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Soil property trends and classification of alluvial floodplains, South Carolina Coastal Plain

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ABSTRACT

Alluvial soils derived from sediments of Piedmont origin occur in the Atlantic Coastal Plain of the southeastern U.S. In South Carolina, high-order rivers receiving sediment are Savannah (SV), Congaree (CN), Wateree (WA), Santee (ST), Lynches (LY), and Great Pee Dee (PD). This study investigated distribution of soil properties on natural levee, valley flat, and backswamp landforms within and among the six river floodplains and compared results to the taxonomic classifications used historically during soil survey production. This study also investigated the contribution of sediment sources to soil characteristics. Data were compiled for 65 soil pedons sampled from 16 soil survey areas during a 41-year time period. Pedons were located in three Major Land Resource Areas (MLRAs), and the results should aid in development of both land resource area and ecological site concepts. Data analyses centered on clay and silt contents, mineralogy, base saturation (BS), and cation exchange activity (CEA) classes. Evaluation of data from the six river floodplains revealed common properties among soils on fluvial landscapes across multiple MLRAs. Four soil systems, each derived from a predominant rock type, composed the Piedmont drainage basin of each river. The absolute area of each soil system differed between rivers, but sediment supplied typically did not result in great soil texture variation per landform. The land area proportion of the Carolina Slate Belt soil system had a close relationship to silt contents of the alluvial soils. On the valley flat landform of five floodplains, particle-size control section (PSCS) median clay content ranged only between 302 g kg^{-1} and 405 g kg^{-1}. Among all valley flats median PSCS silt content ranged between 361 g kg^{-1} and 511 g kg^{-1}. Slight positive downriver trends for clay were observed on SV, WA, and PD and for silt on SV and WA. Although local BS variation could be high between pedons, slight positive downriver BS trends on valley flats were observed on SV, WA, and ST. Negative BS trends were seen on LY and PD. Kaolinite was the dominant clay mineral in soils of all landforms on the six floodplains. Weatherable primary minerals in sand and silt fractions resulted in higher BS except for the LY soils, where resistant minerals composed sand and silt fractions. The semiactive CEA class occurred predominantly on all three landforms. Taxonomic analysis supported soil assignment to the suborders Aquepts or Udepts on all floodplains. Great group level Eutrudepts in South Carolina are first reported here, and they occur extensively enough on SV, CN, WA, and PD to warrant recognition in soil map units. Because most soil properties showed little variability for soils occurring in floodplains for all six rivers, botanical assessments will be needed to determine the magnitude of the role the properties have toward defining ecological sites. Ultimately, the alluvial systems may be aggregated as a single land resource area within the Coastal Plain.

1. Introduction

Alluvial floodplains are distinct physical and, in a sense, biological landscapes found throughout the southeastern U.S. and are valued for their resources and ecological functions (Wharton et al., 1982; McWilliams and Rosson, 1990; Kellison and Young, 1997). The floodplains are physically distinct in the Coastal Plain region because much of the soil parent material was transported to the region from outside sources. Stream headwaters originate from crystalline and sedimentary terrane in the Mid-Atlantic and Gulf Coastal regions. Rivers transport sediment to the Coastal Plain. The floodplains formed from sediment transported from these regions are termed “alluvial” to

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distinguish from blackwater swamps whose headwaters originate exclusively within the Coastal Plain (Hupp, 2000; Ogg et al., 2013).

Floodplain soils and sediments play an important role in water quality and quantity. Many studies highlight these functions related to hydrostratigraphy, hydrogeology, and geotechnical engineering (Bersezio et al., 2007); soil moisture flow paths (Zhu et al., 2010); groundwater flow to aquifers (Bersezio et al., 1999; Teles et al., 2004; Zappa et al., 2006); flooding estimates (Stokes et al., 2012); and sediment storage (Hupp et al., 2015; Phillips, 1991). Floodplain soils and sediments have also been used to detect environmental change imprinted as a result of climate fluctuations and anthropogenic influences (Bridgland and Westaway, 2008; Brown, 2008; Damm and Hagedorn, 2010; Lecce, 1997; Magillian, 1992; May, 2003; Nanson et al., 2008; Taylor and Lewin, 1997).

Rivers and riverine ecosystems provide habitat to fauna and flora for nutrients, refuge, and reproduction. This biological function is linked to the structure and arrangement of fluvial geomorphic features, which are partially controlled by particle size distribution. River channel investigations conducted at various scales can help develop strategies for environmental monitoring, engineering and biological planning, and stream rehabilitation. Work in the Hudson River estuary in New York (Strayer et al., 2006) and the Yuba River basin of California (Wyrick and Pasternack, 2014) found sediment facies effectively identified aquatic and benthic habitats (California) as well as community structure and density of invertebrates, fish forage, and pest species (New York). For a multi-basin study conducted throughout France, Snelder et al. (2011) modeled mean bed surface grain size as a function of distance from headwaters. The key variables found to explain grain size across climatically and physiographically diverse river basins were watershed slope, channel segment slope, stream power, rainfall (climatic) factors, and geologic hardness. On the Indian subcontinent, Singh et al. (2007) determined sediment characteristics and transportation dynamics in the Ganga River act as major transport mechanisms for nutrients (N and P) and contaminants (heavy metals, pesticides, and herbicides). Geomorphological zones in riverine ecosystems provide a framework for portraying diverse flora and fauna complexity in distinct communities (Wharton et al., 1982). Zones are the basis for classifying environmental and biotic systems along a continuum of elevation, hydroperiod (flooding and ponding duration), and soil moisture. Trophic dependence of fauna on flora is summarized by two faunal regimes: 1) a detritus-dominated aquatic regime and 2) a grazing-foraging food web that is more terrestrial than aquatic.

Implicit within river and river basin investigations is the downstream trend (Heitmuller and Hudson, 2009) or longitudinal variation (Rice, 1999) of sediment and how, through time, adjustments and shifts in the fluvial system cause transformation of sediment facies into distinct terrestrial landforms. The resulting suite of soils connects the physical environment to a unique biological system underpinned by a variety of botanical communities (Wharton et al., 1982). The soil-landform unit is the basis for delineating an ecological site (ES), a land resource area nested in the land classification hierarchy used by the Natural Resources Conservation Service (NRCS) and other federal agencies (Salley et al., 2016). Ecological sites are the spatial framework used by the U.S. agencies to develop common ecological regions to effectively coordinate management activities of the nation's land, water, and biological resources in the same natural geographic area (McMahon et al., 2001).

Ecological sites are defined by recurring soil, landform, geological, and climate characteristics that together produce distinctive kinds, amounts, and proportions of vegetation (USDA-NRCS, 2014). In the convention of a hierarchical system, a category at a lower level cannot overlap into a category at a higher level, so an ES cannot cross a MLRA boundary. Alluvial floodplains in South Carolina present a unique problem because they pass through more than one MLRA. Griffith et al. (2002) recognized alluvial floodplains as Level IV ecoregions and divided them by Level III ecoregion boundaries. In contrast, Miller and Robinson (1995) inferred the extensive Alluvial Floodplain Province as a single entity. Scale of their physiographic map prevented inclusion, but Miller and Robinson (1995) stated the single province should be recognized to organize ecological and silviculture research findings for 12 southeastern states. Consistent predictability of soil properties on similar landforms in the downriver direction should enhance the development of ES concepts. Regional verification of soil continuity among separate and similarly developed floodplain systems will be a step toward determining if the application of ES concepts across MLRA boundaries is valid in the Coastal Plain at the scales discussed by Salley et al. (2016).

Plant community composition and structure have not been linked systematically to alluvial soil landforms in the southeastern U.S. except by the foundational work of Matthews et al. (2011) on 100-year floodplains in five river basins in the North Carolina Piedmont. Their thorough quantitative investigation classified and described remnant high-quality alluvial plant communities to seek information for effective conservation and restoration of floodplain ecosystems. Noteworthy geographic and edaphic results were found for the bottomland and swamp forests vegetation group. The group was sorted along a hydrologic gradient and associated with distinct landforms characterized by less fertile, acidic soils containing more silt and clay than the other groups. A relationship to parent material origin was also suggested because three forest types within this group were associated with the Triassic Basin and one was associated with granitic bedrock.

Alluvial soils are well known for their physical and chemical variability. Assessing this variability has been a concern when establishing soil series concepts (Mausbach et al., 1980), map unit concepts at 1st order (Iqbal et al., 2005) and 2nd order (Ameyan, 1986) scales, and when determining taxonomic purity within soil map units (Young et al., 1997). Despite the natural perturbations in fluvial systems (Leopold et al., 1964) producing variability of alluvium (provenance, variable floodwater energy, and sediment load), transfer of material from land surfaces to oceans is characterized by a tendency toward downstream reduction in particle size (Knighton, 1984). Few studies, though, have investigated downstream continuity by combining soils with landform characteristics. Heitmuller and Hudson (2009) incorporated channel bank and overbank terrestrial deposits to discern downstream sediment size and composition trends in central Texas. After combining data from the bank wall and overbank deposits, they found a statistically significant trend for increasing particle size with downstream distance which was contrary to the tendency for downstream fining. Overbank deposits showed an insignificant increasing downstream trend. Particle size increases were attributed to different lithologic sources in the drainage basin. Finer-grained sediment in upper reaches was derived from weathered carbonate soils; coarser sediment in lower reaches was derived from granitic grus.

In South Carolina and nearby states of the southeastern U.S., alluvial floodplain sediments have been researched mainly within the disciplines of geology and geomorphology (Leeth and Nagle, 1996; Sexton, 1999; Thieme, 1999; Leigh, 2008). Two studies reported sediment trends and soil composition. Leeth and Nagle (1996) studied depth, thickness, and character of Savannah River alluvial valley sediment while investigating the effect stream incision had on regional hydrologic flow systems and aquifers. They showed the alluvium thinned coastward, bulk grain size decreased in the downstream direction, and the present river position may be the result of past tectonism. In the middle Coastal Plain of central South Carolina, Sexton (1999) investigated near-surface sediments and geomorphological processes at the confluence of the Congaree, Wateree, and Santee Rivers. Floodplains associated with each river were composed of clay and silt, yet each one exhibited unique fluvial features caused by a change in gradient between the upper and middle Coastal Plain, inherited topography from the Wisconsin, and possible tectonism attributed to uplift of the Cape Fear Arch.

Six alluvial river systems in South Carolina (Fig. 1) represent an