Note

Establishing bahiagrass in subtropical beef cattle pastures with lake-dredged materials

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Dredged materials are often viewed by society and regulators as pollutants, but many have used these materials in coastal nutrient enhancement, land or wetland creation, construction materials, and for soil improvement as a soil amendment. The objective of this study was to assess lake-dredged materials as a soil amendment for early establishment of bahiagrass (BG, *Paspalum notatum* Flügge) in subtropical beef cattle pasture. The treatment combinations consisted of five test plots (30.5 m × 30.5 m). Each of the plots had different ratio of lake-dredged materials (LDM) to natural soil (NS): Plot 1 [0% dry matter (DM) + 100% NS]; Plot 2 (25% DM + 75% NS); Plot 3 (50% DM + 50% NS); Plot 4 (75% DM + 25% NS); and Plot 5 (100% DM + 0% NS). Each plot was seeded with BG and growth establishment and yield were monitored for 34 weeks. Results disclosed significantly taller ($P \leq 0.001$) BG and higher biomass production ($P \leq 0.001$) from plots amended with DM than those of BG planted on plots with 0% DM. Results suggest that DM can serve as source of lime and fertilizer to establish BG beef pasture fields in the subtropics.

Keywords: Dredging; Bahiagrass; Beef cattle pasture; Sediment management; Subtropics; Liming; Soil fertility

Disposal and environmental quality of dredged sediments from navigational channels have been judged as beneficial by combinations of physical, chemical, and biological analyses for over 30 years. However, many scientists find this approach objectionable since data do not provide sufficient environmental protection information, because several site-specific geochemical and biological factors are typically excluded from the decision-making process (Wenning and Wolteringg, 2001). Additional research on disposal options of dredged materials is much needed to supply information on criteria testing and evaluation of the physical and chemical impacts of dredged materials at a disposal site, as well as information on many other aspects of dredging and dredged material disposal (Krause and McDonnell, 2000).

Establishment of an excellent, uniform stand of bahiagrass (BG, *Paspalum notalum* Flügge) in a short time period is important. Failure to obtain a good stand early means the loss of not only the initial investment costs, but production and its cash value (Chambliss, 1999). Forage production often requires significant inputs of lime, N fertilizer, and less frequently, P and K fertilizers. Dredged materials, composted urban plant debris, waste lime, and phosphogypsum are examples of materials that can be used for fertilizing and liming pastures. Often these materials can be obtained at little or no cost to the farmers or landowners (Kidder, 1999). Forage production offers an alternative to waste management since nutrients in the waste are recycled into crops that are not directly consumed by humans.

Disposal or finding beneficial uses of dredged materials is quite challenging. The bottom sediment materials usually are composed of upland soil enriched with nutritive organics. These materials should be regarded as a beneficial resource

0041-3216/2005/040354-06
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to be used productively and not to be discarded as spoilt materials (Sigua *et al.*, 2000; Patel *et al.*, 2001). The goal of this study was to explore the use of the Lake Panasoffkee dredged sediments to improve the physico–chemical properties of existing sandy soils in subtropical beef cattle pastures with calcium carbonate and organic-enriched dredged materials. The lake-dredged materials, if found to be beneficial, could be removed from the spoil containment areas, trucked to other locations, and incorporated into existing pasture fields. The objective of this study was to assess dry matter (DM) as a soil amendment to establish BG in a subtropical beef cattle pasture in Sumter County, Florida, U.S.A.

Materials and Methods

Study site

The study site is located in Coleman Landing (28.798° N; 82.103° W), Sumter County, Florida, U.S.A. Most of the soils at Sumter County are formed in sandy marine or eolian deposits and have water table at a depth of 102–203 cm for more than six months during most years. These soils are hyperthermic, uncoated Typic Quartzipsamments (USDA, 1988). Aerial photographs of the study sites (Lake Panasoffkee and experimental plots) that were taken on 29 March 2002, are shown in Figure 1.

Table 1 shows some of the selected properties of surface soils (0–20 cm) in Coleman Landing (CL). The climate of Sumter County is characterized by long, warm, and relatively humid summers and mild, dry winters. The average total annual precipitation (1988–2000) in the area was about 1191 mm with approximately half (56%) this amount occurring during the mid-June through mid-September period (Figure 2). The lowest average temperature of 15°C occurs during January, but light to moderate frosts are frequent during the winter months. The highest average temperature in the mid to upper 20°C range occurs regularly from May through September.

Dredged materials

Hydraulic suction dredging typically involves excavating the deeper, largely uninhabited sediments and depositing them on top of the ecologically productive surface substrates. One such dredging project of the CL boat ramp and adjacent Lake Panasoffkee was completed in July 2000. A private laboratory (Flowers Chemical Laboratories Inc., Leesburg, FL, U.S.A.) performed the physical and chemical analyses of dredged sediments from Lake Panasoffkee.

Field site preparation

This study encompassed five test plots (30.5 m × 30.5 m) adjacent to the CL spoil disposal site in Sumter County, FL. Each plot was excavated to a depth of about 28 cm, and existing natural soil (NS) and organic materials were completely removed. Excavated NS materials were placed at the south end of the test plots. Existing vegetation from each plot was totally removed prior to backfilling each plot with different ratios of DM and NS: Plot 1 (0% DM + 100% NS); Plot 2 (25% DM + 75% NS); Plot 3 (50% DM + 50% NS); Plot 4 (75% DM + 25% NS); and Plot 5 (100% DM + 0% NS). These ratios of DM to NS represent the treatment combinations of DM_0, DM_{25},

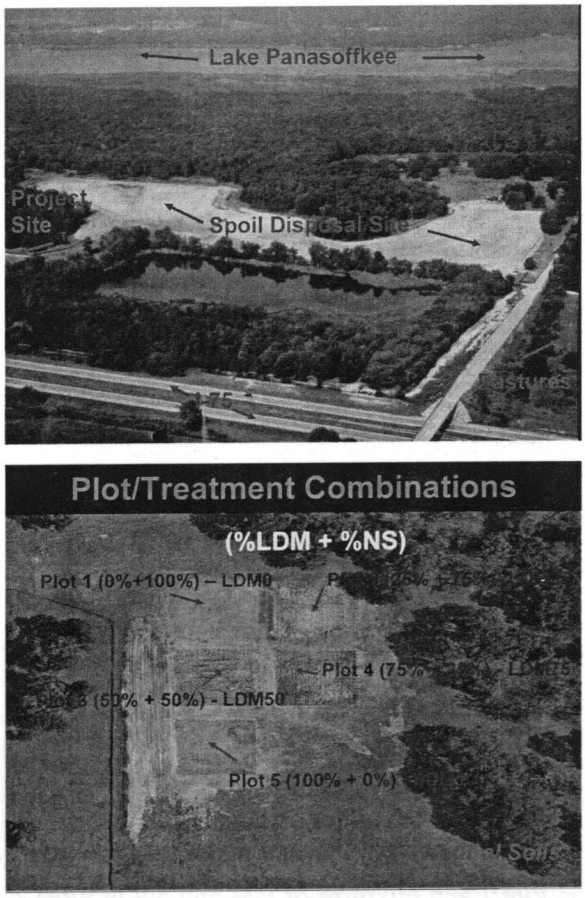

Figure 1 Aerial view of the dredging site at Lake Panasoffkee and the study site at the Coleman Landing in Sumter County, (28.798° N, 82.103° W), FL, U.S.A.

Table 1 Selected physico–chemical properties of soils from the Coleman Landing site and dredged soil materials from Lake Panasoffkee

Property	Unit	Natural soil	Lake-dredged soil materials
Particle size			
Sand	%	87.5 ± 0.0	
Silt	%	1.2 ± 1.8	
Clay	%	11.2 ± 1.8	
pH		5.9 ± 0.01	7.8 ± 0.2
Soil organic	%	2.5 ± 1.2	
Soil organic matter	%	4.5 ± 2.2	
Potassium	mg kg^{-1}	33.9 ± 11.6	4.3 ± 1.8
Total phosphorus	mg kg^{-1}	20.6 ± 38.9	1.6 ± 1.2
Total nitrogen	mg kg^{-1}	2.9 ± 1.5	6.9 ± 0.3
Ammonium-N	mg kg^{-1}	0.3 ± 0.3	
Nitrate-N	mg kg^{-1}	2.6 ± 2.0	0.2 ± 0.05
Nitrite-N	mg kg^{-1}		0.3 ± 0.05
Magnesium	mg kg^{-1}	66.2 ± 29.2	
Zinc	mg kg^{-1}	0.4 ± 0.3	
Manganese	mg kg^{-1}	1.3 ± 0.7	
Copper	mg kg^{-1}	0.2 ± 0.4	
Iron	mg kg^{-1}	4.9 ± 10.0	
Aluminum	mg kg^{-1}	83.4 ± 170.1	
Sodium	mg kg^{-1}	25.1 ± 18.7	
Ca (as $CaCO_3$)	%		82.8
Mg (as $MgCO_3$)	%		0.9

DM_{50}, DM_{75}, and DM_{100}, respectively. Natural soils that were excavated were backfilled to each plot together with DM that was hauled from the adjacent settling pond. The total amount of DM and NS that was returned to each test plot was in accordance with the different ratios of DM and NS that were described above. After mixing the NS and DM, each of the test plots was disked to a uniform depth of 28 cm. Plots were disked in an alternate direction until DM and NS were uniformly mixed. Each plot was seeded with BG at a rate of 6 kg $plot^{-1}$, followed by dragging a section of chain link fence across each test plot to ensure that BG seeds were in good contact with the NS in Plot 1 and mixtures of DM and NS in Plots 2, 3, 4, and 5. Each plot was seeded on 28 January, 2002. Figure 2 shows the aerial photograph of CL site taken on 29 March 2002.

Above-ground biomass measurements

Above-ground biomass measurements of BG during its early establishment were taken from four sub-plots (0.3 m × 0.3 m) that were randomly selected from each main plot (30.5 m × 30.5 m). These sub-plots were permanently marked, using yellow flags placed at the four corners of a 0.3 m × 0.3 m quadrant. Above-ground biomass of BG was measured, using a double ring method (Williams and Hammond, 1999). Freshly cut above-ground growth was oven-dried at 60°C for 24 h at the USDA-ARS Laboratory in Brooksville, FL, U.S.A.

Soil sampling and soil analyses

Five 0–20 cm depth soil samples for background soil values were collected from Plot 1 (0% DM + 100% NS) in the CL site using a steel bucket-type hand auger. Soil samples were air-dried and passed through a 2-mm mesh sieve prior to soil chemical extractions. The Mehlich 1 Method (0.05 N HCl in 0.025 N H_2SO_4) was used for chemical extraction of soil (Mehlich, 1953). Soil chemical analyses were conducted at the University of Florida, Institute of Food and Agricultural Sciences Soil Testing Laboratory, Gainesville, FL, U.S.A. Soil P and other exchangeable cations (Ca, Mg, K, Al, and Fe) were analyzed using an Inductively Coupled Plasma (ICP) Spectroscopy. Organic matter content of NS was analyzed following the method of Walkley and Black (Walkley and Black, 1934). Soil samples were also collected from each test plot at Week 16 to determine the effect of applied DM on soil pH (Thomas, 1996).

Statistical analysis

The establishment characteristics (above-ground biomass) of BG in beef cattle pasture were analyzed statistically following the analysis of variance using the SAS PROC GLM model (SAS, 2000). Where the *F*-test indicated a significant ($P \leq 0.05$) effect, means were separated, following the method of Least Significant Differences (LSD) and Duncan's Multiple Range Test (DMRT), using appropriate error mean squares (SAS, 2000).

Results

Physico–chemical properties of DM and NS

Selected physico–chemical properties of NS and DM are listed in Table 1. The Lake Panasoffkee

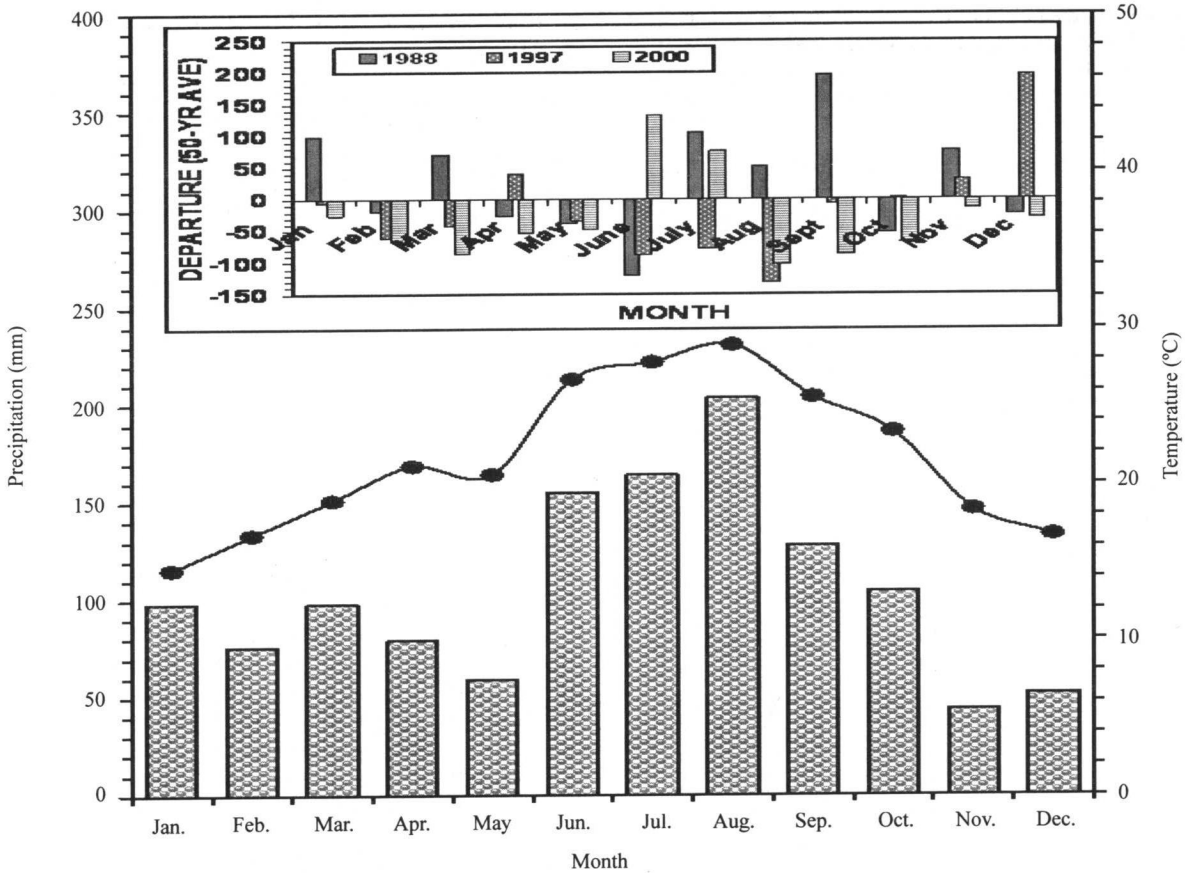

Figure 2 Monthly average rainfall and temperature and deviation of rainfall from a 50-year average precipitation in Sumter-Hernando County (1988–2000). ▩, Temperature; -●-, Precipitation

Table 2 Trace and heavy metals analyses of dredged materials from Lake Panasoffkee

Property	Unit	Mean	Threshold effect levels (TEL)[1]	Probable effect levels (PEL)[2]
Iron	mg kg^{-1}	710.0 ± 1.3		
Silicon	mg kg-1	490.0 ± 1.2		
Copper	mg kg^{-1}	8.7 ± 1.2	18.7	108
Zinc	mg kg^{-1}	7.0 ± 0.6	124	271
Cadmium	mg kg^{-1}	2.5 ± 0.1	0.7	4.2
Lead	mg kg^{-1}	5.2 ± 1.3	30.2	112
Nickel	mg kg^{-1}	14.6 ± 6.4	15.9	42.8
Chromium	mg kg^{-1}	40.5 ± 2.1	52.3	160
Arsenic	mg kg^{-1}	4.4 ± 0.1	7.2	41.6
Mercury	mg kg^{-1}	0.01 ± 0.02	0.1	0.7
Selenium	mg kg^{-1}	0.02 ± 0.02		
Molybdenum	mg kg^{-1}	1.3 ± 0.2		

[1] TEL represents the concentrations of sediment-associated contaminants that are not considered to represent significant hazards to aquatic organisms

[2]PEL defines the lower limit of the range of contaminant concentrations that are usually or always associated with adverse biological effects

dredged sediments had a very high Ca (as $CaCO_3$) content of 82% and an average pH of 7.8 ± 0.2. The TP, TN, and K contents of the dredged materials were relatively low with mean concentrations of 1.6 ± 1.2, 6.9 ± 0.3, and 4.3 ± 1.8 mg kg^{-1}, respectively (Table 1). Trace and heavy metal contents of dredged materials are shown in Table 2. Average values for Cu, Zn, Pb, Ni, Cr, As, and Hg of 8.7 ± 1.2, 7.0 ± 0.6, 5.2 ± 1.3, 14.6 ± 6.4, 40.5 ± 2.1, 4.4 ± 0.1, and 0.01 mg kg^{-1}, respectively, were below the threshold effect levels (TEL) and probable effect levels (PEL) published by Florida Department of Environmental Protection (MacDonald, 1994). Threshold effect level represents the concentrations of sediment-associated contaminants that are not considered to cause significant hazards to aquatic organisms, while PEL represents the lower limit of the range of the contaminant concentrations that are usually or always associated with adverse biological effects.

Soil pH

Soil pH in the CL site varied ($P \leq 0.001$) considerably in response to DM additions. Addition of DM resulted in higher soil pH than those plots with 0% DM (Table 3). Soil pH (averaged across plots with DM) of 7.3 ± 0.05 was higher than plots with 0% DM, which had an average soil pH of 5.9 ± 0.01. The highest soil pH of 7.5 ± 0.06 was observed from plots with the highest DM addition (100%), followed by plots with 75% DM (7.4 ± 0.0), 50% DM (7.4 ± 0.01), and 25% DM (7.1 ± 0.11).

Above-ground biomass

The average biomass of BG from plots amended with DM of 2747.1 ± 309.4 kg ha^{-1} was significantly higher ($P \leq 0.001$) than biomass of BG in plots with no DM additions (1512.8 ± 165.9 kg ha^{-1}). These data show the favourable influence that DM had on growth of BG during its early establishment in plots of subtropical beef cattle pastures (Table 3). The greatest biomass among plots amended with DM was from plots with 100% DM + 0% NS (3348.7 ± 173.8 kg ha^{-1}). The lowest biomass of 1512.8 ± 165.9 kg ha^{-1} was from plots with 0% DM + 100% NS. Mean biomass of BG in plots with 50% DM of 2466.5 ± 320.2 kg ha^{-1} was not significantly different from that in plots with 75% DM (2466.5 ± 320.2 kg ha^{-1}) and 25% DM (2409.2 ± 423.2 kg ha^{-1}), but was greater than that in plots with 0% DM (Table 3).

Table 3 Above-ground biomass of bahiagrass and soil pH during early pasture establishment

Treatment combination (%DM + %NS)	Above-ground biomass (kg ha^{-1})	Soil pH
DM_0 (0 + 100)	1512.8 ± 165.9 c	5.9 ± 0.01 d
DM_{25} (25 + 75)	2409.2 ± 423.2 b	7.1 ± 0.1 c
DM_{50} (50 + 50)	2466.5 ± 320.2 b	7.4 ± 0.01 b
DM_{75} (75 + 25)	2764.3 ± 320.2 b	7.4 ± 0.0 b
DM_{100} (100 + 0)	3348.7 ± 173.8 a	7.5 ± 0.06 a

[1]Means in each column followed by same letter(s) are not significantly different from each other at $P \leq 0.05$

Discussion

Results have shown the favourable influence that DM had on BG during its early establishment in sandy subtropical beef cattle pasture plots. Sediments dredged from Lake Panasoffkee have high $CaCO_3$ content (82%) and when these materials were incorporated into existing topsoil, they would have the same favourable effects as liming the field. Soil pH at Week 34 in the CL site varied considerably in response to DM additions. The highest soil pH of 7.5 ± 0.06 was observed from plots with the highest DM addition (100%), followed by plots with 75% DM (7.4 ± 0.0), 50% DM (7.4 ± 0.01), and 25% DM (7.1 ± 0.11). Although the importance of Ca and Mg in BG nutrition is not addressed directly in this study, the scope of benefits derived from DM applications was much broader than expected. Some of the indirect benefits of liming pasture fields among others would include: enhancing P and micro-element availability, nitrification, nitrogen fixation, and improving soil physical conditions (Russel, 1973; Tisdale and Nelson, 1975). Liming the field could have some direct and indirect effects on early establishment of BG. Perhaps the single direct benefit of liming is the reduction in acidity and solubility of aluminum and manganese (Peevy *et al.*, 1972).

Although DM only contained relatively low nutritional values, its effect on BG in the beef pasture field was remarkable because during its early establishment, BG requires low levels of nutritional needs. The levels of N and P, and the liming effects of DM were enough to promote and sustain the early establishment stage of BG in the beef pasture plots. A similar study on beneficial use of dredged materials in East Central Florida, U.S.A., was reported by Sigua *et al.* (2000). Patel *et al.* (2001) reported that grasses grown in

muck-amended topsoil had adequate and comparable nutrient levels with grasses grown in heavily fertilized and well-maintained golf course soils. Patel *et al.* (2001) further reported that horticultural studies showed encouraging results of several plant species, such as the holly (*Ilex cornuta*), liriope (*Liriope muscari*), oyster plant (*Rhoeo spathacea*), and bermudagrass (*Cynodon dactylon*).

Conclusions

The ability to reuse dredge materials from Lake Panasoffkee for agricultural purposes is important because it reduces offshore disposal and provides an alternative to disposal of the materials in landfills that are already overtaxed. The bottom sediments that were dredged from Lake Panasoffkee contained neither materials that would classify them as a human health risk, nor would require expensive hazardous waste handling and disposal. The heavy and trace metal contents of these materials were below the PEL and TEL. As such, the agricultural or livestock industry could utilize these DM to produce forages. The DM should be regarded as a beneficial resource, as a part of the ecological system. This study is expected to continue for several years to explore and assess the long-term efficacy of DM on productivity and quality of BG beyond its early establishment stage.

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