Managing forage-based cow-calf operations in subtropics: implication to surface and ground water quality

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Abstract
Recent assessments of water quality status have identified eutrophication as one of the major causes of water quality "impairment" around the world. In most cases, eutrophication has accelerated by increased inputs of phosphorus and/or nitrogen due to intensification of crop and animal production systems since the early 1990's. As animal-based agriculture has evolved to larger production in subtropical region of United States, the problems associated with manure handling, storage and disposal have grown significantly. Little information exists regarding possible magnitudes of nutrient losses from pastures that are managed for both grazing and hay production and how these might impact adjacent bodies of water. Trends in water quality parameters and trophic state index (TSI) of lakes associated with beef cattle operations are being investigated. Overall, there was no spatial or temporal build up of soil nutrients despite the annual application of fertilizers and daily in-field loading of animal waste. Our results indicate that when nutrients are not applied in excess, cow-calf systems are slight exporters of nutrients through removal of cut hay. Water quality in lakes associated with cattle production was "good" (30-46 TSI) based upon the Florida Water Quality Standard. Our results indicate that current cattle rotation and current fertilizer application offer little potential for negatively impacting the environment. Properly managed livestock operations contribute negligible loads of nitrogen and phosphorus to shallow groundwater and surface water.

Key Words
Soil-plant-animal system, bahiagrass, soil management, eutrophication, animal production, trophic state index, nutrient cycling.

Introduction

Forage-based animal production systems with grazing have been suggested as one of the major sources of non-point source phosphorus pollution that are contributing to the degradation of water quality in lakes, reservoirs, rivers, and ground water aquifers (Bogges *et al.* 1995; Edwards *et al.* 2000). Cattle manure contains appreciable amounts of nitrogen and phosphorus (0.6 and 0.2%, respectively), and portions of these components can be transported into receiving waters during severe rainstorms. Work in other regions of the country has shown that when grazing animals become concentrated near water bodies, or when they have unrestricted long-term access to streams for watering, sediment and nutrient loading can be high. Additionally, there is a heightened likelihood of phosphorus losses from over fertilized pastures through surface water runoff or percolation past the root zone (Gburek and Sharpley 1998).

Recent assessments of water quality status have identified eutrophication as one of the major causes of water quality "impairment" not only in the United States, but also around the world. In most cases, eutrophication has accelerated by increased inputs of nutrients, especially phosphorus (P) due to intensification of crop and animal production systems since the early 1990's. Despite substantial measurements using both laboratory and field techniques, little is known about the spatial and temporal variability of nutrient dynamics across the landscapes, especially in agricultural landscapes with cow-calf operations. Critical to determining environmental balance and accountability is an understanding of nutrients excreted, nutrient removal by plants, and acceptable losses of nutrients within the manure management and crop production systems and export of nutrient off-farm. Further research effort on optimizing forage-based cow-calf operations to improve pasture sustainability and water quality protection therefore is still warranted.

Reduction of phosphorus transport to receiving water bodies has been the primary focus of several studies because phosphorus has been found to be the limiting nutrient for eutrophication in many aquatic systems (Sigua and Tweedale 2003; Sigua *et al.* 2006). Elsewhere, studies of both large and small watersheds have been performed to answer questions regarding the net effect of agricultural practices on water quality with time or relative to weather, fertility, or cropping practices. We hypothesized that properly managed cow-calf operations would not be major contributors to excess loads of nutrients in surface and ground water. To verify our hypothesis, we examined the comparative concentrations of nitrogen and phosphorus among soils, surface water and groundwater beneath bahiagrass-based pastures with cow-calf operations.

Materials and methods

Surface water quality assessment

The lakes that we studied were adjacent to or within about 14-km radius from the USDA-ARS, Subtropical Agricultural Research Station (STARS), Brooksville, FL. These lakes are associated with forage-based beef cattle operations. The lakes were: (1) Lake Lindsey (28^{o}37.76'N, 82^{o}21.98'W), adjacent to STARS; (2) Spring Lake (28^{o}29.58'N; 82^{o}17.67'W), about 10 km away from STARS; and (3) Bystre Lake (28^{o}32.62'N; 82^{o}19.57'W), about 14 km away from STARS. Monthly water quality monitoring of lakes associated with beef cattle pastures was begun in 1993 and continued until 2002 by the field staff of the Southwest Florida Water Management District (SWFWMD). Monthly water samples were taken directly from the lakes using a water (Van Dorn) grab sampler. Water quality parameters monitored were Ca, Cl, NO_2 + NO_3-N, NH_4-N, total N, total P, K Mg, Na, Fe, and pH. All sampling, sample preservation and transport, and chain of custody procedures were performed in accordance with an EPA-approved quality assurance plan with existing quality assurance requirements. The SWFWMD Analytical Laboratory, using EPA-approved analytical methods, performed the chemical analyses of water samples from the lakes.

Ground water quality assessment

Two adjacent 8-ha pasture fields with cow-calf operation were instrumented with a pair of shallow wells placed at different landscape positions. The different landscape positions are top slope (TS; 10-20% slope, 2 ha; middle slope (MS; 5-10% slope, 2 ha and bottom slope (BS; 0-5% slope, 2 ha). The wells were constructed of 5 cm schedule 40 PVC pipe and had 15 cm of slotted well screening at the bottom. During installation of wells, sand was placed around the slotted screen, and bentonite clay was used to backfill to the soil surface to prevent surface water or runoff from moving down the outside of the PVC pipe and contaminating groundwater samples. A centralized battery-operated peristaltic pump was used to collect water samples. Wells were completely evacuated during the sampling process to ensure that water for the next sampling would be fresh groundwater. Water samples were collected from the groundwater wells every two weeks. However, there were periods when ground water levels were below the bottom level of the wells and samples could not be obtained. In addition to ground water samples, surface water samples were collected in the pasture bottoms or the seep area when present, by taking composite grab samples on the same schedule. The seep area, which is located at the lower end of BS is a remnant of a sinkhole formation and became a small scale lake with varying levels of surface water. The seep area of about 2 ha in size is where runoff and seepage from higher parts of pasture converge. Water samples were transported to the laboratory following collection and refrigerated at 4^{o}C. Water samples were analyzed for NO_3-N and NH_4-N using a Flow Injector Analyzer according to standard methods.

Results and discussion

Surface water quality impact: florida trophic state index

The Florida TSI was devised to integrate different but related measures of lake productivity or potential productivity, into a single number that ranges from 0 to 100. The measures included in the calculation of TSI are water transparency (Secchi depth), chlorophyll *a* (measurement of algae content), TN, and TP. The Florida TSI for Lake Lindsey, Spring Lake, and Bystre Lake were 35, 30, and 46, respectively (Figure 1). Based on this, the TSI of these lakes can be classified as "good" according to Florida Water Quality Standard (TSI of 0-59 = "good"; TSI of 60 to 69 = "fair"; and TSI of 70 to 100 = "poor"). Although the TSI levels of the three lakes did not show any significant change from 1993 to 2002, TSI levels increased numerically for all lakes (Figure 1). This is reflected in a change in the trophic status of Bystere Lake. Lake Lindsey with TSI of 31 and 38 in 1993 and 2002, respectively, remained within the mesotrophic classification, while Spring Lake with TSI of 25 and 26 in 1993 and 2002, respectively, remained in the oligotrophic category. Lake Lindsey (mesotrophic lake) would normally have moderate nutrient concentrations with moderate growth of algae and/or aquatic macrophytes and with clear water (visible depth of 2.4 to 3.9 m).

Bystere Lake, which was at the upper end of the mesotrophic range in 1993 (TSI of 49), shifted into the slightly eutrophic state in 2002 with a TSI value slightly above 50. Eutrophic lakes normally have green, cloudy water, indicating lots of algal growth in the water. Water clarity of most eutrophic lakes generally ranges from 0.9 to 2.4 m. Generally, water quality in Lake Lindsey and Spring Lake was consistently good (1993-2002) while water quality of Bystere Lake ranged from good in 1993 to fair in 2002 (Figure 1). Our results indicate that current fertilizationrecommendations for RP-based pastures in Central Florida offer little potential for negatively impacting the environment, and that properly managed livestock operations based on forage-based beef cattlepastures contribute negligible loads of nutrients (especially P) to surface water. In fact, our results suggest current recommendation for P may be too low to adequately maintain RP growth. Periodic applications of additional P and other micronutrients may be necessary to sustain agronomic needs and to offset the export of nutrients due to animal production.

Groundwater quality impact

Concentrations of NH_4-N, NO_3-N, and TIN in SGW did not vary with landscape position (Figure 2). However, concentrations NH_4-N, NO_3-N, and TIN in the water samples collected from the seep area were significantly ($p \leq 0.05$) higher when compared to their average concentrations in water samples collected from the different landscape positions (Figure 2). Averaged across year, concentration of TIN ranged from 0.5 to 1.5 mg/L. The highest TIN concentration occurred ($p \leq 0.05$) in the surface water while the concentrations from the SGW wells (BS-0.6 mg/L, MS-0.9 mg/L, and TS-0.6 mg/L) were similar to each other and lower than the seepage area. Average concentrations of NO_3-N (0.4 to 0.9 mg/L) among the different sites were well below the maximum, of 10 mg/L, set for drinking water (Figure 2). On the average, the concentrations of NO_3-N did not vary significantly ($p \leq 0.05$) due to LP, and as with TIN, the levels were significantly lower than surface water from seepage area (Figure 2). The maximum NO_3-N concentrations (averaged across landscape position) in SGW for 2004, 2005 and 2006 were also below the drinking water standards for NO_3-N. Similar trends in landscape position were found for average concentrations of NH_4-N (Figure 2). Again, the concentrations of NH_4-N in SGW did not vary ($p \leq 0.05$) significantly among TS, MS, and BS wells. These levels of NH_4-N were significantly lower ($p \leq 0.05$) than that of the surface water (0.5 mg/L).

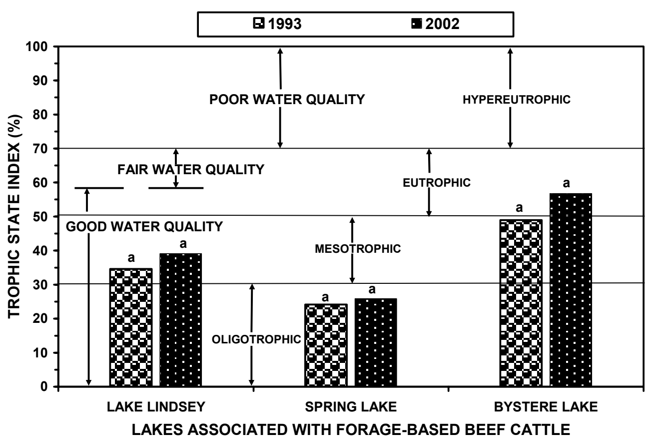

Figure 1. Trophic state index for lakes with forage-based beef cattle pasture system. Trophic state index is sginficantly different ($p \leq 0.05$) when superscripts located at top bars are different. Source: Sigua *et al.* (2006).

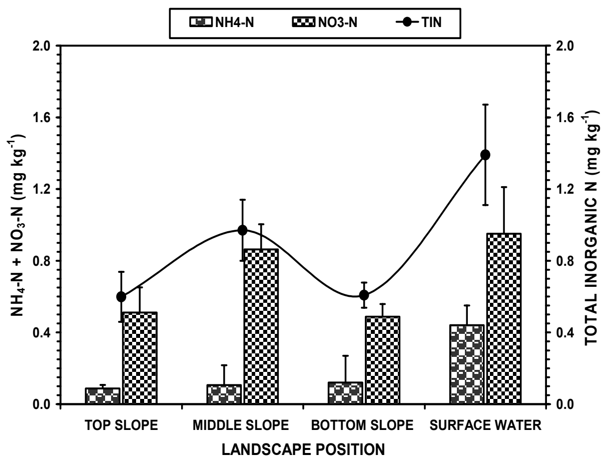

Figure 2. Average concentrations of NH_4-N and NO_3-N in SGW and total inorganic nitrogen at different landscape positions. Line above the bars and across the line represents standard error of the mean.

quality in lakes, reservoirs, rivers, and ground water aquifers, but perennially grass-covered pastures are associated with a number of environmental benefits. Continuous grass cover leads to the accumulation of soil organic matter, sequestering carbon in the soil and thereby reducing the potential CO_2 accumulation in the atmosphere. The increase in soil organic matter is also related to soil quality, with improvements in soil structure, aeration and microbial activity. Effective use and cycling of N or P is critical for pasture productivity and environmental stability. In addition to speeding up N or P recycling from the grass, grazing animals also can increase N or P losses in the system by increasing leaching potential due to concentrating N into small volumes of soil under dung and urine patches, redistributing N or P around the landscape, and removal of N or P in the form of animal products. The overall goal efforts to reduce N or P losses from animal-based agriculture should be to balance off-farm P inputs in feed and fertilizer with outputs to the environment. Source and transport control strategies can provide the basis to increase N and P efficiency in agricultural systems.

Overall,

- Forage-based animal production systems as suggested by regulators are not the major sources of non-point source nutrients pollution that are contributing to the degradation of water quality in lakes, reservoirs, rivers, and ground water aquifers; and
- Properly managed cow-calf operations in subtropical agro-ecosystem would not likely be the major contributors to excess loads of N or P in surface water and/or shallow groundwater.

Conclusion

Current pasture management including cattle rotation in terms of grazing days and current fertilizer (inorganic + manures + urine) application rates for bahiagrass pastures in subtropical regions of USA offer little potential for negatively impacting the environment. Properly managed livestock operations contribute negligible loads of total P and N to shallow groundwater and surface water. Overall, there was no buildup of soil total P and N in bahiagrass-based pasture. These observations may help to renew the focus on improving fertilizer efficiency in subtropical beef cattle systems, and maintaining a balance of P and/or N removed to P and/or N added to ensure healthy forage growth and minimize P or N runoff.

Contrary to early perception, forage-based animal production systems with grazing are not likely one of the major sources of non-point source P pollution that are contributing to the degradation of water

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