Soil Organic Carbon and Nitrogen and Distribution of Carbon-13 and Nitrogen-15 in Aggregates of Everglades Histosols

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Oxidation of Histosols in the Everglades Agricultural Area (EAA) of south Florida leads to decreases in soil depth, changes in biogeochemical properties, and may limit land use options in the future. The objectives of this study were to determine how long-term cultivation influences organic matter dynamics and C and N distribution throughout the profile of a drained Histosol. We measured organic C and N stocks, aggregation, and the natural abundance of $\delta^{13}C$ and $\delta^{15}N$ in aggregates from Histosols 100 yr after drainage for two land uses: sugarcane (*Saccharum officinarum* L.) and prairie. Macroaggregates comprised the bulk of total soil for both land uses, averaging 81% of the total soil in fractions >0.25 mm. Macroaggregation increased with depth and the proportion to whole soil was 65% higher at 30 to 45 cm than 0 to 15 cm. Cultivated soil averaged 13% higher organic C, but 11% lower organic N than prairie throughout the profile (0–45 cm). The majority of the organic C (76%) and N stocks (77%) was in macroaggregate fractions >0.25 mm. The distribution of organic matter among aggregate-size fractions generally did not differ between land uses, except that organic C and N were 39 and 44%, respectively, greater for macroaggregates in prairie than cultivated soil at 0 to 15 cm. The $\delta^{15}N$ decreased with depth for both land uses, indicating that organic matter was more decomposed and humified in surface soil (0–15 cm). The decrease with depth likely resulted from inundation of subsurface soils and low O_2 levels, which subsequently lowered rates of decomposition. The $\delta^{13}C$ decreased with depth for cultivated soil but increased for prairie, and was significantly higher for soil cropped to sugarcane (-25.37‰) than prairie (-26.20‰). Soil organic matter under cultivation was less humified than prairie soil due to recent C inputs from sugarcane. The 2-mm fraction had 12% lower $\delta^{15}N$ than other fractions, indicating that recent organic matter inputs accumulated in macroaggregate fractions. Smaller aggregates contained higher $\delta^{15}N$ and older organic matter. In contrast to most studies of mineral soils, cultivation of Histosols increased C storage relative to prairie, with the major difference between land use being higher soil organic matter levels in the subsurface (15–45 cm). Thus, cropping may reduce the rate of oxidation of Histosols in southern Florida relative to the prairie ecosystem.

Abbreviations: EAA, Everglades Agricultural Area.

Impacts of cropping systems and land use changes on organic matter dynamics is well-documented due to recent attention given to the utilization of soil for sequestration of atmospheric CO_2. Mechanisms to enhance soil C sequestration include diversified cropping systems, residue management, and utilization of no tillage regimes, which tend to increase C storage in macroaggregates (Wright and Hons, 2005). Most studies have shown greater C sequestration for systems that minimize soil disturbance. Tillage improves aeration and enhances microbial decomposition of residues and organic matter, leading to disintegration of aggregates (Six et al., 1998; Wright and Hons, 2005). Differentiation of soils by aggregate-size distribution is used to assess impacts of land use change since protection of organic matter within aggregates enhances soil C sequestration (Jastrow, 1996; Six et al., 1998). Thus, management practices that increase soil aggregation tend to increase C and N sequestration (Six et al., 1998; Wright and Hons, 2005).

A popular method to assess organic C and N cycling or transformations in soil uses the distribution of ^{13}C and ^{15}N in organic matter pools (Boutton et al., 1998; Liao et al., 2006). Changes in land use, particularly vegetation patterns, can be studied using stable isotopes to differentiate sources of organic matter and distribution in soil (Solomon et al., 2002). This method is particularly useful for comparing contrasting land uses after long-term management (Inglett and Reddy, 2006; Liao et al., 2006).

Considerable research has been done on C sequestration for different cropping systems and soil types, but little information is available for Everglades Histosols. Histosols normally

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develop under water-logged conditions when organic matter accumulation exceeds decomposition (Wright and Reddy, 2001; Morris et al., 2004b). These soils are drained for agricultural production because their high fertility is amenable for crop production. However, drainage enhances decomposition relative to accumulation and promotes soil loss by oxidation. Management strategies may be utilized to minimize rates of soil oxidation and increase the duration these soils can be utilized for crop production, which may also have the effect of decreasing the rate of greenhouse gas production (Snyder, 2005).

The Histosols of the Everglades in south Florida developed under seasonally-flooded conditions and were dominated by seasonally-flooded sawgrass (*Cladium jamaicense* Crantz) prairies. A major shift in land use occurred in the past century, as the area south of Lake Okeechobee was drained by canals for conversion to agriculture, mainly for the production of sugarcane and vegetable crops (Snyder, 1994). This region, known as the EAA, is comprised of organic soils that have been drained and subjected to cropping for approximately 100 yr (Shih et al., 1998). These soils typically have 85% organic matter (Snyder, 2005), compared to the 1 to 5% typical range for mineral soils. Because of considerably high C levels, factors affecting C accumulation or release have potentially large global impacts, such as increasing CO_2 and CH_4 emissions when soils are drained, and sequestering C on flooding. The conversion of this historic prairie to an annual cropping system altered soil organic matter and nutrient cycling as demonstrated by increased microbial activity and rates of nutrient transformations (Snyder, 2005). The major result of this land use change was subsidence, or oxidation of the soil organic matter, at rates currently approximating 1.5 cm yr^{-1} (Shih et al., 1998).

Long-term fertilization and nutrients mineralized from soil oxidation have also been implicated in the eutrophication of Everglades wetlands. For the protection of water quality and the unique Everglades ecosystem, considerable attention has been paid to the conversion of cultivated lands in the EAA to their historic use as flooded prairies as part of Everglades restoration projects. Soils under long-term cropping may require extensive management or remediation before reversion to flooded wetlands. Conversion of cultivated soils under annual sugarcane cropping systems to prairie may improve soil structure and aggregation, leading to organic matter protection in soil, thus minimizing potential soil loss by oxidation. However, assessment of total organic C and N stocks for soils under sugarcane and prairie needs to be made to estimate effects of land use change on organic matter dynamics. The objectives of this study were to determine how land use changed soil properties after 100 yr of drainage, assess the distribution of organic C and N in soils under sugarcane cultivation and prairie, and predict effects of current and future land use changes on soil conservation.

MATERIALS AND METHODS

Site Description

The EAA (280,000 ha) is characterized by Histosols underlain by limestone bedrock, with approximately 148,000 ha planted to sugarcane (Glaz, 2002). These organic soils developed under seasonal flooding and low nutrient status and supported vegetation adapted to these conditions. Due to conversion to agricultural use by drainage, the dominant vegetation shifted from *Cladium* to vegetables in the early 1900s and then to sugarcane in the 1950s. In addition to altered vegetation patterns, fertilizer inputs significantly increased with the introduction of cropping. However, small remnants of *Cladium* prairies were not cropped but instead remained intact, although their historic water management was altered to the same conditions as cultivated soil. These sites serve as a reference for investigating effects of cropping systems.

The study site is located at the Everglades Research and Education Center near Belle Glade, FL (26°39′ N, 80°38′ W). The long-term average annual temperature is 24°C and precipitation is 133 cm. The soil is classified as a Dania muck (euic, hyperthermic, shallow Lithic Medisaprists) which formed under *Cladium* over limestone bedrock (Snyder, 1994), and which is currently at an approximately 45-cm depth. Two land uses were utilized for this study: cultivated sugarcane soil and *Cladium* soil, with sites located within a 0.5-km radius. The cultivated soil under sugarcane represents typical management practices for the largest land use in the EAA, while the prairie soil approximates the original land use, although water management for both has been altered from historic patterns. The prairies sites received no historic fertilization or tillage, but were drained for the same duration as cultivated soils. Thus, changes in soil properties between land uses would be due to differences in land management practices such as fertilization, tillage, and vegetation.

Nitrogen fertilizers are seldom applied to sugarcane since organic N mineralization supplies the required N (Gilbert and Rice, 2006). Sugarcane is planted from August through January and harvested from October through April, and is vegetatively propagated by placing stalks into furrows 8 to 20 cm deep. Tillage operations include several diskings (to 15-cm depth) after crop harvest and subsoil chiseling (to 30-cm depth) to improve drainage (Morris et al., 2004a). Frequent in-season tine cultivations (to 4-cm depth) are done for weed control (Gesch et al., 2007).

Soil Sampling and Analysis

Triplicate soil cores (5-cm diam.) were taken before sugarcane harvest in January 2006 at four replicate sites for each land use and sectioned into 0- to 15-cm, 15- to 30-cm, and 30- to 45-cm depth intervals. Soil was passed through a 0.5-mm sieve before C and N analysis.

Fractionation of soil aggregates was achieved using a wet-sieving procedure (Elliott and Cambardella, 1991; Cambardella and Elliott, 1994). Approximately 100 g of soil were capillary-wetted to field capacity to prevent slaking following immersion. Wetted soil was immersed in water on a nest of sieves (2, 1, 0.25, and 0.053 mm) and manually agitated for 50 times during a 2-min period. Soil aggregates retained on sieves were then backwashed into preweighed containers, oven-dried at 50°C for 3 d, and weighed. Material that passed through the 53-μm sieve was not collected, but contents was determined by calculation of the difference between whole soil and the sum of the four aggregate-size fractions. Aggregate-size fractions included large macroaggregates (>2 and 1–2 mm), small macroaggregates (0.25–1 mm), microaggregates (0.053–0.25 mm), and silt + clay associated particles (<0.053 mm). Whole soil and subsamples from aggregate-size fractions were analyzed for organic C and N.

Soils were analyzed for bulk density (Blake and Hartge, 1986), while total organic C was determined by loss-on-ignition at 550°C for 4 h (Anderson, 1976), followed by conversion of organic matter to organic C using a factor of 0.51 (Batti and Bauer, 2002). Total organic N was measured by Kjeldahl digestion followed by NH_4 analysis (Bremner, 1996).

Table 1. Aggregate meanweight diameter (mm) for three depth intervals of soils under sugarcane and prairie. Values in columns followed by different letters were signicantly different at $\alpha = 0.05$. ns = not significant.

Soil depth (cm)	Sugarcane	Prairie	*P* < 0.05
0–15	1.37 b	1.49 b	ns
15–30	1.33 b	1.91 a	*
30–45	1.83 a	1.87 a	ns

For isotopic analysis, soil samples were acidified (vapor mist) using a modified acid-fumigation technique to remove carbonates (Harris et al., 2001). Total C and N isotopic ratios were determined simultaneously using a Costech model 4010 elemental analyzer (Costech Analytical Technologies, Valencia, CA), coupled to a Finnigan MAT Delta^{Plus}XL mass spectrometer via a Finnigan Conflo III interface (Thermo Scientific, Waltham, MA). Isotopic measurements were verified using standard wheat flour (1.85% N, 40.2% C, $\delta^{15}N$ = 2.55‰) (Iso-Analytical Limited, Chesire, UK), $(NH_4)_2SO_4$ (IAEA-N1), and sucrose (NIST 8542). Elemental calibration was achieved using acetanilide (10.4% N, 71.1% C). Ratios of C and N isotopes were expressed as per mille (‰) differences from ratios of the Vienna PDB. Analytical error for isotopic standards was less than 0.1‰ for $\delta^{13}C$ and 0.3‰ for $\delta^{15}N$.

A completely randomized experimental design was utilized with two land uses, three soil depth intervals, and four field replications (CoStat Statistics Software, 2005). Organic C and N concentrations were converted to a volumetric basis utilizing soil bulk density. A three-way ANOVA model was used to determine main effects of land use (cultivated and prairie soil), aggregate-size fraction (>2, 1–2, 0.25–1, 0.053–0.25, and <0.053 mm), and soil depth (0–15, 15–30, and 30–45 cm). A one-way ANOVA model was used to determine differences between individual treatments for each soil depth interval and aggregate-size fraction. Significant treatment comparisons were based on Fisher's LSD at $\alpha = 0.05$.

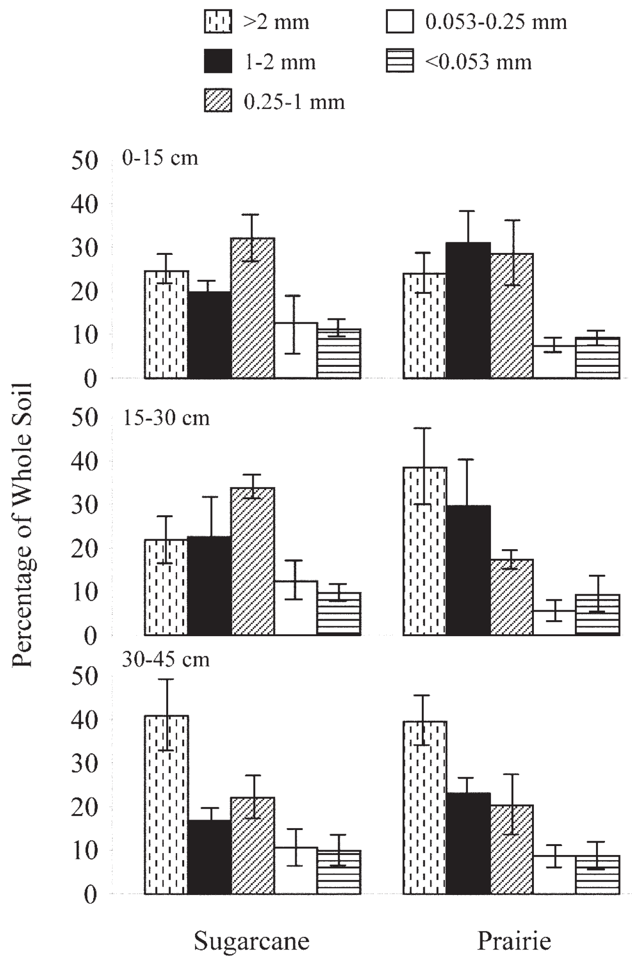

Fig. 1. The proportion of five water-stable aggregate-size fractions in whole soil for three depth intervals in cultivated and prairie soils. Error bars represent the standard error of the mean.

RESULTS AND DISCUSSION

Aggregate-Size Distribution

The mean-weight diameter of aggregates increased with soil depth (Table 1). These results agree with the general consensus that natural systems have better aggregation due to less tillage and soil disturbance. Soil aggregation was greater at depths below the maximum tillage depth for cultivated soil (30 cm), which indicates the destructive effects of cultivation on aggregation. Soil aggregation was similar between land uses except for 15 to 30 cm, where prairie had a greater proportion of macroaggregates than cultivated soil (Fig. 1). Throughout the profile, soil was primarily comprised of macroaggregates greater than 0.25-mm diam. The proportion of the >2-mm fraction to whole soil increased with depth for both land uses, while the proportion of the 0.25- to 1-mm fraction decreased, suggesting disturbance near the soil surface retarded aggregation. The aggregate-size fractions <0.25 mm constituted less than 20% of the total soil, while the >2-mm fraction comprised 40% of the total soil at 30 to 45 cm.

Soil Organic Carbon and Nitrogen Stocks

Soil bulk density seldom varied with depth or between land uses, and averaged 0.47 g cm^{-3} (Table 2). Soil organic C and N concentrations (mg kg^{-1}) were converted to stocks (Mg ha^{-1}) for each 15-cm depth interval for the entire soil profile above bedrock (Table 2). Thus, these values approximate the total soil at this site. Soil organic C for cultivated soil was lower at 0 to 15 cm than other depth intervals, but did not vary with depth for prairie. While organic C at 0 to 15 cm did not differ between land uses, it was higher for cultivated than prairie soil from 15 to 45 cm. The total organic C stored in the soil profile was significantly greater for sugarcane (902 Mg C ha^{-1})

Table 2. Properties of whole soil for three depth intervals under sugarcane cultivation and prairie in the Everglades Agricultural Area.

		Cultivated soil (cm)			Prairie soil (cm)			$LSD_{0.05}$
		0–15	15–30	30–45	0–15	15–30	30–45	
Bulk density	g cm^{-3}	0.38	0.51	0.49	0.44	0.41	0.49	0.06
Total organic C	Mg ha^{-1}	249	340	313	287	263	250	58
Total organic N	Mg ha^{-1}	24	30	29	30	28	34	5.3
C/N		10.4	11.5	10.7	9.5	9.3	7.7	2.0
$\delta^{13}C$	‰	–25.11	–25.37	–25.64	–26.45	–26.23	–25.91	0.42
$\delta^{15}N$	‰	3.06	2.72	2.21	3.86	3.27	2.98	0.34

than prairie (800 Mg C ha^{-1}). These results are in contrast to other studies showing greater soil C storage in grasslands than cropland (Six et al., 1998; Solomon et al., 2002).

Cultivation practices, especially tillage, disrupt soil aggregates and enhance soil organic decomposition, leading to lower soil C and N levels (Wright and Hons, 2005). Furthermore, soil aeration by tillage often enhances microbial activity and decomposition of organic matter and crop residues in surface soils (Morris et al., 2004a). The cultivated and prairie fields have been subjected to similar water management, so primary differences between these land uses were fertilization, tillage, and vegetation patterns. The high biomass production of sugarcane, enhanced by annual P fertilization, may have contributed to higher organic C for cultivated than prairie soil (Shih et al., 1998; Morris and Gilbert, 2005). In addition, the redistribution of aboveground harvest trash and residues into subsurface soil by tillage may have increased organic C levels at the 15- to 45-cm depth interval for sugarcane relative to prairie. The prairie soil is nutrient-limited because it originated under oligotrophic conditions, which likely limited primary production relative to fertilized sugarcane. Differences in rooting depth and belowground biomass production may also explain differences in organic matter levels between land uses. However, because of the relatively shallow soil depths throughout most of the EAA and particularly for these land uses (<45 cm), root penetration to bedrock for vegetation at these sites is common although the majority of root biomass is confined to surface soil (Morris and Tai, 2004).

Soil organic N generally increased with depth in the profile, and was higher for prairie than cultivated soil at 0 to 15 cm (Table 2). Since N fertilizers are seldom applied for sugarcane production, these soils rely on organic matter mineralization to supply N to crops. The total organic N contained in the soil profile averaged 92 Mg ha^{-1} for prairie and 83 Mg ha^{-1} for sugarcane, but was not significantly different between land uses. Uptake of N and removal from fields in harvested sugarcane explain lower organic N in cultivated surface soil. Soil C/N was significantly lower, however, for prairie (8.8) than sugarcane (10.9). The sugarcane soil likely experienced N deficiency due to crop uptake and removal from fields, while N was recycled within the prairie soil.

It was theorized that prairie would retain more C and N and be less prone to oxidation than cultivated soil, or at least minimize soil loss relative to cultivated soil. Thus, comparison of organic matter between these two long-term cultivated and prairie systems was made to elucidate mechanisms for differences in C and N storage. Greater aggregation under minimally disturbed prairie should have enhanced soil C storage relative to the cultivated soil. In fact, prairie did have greater aggregation in surface soil (Fig. 1), but it did not result in higher soil organic C and N stocks than cultivated soil. These results were similar to an earlier study showing lower soil oxidation rates for prairie than cultivated Histosol (Shih et al., 1978). A recent study showed that soil oxidation potential was higher for tilled than no-tilled soil (Morris et al., 2004a), which should decrease C storage for sugarcane compared to prairie soil in this study. However, even with tillage, the soil under sugarcane had higher organic C than prairie. These results may be attributed in part to the dense canopy of sugarcane which decreased soil temperatures and oxidation relative to prairie for this Histosol (Shih et al., 1982).

Most tillage operations occur in the top 15 cm, which increased aeration, lowered bulk density (Table 2), and enhanced aerobic organic matter oxidation (Morris et al., 2004a). Thus, sugarcane did not increase soil C and N in surface soil relative to prairie. Greater C storage in the subsurface (15–45 cm) of cultivated soil resulted in higher total soil profile C than prairie. It appears that subsurface deposition of C by sugarcane and incorporation of harvest residues by tillage had the potential to increase C storage at this depth. The conversion of the annual cropping system to prairie therefore may not enhance C storage for this Histosol under drained conditions. The adoption of minimal tillage and development of better residue management of sugarcane cropping systems may help to minimize soil oxidation.

Oxidation of soils in the EAA was observed soon after they were drained for crop production (Snyder et al., 1978; Snyder, 2005), which was attributed to organic matter oxidation due to aeration resulting from drainage, but also a result of burning and compaction (Snyder, 1994; Morris et al., 2004b). The soil oxidation rate is mainly affected by water-table depth, which limits aerobic decomposition of organic matter (Snyder, 1994; Morris et al., 2004b). Oxidation of these soils historically occurred at rates of 2.5 cm yr^{-1} from the 1930s through the 1970s (Shih et al., 1978). However, over the past 30 yr, the rate of oxidation has slowed to 1.5 cm yr^{-1} (Shih et al., 1998). Cropping systems and residue inputs have failed to increase organic matter accumulation rates relative to decomposition rates for these soils. These soils become more humified during subsidence and the mineral content increases (Snyder, 2005), which explains the decreasing rate of oxidation in recent decades. Based on current soil depths and the oxidation rate, these sites will become depleted within 30 yr. The use of these soils for sugarcane production will be limited before total soil depletion, as the minimum depth for crop production has been estimated at 20 cm (Snyder, 2005), which projects to 17 yr of utilization. Since cultivated soils contain more organic C than prairie soils, they are also a greater potential source of CO_2 to the atmosphere under current land management practices (drained conditions). At current land use and the oxidation rate of 1.5 cm yr^{-1}, 20 and 17.8 Mg C ha^{-1} for cultivated and prairie soil, respectively, may be lost annually as CO_2. Thus, these drained Histosols represent a net source of greenhouse gases to the atmosphere. However, future land use changes related to creation of flooded prairies on agricultural soils would cause a shift from sugarcane to aquatic vegetation and change these soils from serving as a C source to a C sink.

Organic Carbon and Nitrogen in Aggregate-Size Fractions

Both land uses were characterized by increasing organic C and N with increasing aggregate size. Soil organic C in the >0.25-mm fractions was significantly greater for prairie (81.4 Mg ha^{-1}) than cultivated soil (58.5 Mg ha^{-1}) at 0 to 15 cm (Fig. 2). Even at lower depths, the >2-mm fraction generally had the highest organic C of all size fractions. For both land uses, aggregate distribution in the soil profile was characterized by increasing C for both the largest (>2 mm) and smallest (<0.053 mm) aggregate-size fractions with increasing depth.

Subsequently, C contained in 0.25- to 2-mm fractions decreased with depth in the profile. Cultivation increased organic C in the microaggregate and silt + clay fractions from 0 to 30 cm, likely a result of destructive effects of tillage on macroaggregates.

Soil organic N followed similar trends as organic C. Prairie soil sequestered more N in macroaggregates than sugarcane, as prairie had higher macroaggregate N at 0 to 15 and 15 to 30 cm (Fig. 3). These results reflect N removal from soil under sugarcane production and potential N deficiency. For prairie, aggregate-size fractions >1 mm had 64% more organic N than cultivated soil at 0 to 15 cm. At lower depths, the >2-mm fraction had the highest organic N of all fractions. The majority of organic N was contained in aggregates fractions >0.25 mm throughout the soil profile. Similar to organic C, N contained in the >2-mm fraction increased with increasing depth for both land uses. Organic N in the <0.053-mm fraction increased with depth for prairie but not sugarcane. Sugarcane production relies on soil organic N mineralization, so N fertilizers are seldom applied, thus crop removal of N in harvested biomass appeared to lower organic N in these surface soils relative to prairie.

Carbon-13 and Nitrogen-15 Distribution in Soil Aggregates

Histosols in the EAA developed under seasonally-flooded *Cladium*, a C_3 plant, but the cultivated soils have been predominately under sugarcane (C_4) production for the past 50 yr. In the Everglades, *Cladium* typically has $\delta^{13}C$ values ranging from 25 to 27‰ (Inglett and Reddy, 2006), while C_4 plants have values near 14‰, while both sugarcane and *Cladium* have $\delta^{15}N$ in tissue near 6‰. Based on $\delta^{13}C$, the majority of soil organic C for both these land uses originated from organic matter deposited by *Cladium*. Significant differences in the $\delta^{13}C$ signatures of whole soil between land uses were observed throughout the soil profile (Table 2). The greatest differences between land uses occurred at 0 to 15 cm, followed by the 15- to 30-cm depth, and then the 30- to 45-cm depth. The surface soil (0–15 cm) most readily reflected the change in land use from the *Cladium* prairie to sugarcane, while the smaller differences in $\delta^{13}C$ between land uses for 30 to 45 cm reflected the natural $\delta^{13}C$ distribution of organic matter deposited under *Cladium*. Organic C from sugarcane was found throughout the cultivated soil profile, but the contribution of sugarcane-derived C to total soil organic C decreased with depth. Divergent $\delta^{13}C$ between land uses at 30 to 45 cm extending toward the surface soil indicate greater contribution of sugarcane to soil organic matter in surface than subsurface cultivated soils. Similar results were obtained for individual aggregate-size fractions (Fig. 4), as land use influenced the distribution of $\delta^{13}C$ in aggregates. For each depth interval, the >2-mm fraction had the lowest $\delta^{13}C$ for cultivated soil, but had the highest $\delta^{13}C$ for prairie.

Most of the C deposition by sugarcane was not becoming part of the soil organic matter based on the low $\delta^{13}C$ in these soils, indicating most C in these soils was derived from *Cladium*. However, nutrient enrichment, particularly P, can increase $\delta^{13}C$ and $\delta^{15}N$ of plants in this subtropical environment (Inglett and Reddy, 2006). The cultivated soil typically received 30 kg P ha^{-1} yr^{-1}. Thus, P fertilization could have increased $\delta^{13}C$ signatures of cultivated soil relative to prairie, and

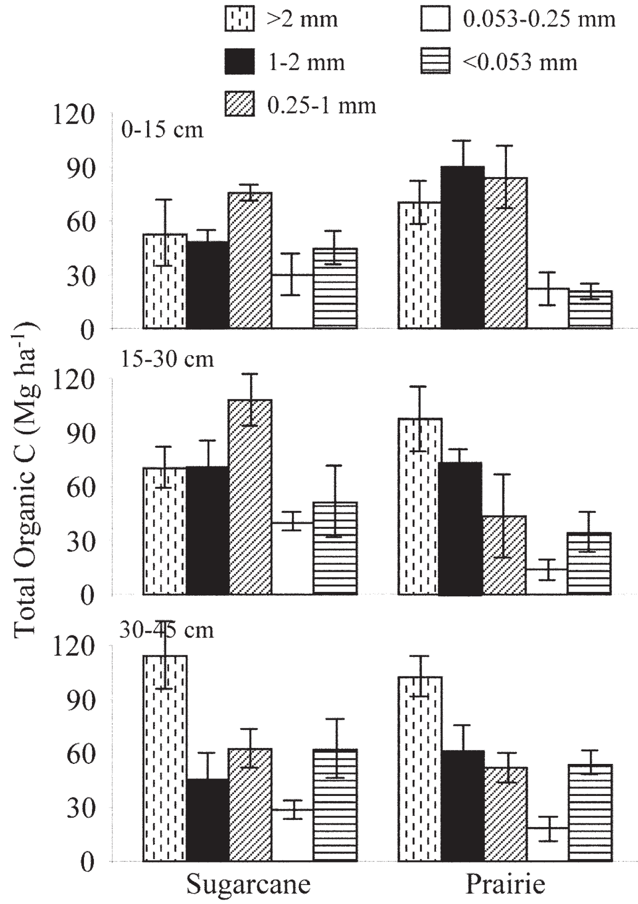

Fig. 2. Soil organic C storage in aggregates for cultivated and prairie soils of the Everglades Agricultural Area. Error bars represent the standard error of the mean.

may be partially responsible for differences in $\delta^{13}C$ between land uses in the surface.

The organic matter under sugarcane and prairie was characterized by older, more decomposed material in surface soil and less decomposed material at 30 to 45 cm. Low $\delta^{15}N$ indicates recently deposited organic matter, while high $\delta^{15}N$ represents older, more humified organic matter (Novak et al., 1999). The depth distribution of $\delta^{15}N$ in whole soil differed from that of $\delta^{13}C$ (Table 2). For whole soil, $\delta^{15}N$ decreased with depth for sugarcane, similar to $\delta^{13}C$, but decreased with depth for prairie, in contrast to $\delta^{13}C$.

The $\delta^{15}N$ of all aggregate-size fractions decreased with depth in the profile for both land uses, suggesting that soil organic matter oxidation was greater in surface than subsurface soil (Fig. 5). Subsurface soils have higher water contents than surface soils after precipitation and by maintenance of elevated water tables, and thus are inundated for longer periods of time resulting in lower O_2 levels and lower organic matter decomposition rates (Morris et al., 2004b). Therefore, these subsurface soils had lower $\delta^{15}N$ and less humified organic matter. In contrast, surface soils are drier and better aerated which enhances their oxidation potential and degree of humification (Morris et al., 2004a, 2004b). The more humified nature of surface soil indicates this depth interval was the likely source of soil organic matter lost by oxidation. Since organic matter levels were greater for cultivated than prairie soils (Table 2), the

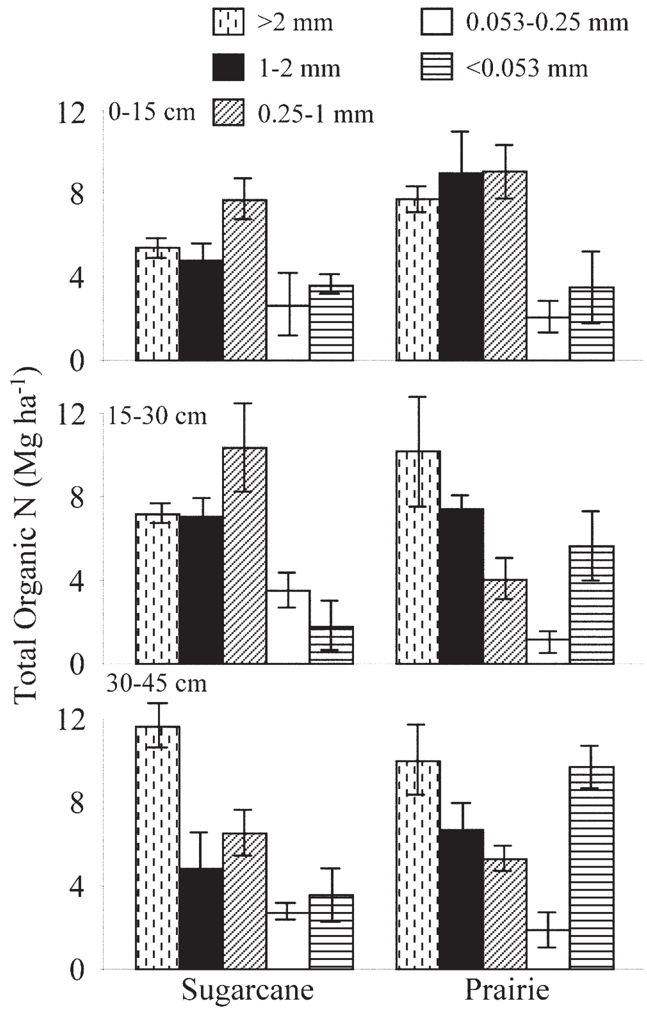

Fig. 3. Soil organic N storage in aggregates for cultivated and prairie soils of the Everglades Agricultural Area. Error bars represent the standard error of the mean.

total C contribution of sugarcane to soil organic matter was apparently greater than that of prairie vegetation. Adoption of no tillage or minimum tillage for sugarcane cropping systems may help to retard soil organic matter decomposition and potentially decrease the rate of soil oxidation.

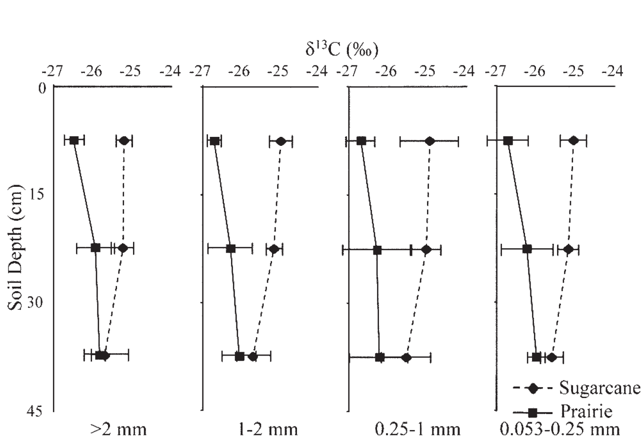

Fig. 4. Distribution of $\delta^{13}C$ among aggregate-size fractions as a function of soil depth for cultivated and prairie soils. Error bars represent the standard error of the mean.

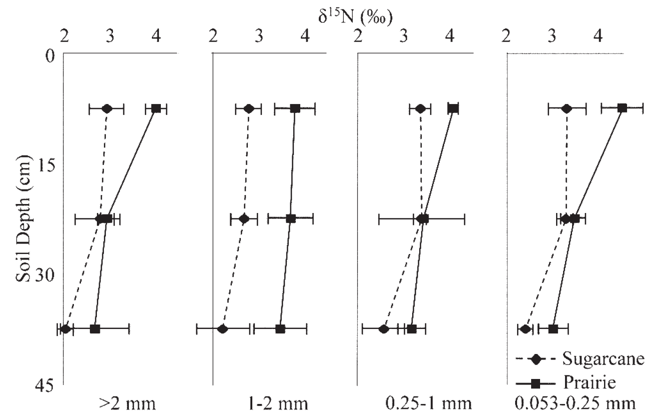

Fig. 5. Distribution of $\delta^{15}N$ among aggregate-size fractions as a function of soil depth for cultivated and prairie soils. Error bars represent the standard error of the mean.

The cultivated soils are tilled to 30 cm, which explains the lack of change in $\delta^{15}N$ from the 0- to 15-cm to the 15- to 30-cm depth interval for sugarcane. Prairie soils do not experience such soil disturbance, thus a more distinct decline occurred with depth, particularly from the 0- to 15-cm to 15- to 30-cm interval. Thus, the oxidation potential of cultivated soils appeared to be the same for 0- to 15-cm and 15- to 30-cm depths, indicating a tillage effect on $\delta^{15}N$ and soil organic matter decomposition.

Prairie soils had higher $\delta^{15}N$ than cultivated soils at 0 to 15 and 30 to 45 cm for all aggregate-size fractions (Fig. 5). Only for the 1- to 2-mm fractions at 15 to 30 cm were differences in land use observed. The >2-mm fraction had the lowest $\delta^{15}N$ of all aggregate-size fractions, indicating accumulation of recently deposited N into macroaggregates, while the 0.25- to 1-mm and 0.053- to 0.25-mm fractions had the highest values, indicating that the smallest aggregate-size fractions contained older and more decomposed N, hence recent C and N tended to accumulate in large aggregates. Similar results of increases in $\delta^{15}N$ with decreasing aggregate size were observed in other studies (Kramer et al., 2003; Liao et al., 2006). The same trend occurred in this Histosol, as the >2-mm fraction had the lowest $\delta^{15}N$ (2.89‰), followed by the 1- to 2-mm fraction (3.10‰), while the <1-mm fractions had the highest $\delta^{15}N$. Land management practices that minimized soil disturbance enhanced aggregation and may afford some degree of organic matter protection in this Histosol. The use of no tillage or minimum tillage regimes may help to conserve soil and reduce rates of oxidation.

CONCLUSIONS

The distribution of soil organic C and N differed between land uses in the EAA. In contrast to most studies, cultivated soils had higher organic C than prairie, but primarily in the subsurface. Improved aggregation of surface soil under prairie did not lead to higher organic C storage, even though recently deposited C and N accumulated in macroaggregate fractions. The majority of organic matter storage in these Histosols was contained in macroaggregate fractions, while the smallest aggregates were characterized by older material. The distribution of $\delta^{13}C$ and $\delta^{15}N$ indicated accumulation of sugarcane-derived C and N in surface soil with decreasing accumulation with depth in the profile. Surface soils of the prairie were characterized by older organic matter. Future projections indicate that under current land use, soil loss would be faster under prairie than sugarcane, but soils under sugarcane would eventually release more organic C to the atmosphere due to their higher organic C stocks. Maintenance of high water tables or adoption of reduced tillage regimes may be necessary to minimize soil oxidation, because at the current rate of soil loss, they may become depleted within 30 yr.

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