Combating the Crisis: Managing Watersheds for Economic Profit and Environmental Quality Improvement

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Abstract

Phosphorus runoff has generated water quality degradation, spawning legislative and regularity actions in several watersheds in Northwest Arkansas. Best management practices (BMPs) can be viable alternatives in dealing with nutrient excess. The profitability of several BMPs deemed effective in addressing such concerns is examined in one Northwest Arkansas watershed.

Key Words: best management practice, poultry-litter management, phosphorus standards, pollution control, water pollution

JEL Classifications: Q25, Q52

Introduction

Watersheds in Arkansas, particularly within the Northwestern area of the state, have been faced with growing economic and environmental crises. On one hand, some agricultural production has been linked to water quality degradation whose impacts can be felt by people and businesses that stretch even across state lines. On the other hand, as lawsuits abound, traditional agricultural production practices, particularly regarding nutrient management for hay and pasture fields, are being banned; this can potentially lead to the failure of many agricultural businesses, the loss of critical jobs, food production and regional economic stability that make up close to 10% of the economic activity in the region (Kemper). Therefore, solutions are desperately needed that will preserve water quality and the economic and agricultural viability of the region.

Often producers in Northwest Arkansas raise poultry and cattle enterprises in order to diversify their income. Poultry litter is applied as a fertilizer to the grass hay crops. Bermuda and Tall Fescue are two of the most common grasses cropped in this region (Gunsaulis). They require high levels of nitrogen (N) but low levels of phosphorus (P). Poultry litter is rich in nutrients especially N and P. For many years litter application rates for these grasses were based on the plant's N needs. As a result, P has been over applied on some fields. This increases the potential for P runoff that can cause eutrophication and consequently water degradation (Norwood and Chvosta). Much of the surface waters in Northwest Arkansas flows next into Oklahoma. Some in Oklahoma point to these traditional agricultural production practices for the resulting degradation of recreational and drinking waters within Oklahoma's borders.

The Oklahoma Scenic River Commission (OSRC) has recommended that the way to address water quality concerns within their borders is to impose a limit on the amount of P that can exist in waters as they reach the Oklahoma borders (OSRC). A previous Supreme Court case (Tulsa v. Fayetteville, 1992) ruled that an upstream state can be held to standards imposed by a downstream state (Soerens, Fite, and Hipp). The OSRC used a study developed by Clark and Meuller to propose a P limit of 0.0375 mg/l in waters at the Oklahoma border. This proposal was accepted by the Environmental Protection Agency (EPA) and, pending appeal, will become the P-standard by 2012. The constantly changing regulatory scene is not encouraging for producers. Solutions are desperately needed that will preserve water quality and the economic and agricultural viability of the region. To facilitate the alleviation of non-point source agricultural pollution and the implementation of environment-friendly agricultural practices, regional BMPs, suggested to be effective in controlling P movement are evaluated for their impacts on production costs and profits.

Data and Procedures

The analysis will be conducted using data for a 1,889 hectare watershed in Arkansas (figure 1). Major land uses in this 14 sub-basin watershed include poultry, cattle and hay production, forestry, and urban. Thirteen of those sub-basins have some grass production in addition to other land uses. The economic analysis was conducted only on the land areas in grass production. The sub-basins, their total area and the land area devoted to Bermuda and Tall Fescue grass production are presented in table 1. Of those 13 sub-basins with grass production, seven (sub-basins 1,2,3,6,9,12, and 13) include poultry operations, the remaining six (sub-basins 4, 5, 7, 8, 10, and 11) do not.

Selection of BMPs

Four BMPs were examined based on their applicability in the region (Chaubey et al.). The Natural Resources Conservation Service (NRCS) recommends the use of the first BMP, buffer *strips*, to farmers who want to achieve economic and environmental sustainability in their operations. A buffer strip of 15.24 meters was examined for its ability to filter nutrients before reaching surface waters (Chaubey et al). The second BMP chosen was *Alum*, for its ability to reduce the amount of soluble P in litter. Where litter was used as a BMP, *Alum* was applied at a rate of 224 kg for each 2.24 tons^{-ha} of litter (Moore et al.). Finally the last two BMPs were related to nutrient application, either from commercial fertilizer or from poultry litter. It was assumed that litter would only be applied on land in sub-basins where litter exists; producers in sub-basins with no poultry production were assumed to rely solely on commercial fertilizers. Thus, the analysis will include separate discussions for “With Litter” and “Without Litter” sub-basins.

Across all 13 sub-basins, potash was applied at a constant rate of 336 kg/ha for Bermuda grass and 67 kg/ha for Tall Fescue grass (Gunsaulis). Soils in the watershed were assumed to be P limiting; no additional P was needed for production. However, in the “Litter” sub-basins, P applications are often made as they are tied to litter usage. P applications in the “Litter” sub-basins were as follows: 0 tons of litter/ha = 0 kg/ha P; 2.24 tons of litter/ha = 29 kg/ha P; 4.48 tons of litter/ha = 58 kg/ha P (Vandevender). In the “No Litter” sub-basins, no commercial P was applied since soil P alone satisfies this nutrient need (Gunsaulis).

Grass hay production is highly dependent upon N for optimal growth. Four levels of total N were examined. The first three levels of N were used across both Bermuda and Tall Fescue grass (hay) production: 0 kg/ha; 67 kg/ha, equivalent to the N in 2.24 tons of litter/ha; and 135 kg/ha, equivalent to the N in 4.48 tons of litter/ha (Vandevender). Additionally a fourth rate was chosen that would maximize grass production for each type of hay. This rate was 280 kg/ha for Bermuda grass and 224 kg/ha for Tall Fescue grass (Gunsaulis; Hankins and Chapman). In “Litter” sub-basins, N needs were met with litter first. Commercial fertilizer was used only when nutrient levels in litter fell short of targeted N levels. In “No Litter” sub-basins, all N came from commercial fertilizer (i.e., urea). Yield response to N for Bermuda and Tall Fescue grasses were taken from Gunsaulis and Hankins and Chapman.

Fifty-two combinations of riparian buffer strips (0 and 15.24 meters wide), litter application rates (0, 2.24 and 4.48 tons of litter/hectare), commercial fertilizer rates (based on soil needs) and alum application rates (10 percent by weight of the litter) were examined in the watershed for their impacts on agricultural profits. Various combinations of the BMPs were evaluated. These combinations are shown in tables 2 and 3.

Yield and Water Quality Impacts

Preliminary results (under simulated conditions) from BMP effectiveness research in this watershed have shown that combinations of the different BMPs (i.e., buffer strips, alum-treated litter and optimal N fertilization) studied can reduce excess nutrient runoff into the water.

Although total forage yield can be reduced by the amount of land dedicate to buffer strips, it may be an extremely effective way to control nutrient runoff. For instance, Chaubey and Daniel concluded that Tall Fescue filter strips of 21.4 meters reduce incoming mass transportation of TKN, NH_3-N, TP, PO_4-P, and FC from 81% to 99%. Likewise, Overman and Schanze concluded that Bermuda grass filters can remove TN and TP by 67% and 39% respectively.

Alum applied directly to the litter reduces the amount of soluble P in the litter. This increases the amount of N available for grass production. Moore, Daniel, and Edwards concluded that treating poultry litter with alum will reduce non-point source P runoff by 87 %; moreover, more recent research (Moore and Edwards; Moore) found that the eight-year average cumulative yields for grass fertilized with alum-treated litter were 6% higher than with no treated-litter[1].

It is well known that added fertilizer, especially N, increases forage production. Hankings and Chapman suggested that by applying P and potassium (K) - according to soil test recommendations - and 280 kg of N/ha to Bermuda and Tall Fescue grasses, they can yield over 15 tons/ha. However, Coblentz et al. found annual P removal within the Bermuda-grass hay from 30 to 50 kg/ha if N applications are reduced to 168 Kg/ha. This suboptimal fertilization alternative will decrease hay yield considerably. Hence, water quality improvement does not come without cost.

BMP Analysis

Based on the above information and assumptions, costs of production and revenues from yields were calculated for each scenario. Costs of production for Bermuda and Tall Fescue were estimated in dollars per hectare ($\$^{-ha}$). BMPs cost data came from the USDA Natural Resource Conservation Service (buffer strip establishment and maintenance and alum application rates and prices) and University of Arkansas Cooperative Extension Service (litter and commercial fertilizer costs). Relevant production practices and the costs of those production practices and BMPs were gathered from Goodwin, King-Brister, Laughlin and Spurlock, Popp, and West. Sales prices for grass hay were taken from Popp. Per hectare cost, revenue and profit were estimated as follows:

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[1] No research has been conducted in the region regarding the impacts of alum on yields when both litter treated with alum and commercial fertilizers are used to meet the N needs of the plant. It is assumed here that the yield increases brought on by alum use in litter disappear when addition N is made available from commercial fertilizer. Research is therefore needed to determine the exact relationship between alum treated litter and commercial fertilizer on yields.

$$Cost_{Ht}^{-ha} = \sum_{1}^{i} PP_{i,t}^{-ha} \quad + \sum_{1}^{j} BMP_{j,t}^{-ha} \tag{1}$$

$$\mathrm{Re}venue_{Ht}^{-ha} = P_{H_t} * Y_{Ht} \tag{2}$$

$$\mathrm{Pr}ofit_{H_t} = \mathrm{Re}venue_{Ht}^{-ha} - Cost_{Ht}^{-ha} \tag{3}$$

where *PP* is cost of production practices 1 through *i* (where i includes typical production expenses such as labor, tractor, fuel, twine, fertilizer, etc) *BMP* is cost of best management practices 1 through *j* (where j is N application, riparian zone or alum), and *H* is either Bermuda or Tall Fescue grass hay, *P* is the price of grass hay, *Y* is yield of grass hay, and *t* is time.

Costs, revenue and profit were estimated at the sub-basin level as follows:

$$Cost_{SHt} = Cost_{Ht}^{-ha} * (A_{SH} - RZA_{SH}) \tag{4}$$

$$\mathrm{Re}venue_{SHt} = \mathrm{Re}venue_{Ht}^{-ha} * (A_{SH} - RZA_{SH}) \tag{5}$$

$$\mathrm{Pr}ofit_{SHt} = \mathrm{Pr}ofit_{Ht}^{-ha} * (A_{SH} - RZA_{SH}) \tag{6}$$

where *S* is the sub-basin, *A* is the total land area in grass hay and *RZA* is the area in the grass hay area of the sub-basin occupied by a buffer strip.

Scenarios were broken into four general groups: 1) Bermuda production in “Litter” sub-basins; 2) Tall Fescue production in “Litter” sub-basins; 3) Bermuda production in “No Litter” sub-basins; and 4) Tall Fescue production in “No Litter” sub-basins. A baseline scenario was created for each group that is expected to maximize profits. The baselines for each group are represented by the shaded scenarios 4, 22, 40, and 48 in tables 2 and 3. Profit levels were calculated for all scenarios. Results from each scenario were then compared to the relevant baseline to determine if profits were reduced from the baseline, and if so, by what percentage. Per hectare impacts of BMPs are presented in table 4.

Results and Discussion

All remaining scenarios were less profitable than the baselines because they increased costs, reduced profits or both. The combination of BMPs applied to the baseline scenario impacted the extent of the loss. For instance, buffer strips proved to be effective reducing nutrients runoff while keeping profits almost unchangeable. However, treating litter with alum can reduce P runoff but decrease profits drastically. Results for all 52 scenarios can be found in tables 5 and 6.

Buffer Strip

Scenarios 8, 26, 44, and 52 show that inclusion of a buffer strip results in little added cost and nearly no loss of revenue to the producer. The reason for these minimal impacts is that land area encompassed by buffer strips of 15.24 meters wide is very small (refer to table 2 and 3). Profits can remain relatively unchanged while water quality issues are addressed.

Alum

Alum was applied as a BMP in some scenarios for Bermuda and Tall Fescue grasses in the "Litter" sub-basins only. Scenarios 11 and 29 show results for the addition of A*lum* to the baseline scenario. In these cases, cost of production per hectare increase significantly ($148/ha on average across sub-basins). Even though, these scenarios produce the same revenue per hectare (across all sub-basins) as the baseline, the A*lum* costs are not offset and therefore, profits fall on average by 17% and 35% for Bermuda and Tall Fescue, respectively (table 5).

Nutrient Application Rates

The purpose of the nutrient BMPs was to identify the impact of managing litter application rates to reduce the potential for P movement from the field. These scenarios are presented in table 5. Some scenarios in table 6 show equivalent reductions from the baseline in nutrient applications from commercial fertilizer. While these scenarios are unlikely to occur they are presented to show the impact of reducing required N rates. The focus of this discussion is on changes in litter application rates presented in table 5. Producers in the "Litter" sub-basin can respond to P reduction regulations in four ways: 1) reduce the amount of litter used; 2) reduce the amount of litter used and supplement with commercial N; 3) reduce the amount of litter used, supplement with commercial N and apply A*lum* to remaining litter; or 4) maintain high (4.48 tons^{-ha}) litter use and apply A*lum* to reduce soluble phosphorus content in the litter.

Poultry Litter

One way to address P concerns is to simply reduce the amount of P applied. It has been suggested that some producers will not replace the lost N with commercial fertilizer (Gunsaulis). Thus, the impact of that decision is examined first. Scenarios 1, 2, 19 and 20 in table 5 show the impact of reducing litter use of 4.48 tons$^{–ha}$ in the baseline to 0 or 2.24 tons$^{–ha}$. Reducing the use of litter can reduce costs from the baseline, as litter spreading costs can fall. However, when the nutrients lost by a decrease in litter are not replaced with commercial fertilizer, yields can fall dramatically, leading to large losses in revenue. When litter is reduced from 4.48 to 2.24 tons$^{–ha}$, costs fall slightly, yields fall by nearly 10 tons^{-ha} for Bermuda and 6 tons^{-ha} for Tall Fescue; profits fall by 85% in Bermuda grass areas and 56% in Tall Fescue grass areas. When litter is completed omitted, Tall Fescue production has lost nearly 84% of its potential baseline profits, and Bermuda is grown at a loss.

The next way to address these concerns is to reduce litter and replace remaining N needs with commercial fertilizer. As it has been assumed that litter would always be applied when fertilizer is used in "Litter" sub-basins, the relevant scenario examines the use of 2.24 tons$^{–ha}$ with an additional 213 kg $^{–ha}$ of commercial N for Bermuda grass and 157 kg $^{–ha}$ of commercial N for Tall Fescue grass. Results are found in scenarios 18 and 36. In these cases, yields are maintained but costs increase slightly. As a result, profits fall slightly from the baseline, by 5 to 8%, respectively.

Litter plus Alum

The remaining two options examine some combination of litter, alum and potentially commercial fertilizer. In the first case, A*lum* is applied to the scenarios 18 and 36 described above. Results are found in scenarios 15 and 33. Costs increase greatly ($\$101^{-ha}$) over the baseline because the additional costs of commercial N and A*lum* outweigh the small savings in from a reduction in the amount of litter spread. So, while yields remain high, profits in each sub-basin fall 8 to 21% for Bermuda grass and Tall Fescue grass hay production, respectively. Finally, a producer may choose to meet optimal N needs using 4.48 tons^{-ha} of litter in addition to commercial N but may opt to treat that litter with A*lum* (scenarios 11 and 29). As a result of increasing baseline costs with alum, profits fall 17% to 35% across sub-basins.

Combining BMPs

Producers may decide on using some combination of BMPs. In the "No Litter" sub-basins any combination of commercial application rates and riparian areas can be used. However, if nutrient concerns are limited to P, producers are likely to use optimal N rates. As a result, the relevant scenarios are reduced to two for both Bermuda and Tall Fescue. Producers will use optimal N only (scenarios 40 and 48, for Bermuda and Tall Fescue, respectively) or they will combine optimal N with a riparian buffer strip (scenarios 44 and 52, for Bermuda and Tall Fescue, respectively). Including the riparian buffer strip does reduce profits; however, this loss may be acceptable if this practice is successful in reducing P movement from the fields.

Producers in the "Litter" sub-basins have many more combinations to choose from. The option will depend upon the goal. Should the producer choose to maximize profit, he will maintain the baseline scenario (scenarios 4 and 22). That is, he will meet nutrient needs on each hectare of land with 4.48 tons^{-ha} of litter first and supplement with commercial N; he will forgo the use of *Alum* and riparian buffer strips. However, if minimizing potential P runoff is required, Bermuda and Tall Fescue grass hay producers could choose to reduce litter use to 2.24 tons^{-ha} and supply all remaining N needs for commercial fertilizer (scenarios 18 and 36) with relatively small losses in profits.

Conclusions

This study provided an examination of the economic impacts to a producer of using BMPs to manage P in a small Arkansas watershed. While these results are specific to this watershed, some general conclusions may be made. As expected for both Bermuda and Tall Fescue grass production, regardless of sub-basin examined, the baseline scenarios produced the highest profits of all scenarios. However, water quality improvement does not come without cost. The addition of BMPs can reduce a producer's profits; in this case, profits fell from 1% to 118% compared to those of the baseline.

These results highlight the need for economic incentives to adopt BMPs. From a purely economic perspective, these producers are better off by avoiding BMPs. In "No Litter" sub-basins, producers will maximize profits by applying recommended commercial N rates. In "Litter" sub-basins, producers will maximize profits by applying the maximum amount of available litter (in this case, 4.48 tons^{-ha}) and meet remaining N needs with commercial fertilizer. However, when producers' goals include managing for water quality, the best management strategies may change. In both "Litter" and "No Litter" sub-basins, producers can add a buffer strip to their fields at little cost and with little loss to revenues. In "Litter" sub-basins, producers also have the option of using A*lum*, reducing litter to 2.24 tons$^{–ha}$, or both. When commercial fertilizer can be used to replace nutrients from litter, reducing litter usage to 2.24 tons^{-ha} will reduce profits less than treating 4.48 tons^{-ha} with *Alum*. However, the ultimate choice of management practices must be made by comparing the net returns to production to the efficacy of the BMP employed. It is hoped that federal and state conservation programs will continue existing incentives (such as EQIP) and expand others (such as the Conservation Security Program) so that farmers in this and other watersheds can attain environmental sustainability while maintaining a profit.

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Table 1. Total grass land areas by sub-basin (hectares)

Sub-Basin	Land Area without Buffer Strip [a]			Buffer Strip Area [b]		
	Sub-Basin	Bermuda	Tall Fescue	Buffer Strip	Bermuda	Tall Fescue
1	115.20	33.28	42.92	2.50	1.09	1.41
2	261.63	21.41	50.07	1.81	0.54	1.27
3	130.32	40.48	43.97	0.88	0.42	0.46
4	35.46	15.17	8.44	0.82	0.52	0.29
5	44.64	18.96	21.23	1.78	0.84	0.94
6	122.94	77.18	35.81	2.40	1.64	0.76
7	102.87	54.42	18.40	1.15	0.86	0.29
8	27.45	17.59	7.82	0.48	0.33	0.15
9	322.02	175.41	103.54	4.41	2.77	1.64
10	100.26	24.51	75.75	0.45	0.11	0.34
11	97.20	14.18	7.52	0.04	0.03	0.02
12	89.64	66.11	23.53	0.29	0.21	0.08
13	258.66	40.90	119.06	3.49	0.89	2.60
14	180.55	0.00	0.00	0.00	0.00	0.00
Total	1888.84	599.59	558.06	20.50	10.27	10.23

[a] Total land per sub-basin (hectares)

[b] Total grass land area in buffer strip (hectares)

Table 2. Scenarios created for Bermuda and Tall Fescue grass production in "Litter" Sub-basins

Scenario [a]	Alum [b]	Buffer Strip	Litter Applied [c]		Nitrogen Applied [d]			Yield [e]
					Litter	Commercial	Total	
	Kg/ha	Meters Width	Tons /ha	Kg/ha	Kg/ha	Kg/ha	Kg/ha	$Tons^3$/ha
1	0	0.00	0	0	0	0	0	3.80
2	0	0.00	2.24	2,242	67	0	67	6.82
3	0	0.00	4.48	4,484	135	0	135	9.88
4 [f]	**0**	**0.00**	**4.48**	**4,484**	**135**	**145**	**280**	**16.42**
5	0	15.24	0	0	0	0	0	3.80
6	0	15.24	2.24	2,242	67	0	67	6.82
7	0	15.24	4.48	4,484	135	0	135	9.88
8	0	15.24	4.48	4,484	135	145	280	16.42
9	224	0.00	2.24	2,242	67	0	67	7.23
10	448	0.00	4.48	4,484	135	0	135	10.47
11	448	0.00	4.48	4,484	135	145	280	16.42
12	224	15.24	2.24	2,242	67	0	67	7.23
13	448	15.24	4.48	4,484	135	0	135	10.47
14	448	15.24	4.48	4,484	135	145	280	16.42
15	224	0.00	2.24	2,242	67	213	280	16.42
16	224	15.24	2.24	2,242	67	213	280	16.42
17	0	15.24	2.24	2,242	67	213	280	16.42
18	0	0.00	2.24	2,242	67	213	280	16.42
19	0	0.00	0	0	0	0	0	4.01
20	0	0.00	2.24	2,242	67	0	67	6.79
21	0	0.00	4.48	4,484	135	0	135	9.61
22 [f]	**0**	**0.00**	**4.48**	**4,484**	**135**	**89**	**224**	**13.30**
23	0	15.24	0	0	0	0	0	4.01
24	0	15.24	2.24	2,242	67	0	67	6.79
25	0	15.24	4.48	4,484	135	0	135	9.61
26	0	15.24	4.48	4,484	135	89	224	13.30
27	224	0.00	2.24	2,242	67	0	67	7.20
28	448	0.00	4.48	4,484	135	0	135	10.19
29	448	0.00	4.48	4,484	135	89	224	13.30
30	224	15.24	2.24	2,242	67	0	67	7.20
31	448	15.24	4.48	4,484	135	0	135	10.19
32	448	15.24	4.48	4,484	135	89	224	13.30
33	224	0.00	2.24	2,242	67	157	224	13.30
34	224	15.24	2.24	2,242	67	157	224	13.30
35	0	15.24	2.24	2,242	67	157	224	13.30
36	0	0.00	2.24	2,242	67	157	224	13.30

[a] Scenarios 1 through 18 represented Bermuda grass, Scenarios 19 through 36 represent Tall Fescue grass
[b] Alum treatment kilogram per 2.24 ton of litter per hectare
[c] Short ton equal to 2,242 kilograms per hectare
[d] Nitrogen applied from litter, commercial and litter plus commercial (total)
[e] Metric tons per hectare
[f] These baselines included nutrient application rates that maximized hay production, but no other BMPs

Table 3. Scenarios created for Bermuda and Tall Fescue grass production in "No Litter" Sub-basins

Scenario [a]	Alum [b]	Buffer Strip	Litter Applied [c]		Nitrogen Applied [d]			Yield [e]
					Litter	Commercial	Total	
	Kg/ha	Meters Width	Tons /ha	Kg/ha	Kg/ha	Kg/ha	Kg/ha	$Tons^3$/ha
37	0	0.00	0	0	0	0	0	3.80
38	0	0.00	0	0	0	67	67	6.82
39	0	0.00	0	0	0	135	135	9.88
40 [f]	**0**	**0.00**	**0**	**0**	**0**	**280**	**280**	**16.42**
41	0	15.24	0	0	0	0	0	3.80
42	0	15.24	0	0	0	67	67	6.82
43	0	15.24	0	0	0	135	135	9.88
44	0	15.24	0	0	0	280	280	16.42
45	0	0.00	0	0	0	0	0	4.01
46	0	0.00	0	0	0	67	67	6.79
47	0	0.00	0	0	0	135	135	9.61
48 [f]	**0**	**0.00**	**0**	**0**	**0**	**224**	**224**	**13.30**
49	0	15.24	0	0	0	0	0	4.01
50	0	15.24	0	0	0	67	67	6.79
51	0	15.24	0	0	0	135	135	9.61
52	0	15.24	0	0	0	224	224	13.30

[a] Scenarios 37 through 44 represented Bermuda grass, Scenarios 45 through 52 represent Tall Fescue grass

[b] Alum treatment kilogram per short ton of litter per hectare

[c] Short ton equal to 2,242 kilograms per hectare

[d] Nitrogen applied from litter, commercial and litter plus commercial (total)

[e] Metric tons per hectare

[f] These baselines included nutrient application rates that maximized hay production, but no other BMPs

Table 4. Impacts of Best Management Practices on Costs and Yields per Hectare

Best Management Practice	Impact on cost (hectare)	Impact on yield (hectare)
	$/ha	**Tons[3]/ha**
Per ton of litter applied	$16	+ 3 to + 6
Alum use per ton of litter applied	$75	0
Riparian buffer strip [a]	$116	- 3 to - 17

[a] While these per hectare costs and yield losses appear high, average riparian area is only 0.001 hectare

Table 5. Scenario Results for Bermuda and Tall Fescue Grass Areas in "Litter" Sub-Basins

Scenario[a]	Average[b]		Total Profits Per Sub-Basin							Loss in Profits[c]
	Cost	Revenue								
	$ / Ha	$ / Ha	1	2	3	6	9	12	13	%
1	313	228	-2,823	-1,816	-3,434	-6,547	-14,880	-5,608	-3,470	115-116
2	329	409	2,685	1,727	3,266	6,226	14,150	5,333	3,299	85-86
3	344	593	8,272	5,321	10,063	19,185	43,603	16,433	10,167	54-55
4	436	985	18,291	11,766	22,251	42,420	96,411	36,336	22,480	0
5	321	232	-2,857	-1,833	-3,447	-6,598	-14,967	-5,615	-3,497	115-116
6	337	417	2,469	1,620	3,183	5,903	13,605	5,291	3,124	86-87
7	353	604	7,873	5,123	9,910	18,587	42,592	16,356	9,842	54-57
8	446	1,004	17,563	11,404	21,972	41,328	94,565	36,195	21,886	0-4
9	403	434	1,036	666	1,260	2,402	5,458	2,057	1,273	94-95
10	493	628	4,515	2,904	5,493	10,471	23,799	8,969	5,549	75-76
11	584	985	15,332	9,863	18,652	35,558	80,816	30,458	18,844	16-17
12	412	442	874	586	1,198	2,160	5,050	2,026	1,141	94-96
13	504	640	4,240	2,768	5,387	10,058	23,101	8,916	5,324	75-77
14	597	1,004	14,701	9,549	18,410	34,612	79,216	30,336	18,329	17-20
15	537	985	16,893	10,867	20,551	39,180	89,047	33,560	20,763	7-8
16	549	1,004	16,211	10,528	20,290	38,157	87,317	33,429	20,206	8-12
17	473	1,004	16,686	10,836	20,881	39,271	89,864	34,401	20,797	5-9
18	463	985	17,384	11,183	21,148	40,318	91,634	34,536	21,366	4-5
19	103	160	2,454	2,864	2,515	2,048	5,921	1,346	6,809	83-84
20	119	272	6,553	7,646	6,714	5,468	15,809	3,593	18,179	55-56
21	135	384	10,720	12,508	10,985	8,945	25,863	5,878	29,741	26-27
22	191	532	14,653	17,097	15,014	12,226	35,350	8,034	40,650	0
23	106	161	2,210	2,643	2,436	1,916	5,638	1,333	6,359	83-85
24	122	273	6,174	7,304	6,592	5,263	15,369	3,573	17,481	55-58
25	138	386	10,204	12,043	10,818	8,667	25,264	5,850	28,790	27-31
26	194	535	14,007	16,515	14,806	11,878	34,601	8,000	39,462	1-5
27	193	288	4,074	4,754	4,175	3,400	9,829	2,234	11,303	72-73
28	283	408	5,351	6,244	5,483	4,465	12,910	2,934	14,846	63-64
29	339	532	8,288	9,670	8,493	6,916	19,995	4,544	22,993	34-35
30	196	289	3,777	4,486	4,079	3,239	9,484	2,218	10,755	72-75
31	287	410	5,012	5,938	5,374	4,282	12,516	2,916	14,221	64-66
32	343	535	7,852	9,278	8,352	6,680	19,489	4,521	22,190	34-38
33	292	532	10,302	12,020	10,556	8,596	24,853	5,648	28,580	20-21
34	296	535	9,800	11,567	10,394	8,325	24,270	5,622	27,655	22-25
35	221	535	12,877	15,186	13,621	10,924	31,827	7,361	36,291	8-13
36	218	532	13,484	15,733	13,817	11,251	32,531	7,393	37,408	7-8

[a] Scenarios 1 through 18 represented Bermuda grass, Scenarios 19 through 36 represent Tall Fescue grass

[b] Average cost and revenue across sub-basins in dollars ($) per hectares

[c] Loss in profits from baseline across sub-basins (%)

Table 6. Scenario Results for Bermuda and Tall Fescue Grass Areas in "No Litter" Sub-Basins

Scenario [a]	Average [b]		Total Profits Per Sub-Basin						Loss in Profits [c]
	Cost	Revenue							
	$/ Ha	$ / Ha	4	5	7	8	10	11	%
37	313	228	-1,287	-1,609	-4,616	-1,492	-2,079	-1,202	117-118
38	355	409	820	1,025	2,940	950	1,324	766	89-90
39	398	593	2,954	3,692	10,596	3,424	4,771	2,760	60-61
40	489	985	7,521	9,401	26,979	8,719	12,149	7,027	0
41	317	228	-1,303	-1,635	-4,643	-1,502	-2,082	-1,203	117-118
42	359	409	730	881	2,794	894	1,305	761	89-91
43	402	593	2,791	3,431	10,329	3,321	4,737	2,751	61-64
44	493	985	7,200	8,886	26,454	8,516	12,081	7,010	0-5
45	103	160	483	1,214	1,052	447	4,332	430	80-81
46	152	272	1,013	2,549	2,209	938	9,094	903	58-59
47	188	384	1,653	4,160	3,605	1,531	14,843	1,474	31-32
48	244	532	2,427	6,105	5,291	2,248	21,784	2,163	0
49	108	160	432	1,051	1,002	421	4,273	428	80-83
50	157	272	944	2,326	2,140	903	9,014	899	58-62
51	194	384	1,562	3,866	3,515	1,485	14,736	1,469	32-37
52	250	532	2,309	5,725	5,174	2,188	21,646	2,157	0-5

[a] Scenarios 37 through 44 represented Bermuda grass, Scenarios 45 through 52 represent Tall Fescue grass
[b] Average cost and revenue across sub-basins in dollars ($) per hectares
[c] Loss in profits from baseline across sub-basins (%)

Figure 1. Sub-basins in the studied watershed