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Nonriparian Shade as a Water Quality Best Management Practice for Grazing-Lands: A Case Study

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On the Ground

- Cattle within riparian zones can negatively impact water quality and riparian health, which are important environmental concerns for grazing lands.
- Best management practices (BMPs) help mitigate agricultural pollution. Since BMPs are primarily voluntary, stakeholder acceptance is critical, and agricultural producers need BMPs that are relevant to their operation and will not negatively impact production.
- Alternative shade has been suggested as a water quality BMP, with both environmental and agricultural benefits. After implementing the nonriparian shade structure, a 30% average reduction was observed in the time cattle spent within the riparian zone.

Keywords: best management practice, water quality, riparian zone, shade.

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Cattle loafing within riparian zones or waterways can negatively impact water quality and riparian zone health. Riparian health and stream water quality are intricately linked and important to the sustainability of in-stream contact recreation, aquatic life habitat, and fishing. Water pollution has been a prominent environmental concern since the late 1960s. According to the Environmental Protection Agency, there are 16,608 km (10,320 miles) of impaired rivers and streams known in Texas.[1] Over half of these streams are impaired from nonpoint sources, such as urban runoff, wildlife (avian and nonavian), grazing, irrigated cropland, mining, and others. Agricultural operations have been cited for contributing over 20% of all in-stream pollutants in Texas.[1] To help mitigate pollution, state and federal agencies have initiated total maximum daily loads (TMDLs) or watershed protection plans to target needed water quality best management practices (BMPs) to reduce pollutant loading. By studying and developing additional BMPs, agricultural producers and environmental conservationists may be able to more effectively mitigate degradation of water quality.

Contaminant Fate Modification

Much work has been done in examining the effects of livestock on riparian health and water quality.[2–5] Studies have examined the links between proximity of contaminant deposition and in-stream water quality. It is generally recognized that shorter distances between the contaminant deposition and the waterway have a greater negative effect on water quality.[6] In an attempt to control contaminant deposition and fate processes, structural BMPs have been implemented to modify animal behavior. Specifically, cattle travel and grazing patterns have been modified by using a variety of practices that alter fecal deposition locations. In the past, researchers were limited to visual observation to collect spatial positions of grazing livestock or fecal deposits.[7,8] With global positioning system (GPS) technology, not only can more data be collected, but they are often more accurate and allow cattle location to be observed in the context of a herd and at all hours of the day. GPS data points taken at evenly spaced time-intervals can be used to correlate the amount of time that cattle spend within a given area.[9] Fecal deposition is acknowledged to be directly correlated to the time that cattle spend at any given location.[10]

Some common BMPs used to reduce pollution from livestock grazing operations include riparian buffer strips, exclusion fencing, prescribed grazing, off-stream water sources, and rotational stocking. Despite the variety of BMPs available, the need to develop and test additional, cost-effective BMPs persists. This is because landscapes and operations, which BMPs are intended to facilitate, are highly diverse. Producers need BMPs that are relevant to their operation and will not negatively impact production. For this reason, there should be an assortment of BMPs that producers could select and implement as appropriate for their specific situations.

One BMP that has met much resistance from cattle producers is exclusion fencing.[11] Exclusion fencing is the practice of fencing off the stream and riparian zone to prevent livestock from grazing and watering within those areas. Although it has proven very effective in keeping livestock out of riparian zones and has been shown to reduce bacterial and nutrient loading in some cases,[4,12] its use has been highly unpopular among stakeholders. From a ranch management perspective, it is costly,[13] labor intensive, overly restrictive,[14] and not always effective.[15] Many stakeholders agree that environmental stewardship is very important, but opposition exists because this BMP offers little practical benefit from a ranch productivity or management standpoint.[16,17]

Water quality BMPs providing more practical and diversified benefits from a farm or ranch management context encourage higher adoption rates.[18] Since BMPs are primarily voluntary, stakeholder acceptance is critical. It is necessary to provide stakeholders with simple, cost-effective BMPs beneficial to the agricultural operation.[16] For this reason, alternative shade has been suggested as an attractive water quality BMP from the standpoints of both environmental quality and ranch management.[19] Alternative shade is thought to offer water quality benefits, without the drawbacks of exclusion fencing, as well as additional ranch-related benefits, such as soil conservation[20] and improved pasture utilization.[21] Still, relatively little is known about the effectiveness of alternative shade as a water quality BMP.

In pastureland, natural shade is often located along the riparian zone. In summer months, cattle seek shade to cool off.[22] Temperature and relative humidity have been found to be two of the main driving factors behind cattle seeking shade.[23] Byers observed that cattle spent 80% of their time in the shade while in the riparian zone.[24] Providing an alternative shade source outside of the riparian zone has been suggested as a potential water quality BMP for grazing lands.[24–26] However, few studies have evaluated the effectiveness of alternative shade in modifying cattle behavior; thus, this remains a BMP that should be studied to a greater extent.[27] Most shade studies have primarily focused on optimizing metabolism or milk production in cattle,[28] rather than providing water quality benefits.

One geographical information system (GIS) study testing the effectiveness of an alternative shade structure concluded that it "did not decrease the amount of time cattle spent along the streambanks."[25] However, Agouridis et al. conceded that the lack of treatment effects may have resulted from data constraints.[25] Another possible reason for this may be the shade configurations at the study site. The presence of nonriparian shade trees[9] may confound the results because trees act as a natural BMP. For this reason, control data from this study may not have varied significantly from treatments. This may explain why alternative shade BMP results of the study[25] were ineffective in reducing the time cattle spent in or near a stream. This underscores the importance of proper placement of alternative shade structures because abundant natural nonriparian shade may negate the necessity for, and compromise the effectiveness of, an alternative shade structure.

What We Did

The alternative shade BMP was evaluated at the Texas A&M AgriLife Research Center in McGregor, Texas. As shown in Figure 1, the study site was a 28.7-ha (71-acre) grazed pasture with an intermittent headwater stream of the South Bosque River flowing through it. An estimated 6% of the pasture area was vegetated by trees large enough for shade coverage. Shade was almost exclusively within the riparian zone. The pasture was provided with an off-stream water trough at the southeast corner of the pasture. The pasture had been heavily stocked, and there was evidence of erosion of the stream bank at sites where cattle frequently crossed the creek. We placed six to eight Lotek GPS 3300LR collars (Lotek Wireless Inc., Newmarket, Ontario, Canada) on randomly selected cows (Angus-Nelore cross) and used them to record the locations of cattle over three 21- to 23-day trials. Each GPS collar was calibrated to take a single locational data point every 5 minutes. The creek, pasture boundaries, and riparian zone were delineated by remote sensing.

Before beginning the trials, we placed the GPS collars on cattle and then released the cattle into the study pasture. We programmed the collars to begin collecting GPS data points on the midnight hour after cattle were turned into the pasture. Data points were collected at each 5- minute interval for the remainder of the trial. The first 10 to 12 days of each trial served as the control period, in which GPS collars were initiated to monitor cattle location prior to BMP implementation (Fig. 2). Halfway through the trial, we implemented the BMP (i.e., erected the shade cloth), while the collars continued to collect data-points for another 10 to 12 days. This "post-implementation" period served as the treatment period, allowing cattle behavior to be compared between the BMP treatment period and the control period. We erected a 9.1 × 9.1 m (30 × 30 feet) SunBlocker Economy Shade Frame,[29] with shade cloth for the alternative shade BMP. The shade structure was placed approximately 541 m (1775 feet) from the water trough and 140 m (459 feet) away from the creek and from the riparian zone where other large trees could serve as potential shade locations for cattle. We conducted trials in October 2010, May and June 2011, and March and April 2012 (Table 1). We analyzed the alternative shade BMP by counting the number of data points within different buffer zones (i.e., riparian zone and shade pavilion) before and after BMP implementation. At the end of each trial, we removed the GPS collars and downloaded the data. We plotted the GPS data points in ArcMap and then counted the points within each buffer zone. Data points were normalized to account for the differences between the total number of data points collected before and after BMP implementation (see equations 1 and 2 in Fig. 3). We calculated the percent differences between the pre- and post-BMP periods by using equation 3 (see Fig. 3).

Figure 1. Aerial photo of McGregor best management practice (BMP) study pasture, P-6. Fence boundaries are delineated by black lines. The creek and water trough are outlined in blue. The shade pavilion is marked in orange.

What We Found

Trials 1, 2, and 3, as shown in Table 1, assessed the effectiveness of a shade pavilion at reducing the time that cattle spent in or near the creek.

In contrast to the results of Agouridis et al.[25] after implementing the shade pavilion, we repeatedly observed reductions in the amount of time that cattle spent within the riparian zone. On average, cattle spent 30% less time within the riparian zone following implementation of an alternative shade pavilion. Percent reductions ranged from 31% to 45% (Table 2). The average of the collective trials, as calculated from Table 3, showed that cattle spent 51 minutes/day within 8 m of the creek prior to implementing the shade structure. Another 61 minutes/day were spent within 8 to 16 m of the creek. Following BMP implementation, the average collective minutes per day spent in the riparian zones were reduced by 10.9 minutes and 22.4 minutes for the 0 to 8 m and 8 to16 m riparian buffers, respectively.

Moreover, the amount of time that cattle spent at the site of the shade pavilion increased following implementation of the shade pavilion. Cattle increased the time they spent within the 0 to 8 m and 8 to 16 m pavilion buffers by 7.6 minutes/day and 2 minutes/day, respectively. This accounts for almost a third of the time reductions seen at the riparian zone and provides supporting evidence that percent reductions seen at the riparian zone are due to the alternative shade structure and

Figure 2. Shade pavilion without the shade cloth. The riparian zone and cattle can be seen in the background.

Table 1. Start and end dates of GPS trials

	Start	BMP implemented	End
Trial 1	7 October 2010	15 October 2010	27 October 2010
Trial 2	26 May 2011	6 June 2011	18 June 2011
Trial 3	28 March 12	7 April 2012	18 April 2012

not some other cause. The 2 minutes/day increase in the 8 to 16 m pavilion buffer suggested that cattle would graze more in areas surrounding the shade pavilion, which would result in more grazing on previously underutilized sections of a pasture. It is likely that the other half of the time reductions seen in the riparian zone was distributed across the pasture at further distances from the shade pavilion.

It must be noted that there were several limitations to this study, the presence of severe drought being the most prominent. Drought limited the water within the creek, as well as forage quantity and quality, which affected the number of trials that could be completed and the timing between trials. Trials were conducted concurrently with the McGregor Agrilife Extension's grazing rotation plan; however, stocking rate was managed individually between trials. Herd size varied and may have contributed to differences between trials in treatment effects. The low number of repetitions and the low ability to install environmental controls did not lend to more in-depth statistical analysis. For this reason, the analysis was kept as simple as possible, using only a percent difference equation. Although the results of these trials suggest a significant reduction in the amount of time that cattle spent near the creek following implementation of a nonriparian shade structure, further statistical analysis would be needed to confirm this assertion.

On the days that cattle used the shade pavilion the most, it was expected that the time that cattle spent within the riparian zone would be significantly less. Although minutes-per-day increases at the shade pavilion are evident across the average of the trials, interestingly, no clear trends were observed between individual days. Similarly, as temperature, relative humidity, and solar radiation increased (Tables 5–7), it was expected that the time that cattle spent in the riparian zone would also increase. Although seasonal trends were observed between trials, no significant trends were observed on a day-to-day basis within trials. Seasonal climatic differences and changes in forage type and quality are reasonable assumptions as to why cattle used the riparian zone differently between the three trials[6,24]; however, it is unclear why daily trends were not observed for the temperature, relative humidity, and solar radiation parameters.

On one occasion, following implementation of the shade pavilion, a 2.5% increase was observed in the time that cattle spent within the 0 to 8 m riparian buffer; however, the same trial showed a 31% reduction in the 8 to 16 m riparian buffer. This abnormality may have resulted from a number of possible factors; however, because no water was flowing in the creek during Trials 1 and 2, increased usage during Trial 2 is not assumed to have been caused by cattle accessing water. It is possible that cattle sleeping in the creek bed caused the divergence seen in Trial 2. In fact, on several occasions during Trial 2, time data corresponding with GPS locations indicated that several cows had spent the night within 8 m of the creek. Higher temperatures may also have caused the divergence seen in Trial 2. Trials 1 and 3 were completed in October and April, respectively, while Trial 2 was completed in the hotter month of May. Prior to BMP implementation, cattle spent a higher percentage of time within 0 to 16 m of the creek during Trial 2 (11.3%) compared with Trials 1 (7.7%) and 3 (4.5%). Although the Trial 2 percent reductions were smaller, the minute-per-day reductions were larger for the 8 to 16 m riparian buffer than in Trial 1 or 3. These data suggest that an alternative shade pavilion may still effectively reduce the amount of time that cattle spend within the riparian zone.

We assumed that cattle grazing was evenly distributed across the pasture when estimating expected percentages of cattle usage. Surprisingly, cattle used the riparian zone less when water was flowing in the creek in Trial 3 (Table 4). It is difficult to explain exactly why this occurred. Some possible suggestions are that when the creek is dry, cattle will bed

$$\frac{No.of\ points\ prior\ to\ BMP\ at\ buffer\ zone}{Total\ points\ prior\ to\ BMP} = \%\ Pre \qquad (1)$$

$$\frac{No.of\ points\ post\ BMP\ at\ buffer\ zone}{Total\ points\ post\ BMP} = \%\ Post \qquad (2)$$

$$\frac{\%\ Post - \%\ Pre}{(\%\ Pre)} * 100 = \%\ Diff \qquad (3)$$

Figure 3. Equations used to calculate percent difference.

Table 2. Percent difference calculations per trial represent the percent reduction or increase between pre- and postbest management practice (BMP) implementation within the 0 to 8 m and 8 to 16 m stream or shade pavilion buffers, respectively				
	Shade pavilion 0–8 m	Shade pavilion 8–16 m	Riparian zone 0–8 m	Riparian zone 8–16 m
Trial 1	257.2	108.7	−45.1	−39.8
Trial 2	2,801.6	616.2	2.5	−31.6
Trial 3	500.0	84.6	−39.2	−43.9
Mean	**1,186.2**	**269.8**	**−27.3**	**−38.4**

down, loaf in the shade, or even travel in the creek bed. Of the time cattle spent within the creek during Trials 1 and 2, 20% of the data points were in the creek bed beneath one small riparian thicket. From visual observations, it was obvious that cattle used the area extensively, as it was easily accessible and well shaded.

More important, as shown in Table 4, percent usage decreased at the riparian zone and increased in the shade pavilion following BMP implementation. Comparison of the observed shade pavilion values against expected values reveals how dramatically an alternative shade pavilion can alter cattle pasture utilization. Following implementation of the BMP in Trial 1, cattle proceeded to use the area within the 0 to 8 m shade pavilion buffer, an area representing 0.05% of the total pasture area, almost 1% of the total time spent within the pasture.

Byers observed that cattle rested within the riparian zone between 1.4% and 4.2% of the time between December and March, whereas between April and November, they spent anywhere from 5.3% to 8.1% of their time within the riparian zone.[24] In our study, prior to BMP implementation, cattle spent close to 7.7% of their time within the riparian zone during October and 4.5% from late March to early April. This falls within the range found in a study conducted by Byers in Georgia. However, during May, cattle spent 11.2% of their time within 16 m of the stream. The largest percent of riparian usage found by Byers was 8.1%.[24] The difference is likely caused by the presence of abundant nonriparian shade in the pasture configurations in the Byers study. This suggests that pastures with little nonriparian shade may see increased usage of riparian shade, potentially causing more riparian and water quality degradation. Following BMP implementation at the McGregor pasture, riparian usage was reduced to 9.45% for the month of May. Although a single shade pavilion appeared to reduce cattle dependence on riparian shade, during the hotter months, the abundance of riparian shade may draw cattle to riparian zones more frequently and for longer periods. Strategic placement of multiple shade pavilions may optimize pasture utilization and further minimize cattle dependence on riparian shade. Shade pavilions capable of being disassembled and reassembled or transported may also benefit cattle producers and other livestock producers using an intensive rotational grazing management method.

The scope of our case study was narrow in that it focused mainly on cattle behavior modification following implementation of a nonriparian shade structure. Further study should be done to expand on the data presented here and include other relevant parameters, such as differences in water quality, reduced erosion rates, and forage utilization following implementation of a nonriparian shade structure. Similarly, further analysis should be done to ascertain environmental and agricultural economic costs, benefits, and longevity of nonriparian shade relative to other water quality BMPs. Herd size and shade area per cow should be considered when shade area may limit the total number of cattle that can use the structure.

Table 3. Comparison of average minutes/day calculations pre- and postbest management practice (BMP) implementation per shade trial within the 0 to 8 m and 8 to 16 m stream or shade pavilion buffers, respectively								
	Shade pavilion 0–8 m		Shade pavilion 8–16 m		Riparian zone 0–8 m		Riparian zone 8–16 m	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Trial 1	3.8	13.6	2.7	5.6	46.9	25.7	64.1	38.6
Trial 2	0.4	12.2	0.3	2.4	73.2	75.0	89.3	61.1
Trial 3	0.3	1.7	1.2	2.2	34.3	20.8	30.6	17.2
Mean	1.5	9.1	1.4	3.4	51.4	40.5	61.3	39.0

Table 4. Observed and expected percent usage of shade pavilion and riparian buffers per trial*								
	Riparian zone 0–8 m		Riparian zone 8–16 m		Shade pavilion 0–8 m		Shade pavilion 8–16 m	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Trial 1	3.25	1.78	4.45	2.68	0.26	0.94	0.19	0.39
Trial 2	5.08	5.21	6.20	4.24	0.03	0.85	0.02	0.17
Trial 3	2.38	1.45	2.12	1.19	0.02	0.12	0.08	0.15
Mean	3.57	2.81	2.71	2.71	0.10	0.64	0.10	0.24
Expected		3.93	3.93		0.05		0.15	

*** Expected values were calculated by assuming cattle grazing was normally distributed across the pasture. Expected values simply represent the area of the buffered zone as a percentage of the total pasture.**

Implications

Cattle repeatedly spent less time near the riparian zone following implementation of the nonriparian shade structure. During the warmer months, cattle relied more heavily on riparian shade. The time that cattle spent near the shade structure greatly increased; thus, providing alternative shade structures could assist producers in encouraging cattle to graze underutilized pasture and may help reduce erosion caused by excessive loafing by cattle near riparian shade. Improved water quality may be one of the greatest benefits of providing

Table 5. Temperature, relative humidity, and solar radiation daily maximum and minimum values for Trial 1					
Date	**Temperature (°F)**		**Relative humidity (%)**		**Solar radiation (W/m^2)**
	Max	**Min**	**Max**	**Min**	
7 October 2010	81	42	93	21	896
8 October 2010	85	45	92	19	890
9 October 2010	85	48	87	21	879
10 October 2010	86	49	89	24	873
11 October 2010	85	57	98	37	778
12 October 2010	86	63	100	46	535
13 October 2010	84	58	100	29	843
14 October 2010	83	56	83	37	801
15 October 2010	77	46	78	20	859
16 October 2010	83	40	93	15	859
17 October 2010	84	46	84	20	850
18 October 2010	83	54	94	40	704
19 October 2010	85	63	97	41	785
20 October 2010	86	60	97	39	808
21 October 2010	86	59	98	45	599
22 October 2010	87	58	98	41	764
23 October 2010	85	67	99	51	403
24 October 2010	81	62	100	70	519
25 October 2010	86	63	100	53	509
26 October 2010	86	65	100	52	671
27 October 2010	79	59	91	26	781

Table 6. Temperature, relative humidity, and solar radiation daily maximum and minimum values for Trial 2					
Date	**Temperature (°F)**		**Relative humidity (%)**		**Solar radiation (W/m^2)**
	Max	**Min**	**Max**	**Min**	
26 May 2011	99	73	91	13	1162
27 May 2011	87	61	72	29	1155
28 May 2011	99	66	83	28	1102
29 May 2011	98	73	89	33	1088
30 May 2011	97	73	89	36	1101
31 May 2011	95	75	86	35	907
1 June 2011	95	74	90	37	1013
2 June 2011	94	71	89	24	1118
3 June 2011	97	65	82	29	1107
4 June 2011	98	68	81	23	1125
5 June 2011	95	67	93	27	1131
6 June 2011	99	68	76	28	1030
7 June 2011	100	68	87	23	1076
8 June 2011	98	69	80	27	1065
9 June 2011	96	72	91	33	1103
10 June 2011	96	72	88	27	1085
11 June 2011	96	72	91	31	1081
12 June 2011	97	72	87	31	1104
13 June 2011	98	72	88	27	1104
14 June 2011	100	73	84	25	1114
15 June 2011	101	75	85	23	1129
16 June 2011	101	76	83	22	1098
17 June 2011	102	75	85	26	1108
18 June 2011	103	79	80	23	1082

alternative shade, as providing cattle with an alternative to riparian shade increases the buffer distance between fecal deposition and the stream. This also provides producers with an alternative to total exclusion fencing, which may be overly burdensome from a range management perspective.

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Table 7. Temperature, relative humidity, and solar radiation daily maximum and minimum values for trial 3					
Date	**Temperature (°F)**		**Relative humidity (%)**		**Solar radiation (W/m^2)**
	Max	**Min**	**Max**	**Min**	
28 March 2012	77	58	91	57	965
29 March 2012	71	61	95	68	260
30 March 2012	79	63	98	65	926
31 March 2012	81	65	98	67	913
1 April 2012	84	63	98	56	1021
2 April 2012	86	66	96	52	1031
3 April 2012	82	68	95	51	917
4 April 2012	80	60	96	71	614
5 April 2012	76	51	98	58	1003
6 April 2012	80	57	95	38	1047
7 April 2012	79	52	96	51	998
8 April 2012	82	63	97	49	919
9 April 2012	81	60	96	50	978
10 April 2012	79	58	98	55	943
11 April 2012	81	60	95	47	680
12 April 2012	81	59	96	46	1012
13 April 2012	80	66	93	53	780
14 April 2012	81	63	93	59	718
15 April 2012	81	70	87	64	579
16 April 2012	74	56	88	42	576
17 April 2012	72	51	93	53	641
18 April 2012	79	50	94	29	1108

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