Bulk-Density and Organic-Carbon Characterization of Soil/Sediment in the Mississippi River Deltaic Plain

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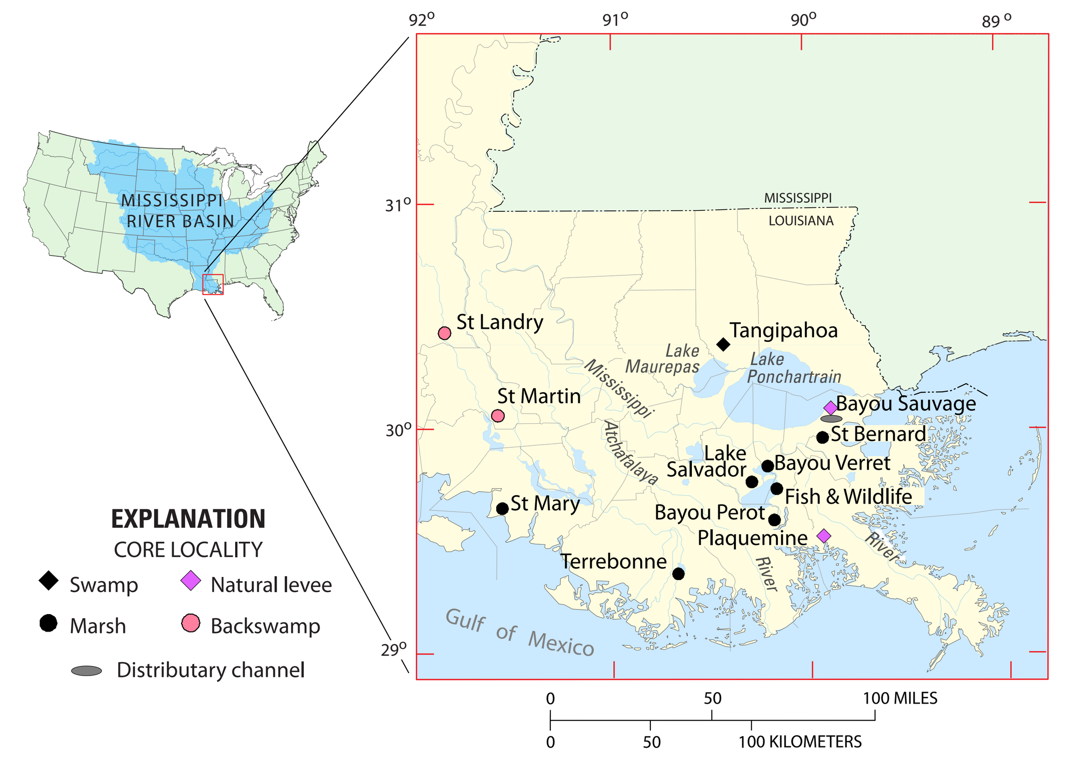

Figure 1. Map showing site locations for cores taken by the U. S. Geological Survey for terrestrial-carbon sequestration studies in the Mississippi River deltaic plain and the location of the study area in the Mississippi River Basin, near the terminus of the Mississippi River where it flows into the Gulf of Mexico.

Abstract #37260

Precise bulk-density (BD) measurements of organic soils, and mineral soils with high organic carbon content, are difficult to make but critical for accurate estimates of soil-mass properties such as soil-organic carbon (SOC) storage. For a SOC-sequestration study in the Mississippi River Deltaic Plain, 58 cores (fig. 1, site locations) were collected using seven methods. Percent core compaction was variable by method (table 1). Number of cores, and mean percent compaction, by core method, were 7, 35.5, pushed whole core; 19, 6.6, pushed half core; 10, 6.5, pounded half core; 7, 22.2, whole vibracore; 6, <1, Hargis sampler; and 7, <1, McCauley sampler (fig. 2). Cores were sampled every two centimeters for BD and SOC analyses (fig. 3, cores). Bulk-density and SOC data from the short push-cores and longer vibracores were used to estimate the SOC storage at locations within fresh, intermediate, and brackish marsh, backswamp, swamp, levee, and distributary environments (fig. 4–7). Bulk density varied inversely with SOC when SOC was <30 weight percent and showed no relation when SOC was >30 weight percent (fig. 8). Median BD values (g cm^{-3}) stratified by SOC content (<12, ≥12<18, ≥18<30, >30) ranged from 0.07-0.56 (fresh marsh, n=16), 0.07-0.41 (intermediate marsh, 5), 0.04-1.50 (brackish marsh, 21), 0.24-1.13 (levee, 6), 0.17-0.53 (distributary, 4), 1.32-1.35 (backswamp, 2), and 0.12 (swamp, 1). Median SOC values for these same groups ranged from 1.05-45.08 weight percent (fresh marsh), 6.33-39.67 (intermediate marsh), 0.47-39.25 (brackish marsh), 0.76-23.61 (levee), 8.55-30.43 (distributary), 0.97-1.09 (backswamp), and 37.81 (swamp) (table 2). Data from cores collected with the Hargis and McCauley samplers at fresh and intermediate marsh localities were compared with push-core and vibracore data in a balanced ANOVA to test the effects of coring method on the reproducibility of BD measurements (fig. 4 and table 3). Spatial variability and sampling technique both contributed to observed BD differences between push-core data and data from the other methods. Samples obtained by push-core methods provided the most consistent results.

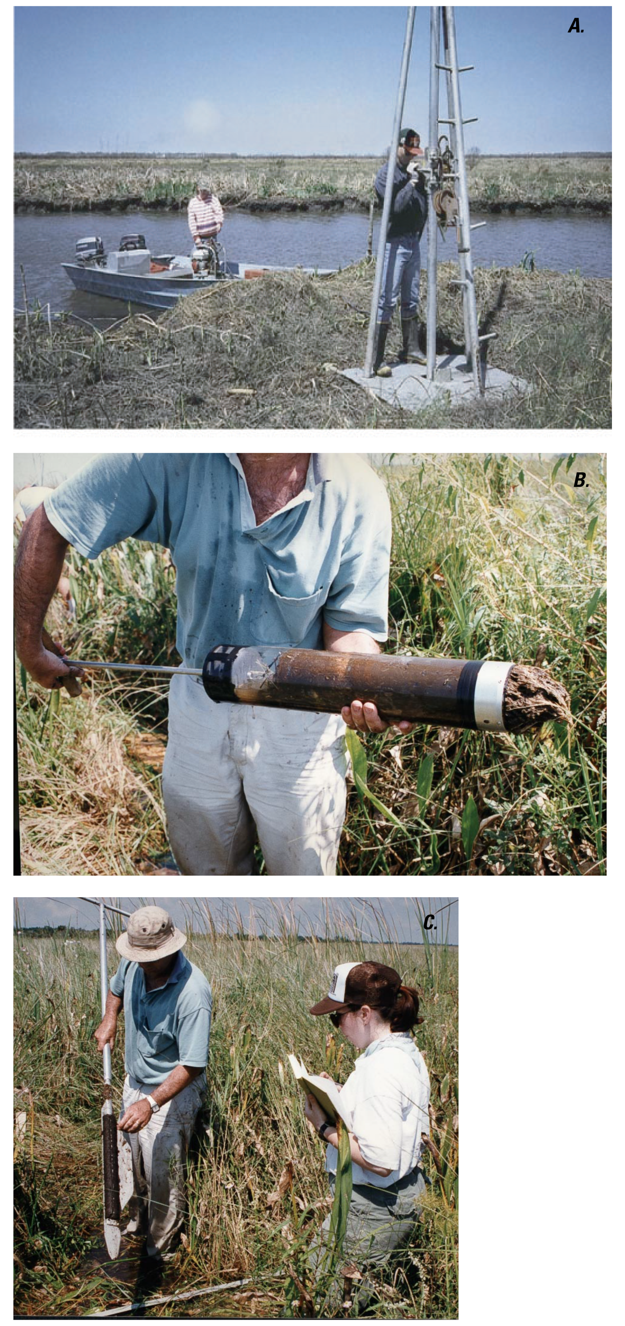

Figure 2. Marsh samplers, Bayou Perot intermediate-marsh sample locality—(A) vibracore equipment, (B) Hargis sampler, and (C) McCauley peat borer (Russian peat borer).

Table 1. Percent core-compaction by core type (sampling method) for selected cores, U.S. Geological Survey soil/sediment-carbon studies, Mississippi River Deltaic Plain, southeastern Louisiana

Location	Core Id	Mean percent compaction
	pounded half core	
Plaquemine levee	PLAQb	5.26
	PLAQc	5.26
	PLAQd	5.00
Bayou Sauvage levee	BSL2a	2.03
	BSL2b	5.26
	BSL2d	12.82
St. Martin backswamp	MR1b	15.25
	MR1c-splits1 and 2	10.20
	MR1d	4.26
St. Landry backswamp	SL1a	0.00
		6.53
	pushed half core	
Bayou Perot intermediate marsh	BPPa	17.65
	BPPb	4.88
	BPPc	13.51
Bayou Sauvage distributary	BSDb	2.04
	BSDc	1.93
	BSDd	1.92
Bayou Sauvage levee	BSLa	2.02
	BSLb	0.00
Lake Salvador fresh marsh	LSPa	5.88
	LSPb	8.23
	LSPc	5.00
St. Landry backswamp	SL1b	8.33
	SL1c	0.00
St. Mary fresh marsh	SM1a	0.00
	SM1b	5.66
Terrebonne brackish marsh	TB2a	5.89
Tangipahoa swamp	TN1b	22.73
	TN1c	6.78
	TN1d	13.33
		6.62
	pushed whole core	
Fish and Wildlife brackish marsl	FW	48.98
Bayou Verret fresh marsh	BV	32.65
St. Bernard brackish marsh	SB1a	6.97
	SB1b	8.88
Terrebonne brackish marsh	TB1a	53.85
	TB1b	44.78
	TB1c	52.38
		35.50
	whole vibracore	
Bayou Perot intermediate marsh	BPPf	15.35
	BPPg	11.70
Lake Salvador fresh marsh	LSPe	12.89
	LSPf	10.01
St. Bernard brackish marsh	SB1c	29.12
St. Mary fresh marsh	SM1c	21.35
Terrebonne brackish marsh	TB2c	54.60
		22.15
	Hargis sampler	
	assumed no compaction	
	McCauley sampler	
	assumed no compaction	

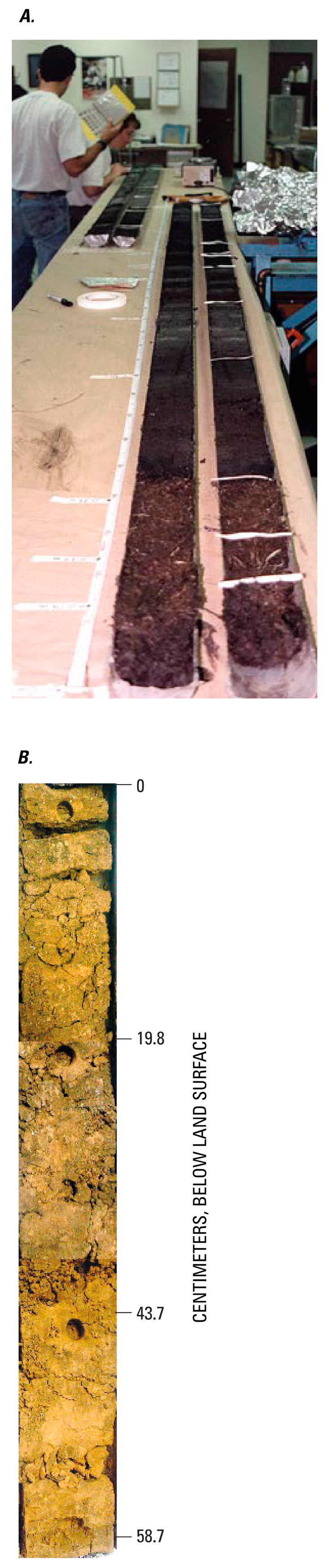

Figure 3. *A.* Both halves of Lake Salvador fresh-marsh vibracore LSPe on the right, and the Bayou Sauvage distributary push-core BSDc on the left to the rear of the laboratory table at the U.S. Army Corps of Engineers, New Orleans. Peat is the primary component in the fresh-marsh core LSPe and in the upper one third of distributary core BSDc.

B. Photograph of St. Martin backswamp push-core MR1d, St. Martin Parish (overlapping photographs spliced together). Typical back-swamp sediment in the region are dominantly very-fine sand and silt with zones of higher organic-carbon content that probably indicate the presence of buried soil A horizons. Delta^{14}C data for a sample in the lower third of push-core MR1d indicate a MODERN (about 1950) age at about 59 centimeters (cm) suggesting a sedimentation rate of 1.32 cm/yr which is significantly less than the 1.94 cm/yr rate indicated by the 1963 depth-to-peak ^{137}Cs activity at about 63 cm in adjacent push-core MR1c (no picture). These differences in paired cores demonstrate the difficulties inherent in using organic carbon that is associated with fluvially deposited mineral sediment for age estimations. The small bore-holes evident in the core are for 1-cm depth x 1-cm diameter samples taken for bulk density analysis. Core descriptions are in table 1-1, USGS Professional Paper 1686B.

Table 2. Summary descriptive statistics for organic-carbon and bulk-density analyses of selected cores, U.S. Geological Survey soil/sediment-carbon studies, Mississippi River deltaic plain, southeastern Louisiana.

[ocgrp, organic carbon group; ocgrp (by weight percent): 1, <12; 2, ≥12<18; 3, ≥18<30; 4, ≥30; <, less than; > greater than; ≥, less than or equal to; No., number of samples; g cm^{-3}, gram per cubic centimeter]

Core identifier[1]	ocgrp	Organic carbon No.	Mean	Median	Minimum	Maximum	Bulk density No.	Mean	Median	Minimum	Maximum
			Weight percent					g cm^{-3}			
Fresh marsh											
BV	1	5	8.75	9.28	5.82	10.70	5	0.19	0.19	0.13	0.28
	2	5	14.54	13.70	13.10	16.20	5	0.11	0.11	0.07	0.16
	3	2	20.88	20.88	19.60	22.15	2	0.11	0.11	0.07	0.14
LSPb	3	14	25.32	25.10	19.68	29.53	14	0.10	0.10	0.06	0.15
	4	18	37.27	36.58	30.21	43.79	18	0.07	0.06	0.03	0.11
LSPe	1	14	1.83	1.05	0.40	7.47	14	0.60	0.56	0.44	0.89
	2	2	13.91	13.91	13.61	14.22	2	0.26	0.26	0.24	0.29
	3	1	22.93	22.93	22.93	22.93	1	0.26	0.26	0.26	0.26
	4	10	39.22	39.72	30.34	45.77	10	0.15	0.16	0.10	0.22
SM1a	1	2	10.48	10.48	9.52	11.45	2	0.32	0.32	0.28	0.36
SM1a	2	8	14.93	15.57	12.36	16.62	8	0.23	0.21	0.17	0.36
SM1a	3	6	24.86	25.67	18.08	29.55	6	0.13	0.13	0.10	0.16
SM1a	4	13	40.09	41.21	32.96	42.92	13	0.10	0.10	0.07	0.13
SM1c	2	2	14.05	14.05	14.04	14.06	2	0.18	0.18	0.15	0.22
SM1c	3	8	24.46	25.16	18.18	28.83	8	0.15	0.12	0.07	0.30
SM1c	4	10	44.28	45.08	34.88	50.64	10	0.14	0.07	0.07	0.31
Intermediate marsh											
BPPb	4	29	39.43	39.67	30.89	48.62	29	0.07	0.07	0.05	0.09
BPPg	1	14	5.83	6.33	0.56	10.67	14	0.56	0.41	0.26	1.60
BPPg	2	4	17.19	17.20	16.60	17.78	4	0.21	0.21	0.17	0.25
BPPg	3	11	23.27	22.24	18.21	28.73	11	0.19	0.18	0.13	0.35
BPPg	4	7	38.25	38.44	32.21	44.79	7	0.12	0.12	0.08	0.17
Brackish marsh											
FW	2	1	15.00	15.00	15.00	15.00	1	0.10	0.10	0.10	0.10
FW	3	6	23.43	21.80	19.00	29.60	6	0.06	0.06	0.03	0.11
FW	4	2	31.60	31.60	30.50	32.70	2	0.04	0.04	0.03	0.04
SB1a	2	4	14.86	14.90	12.31	17.32	4	0.15	0.15	0.11	0.18
SB1a	3	16	26.63	26.22	23.09	29.98	16	0.11	0.11	0.08	0.16
SB1a	4	15	34.48	33.40	31.22	39.24	15	0.10	0.10	0.08	0.13
SB1c	1	3	7.65	10.23	1.84	10.89	3	0.19	0.21	0.12	0.23
SB1c	2	3	15.22	15.75	12.61	17.29	3	0.21	0.23	0.12	0.28
SB1c	3	7	22.73	22.23	20.94	26.10	7	0.20	0.18	0.14	0.29
SB1c	4	11	34.81	33.99	31.92	38.18	11	0.12	0.12	0.09	0.19
TB1a	1	6	10.72	10.65	10.27	11.47	6	0.11	0.10	0.10	0.14
TB1a	2	9	15.27	15.72	12.85	16.88	9	0.08	0.08	0.07	0.10
TB1a	3	3	21.50	21.38	20.58	22.54	3	0.08	0.07	0.06	0.10
TB2a	1	6	10.24	10.38	9.15	11.09	6	0.17	0.16	0.13	0.22
TB2a	2	14	14.96	15.20	12.37	17.27	14	0.12	0.12	0.10	0.17
TB2a	3	13	21.06	20.72	18.06	29.97	13	0.11	0.10	0.09	0.13
TB2a	4	15	36.27	37.63	30.32	39.88	15	0.07	0.07	0.06	0.09
TB2c	1	45	2.58	0.47	0.04	9.96	45	1.29	1.50	0.30	1.92
TB2c	2	6	14.38	13.97	13.00	16.63	6	0.11	0.10	0.07	0.15
TB2c	3	3	24.14	25.51	20.90	25.99	3	0.07	0.07	0.05	0.08
TB2c	4	11	38.27	39.25	31.50	40.86	11	0.05	0.05	0.04	0.06
Natural levee											
PLAQb	1	28	1.38	0.76	0.51	5.42	28	1.09	1.13	0.40	1.42
BSLa	1	29	3.03	2.50	0.73	9.03	29	0.93	0.84	0.34	1.43
BSLa	2	3	16.34	17.10	14.06	17.87	3	0.27	0.25	0.25	0.32
BSLa	3	9	22.88	23.23	19.27	25.79	9	0.28	0.26	0.21	0.37
BSL2b	1	27	2.07	1.48	0.73	10.62	27	0.91	0.94	0.41	1.13
BSL2b	3	1	23.61	23.61	23.61	23.61	1	0.24	0.24	0.24	0.24
Distributary											
BSDb	1	6	8.33	8.55	5.51	11.24	6	0.53	0.53	0.46	0.59
BSDb	2	1	15.42	15.42	15.42	15.42	1	0.33	0.33	0.33	0.33
BSDb	3	19	26.95	27.12	19.91	29.92	19	0.20	0.19	0.14	0.32
BSDb	4	10	30.55	30.43	30.05	31.66	10	0.19	0.17	0.13	0.32
Backswamp											
MR1c	1	32	1.22	1.09	0.62	2.61	32	1.24	1.32	0.80	1.62
SL1b	1	31	1.71	0.97	0.37	6.40	31	1.31	1.35	0.55	2.05
Swamp											
TN1c	4	37	37.56	37.81	31.29	45.28	37	0.12	0.12	0.07	0.17

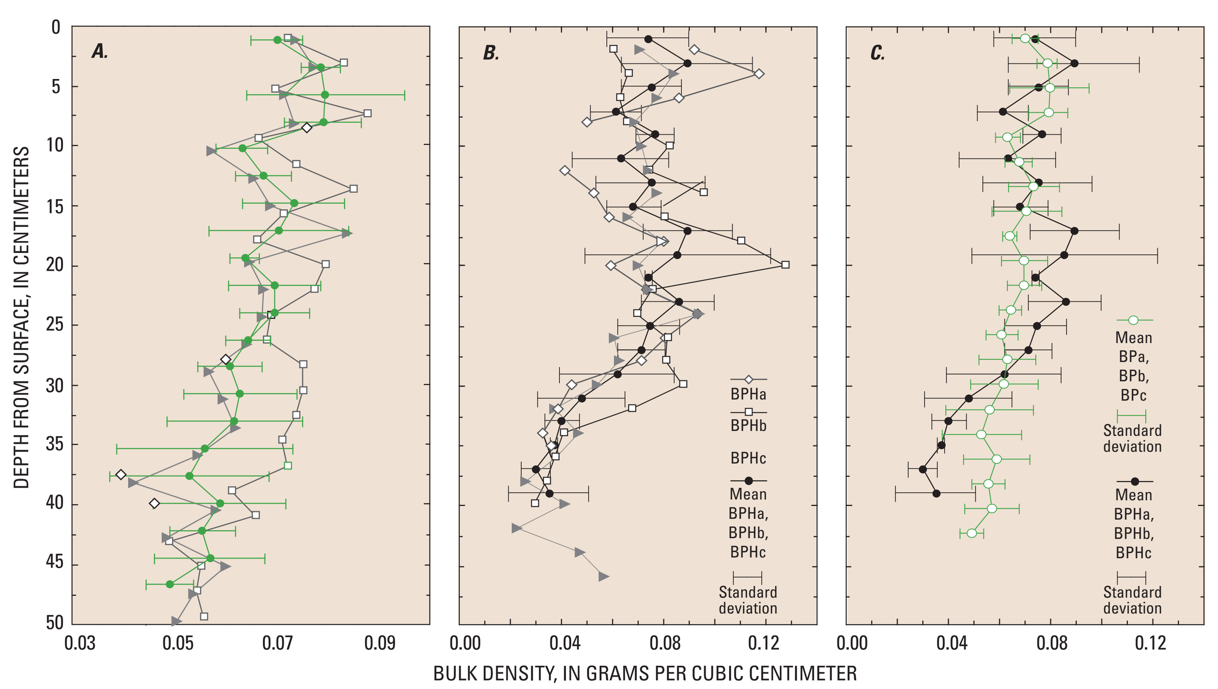

Figure 4. Comparison of Bayou Perot bulk-density values for samples from the surface 50 centimeters of marsh—(*A*) push-core samples, (*B*) Hargis samples, and (*C*) mean and standard deviation for push-core and Hargis samples (x-axis same as in *B*). The x-axis scales for *A* and *B* differ; *B* and *C* are the same. Note the greater range in bulk-density values for the Hargis samples in *C*.

Table 3. Balanced analysis of variance looking at the effects of three coring techniques on bulk-density measurements for sediment from fresh- and intermediate-marsh environments, U.S. Geological Survey soil/sediment-carbon studies, Mississippi River deltaic plain, southeastern Louisiana.

[g cm–3, gram per cubic centimeter; ANOVA, analysis of variance; Pm, push-core measured bulk density (not corrected for compaction); Pc, push-core compaction-corrected bulk density; H, Hargis; M, McCauley; LS, Lake Salvador; BP, Bayou Perot; outline of Mississippi River deltaic plain shown in figure 3A]

Shallow-core comparison

Core site	Core	Number of intervals	Mean bulk density (g cm^{-3}) Pm	Pc	H	ANOVA results (alpha = 0.05)
LS	1	20	0.080	0.076	0.057	PmH–core, method; PcH–core, method
	2	20	0.095	0.090	0.072	
	3	20	0.092	0.087	0.056	
BP	1	18	0.088	0.077	0.064	PmH–method, core*meth PcH–nsd
	2	18	0.077	0.075	0.076	
	3	18	0.075	0.068	0.067	

Deep-core comparison

Core site	Core	Number of intervals	Mean bulk density (g cm–3) Pm	Pc	M	ANOVA results (alpha = 0.05)
LS	1	7	0.213	0.152	0.088	PmM–method PcM–method
	2	7	0.166	0.115	0.091	
BP	1	11	0.185	0.138	0.154	PmM–nsd PcM–core
	2	11	0.29	0.23	0.189	

[1] Multiple cores were collected by three different methods at Lake Salvador (LS, fresh marsh, St. Charles Parish) and Bayou Perot (BP, intermediate marsh, Lafourche Parish). Three shallow cores were collected by push-core (P) and Hargis (H) methods and 2 deep cores by push-core (P, vibracore) and McCauley (M) methods. Each core was sub-sampled and bulk-density measurements made on selected depth intervals. Bulk-density measurements of the push-core samples were corrected for core compaction. Compaction was negligible in cores collected by the Hargis and McCauley methods. ANOVA results listed indicate significant differences in mean bulk densities are due to spatial variability at the site (core), core-collection method (method), and(or) interaction between core and method (core*meth); nsd, no significant differences. The comparisons tested are PmH (push-core, measured, with Hargis), PcH (push-core, compaction-corrected, with Hargis), PmM (vibracore, measured, with McCauley), and PcM (vibracore, compaction-corrected, with McCauley).

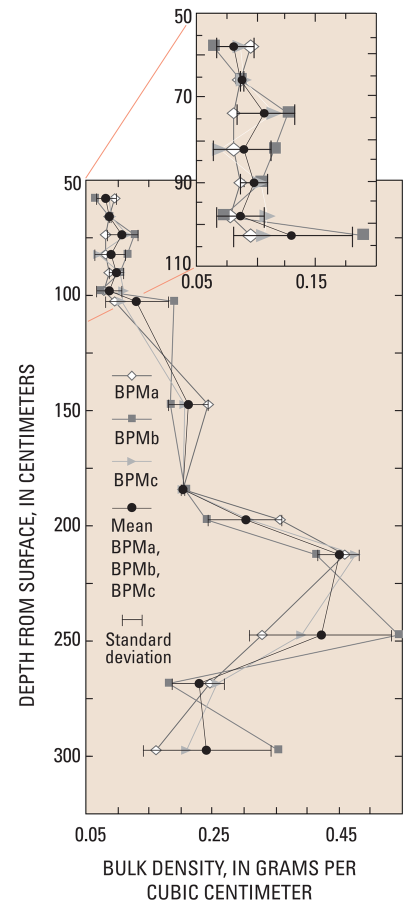

Figure 5. Bulk-denisty values for Bayou Perot intermediate-marsh McCauley- peat-borer samples. Smaller box is enlargement of the 50–110 centimeter depth interval.

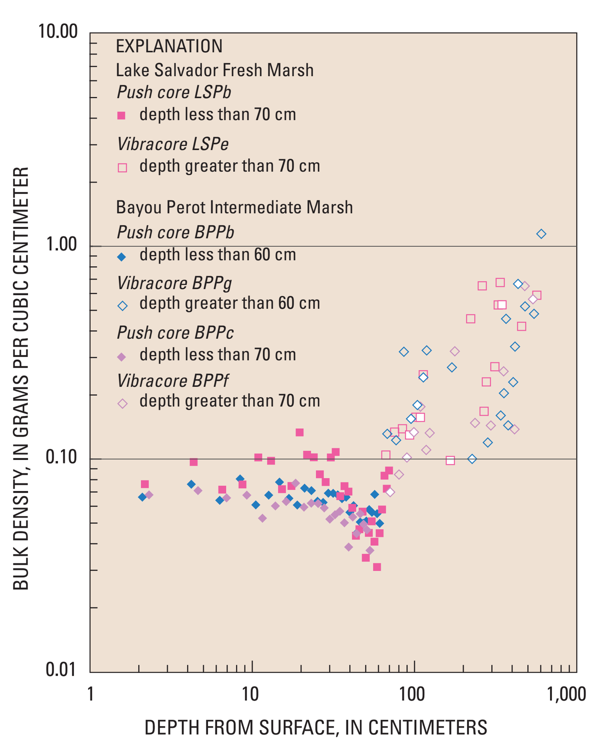

Figure 6. Bulk-density values for Lake Salvador fresh-marsh and Bayou Perot intermediate marsh push-core and vibracore samples. Note decrease in bulk density in the 30–70 centimeter depth interval. This zone may mark the base of the flotant (floating marsh) surface peat.

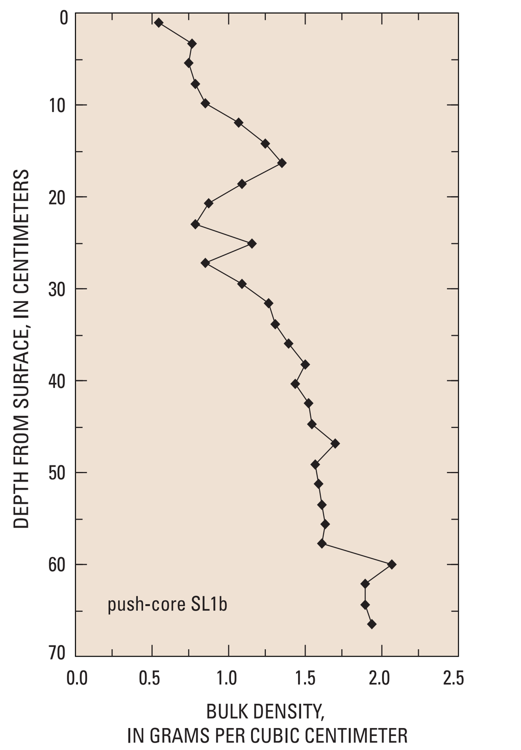

Figure 7. Bulk-density values for st. Landry backswamp push-core SL1b samples.

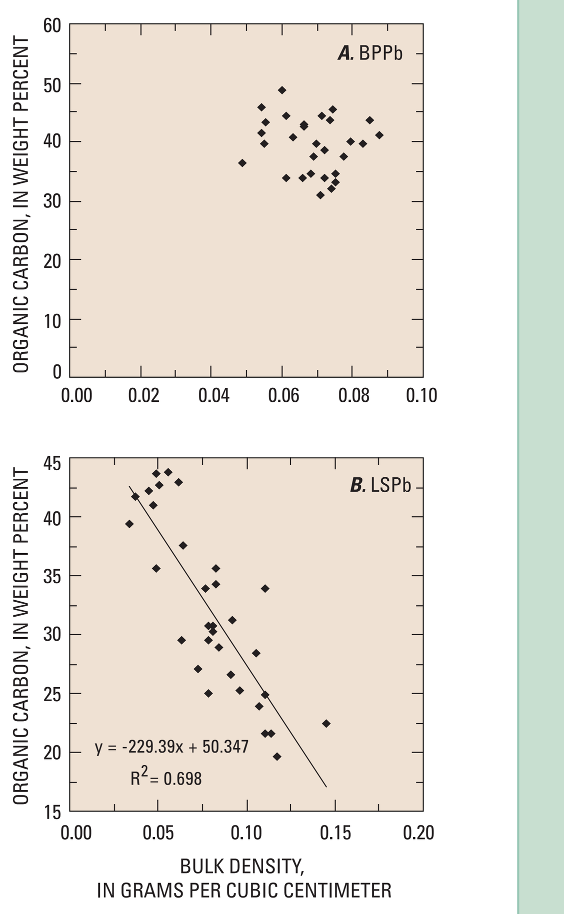

Figure 8. Bulk-density values versus organic-carbon (OC) concentration-(*A*) Bayou Perot intermediate marsh push-core BPPb, and (*B*) Lake Salvador fresh-marsh push-core LSPb. OC concentration for BPPb is ≥ 30 weight percent; for LSPb, OC concentration varies and is inversely related to bulk density.

CONCLUSIONS

Precise bulk-density (BD) measurements of organic soils, and mineral soils with high organic carbon content, are difficult to make but critical for accurate estimates of soil-mass properties such as soil-organic carbon (SOC) storage.

Bulk-density values for high organic-carbon content soil/sediment are difficult to obtain because the soil/sediment is commonly saturated and because the bulk-density values are much lower than those of mineral soil/sediment and are more sensitive to error-regardless of the source of the error (field or laboratory).

Bulk density varied inversely with SOC when SOC was <30 weight percent and showed no relation when SOC was >30 weight percent.

Bulk-density data for cores taken by the "short push-core method" are more internally consistent than data for samples collected by other methods.

Measured bulk-density values <0.06 g cm^{-3} probably have a standard error of ±100 percent.

Spatial variability and sampling technique both contributed to observed BD differences between push-core data and data from the other methods. Samples obtained by push-core methods provided the most consistent results.

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