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Soil Profile Variability in an Established Residential Community

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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 collected to a depth of 48 inches from ornamental landscape beds at 16 of the 48 residences and from two park locations using a bucket auger. Chemical and physical characteristics varied widely in residential landscapes compared to park soil. Vegetative cover influenced chemical composition and OM of soils (except pH). Landscape management practices should be addressed per individual building unit.

Examination of physical and chemical variability properties is essential to understanding how urban soils behave (e.g., limitations and capabilities) in residential communities. According to Craul (1992) there are eight general characteristics of urban soils that emerge: spatial variability, modified soil structure; surface crust on bare soils, elevated pH, restricted aeration and water drainage, interrupted nutrient cycling, modified soil organism activity, presence of anthropogenic materials and other contaminants and modified soil temperature regimes. Further landscape management practices such as mowing, supplemental fertilization, and irrigation may alter urban soil properties and functionality (Kaye et al., 2006). Bockheim (1974) defined an urban soil 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." The physical, chemical and biological properties of urban soils (e.g., soil texture, structure, pH, and water holding capacity) are typically altered as a result of construction activities (Pouyat et al., 2006) or other anthropogenic activities associated with urbanization (Lorenz and Kandeler, 2006). In addition, further landscape management practices such as mowing, supplemental fertilization, and irrigation may alter urban soil properties and functionality and water quality (Erickson et al. 2001; Kaye et al., 2006). Spatial and temporal differences of urban soils are directly impacted by human activity and urbanization (Effland and Pouyat, 1997). Construction of residential units is a process that can take several months to years to complete, with large communities often built out in phases over time. As a result, soils within a single community may vary significantly due to differences in exposure to heavy equipment, the source of fill soil, burial of debris and other activities at the lot scale. As a result, urban soil properties can differ drastically from properties of natural soils.

A detailed characterization of urban soils is often lacking in soil survey reports (De Kimpe and Morel, 2000). In many cases, the soil survey provides no description of soils in urban areas or existing soil survey descriptions are based on the natural soil that existed at the site prior to development. (De Kimpe and Morel, 2000) suggest the need for more detailed classification of urban soils to ensure human health in cases where food is grown on disturbed and potentially contaminated soils. In addition, we suggest that detailed descriptions of soil in urban areas could be used to guide better landscape management decisions and prevent environmental degradation.

To our knowledge, few studies have evaluated the chemical properties of residential soils at the neighborhood scale, subdivision, or individual parcel. In addition, detailed descriptions of residential soil profiles are lacking. 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 building phase on soil chemical properties.

Materials and Methods

Study location. The study was conducted in Rivendell, a master-planned community located in Osprey, Sarasota County, FL. Rivendell was developed in five phases between 2000 and 2002; the median home price in Rivendell at the time of construction was $365,000. Homes were selected for intensive soil sampling

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*Corresponding author; phone: (941) 457-0219; email: drainey@ufl.edu from a list of Rivendell residents who responded to a landscape preferences survey conducted by the University of Central Florida Stormwater Academy. Soil samples were collected with homeowner consent. Rivendell is bordered on the south and east by Oscar Scherer State Park; soil samples were also collected from the park location.

Composite soil samples were collected at a depth of 0 to 6 inches 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) 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) were randomly sampled using a soil probe per vegetative area 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 Texturing Field Flow Chart description card by Midwest Geosciences group, organic matter by loss on ignition, and pH by 1:2 soil to deionized water ratio. Soils were extracted with 2 M KCl (1:25 soil to solution ratio) (Mulvaney, 1996) and analyzed for soil ammonium-N (NH_4-N) and nitrate + nitrite-N (NO_x-N) using standard EPA methods 305.1 (U.S. Environmental Protection Agency, 1993a) and 353.2 (U.S. Environmental Protection Agency, 1993c), respectively. Soils were also digested using USEPA Method 351.2 (U.S. Environmental Protection Agency 1993b) and analyzed for total Kjeldahl N (TKN) using a discrete analyzer (AQ2, Seal Analytical, West Sussex, UK). Soils were also extracted using the Mehlich 3 (M3) (Kovar and Pierzynski, 2009) extraction 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 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 Mehlich 1 and M3 as reported by (Mylavarapu et al., 2002).

Deep core samples were collected from ornamental landscape beds (cover) 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 4-inch-diameter bucket auger from the soil surface to the water table or 48 inches below grade, whichever was deeper. Samples collected with the auger were deposited onto a section of 4 inch × 48 inch 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* to characterize soil profiles (Schoeneberger et al., 2002).

1) Depth—Depth was recorded at the "bottom depth" for the specific horizon property.

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 *USDA Soil Texturing Field Flow Chart* 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) 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.

Results and Discussion

Soil texture for all composite samples was sand or loamy sand (data not shown). 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). Therefore, irrigation and fertilization are very important for these soils, but should occur more frequently with smaller quantities of water/nutrients per application.

Soil OM content ranged from 12.8 to 81.9 $g\cdot kg^{-1}$ for all composite samples collected from Rivendell (Table 1). The OM content in soils collected from 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). Furthermore, there was a significant vegetative cover effect on OM content, where soils collected from ornamental areas had higher OM (Table 4). Higher OM values in ornamental beds may be due to the common use of mulches and other organic materials. Similarly, turf clippings that may be removed from the sites after mowing, thereby limiting the recycling of organic matter back into soils in turf areas.

Overall, the pH of composite soil sample collected in residential landscapes ranged from slightly acidic to alkaline (Table 1), and do not fall within target pH levels for establishment and growth of turf and ornamental plant species (Kidder et al. 1998). In contrast, undisturbed composite soil samples from Oscar Scherer State Park (natural soil) were very acidic, with soil pH ranging from 4.05 to 4.30 (Table 2). Building unit influenced soil pH levels, where samples collected from homes in phase 4B exhibited significantly lower (neutral) than samples collected

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 units of Rivendell in Osprey, FL.

Variable	Mean	Std Dev	Median	Min	Max
OM, $g\cdot kg^{-1}$	32.6	11.3	30.2	12.8	81.9
pH	7.54	0.32	7.60	6.50	8.10
EC, $dS\cdot m^{-1}$	0.57	0.27	0.50	0.26	1.72
NO_3-N, $mg\cdot kg^{-1}$	6.74	10.4	3.63	0.89	77.5
NH_4-N, $mg\cdot kg^{-1}$	2.70	7.19	1.79	0.58	72.0
TKN, $mg\cdot kg^{-1}$	988	372	988	308	1965
M3-P, $mg\cdot kg^{-1}$	86.1	44.9	79.0	18.3	240
M3-K, $mg\cdot kg^{-1}$	38.9	27.2	34.6	4.81	158
M3-Ca, $mg\cdot kg^{-1}$	2887	1354	2585	1090	7560
M3-Mg, $mg\cdot kg^{-1}$	208	53.8	207	102	358

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

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	Min	Max
OM, g·kg^{-1}	27.6	7.0	27.6	21.3	34.1
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
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
TKN, mg·kg^{-1}	635	149	616	502	804
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

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

Building unit	pH	EC	OM	TKN	NO_3-N	NH_4-N
		dS·m^{-1}	g·kg^{-1}	---------- mg·kg^{-1} ---------		
2	7.44 bc	0.50 b	30.8 b	983 b	7.41 a	1.94 a
3A	7.50 abc	0.66 ab	34.2 ab	1099 ab	8.54 a	1.98 a
3B	7.72 ab	0.77 ab	35.5 ab	1115 ab	4.48 a	1.88 a
3C	7.80 ab	0.82 ab	39.0 ab	1146 ab	6.96 a	2.30 a
3D	7.86 a	0.44 b	26.7 b	845 b	2.92 a	1.43 a
3E	7.60 abc	0.94 a	46.5 ab	1422 a	14.4 a	2.61 a
4A	7.43 bc	0.56 b	35.2 ab	898 b	4.56 a	2.05 a
4B	7.16 c	0.44 b	27.9 b	811 b	7.97 a	2.41 a
5	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.

Table 4. Vegetative cover effects on selected physical and chemical properties of soil samples collected from 0 to 6 inches 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

Table 5. Mehlich 1 soil test interpretations for environmental horticulture crops (Kidder et al. 1998) and the corresponding interpretation for the Mehlich 3 soil test based the relationship between Mehlich1 and Mehlich 3 as reported by Mylavarapu et al. (2000).

	Phosphorus		Potassium	
Category	Mehlich 1	Mehlich 3	Mehlich 1	Mehlich 3
Very low	<10	<33	<20	<22
Low	10–15	33–40	20–35	22–36
Medium	16–30	41–62	36–60	37–60
High	31–60	63–104	61–125	61–122
Very high	>60	>104	>125	>122

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

Building unit	M3-P	M3-K	M3-Ca	M3-Mg
2	94.4 ab	42.8 abc	2275 bc	201 ab
3A	85.5 b	60.7 ab	4317 a	222 ab
3B	67.6 b	10.2 c	3862 ab	240 ab
3C	86.0 ab	27.0 abc	3710 abc	276 a
3D	91.6 ab	25.7 bc	3394 abc	206 ab
3E	74.8 b	70.7 a	4344 a	251 a
4A	73.4 b	23.3 c	2062 c	188 ab
4B	142 a	41.4 abc	1793 c	159 b
565.5 b	34.3 bc	2523 bc	202 ab	

from homes built in phase 3B, 3C, 3D, and 5 (Table 3). Higher soil pH values in unit 3B, 3C, 3D, 3E, 4A and 5 could be related to origin of the soil fill materials within these units. For example, fill materials containing high concentrations of calcium carbonate from marine deposits (visible shell fragments) and/or construction debris (concrete materials/drywall materials) could result in semi-alkaline to alkaline soil pH. Vegetative cover did not affect soil pH (Table 4), suggesting that use of acidifying fertilizers or other management practices that may differ between turf and ornamental areas did not affect soil pH levels.

All residential landscape soils appeared to have elevated levels of NH_4-N, NO_3-N and TKN concentrations (Table 1) than the corresponding Oscar Scherer Park samples (Table 2). Building unit had an effect on soil TKN, but not 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). Vegetative cover also influenced concentrations of NH_4-N, NO_x-N, TKN and 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.

Based on the M3 adjusted soil test interpretations for Florida (Table 5), overall soil test P concentrations in composite samples collected from residential landscapes in Rivendell ranged from “very low” to “very high.” 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” or “very high” category (Kidder et al., 2003). In contrast, the mean concentration of M3-P in the Oscar Scherer samples was 10.4 mg·kg^{-1}, which would be categorized as “very low” based on Florida interpretations (Table 3).

Building unit 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 unit 4B could be related to the soil fill material used during construction or the fertilization patterns of homeowners within that phase. 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. It is possible that higher M3-P in ornamental areas is related to the use of high fertilization rates and frequent application of ornamental fertilizers, which have higher P than turf fertilizers (usually to promote flowering).

Overall soil test M3-K concentrations ranged from “very low” to “very high” (Table 1) based on the adjusted Florida soil test interpretations (Table 5). Building unit influenced M3-K concentrations, where samples collected from unit 3E had significantly higher M3-K values than for samples collected from units 3B, 3D, 4A, 4B, and 5 (Table 6). Higher M3-K concentrations in unit 3E could be related to significantly higher OM values (Table 3). High OM levels may influence K adsorption (retention in sandy soils). In addition, 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 have higher K contents than ornamental fertilizer. Statistical analysis of other nutrients (e.g., Mg and Ca) extracted using the M3 method is listed in Table 6. Mehlich 3 soil test interpretations are not available for these nutrients. Any reported building unit or vegetative cover effects are 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 (NRCS Web Soil Survey, 2011). Characteristics of individual horizons for each deep core sample were not similar in composition to mapped soil series (Fig. 1). Characteristics of deep core samples were highly variable from property lot to lot, 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) (Fig. 1). Samples from native park deep core samples were contrasted with residential deep core samples. Natural physical and chemical weathering process were inconsistent, for example, distinct horizons, consistent color and depth and presence of a spodic horizon. Native soil samples contained fewer, but more dominate horizon boundary distinction by abrupt to gradual transitional boundaries and redoxmorphic features (Fig. 1). Residential deep cores revealed human transported materials, mixing of parent material, shell aggregate, heterogeneous textures and structure.

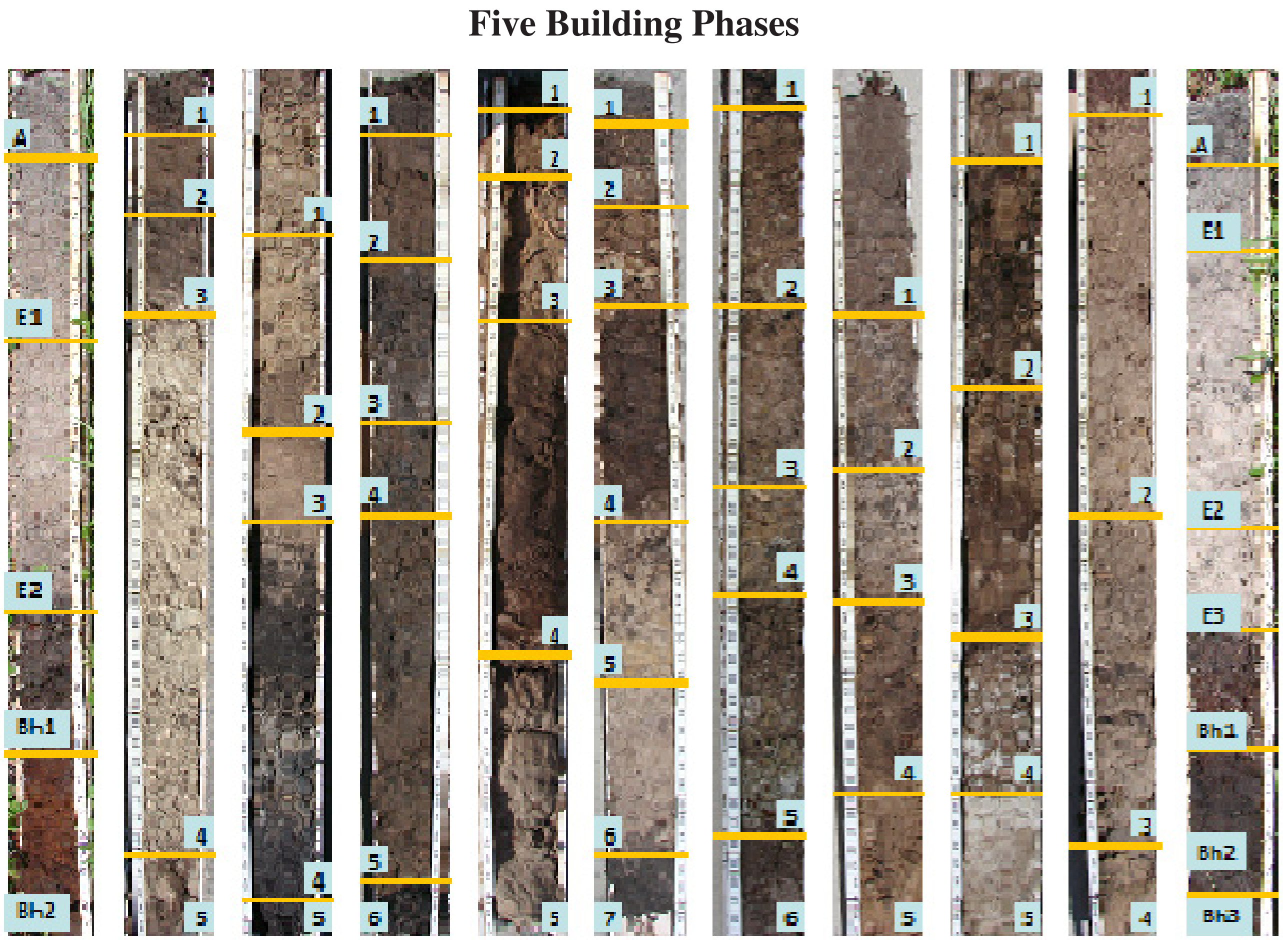

Fig. 1. Selected soil profiles collected from Oscar Scherer State Park (Park A and B) and residential landscapes in Rivendell subdivision, Osprey, Sarasota County, FL. One profile from each phase of development is included in the photo to show variability between soils at the individual lot scale, which 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.

Summary and Conclusion

Chemical and physical characteristics varied widely in residential landscapes compared to park soil. 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 O.M. of soils (except pH). Phosphorus levels were found to be adequate for established turfgrass areas; therefore, judicious application of P is necessary to reduce negative water quality impacts. Therefore, pre-planting and routine soil testing for pH, P, K and secondary nutrients should benefit the homeowner or professional landscape manager regarding application of nutrients. Consideration of adopting a “Right plant, Right place” planting scheme, for new and renovated landscapes, will help to reduce nutrient and water needs and match the best plant to soil characteristics necessary to provide and maintain plant health. To this end, the physical and chemical variability found at each residential unit supports further research in an integrated landscape management approach; for example, practices that quickly stabilize cover and reduce post-plant establishment maintenance inputs (fertilizer, irrigation).

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