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Wetland Soil Formation in the Rapidly Subsiding Mississippi River Deltaic Plain: Mineral and Organic Matter Relationships

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The elevation of submerging coastal marshes is maintained by vertical accretion of mineral and organic matter. Submergence rates currently exceed 1·0 cm year^{-1} in the Mississippi Deltaic Plain and are expected to increase. Mineral matter–organic matter relationships were examined in surface profiles of Mississippi Deltaic Plain soil from both Active Delta Zone marsh (which receives freshwater and mineral sediment from the Atchafalaya or Mississippi Rivers) and Inactive Delta Zone marsh (which relies on rainfall for freshwater and on reworked sediments for mineral matter) to gain insights into marsh soil structure and formation.

Mineral and organic matter accounted for 4–14% of soil volume. The remainder was pore space and was occupied by water and entrapped gases. Organic matter occupied more volume than mineral matter in all but saline marsh soil. The regular influx of mineral matter to active fresh marsh resulted in active fresh marsh soil containing twice as much mineral and organic matter as inactive fresh marsh soil. Within the Inactive Delta Zone, the volume of mineral and organic matter increased from fresh (inland) to saline (seaward) marshes.

Saline marsh soil required 1·7 times as much mineral matter as brackish marsh soil to vertically accrete at similar rates, possibly as a result of soil bulk density requirements of the dominant saline marsh plant, *Spartina alterniflora*. Vertical accretion rates were highest in the Active Delta Zone, probably as a result of increased mineral matter availability and delivery.

Current, best estimates of the combination of mineral and organic matter required (g m^{-2} year^{-1}) to maintain marsh surface–water level relationship are fresh marsh: organic matter $=1700+269x$, mineral matter $=424x$; brackish marsh: organic matter $=553+583x$, mineral matter $=1052x$; saline marsh: organic matter $=923+601x$, mineral matter $=1798x$, where $x=$ the rate of submergence (cm year^{-1}).

Introduction

Global sea-level rise during the last 4000 years averaged 0·08 cm year^{-1} (Redfield, 1967), and marsh elevation was maintained by vertical accretion of mineral and organic matter; but global sea-level rise is currently estimated at 0·2 cm year^{-1} (Peltier & Tushingham,

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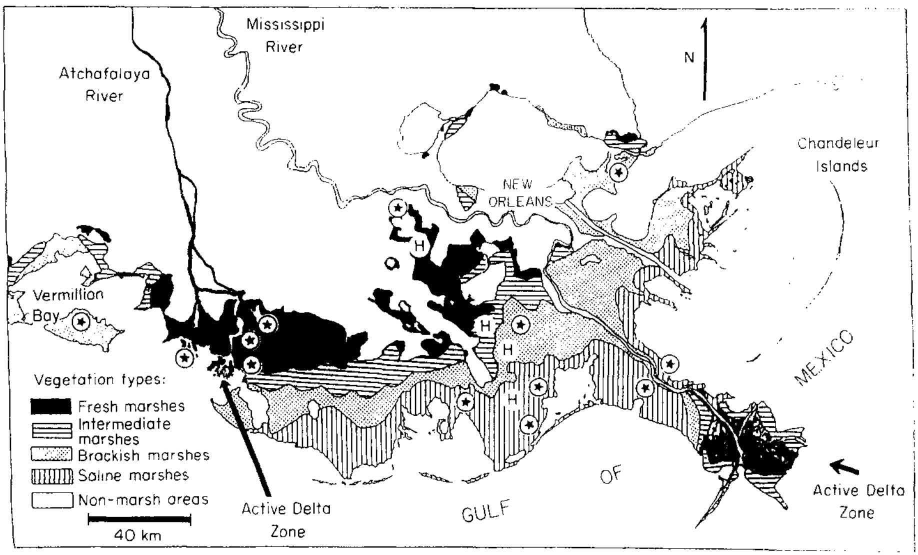

Figure 1. Marsh types within the Active and Inactive Delta Zones of the Mississippi River Deltaic Plain (adapted from Chabreck, 1970; Chabreck & Linscombe, 1978); stars are approximate locations of sample sites from which individual core data were analysed; H's are approximate locations of sites from which composite data (mean of seven cores from each site); from Hatton *et al.* (1983) were analysed.

1989), and may reach 1·0 cm year^{-1} by 2050. Submergence of many coastal marshes may result, causing substantial wetland loss (EPA, 1988).

Vertical accretion of coastal marshes must counter not only global sea level rise, but also subsidence. Subsidence is greater in the Mississippi Deltaic Plain than at any other location on the northern Gulf of Mexico coast (Penland & Ramsey, 1990). Subsidence is greatest on the coast and decreases inland (Kolb & Van Lopik, 1958), but there are few estimates of subsidence rates. On the Louisiana coast, subsidence and global sea-level rise combine to produce submergence rates up to 1·11 cm year^{-1} (Penland & Ramsey, 1990).

Knowledge of organic and mineral relationships in marsh soils of the Louisiana Deltaic Plain is limited. The purpose of this paper is to examine mineral–organic matter relationships in the different marsh types found in the Mississippi Deltaic Plain and, from this information, to initiate estimates of sediment requirements within these marshes in relation to various submergence rates. Furthermore, the relationship between vertical accretion and incorporation of mineral and organic matter into these soils was also examined. An understanding of these relationships may be useful in efforts to mitigate coastal wetland loss in Louisiana and other areas.

Study area

The Mississippi River Deltaic Plain contains $1{\cdot}22 \times 10^6$ ha of coastal marshes and was formed by sediment deposition of the Mississippi River over the past 6000 years. It is the site of present and former delta complexes of the Mississippi River and extends from the Chandeleur Islands, west to Vermillion Bay (Figure 1). Only marshes at the mouths of the Mississippi and Atchafalaya Rivers are active, i.e. under the direct influence of riverine processes. Marshes in the remainder of the area are inactive and depend on local rainfall for freshwater inputs, and on reworked sediments for mineral matter inputs. Before the Mississippi River was levied for flood control, many of these marshes also received periodic inputs of freshwater and mineral matter from overbank flooding by the Mississippi River and its distributaries (Gagliano & Van Beek, 1970).

Coastal marshes in Louisiana have been classified on the basis of plant communities and associated water salinity (Chabreck & Linscombe, 1978). Fresh, brackish and saline marshes each occupy roughly 30%, with intermediate (to fresh and brackish occupying about 11% of the marsh area. Only fresh and intermediate marshes occur in the Active Delta Zones near the mouths of the Mississippi and Atchafalaya Rivers. In the Inactive Delta Zone, the bands of saline and brackish marsh have expanded at the expense of fresh and intermediate marsh in recent years (Chabreck & Linscombe, 1982).

Coastal marshes in Louisiana have experienced substantial net loss within the last 30 years (Gagliano & Van Beek, 1970; Adams *et al.*, 1976; Turner & Cahoon, 1987). These marshes have always experienced wetland loss, but until recently, loss in one area was more than offset by natural marsh creation in another area as a result of channel switching and sediment deposition by the Mississippi River. The Mississippi River is now not being allowed to switch channels because of flood control and navigation practices, and has long since prograded to the edge of the continental shelf, and is unable to create new marsh in such deep water. Natural marsh creation in coastal Louisiana is now occurring only at the mouth of the Atchafalaya River, and is inadequate to offset marsh loss.

Measurements of vertical marsh accretion rates indicate that many eroding coastal Louisiana marshes are not accreting at rates sufficient to maintain them in the intertidal zone (Delaune *et al.*, 1978, 1983*a*; 1986*a*; Hatton *et al.*, 1983). Furthermore, man-made canals have directly destroyed 4–5% of the wetland area in Louisiana, and altered the natural hydrological conditions as well (Turner & Cahoon, 1987). Wetland vegetation, which is important in the structure of marsh soils, is sensitive to hydrological conditions; but the relative importance of subsidence and altered hydrological conditions to wetland loss is unknown. The rate of marsh loss in these coastal marshes is variable, with some locations losing up to 1·89% year^{-1} (Adams *et al.*, 1976).

Inland marsh soil contains less mineral matter than streamside marsh soil in all four marsh types (Hatton *et al.*, 1983) and, as a result of elevational differences, saline marsh vegetation is less robust in inland marshes than in streamside marshes (Delaune *et al.*, 1983*b*; Mendelssohn & McKee, 1988; Pezeshki & Delaune, 1988). The majority of wetland loss in coastal Louisiana, 70–90%, has occurred in inland marshes (Turner & Cahoon, 1987).

Sampling and analytical methods

Soil bulk density and per cent organic matter from 30 cores from 13 sites throughout the Mississippi Deltaic Plain and from published data from an additional four sites, one composite profile ($n = 7$ cores) from each site, were analysed (Hatton *et al.*, 1983). The cores were from 38 to 50 cm in depth and represented sites from which samples had been taken for ^{137}Cs dating. Published vertical accretion measurements were from 69 cores from the same 17 sites (Delaune *et al.*, 1986*b*). In this paper, active will be used to denote Active Delta Zone marshes, but to reduce wordiness, the term inactive will be dropped when referring to marsh types from the Inactive Delta Zone when possible. Only data from inland marsh areas were used in these analyses, and only active intermediate marshes were not sampled. All active marsh cores were taken from fresh marsh near the mouth of the Atchafalaya River.

Soil cores were collected with a 15-cm diameter, thin-walled, sharpened coring tube as described by Delaune *et al.* (1983*a*), with the exception that some cores were sectioned into 2-cm increments rather than 3-cm increments. Soil bulk density and per cent organic and mineral matter were measured in each increment in some cores, and in every other increment in other cores. Soil bulk density was determined from the oven-dried weight of a known volume of wet soil. Per cent mineral matter and per cent organic matter by weight in oven-dried soil was determined by loss on ignition as described by Ball (1964). Ignition at low temperature to determine organic matter is accurate for calcareous (Davies, 1974), as well as non-calcareous soils (Ball, 1964).

Mineral and organic matter relationships were examined on a volume basis because volume probably more closely reflects structural importance in marsh soil than weight. Particle density of mineral matter (2·61 g cm^{-3}) and organic matter (1·14 g cm^{-3}) (Delaune *et al.*, 1983*a*), and the measurements of soil bulk density and per cent weight of organic and mineral matter were used to estimate the volume of the mineral and organic matter in soil increments. Volume not occupied by mineral or organic matter (pore space) was assumed to be occupied by water and gas. Volume profiles for each of the soil cores were created in this way. Composite volume profiles for each marsh type were created from the individual volume profiles.

The volume of mineral matter, organic matter and water and gas in the upper 10 cm of soil was compared between Active and Inactive Delta Zones, and also among the marsh types of the Inactive Delta Zone, as weighted randomized block design-analysis of variances (ANOVA) blocking on site, with Proc GLM of SAS (SAS Institute Inc., Cary, NC 27512-800, U.S.A.). The Waller–Duncan K-ratio t-test was used as a post-ANOVA technique to determine which of the marsh types of the Inactive Delta Zone differed from one another. For these analyses, it was assumed that there was no relationship between depth and the volume of organic matter, mineral matter, or porosity in the upper 10 cm of soil. To test this assumption, depth was regressed against these variables within each marsh type as a weighted randomized block design blocking on site, with Proc Reg of SAS. An α level equal to 0·0500 was chosen as the critical limit for all analyses.

In the statistical analyses, the assumption of independent and normally distributed error was suspect because these are percentage data near the limits of 0 and 100 (Steele & Torrie, 1980, pp. 233–237). Normality could not be tested directly with available methods because these are unbalanced data. Therefore the means of the residual error terms were tested using Proc Univariate of SAS. The S-statistic, box plot and distribution of residuals were all considered before concluding normality. Several transformations were tried for each variable, and the log and square root transformations (Steele & Torrie, 1980, pp. 234–235) were found to produce the most normally distributed error terms.

The weight of organic and mineral matter required to form 0·5, 1·0 and 1·5 vertical cm of marsh soil in the marsh types of the Inactive Delta Zone was calculated from the average soil bulk density and per cent organic and mineral matter within the top 10 cm of soil. The weight of organic and mineral matter was used rather than volume because sediment availability and organic matter production are more likely to be reported on a weight basis. The weights of mineral and organic matter were plotted against vertical accretion, and the equation of the resulting line was calculated. The slope of the line is the organic and mineral matter requirements (g m^{-2} per vertical cm) for soil formation in relation to submergence. Only the top 10 cm of soil were used because at some point in the column the soil begins to compact and dewater. Inclusion of soil below this point would overestimate mineral and organic matter, and underestimate water and gas in the soil at the time of formation.

Results

Regression analysis showed that there were no significant effects of depth on the per cent volume of organic matter ($P=0{\cdot}9575$), mineral matter ($P=0{\cdot}1409$) or water and gas ($P=0{\cdot}2649$) within the upper 10 cm of soil in any marsh type. Compaction must begin deeper in the soil profile.

ANOVA indicated that active fresh marsh soil differed from inactive fresh marsh soil with respect to the volumes of organic matter, mineral matter and water and gas. Active fresh marsh soil had more mineral ($P=0{\cdot}0001$) and organic matter ($P=0{\cdot}0001$) than inactive fresh marsh soil, hence porosity was lower ($P=0{\cdot}0001$). Organic matter ($P=0{\cdot}0001$), mineral matter ($P=0{\cdot}0061$) and water and gas ($P=0{\cdot}0070$) differed among sites, although replicate cores within sites did not differ (organic matter: $P=0{\cdot}1756$; mineral matter: $P=0{\cdot}1845$; water and gas: $P=0{\cdot}1319$).

Within the Inactive Delta Zone, bulk density increased from fresh (inland) to saline (seaward) marshes; whereas per cent organic carbon by weight generally decreased (Table 1). However, intermediate marsh had a higher per cent of organic carbon than fresh marsh. Porosity was greater than 85% throughout the upper 50 cm of soil in all but saline marsh (Figure 2). Among inactive marsh types, porosity in brackish marsh soil most resembled porosity in active fresh marsh soil (Figures 2 and 3). Bulk density and per cent organic matter in brackish marsh were also more similar to active fresh marsh than were other marsh types of the Inactive Delta Zone.

ANOVA indicated differences in the volumes of organic matter, mineral matter and water and gas among the marsh types within the Inactive Delta Zone. Post-analyses comparisons indicated that intermediate marsh soil was similar to brackish and saline marsh soils with respect to organic matter, but more like fresh marsh soil with respect to mineral matter and water and gas. Saline marsh soils had more mineral matter and less water and gas than other marsh types. Organic matter ($P=0{\cdot}0039$), mineral matter ($P=0{\cdot}0001$) and water and gas ($P=0{\cdot}0001$) differed among sites within different marsh types. Replicate cores from the same site did not differ with respect to organic matter ($P=0{\cdot}2109$) or porosity ($P=0{\cdot}3346$), but mineral matter did differ among some replicate cores ($P=0{\cdot}0071$).

Within the upper 10 cm of Inactive Delta Zone marsh, the volume of organic matter increased from inactive fresh (inland) to saline (seaward) marsh, but for mineral matter this trend was interrupted in intermediate marsh (Table 1). Saline marsh contained 2·2 and 4·2 times more organic matter and mineral matter than inactive fresh marsh. Porosity differed by 10% between inactive fresh and saline marsh, and generally decreased from fresh (inland) to saline (seaward) marshes, but this trend was also interrupted in intermediate marsh. On a volume basis, organic matter was more important than mineral matter in all but saline marsh soil. The ratio of organic matter to mineral matter was similar in active fresh (1·5:1), inactive fresh (1·4:1) and brackish marsh (1·3:1). In inactive intermediate marsh soil the organic matter to mineral matter ratio was 3·0:1, and in saline marsh soil it was 0·8:1.

Vertical accretion rates were greatest in the Active Delta Zone (Table 1). Within the Inactive Delta Zone, accretion rates in brackish and saline marsh were similar, and greater

TABLE 1. Bulk density, per cent organic carbon by weight, vertical accretion rates and volumes of organic matter, mineral matter and water and gas in the upper 10 cm of soil from inland marshes of the Mississippi Deltaic Plain

Marsh type	No. of sites	No. of Cores	Bulk density ($g\ cm^{-3}$)		Organic carbon (% dry wt)		Vertical accretion[a] ($cm\ year^{-1}$)		Per cent by volume		
			mean	(SD)	mean	(SD)	mean	(SD)	Organic matter	Mineral matter	Water and gas
Active											
Fresh	3	7	0·14	(0·05)	19·19	(4.32)	0·86	(0·108)	4·91	3·18	91·91
Inactive											
Fresh	2	8	0·07	(0·03)	17·29	(4·91)	0·67	(0·015)	2·36	1·63	96·02
Intermediate	1	7	0·08	(0·05)	25·50	(5·52)	0·64	(0·38–1·06)[b]	3·96	1·33	94·70
Brackish	4	17	0·16	(0·07)	16·45	(4·41)	0·72	(0·077)	5·11	4·03	90·86
Saline	7	18	0·24	(0·11)	12·24	(5·95)	0·72	(0·137)	5·27	6·89	87·84

[a]Vertical accretion rates were determined at the same sites, but from a total of 69 cores.
[b]Range.

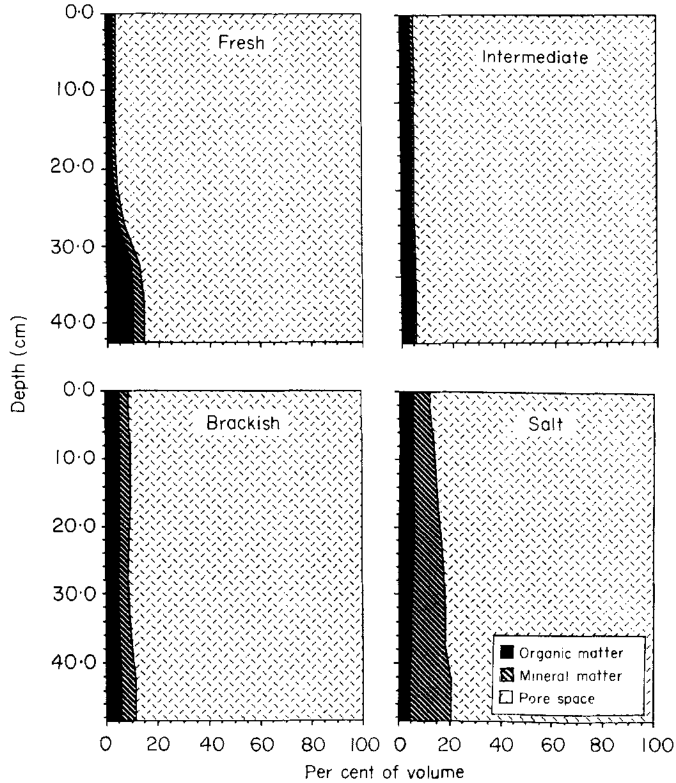

Figure 2. The relationship of organic matter, mineral matter and pore space in soil of the different marsh types of the Inactive Delta Zone, Mississippi River Deltaic Plain.

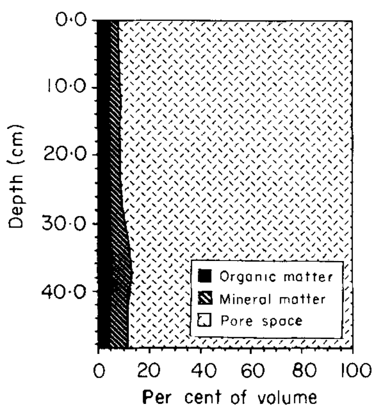

Figure 3. The relationship of organic matter, mineral matter and pore space in soil of fresh marsh of the Active Delta Zone, Mississippi River Deltaic Plain.

than in fresh and intermediate marsh (Table 1). Accretion rates were most variable in saline and active fresh marshes, presumably where mineral matter availability was greater (Table 1). On a weight basis, the requirements for mineral matter were greater than for organic matter in all marsh types (Figure 4).

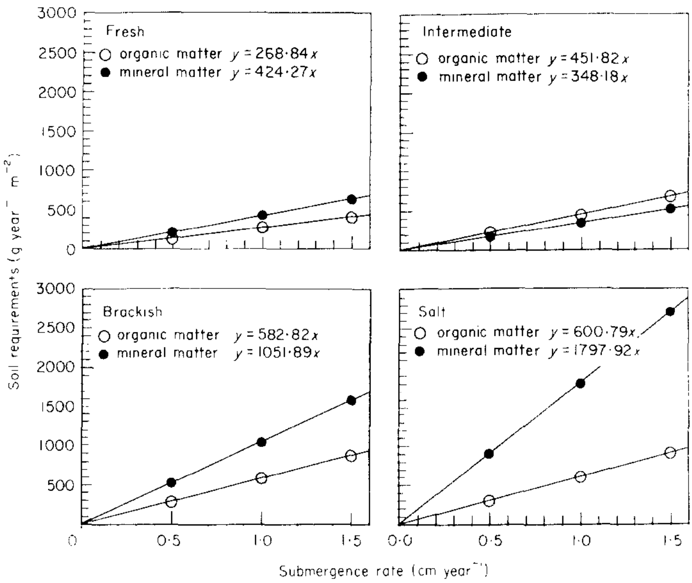

Figure 4. Preliminary estimates of organic matter and mineral matter requirements in the different marsh types of the Inactive Delta Zone, Mississippi River Deltaic Plain.

Discussion

Mineral matter

Plant growth in these marshes is enhanced by mineral matter because mineral matter releases mineral nutrients such as calcium, potassium and phosphorus, and under reduced conditions provides cation exchange and sorption sites for orthophosphate which restricts phosphate leaching (Patrick & Khalid, 1974). Mineral matter has little effect on nitrogen, the other major limiting plant nutrient, and these marshes are nitrogen limited (Buresh *et al.*, 1980; Delaune *et al.*, 1986*c*; Patrick & Delaune, 1976), and depend on the mineralization of organic matter for nitrogen.

Comparison between delta zones. Fresh marsh in the Active Delta Zone contained 2·1 times more mineral matter than fresh marsh in the Inactive Delta Zone. Mineral matter availability was undoubtedly greater in active fresh marsh water bodies than in inactive fresh marsh water bodies. Furthermore, the inactive fresh marsh sampled was floating marsh which is seldom covered by water, whereas active fresh marsh is regularly covered by flood waters. The combination of greater availability and delivery of mineral matter in active fresh marsh was most likely responsible for the greater volume of mineral matter in active fresh marsh soil.

Comparisons among marsh types. To some degree, mineral matter appeared to be incorporated into soil in proportion to availability. In fresh and intermediate marshes, where mineral matter is probably not as available, mineral matter contributed less than 2·0% to the volume of these soils. In the other marsh types, mineral matter contributed 4·0–6·9% of the volume. The low volume of mineral matter in inactive fresh marsh soils was not a result of marsh type; active fresh marsh, where mineral matter is more available, incorporated more mineral matter.

Organic matter

A given volume of organic matter probably contributes more to soil structure than a similar volume of mineral matter because soil organic matter is either living root mass, or is partially decomposed plant parts which retain some structural integrity. Thus, soil organic matter forms interlocking networks that particulate mineral matter alone cannot. This network was in all soil increments, but appeared strongest from a few cm below the surface down to 10–20 cm below the surface, i.e. within the living root zone. There may be an optimal ratio of organic matter to mineral matter to pore space which would require the least amount of organic and mineral matter to produce structurally strong soils and promote vigorous plant growth.

Comparison between delta zones. Fresh marsh in the Active Delta Zone contained 2·0 times more organic matter than fresh marsh in the Inactive Delta Zone. The reason for the greater volume of organic matter in active fresh marsh soil than in inactive fresh marsh soil is not clear, but perhaps the annual influx of mineral matter in active fresh marsh supplied phosphate, a limiting nutrient in inactive Louisiana fresh marsh vegetation (Mitsch & Gosselink, 1986, pp. 267–268). Unlike inactive fresh marsh vegetation, vegetation in Louisiana saline marsh contains more mineral matter and is not phosphate limited (Buresh *et al.*, 1980; Patrick & Delaune, 1976), probably as a result of the relatively unweathered sediments and to an abundance of sorption sites for phosphate.

Comparisons among marsh types. Within the Inactive Delta Zone, fresh marsh soils were different from other marsh soils with respect to the volume of organic matter. Net aerial primary production has been estimated at 1960 g organic matter year^{-1} m^{-2} in inactive fresh marshes (Sasser & Gosselink, 1984) where the volume of soil organic matter was lowest, and 1540 g organic matter year^{-1} m^{2} in inland saline marshes (Kirby & Gosselink, 1976) where the volume of soil organic matter was highest. Although these are estimates of above-ground productivity, and soil organic matter is probably mostly derived from below-ground biomass, this suggested that the availability of organic matter for soil formation was similar in fresh and saline marsh. Intermediate marsh soil contained low volumes of mineral matter similar to fresh marsh, but more organic matter than inactive fresh marsh, which suggested that the low volume of mineral matter in fresh marsh soil did not limit incorporation of organic matter. It therefore appeared that neither the availability of organic matter nor mineral matter limited incorporation of soil organic matter in inactive fresh marsh, and it could not be determined from these data why fresh marsh soil contained less organic matter than other Inactive Delta Zone marsh types.

Intermediate marsh soil had low volumes of mineral matter similar to inactive fresh marsh, but high volumes of organic matter similar to brackish and saline marsh. Although this marsh type may be grouped with brackish marsh because both are often dominated by *Spartina patens*, these data suggest that these marshes deserve separate classification. The volume of organic matter was greatest in saline marsh, but mineral matter occupied more volume; this was the only marsh type in which mineral matter occupied substantially more volume than organic matter.

Vertical accretion

Comparison between delta zones. Only in the Active Delta Zone, where mineral matter availability was greatest, did mean accretion rates exceed 0·70 cm year^{-1}. This was most likely a result of the high sediment load of these waters. These active fresh marsh soils incorporated half as much mineral matter as saline marsh but vertically accreted faster, and have expanded in recent years, whereas salt marshes have experienced substantial loss in recent years (Adams *et al.*, 1976).

Comparisons among marsh types. Mineral matter availability and subsidence rates are low in inactive fresh and intermediate marsh, so which was limiting vertical accretion rates in these marshes could not be determined. At low rates of submergence, vertical accretion is limited by the rate of submergence (see Mitsch & Gosselink, 1986, pp. 178–181).

Rates of vertical accretion in brackish and saline marshes were similar, but saline marshes contained greater volumes of mineral matter. The dominant saline marsh plant, *Spartina alterniflora*, does not grow in soils with bulk density much less than 0·20 g cm^{-3} (Delaune *et al.*, 1979). *Spartina patens*, the dominant plant in brackish and intermediate marsh, and *Panicum hemitomon*, the dominant fresh marsh plant, occupy soils with lower density where permitted by low salinity. This extra need for mineral matter by saline marsh vegetation was probably required to precipitate sulphide. Sulphide is toxic to marsh vegetation (Pezeshki & Delaune, 1988) and is formed from sulphate under reduced conditions; it appears in the soil solution after all available iron has precipitated with sulphides. The primary source of sulphate in coastal marshes is seawater. This may explain why saline marsh required almost twice as much mineral matter as inactive brackish marsh, but accreted at a similar rate. Allocation of limited mineral matter in a way that increases the rate of vertical accretion at the expense of soil bulk density may lead to vegetation die-back in saline marsh. With plant mortality, the structurally important root network would be lost and soil disintegration may follow. In this way, saline marsh soil formed with a density less than 0·20 g cm^{-3} would be eroded away.

Soil formation requirements

Soil formation requirements were not estimated for Active Delta Zone marsh because the organic and mineral matter contents of those marshes probably reflected fluctuations in the excess of mineral matter availability rather than amounts required for soil formation. In the Inactive Delta Zone however, the organic and mineral matter contents in the near surface are more typical of the amounts required for soil formation in submerging coastal marshes. In these marsh types, mineral matter requirements were greater than organic matter requirements on a weight basis (Figure 4). Saline marsh required almost twice as much mineral matter as brackish marsh. Inactive fresh and intermediate marsh required less than half as much mineral matter as brackish marsh.

Comparison of mineral matter availability with the estimates of mineral matter requirements could indicate if mineral matter was limiting vertical accretion at a given submergence rate, but we are unaware of mineral matter availability estimates. Estimates of mineral matter availability should be made in inland marsh rather than merely of the sediment load in bayous and ponds because much of the mineral matter in water bodies is deposited on streamside marsh and is thus unavailable to inland marsh. Also, the actual delivery of mineral matter to inland marsh is probably a function of the settling properties of the suspended particles and the standing time of the water on the marsh, as well as the sediment load of the flooding waters.

Future efforts to determine if production of organic matter is limiting vertical accretion should compare organic matter availability to soil formation requirements. Availability is a result of the interactions of above- and below-ground productivity with detrital export, fire and herbivory. Estimates of below-ground productivity and the effects of herbivory

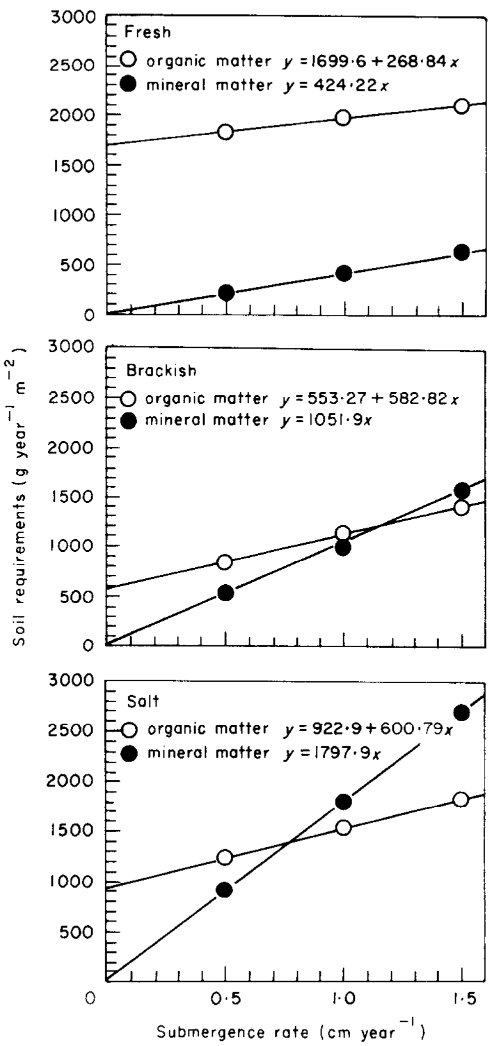

Figure 5. Organic matter and mineral matter requirements in different marsh types of the Inactive Deltaic Zone of the Mississippi River Deltaic Plain, accounting for conversion of soil organic matter to CO_2 and CH_4.

and fire are lacking in these marshes. Demand is a combination of oxidation of soil organic matter by soil microbes to CO_2 and CH_4, and soil formation requirements. Oxidation of soil organic matter to CO_2 and CH_4 have been estimated in inactive fresh, brackish and saline marshes (Smith *et al.*, 1983; Delaune *et al.*, 1983*c*), but are lacking for active fresh and intermediate marshes, and inactive intermediate marshes. Replacement of soil organic matter oxidized by microbial respiration increases the organic matter requirements (Figure 5). These figures and equations represent our current best estimate of organic and mineral matter requirements of the marsh types in the Inactive Delta Zone of the Mississippi River Deltaic Plain. At submergence rates of 1·0 cm year^{-1}, organic matter requirements approach estimates of net aerial primary production, although below-ground productivity probably contributes the bulk of organic matter. Estimates of below-ground productivity in these marshes are lacking but range from equal to above-ground productivity in a Mississippi brackish *Juncus roemerianus* marsh (de la Cruz & Hackney, 1977), to eight times net aerial primary productivity in a Massachusetts inland saline *Spartina alterniflora* marsh (Valiela *et al.*, 1976).

Brackish and saline marsh are expanding at the expense of fresh and intermediate marsh (Chabreck & Linscombe, 1982). Perhaps efforts to prevent conversion of brackish to saline marsh (in Louisiana, freshwater diversion from the Mississippi River is planned) could reduce wetland loss where brackish marsh vegetation dies as a result of salinity increases, and the establishment of saline marsh vegetation is prohibited by a combination of low soil bulk density and high sulphate supply. Perhaps freshwater diversion to convert saline marsh to brackish marsh will also prevent marsh loss by lowering sulphate supply and salinity, and allowing the establishment of *Spartina patens* in low density soils that induce *Spartina alterniflora* mortality. However, freshwater diversion will not prevent marsh loss where such loss is occurring because organic or mineral matter availability is limiting vertical accretion and/or hydrologic changes resulting from man-made canals are causing wetland loss via other mechanisms. Therefore, freshwater diversion alone may or may not reduce wetland loss, depending on which mechanisms are causing wetland loss at the specific locations affected by the freshwater diversion.

Conclusions

Ideally, efforts to mitigate coastal wetland loss should include measures that assure adequate mineral sediment is supplied to inland marsh. In areas where this is not possible, perhaps increasing the freshwater supply will reduce wetland loss where salinity increases cause *Spartina patens* mortality, and the soil bulk density is too low to allow the establishment of *Spartina alterniflora*, or where reduced salinity allows the introduction of *Spartina patens* into low density saline marsh soils. Other factors may also be at work and freshwater diversion alone may be of limited value in some areas. We suspect that substantial reductions in wetland loss rates in coastal Louisiana may not occur until diversions are designed to allow sediments as well as freshwater to escape from the Mississippi River.

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