Variability of Soil Physical and Chemical Properties in an Established Residential Community

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Abstract. Urban soils have highly variable chemical, physical, and biological properties compared to undisturbed natural soils. The objective of this study was to describe the variability in chemical properties from soils collected from established (>10 years) residential landscapes. Composite soil samples were collected at a depth of 0 to 6 inches from lawn and landscape plant beds at 48 residential units and four park locations in Osprey, Sarasota County, FL. Composite soil samples were analyzed for pH, electrical conductivity, organic matter, total Kjeldahl nitrogen, ammonium nitrogen, nitrate nitrogen, and Mehlich 3 phosphorus, potassium, calcium and magnesium. Deep core samples were also collected to a depth of 48 in from ornamental landscape beds at 16 of the 48 residences and from two park locations using a bucket auger to further investigate soil variability. Chemical and physical characteristics varied widely in residential landscapes compared to park soil. Vegetative cover influenced chemical composition and organic matter (OM) of soils (except pH). Soil and landscape management practices should be addressed at the lot scale.

INTRODUCTION

In 2009, the United Nations announced the start of the "Urban Millennium". This marked a significant change in human population trends worldwide, where rural habitation shifted to developing suburban and urban areas (Marcotullio et al., 2008; United Nations Population Fund, 2011). From this point forward, sustainable urban development will depend largely on proper management and protection of natural resources (World Bank, 2000). Current building practices alter the natural soil habitat affecting physical and chemical properties that, in turn, affect soil formation and the behavior of ecological systems (Craul, 1985; 1994). Housing will be concentrated within smaller residential parcels, consequently affecting urban ecosystems (De Kimpe and Moral, 2000). Soil disturbance and the associated changes in physical, chemical, and biological soil characteristics will have lasting effects on ecological services provided by urban soils, such as gardening, landscape aesthetics, and regulation of temperature (Pataki et al., 2006). Changes in soil physical properties related to hydrology and atmospheric gas exchange are typically associated with urban development (Craul, 1994). For example, foot and vehicular traffic on bare soils during construction can decrease air and water infiltration and increase runoff of sediments (Jim, 1998b). Soil temperature regimes change as a result of soil modifications that reduce water infiltration and effectively create an "island heat" sink (Oke, 1995). The increase in soil temperature stimulates metabolic degradation of soil organic matter and carbon and nitrogen cycling (Lorenz and Lal 2009), which may influence nutrient and moisture holding capabilities of the soil (Craul, 1985; Lorenz and Lal, 2009). Because of the broad impacts of construction on urban soils, emphasis on how ecological systems maintain their ability to function under an outpacing population will continue to be a focal point for soil scientists and ecologists (Rees and Wackernagel, 1996).

Urbanization and Soil Function

Natural, undisturbed soils play a vital role in supporting ecosystem services; however, much is still unknown regarding how naturally functioning systems will continue to be productive once impacted by urbanization. Researchers continue to questions how quickly disturbed soils can become functional and sustaining (De Kimpe and Moral, 2000; Zipperer et al., 2000; Pataki et al., 2006). What we do know, is that it is critical for soils to continue to function within urban environments. Several studies have documented the benefits of natural soils related to biogeochemical cycling (Lorenz and Lal, 2009), human safety, water quality, and climate regulation (Grimm et al., 2008). For example, natural soils influence nitrogen (N) and carbon (C) cycles, filtering and sorption of heavy metals, immobilization of harmful bacteria, and regulation of ambient air temperature and gas exchange and food supply (De Kimpe and Moral, 2000; Scharenbroch et al., 2005 Grimm et al., 2008; Lorenz and Lal, 2009). Urbanization involves a transformational process for natural, native soils as they undergo pedological formation, and changes to chemical and physical properties. To model this concept, Pouyat et al. (2010) described three major alternations of natural soil formation and function, beginning with parcelization, or the division of land mass designated by larger to smaller land use parcels (e.g., division of states into counties to municipalities to specific developments). Parcelization is followed by fragmentation, which is the sub-division of larger parcels resulting in predetermined land uses (e.g., industrial, residential, green space areas, etc.). It is at the lot scale where native soil becomes segmented based on use and changed by anthropogenic interactions (Pouyat et al., 2010; Pouyat et al., 2007).

According to Pickett and Cadenasso (2009), "disturbances refer to an event that alters the structure of an explicit specified system." Soil disturbance changes result from direct or indirect anthropogenic interactions (Pouyat et al., 2010). Direct interactions result in the introduction of impervious surfaces, soil compaction, mixing of soil parent materials, and the introduction of construction artifacts, all of which alter soil properties and behavior, physically, chemically, and/or biologically (Pouyat et al., 2010). In some cases, fill material must be spread over the residential lot to allow for the construction of a home or home septic system, thus affecting soil percolation and nearby soil chemistry. Regardless of the fill source, the spreading of fill material can affect soil texture, porosity, and moisture holding capacity at the construction site. According to Pouyat et al. (2010), indirect interactions exist as changes in abiotic and biotic factors. For example, resource competition of invasive plant species, atmospheric deposition and phytotoxic chemical interactions from construction artifacts. Studies have documented the variability of soil chemical properties between urban soils and undisturbed soils; for example, soil pH was significantly influenced by length of time from disturbance (Park et al., 2010; Hagan et al., 2012). Ultimately, direct and indirect modifications to natural soils lead to alterations in soil texture, structure, pH, and water holding capacity and filtration (De Kimpe and Moral, 2000; Kaye et al., 2006; Pouyat et al., 2010).

Spatial Variability of Urban Soils

According to Craul (1994), the degree of disturbance resulting from the mixing of native soils determines the overall characteristics of urban soils. Fill materials and layer of displaced soils dictate the nature and behavior of soil's biological, chemical, and physical attributes including structure, texture, air exchange, water movement, compaction, pH, C: N ratio, and overall productive capacity of the soil (Craul, 1992; Jim, 1993; Lorenz and Lal, 2009). Urban soils are differentiated by abrupt changes in physical and chemical properties (Pickett and Cadenasso, 2009). Abrupt changes in material composition can affect rooting and infiltration capacity, resulting in poor plant establishment and health in urban soils (De Kimpe and Morel, 2000; Jim, 1993; Yung, 1993). Organic content is important to sustaining microbial populations, which in turn, contributes to soil formation process; for example, organic debris mixed or stratified within layers of urban soils can affect root growth and impede aeration and water movement, thus, affect formation properties (Bullock et al., 1991; Craul, 1994). Therefore, variability in soil composition and biotic and abiotic factors can influence soil properties and should be a considered in pre-post landscape management decisions.

Characteristics and Uses of Urban Soils

The term “urban soil” was first used in 1847 by Ferdinand Senft, who mentioned that waste associated with industrialization affected soil fertility (Lehmann and Stahr, 2007). Urban soils provide function in residential development, and are used for several purposes including as a medium for landscape plant material, base support for dwellings, road bed foundations, stormwater embankments, and fill material for leveling lot parcels (De Kempe and Moral, 2000). Subsequently, “urban soil” was noted to have identifiable physical and chemical properties by Zemlyanitsky (1962). Today, soil taxonomists continue to evaluate and classify urban soil by describing their chemical, physical properties, as well as significant difference in state factors compared with natural, undisturbed soils (Lehmann and Stahr, 2007; Pickett and Cadenasso, 2009) as introduced by Jenny (1941). The classical definition of urban soil was described by Bockheim (1974) as “a soil material having a non-agricultural, man-made surface layer more than 50 cm thick, which has been produced by mixing, filling, or by contamination of land surfaces in urban and suburban areas”. Maechling et al. (1974) defined an urban soil as “a soil material having a nonagricultural, manmade surface layer more than 20 inches thick that has been produced by mixing, filling, or by contamination of the land surface in urban and suburban areas”. Later, Lehmann and Stahr (2007) enhanced the level of understanding of urban soils by providing a more pedological definition:

> "Urban soils are those strongly influenced by human activities such as construction, transportation, manufacturing processes, industry, mining, rural housing and similar activities".

Natural or undisturbed soil genesis is expressed using the traditional framework to describe the five state factors associated with soil formation and ecological development as described by Jenny (1941). These factors include: climate, organisms, parent material, relief and time (Jenny, 1941). According to Jenny (1941), natural soils exhibit intact soil profiles that can be keyed based on diagnostic horizon development. However, it was later found that direct and indirect anthropogenic interactions imparts changes and alterations that introduce new pedogenic situations (Effland and Pouyat, 1997) and that urban soils become unique materials made up of a new or novel composite of once naturally stratified horizon layers (Pavao-Zuckerman, 2008). Effland and Pouyat (1997) used this new knowledge to modify Jenny's model to account for anthropogenic factors in the states of soil formation framework. Now within the natural soil genesis framework, urban soils are considered to be pedologically reset, starting over from a new parent material within the confines of the framework previously documented by Jenny (1941) and Effland and Pouyat (1997).

Study Objectives

Given that human populations will continue to move from rural areas to urbanized cities, a critical look at how anthropogenic activity influences urban soil behavior is necessary. Previous research contended that more study was required to differentiate (e.g. pH, bulk density, structure, texture) urban soils based on in-situ characteristics (Pouyat et al., 2007). Our study attempts to answer how anthropogenic activity affects soil properties at the residential community scale. Residential development often involves the construction of housing in phases (i.e., groups of homes); a process that can take several months to years to complete. Studies have found that soils within urban areas vary significantly due to differences such as, exposure to heavy mechanical equipment, multiple sources of fill soil, and burial of native soils and debris (Effland and Pouyat, 1997). Similarly, our study will identify soil physical and chemical composition and the extent of variability within soil horizons and soil properties within a single residential community, which can be compared with results of other urban soil studies conducted at the metropolitan and regional scales (Effland and Pouyat, 1997; Pouyat et al., 2010; Shuster, 2011; Hagan et al., 2012). To our knowledge, few studies have intensively compared native soils to similarly mapped soils in a nearby residential neighborhood community to evaluate differences in chemical and physical soil properties at the residential lot scale. Therefore, the objective of this study was to determine the variability of chemical properties in collected from established (>10 years) residential yards by examining the properties of surface soils and soil profiles. We also investigated the influence of vegetation (ornamental plants vs. turfgrass) and phase of development on soil chemical properties. The long-term goal of this study is to integrate this knowledge into a systems management approach to remediating urban soils based on pre- and post-management decisions using specific analysis of the building phase or housing unit.

Materials and Methods

Study Location

The study was conducted in Rivendell, a master-planned residential community located in Osprey, Sarasota County, FL (Fig. 1). Rivendell was developed in five primary development phases and associated sub-phases (Fig. 1) The development phases (listed as units on the community map; Fig. 1) were built out between the years of 1998 and 2004. The median home price in Rivendell at the time of construction was $365,000. Residential lots in phases 2 (home built in 1998-2003), 3A (1999-2002), 3B (2001-2002), 3C (2001-2002), 3D (2002-2003), 3E (2001-2002), 4A (2002-2004), 4B (2002-2003), and 5 (2002-2004) were sampled. We hypothesized that soil fill materials and constructions practices that would impact soil properties would be similar within a single building phase. Homes were selected for intensive soil sampling from a list of Rivendell residents who responded to a landscape preferences survey conducted by the University of Central Florida Stormwater Academy; all soil samples were collected with homeowner consent. Soil samples were also collected from Oscar Scherer State Park, which bordered Rivendell on the south and east sides.

Soil Sampling and Analysis

Composite soil samples were collected at a depth of 0 to 15 cm at two locations per residence (i.e., turfgrass areas and ornamental plant beds) for a total of 98 residential landscape composite soil samples. Four additional composite samples were collected from Oscar Scherer State Park to provide a baseline (natural soil) with which to compare physical and chemical properties of soils collected from Rivendell residential areas. Approximately 10 to 15 soil cores (75 to 100 g of soil) per composite sample were randomly sampled using a soil probe at each residence and in the park areas. Composite soil samples were air-dried and sieved to pass a 2-mm screen. Soil texture was determined using the *USDA Soil Texture by Feel Method* guide introduced by Thien (1979). Soil bulk density (D_b) was determined in the top 10-cm of soil within the ornamental landscape bed area of each residential lot using the standard method presented by Blake and Hartge (1986). Bulk density was not determined in the turf areas due to the presence of excessive thatch in most St. Augustinegrass lawns and the resulting risk of severe damage to the turf. Bulk density measurements were not completed on the Oscar Scherer park samples.

Organic matter (OM; loss on ignition), pH (1:2 soil to deionized water ratio), and electrical conductivity (EC; 1:2 soil to deionized water ratio) were determined using the standard methods of the University of Florida Institute of Food and Agricultural Sciences (UF-IFAS) extension soil testing laboratory (Mylavarapu and Kennelley, 2002b). Soils were extracted with 2M KCl (1:25 soil to solution ratio) (Mulvaney, 1996) and analyzed for soil ammonium-N (NH_4-N) (U.S. Environmental Protection Agency, 1993a) and nitrate + nitrite-N (NO_x-N) (U.S. Environmental Protection Agency, 1993c) using a discrete analyzer (AQ2, Seal Analytical, West Sussex, UK). Soils were also digested using and analyzed for total Kjeldahl N (TKN) (U.S. Environmental Protection Agency, 1993b) using a discrete analyzer (AQ2, Seal Analytical, West Sussex, UK). Soils were also extracted using the Mehlich 3 (M3) extraction (Kovar and Pierzynski, 2009) and analyzed for P, K, Ca, and Mg using inductively coupled plasma – atomic emission spectroscopy (ICP-AES). Current UF-IFAS soil test interpretations are based on the Mehlich 1 (M1) soil test (Kidder et al., 2003); however, since M3 provides better results when soil pH tends to be slightly alkaline (as was the case with residential soils in Rivendell) we opted to use M3. Therefore, soil test interpretations for P and K were converted to M3 equivalents based on the relationship between M1 and M3 as reported by Sikora (2002).

Deep core samples were also collected from ornamental landscape beds at 16 selected residences within the Rivendell community and from two locations in Oscar Scherer Park (representing more natural soil conditions). Deep core samples were collected with a 10-cm diameter bucket auger from the soil surface to the water table or 122 cm below grade, whichever was deeper. Samples collected with the auger were deposited onto a section of 10 cm × 122 cm PVC tube that was cut in half for viewing. Deep core samples were described based on methods outlined in the USDA *Field Book for Describing and Sampling Soils* (Schoeneberger et al., 2002) to characterize soil profiles. The following characteristics were described for each soil core sample:

1. **Depth** – Depth was recorded as the "bottom depth" of each specific horizon or layer.
2. **Color** – Munsell soil color charts were used to determine the hue, value, and chroma and the associated color name on moist samples from each horizon. For example, 10YR 4/4 would be noted as "reddish brown".
3. **Texture** – The soil texture by feel method (Thien, 1979) was used to estimate texture class based on the soil textural triangle (e.g., sand, sandy loam, loamy sand, etc.)
4. **Water Laid or Transported Deposits** – This term refers to the identification of parent materials. Multiple parent materials were identified as "marine deposits" based on the presence of fine to medium shell fragments within the samples.
5. **Redoximorphic features (RMF) –** Color patterns in the soil, surfaces of peds, pores or beneath the surfaces of peds were identified. Redoximorphic features descriptions included redox concentrations, redox depletions, or reduced matrix.
6. **Horizon boundary –** The horizon boundary is also known as the distinctness of boundary and describes the point at which a different horizon becomes more dominant. It is the

transition of another horizon (top depth) based on abrupt or diffuse morphological differences.

Data Analysis

Descriptive statistics (e.g., mean, median, range, etc.) were determined for all composite samples using the PROC MEANS procedure in SAS (Sas Institute, 2003). The effect of vegetative cover (turfgrass vs. ornamental) and building phase were assessed using the a mixed model ANOVA using PROC MIXED procedure in SAS (Sas Institute, 2003) with vegetation or building phase as a fixed effect. The normality assumption was checked by examining histogram and residual plots. Mean separations were determined using Tukey's honestly significant difference test (HSD) at $\alpha = 0.05$. Deep core samples were described to provide a qualitative view of differences between samples collected at the park and residential sites (i.e., differences in horizonation and general properties between natural and residential soils and between soils collected from individual lots). Statistical analysis was not completed on the deep core sample characteristics due to the descriptive nature of the data.

RESULTS AND DISCUSSION

Residential Topsoil Composite Samples

Soil texture for all composite samples was sand or loamy sand with no trend for differences in soil texture based on vegetative cover. Texture was identified by feel (qualitative measure); qualitative data regarding percent of sand, silt, and clay was unavailable due to time and funding constraints. Sandy soils have high bulk densities (due to the heavier weight of sand-sized particles) and are well suited for construction of roads and buildings (Brown, 2003).

Soils in both of these textural classes are dominated by sand-sized particles and tend to have high permeability, low organic matter content, and low natural fertility (i.e. low cation exchange capacity). Due to the low production capacity of sandy soils, we suggest that establishment and maintenance of plants will depend on frequent, but judicious application rates of water and nutrients to urban residential soils (Erickson et al., 2001).

Soil organic matter (OM) content ranged from 12.8 to 81.9 g kg^{-1} with a mean OM g kg^{-1} equal to 32.6 for all composite samples collected from the Rivendell residential landscapes (Table 1). Organic matter content in soils collected from Rivendell homes constructed in building phase 3A, 3B, 3C, 3E, and 4A was significantly higher than for samples collected from homes in building phase 2, 3D, 4B, and 5 (Table 3). Variability of OM content in urban soils across building phases may be due to differences in fill material quality, which was possibly associated with nearby remnant soils applied at final grade (Pouyat et al., 2007). Soil samples from Oscar Scherer Park (Table 2) had similar levels of OM (mean OM = 27.6 g kg^{-1}) as samples collected from the residential lots (Table 3). However, variability of soils within the residential lots were found to have significant higher levels, for example, mean value for one residential set was 81.9 g Kg-1. Similar to our study, Scharenbroch et al. (2005) found that the OM content of urban soils was highly variable, as was soil biological activity, and nutrient content. There was a significant vegetative cover effect on OM content in our study, where soils collected from ornamental areas had higher OM than soils in turf areas (Table 4). Higher OM values in ornamental beds may be due to the regular use of mulches or other organic materials during bed preparation, such as enriched top soil, compost, leaf litter and other organic materials (Craul, 1999). Alternatively, soils with low organic matter content may be affected by inappropriate cultural practices, such as the removal of turf clippings that from lawns after mowing, which limits the recycling of OM back into soils in turf areas (Craul, 1999).

Overall, bulk density (D_b) values of soils collected within the ornamental beds in 48 Rivendell residential units varied widely (Table 1). Bulk density was not determined in lawn or park areas due to difficulties obtaining a reliable sample. The D_b of ornamental bed soils in Rivendell ranged from 0.48 to 2.37 g cm^{-3}, with a mean soil Db in ornamental beds of 1.44 g cm^{-3} (Table 4). It is clear that the D_b of some soils was approaching or exceeding the 1.7 g cm^{-3} threshold for D_b in sandy soils, indicating severely compacted conditions. Severe compaction may impact soil functions like nutrient adsorption, gas exchange, root penetration, drainage and other natural biological processes (Hanks and Lewandowski, 2003). Soil D_b values reported in our study were significantly higher than soil D_b values reported by Hagan et al. (2012). Hagen et al. (2012) reported a mean bulk density of 1.01 g/$cm^3$for soils in older residential landscapes in Florida (< 20 yr). In contrast, Scharenbroch et al. (2005) reported that soil D_b values decreased with age of landscape. In our study, building phase had an influence on soil D_b values, where soils collected from residential landscape beds within building units 3A and 4B had significantly higher soil D_b than soils collected from units 2, 3B, 3C, 3D, 3E, 4A, 5 (Table 3). Higher D_b values recorded for building units 3A and 4B could be related to the sources of the soil fill material, the use of heavy equipment during construction, the excessive foot traffic, or other human activity on wet soils (Craul, 1994).

Overall, the pH of composite soils collected in residential landscapes ranged from slightly acidic to alkaline, ranging from 6.50 to 8.10 with a mean pH of 7.54 (Table 1). Overall, soil pH in residential landscapes did not fall within target pH levels (6.0 to 6.5) for establishment and growth of turf and ornamental plant species (Kidder et al., 1998). In contrast, undisturbed composite soil samples from nearby Oscar Scherer State Park were very acidic, with soil pH ranging from 4.05 to 4.30 with a mean pH of 4.20 (Table 2). This is typical of sandy Flatwoods soils due to soil formation under pine vegetation and facultative organism activity. Pouyat et al. (2007) reported a significant relationship between land use and/or land cover and soil pH associated with turfgrass management. Vegetative cover did not affect soil pH (Table 4); we suggest that the use of acidifying fertilizers or other management practices were similar in turf and ornamental areas and therefore did not affect soil pH (Jim, 1998a; Pouyat et al., 2007). In our study, building phase influenced soil pH levels, where samples collected from homes constructed in phase 4B exhibited significantly lower (neutral) than samples collected from homes built in phase 3B, 3C, 3D, and 5 (Table 3). Higher soil pH values in phase3B, 3C, 3D, 3E, 4A and 5 could be related to origin of the soil fill materials. For example, fill materials may have significant alkaline buffering capacities (Marcotullio et al., 2008) and/or were of limestone origin (USDA-NRCS, 2004), which is typical of Florida soils. We did identify fill materials containing high concentrations of calcium carbonate from marine deposits (as evidenced by the presences of visible shell fragments) and/or construction debris containing concrete materials in some landscapes, which could result in semi-alkaline to alkaline soil pH (Pouyat et al., 2007).

All residential landscape soils appeared to have elevated levels of NH_4-N, NO_3-N and TKN, with concentrations ranging 308 to 1965 mg kg^{-1} (mean = 988 mg kg^{-1}) (Table 1) compared to samples collected from the nearby Oscar Scherer Park (TKN range = 502 to 804 mg kg^{-1}; mean = 635 mg kg^{-1}) (Table 2). Law et al. (2004) and Hagan et al. (2012) observed similar differences in TKN elevated levels and related them to socioeconomic factors. For example, high income was associated with more intensive landscape practices (e.g. fertilization and Irrigation) that could increase soil TKN. Elevated levels of soil N could be a result of anthropogenic factors, landscape irrigation, or fertilizer amendments (Pouyat et al., 2010). Vegetative cover also influenced concentrations of NH_4-N, NO_x-N, and TKN in soils, where soils collected from turf areas had significantly higher concentrations of inorganic N than soils from the ornamental area (Table 4). It is possible that mineralization of N in turf clippings increased the amount of extractable soil N, or that inputs of N from turf fertilization could explain the higher extractable N in turf areas (Kopp and Guillard, 2004). Building phase also had an effect on soil TKN, but not on soil NO_x-N or NH_4-N (Table 3). Soil TKN values were significantly higher from homes built in phase 3E than for homes built in phase 2, 3D, 4A, or 5 (Table 3).

Runoff and leaching of P is a concern for a majority of Florida's sandy soils, because pollutants in runoff and leachate can alter freshwater aquatic life and impact overall water quality (Sharpley et al., 1996). Based on the soil test interpretations for Florida presented in (Table 5), overall soil test M3-P concentrations ranged from "low" to "high" (Table 1). For reference, no plant response is expected from additions of P when crops are grown in soils where the soil test levels falls within the "high" (41-65 mg kg^{-1}) or "very high" (> 65 mg kg^{-1}) soil test M3-P categories (based on the mathematical relationship between M1 and M3 for Florida soils presented by Mylavarapu et al. (2002), In fact, based on soil test P concentrations, crop response was expected for only 8 of the 96 soils sampled. In contrast, the mean concentration of M3-P in the Oscar Scherer samples was 10.4 mg kg^{-1}, which would be categorized as "low" and "very low" based on the Florida soil test M1 and M3-P interpretations (Table 3).

In addition, there was a significant vegetative cover effect on M3-P, where soils collected from turf areas had lower M3-P concentrations than soils collected from ornamental beds (Table 4). It is possible that higher M3-P in ornamental areas is related to the use of higher fertilization rates and frequent application of high P ornamental fertilizers when compared to turf areas; ornamental fertilizer tend to have higher P contents (usually to promote flowering) than turf fertilizers, which were recently mandated by state law to contain no more than 2% P_2O_5 (Hochmuth et al., 2011). There was a significant building unit phase effect on M3-P, where soils collected from phases 4B and 5 (Table 6.) Fill material may be associated with a higher M3-P value.

Overall soil test M3-K concentrations ranged from “very low” (0-50 mg kg^{-1}) to “very high” (>351 mg kg^{-1}) (Table 1) based on M3 soil test interpretations (Table 5) (based on the mathematical relationship between Mehlich-1 and M3 for Florida soils presented by Mylavarapu et al. (2002). There was a significant vegetative cover effect on M3-K; soils collected from turf areas had slightly higher M3-K concentrations than soils collected from ornamental beds (Table 4). It is possible that higher M3-K in turf areas is related to the use of high fertilization rates and frequent application of turf fertilizer, which tend to have higher K contents than fertilizers formulated for use on ornamental plants. Building phase also influenced M3-P concentrations, where samples collected from homes built in phase 4B had significantly higher M3-P values than for samples collected from homes in phase 3A, 3B, 3E, 4A, and 5. Higher values in 4B could be related to the soil fill material used during construction or the fertilization patterns of homeowners within that phase. In addition, samples collected from phase 3E had significantly higher M3-K values than samples collected from units 3B, 3D, 4A, 4B, and 5 (Table 6). Higher M3-K concentrations in phase 3E could be related to significantly higher OM values (Table 3), because high OM levels may influence K absorption (retention in sandy soils) (Van Cleve and Moore, 1978). Statistical analysis of other nutrients (e.g., Mg and Ca) extracted using the M3 method is listed in Table 6 for reference. Mehlich 3 soil test interpretations are not available for these nutrients. Any reported building phase or vegetative cover effects were unlikely to impact water quality.

Deep Soil Cores

Mapped soil series within the Rivendell community were predominantly EauGallie and Myakka fines sands, with smaller areas of St. Augustine fine sand and Holopaw fine sand, depressional (USDA-NRCS, 2004). Characteristics of individual horizons for each deep core sample were not similar in composition to mapped soil series (Figures 2). Characteristics of deep core samples were highly variable between property lots, which was likely due to differences in soil fill materials and/or management practices followed at each individual residential unit. In contrast, soil core samples collected from the Oscar Scherer State Park were very similar to the mapped soil series for the park (Eau Gallie and Myakka fine sands). Park soils expressed chemical weathering processes indicative of distinct horizons, consistent color and depth, and presence of a spodic horizon. Park samples also contained fewer, but more distinct horizon boundaries (abrupt to gradual transitional boundaries) and redoxmorphic features. Residential deep cores revealed human transported materials, mixing of parent material, shell aggregate and heterogeneous textures and structure. Similar research methods applied by Shuster (2011) described differences in diagnostic horizon variation and anthropogenic, non-soil materials between city park soils and vacant housing lots.

Summary and Conclusion

Chemical and physical characteristics varied widely in residential landscapes compared to the more natural park soils. Differences in horizon boundaries, depth, color, and texture were observed. These differences may affect water and air movement below and above ground, soil weathering processes, and plant health. Materials used for residential fill contained a mixture of transported materials, such as marine/water laden deposits. Elevated levels of Ca in the soil associated with marine materials may modify pH levels (alkaline range). Vegetative cover influenced chemical composition and OM of soils (with the exception of soil pH). Phosphorus levels were found to be adequate for established turfgrass areas. Therefore, pre-plant and routine soil testing for pH, P, K and secondary nutrients should benefit the homeowner or professional landscape manager, reducing the need for additional applications of nutrients.

Residential urban soils are unique and require specific management practices to promote soil function and minimize adverse environmental impacts (Kaye et al., 2006). Disruption of natural soils poses an environmental risk (i.e. runoff and leaching) and must be addressed in a timely manner. Remediation of urban soils requires proper landscape design and maintenance to optimize physical and chemical soil conditions (Pavao-Zuckerman, 2008). Established building and development practices should incorporate pre/post-construction best management practices that address unique and varied dynamic soil systems found in residential developments. These practices include evaluating physical and chemical properties, elevating compaction, preserving existing vegetation, and protecting native soil during construction. Installation and establishment landscaping maintenance practices should include planting the right plant in the right place and amending/conditioning soil before planting to provide a favorable environment for microbial activity and optimal soil reactivity (i.e., pH and CEC). Routine landscape maintenance practices should include maintaining existing vegetation, mulching bare soil, and routine aeration to improve water and nutrient holding capacity, sorption of anthropogenic related pollutants, and to reduce ambient temperate (heat island) effect and landscape sustainability (Hawver and Bassuk, 2007).

To this end, the physical and chemical variability is probable within each residential unit. Adoption of integrated landscape management practices that quickly stabilize cover and reduce post-plant establishment maintenance inputs is necessary to reduce environmental impacts in established residential communities as we enter a new millennium.

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Table 1. Descriptive statistics for physical and chemical properties of composite soil samples (*n*=96) collected at no more than 15 cm in depth from ornamental and turf areas within 48 residential lots of Rivendell in Osprey, FL.

Variable	Mean	Std Dev	Median	Minimum	Maximum
D_b, g cm^{-3}	1.44	0.26	1.47	0.48	2.37
pH	7.54	0.32	7.60	6.50	8.10
EC, dS m^{-1}	0.57	0.27	0.50	0.26	1.72
TKN, mg kg^{-1}	988	372	988	308	1965
NO_3-N, mg kg^{-1}	6.74	10.4	3.63	0.89	77.5
NH_4-N, mg kg^{-1}	2.70	7.19	1.79	0.58	72.0
OM, g kg^{-1}	32.6	11.3	30.2	12.8	81.9
M3- P, mg kg^{-1}	86.1	44.9	79.0	18.3	240
M3- K, mg kg^{-1}	38.9	27.2	34.6	4.81	158
M3- Ca, mg kg^{-1}	2887	1354	2585	1090	7560
M3- Mg, mg kg^{-1}	208	53.8	207	102	358
M3-Zn, mg kg^{-1}	12.3	17.3	8.84	3.72	170
M3-Mn, mg kg^{-1}	30.8	22.2	23.7	6.08	115
M-3 Cu, mg kg^{-1}	2.62	2.04	2.03	0.53	14.6
M3- Fe, mg kg^{-1}	136	30.6	134	70.2	210
M3- Al, mg kg^{-1}	235	182	184	2.28	210
M3-Na, mg kg^{-1}	37.5	10.5	35.1	23.3	73.2

*Minimum of 5.00 is (0.5) the detection limit; values <10.0 mg/kg were assigned this value

**Reported values as received from APL values below 4.00 mg/kg may not be accurate because they are lower than the PQL (Practical Quantitation Limit).

Table 2. Physical and chemical properties of composite soil samples collected from Oscar Scherer State Park (*n*=4) at 0-6 in depth.

Variable	Mean	Std Dev	Median	Minimum	Maximum
pH	4.20	0.12	4.22	4.05	4.30
EC, dS m^{-1}	0.10	0.01	0.10	0.08	0.10
TKN, mg kg^{-1}	635	149	616	502	804
NO_3-N, mg kg^{-1}	0.19	0.01	0.19	0.18	0.20
NH_4-N, mg kg^{-1}	3.06	0.37	3.02	2.67	3.53
OM, g kg^{-1}	27.6	7.0	27.6	21.3	34.1
M3- P, mg kg^{-1}	10.4	11.5	5.02	3.89	27.6
M3- K, mg kg^{-1}	17.4	12.9	13.3	6.64	36.1
M3- Ca, mg kg^{-1}	244	55.0	240	186	309
M3- Mg, mg kg^{-1}	62.2	21.4	59.2	40.1	90.4
M3-Zn, mg kg^{-1}	5.50	2.60	4.66	3.47	9.20
M3-Mn, mg kg^{-1}			Not detected		
M3- Cu, mg kg^{-1}	3.29	1.45	3.00	2.03	5.12
M3- Fe, mg kg^{-1}	48.8	11.5	51.9	32.4	59.0
M3- Al, mg kg^{-1}	90.2	26.6	91.7	61.6	115.8
M3-Na, mg kg^{-1}	32.5	6.8	33.7	23.6	38.9

Table 3. Building phase effects on selected physical and chemical properties of soil samples collected from 0-6 in from turf and ornamental areas of 48 Rivendell landscapes, Osprey, FL.

Building Phase	**D_b**	**pH**	**EC**	**OM**	**TKN***	**NO_3-N**	**NH_4-N****
	g cm^{-3}		dS m^{-1}	g kg^{-1}	--------------mg kg^{-1}	------------	
2	1.41 ab***	7.44 bc	0.50 b	30.8 b	983 b	7.41 a	1.94 a
3A	1.69 a	7.50 abc	0.66 ab	34.2 ab	1099 ab	8.54 a	1.98 a
3B	1.28 ab	7.72 ab	0.77 ab	35.5 ab	1115 ab	4.48 a	1.88 a
3C	1.38 ab	7.80 ab	0.82 ab	39.0 ab	1146 ab	6.96 a	2.30 a
3D	1.50 ab	7.86 a	0.44 b	26.7 b	845 b	2.92 a	1.43 a
3E	1.04 b	7.60 abc	0.94 a	46.5 ab	1422 a	14.4 a	2.61 a
4A	1.47 ab	7.43 bc	0.56 b	35.2 ab	898 b	4.56 a	2.05 a
4B	1.61 a	7.16 c	0.44 b	27.9 b	811 b	7.97 a	2.41 a
5	1.44 ab	7.66 ab	0.46 b	28.3 b	850 b	4.53 a	1.62 a

* NO_3-N + NO_2-N: Nitrate-N species
**NH_4: Ammonium-N
*** Values with the same letter are not statistically significant based on Tukey's honestly significant difference test at $\alpha = 0.05$.

Table 4. Vegetative cover effects on selected physical and chemical properties of soil samples collected from 0-6 in from turf and ornamental areas of 48 Rivendell landscapes, Osprey, FL.

Variable	Ornamental	Turf
Db, g cm-3	1.44	--
pH	7.56 a*	7.51 a
EC, dS m^{-1}	0.565 b	0.68 a
TKN, mg kg^{-1}	821b	1217 a
NO_3-N, mg kg^{-1}	4.52 b	8.96 a
NH_4-N, mg kg^{-1}	1.64 b	2.29 a
OM, g kg^{-1}	31.4 a	33.8 a
M3-P, mg kg^{-1}	106 a	67.1 b
M3-K, mg kg^{-1}	35.1 a	42.6 a
M3-Ca, mg kg^{-1}	2970 a	2803 a
M3-Mg, mg kg^{-1}	207 a	209 a
M3-Zn, mg kg^{-1}	15.4 a	9.18 a
M3-Mn, mg kg^{-1}	39.5 a	22.0 a
M3- Cu, mg kg^{-1}	3.01 a	2.23 a
M3- Fe, mg kg^{-1}	138 a	133 a
M3- Al, mg kg^{-1}	249 a	220 a
M3-Na, mg kg^{-1}	37 a	38 a

* Values with the same letter are not statistically significant based on Tukey's honestly significant difference test at $\alpha = 0.05$.

Table 5. Current interpretation for Mehlich-1 and equivalent Mehlich 3 soil test interpretations used for environmental horticulture crops (Kidder et al., 2003). Mehlich 1 values were converted to Mehlich 3 based on the relationship presented in (Mylavarapu and Kennelley, 2002a)

Category	Phosphorus		Potassium	
	Mehlich 1	Mehlich 3	Mehlich 1	Mehlich 3
	----------------------------------mg kg^{-1}	----------------------------------		
Very low	>10	>33	<10	<12
Low	10-15	34-41	20-35	22-36
Medium	16-30	42-61	36-60	37-60
High	31-60	61-104	61-125	61-122
Very high	>60	>104	>125	>122

Table 6. Building phase effects on Mehlich 3 soil test nutrient concentrations in soil samples collected from 0-6 in from turf and ornamental areas of 48 Rivendell landscapes, Osprey, FL.

Building Unit	**M3-P**	**M3-K[1]**	**M3-Ca**	**M3-Mg**	**M3-Zn**	**M3-Mn**	**M-3 Cu**	**M3-Fe**	**M3-Al**	**M3-Na**
	----------	----------	----------	----------	mg kg^{-1}	----------	----------	----------	----------	----------
2	94.4 ab*	42.8 abc	2275 bc	201 ab	10.6 a	39.6 a	2.09 a	142 a	309 bc	37.6 bc
3A	85.5 b	60.7 ab	4317 a	222 ab	11.7 a	32.0 a	2.35 a	149 a	56.8 d	42.6 abc
3B	67.6 b	10.2 c	3862 ab	240 ab	9.76 a	34.1 a	3.08 a	133 ab	110 d	42.5 abc
3C	86.0 ab	27.0 abc	3710 abc	276 a	13.5 a	36.0 a	4.57 a	162 a	80.3 cd	47.1 ab
3D	91.6 ab	25.7 bc	3394 abc	206 ab	8.68 a	34.4 a	2.29 a	139 a	169 cd	29.4 c
3E	74.8 b	70.7 a	4344 a	251 a	14.7 a	30.2 a	4.08 a	150 a	66.5 d	52.8 a
4A	73.4 b	23.3 c	2062 c	188 ab	9.60 a	20.6 a	2.63 a	97 b	384 ab	32.9 bc
4B	142 a	41.4 abc	1793 c	159 b	32.4 a	32.0 a	3.02 a	150 a	485 a	31.1 bc
5	65.5 b	34.3 bc	2523 bc	202 ab	8.28 a	20.0 a	2.18 a	126 ab	199 cd	32.8 bc

* Values with the same letter are not statistically significant based on Tukey's honestly significant difference test at $\alpha = 0.05$.

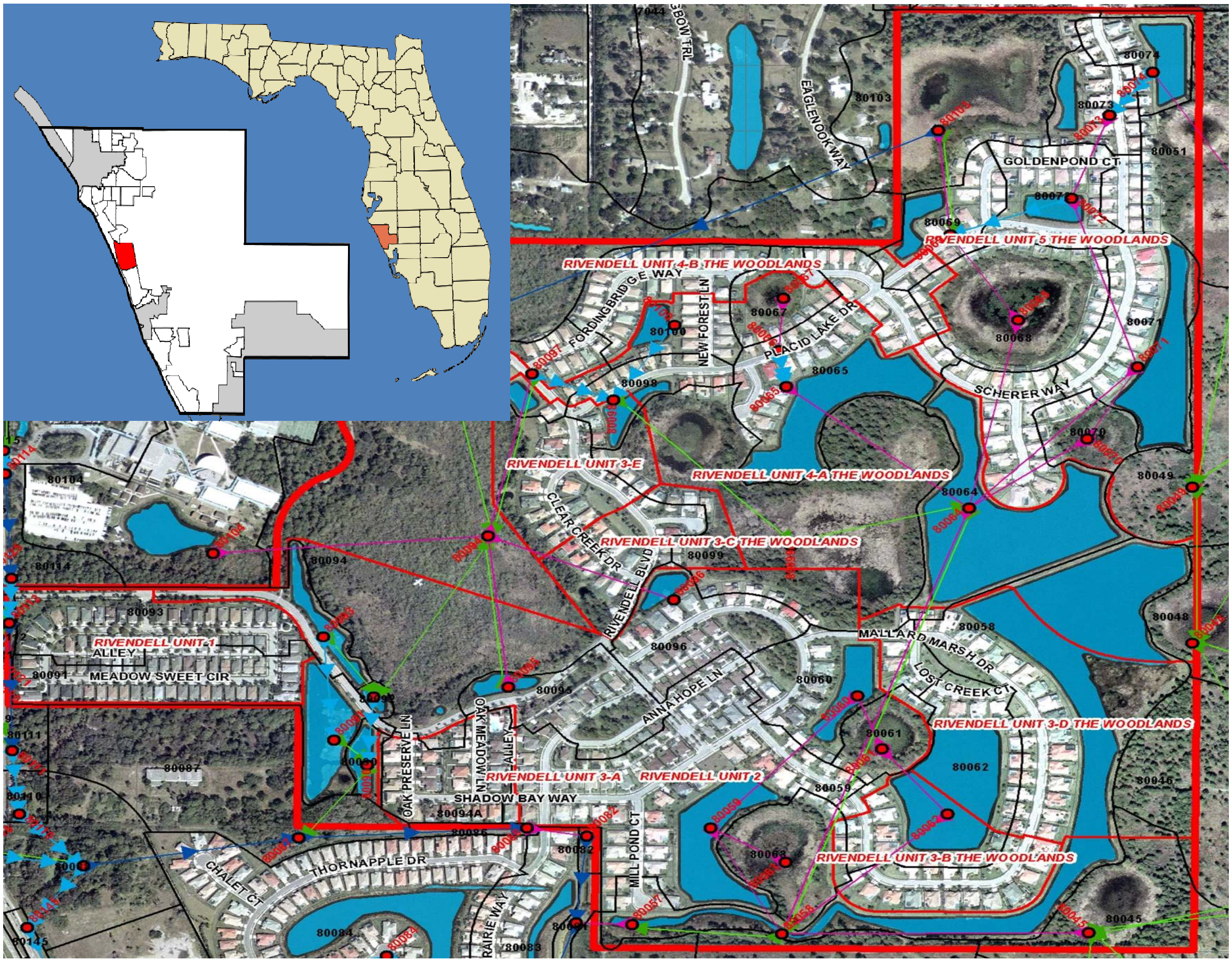

Figure 1. General location (inset) and building phase map (units) of Rivendell in Osprey, Sarasota County, FL. Oscar Scherer State Park borders the community on the east and south sides.

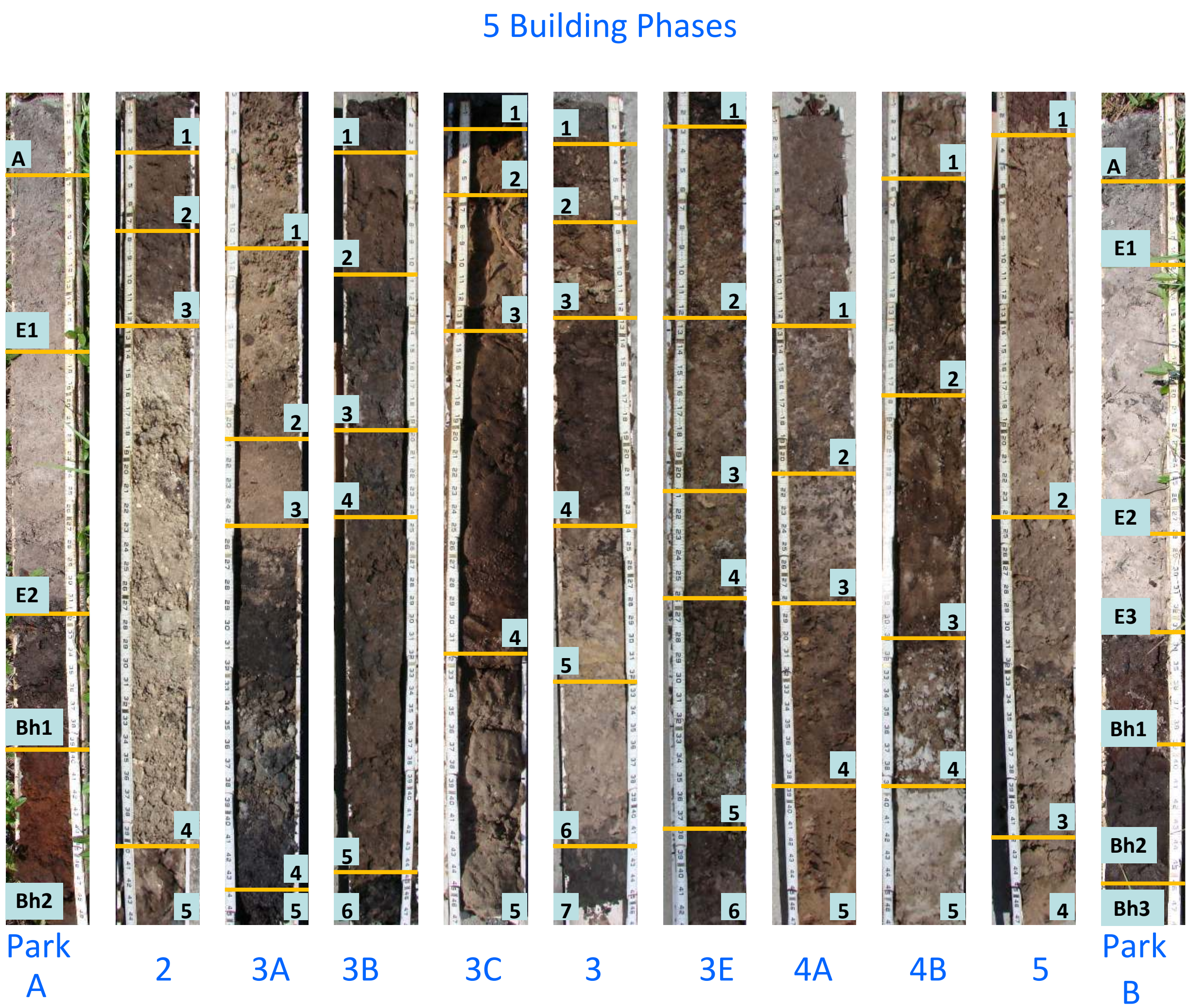

Figure 2. Selected soil profiles collected from Oscar Scherer State Park (Park A and B) and residential landscapes in Rivendell subdivision, Osprey, Sarasota County, FL. One profile from each phase of development is included in the photo to show variability between soils at the individual lot scale, which was likely due to the use of different fill materials. Oscar Scherer State Park samples (Park A and B) are mapped as Eau Gallie and Myakka fine sand (complex), which is the predominant map unit identified within the Rivendell subdivision. It is apparent that residential samples are extremely disturbed because they bear little to no physical resemblance to mapped soils. Top soil conditions in the residential soils were also very different from the park samples.