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Variation in Redoximorphic Features of Four Adjacent Inceptisols

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Abstract

Hydric soils are soils having periods of water saturation sufficient to promote anaerobic conditions throughout the soil profile during the growing season. Hydric field indicators include development of a depleted matrix with hue/value/chroma criteria. In the USA hydric soils have regulatory and suggested best management practices for proper land stewardship. This study focuses on four closely spaced pedons of the Wilbur series (Coarse-silty, mixed, superactive, mesic Fluvaquentic Eutrudepts) that vary in redoximorphic features with the objective to determine if the variation in these redoximorphic features corresponds to selected physical, chemical, and mineralogical differences. Pedon 1 exhibits matrix and redoximorphic features implying a more oxic regime than the remaining three pedons, which corresponded to pedon 1 having smaller Fe and Fe-Mn accumulations as nodules within the sand separate of the soil profile. Fluctuating water tables within pedons 2, 3 and 4 are more conducive to nodule formation and this more active soil forming process is reflected in the soil morphological description.

Keywords: hydric soils, Inceptisols, glabules, concretions

VARIATION IN REDOXIMORPHIC FEATURES OF ADJACENT INCEPTISOLS

Hydric soils are commonly defined as soils having sufficient water saturation during the growing season to support anaerobic conditions in the upper soil regions [3, 8]. Gray mottles and a depleted matrix (chroma less than or equal to two) and reduction-oxidation potentials smaller than 200mV (adjusted to pH 7) are good field indicators suggesting water saturated soil conditions. The criteria for hydric soils include: (i) soil order (ex. all Histosols except Folists), (ii) soils that are frequently flooded or ponded for more than seven consecutive days for forests or 15 days for agricultural crops

during the growing season, (iii) Aquic or Albolls suborders, and (iv) Aquic subgroups, and (v) Cumulic subgroups that meet drainage, texture, permeability, timing and water table depth criteria [3, 6].
Faulkner and Patrick [5] investigated seasonally inundated soils in bottomland hardwood forests of the lower Mississippi River Valley and observed that 60 to 80% of these soils were oxidized and aerobic throughout the root zone during the growing season. Thus, soil morphology descriptions must be better understood to predict water saturation relationships. Stolt et al. [16] similarly studied Paleudults having strongly contrasting redoximorphic patterns. Iron depletions in these soils generally occurred in voids and that fluctuating water tables concentrated Fe as pore linings. Jacob et al. [7] in Georgia studied Kandiudults and Paleudults having seasonal water tables. Seasonal water saturation was associated with the development of a gray matrix. Iron-depletions and Fe-accumulations were associated with relatively short water saturation periods. In Iowa, Khan and Fenton [10] observed aquic soil conditions in a Mollisol catena. They documented a decrease in total Fe as the degree of water saturation became more pronounced. Dithionite-citrate-bicarbonate extractable Mn and Fe showed Mn/Fe ratios having relative maxima in soil profiles corresponding with the depth of the mean water table fluctuations.

Anaerobic soil conditions are impacted by the soil water potential, soil temperature, reduction-oxidation potentials, watertable fluctuations, soil oxygen activity, ferrous (Fe^{2+}) activity, parent materials, soil age, and the landscape hydrology [3, 8, 9, 12, 17]. Megonigal et al. [12] underscored the reality that delineating wetlands remains a difficult protocol because of the numerous soil properties and climate-landscape characteristics that influence soil moisture expression. Additionally, they noted that monitoring soil moisture, soil temperature, water table fluctuations, oxygen activities, and reduction-oxidation potentials are both time consuming and require equipment intensive protocols.

Evans and Franzmeier [4] investigated an Indiana glacial topographic soil sequence and related differences in soil water saturation and oxygen depletion to soil matrix color expression and accumulations-depletions of Fe and Mn and also to differences in ped coatings. In this investigation Evans and Franzmeier (1986) defined a chroma index (CI) as: (1) $CI = [\sum X_{matrix} C_{matrix}] + [\sum X_{mottle} C_{mottle}]$, where the summation is over each soil matrix and mottle feature, X is the abundance as a fraction, C is the Munsell chroma. Thompson and Bell [17] noted a strong correlation between the CI index and the duration of saturation and reducing soil conditions across a series of soil profile depths. Jien et al. [8] inferred that gray mottles and matric chromas of one and two are important indicators of extensive durations of water saturation and development of anoxic soil conditions. Having measured the reduction-oxidation potential, they effectively correlated the CI values with water saturation and the duration of anoxic soil conditions.

Soil nodules are distinguished from the soil matrix by their shape, color, hardness, elemental composition and mineralogy [11, 18]. Soil conditions critical to nodule formation include an alternating oxic-anoxic regime, usually imposed by a seasonal period of wetness and restricted drainage [11, 19]. Spherical soil nodules may show concentric banding (concretions), with each band possibly characterized by a distinctive Fe/Mn ratio. Irregularly shaped nodules may be composed of discrete masses of Fe and Mn, commonly containing clastic materials [1, 11, 18].

Fiedler and Sommer [6] investigated redoximorphic features and pedochemical indicators to correlate soil suboxic-anoxic soil conditions with the translocation of Fe and Mn. The key indicators were the ratio of Mn/Fe from whole soil oxide analysis, crystallinity of the Fe-oxyhydroxides from selective sequential extractions and soil color. D'Amore et al. [3] investigated redoximorphic features in Oregon soils. Measuring long term values for soil water saturation and reduction-oxidation potential, they inferred mechanisms for the development of Fe and Mn accumuations, including nodules/concretions and also soft masses of Fe accumulation. Nodule chemical composition derived from selected sequential extractions, nodule abundance, nodule density, the quantity of diffuse Fe in the matrix, and the sharpness of the nodule-matrix boundary were used to infer if nodule formation was a relic or contemporary process. The goal of our research was: (1) to assess the soil properties of four pedons of the Wilbur series (Coarse-silty, mixed, superactive, mesic Fluvaquentic Eutrudepts), (2) to demonstrate the variation of the redoximorphic features, and (3) relate differences in the redoximorphic feature expressions to soil profile variations

MATERIALS AND METHODS

Study Area

The study area is a 40 ha land-graded agriculture field in Cape Girardeau County, Missouri. The land parcel is an occasionally flooded alluvial bottomland located within the Williams Creek watershed. The watershed is primarily agricultural; however, the upper portion of this watershed collects water from selected areas of the City of Jackson, Missouri. The average flood duration is brief, lasting one to two days; after which, the soil may remain saturated for several weeks. The dominant soil series are the Wakeland (Coarse-silty, mixed, superactive, nonacid, mesic Aeric Fluvaquents) and Wilbur (Coarse-silty, mixed, superactive, mesic Fluvaquentic Eutrudepts). The Wilbur series is approximately 80% of the study area.

The regional climate is continental and humid. Summers are hot and humid with a mean July temperature of 26°C and winter temperatures are mild with a mean January temperature of 2°C. The mean annual precipitation of 1.19 m is relatively evenly distributed, with slightly greater rainfall in Spring. Pre-settlement vegetation was a mixed hardwood forest. Canopy dominants surrounding the study area include sweetgum (*Liquidambar styraciflua* L.), white oak (*Quercus alba* L.), southern red oak (*Quercus falcata* L.), yellow poplar (*Liriodendron tulipifera* L.) and baldcypress (*Taxodium distichum* L.).

Field and Laboratory Analysis

Four soil profiles were described and sampled in excavated pits by soil morphologists of the Missouri Department of Natural Resources using standard protocols [15]. In addition, a hydraulic soil probe sampled two sites with arbitrarily-defined substrate layers at 4.3 - 6.1 m (14 – 20 ft) and 6.1 to 7.0 m.

Air-dried samples were lightly crushed and sieved to separate the fine earth fraction (2 mm). Soil pH in water involved mixing equal volumes of soil:water and equal volumes of soil: 0.01 M $CaCl_2$, with pH measurement performed using a combination pH electrode. The exchangeable cations (Ca, Mg, K and Na) were estimated using a 1M ammonium acetate (pH 7) extraction followed by elemental analysis using air-acetylene flame atomic adsorption spectroscopy. The total acidity was estimated by titration with 0.01 M NaOH to pH 8.0 [2]. The soil organic matter content was estimated by loss on ignition at 450°C (LOI) [2]. The clay, silt and sand separates were isolated by Na-saturation of the exchange complex, washing with water-methanol mixtures to remove excess electrolyte, dispersion in Na_2CO_3 (pH 9.2) followed by centrifuge fractionation and wet sieving [2].

An aqua regia digestion was employed to obtain a near total estimation of elemental abundance associated with all but the most recalcitrant soil chemical environments. Aqua-regia digestion does not appreciably degrade quartz, albite, orthoclase, anatase, barite, monazite, sphene, chromite, ilmenite, rutile and cassiterite; however, anorthite and phyllosilicates are partially digested. Homogenized samples (0.75g) were equilibrated with 0.01 liter of aqua-regia (3 mole nitric acid: 1 mole hydrochloric acid) in a 35ºC incubator for 24 hours. Samples were shaken, centrifuged and filtered (0.45 µm), with a known aliquot volume analyzed using inductively coupled plasma – mass spectrometry (ICP-MS). The aqua regia digestion was assayed for V, Cr, Mn, Fe, Co, Ni, Cu, and Zn. The aqua regia digestion procedure was performed by Activation Laboratories (Toronto, Canada). In this procedure, selected samples were duplicated and known reference materials were employed to guarantee analytical accuracy. Noncrystalline oxyhydroxides were estimated using a 0.2 mol / L ammonium oxalate (pH 3.3) extraction using published protocols from Shuman [14].

Oriented whole clay (<2 µm) samples were prepared for X-ray diffraction (XRD). Magnesium-saturated and glycerol-solvated samples were air-dried on glass-slides, producing oriented mounts. X-ray diffractograms were obtained with a Scintag diffractometer using CuKα radiation (45 kv and 40 ma). Spectra were scanned from 2 to 30º 2θ at 0.016 θs^{-1}. Peak positions of 1.77 to 1.8 nm, 1.4 to 1.5 nm, 0.99 to 1.01 nm, and 0.71 to 0.72 nm were used to identify smectite, hydroxy-Al interlayered vermiculite, clay mica (hydrous mica) and kaolinite, respectively [13]. Peak heights were determined after background removal and were used to qualitatively compare clay mineral differences among soil horizons.

RESULTS

Soil Profile Characterization

The Wilbur series consists of very deep, moderately well-drained soils that formed in alluvium. The four pedons have uniform silt loam textures generally displaying Ap – Bw – Cg horizon sequences (Table 1). The ratio of fine to coarse silt (data not displayed) shows a gradual transition to a greater abundance of coarse silt with increasing soil depth in pedons 1, 3 and 4, whereas pedon 2 shows relatively uniform ratio of the silt sub-separates throughout its soil profile. Soil pH generally ranges from strongly acid to neutral in the Ap horizons to very strongly acid to neutral in the Bw horizons and very strongly acid to slightly acid in the Cg and C horizons. The soil organic matter contents are generally low and decline upon transition to deeper soil depths (Table 2). Exchangeable calcium is the dominant exchangeable cation, especially in the near-surface soil horizons. The total acidity is appreciable, particularly in the deeper soil horizons. The CEC is generally either low (<12 $\text{cmol}_{p(+)}$ / kg) or medium (12-18 $\text{cmol}_{p(+)}$ / kg) and the CEC roughly corresponds with the clay and soil organic matter contents.

Table 1. Selected soil profile characterization for four pedons of the Wilbur series

Horizon	Depth	Structure	Matrix	Clay	Silt	Sand
cm			%	%	%	
Pedon 1						
Ap	15	2fpl	10YR 4/3	16.3	82.4	1.3
A	28	2mpr to 2msbk	10YR 4/3	17.8	80.4	1.8
Bw1	41	1mpr to 2msbk	10YR 4/4	16.7	80.1	3.2
Bw2	74	1cpr to 1msbk	10YR 4/4	9.7	84.6	5.7
C1	97	1mpr to 1msbk	10YR 5/4	8.3	83.3	8.4
C2	124	1mpr to 1msbk	10YR 4/4	7.7	83.3	9.0
C3	145	1cpr	10YR 4/4	9.7	80.6	9.7
C4	170	2cpr	10YR 4/4	8.5	81.3	10.2
Pedon 2						
Ap	25	1cpl	10YR 4/3	13.3	85.6	1.1
Bw1	41	1mpr to 1msbk	10YR 4/4	15.2	83.4	1.4
Bw2	64	1mpr to 1msbk	10YR 5/3	9.2	87.0	3.8
Bw3	97	1mpr to 1msbk	10YR 4/4	11.6	84.3	4.1
Cg1	130	1mpr to 1msbk	10YR 5/3	16.9	77.9	5.2
Cg2	163	1msbk	10YR 6/3	10.2	86.0	3.8
Cg3	203	1cpr to 1msbk	10YR 6/2	12.9	83.6	3.5
Pedon 3						
Ap1	8	3pl	10YR 4/3	19.0	79.0	2.0
Ap2	28	2pl	10YR 4/3	26.7	71.4	1.9
Bw1	66	2cpr to 1msbk	10YR 5/2	18.8	77.5	3.7

Bw2	97	2cpr to 1msbk	10YR 4/2	17.0	78.6	4.4
Cg1	132	2cpr	10YR 5/2	13.7	81.9	4.4
Cg2	152	2cpr	10YR 6/2	13.4	84.1	2.5
BC1	178	1vcpr	10YR 6/2	9.1	86.6	4.3
BC2	203	1vcpr	10YR 6/2	11.4	85.6	3.0
Pedon 4						
Ap	25	2cpl to 1fpl	10YR 5/3	12.4	86.4	1.2
Bw1	41	2mpl	10YR 6/2	12.4	86.4	1.2
Bw2	61	1fpr to 1msbk	10YR 6/3	13.6	84.7	1.7
Bw3	76	2cpr to 1msbk	10YR 5/3	15.0	82.8	2.2
Cg1	89	1cpr to 1msbk	10YR 5/2	17.0	81.7	1.3
Cg2	109	1cpr to 1msbk	2.5Y 5/2	14.4	83.6	2.0
Cg3	137	2msbk	10YR 4/2	23.9	68.5	7.6
Cg4	170	1cpr to 1msbk	10YR 5/4	24.0	68.1	7.9
Cg5	203	1cpr	10YR 6/2	24.6	72.5	2.9

All textures are silt loam
1 is weak, 2 is moderate, 3 is strong structure
f is fine, m is medium and c is coarse structure
pl is platy, sbk is subangular blocky and pr is prismatic.

Table 2. Chemical properties

Horizon	Ex. Ca	Total Acidity	NH_4OAc	Organic C.	pH
------------cmolp(+)/kg-----------------			%	water	
Pedon 1					
Ap	7.2	5.2	12.9	0.9	5.2
A	8.0	4.6	13.2	0.5	5.6
Bw1	7.2	4.4	11.4	0.4	5.4
Bw2	3.9	3.6	6.9	0.2	4.9
C1	2.1	5.4	6.6	0.1	4.4
C2	3.1	4.0	6.7	0.1	4.7
C3	4.6	3.1	7.8	0.1	5.2
C4	4.8	2.5	7.5	0.1	6.0
Pedon 2					
Ap	6.9	3.0	10.6	0.5	6.3
Bw1	5.7	4.1	10.3	0.5	5.9
Bw2	3.8	3.5	7.7	0.3	5.6
Bw3	3.5	6.4	10.3	0.3	4.9
Cg1	3.3	8.5	11.6	0.3	4.8
Cg2	1.9	6.1	7.1	0.2	4.6
Cg3	3.1	5.9	9.5	0.1	4.8

Pedon 3					
Ap1	9.3	5.9	16.0	1.3	5.7
Ap2	12.7	4.8	18.5	0.9	6.7
Bw1	5.8	6.7	13.4	0.4	5.0
Bw2	4.8	7.2	12.7	0.3	4.8
Cg1	4.6	5.0	10.7	0.2	5.0
Cg2	4.1	4.4	10.2	0.1	5.0
BC1	3.4	3.9	7.3	0.1	5.1
BC2	3.4	4.4	7.8	0.1	5.2
Pedon 4					
Ap1	7.3	1.5	10.0	1.2	5.8
Bw1	5.9	2.0	8.3	0.3	7.0
Bw2	6.2	2.3	9.1	0.3	6.7
Bw3	6.7	3.6	10.3	0.4	6.4
Cg1	6.8	4.2	10.8	0.4	6.2
Cg2	6.0	3.7	9.4	0.3	6.1
Cg3	8.3	9.0	17.2	0.9	5.7
Cg4	6.4	7.4	13.5	0.4	5.6
Cg5	7.5	3.9	13.7	0.1	6.4

Ex. Ca is exchangeable calcium
CEC is cation exchange capacity by ammonium acetate saturation (NH_4OAc).
Organic C. is organic carbon

Soil structures typically present as moderate medium platy structures in the near surface horizons grading to weak and moderate, medium to coarse prismatic structures in the Bw and Cg horizons. The prismatic structures typically part to weak medium subangular blocky structures in the Bw and Cg horizons. Soil matrix colors have a 10YR hue and values ranging from 4 to 6. Soil chromas ranged from 3 to 4 in pedons 1 and 2 and ranged from 2 to 3 in pedons 3 and 4. The soil chroma colors suggest that pedons 3 and 4 experienced either greater periods of soil saturation or the intensity of soil gleziation was more pronounced.

Table 3. Description of the redoximorphic features for four pedons of the Wilbur series.

--Fe-Mn Accumulations--			----Fe Accumulations---			
Horizon	%	Size	Color	%	Size	Color
Pedon 1						
Ap	1	f	10YR2/1	0		
A	1	f	10YR 2/1	0		
Bw1	1	f	10YR 2/1	1	f	7.5YR4/6
Bw2	1	f	10YR 2/1	1	f	7.5YR4/6
C1	1	f	10YR 2/1	1	f	7.5YR4/6

C2	12	f	10YR 2/1	1	f	7.5YR4/6
C3	12	f	10YR 2/1	1	f	7.5YR4/6
C4	30	f	10YR 2/1	1	f	7.5YR4/6
Pedon 2						
Ap	5	f	10YR 2/1	9	f	7.5YR4/6+10YR4/6
Bw1	5	f	10YR 2/1	2	f	2.5YR3/6
Bw2	5	f	10YR 2/1	25	f	5YR4/6
Bw3	4	f	10YR 2/1	15	f	10YR4/6
Bw3	10	f	10YR 2/1	3	f	10YR4/6
Cg1	10	f	10YR 2/1	20	f	10YR4/4
Cg2	3	f	10YR 2/1	35	f	10YR4/6+7.5YR4/6
Cg3	1	f	10YR 2/1	45	f+m	10YR4/4
Pedon 3						
Ap1	2	f	10YR 3/2	0		
Ap2	10	f	10YR 2/1	5	f	5YR4/6
Bw1	10	f	10YR 2/1	30	f+m	7.5YR5/8
Bw2	10	f	10YR 2/1	30	f+m	7.5YR5/6+7.5YR4/6
Cg1	10	f	10YR 2/1	25	f	7.5YR5/6+7.5YR4/6
Cg2	10	f	10YR 2/1	25	f+m	7.5YR5/6+7.5YR5/8
BC1	2	f	10YR 2/1	7	f+m	7.5YR5/6+7.5YR5/8
BC2	2	f	10YR 2/1	5	f+m	7.5YR5/6+7.5YR5/8
Pedon 4						
Ap1	2	f	10YR 3/2	1	f	7.5YR5/6
Bw1	5	f	10YR 3/2	6	f	7.5YR4/6
Bw2	15	f	10YR 2/1	23	f	7.5YR4/6+10YR3/3
Bw3	8	f	10YR 2/1	18	f	7.5YR4/6+10YR3/3
Cg1	2	f	10YR 2/1	32	f	5YR3/4+7.5YR5/6
Cg2	15	f	210YR /1	30	f	5YR3/4+7.5YR5/6
Cg3	15	f	10YR 2/1	10	f	7.5YR3/4+10YR3/4
Cg4	20	f	10YR 2/1	15	f	10YR4/4
Cg5	3	f	10YR 2/1	23	f	7.5YR4/6+5YR4/6

Size: f = fine, m = medium.

Iron-Mn-accumulations were distinguished from Fe-accumulations by color, with Fe-Mn-accumulations having 10YR2/1 (black) color and Fe-accumulations having hues of 2.5 to 10, with 7.5 being the most common. Munsell color values for Fe-accumulations ranged from 3 to 5 and Munsell chromas ranged from 3 to 6. Iron depletions have a 10YR hue, with Munsell values ranging from 5 to 6 and Munsell chromas ranging from 2 to 4.

Iron-Mn-accumulations were more abundant than Fe-accumulations in Pedon1, whereas Fe-accumulations were more abundant in Pedons 2 to 4, particularly below the near-surface horizons (Table 3). The greater abundances of Fe-accumulations in Pedons 2 to 4 correspond with the assessment that these pedons experienced either greater periods of soil saturation or the intensity of soil gleziation was more pronounced.

The clay mineralogy is mixed, with an abundance of hydroxyl Al-interlayered vermiculite and smectite with secondary abundances of hydrous mica and kaolinite. X-ray diffraction peak areas suggest that hydroxyl Al-interlayered vermiculite and kaolinite have greater abundances in the near-surface horizons, whereas smectite has a relatively greater abundance in the deeper cambic horizons and C and Cg soil horizons.

Substrate Material Analysis

A fault line, trending roughly north-south, marks the western boundary of the study area. The study area consists of approximately 4.6 m (15 ft) of coarse-silty alluvium. Beneath the coarse-silty alluvium rests an approximately 10.6 m (35 ft) thick layer of silty clay loam material, which rests unconformably on limestone (drill log data from the study area). The silty clay loam material has a neutral to slightly alkaline reaction and a medium (12 to18 $\mathrm{cmol}_{p(+)}$ / kg) to large (greater than 18 $\mathrm{cmol}_{p(+)}$ / kg) CEC (data not shown). Calcium is the dominant exchangeable cation and the total acidity concentrations are negligible to small. The soil organic matter contents range from 1 to near 3%. The silty-clay loam substrate acts as an aquitard, assisting in reducing the drainage of the overlying coarse-silty alluvium.

Iron and Manganese Analysis

Iron and Mn concentrations of the whole soil were assayed using aqua regia digestion (Table 4). Iron concentrations varied slightly by soil horizon in each pedon, with pedon 4 having more variance. Pedon 1 exhibited greater near-surface Fe and Mn whole soil concentrations than the lower Bw and C (Cg) horizons. Pedon 2 exhibited rather uniform Fe and Mn soil profile distributions. Pedon 3 showed Fe and Mn maxima in the near surface horizons, whereas pedon 4 showed Fe and Mn maxima in the deeper Cg3 and Cg4 horizons. The whole soil Fe/Mn ratio illustrates the relative abundance of Fe, with no discernable soil profile trends evident.

Table 4. Aqua regia digestion of four soil profiles of the Wilbur series

	Whole Soil			Sand Separate (nodules)		
Horizon	Fe	Mn	Fe/Mn	Fe	Mn	Fe/Mn
	---mg / kg ---			---mg / kg ---		
Pedon 1						
Ap	17600	1120	15.7	9560	2660	3.6
A	16600	1000	16.6	9500	3110	3.1
Bw1	17400	1010	17.2	9200	6870	1.3
Bw2	13800	460	30.0	3100	1450	2.1
C1	14300	820	17.5	7600	2230	3.4
C2	11600	520	22.9	9400	2600	3.6
C3	15200	870	17.6	5300	2700	2.0
C4	12600	720	17.5	3900	1700	2.3
Pedon 2						
Ap	15200	740	20.5	9700	4390	2.2
Bw1	16500	720	22.9	6400	3150	2.0
Bw2	13200	640	20.6	8200	1980	4.2
Bw3	14300	760	18.9	18000	3620	5.0
Cg1	15700	730	21.5	27400	3720	7.4
Cg2	14700	820	18.0	17700	5130	3.4
Cg3	13600	590	23.1	8200	3180	2.6
Pedon 3						
Ap1	18600	1060	17.5	11800	1940	6.1
Ap2	23000	1080	21.3	18200	2760	6.6
Bw1	19900	400	49.8	50000	1570	31.8
Bw2	15600	600	26.2	52200	1300	40.3
Cg1	15600	680	23.0	28700	2480	11.6
Cg2	13100	370	35.3	22000	1500	14.7
BC1	12400	250	49.0	19900	1460	13.6
BC2	12400	230	53.9	19800	1400	14.1
Pedon 4						
Ap1	14600	670	21.9	4600	2280	2.0
Bw1	13200	580	22.6	4800	2220	2.2
Bw2	14000	590	23.9	9400	1450	6.5
Bw3	17000	990	17.2	23900	4330	5.5
Cg1	14500	530	27.6	34900	4010	8.7
Cg2	13900	770	18.0	25500	5060	5.0
Cg3	19000	3200	2.9	25200	5520	4.6
Cg4	20800	2300	9.0	18400	6070	3.0
Cg5	20300	310	66.3	21000	1590	13.3
Detection Limit	*100*	*1*				

Iron and Mn aqua regia digestion concentrations of the sand separate were performed to estimate the extent of nodule formation. Individual quartz grains in the sand separate were not visibly coated with Fe-oxyhydroxides, thus the majority of the Fe and Mn appeared to be associated with nodules. The sand separate's aqua regia Fe concentrations were smaller than those of the corresponding whole soil in pedon 1 and were generally smaller than those of the corresponding whole soil in the near-surface horizons of pedons 2 to 4. Conversely, the Cambic and Cg horizons of pedons 2 to 4 revealed generally much greater aqua regia Fe concentrations in the sand separate than those of the corresponding whole soil. The aqua regia Mn distribution was relatively uniform in pedons 1 to 3, whereas the Mn distribution showed a pronounced maxima in the Bw3 to Cg4 horizons. Manganese concentrations in the sand separate were decidedly greater than those of the corresponding whole soil for all pedons. Thus more Fe was incorporated into nodule formation than Mn; however, the Fe/Mn ratios of the sand separate were substantially smaller because of preferential Mn incorporation.

Noncrystalline Fe and Mn oxyhydroxide concentrations were substantially smaller than the corresponding whole soil aqua regia digestion concentrations, particularly for Fe. The noncrystalline Fe concentrations ranged from 1,800 to 2,900 mg Fe/kg in pedon 1, 1,800 to 4,300 mg Fe/kg in pedon 2, 1,500 to 5,800 mg Fe/kg in pedon 3 and 1,400 to 5,000 mg Fe in pedon 4. The noncrystalline Mn concentrations ranged from 270 to 460 mg Mn/kg in pedon 1, 360 to 610 mg Mn/kg in pedon 2, 40 to 460 mg Mn/kg in pedon 3 and 50 to 610 mg Mn in pedon 4. The Fe/Mn ratios are generally smaller than the corresponding ratios for the aqua regia digestion, showing that proportionally more Mn exists as ammonium oxalate extractable species. No discernable noncrystalline Fe and Mn concentration distribution patterns were evident with respect to soil profile depth.

Soil Evaluation

Four adjacent and similar Fluvaquentic Eutrudepts pedons (high base status Inceptisols derived from alluvium and are typically more moist than normal for the udic moisture regime, but not sufficiently wet to warrant placement of an aquic moisture regime) were characterized for their redoximorphic feature expression and their physical, chemical and mineralogical properties. These pedons are also prior-converted wetlands that are currently in agricultural production. Pedons 2, 3 and 4 exhibit redoximorphic features implying more anoxic moisture regimes and the sand separate has greater concentrations of Fe and Mn expressed as nodules. Thus, microvariation in the detailed soil morphology descriptions is reflected by intensity differences in soil processes.

Except of prior-converted wetlands, these preserved landscapes are important for (i) flood damage reduction by intercepting runoff, (ii) erosion control, (iii) water quality maintenance by intercepting soil particles, agrichemicals and other pollutants, and (iv) aesthetics and recreational use.

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