Pasture Rental Rates for Fall-Winter Grazing of Winter Wheat

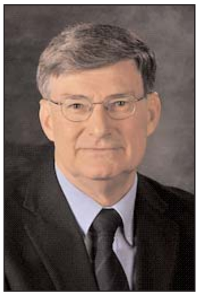
By Brandon T. Varner, Francis M. Epplin, Damona G. Doye, R. Joe Schatzer, and Jeffrey T. Edwards

Abstract

Winter wheat can be managed to produce a substantial quantity of high quality fall-winter forage. Wheat producers may lease the grazing rights to livestock producers. This system generates income from both forage and grain, but results in a lower expected grain yield than wheat managed to produce only grain. The rental rate in terms of cents per pound of livestock weight gain required to offset the additional costs and lower grain yield depends on the market price of wheat. This study was conducted to determine the minimum pasture rental rate necessary for dual-purpose wheat to breakeven with grain-only wheat.

Introduction

Winter wheat may be managed in the Southern Plains to produce high quality forage that can be grazed by livestock, typically from mid-November through February. If livestock are removed from the wheat prior to the first hollow stem stage of development (emergence from winter dormancy), the wheat will mature and produce wheat grain. True et al. (2001) found that in 1996 two-thirds of Oklahoma's wheat acres were planted with the intention of being used to produce both fall-winter forage and grain. Wheat producers often lease the rights to graze the fall-winter forage to livestock producers (True et al.; 2001;Hossain et al., 2004). Typically wheat pastures are stocked with light weight (450 to 550 pound) steers or heifers that have an opportunity to gain 200 to 300 pounds during the season. Kaitibie et al. (2003a) reported an optimal stocking rate of 0.6 steers per acre with an initial weight of 503 pounds per steer (302 pounds of animal stocked per acre). During a typical grazing season of 112 days for a typical rate of gain of two pounds per day, a stocking density of 0.6 steers per acre would produce 134 pounds of gain per acre (Kaitibie et al., 2003b). The most typical lease arrangement is for the livestock owner to pay the wheat producer a fixed rental rate per pound of weight gained by the grazing livestock.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Dual-purpose wheat is planted early to establish a forage base before winter so that livestock have sufficient forage throughout the fall-winter grazing season. Previous small-plot studies have found that expected grain yield is less for early planted wheat (dual-purpose) than for wheat (grain-only) planted later to maximize grain yield due to planting date effects (Duke et al., 2011; Edwards et al., 2009; Epplin, Hossain, & Krenzer, 2000; Hossain, Epplin, & Krenzer, 2003; Lyon, Baltensperger, & Siles, 2001). Typically, producers plant dual-purpose wheat in mid September (Hossain et al., 2004; Krenzer, 2000; True et al., 2001); grain-only wheat is planted in October (Heer & Krenzer, 1989; Krenzer, 2000; Lyon et al., 2007). On average wheat planted in early September yields substantially more fall-winter forage but less grain than wheat planted in October.

Dual-purpose wheat requires more seed and more nitrogen. Agronomists report that the optimal seeding rate for dual-purpose wheat is two times greater than the optimal seeding rate of grain-only wheat (Edwards et al., 2011; Krenzer, 1991). Early sowing, increased plant population density, and the additional nitrogen increase the level of expected fall vegetative growth available for grazing livestock (Edwards et al., 2011; Krenzer, 1991; Edwards, 2009).

Doye and Sahs (1991-2006) conducted biennial surveys of wheat pasture rental rates. From 1991 to 2006, the average Oklahoma wheat pasture rental rate ranged from $0.31 to $0.34 per pound of gain. As a result of the reduction in grain yield, the wheat pasture rental rate required for dual-purpose wheat to break even with grain-only wheat depends in part on the price of wheat grain. Wheat grain prices increased in 2007 and 2008 and wheat pasture rental rates increased in 2008 to an average of $0.44 per pound of gain (Doye & Sahs, 2008). Wheat prices declined in 2009 and 2010 and average rental rates declined to $0.39 per pound of gain in 2010 (Doye and Sahs, 2010).

In late summer wheat producers must decide if they are going to attempt to produce dual-purpose wheat or to produce grain-only wheat. At this time the price of nitrogen fertilizer as well as the price of most other inputs will be known. Also at this time a wheat futures price for the upcoming crop year will be known. Based on the wheat futures price and expected basis, local elevators will have a posted wheat price at which the grower can contract for delivery at harvest in the following June. When it is time to decide to plant either dual-purpose or grain-only wheat, the producer is expected to have access to a very good estimate of the price of fertilizer and a good estimate of the wheat price. The decision to produce dual-purpose wheat or grain-only wheat then depends on the (a) expected grain yield of grain-only wheat; the (b) expected grain yield of dual-purpose wheat; the (c) expected livestock weight gain on dual-purpose wheat; and the (d) lease rate that can be obtained from leasing the rights to graze the wheat forage.

The objective of this study is to determine the minimum rental rate for fall-winter grazing necessary for dual-purpose wheat to break even with grain-only wheat. The findings will be of value for managers who must decide whether to plant wheat with the intention of producing both fall-winter forage and grain, or to plant with the intention of producing only grain; for managers who must decide a rental rate to accept from livestock producers; and for livestock managers who must decide a rental rate to offer wheat producers.

There is a considerable amount of variability from year to year in grain yield from both dual-purpose and grain-only wheat (Table 1) and steer gain from steers grazing dual-purpose wheat (Table 2) that results from the unknown growing season weather. Empirical data from controlled experiments are used to address the production risk and to compute the lease rate required for dual-purpose wheat to breakeven with grain-only wheat. The wheat producer can use these findings to negotiate an actual lease rate with livestock producers. If livestock producers offer more than the breakeven price then the wheat producer can elect to produce dual-purpose wheat. However, if the livestock producers offer less than the breakeven price then grain-only wheat is the better choice for the wheat producer.

Methods

Two base enterprise budgets, one for grain-only wheat and the other for dual-purpose wheat, are constructed (Table 3). Estimates are computed for wheat grain prices of $3, $5, and $7 per bushel. The $3 per bushel grain price roughly reflects the average marketing year price from 1986 to 2005. The $5 per bushel price is more consistent with the average from 2006 to 2010. To determine the consequences of higher grain prices on the breakeven rental rate for wheat pasture, results are also computed for $7 per bushel wheat grain. The equation (1) used to compute a breakeven lease rates is included in the Appendix.

Total cash costs will be estimated by summing the cost of inputs and services. The price of seed wheat is correlated with the price of wheat grain. Historical prices of seed wheat and wheat grain were retrieved from NASS for the time period of 2002-2010. Ratios were calculated for each year to determine that the average price of seed wheat is 2.41 times greater than the price received for the preceding wheat crop. The price of seed in the budget is set equal to 2.41 times the market price of wheat and in equation (1) P_S is set equal to 2.41^*P_W. Fertilizer and herbicide prices were obtained from dealers and distributors in the region. Fertilizer application, herbicide application, and custom harvesting costs were obtained from a survey conducted by Doye and Sahs (2009).

Three common assumed differences in total costs between the two wheat systems are based on the seeding rate, the amount of nitrogen applied, and harvest cost. Grain-only wheat has a budgeted seeding rate of 60 pounds per acre, while the dual-purpose wheat has a budgeted seeding rate of 120 pounds per acre. All nitrogen is assumed to be applied pre-plant using anhydrous ammonia and diammonium phosphate. Grain-only is budgeted to receive 82 pounds of nitrogen per acre, while the dual-purpose wheat is budgeted to receive 115 pounds of nitrogen per acre. The hauling cost as represented by HL in equation (1) differs between wheat systems because the hauling cost is a function of the number of bushels hauled [(HL^*W_{GO}) and (HL^*W_{DP})]. Since the expected yield of dual-purpose wheat is less than the expected yield of grain-only wheat, the harvesting and hauling cost is expected to be less for the dual-purpose system.

Wheat yields and livestock weight gain are stochastic variables affected by weather and management effects. Empirical grain yield and weight gain distributions can be used to estimate a distribution of net returns for both wheat systems using the breakeven rental rate as a proxy for the price of gain assuming that prices and input levels are fixed and assuming that dual-purpose wheat yield and gain are independent.

Stochastic efficiency with respect to a function (SERF) can be used to compare the distributions of net returns. SERF can also be used to estimate a risk premium relative to grain-only wheat for several absolute risk aversion coefficients. These risk premiums can be used to determine the addition to the rental rate required by producers with varying levels of risk aversion to be indifferent between grain-only and dual-purpose wheat. The key assumptions necessary for SERF are that the empirical data must represent the entire distribution and that each year represented is equally likely to occur. SERF ranks the two production systems in terms of certainty equivalents (CE) for a given level of risk aversion enabling determination of the risk premiums (Hardaker et al., 2004; Meyer, Richardson, & Schumann, 2009; Archer & Reicosky, 2009; Hardaker & Lien, 2010; Williams et al., 2010). The difference between CE for any two production systems represents the risk premium, which is a monetary estimate of the minimum amount a producer would have to be paid to switch from a production system that has a greater CE to the production system with a lower CE. The spreadsheet add-in SIMETAR can be used to calculate certainty equivalents and risk premiums using SERF (Richardson, Schumann, & Feldman, 2001).

Data

Wheat yield data for both dual-purpose and grain-only production systems were obtained from side-by-side experiments conducted at the Oklahoma State University Wheat Pasture Research Unit (WPRU) near Marshall, OK (36° 6' 57.78" N, 97° 35' 42.51" W) from 1999 to 2011. In each year trials consisting of 18-24 varieties were tested (Edwards et al., 2011). The two production systems were adjacent, but were separated by an electric fence so that the grain-only plots were not grazed. Grazing was initiated on the dual-purpose plots 45 to 60 days after planting. Grazing on dual-purpose plots was terminated at the first hollow stem stage of growth for the earliest variety, usually near March 1.

Steer weight gain data were obtained from the WPRU from 1990 to 2000. Steers were grazed on dual-purpose wheat managed the same way as the dual-purpose wheat in the variety trial experiments. Grazing was initiated after the wheat had become well anchored into the soil and steers were removed from the wheat at the development of first hollow stem. During the grazing period the steers did not receive any supplemental feed other than hay during periods when snow covered the wheat field. Steers were weighed prior to grazing wheat and were weighed again after grazing was terminated to determine steer weight gain (Kaitibie et al., 2003b).

Duke et al. (2011) found that experienced Oklahoma wheat producers who produce dual-purpose wheat regard average daily gain and wheat grain yield to be uncorrelated. Weather events that affect forage yields occur in the fall and weather events that affect grain yields largely occur in the early spring after the cattle have been removed from the wheat. Kaitibie et al. (2003b) reported results of a seven-year study of dual-purpose wheat that was grazed and produced both steer weight gain and grain yield data. A statistical test of the correlation between these grain yields and steer gains could not reject the null hypothesis of zero correlation. Based on these findings, dual-purpose wheat grain yields and steer gain on dual-purpose wheat pasture is independent.

Net returns distributions were computed from the 13 years of observations for grain-only and dual-purpose wheat yields and the 11 years of observations of beef gain per acre. Stochastic efficiency with respect to a function (SERF) was used to compare the two distributions. In years when 24 varieties were included, the four replications produced 96 grain yield observations. For years when less than 24 wheat varieties were tested, the number of observations was supplemented with as many observations of the mean yield as required for that year so that 96 total observations were available for each year. This provided an empirical distribution of 1,248 observations for both dual-purpose and grain-only yields. One steer weight gain observation was randomly drawn from the empirical distribution of gains for each of the 1,248 dual-purpose wheat grain yield observations. Net returns were then estimated for each of the 1,248 grain-only yields and each of the 1,248 pairs of dual-purpose yields and weight gains.

Results

Mean yields by year and production system are reported in Table 1. Wheat yields were statistically different between wheat systems. Grain-only wheat yielded on average 40 bushels per acre, which was greater ($P \leq 0.05$) than the dual-purpose average yield of 33 bushels per acre. This finding is consistent with results reported by Duke et al. (2011), Edwards et al. (2011), and Lyon, Baltensperger, & Siles (2001).

Mean steer gains per acre are reported by year in Table 2. Gain per acre ranged from a low of 0 pounds per acre in 1996 to a high of 199 pounds per acre in 1994. During the 1996 growing season insufficient wheat pasture was produced on the dual-purpose pastures due to drought to permit grazing and zero gain was recorded. The mean grazing season steer gain from 1990 to 2000, including the zero observed gain for 1996, was 134 pounds per acre. If the zero observation is excluded the mean was 147 pounds per acre.

Base budgets with a wheat grain price of $5 per bushel are reported in Table 3. Break-even pasture rental rates were computed and used in the enterprise budget so grain-only wheat and dual-purpose wheat have the same expected net return of $22 per acre for a wheat grain price of $5 per bushel. Expected net returns are -$53 per acre for $3 per bushel wheat and $98 per acre for $7 per bushel wheat. Dual-purpose wheat has greater total costs as a result of higher seeding rate and a higher rate of nitrogen fertilizer. Because expected harvest costs are a function of grain yield, they are slightly lower for dual-purpose wheat.

Table 4 includes the pasture rental rates required for dual-purpose wheat to breakeven with grain-only wheat for the mean levels of steer weight gain and mean levels of dual-purpose and grain-only wheat yields. When the price of wheat grain is $3 per bushel, a $0.30 per pound of gain pasture rental rate is required for dual-purpose wheat to breakeven with grain-only wheat. The break-even rental rates are $0.44 and $0.59 per pound of gain for wheat prices of $5 and $7 per bushel, respectively. Since the cost difference between dual-purpose and grain-only wheat is sensitive to the cost of the additional nitrogen fertilizer, solutions were obtained for three prices of anhydrous ammonia. Fifty percent price changes were used for the price of anhydrous ammonia since the mean price of anhydrous ammonia fluctuated by 50 percent during the 1999-2010 period. The break-even rental rates for each of the three anhydrous ammonia prices and each of the three wheat prices are reported in Table 4. When the price of anhydrous ammonia is reduced by 50 percent, the break-even pasture rental rates are $0.25, $0.39, and $0.53 per pound of gain for $3, $5, and $7 wheat, respectively. When the price of anhydrous ammonia is increased by 50 percent, the break-even pasture rental rates are $0.36, $0.50, and $0.65 per pound of gain for $3, $5, and $7 wheat, respectively.

Results from the SERF analysis are reported in Table 5 for wheat grain prices of $3, $5, and $7 per bushel. Net returns CE are reported for both wheat systems for five constant absolute risk aversion coefficients (ARAC). Since the breakeven pasture rental rate was used in the formulation of the net returns distribution, it is expected that the risk neutral producer (ARAC= 0.000) would be indifferent between grain-only and dual-purpose wheat. The CE are not equal for the risk neutral producer (ARAC= 0.000) due to rounding error in the breakeven pasture rental rate. Grain-only wheat is the preferred system for risk-averse producers (ARAC between 0.002 and 0.008) when the value of livestock gain is priced at the breakeven level because variability in net returns is less for grain-only than for dual-purpose. The standard deviation in net returns was 24, 21, and 20 percent greater for dual-purpose wheat when compared to grain-only wheat at grain prices of $3, $5, and $7 per bushel.

Risk premiums are also reported in Table 5. Risk premiums in these tables represent the difference in CE between grain-only wheat and dual-purpose wheat. The risk premium is positive for the risk neutral wheat producers (ARAC=0.000) when grain price is three dollars per bushel and the value of livestock weight gain is set at the breakeven level, which indicates a preference for dual-purpose wheat. Risk premiums become negative for levels of the ARAC that would be appropriate for risk averse producers (ARAC= 0.002 to 0.008). A risk-averse producer would require a rental rate for the fall-winter wheat pasture in excess of that required to breakeven to prefer dual-purpose to grain-only wheat. For risk-averse producers with ARAC of 0.002 and greater, a rental rate in excess of the breakeven rate would be required to entice production of dual-purpose wheat.

For the mean steer weight gain level of 134 pounds per acre, risk-averse producers (ARAC=0.004) would require an additional one dollar per acre (so the pasture rental rate would have to increase approximately two percent to $0.31 per pound of gain) to be indifferent between grain-only and dual-purpose wheat. For a more strongly risk averse producer (ARAC= 0.008), the pasture rent would have to generate an additional $2.61 per acre, which would increase the price per pound of gain by approximately six percent to $0.32 per pound of gain.

When the price of wheat grain is $5 and $7 per bushel, risk premiums are negative for producers with ARAC of 0.002 and greater, which indicates that a greater expected return is required to entice risk averse producers to switch from grain-only to dual-purpose wheat. For dual-purpose wheat to be economically competitive with grain-only wheat, the wheat pasture rental rate must be in the range of $0.43 to $0.50 per pound of gain for an expected grain price of $5 per bushel and $0.58 to $0.71 per pound of gain for an expected grain price of $7 per bushel depending on the wheat producer's level of risk aversion.

Conclusion

This study was conducted to determine the minimum rental rate for fall-winter grazing necessary for dual-purpose wheat to breakeven with grain-only wheat. Break-even pasture rental rates were determined for three levels of wheat grain price. The break-even pasture rental rate was determined to be $0.30, $0.44, and $0.59 per pound of gain for expected wheat prices of $3, $5, and $7 per bushel. The breakeven pasture rental rate is sensitive to the price of wheat grain and also to the price of nitrogen fertilizer. When anhydrous ammonia costs $0.17 per pound estimated breakeven pasture rental rates were $0.25, $0.39, and $0.53 per pound of gain for grain prices of $3, $5, and $7 per bushel, respectively. When the price of anhydrous ammonia was increased to $0.52 per pound, breakeven pasture rental rates were $0.36, $0.50, and $0.65 per pound of gain for grain prices of $3, $5, and $7 per bushel, respectively. These estimated breakeven wheat pasture rental rates are the minimum rates that risk-neutral wheat producers would require to manage wheat to produce both fall-winter forage and grain and to lease the grazing rights to a livestock producer rather than producing wheat for grain-only.

For risk-averse wheat producers, these break-even rates would be insufficient to entice a switch from grain-only to dual-purpose wheat production. Risk-averse producers would require a higher pasture rental rate before they would consider switching from grain-only to dual-purpose wheat. Pasture rental rates are highly dependent on the expected price of wheat grain and the cost of nitrogen fertilizer. However, when it is time to decide to plant either dual-purpose or grain-only wheat, the producer is expected to have access to a good estimate of the price of fertilizer and a good estimate of the price at which wheat grain can be contracted for delivery at harvest. Armed with this information the wheat producer can use the findings reported in Tables 4 and 5 in lease rate negotiations with livestock producers. Depending on the lease rate offered by livestock producers, the wheat producer can decide to produce either dual-purpose or grain-only wheat.

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Table 1. Mean wheat yield by management system by year produced in experiments conducted at the Wheat Pasture Research Unit near Marshall, Oklahoma (bushels/acre)

Year	Dual-Purpose	Grain-Only
1999	33	43
2000	44	42
2001	38	44
2002	45	49
2003	53	50
2004	39	51
2005	16	30
2006	22	28
2007	16	30
2008	56	64
2009	8	21
2010	44	36
2011	18	29
Average	33	40
Standard Deviation	7	8
F-Value	362.43	
P-Value	<.0001	

Source: Edwards et al.

Table 2. Steer gain per acre by year produced in dual-purpose wheat fall-winter grazing experiments conducted at the Wheat Pasture Research Unit near Marshall, Oklahoma (pounds/acre)

Year	Gain per acre
1990	123
1991	126
1992	94
1993	99
1994	199
1995	196
1996	0
1997	169
1998	163
1999	153
2000	149
Average	134
Standard Deviation	43

Source: Kaitibie et al. (2003b).

Table 3. Budgets for grain-only and dual-purpose wheat when wheat grain is $5 per bushel and the pasture rental rate is $0.44 per lb. of gain

			Grain-only Wheat		Dual-purpose Wheat	
Item	Unit of Measure	Price per unit	Quantity	Value	Quantity	Value
Production						
Wheat	bu	$ 5.00	40	200.00	33	165.00
Steer Weight Gain		$ 0.44 [a]			134	58.96
Gross Returns	acre			**$ 200**		**$ 224**
"Cash" Costs						
Wheat Seed	bu	$ 12.03	1	12.03	2	24.06
Anhydrous Ammonia (82-0-0)	lbs	$ 0.35	89	30.93	130	45.18
Fertilizer Application	acre	$ 9.00	1	9.00	1	9.00
DAP (18-46-0)	lbs	$ 0.34	50	16.75	50	16.75
Fertilizer Application	acre	$ 4.00	1	4.00	1	4.00
Herbicide (broadleaf)	acre	$ 3.50	0.75	2.63	0.75	2.63
Herbicide (grass)	acre	$ 10.31	1	10.31	1	10.31
Herbicide Application	acre	$ 5.00	1	5.00	1	5.00
Insecticide (e.g. dimethoate)	pint	$ 5.75	0.75	4.31	0.75	4.31
Foliar Fungicide (1 of 3 years)	acre	$ 19.70	0.33	6.50	0.33	6.50
Aerial Pesticide Application	acre	$ 5.00	1.33	6.65	1.33	6.65
Wheat Crop Insurance	acre	$ 7.00	1	7.00	1	7.00
Fuel	gallon	$ 3.35	4.92	16.48	4.92	16.48
Lube	acre			2.47		2.47
Repair	acre			7.12		7.12
Annual Operating Capital	$	$ 0.07	70.59	4.94	83.73	5.86
Wheat Custom Harvest & Haul						
Base Charge	acre	$ 20.00	1	20.00	1	20.00
Excess for > 20 bu./a	bu	$ 0.20	20	4.00	13	2.60
Hauling	bu	$ 0.20	40	8.00	33	6.60
Total "Cash" Costs	acre			**$ 178**		**$ 203**
Net Returns to Land, Machinery Fixed Costs, Labor, Overhead, and Management	acre			**$ 22**		**$ 21**

[a] The calculated wheat pasture rental price per pound of livestock weight gain at which the net returns to land, machinery fixed costs, labor, overhead, and management are equal for the grain-only and dual-purpose wheat production systems.

Table 4. Pasture rental rate required for dual-purpose wheat to breakeven with grain-only wheat for three wheat prices and three anhydrous ammonia (NH3) prices ($ per pound of gain)

	Base Assumptions		
Wheat Price ($/bu.)	$0.35/ lb. NH_3	$0.17/ lb. NH_3	$0.52/ lb. NH_3
$3	$ 0.30	$ 0.25	$ 0.36
$5	$ 0.44	$ 0.39	$ 0.50
$7	$ 0.59	$ 0.53	$ 0.65

Table 5. Net returns certainty equivalents and grain-only wheat risk premiums by wheat system for five absolute risk aversion coefficients and wheat grain prices of $3, $5, and $7 per bushel

	Absolute Risk Aversion Coefficients (ARAC)				
	0.000	0.002	0.004	0.006	0.008
Wheat Grain Price of $3 per bushel					
	Certainty Equivalents ($ per acre)				
Grain-only	-53	-54	-56	-57	-58
Dual-purpose	-52	-54	-57	-59	-61
	Risk premium relative to grain-only wheat ($ per acre)				
Dual-purpose	1[a]	0	-1	-2	-3
	Breakeven Rental Rate ($ per lb. of gain)				
	0.30[b]	**0.30**	**0.31**	**0.31**	**0.32**
Wheat Grain Price of $5 per bushel					
	Certainty Equivalents ($ per acre)				
Grain-only	22	18	14	10	6
Dual-purpose	23	17	11	5	-1
	Risk premium relative to grain-only wheat ($ per acre)				
Dual-purpose	1[a]	-1	-3	-6	-8
	Breakeven Rental Rate ($ per lb. of gain)				
	0.43	**0.45**	**0.47**	**0.48**	**0.50**
Wheat Grain Price of $7 per bushel					
	Certainty Equivalents ($ per acre)				
Grain-only	98	89	81	73	66
Dual-purpose	99	86	74	62	50
	Risk premium relative to grain-only wheat ($ per acre)				
Dual-purpose	1[a]	-3	-7	-11	-16
	Breakeven Rental Rate ($ per lb. of gain)				
	0.58	**0.61**	**0.64**	**0.68**	**0.71**

[a] For a ARAC value of zero when the decision maker is assumed to risk neutral, at the precise breakeven rental rates, the risk premium for dual-purpose relative to grain-only would be exactly zero. These values differ slightly due to rounding error when using equation (1) to compute the breakeven rental rate.

[b] For a wheat price of $3 per bushel, a rental rate of $0.30 per pound of gain would be required to offset the additional cost and reduced grain yield of producing dual-purpose relative to grain-only winter wheat.

Appendix

The breakeven rental rate for wheat pasture can be computed by equation (1).

$$(1) \qquad BE_G = ((P_w)(W_{GO} - W_{DP}) + \left[\left(1 + r\left(\frac{m}{12}\right)\right) * \left(P_n(N_{DP} - N_{GO}) + P_s(S_{DP} - S_{GO})\right)\right] -$$

$$(H) * ((1-\lambda) * \left((W_{GO} - 20)\right) - ((1-\ \omega) * (W_{DP} - 20))\right) \ - \ (HL)(W_{GO} - W_{DP}))/G$$

where BE_G is the breakeven wheat pasture rental rate in \$ per pound of gain,

P_W is the price of wheat grain in \$ per bushel,

W_{GO} is the grain-only wheat grain yield in bushels per acre,

W_{DP} is the dual-purpose wheat grain yield in bushels per acre,

r is the interest rate,

m is the number of months between planting (investment in seed and nitrogen) and harvest,

P_n is the price of anhydrous ammonia in \$ per pound,

N_{DP} is the anhydrous ammonia rate required for dual-purpose production in pounds per acre,

N_{GO} is the anhydrous ammonia rate required for grain-only production in pounds per acre,

P_s is the price of seed wheat in \$ per bushel,

S_{DP} is the seeding rate required for dual-purpose production in bushels per acre,

S_{GO} is the seeding rate required for grain-only production in bushels per acre,

H is the additional harvesting cost above 20 bushels per acre in \$ per bushel,

λ is equal to 1 if $W_{GO} < 20$,

ω is equal to 1 if $W_{DP} < 20$,

HL is the hauling cost in \$ per bushel, and

G is the weight gained by the pastured animal in pounds per acre.

Equation (1) can be solved to determine the rental price per pound of animal weight gain at which the net returns from the dual-purpose system equal the net returns from the grain-only system. The breakeven rental price of gain (BE_G) is the rental rate at which a risk-neutral wheat producer would be indifferent between growing wheat for grain-only and growing wheat for dual-purpose and leasing the forage to a livestock producer. However, the market would have to provide a greater wheat pasture rental rate to entice a risk-neutral producer to grow dual-purpose wheat and lease the grazing rights.