyphosate costs, and lower commodity prices than currently exist may also contribute to wheat stubble being burned.

The results of this study suggest that minor policy changes that increase the transaction costs for burning crop residue may be all that are needed to reduce crop residue burning. The risk premium that would need to be paid to encourage NTWW instead of BWW is $3.16/acre at its largest under the 2006 through 2010 wheat price series and highest glyphosate price scenario. Possible additional polices include requiring an approved burning plan, charging for a burn permit, and notification of intent to burn, providing a subsidy to use no-tillage, or requiring the land manager to get approval for burning based upon predictions of smoke impact on air quality with an environmental smoke model, each of which would increase the relative cost of burning and make NTWW more economically viable.

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