The Investment Potential of Warm-Season Grasses for Hill-Land Beef Producers

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The investment potential of warm-season grasses is compared with that of cool-season grasses, with special emphasis on hill-land beef production. In addition to evaluating relative costs and returns for various grazing systems, a sensitivity analysis is conducted. The results are then illustrated for a representative hill-land farm in West Virginia, and both an optimal and a set of quasi-optimal solutions are generated within the linear programming framework. In general, warm-season grasses are found to be a superior investment alternative for hill-land beef producers.

In most temperate regions, native cool-season grasses (CSG) such as Kentucky Bluegrass, comprise the major source of summer feeding for beef cattle. Cattlemen and researchers have observed, however, that CSG become essentially dormant by mid-summer. As an option, scientists have recommended the introduction of warm-season grasses (WSG) such as Switchgrass, Big Bluestem, and Caucasian Bluestem, which are tropical in origin and achieve their maximum growth potential in mid-summer (Kruger and Curtis). Besides their characteristic seasonal pattern of growth, WSG can grow in soils with relatively low fertility levels, or on marginal hill lands. These conditions are common in, among other areas, the state of West Virginia—the study area.

While the technical feasibility of incorporating WSG into beef grazing systems for West Virginia has been established (Reid and Jung), the economic impacts associated with this approach are unknown. This analysis provides such information by evaluating and comparing the costs and returns associated with selected grazing systems incorporating various species of CSG, WSG, and native grasses. The main objective is, therefore, to determine whether the establishment of pastures comprising WSG is a feasible investment alternative for hill-land beef producers such as those in West Virginia.

In addition to an optimal solution for a representative farm, a range of quasi-optimal or nearly-optimal solutions are also generated. The latter are solutions that deviate from the efficient frontier by some specified percentage, and thereby can provide decision makers—beef cattle producers—with a set of choices more consistent with their unique preferences. Thus, if the level and/or types of activities contained in an optimal solution to a given problem deviate from a producer's preferences, the problem can be reformulated and solved to generate a set of quasi-optimal solutions that could conform to these preferences. Generating and reporting more than a single optimal solution enhances the potential usefulness of optimization models. Previous empirical studies utilizing these models have been criticized for their failure to generate and/or report such multiple solutions (Paris).

Model Specification

A linear programming (LP) model, incorporating the quasi-optimal solution technique, determines the optimal configuration of pastures and other production activities for the representative hill-land beef farm. The LP model is based on a formulation by Rubin, and can be represented by

(1) Maximize $c^T x$

(2) subject to $Ax \leq b$, and

(3) $x \geq o$,

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where: c^T is an n-dimensional row vector whose elements, c_j, represent the unit return to unpaid resources (b_i) for the jth activity; x is an n-dimensional column vector whose elements, x_j, represent the level of the jth activity; A is a matrix whose elements, a_{ij}, represent the amount of the ith resource required per unit of the jth activity; and b is an n-dimensional column vector whose elements, b_i, represent the amount of the ith resource available.

The feasible region is the convex polyhedral set

$$P = \{x \geq o/Ax \leq b\}. \tag{4}$$

To find all alternative solutions, each point in the polyhedral set

$$P_A = \{x \geq o/Ax \leq b,\ c^Tx \geq \theta^*\} \tag{5}$$

must be identified. Likewise, to find all points for which the objective function is within some percentage of the optimal value, θ*, all points in the polyhedral set

$$P_N = \{x \geq o/Ax \leq b,\ c^Tx \geq (1 - \alpha)\theta^*\} \tag{6}$$

must be identified.

In order to generate a set of alternative solutions that are optimal or nearly optimal, the technique of "modeling to generate alternatives" (MGA) is used. Of the several MGA techniques available (Gidley and Bari), the Hop, Skip and Jump (HSJ) approach as formulated by Brill et al. is used. This one-phase MGA technique generates a tractable number of alternatives. The HSJ method forces into the LP basic solution those activities that are nonbasic in prior solutions. Thus, each succeeding solution differs from previous solutions. As with all MGA techniques, the HSJ method accomplishes this by converting the original objective function into a constraint.

The objective function of the model is specified to maximize returns to fixed resources, which in this analysis are land owned, equity capital, and management. The activities are categorized into crop and livestock groups. The crop activities consist of pastures comprising various CSG and WSG species. The livestock activities are cattle liveweight gains. The constraints are limitations on producer resource endowments including land, labor and operating capital. The empirical model has 13 production activities, 22 resource constraints, 1 right-hand-side, and 1 objective function.

The model is solved initially using standard LP procedures. Subsequent quasi-optimal solutions are obtained by appropriate modifications of the LP matrix. For this analysis, a procedure developed by James Gidley of the Civil Engineering Department at West Virginia University was employed. This procedure consists of making simultaneous modifications in the objective function activities and the appropriate constraints each time a quasi-optimal solution is generated. One of these constraints ensures that the resulting objective function value conforms to the *a priori*, quasi-optimal specification.

Analytical Procedure and Data Requirements

Four types of grazing systems, consisting of various sub-systems, are initially analyzed. While the systems involve different stocking rates, grass species and grazing sequences, the grazing season is constant for all systems, 92 days from mid-June to mid-September. The parameters associated with these systems were established in grazing trials by plant and animal scientists, and are intended to reflect situations confronting a cross-section of West Virginia beef cattle farms.

The preliminary analysis evaluates enterprise budgets to compare the costs (of pasture establishment, when appropriate, and pasture maintenance) and returns (specified in terms of net present values) of alternative grazing systems over time. The base year for the analysis is 1984.

Technical coefficients of the enterprise budgets for the pastures in different grazing systems come from field experiments conducted by plant and animal scientists at the West Virginia University Experiment Station farm at Wardensville, West Virginia (Reid and Jung). Sixteen enterprise budgets were developed—four for pasture establishment and 12 for pasture maintenance.

The key factors hypothesized to determine relative profitability of alternative grazing systems include animal liveweight gain, sward production, operating costs, fixed costs (excluding those for land owned, management, and operator's equity), cost of capital, and expected net income. All pastures are assumed to have a useful life of 30 years for net present value (NPV) computations. Data to compute the net cash flows for the first five years of this 30-year period are based on results from the field experiments mentioned earlier, coupled with costs and prices from records of the representative farm, and using secondary data (*Agricultural Prices* and *Agricultural Statistics* (USDA); *Census of Agriculture* (U.S. Department of Commerce); and *West Virginia Agricultural Statistics* (WV Department of Agriculture). The net cash flow values for the remainder of the investment are forecasted by exponential smoothing. Both the net cash flows and the cost of capital are specified in "real" terms.

All investments are analyzed using the weighted average, after-tax, cost of capital method described in Casler et al. Finally, a sensitivity analysis incorporating variations in the price and production levels of beef, and the cost of capital is conducted.

A representative farm is used to illustrate results typical of a West Virginia hill-land farm. The selection was based on attributes such as size, topography and resource endowments. The representative farm is assumed to employ borrowed and equity capital in a 5 to 2 ratio during the production season, and to be in the 20% tax bracket. While a debt/equity ratio of 2.5 may not be representative of all West Virginia farmers,it is fairly representative of those who do borrow operating capital. Further details on model structure, model coefficients, and estimation procedure can be found in Romero.

Results

The results presented in Table 1 indicate that, on average, establishment costs for WSG are approximately three times greater than for conventional (CSG) grazing systems. This differential is a result of both the higher cost of seed for WSG and the lack of establishment costs for native pastures. However, in general, annual returns to fixed resources (profits above costs of items such as seed, fuel, chemicals, and labor, but excluding costs of land, equity capital, and management), are substantially higher for WSG systems than for traditional systems. When establishment costs are included in the NPV computations, a native CSG sub-system—Bluegrass/White Clover in grazing system I—is the best investment alternative. This finding implies that certain traditional CSG pasture

Table 1. Types of Grazing Systems Modeled, and Associated Costs, Returns and Net Present Values, West Virginia, 1984

Grazing System	Animals per Acre	Type of Pasture	Establishment Cost	Annual Return[a]	NPV[b]	NPV[c]
			($/acre)			
I	2	WARM-SEASON:				
		I.a Big Bluestem	153	13	138	−14
		I.b Caucasian Bluestem	173	24	260	87
		I.c Switchgrass	176	23	251	75
		COOL-SEASON:				
		I.d Bluegrass/W. Clover	0	13	138	138
		I.e Tall Fescue	65	−7	−77	−142
II	2	NATIVE and WARM-SEASON:				
		II.a Native/Big Bluestem	153	10	110	−42
		II.b Native/Cauc. Bluestem	173	16	176	2
		II.c Native/Switchgrass	176	13	138	−37
		NATIVE and COOL-SEASON:				
		II.d Native/Tall Fescue	65	−1	−2	−67
III	.27	COOL-SEASON:				
		III.a Bluegrass/W. Clover	0	−31	−339	−339
		III.b Tall Fescue	0	−33	−367	−367
IV	2	SEQUENTIAL COOL- and WARM-SEASON:				
		Various Species	326	2	26	−300

[a] Net returns to land, equity capital and management, year 2 to year 30.

[b] Net present values, excluding pasture establishment costs, 30-year investment life, 7.3% after-tax cost of capital.

[c] Net present values, including both pasture establishment and maintenance, 30-year investment life, 7.3% after-tax cost of capital.

Note: 1. Maintenance costs were assumed to be constant ($36.70/acre/year) for all grazing systems.
2. Values in the table are rounded-off to whole dollars.

systems may be the better alternative for some farms, provided that they are the existing native pasture.

It is important to note that only 4 out of 12 subsystems, either WSG or CSG, generated positive returns over the life of the respective investment when establishment and maintenance costs are included. This outcome justifies the claim by many producers that, under current conditions a profitable summer steer production system is not a sustainable proposition. On the other hand, the positive net returns (and NPVs) for certain subsystems support the hypothesis that, in some cases, a modified grazing system, incorporating the more profitable grass species, may provide a solution to the problem of low or negative net returns from beef cattle enterprises in West Virginia—with attendant implications for beef cattle producers in other areas of the Northeast. At the same time, the results indicate that establishment costs are important when incorporating either a different CSG or a WSG into a grazing system. Finally, stocking rates influence relative profitability. As Table 1 shows, the NPV for Bluegrass/White Clover in grazing system III, with approximately one animal for four acres, is negative, while the NPV for Bluegrass/White Clover in grazing system I, with two animals per acre, is positive. Although the magnitude of the NPVs could change with the cost of capital, the time period, the management factor, and specific area, the substantial relative difference in NPVs should not be ignored by decision-makers.

Sensitivity Analyses

The preceding results are found to be sensitive, by varying degrees, to changes in beef prices, liveweight gains, and the cost of capital. Table 2 shows the variations in annual per acre returns to fixed factors (land, equity capital and management) if the average price of beef and animal liveweight gain changes by 15%. While a 15% increase in beef cattle prices (or liveweight gain) increases net annual returns for all WSG sub-systems, the increase is insufficient to generate positive net returns for some CSG sub-systems. Further, even with a 15% decrease in the value of these variables, all but one WSG sub-system still yielded a positive net return. However, only one of five CSG sub-systems generated a positive return when beef cattle prices and liveweight gain decreased by 15%. These findings have implications for the strategies of beef cattle producers confronted with varying degrees of price and production risks. For example, WSG can be a profitable alternative (especially in hill lands, where they are better suited than CSG), even when price decreases occur.

Table 2. Sensitivity of Results to Changes in Beef Cattle Price and Liveweight Gain, and Break-Even Prices, West Virginia, 1984

Grazing System and Type of Pasture		Annual Net Returns				
		15% Price Increase	15% Price Decrease	15% Liveweight Increase	15% Liveweight Decrease	Break-Even Prices[b]
		($/acre)				($/cwt)
I.a	Big Bluestem	19.9	5.1	26.3	8.3	31.65
I.b	Caucasian Bluestem	32.6	14.5	35.3	17.3	25.85
I.c	Switchgrass	31.7	8.0	35.3	8.3	26.22
I.d	Bluegrass/W. Clover	19.9	5.1	26.3	8.3	31.65
I.e	Tall Fescue	N[a]	N	3.8	N	52.44
II.a	Native/Big Bluestem	17.0	3.0	21.8	3.8	33.37
II.b	Native/Caucasian Bluestem	23.8	8.0	28.6	9.7	29.60
II.c	Native/Switchgrass	19.9	5.1	26.3	4.7	31.65
II.d	Native/Tall Fescue	5.3	N	12.8	N	42.69
III.a	Bluegrass/W. Clover	N	N	N	N	>70.00
III.b	Tall Fescue	N	N	N	N	>70.00
IV.	Sequential Cool- and Warm-Season	8.2	N	17.3	N	39.90

[a] "N" indicates a negative value.

[b] Derived from the respective enterprise budgets.

Table 3. Sensitivity of Results to Changes in Cost of Capital, West Virginia, 1984

Grazing System and Type of Pasture		NPV at 5.3%[a]		NPV at 12%[a]	
		Maintenance	Establishment & Maintenance	Maintenance	Establishment & Maintenance
		($/acre)			
I.a	Big Bluestem	174	22	90	−63
I.b	Caucasian Bluestem	328	154	169	−5
I.c	Switchgrass	316	141	163	−13
I.d	Bluegrass/W. Clover	174	174	90	90
I.e	Tall Fescue	−97	−162	−50	−115
II.a	Native/Big Bluestem	139	−14	72	−81
II.b	Native/Caucasian Bluestem	222	48	114	−59
II.c	Native/Switchgrass	174	−1	90	−86
II.d	Native/Tall Fescue	−3	−67	−1	−66
III.a	Bluegrass/White Clover	−428	−428	−220	−220
III.b	Tall Fescue	−463	−463	−239	−239
IV.	Sequential Cool- and Warm-Season	33	−293	17	−309

[a] Represents the weighted average, after-tax cost of capital, assumed to remain constant over the 30-year investment life.
Note: The above values are rounded-off to the nearest dollar.

One important use of the sensitivity analyses is to determine break-even prices. Table 2 shows that for traditional pastures (system III) positive returns only occur when the price of beef increases above $70.00 per cwt. This reinforces the notion that traditional grazing systems should be modified, possibly including WSG, for beef production to regain profitability in West Virginia.

Table 3 reveals the variations in NPV for different grazing systems when the weighted average, after-tax cost of capital is changed from 7.3% (the most likely scenario when the analysis was conducted), to 5.3% and 12%. In general, as expected, a decrease in the cost of capital increases the NPV, and vice-versa. Again, the results demonstrate the relatively higher profitability levels associated with grazing systems incorporating WSG. However, this is true only when the cost of capital is below 7.3%. On the other hand, when capital costs are at 12%, only Bluegrass/White Clover (a CSG) in grazing system I yields a positive NPV. The consistently positive net returns—and NPVs—associated with Bluegrass/White Clover in grazing system I, even under unfavorable conditions with respect to beef prices, liveweight gains and interest rates, imply that this system may be the best alternative for those beef cattle producers with Bluegrass/White Clover pastures and without a large proportion of hill land. However, if the pasture is not established, its economic appeal diminishes significantly, as does any system that involves establishment costs. For farms with substantial proportions of hill land, WSG is usually the better alternative.

Impacts of WSG on the Representative Farm

The optimal resource use and output levels for the representative farm from the LP model is presented in Table 4. When a WSG such as Caucasian Bluestem is introduced into the grazing system of the representative farm, annual returns to fixed resources more than doubled, from $13,927 to $31,424. This increase is the result of more steers stocked and sold when a WSG is established on land that previously was unused because of its marginal (hill-land) nature. Thus, grazing systems incorporating WSG on hill lands may enhance net returns, while intensifying production and enabling a more efficient use of farm resources. This is especially true in areas with a predominantly hilly terrain that often precludes the extensive use of land and other capital inputs.

Quasi-Optimal Solutions

Quasi-optimal solutions—solutions that represent feasible alternatives to the optimal strategy, and are within a specified percentage of the optimal solution—are also generated. These solutions provide decision-makers with more alternatives.

The percentage by which the objective function

Table 4. Comparison of Optimal Solutions With and Without Warm-Season Grasses (WSG) for a Representative Hill-Land Farm in West Virginia, 1984

		Optimal Solutions[a]	
Item	Unit	Without WSG	With WSG
Activities:			
1. Grow Hay	Acres	41	33
2. Grow CSG	Acres	79	87
3. Sell Hay	Tons	91	67
4. Grow WSG[b]	Acres	0	80
5. Raise Steers	Animals	31	83
Resources Used:			
1. Total Land	Acres	120	200
2. CSG + Hay Land	Acres	120	120
3. WSG Land	Acres	0	80
4. April Labor	Hours	40	80
5. September Labor	Hours	240	240
6. Equity Capital	$	1,882	1,726
7. Borrowed Capital	$	1,155	1,964
Slack Activities:			
1. Total Land	Acres	80	0
2. CSG + Hay Land	Acres	0	0
3. WSG Land	Acres	80	0
4. April Labor	Hours	200	160
5. September Labor	Hours	0	0
6. Equity Capital	$	119	274
7. Borrowed Capital	$	3,845	3,036
OBJECTIVE FUNCTION VALUE[c]	$	13,927	31,424

[a] Values are rounded-off to the nearest whole number.
[b] Caucasian Bluestem was the only WSG that appeared in the optimal solution.
[c] Returns to fixed resources.

is relaxed to yield quasi-optimal solutions can arbitrarily be selected. For this analysis, quasi-optimal solutions within 5 and 15% of the optimal objective function value were generated (Table 5). In this case, the quasi-optimal solutions incorporate changes in the number of steers, the acreage devoted to other production activities such as producing and selling hay, or establishing a specific WSG. While the activities and resources utilized among the two solution sets differ, the major difference is in the WSG activities. Big Bluestem and Caucasian Bluestem are "forced out" of quasi-optimal solutions #1 and #4; Caucasian Bluestem and Switchgrass out of solutions #2 and #5; and Big Bluestem and Switchgrass out of solutions #3 and #6. The selection of activities to include in each solution is accomplished by specifying an objective function that maximizes the difference from previous alternatives. This enables decision-makers to easily discern differences in alternatives and select the alternative that best approximates their preference. *A priori* knowledge of the association between specific activities and net returns arising from this set of activities also enables producers to more easily match their resource availabilities, expertise and preferences with the output to be produced. While this facilitates the planning process, obviously any deviation from the optimal solution reduces profits. For example, solution #4 in Table 5 does not include any hay production. This may be appropriate for a producer who either lacks the hay producing equipment or does not wish to produce hay. The "cost" of this approach, however, is a net return 15% less than the maximum obtainable. Further, the ability to substitute WSG for one another is important because seed availability varies among regions.

The level of objective function value relaxation can be varied considerably. The resulting solutions have great potential utility to individual farmers, both to provide better insights into the problem and to increase the likelihood of generating a solution more consistent with the unique preferences of each farmer.

Table 5. Quasi-Optimal Solutions Generated for the Representative Farm in West Virginia, 1984

		Quasi-Optimal Solutions[a]					
		Within 5% of Optimal Value			Within 15% of Optimal Value		
Item	Unit	#1	#2	#3	#4	#5	#6
Activities:							
1. Grow Hay	Acres	9	10	9	0	10	7
2. Grow CSG	Acres	111	110	108	104	110	79
3. Sell Hay	Tons	0	0	0	0	0	0
4. Grow Big Bluestem	Acres	0	80	0	0	80	0
5. Grow Cauc. Bluestem	Acres	0	0	80	0	0	80
6. Grow Switchgrass	Acres	80	0	0	80	0	0
7. Raise Steers	Animals	87	87	87	77	79	78
Resources Used:							
1. Total Land	Acres	200	200	197	184	199	166
2. CSG + Hay Land	Acres	120	120	117	104	119	86
3. WSG Land	Acres	80	80	80	80	80	80
4. April Labor	Hours	80	80	79	74	79	68
5. September Labor	Hours	126	126	125	74	126	102
6. Equity Capital	$	1,283	1,285	1,256	957	1,278	924
7. Borrowed Capital	$	1,307	1,310	1,304	1,040	1,309	1,234
Slack Activities:							
1. Total Land	Acres	0	0	3	16	1	34
2. CSG + Hay Land	Acres	0	0	3	16	1	34
3. WSG Land	Acres	0	0	0	0	0	0
4. April Labor	Hours	160	160	161	166	161	172
5. September Labor	Hours	114	114	115	166	114	138
6. Equity Capital	$	717	715	744	1,043	722	1,076
7. Borrowed Capital	$	3,693	3,690	3,696	3,960	3,691	3,766
OBJECTIVE FUNCTION VALUE[b]	$	29,853	29,853	29,853	26,710	26,710	26,710

[a] Values are rounded-off to the nearest whole number.

[b] Returns to fixed resources.

Summary and Conclusions

The main objective of this analysis was to evaluate the investment potential of using warm-season grasses for beef-cattle feeding in hill-land areas, such as those in West Virginia. This was accomplished by comparing the costs and returns of warm-season grasses with those for cool-season grasses. Four types of grazing systems involving different stocking rates, and including various species of cool- and warm-season grasses and native pastures, were analyzed. The results were evaluated for their sensitivity to changes in beef prices, liveweight gains, and the cost of capital. Both optimal and a set of quasi-optimal solutions for a representative hill-land farm in West Virginia are generated using a linear programming model, incorporating the quasi-optimal solution technique. Data for 1984 were obtained from field experiments, farm records, and secondary sources.

In general, pasture systems incorporating warm-season grasses yielded higher annual returns to fixed resources than those consisting of conventional, cool-season grasses. However, the much higher establishment costs associated with warm-season grasses somewhat diminished their appeal as long-term investments. On the other hand, not all cool-season grass systems generated positive net returns over their respective investment lives either. Modifying some existing grazing systems, and possibly establishing warm-season grasses in hill-land areas, could be a profitable strategy for beef producers under certain conditions.

The results were sensitive to changes in beef prices, liveweight gains, and the cost of capital. For most grazing systems, increases in the cost of capital reduced the investment appeal much more than decreases in either beef cattle prices or liveweight gains. Further, estimated break-even prices were generally lower for warm-season grasses than for cool-season grazing systems. When the pasture is an existing native grass, one cool-season grass, Bluegrass/White Clover, was profitable even under adverse price, production and interest rate conditions.

When a warm-season grass such as Caucasian Bluestem was introduced into the grazing system of the representative farm, annual returns to fixed resources more than doubled over the existing farm plan. Thus, grazing systems incorporating warm-season grasses, particularly in hill-lands, may enhance net returns to beef producers, while making more efficient use of farm resources.

The generation of quasi-optimal solutions demonstrates the potential for a wider applicability of the results than with traditional optimization analyses. Further, the alternative solutions may capture some issues left out of the original model development; issues which may be as relevant to the solution of a problem as those included initially.

Incorporating warm-season grasses into the farm plans of hill-land beef producers in West Virginia—and those in other areas with similar resource and management attributes—may not be a panacea for the relatively low, and often negative, returns characterizing many of these operations. However, the potential for increasing producers' net returns is present, even if used merely to complement current grazing systems that consist primarily of cool-season grasses. This is especially important at a time when the competitive position of beef producers has diminished.

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