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A Study of Soil Organic Matter
and Its Controlling Factors
in Portland, Oregon

by

Megan Dillon

A thesis submitted in partial fulfillment of the
requirements for the degree of

Master of Science
in
Biology

Thesis Committee:
Todd Rosenstiel, Chair
Sarah Eppley
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Portland State University
2011

Abstract

Traditionally, local above- and below-ground plant and microbial communities, temperature and precipitation, topography and texture and composition of parent material have been thought to govern the soil processes that lead to soil organic matter accumulation over decades or centuries. Soil organic matter is a substantial global reservoir of carbon and disturbance of equilibrated soils often leads to efflux of significant quantities of CO₂. Anthropogenic influences shift the inputs, disturb the structure and alter the biochemistry of soil, profoundly disrupting soil-forming processes. Urbanization leads to soil organic matter equilibria that are different from those in naturally forming soils. Measurement of soil organic matter in diverse cities suggests that they differ in their capacity to accumulate soil organic matter. Here I quantify soil organic matter and examine the limitations of its accumulation within cities by comparing differences in soil organic matter and natural and anthropogenic characteristics at the neighborhood, city and regional scales in Portland, Oregon to that in the Pacific Northwest. I found that each Portland neighborhood has distinct urban characteristics and tree and shrub community composition, but soil organic matter content is indistinguishable among them. Across Portland, neither vegetation structure nor urban factors appear to directly influence soil organic matter content. Rather, microbial biomass, bulk density and total nitrogen appear to be important factors controlling soil organic matter content in Portland. The amount of soil organic matter stored in Portland's soils is statistically indistinguishable from Pacific Northwest soils, in contrast to other temperate cities.

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Table of Contents

Abstract	i
Acknowledgements	ii
List of Tables	iv
List of Figures	v
Introduction	1
Methods	11
Results	21
Discussion	29
Tables	42
Figures	52
References	65
Appendix A. Genera Recorded at Each Site	77
Appendix B. Coordinates of Each Site	142

List of Tables

Table 1. Summary of Vegetation Statistics for Downtown	42
Table 2. Summary of Vegetation Statistics for Lloyd District	42
Table 3. Summary of Vegetation Statistics for Gateway	43
Table 4. Summary of Vegetation Statistics for Lents	43
Table 5. Summary of Vegetation Statistics for Portland	44
Table 6. Summary Soil Statistics for Downtown	44
Table 7. Summary Soil Statistics for Lloyd District	45
Table 8. Summary Soil Statistics for Gateway	45
Table 9. Summary Soil Statistics for Lents	45
Table 10. Summary of Soil Statistics for Portland	46
Table 11. Summary of Urban Statistics for Downtown	46
Table 12. Summary of Urban Statistics for Lloyd District	46
Table 13. Summary of Urban Statistics for Gateway	47
Table 14. Summary of Urban Statistics for Lents	47
Table 15. Summary of Urban Statistics for Portland	48
Table 16. Principle Components Loadings of Urban Variables for Portland	48
Table 17. Summary of Regression Analysis for Downtown	49
Table 18. Summary of Regression Analysis for Lloyd District	49
Table 19. Summary of Regression Analysis for Gateway	50
Table 20. Summary of Regression Analysis for Lents	50
Table 21. Summary of Regression Analysis for Portland	50
Table 22. Publications Used to Compare Portland to Pacific Northwest Soil Organic Carbon	51
Table 23. Comparison of Pacific Northwest Forest Soils to Portland Soils	51

List of Figures

Figure 1. Sampling Sites	52
Figure 2. Differences in Vegetation Structure Among EcoDistricts	53
Figure 3. ANOSIM of Bray-Curtis Distance Among EcoDistricts	54
Figure 4. Differences in Soil Properties Among EcoDistricts	55
Figure 5. Soil Organic Matter Among EcoDistricts	56
Figure 6. Map of Soil Organic Matter in Portland	57
Figure 7. Distribution of Soil Organic Matter in Portland	58
Figure 8. Differences in Urban Characteristics Among EcoDistricts	59
Figure 9. Expected vs. Observed Soil Organic Matter Values for Portland	60
Figure 10. Soil Organic Matter in Portland and the Pacific Northwest	61
Figure 11. Soil Organic Matter Varies by Biome	62
Figure 12. Soil Organic Matter in Temperate Cities	63
Figure 13. Changes in Soil Organic Matter with Urbanization in Temperate Cities	64
Figure 14. Changes in Soil Organic Matter with Urbanization by Biome	65

Introduction

Soils are unique and extraordinarily complex systems that serve as a vital hub for the transformation and redistribution of the myriad chemical constituents of life. The canonical source-and-sink duality of ecological systems is particularly apparent in the biogeochemistry of soils. Almost all organic detritus of terrestrial origin is decomposed on the vast surfaces of soil particles or within the intervening interstices (Swift *et al.*, 1979). The products of this decomposition are either sequestered in refractory form or rendered into trophically available forms that can be assimilated by soil organisms or exported from the soil as a gas or aqueous solutes (Sollins *et al.*, 1996). The enormous throughput of these processes is crucial to the global biogeochemical cycling of carbon, nitrogen, oxygen, sulfur and many other elements.

The role of soils in the global carbon cycle is of particular interest, due in part to the fact that a vast quantity of carbon resides in the world's soils. Concerns have been voiced that this reservoir will contribute to atmospheric carbon (positive feedback) under progressively warming climate conditions (Jones *et al.*, 2003; Lenton & Huntingford, 2003; Kirschbaum, 2000). Liberation of carbon from soils could amplify and accelerate any gradual positive change in global temperatures. The metabolic rates (Q_{10} approximately 2-4, depending on the recalcitrance of the substrate) of detritivorous soil flora and fauna increase dramatically with increases in soil temperature (Conant *et al.*, 2008) and this increase in CO₂ evolution from soils could outpace the marginal increase in CO₂ fixation by plants at the global scale (Luo *et al.*, 2004).

Soils, however, are remarkably diverse, and the contributions of a particular soil type to biogeochemical cycles, including the carbon cycle, are governed by its chemical and biological composition and its physical structure. The structural organization of terrestrial soils is observable as strata called horizons. The numbers, thicknesses and types of horizons in any given soil depend on local climate, topography, biological factors, the composition of the parent material, the age of the soil, and the degree and frequency of physical disturbance (Jenny, 1946). Soil carbon is non-uniformly distributed throughout soil horizons; organic carbon mostly accumulates in the surface horizons of mineral soils (Batjes, 1996).

Four soil processes describe the movement of carbon through the soil system: addition, loss, translocation and transformation (Brady & Weil, 2008). Addition denotes the deposition of new carbon, mostly as plant and animal detritus, both above- and below-ground. Carbon is lost from soil via leaching of carbonates and dissolved organic carbon into ground and surface water (Laudon *et al.*, 2011), a common phenomenon in northern latitude ecosystems. Translocation is the movement of carbon laterally, vertically or between horizons. Transformation refers to chemical changes, including those involved in respiration and humification. Widespread increases in the rate of transformation of soil carbon into CO₂ is of great concern to global change scientists (Davidson *et al.*, 2000).

Soil organic matter is a confusion of complex molecules derived from partially decomposed terrestrial organisms. The C:N ratio of soil organic matter can range from 8:1 to 15:1. To understand how increases in temperature and atmospheric CO₂ concentration might influence soil carbon dynamics, it is necessary to consider the

various pools of soil organic matter and the individual dynamics of each pool. Although the carbon-containing molecules within a soil range from extreme chemical simplicity to staggering complexity, they are often designated as belonging to one of three pools differing in cycling time and lability: fast, slow and passive (Parton *et al.*, 1987). Fast-turnover carbon describes simple, bioavailable compounds like sugars that are rapidly transformed. Slow-turnover carbon describes more complex organic molecules, like lignin, that are significantly more persistent and recalcitrant to biotic and abiotic degradation. Passive carbon compounds, such as clay-protected humic acids, are extremely long-lived, refractory and may persist in some soils for millennia (Paustian *et al.*, 1992).

Soil organic matter comprises a class of soil carbon that is vulnerable to transformation in response to global change (Pendall *et al.*, 2004; Davidson & Janssens, 2006). The effects of increasing global temperatures and atmospheric CO₂ concentrations have generally been predicted to influence soil carbon reserves by three distinct, but interrelated mechanisms. First, the metabolic rates of detritivorous soil microorganisms increase dramatically as soil temperature rises (Chen & Tian, 2005; Davidson & Janssens, 2006). Second, deposition of simple, bioavailable carbon compounds by plant roots into deep soil horizons, termed soil priming, may increase with increasing CO₂ and precipitation. The increased deposition of simple carbon compounds tends to cause microbial decomposition of recalcitrant substrates that would otherwise not readily be transformed into CO₂ (Guenet *et al.*, 2010). Finally, soils tend to become nitrogen depleted over time under conditions of elevated temperature and atmospheric CO₂. This progressive nitrogen limitation may increase the metabolism of passive carbon

compounds by soil fungi (Carreiro *et al.*, 2000; Waldrop & Zak, 2006), consequently increasing CO₂ production.

Predictions of the changes that may occur in soil organic matter under the conditions likely to attend global climate change vary widely. Not only are responses predicted to vary by ecosystem, but, also, different carbon reservoirs will respond to temperature differently, and, of course, environmental attributes and the availability of soil carbon (and nitrogen) substrates affect each other (Davidson & Janssens, 2006). Such entanglement has been confirmed by field and laboratory research as well as modeling studies. In tropical forests, increasing temperatures have been observed to decrease soil organic matter at a rate of -8 Mg C/°C, offsetting gains in net primary productivity (Raich *et al.*, 2006). Similarly, in arctic soils, CO₂ emission from soils is associated with increasing temperatures (Parsons *et al.*, 2004). Experimental warming of identical soil subsamples by Hartley and Ineson (2008) revealed that decomposition rate increased over time, supporting the hypothesis that relatively recalcitrant carbon pools are more sensitive to rising temperatures (Hartley & Ineson, 2008). Similar experiments, however, have demonstrated that depth and incubation time affected decomposition rate while temperature sensitivity was not affected by incubation time, implying that soil organic matter pools would respond to increasing temperatures uniformly (Fang *et al.*, 2005). In stark contrast, after conducting a meta-analysis of global decomposition rates across a gradient of mean annual temperature, Giardina and Ryan (2000) refuted the hypothesis that soil organic matter decomposition increases with rising temperatures, citing similar rates across different latitudes. Models calculated by Jones *et al.* (2003) indicate that the effects of temperature increases on soil organic matter decomposition are

likely to overwhelm gains in net primary productivity, but that the relationship between the two is crucial to determining whether the terrestrial biosphere becomes a carbon source or remains a carbon sink over the course of the next century.

Elevated CO₂ concentration is predicted to increase the net primary productivity of plants, possibly to such an extent as to balance losses of soil carbon, but nitrogen availability has been observed to limit such a response. For example, in a long-term study, Reich *et al.* (2006) saw early gains in plant biomass under elevated CO₂ in fertilized and unfertilized plots, but only fertilized plants continued to increase in biomass after four to six years. The greatest gains in net primary productivity appear to be in root biomass, in both number and length (Zak *et al.*, 1993; Pregitzer *et al.*, 2000). Zak *et al.* (1993) observed increased root biomass in nitrogen limited, elevated CO₂ treatments, and found greater labile carbon and microbial biomass in the rhizosphere of elevated CO₂-grown plants. In their *P. tremuloides* study, Pregitzer *et al.* (2000) only observed increased root biomass under elevated CO₂ with nitrogen fertilization, but found that soil respiration was significantly greater with elevated CO₂ and with high nitrogen treatments. These conflicting results are resolved to some extent by a meta-analysis performed by Zak *et al.* (2000). Their results indicate that while elevated CO₂ definitely increases soil and microbial respiration, effects of nitrogen vary widely with plant species (Zak *et al.*, 2000). Regardless of the magnitude or longevity of increased primary productivity with elevated atmospheric CO₂, Heimann and Reichstein (2008) point out that increased net primary productivity, itself, can increase soil respiration via progressive nitrogen limitation and the priming effect (Heimann & Reichstein, 2008).

Field-scale experiments that manipulate ecosystem-scale CO₂ and temperature simultaneously are generally lacking, primarily due to technical difficulties of doing both simultaneously. Results from the few such studies that report combined elevated CO₂ and elevated temperature include increased root turnover without interaction (Wan *et al.*, 2004), increased fine root biomass in some species but not others (King *et al.*, 1996) and reduced root biomass (Soussana *et al.*, 1996). In their literature review, Pendall *et al.* conclude that the interactive effects of elevated CO₂ and elevated temperature are likely to enhance soil carbon decomposition. In support of that hypothesis, a model generated by Lu *et al.* (2009) indicates that rising levels of atmospheric CO₂ and global temperatures are unequally increasing both plant carbon fixation and soil organic matter decomposition, resulting in the Mongolian plateau becoming a CO₂ source whereas it was previously a sink. Given the inherent uncertainties in the system, and despite good preliminary observations, the ability to quantify the changes that may occur in soil organic matter with global climate change remains elusive (Zak *et al.*, 2000). A better understanding of the factors influencing soil organic matter formation in soils (across a wide range of biomes) in response to simulated global change would improve our predictive capabilities.

Urban ecosystems offer an experimental system to examine the simultaneous impacts of temperature and CO₂ on soil organic matter dynamics. The urban heat island effect increases temperatures via decreased albedo, reduced vegetation, increased latent heat in urban infrastructure, and urban heat generation (George *et al.*, 2007; Akbari *et al.*, 2008). CO₂ domes (Rice & Bostrom, 2011) envelop cities and trap and elevate key climate change drivers such as ozone. Further, urban soils experience increased effective

precipitation due to watering and runoff (Gill *et al.*, 2007). In cities, natural vegetation patterns are disturbed by the presence of invasive and exotic species, fragmentation and changes in vegetation density (Hall *et al.*, 2002; Lorenz & Lal, 2009; Ren *et al.*, 2011). Thus, urbanization may, in some ways, act as a space-for-time substitution for the effects of changes in local temperature, precipitation, atmospheric CO₂, available nitrogen, and the type and density of resident vegetation that are expected to accompany climate change (Carreiro & Tripler, 2005; George *et al.*, 2007; Grimm *et al.*, 2008). Insights into future trends in soil organic matter dynamics might therefore be provided by knowledge of the trends of soil organic matter accumulation and dynamics in urban ecosystems.

Compared to natural systems, however, there are relatively few studies of soil organic matter dynamics in urban soils. Consideration of the effects of increased CO₂ and elevated temperature on net primary productivity and soil respiration in non-urban systems might lead to speculation that soil organic matter in cities would be low. Nitrogen in cities, though, is also increased, via fertilization, precipitation and dry deposition, which implies that net primary productivity, and rhizodeposition might contribute more carbon substrates, especially where water stress is less of an issue, due to watering by residents. In the few studies that exist, urban areas show considerable variation in the quantity of soil organic matter in resident soils. Both increases and decreases in soil organic matter have been observed following urbanization. For example, Pouyat *et al.* (2009) suggest that soils in urban ecosystems may store as much as twice the amount of carbon as soils from natural systems due to the effects of management. They propose that anthropogenic drivers of soil organic matter accumulation replace natural ones (Pouyat *et al.*, 2009). In contrast, Jo *et al.* (2002) found that urban green

spaces in Chucheon, Korea retain less soil carbon than natural ones and Pavao-Zuckerman and Coleman (2005) found decreased soil organic matter in urban areas compared to rural ones in Asheville, NC. In some cities, increases in soil organic matter depend on anthropogenic effects, such as time since disturbance. In 2006, Golubiewski found that urban soils equilibrate to greater carbon pools than non-urban native or agricultural land as soon as 25 years after development, suggesting that the factors influencing soil organic matter accumulation may be highly dynamic. The wide variety of patterns of soil organic matter accumulation observed in urban systems suggests that processes controlling soil organic matter accumulation are diverse, and the mechanisms contributing to these differential responses have yet to be fully elucidated. The contrasting results of these studies underscore the need to understand how the mechanisms of soil organic matter accumulation in cities differ from the mechanisms contributing to soil organic matter accumulation in non-urban native soils, if at all. It seems likely that mechanistically divergent processes might explain the variability observed in previous studies, but a mechanistic understanding of the factors influencing soil organic matter accumulation in urban ecosystems is lacking.

The aim of this thesis is to examine the factors influencing soil organic matter dynamics in an urban ecosystem. Using Portland, Oregon as a model system, I used an exhaustive stratified sampling methodology to quantify the effects of soil, vegetation and urban variables on soil organic matter. Further, through direct comparison between soil organic matter stocks in soils of Portland, Oregon and other locales throughout the Pacific Northwest I provide a first indication of the consequences of urbanization for soil organic matter accumulation in soils of this region. Finally, I extend the work presented

here by examining the differences in soil organic matter accumulation between urban centers and non-urban areas in temperate, desert and tundra biomes throughout the globe with the goal of understanding how biome-specific effects may explain patterns of soil organic matter accumulation in urban ecosystems.

In this thesis, I address three specific hypotheses. First, I investigate the influence of urbanization on soil organic matter accumulation in the Pacific Northwest. As urban landscapes are likely to have lower (or similar) input to soil organic matter pools, greater average soil temperatures and lower seasonal water availability, I predict that soils within Portland will have lower soil organic matter compared to regional, non-urban soils.

Second, I investigate which variables are most important for predicting soil organic matter content of soils Portland's urban ecosystem. Biotic factors such as vegetation type and microbial biomass are thought to strongly influence soil organic matter accumulation in non-urban environments. However, I hypothesize that urban factors such as impervious surface and building footprint area may better predict soil organic matter accumulation in Portland soils, as urbanization disrupts natural soil organic matter accumulation processes like incorporation of detritus and leaf litter.

Finally, I investigate how urban heterogeneity and development history influence soil organic matter accumulation in Portland by examining patterns of soil organic matter accumulation in four of Portland's neighborhood-scale EcoDistricts. The results presented in this thesis specifically address the three following hypotheses:

1. Soil organic matter accumulates less in Portland than in non-urban ecosystems of the Pacific Northwest.

2. The pattern of soil organic matter accumulation in Portland soils is primarily influenced by urban metrics such as impervious surface coverage per plot and total building footprint.
3. Soil organic matter accumulation in Portland soils is not influenced by spatial factors such as longitude and latitude or distance from city center.

Methods

Portland, Oregon (45°31'12"N, 122°40'55"W) straddles the Willamette River just south of the Columbia River. It was incorporated in 1851, but settled 200 years previously by Upper Chinook Indians (Marschner, 2008). As of the 2010 census, Portland has a population of 583,776 persons and spatial extent of 133.4 mi², equivalent to 4,375.3 persons/mi² (Portland State University Population Research Center, 2011). In the Pacific Northwest, Seattle, Washington and Vancouver, British Columbia, Canada are more populous than Portland, Oregon (Statistics Canada, 2007; Census Bureau, 2010).

Coarse-loamy and sandy soils with basalt and andesite fragments typify the Multnomah Series, found in Portland. Cation exchange capacity to clay ratio is greater than 0.6 with few anions adhered to clays. The mean annual soil temperature is 8 to 15°C (National Cooperative Soil Survey, 2001); mean annual precipitation is 36.03 inches (National Oceanic & Atmospheric Administration, 2011). The soils are generally moist and well drained with slow runoff and moderate permeability, but are dry up to a depth of 12 inches during the summer season. Soils display minimal horizon formation. Depth of solum, texture shift and bedrock are 20-30 inches, 24-40 inches and more than five feet, respectively (National Cooperative Soil Survey, 2001). *Acer*, *Quercus*, *Populus*, *Fraxinus*, *Salix*, *Malus*, *Corylus*, *Pseudotsuga*, *Thuja*, *Symphoricarpos* and *Rosa* are the dominant native genera (National Cooperative Soil Survey, 2001; United States Department of Agriculture, 1983).

All data pertains to plots within four neighborhoods in the city of Portland, Oregon. The neighborhoods, Downtown, Lloyd District, Gateway and Lents, are part of

a larger project called the EcoDistrict Program that the City of Portland is beginning to develop. The neighborhoods have been surveyed for socioeconomic, transportation and demographic information that is beyond the scope of my research.

Site Selection

I used a Geographic Information System (GIS) (Shandas, 2008) and a 2007 high-resolution digital orthophoto supplied by Portland-METRO to quantify and characterize Portland's vegetation. FRAGSTATS (McGarigal & Cushman, 2002) and a fishnet grid were applied to the vegetation data using ArcGIS 9.3 to quantify relative percent canopy vs. non-canopy at 25 m x 25 m resolution. In total, 312 25 m x 25 m plots were identified within the Portland EcoDistrict boundaries that had a 1:1 ratio of canopy to non-canopy vegetation; 57 in Downtown, 72 in Lloyd District, 75 in Gateway and 108 in Lents. All 312 field plots were then physically scouted and deemed inaccessible (fenced and private property), private (unfenced private property) or accessible (public property). Following inspection for accessibility, 154 accessible sites (55%) were chosen for sampling (Figure 1): 93% of Downtown's potential plots, 55% of Lloyd District's potential plots, 28% of Gateway's potential plots and 53% of Lents's potential plots. The latitude and longitude of each site (Appendix B) were recorded using a Trimble Juno SB portable GPS unit with TerraSync software and corrected using GPS Pathfinder Office. In total 48 plots were sampled within downtown, 34 plots were sampled within Lloyd District, 53 in Lents and 19 in Gateway.

Soil Sampling

From 26 August through 4 December 2010, I collected and composited three soil cores per plot within an approximately 180 cm² area using a commercially available 12" x 1" steel soil corer (Cole-parmer, model R-99025-30). Location of soil samples within each plot was chosen randomly. Slope topography was controlled by sampling only level ground (0-15°). In the field, soil cores were removed from the bore of the coring device using a metal scoopula and composited soil samples were placed in plastic bags and kept on ice, in an ice chest, until they could be refrigerated at 4°C at Portland State University. Sampling depth was calculated by averaging the depth of each of the three cores taken per sample. At time of sampling, the soil temperature was measured at sampling depth using a handheld thermocouple with soil probe attachment (Cole-parmer Digi-Sense Thermometer Model 91100-20).

Vegetation Sampling

Within each plot, all stems within 20 m of the soil coring locations were exhaustively surveyed. Genus of each perennial plant (trees and shrubs) was noted; where unknown stems were found, pictures and samples were taken for later identification. For all trees, diameter at breast height (DBH) was recorded using an 800 mm DBH Caliper with Gator Eyes (Haglof Mantax); trees larger than 80 cm in diameter were measured using DBH tape. Canopy area of shrubs was measured with field tape. Distance and bearing to each stem from the soil sampling locations were recorded using a

laser rangefinder device (Atlanta Advantage RO Laser Rangefinder). Ground cover at the sampling sites, though a possible contributing variable (Qian *et al.*, 2010), was not recorded because ground cover removal and replacement at sampling sites was frequently observed. From these samples, 16 vegetation metrics were analyzed: fine root biomass, stems/ha per plot, trees/ha per plot, shrubs/ha per plot, evergreens/ha per plot, deciduous stems/ha per plot, conifers/ha per plot, dominant functional group per plot, DBH per stem, average DBH per plot, total basal area per plot, most abundant genus per plot, most abundant family per plot, genus with the most basal area per plot, importance values per plot and Shannon Diversity Index per plot.

Laboratory Analyses

In total, 10 soil metrics were determined: soil organic matter, soil organic carbon, total carbon, total nitrogen, C:N ratio, soil temperature, bulk density, soil texture, clay content and soil moisture. Soil texture was determined by hand texturing and categorized into one of eleven textural classes (Brady & Weil, 2008). To determine bulk density, a 64 cm³ (the volume of a 2" depth x 2" diameter brass ring) of soil from each sampling location was dried in tin envelopes at 105°C for 48 hours and subsequently weighed. Any rocks or gravel in the sample were removed and weighed; their volume was measured by water displacement. The mass and volume of the rocks was subtracted from the soil dry weight and soil volume, respectively. To determine root biomass, three 10g (field moist) subsamples of the composited soil were randomly chosen and all visible root tissue was manually harvested and weighed fresh. The remaining soil of each

commingled sample was sieved with 2 mm mesh (Brass Cole-parmer USA Standard Test Sieve ASTM E-11 Specification). 15 g subsamples of field-moist soil were weighed and then subsequently dried at 105°C for 48 hours to determine soil water content by mass difference. Dry samples were stored in desiccators with Drierite.

Microbial biomass of the residual soil from the three rootless samples was determined by chloroform fumigation and microbial biomass carbon extraction. The replicates were placed in a vacuum desiccator with 25 mL ethanol-free chloroform, which was boiled three times for two minutes each by drawing a vacuum. The desiccator was vented between each vacuum application. The final vacuum was maintained and the desiccator was covered with two black, plastic bags for five days. Following fumigation, the soil samples were transferred to 125 mL flasks and 50 mL 0.5 M K₂SO₄ was added. The soil slurry was shaken for one hour and then filtered using a 20-25 µm filter (Whatman Grade 4). Samples were stored at –20°C until they were analyzed for non-purgeable organic carbon using a Shimadzu TOC-V CSH total organic carbon analyzer. TOC Control V software was used to program the total organic carbon analyzer. Standard total carbon and inorganic solutions (1000 ppm C each) were prepared using potassium hydrogen phthalate and a mixture of sodium hydrogen carbonate and sodium carbonate, respectively (Shimadzu Corporation, 2001). Standard curves were constructed by measuring peak areas under diluted standard solutions (10, 25, 50, 100, 150, 200, 250, 300, 400 and 500 ppm C) and nanopure water (0 ppm C) and finding the best linear relationship. Microbial biomass was calculated by dividing the chloroform labile C (NPOC) by 0.45 (Beck *et al.*, 1997).

Soil organic matter of composited samples was measured by loss-on-ignition using modifications to Smith (2003). 10 g sieved, dried soil was heated to 550°C for three hours in a muffle furnace in ceramic crucibles. A temperature controller (Watlow) was used to heat the dry samples to 550 °C, keep the temperature stable for three hours and then cool the ignited samples to 105°C until they were placed in desiccators with Drierite, where they were cooled to room temperature before being weighed. Soil organic carbon is calculated as 50% of soil organic matter (Brady & Weil, 2008; Pribyl, 2010) for use in comparison to studies that do not report loss-on-ignition data. Consideration of the ongoing disagreement regarding the correct conversion factor from soil organic matter to soil organic carbon, especially arguments discussed by Pribyl (2010) regarding empirical evidence that the traditional 58% conversion factor is incorrect, compelled me to use the 50% conversion factor.

Total carbon and total nitrogen were measured by elemental analysis on a Flash EA 1112 elemental analyzer using standard operating procedures for NC-Soils (Thermo Scientific, 2005). Eager Xperience software (Part No. 317 110 55, Revision B, September 2009) was used to program the elemental analyzer. Samples were stored in desiccators with Drierite until they were analyzed for total carbon and total nitrogen. Samples were homogenized using a mortar and pestle in preparation for analysis. Elemental tin crucibles were used to contain the samples to be analyzed. Aspartic acid and Reference Standard Soil (Thermo Scientific Soil Reference Material Part No. 338 400 26) were used to calibrate the analyzer before each use; Eager Xperience software (Thermo Scientific, 2009) generated curves automatically.

Quantification of Urban Metrics

Latitude and longitude of each plot were added as a layer in a GIS using ArcGIS 10. The November 2010 Regional Land Information System (RLIS) tax lot shape file was added to the GIS, which provided total value (real market value of land and buildings), square footage of buildings, years since development and footprint (in acres) of buildings; the information was originally supplied by the Metro Data Resource Center. Impervious surface data was obtained from the National Land Cover Database as a total impervious area shape file, also added to the GIS. A 20 m buffer surrounding the latitude and longitude coordinates was used to constrain the above urban variables. Distance to urban center was calculated using Pioneer Courthouse Square as the urban center in Portland. Maps supplied by the City of Portland (City of Portland, 2010, 2011) were used to assign years since annexation and zoning code for each plot. EcoDistrict, years since annexation, zoning code, distance to urban center, impervious surface coverage per plot, total value of buildings within 20 m of sampling site, total square footage of buildings within 20 m of sampling site, average years since development of buildings within 20 m of sampling site and total footprint of buildings within 20 m of sampling site are the nine urban variables collected for analysis.

Statistical Analyses

ArcGIS 10 was used to generate spatial urban data specific to each plot. FRAGSTATS was used to calculate landscape metrics for each plot. R statistical

software version 2.13.0 (R Development Core Team, 2011) was used to perform all additional statistical analyses. Analyses of Variance (ANOVA), with all categorical variables used as factors for soil organic matter, were performed. Where appropriate, log transformation was employed to normalize distributions of independent variables before ANOVA were conducted. Principal Components Analysis (PCA) was performed on the urban variables to determine their suitability as a set of regressors along which non-urban variables might change. To examine the spatial heterogeneity of soil organic matter in Portland, multiple regression analyses and ANOVA were conducted for each EcoDistrict.

To determine which factors influence soil organic matter accumulation in Portland, I performed multiple regression analysis of soil, vegetation and urban factors against soil organic matter using an all-possible regressions procedure (Kleinbaum *et al.*, 1998; Lumley, 2009). This allowed me to test whether the same variables that influence soil organic matter accumulation in Pacific Northwest forest soils are also influential in Portland, or, alternatively, that urban variables govern soil organic matter accumulation in an urban area. Mallow's C_p was used to determine the best sub-models and an overall model. Thirty-two quantitative independent variables were tested for their ability to accurately predict soil organic matter by assigning the independent variables to one of three sub-models.

The ability of the traditional soil-forming paradigm to predict soil organic matter was tested using the factor-based sub-models. The factor-based sub-models were generated by grouping the quantitative independent variables by soil forming factor. The biology sub-model includes total nitrogen, microbial biomass, fine root biomass, stems/ha, trees/ha, shrubs/ha, evergreens/ha, deciduous stems/ha, conifers/ha, average

DBH, total basal area and Shannon Diversity Index. The texture sub-model includes bulk density and clay content. The climate sub-model includes day of year, soil temperature and water content. The time sub-model includes years since annexation and years since development.

Additionally, the Pacific Northwest-based sub-model tests the variables that are crucial for the accumulation of soil organic matter in Pacific Northwest forest studies. Specific variables found to be significant predictors of soil organic matter in Pacific Northwest forest soil studies were tested singly. The correlation between soil organic matter and average DBH, stem density, microbial biomass, total nitrogen, soil moisture, clay content and years since development was initially examined using Pearson's correlation coefficient and then variables significantly correlated to soil organic matter (total nitrogen, microbial biomass and water content) were combined to create the Pacific Northwest-based sub-model.

Finally, an urban-based sub-model was constructed using urban variables, which I hypothesize strongly influence soil organic matter in Portland. The urban-based sub-model tests the urban variables' ability to predict soil organic matter. The urban-based sub-model comprises distance to urban center, impervious surface coverage, total value, building square footage and building footprint.

To develop the overall model, significant variables ($\alpha = .05$) from all sub-models were combined, including total nitrogen, microbial biomass, bulk density, soil temperature, water content and years since development. After regression analysis was performed, variables that failed to significantly contribute to model performance were eliminated. The abilities of each sub-model and the overall model to predict soil organic

matter were compared using residual sums of squares generated by ANOVA. The overall model predicts soil organic matter using microbial biomass, bulk density and total nitrogen as independent variables.

Comparative Analyses

Seven previously published Pacific Northwest studies (Klopatek, 2002; Homann *et al.*, 2004; Sun *et al.*, 2004; Homann *et al.*, 2007; Chaer *et al.*, 2009; Griffiths *et al.*, 2009; Kluber *et al.*, 2010) that contain soil organic carbon data were used to compare urban to undisturbed soils. Where necessary, reported bulk density was used to convert between Mg/ha and g/kg. Only data from samples taken from the A horizon or superficial 30 cm were used.

Results

Over 300 potential research plots were identified from our analysis of the digital orthophotograph and 154 plots were ultimately found suitable for inclusion in this study: 48 in Downtown, 34 in Lloyd District, 53 in Lents and 19 in Gateway. The uneven distribution of plots among EcoDistricts results from differences in the number of potential plots and differences in accessibility. Results of analyses associated with each EcoDistrict are possibly unreliable due to insufficient sampling size, but results associated with all 154 25m x 25m research plots are robust.

Vegetation Analyses

Although the 154 plots were chosen because they displayed the 1:1 ratio of high structure to low structure vegetation (as inferred from analysis of the high-resolution digital orthophotograph), field-surveys revealed that there were significant differences in above-ground vegetation structure among the four EcoDistricts (Tables 1-4). Lloyd District has significantly fewer stems (512.703/ha) than the other EcoDistricts (average $\approx$ 986.709/ha) (Figure 1). Downtown has the greatest basal area (1.867 m²), Lents and Lloyd significantly less (average $\approx$ 0.807 m²) and Gateway is indistinguishable from the two extremes (Figure 1). Average DBH did not vary among EcoDistricts.

Plant functional type differed between EcoDistricts to some extent as well. Lents has significantly more trees (423.6075/ha) than Downtown and Lloyd District (average $\approx$ 253.387/ha), and Gateway is indistinguishable from either of these two groups (Figure 1).

Gateway has the most shrubs (813.021/ha), followed by Lents (490.423/ha); Downtown and Lloyd District have fewer shrubs and are indistinguishable (average ≈ 257.189 /ha) (Figure 1). Gateway has the most evergreens (829.411/ha), Lents is indistinguishable from both Gateway and Downtown, which has an intermediate number of evergreen stems (284.531/ha), and Lloyd District has the fewest evergreens (235.756/ha) (Figure). Conifer density in Gateway and Lents are indistinguishable and is the highest (average ≈ 197.385 /ha); Downtown and Lloyd, also indistinguishable, contain fewer conifers (average ≈ 26.570 /ha) (Figure 1). Downtown, the dominant functional group is deciduous trees; Lloyd District's and Gateway's dominant functional group is evergreens; the dominant functional group in Lents is shrubs. There were no significant differences between deciduous stems/ha among the EcoDistricts.

Similar to results for plant functional type, there are significant differences in the diversity of plant genera observed in each EcoDistrict. Lents (98 genera) has a significantly higher Shannon Diversity Index (1.726), followed by Gateway (1.389, 48 genera); Downtown (77 genera) and Lloyd District (56 genera) are indistinguishable (average ≈ 1.010) (Figure 1). Additionally, in Gateway, the genus with the highest importance value and the genus with the most basal area distinguished plots in terms of soil organic matter content. Finally, Analysis of Similarity (ANOSIM) shows that genus composition differs between Lents and Lloyd District and Lents and Downtown (Figure 2). Downtown and in Lloyd District, the most abundant genus is *Acer* and the most abundant family is *Sapindaceae*. In Gateway, the most abundant genus is *Pseudotsuga* and the most abundant family is *Cupressaceae*. In Lents, the most abundant genus is

Rosa and the most abundant family is *Rosaceae*. In all EcoDistricts, the genus with the most basal area and with the greatest importance value is *Acer*.

When results from all plots are considered I found that the average stem density is 882 stems/ha (2,907 total stems). Tree diameter averages 28.8 cm and mean basal area averages 48.76 m²/ha. There are a wide variety of genera of trees and shrubs in the 154 research plots (Appendix A). Evergreen stems and shrubs (deciduous and evergreen), which compose 46.7% and 46% of all stems, respectively, dominate vegetation throughout Portland. Specific functional types average: 412 evergreens/ha, 406 shrubs/ha, 328 trees/ha 278 deciduous stems/ha and 106 conifers/ha. The most abundant genus of plant in Portland is *Acer*, which includes only trees, and the most abundant family is *Rosaceae*, which includes trees and shrubs. *Acer* is the genus with the most basal area/ha and the highest importance value throughout the city. Portland's Shannon Diversity Index value is 1.303 (Table 5), comprising 162 genera.

Soil Analyses

Field-surveys revealed that there were some significant differences in soil properties among the four EcoDistricts. Lents and Lloyd District have greater total nitrogen (average ≈ 3.216 g/kg) than Downtown (2.039 g/kg), and Gateway is indistinguishable from either group (Figure 3). Downtown and Lloyd have a larger C:N Ratio (average ≈ 18.789) than Lents (14.674), and Gateway, again, is indistinguishable from either group (Figure 3). Total carbon (47.872 g/kg), fine root biomass (25.866 g/kg),

microbial biomass (74.66 $\mu\text{g/g}$) and soil organic matter (107.25 g/kg) did not significantly vary among EcoDistricts (Tables 6-9).

There are significant differences in soil physical properties observed in each EcoDistrict. Lloyd District has a significantly lower bulk density (0.551 g/cm^3), than the other EcoDistricts, which are indistinguishable (average $\approx 0.752 \text{ g/cm}^3$) (Figure 3). Soils in Gateway and Lents are the most clayey (average $\approx 37.986\%$) and Downtown and Lloyd District are significantly less clayey (average $\approx 23.390\%$) (Figure 3). Soil Texture in Downtown and Lloyd District is coarse loamy sand; soil texture in Gateway is fine clay; soil texture in Lents is fine silty clay.

When considered across all four EcoDistricts, soil organic matter makes up approximately 10.74% of the A horizon in Portland (Figures 5 and 6). Total carbon concentration averages 47.782 g C/kg soil and total nitrogen concentration averages 2.872 g N/kg soil; C:N ratio is 17.096. Mean microbial biomass carbon was found to be 74.659 $\mu\text{g MBC/g soil}$. Mean fine root biomass was found to be 25.866 mg fresh weight/g soil. The predominant soil texture is coarse loamy sand; mean clay content is 30%. Bulk density averages 0.71 g/cm^3 .

Analysis of Urban Metrics

Some urban variables differ between EcoDistricts (Tables 11-14). Downtown was annexed first (123.958 years ago), followed by Lloyd District (101.177 years ago), then Lents (61.698 years ago) and finally Gateway (23.158 years ago) (Figure 7). Downtown is also closest to the urban center (.899 km), followed by Lloyd District

(2.041 km), then Gateway (9.396 km) and finally Lents (10.025 km) (Figure 7).

Downtown and Lloyd District have the most impervious surface (average $\approx 72.71\%$), Gateway has an intermediate amount (60.76%) and Lents (51.10%) has the least (Figure 7). Downtown and Lloyd District have the most average building square footage (72,465 ft²), Lents the least (4,219 ft²), and Gateway is indistinguishable from either groups (Figure 7). The most prevalent zoning code in Downtown and Lloyd District is central commercial; Gateway is mostly zoned central commercial and institutional residential; and Lents's most prevalent zoning code is open space. Average years since development does not differ among EcoDistricts.

Across Portland, time since annexation at the sampling plots averages 85 years, and time since development averages 31 years. Zoning classification is primarily central commercial. The mean footprint of tax lots within a 20 m radius of each sampling location is 2.546 acres. The average square footage of the buildings within 20 m of sampling locations is 47,481 ft² and the mean value of the land and buildings combined is approximately \$9 million. Impervious surface in a radius of 20 m surrounding each sample averages 63.8% (Table 15).

Principal component analysis of the urban variables revealed that the urban characteristics are heavily loaded onto individual components. Principal components analysis was performed on the urban variables to determine the suitability of the variables as a set of regressors against the soil and vegetation data. However, I found that all of the variation in the urban variable set loaded onto one principal component and each urban variable loaded separately onto its own independent axis (Table 16).

Correlates to Soil Organic Matter Content in Portland Soils

Soil organic matter among Downtown plots can be estimated by measuring only two soil characteristics: total carbon and total nitrogen (Eq 1, Table 17). To estimate soil organic matter among Lloyd District plots, however, soil attributes (total carbon, total nitrogen, soil temperature, bulk density and soil moisture), vegetation structure (Shannon Diversity Index) and urban variables (impervious surface coverage and total value of adjacent tax lots) must be measured (Eq 2, Table 18). Soil organic matter among Gateway plots can be estimated by measuring total carbon, total nitrogen and the number of conifers per hectare (Eq 3, Table 19). Soil organic matter in Lents can be estimated by measuring total carbon, total nitrogen and the number of trees per hectare (Eq 4, Table 20).

$$\text{Eq 1. } \text{SOM}_{\text{Downtown}} = -234.58 \times \log(\text{Total Carbon}) + 516.73 \times \log(\text{Total Nitrogen}) + 98.07 \times \sqrt{\text{C:N Ratio}} + -63.36$$

$$\begin{aligned} \text{Eq 2. } \text{SOM}_{\text{Lloyd}} = & -617.27 \times \log(\text{Total Carbon}) + 928.34 \times \log(\text{Total Nitrogen}) \\ & + 314.00 \times \sqrt{\text{C:N Ratio}} + -36.80 \times (\text{Shannon Diversity Index}) + -1.72 \\ & \times (\text{Impervious Surface}) + 4.37 \times \log(\text{Total Value}) + -2312.45 \times \log(\text{Day} \\ & \text{of Year}) + -8.93 \times (\text{Temperature}) + -98.93 \times (\text{Bulk Density}) + 3.50 \times \\ & (\text{Soil Moisture}) + 13400.86 \end{aligned}$$

$$\text{Eq 3. } \text{SOM}_{\text{Gateway}} = 117.97 \times \text{sqrt}(\text{C:N Ratio}) + 0.98 \times \text{sqrt}(\text{Conifers/ha}) + \\ -384.27$$

$$\text{Eq 4. } \text{SOM}_{\text{Lents}} = 88.98 \times \log(\text{Total Nitrogen}) + 35.61 \times \text{sqrt}(\text{C:N Ratio}) + -0.21 \\ \times \text{sqrt}(\text{Trees/ha}) + -154.95$$

With the exception of fine root biomass, all vegetation variables were uncorrelated with soil organic matter when considering Portland as a whole. Significant differences in soil organic matter do not exist among genera, among dominant functional types at each site or among sites where different genera had dominant importance values. Significant differences in soil organic matter do not exist between textural classes. None of the urban characteristics that I measured were correlated with soil organic matter. Significant differences in soil organic matter do not exist between different zoning designations.

Fine root biomass, total carbon, total nitrogen, water content, bulk density and microbial biomass correlate strongly with soil organic matter. Of these factors, total nitrogen, microbial biomass and bulk density are significant predictors of soil organic matter in Portland according to the overall regression model (Equation 5, Table 21, Figure 8).

$$\text{Eq 5. } \text{Soil Organic Matter} = 66.01 \times \log(\text{Total Nitrogen}) + 24.44 \times \\ \log(\text{Microbial Biomass}) + -118.41 \times (\text{Bulk Density})$$

Factor-based, Pacific Northwest-based and urban-based sub-models yield congruent results. The same variables remain significant or insignificant no matter which specific sub-model they are a part of. Many variables have no predictive power: years since annexation, years since development, distance to urban center, footprint of adjacent tax lots, zoning designation, shrubs/ha, evergreens/ha, deciduous stems/ha, average DBH, total DBH, stems/hectare, total basal area, fine root biomass, soil texture, clay content and sampling depth were neither significant in any EcoDistrict nor in Portland as a whole.

Comparison of soil organic matter in Portland and the Pacific Northwest

Figure nine compares seven Pacific Northwest studies (Table 22) of undisturbed forest soil to the data I collected in Portland. Soil organic carbon (soil organic matter $\times$ 0.50) was used for the comparison because many studies do not report soil organic matter. The two samples are statistically indistinguishable, though there is greater variety in the Pacific Northwest data set.

Discussion

The aim of this study was to examine the factors influencing soil organic matter storage in an urban ecosystem by quantifying how biotic and urban variables influence soil organic matter dynamics in Portland, Oregon. As soil organic matter is a critical component of the global carbon cycle, understanding the factors influencing soil organic matter dynamics is fundamental to our abilities to predict how components of global change, including urbanization, might influence the carbon storage potential of soils. Previous studies have primarily focused on the roles of biology (Klopatek, 2002; Sun *et al.*, 2004; Adams *et al.*, 2005; Rezácová *et al.*, 2006; Chaer *et al.*, 2009; Eskelinen *et al.*, 2009, 2009; Kluber *et al.*, 2010; Waldrop *et al.*, 2010; Blagodatskaya *et al.*, 2011; Crow *et al.*, 2009b; Johnson *et al.*, 2009), parent material (Adams *et al.*, 2005; Homann *et al.*, 2007; von *et al.*, 2008; Johnson *et al.*, 2009; Kong *et al.*, 2009), climate (Homann *et al.*, 2004; Sun *et al.*, 2004; Raich *et al.*, 2006; Homann *et al.*, 2007; Griffiths *et al.*, 2009) and time (Sun *et al.*, 2004) in influencing soil organic matter dynamics. Research conducted in Pacific Northwest forests indicates that several soil-forming factors contribute to soil organic matter accumulation.

Biology has been found to be a significant contributor to soil organic matter in Pacific Northwest forest soils. Sun *et al.* (2004) found that soil carbon accumulated as a function of increased primary productivity, as measured by tree and shrub dimensions and biomass calculations. In his 2002 study, Klopatek (2002) attributed greater soil carbon to increased detrital pool input from coarse woody debris. Chaer *et al.* (2009) found that soil organic carbon is strongly correlated with microbial biomass and

phosphatase activity due to the greater nutritional value of soil organic matter-rich soil. Nitrogen concentration has been seen to variably affect soil organic matter. Klopatek (2002) found that nitrogen fertilization reduced soil respiration and decomposition; Homann *et al.* (2001) found that nitrogen fertilization decreased soil respiration, cellulase activity and possibly contributed to the formation of recalcitrant organic matter, although no effect on soil organic carbon pools was found; and Adams (2005) found that soil carbon significantly increased with nitrogen fertilization. Significant increases in soil organic matter have been attributed to increased precipitation in studies conducted by Sun *et al.* (2004), Homann *et al.* (2004, 2007) and Griffiths *et al.* (2009). In a regional study, Homann *et al.* (2007) found no response in soil carbon to increasing temperature. They attribute this to greater detrital input, affected by mixing by soil fauna, which balances the enhanced decomposition of higher temperature soils. Texture was found to be a significant factor in some Pacific Northwest studies as well: Homann *et al.*'s 2007 study found that clay content and soil organic matter were directly related. Finally, time has proven a significant variable in Pacific Northwest soil organic matter research. Sun *et al.* (2004) discovered that forest stands less than 50 years old suffered from soil organic carbon loss, but after that amount of time, soil organic carbon accumulates until forest stand age reaches approximately 150-200 years, at which time it plateaus.

In Pacific Northwest soils, then, it seems that greater above-ground biomass leads to greater detrital input and both increase soil organic matter. Wetter soils limit decomposition and retain soil organic matter. Greater soil nitrogen contributes to above ground biomass and possibly limits decomposition of existing soil organic matter. A soil organic matter steady state seems to be reached at about 150-200 years.

Surprisingly, most traditional soil forming factors do not correlate to or predict soil organic matter content in Portland. Exhaustive sampling of 154 discrete research plots in Portland indicates that soil organic matter is primarily predicted by microbial biomass, nitrogen and bulk density. After modeling each factor separately, combining significant variables into one model and eliminating insignificant variables, the overall predictive soil organic matter model includes only microbial biomass, total nitrogen and bulk density. The accumulation of soil organic matter in Portland likely depends on above ground biomass, dominant vegetation genera, rhizodeposition, effective precipitation and clay content in addition to nitrogen content, microbial biomass and bulk density, as is the case for Pacific Northwest forest soils, but the effects of those variables appear to have been masked by urbanization.

Numerous previous studies have suggested that vegetation plays a key role in modulating soil organic matter content. For example, in their meta-analysis, Cebrian and Duarte (1995) found a strong linear correlation between carbon entering the detrital pool and primary productivity. The importance of plant community composition has also been documented. Eskelinen *et al.* (2009) found that the proportion of forbs to woody shrubs alters the quality of soil organic matter, specifically the proportions of soluble N, phenolics and the C:N ratio. Further, this difference in vegetation is associated with fungi-dominated (shrubs) or bacteria-dominated (forbs) microbial communities (Eskelinen *et al.*, 2009). Similarly, Johnson *et al.* (2009) found that mixed forest stands correspond with greater soil organic matter than homogenous stands (Johnson *et al.*, 2009). The mechanism by which species richness leads to increased soil organic matter

may be two-fold: decreased soil carbon losses and stimulation of deposition (Steinbeiss *et al.*, 2008).

Tsuga, *Pseudotsuga* and *Abies* dominate Pacific Northwest forests (Schoonmaker & McKee, 1988). Belowground ectomycorrhizal mats are extensive in such forests (Griffiths *et al.*, 1996), where net primary productivity (Homann *et al.*, 2007) and the amount of coarse woody debris found on the forest floors influence soil organic matter stocks. Portland has shifted to a deciduous dominated vegetation cover. This shift in vegetation does not appear to significantly affect soil organic matter, however, because fine root biomass is the only vegetation variable correlated to soil organic matter; fine root biomass is not correlated to any other vegetation variable (stem density, Shannon diversity index, etc.). This implies that the amount and composition of vegetation in Portland does not directly affect soil organic matter.

In contrast, a recent meta-analysis comprising several studies on decomposition indicates that plant community composition is important in determining the extent to which litter decomposes (Cornwell *et al.*, 2008). Cornwell *et al.* assert that correctly interpreting the relationship between community composition and litter decomposition rates is crucial for understanding carbon cycling. However, urban ecosystems, where blowers, raking, mowing etc. remove surface litter, defy the traditional paradigm of carbon inputs and decomposition dynamics.

Litter removal experiments reveal that soil organic matter beneath deciduous forests is stabilized by rhizodeposition, whereas needle litter produced in coniferous forests induces a priming effect (Crow *et al.*, 2009b). As the vegetation shift in Portland is from a coniferous dominated vegetation pattern to a deciduous pattern, the rate of

below-ground input may have increased. Also, rates of decomposition of soil organic matter in Portland may be lower than decomposition rates in Pacific Northwest forests due to the elimination of a needle litter induced priming effect following the shift in tree community composition with urbanization. Conceivably, higher rates of rhizodeposition, coupled with low microbial biomass have acted to recover soil organic matter that was lost with initial disturbance in Portland, but whether rhizodeposition is greater in Portland compared to Pacific Northwest forests can only be speculated. Further, none of the regression models, either specific to an EcoDistrict or for Portland, include fine root biomass, so the direction of the correlation between fine root biomass and soil organic matter remains conjecture. It is reasonable to imagine that greater soil organic matter might support groundcover with more extensive root structure.

Differences in quality of below-ground carbon substrates between Portland and Pacific Northwest soils may also exist. The shift in above-ground vegetation may have altered rhizodeposited carbon sources and the ability of the microbial community to modify root-derived litter. In urban litter-bag experiments, Vauramo and Setälä (2011) found that the nearby plant community did not affect decomposition rates, while litter type did, suggesting that above-ground litter may have more effect than below-ground litter on soil organic matter composition. However, the mycorrhizae beneath conifers confer specific metabolic capabilities to the soil microbial community (Kluber *et al.*, 2010) and their displacement in Portland may have shifted the identity or enzymatic profiles of the soil microbiota, limiting their ability to decompose available substrates.

Some Pacific Northwest studies (Sun *et al.*, 2004; Griffiths *et al.*, 2009) suggest that soil characteristics indirectly affect soil organic matter by influencing microbial

biomass and decomposition rates. Microbial biomass in Portland is significantly lower than values reported for Pacific Northwest forests (Selmants *et al.*, 2005; Chaer *et al.*, 2009; Kluber *et al.*, 2010), suggesting that soil respiration in Portland may be lower than in Pacific Northwest forests. Considering the reduced microbial biomass, the most probable scenario explaining the lack of difference between Portland and Pacific Northwest soil organic matter is reduced carbon input and accompanying reduced decomposition in Portland compared to Pacific Northwest forests. Alternatively, increased carbon input, via rhizodeposition, and increased decomposition may be occurring. One method to distinguish these two possibilities would be to examine the activity of the microbial community by measuring soil respiration.

Biomass, activity, respiration rate and metabolic quotient of soil microbiota are likely universally important in understanding the timescales of soil organic matter turnover and the mechanisms of its accumulation and degradation. For example, a recent laboratory study found that the magnitude of priming effect depends on the existing microbial biomass (Blagodatskaya *et al.*, 2011). Similarly, the low metabolic quotient and carbon flux of arctic permafrost depend on low microbial biomass rather than soil organic matter recalcitrance (Waldrop *et al.*, 2010). In a laboratory study, Rezacova *et al.* (2006) tested the response of fulvic and humic acids, which are major constituents of soil organic matter, in incubations with different communities of microfungi. They found that the chemical complexity of soil organic matter decreased in the presence of the basidiomycete *Trametes versicolor* implicating microbial community composition in regulating soil organic matter (Rezacová *et al.*, 2006).

Insufficient data limits knowledge of the role of microorganisms in Portland's soils. While microbial biomass is significantly lower in Portland than in Pacific Northwest forest soils, the activity of the microbial biomass, soil enzymatic profile and community composition remain unexplored. Low soil microbial biomass generally indicates low soil organic matter content (Nourbakhsh, 2007; Chaer *et al.*, 2009). Low microbial biomass coupled with ambient soil organic matter implies that soil microbial activity in Portland may be low. Further, a low microbial biomass to soil organic matter ratio signals slow biogeochemical cycling of key plant nutrients (Wang *et al.*, 2011). Additionally, low microbial biomass may mean that Portland's soils are vulnerable to soil priming because relatively small amounts of readily available carbon substrate will trigger the priming effect (Blagodatskaya *et al.*, 2011).

The effect of urbanization on soil microbial biomass has been studied but little. Many of the urban studies that examine soil microbial communities and their functions focus on the effects of urban heavy metal contamination. In Aberdeen city, Scotland, Yang *et al.* (2006) recently found that the metabolic quotient of soil microbiota is comparable in urban and non-urban areas, but that the rate of carbon substrate utilization is higher and soil organic carbon is lower in cities. They speculate that their results may be explained by heavy metal contamination of urban soils (Yang *et al.*, 2006). Yakovlev *et al.* (2008) also cite heavy metal contamination as a causative agent of soil organic matter differences between urban and native soils. In Norilsk, Russia, though, soil organic matter increased by approximately 150% (Yakovlev *et al.*, 2008). Wang *et al.* (2011) found that microbial biomass and activity were not significantly disturbed by heavy metal contamination. More perplexing than inconsistencies in the effects of

urbanization on soil microbial biomass and activity is the notion that disturbance not only alters soil biology, but disrupts relationships and correlations among soil properties (Nourbakhsh, 2007).

Urbanization is a significant disturbance event for soils (Lehmann & Stahr, 2007), physically, chemically and biologically. Urban characteristics, such as time since disturbance (Scharenbroch, 2005; Golubiewski, 2006) and distance to urban center (Sun *et al.*, 2010), have proven significant explanatory variables in other urban soil organic matter studies. In contrast, urban variables have a limited effect on soil organic matter accumulation in Portland. The amount of soil organic matter in Portland is not statistically distinguishable from the amount in Pacific Northwest forest soils, urban variables do not correlate with soil organic matter, nor are they significant regressors of soil organic matter and the urban landscape does not combine to form an ecological gradient, as non-urban ecosystem attributes do. Urbanization of the Pacific Northwest appears not to have directly affected soil organic matter accumulation.

That urban variables are not significant predictors of soil organic matter in Portland is, perhaps, unsurprising, considering that there is no significant difference in soil organic matter between Portland and Pacific Northwest forest soils. If there had been a significantly greater or lesser amount of soil organic matter between the two areas, it would be reasonable to expect to find the urban metric (or combination of metrics) responsible. Possibly, an important urban variable was overlooked. For example, investigation into social aspects of urbanization, such as management or demographics, may have proved fruitful.

The influence of urbanization on native Pacific Northwest soils may manifest only as an artificial steady state. In Pacific Northwest forests, soil organic matter declines for approximately 50 years after disturbance, implying that soil organic matter in Portland (where the average number of years since development is 50) is decreasing. But, as the pool of soil organic matter in Portland is statistically indistinguishable from that in Pacific Northwest forest soils, the notion that soil organic matter in the Portland area pre-urbanization was significantly greater than it is now is doubtful. If urban soil organic matter is not decreasing, it must either be at equilibrium or it must be increasing. I suggest that if urban soils were left undisturbed, they would accumulate soil organic matter. But, it seems that urban soils are not left undisturbed. There is no correlation between years since annexation and years since development; that is, even locations in Portland that have been urban for over a century have been developed (redeveloped) within the last decade. Portland's soils are harassed by frequent disturbance.

In Portland, it seems that nearly all input to the soil organic matter pool must be below-ground via rhizodeposition of deciduous trees. High microbial biomass, high nitrogen and low bulk density predict soil organic matter. Frequent disturbance precludes further buildup of soil organic matter. Three possible mechanisms explain the parity between Pacific Northwest and Portland soils. First, input and loss from Pacific Northwest and Portland soils could be comparable. That is, rhizodeposition from Portland's maples might balance above-ground litter from Pacific Northwest conifer stands and decomposition in Portland's microbial biomass-poor soils might balance wetter Pacific Northwest soils. However, it seems implausible that below-ground input from fewer, smaller trees in Portland is able to match above- and below-ground input

from more, larger trees in the Pacific Northwest forests. If input to soil organic matter pools in Portland are reduced compared to Pacific Northwest forests, then decomposition of soil organic matter must also be reduced. The fact that Portland receives less precipitation than Pacific Northwest forest soils challenges this hypothesis, but it is supported by the fact that Portland sustains less microbial biomass than Pacific Northwest forest soils (Table 23).

Responses of soil organic matter to urbanization in temperate cities vary widely. Compared with other temperate urban cities, Portland contains more soil organic matter than some cities and less than others (Figure 12). The difference between the amount of soil organic matter in the Pacific Northwest and Portland is intermediate compared to differences in soil organic matter between temperate native non-urban soils and temperate city soils (Figure 13), which range from -27% to 157% . My results reinforce traditional concepts of soil organic matter and soil organic matter accumulation in an urban area and support the framework proposed by Pickett and Cadenasso (2009), where the five state factors (parent material, biology, climate, topography and time) (Jenny, 1946) are affected by urbanization as they would be by any other cause of disturbance. Soil organic matter accumulation in cities may not be fundamentally different than soil organic matter accumulation in undisturbed areas. In as much as cities have similar biology, parent material, climate, texture and topography they will have similar soil organic matter values.

Several studies, conducted in a variety of biomes, have reported soil organic matter. Soil organic matter in undisturbed soils appears to be greater in climates with lower temperatures (Figure 11). Far less research has been undertaken to examine the

factors that influence increases or decreases in soil organic matter with urbanization. Biome-specific processes may underlie the wide variation in soil organic matter observed in urban studies (Figure 12). For example, the heterotrophic respiration of soil organic matter is sensitive to soil temperature in tropical, temperate and boreal biomes but to increasing degrees, respectively (Chen & Tian, 2005). Further evidence that regional or biome-scale environmental conditions influence the effects of urbanization on soil organic matter may be seen by comparing reported differences in soil organic matter after urbanization in different biomes. After urbanization, soils equilibrate to higher, similar and lower amounts of soil organic matter, and differences between biomes can be discerned. Urban areas in desert biomes have greater soil organic matter than their undisturbed counterparts whereas in temperate biomes, urbanization has mixed effects on soil organic matter (Figure 13). In deserts, constraints to soil organic matter accumulation are likely related to water stress and lack of carbon input, which are alleviated in urban areas due to residential installation of lawns and their concomitant management (Green & Oleksyszyn, 2002; Jenerette *et al.*, 2006). Further, similar urban attributes may affect soil organic matter accumulation differently in different biomes. Urban soil organic matter studies conducted across a variety of climates will help to clarify any regional or biome influences on the effects of urbanization. Specifically, matched studies of urban soil organic matter and suspected contributing factors, such as microbial biomass, activity and community structure and vegetation composition, will help to elucidate explicit effects of biomes.

Increasing global temperatures and CO₂ concentrations have both direct and indirect effects on global stocks of soil organic matter (Pendall *et al.*, 2004). Microbial

respiration of previously unavailable substrates from thawing or drying soils and increased metabolic rates are likely to increase the rate of decomposition. Free air CO₂ exchange experiments that included nitrogen treatments revealed increased turnover rates of 6.3% in topsoils and 4.7% in subsoils compared to controls (Leavitt *et al.*, 2001). But, increases in net primary productivity (Norby *et al.*, 2005), and, therefore, increased carbon inputs to soil are also expected. Observations of net primary productivity reflect agreement with predictions in some regions, but not in others. For example, in a tundra ecosystem, plant biomass increases with experimental warming do not alter plant community composition (Biasi *et al.*, 2008) whereas in tropical climates, increases in temperature lead to changes in ecosystem structure, but not total carbon storage (Raich *et al.*, 2006). As Crow *et al.* (2009) point out, even in ecosystems where net primary productivity increases in response to increased temperature, carbon balances will likely shift between vegetation and soil pools uniquely per ecosystem. Experimental evidence supports this hypothesis: in a field-warming study, composition of soil organic matter shifted from lignin-derived compounds to leaf-cuticle-derived compounds in temperate soils (Feng *et al.*, 2008).

Urbanization and global climate change both disturb existing patterns of local temperature, precipitation, atmospheric CO₂ and vegetation structure. But, despite circumstantial evidence that the change in genus composition in Portland may have buffered decreases in soil organic matter, vegetation appears divorced from soil organic matter in Portland. This disconnection is unlikely to result from global climate change in undisturbed ecosystems. Thus, though they are increasingly important ecosystems

because they are growing in size and number, cities appear not to act as a surrogate model for changes in soil organic matter that might accompany global climate change.

These results emphasize the amount of work left to be done to understand the mechanisms of soil organic matter formation, disturbance and equilibrium in urban ecosystems. Several specific changes to the current strategic approach of urban soil organic matter studies would help to clarify the remaining issues. First, measurement of a wide variety of factors should be standard operating procedure when studying the urban environment because urban systems are dynamic and constraints on their biogeochemical cycles are relatively poorly understood. Further, studies should be undertaken in a greater number of cities across a variety of climates to allow researchers to determine which variables are important to soil organic matter accumulation universally and which might be regionally or locally influential. Additionally, results from urban soil organic matter studies conducted across a variety of scales will help to bring to light which human-related variables constrain soil organic matter in cities. Large- or small-scale urban variables that were not investigated here may link people and their behavior and consumption choices to soil organic matter. Most importantly, urban soil microbiota needs to be studied more thoroughly and methodically. Measurement of respiration, calculation of metabolic quotient and evaluation of community profiles should be variables in all future studies of soil organic matter. Making the effort to unify techniques and discuss and compare results will help urban ecologists overcome the challenges inherent to the study of biogeochemistry in a novel environment.

Tables

Table 1. Summary of Vegetation Statistics for Downtown. Downtown-specific vegetation statistics (48 plots).

	Mean	Mode	SE
Fine Root Biomass (mg/g)	5.609		1.778
Stems/ha	1021.400		185.132
Trees/ha	246.400		27.880
Average DBH	32.680		3.113
Shrubs/ha	261.800		78.589
Evergreens/ha	284.500		57.177
Deciduous/ha	218.900		53.016
Conifers/ha	21.070		6.651
Dominant Functional Type		Deciduous Trees	
Shannon Diversity Index	1.030		0.147
Most Abundant Genus		<i>Acer</i>	
Most Abundant Family		<i>Sapindaceae</i>	
Most Basal Area		<i>Acer</i>	
Average Basal Area (m ²)	1.867		0.193
Greatest Importance Value		<i>Acer</i>	

Table 2. Summary of Vegetation Statistics for Lloyd District. Lloyd District-specific vegetation statistics (34 plots).

	Mean	Mode	SE
Fine Root Biomass (mg/g)	9.7427		1.280
Stems/ha	512.700		29.137
Trees/ha	263.200		34.645
Average DBH	31.790		0.287
Shrubs/ha	250.600		15.074
Evergreens/ha	235.756		40.814
Deciduous/ha	219.700		15.252
Conifers/ha	34.330		29.597
Dominant Functional Type		Evergreens	
Shannon Diversity Index	0.983		0.057
Most Abundant Genus		<i>Acer</i>	
Most Abundant Family		<i>Sapindaceae</i>	
Most Basal Area		<i>Acer</i>	
Average Basal Area (m ²)			0.057
Greatest Importance Value		<i>Acer</i>	

Table 3. Summary of Vegetation Statistics for Gateway. Gateway-specific vegetation statistics (19 plots).

	Mean	Mode	SE
Fine Root Biomass (mg/g)	8.800		1.087
Stems/ha	1187.800		195.475
Trees/ha	383.000		49.307
Average DBH	21.670		3.008
Shrubs/ha	813.000		176.527
Evergreens/ha	829.400		193.685
Deciduous/ha	366.600		58.350
Conifers/ha	239.600		54.319
Dominant Functional Type		Evergreens	
Shannon Diversity Index	1.389		0.112
Most Abundant Genus		<i>Pseudotsuga</i>	
Most Abundant Family		<i>Cupressaceae</i>	
Most Basal Area		<i>Acer</i>	
Average Basal Area (m ²)	0.864		0.103
Greatest Importance Value		<i>Acer</i>	

Table 4. Summary of Vegetation Statistics for Lents. Lents-specific vegetation statistics (53 plots). *Median fine root biomass in Lents is 5.569 mg/g, the Lents Fine Root Biomass distribution suffers from four distant outliers.

	Mean	Mode	SE
Fine Root Biomass (mg/g)	60.673*		1.327
Stems/ha	883.200		197.278
Trees/ha	423.600		102.866
Average DBH	25.930		4.054
Shrubs/ha	490.400		174.077
Evergreens/ha	491.200		172.199
Deciduous/ha	339.200		88.685
Conifers/ha	182.200		
Dominant Functional Type		Shrubs	
Shannon Diversity Index	1.726		0.116
Most Abundant Genus		<i>Rosa</i>	
Most Abundant Family		<i>Rosaceae</i>	
Most Basal Area		<i>Acer</i>	
Average Basal Area (m ²)	1.123		0.220
Greatest Importance Value		<i>Acer</i>	

Table 5. Summary of Vegetation Statistics for Portland. Means and modes are averages and counts across all EcoDistricts (154 plots).

	Mean	Mode	SE
Fine Root Biomass (mg/g)	25.866		20.215
Stems/ha	882.056		124.882
Trees/ha	328.000		48.827
Average DBH	28.800		
Shrubs/ha	406.000		93.687
Evergreens/ha	412.100		87.576
Deciduous/ha	278.700		49.875
Conifers/ha	106.400		37.962
Dominant Functional Type		Evergreens	
Shannon Diversity Index	1.303		0.110
Most Abundant Genus		<i>Acer</i>	
Most Abundant Family		<i>Rosaceae</i>	
Average Basal Area (m ²)	1.253		0.252
Most Basal Area		<i>Acer</i>	
Greatest Importance Value		<i>Acer</i>	

Table 6. Summary Soil Statistics for Downtown. Downtown-specific soil statistics (48 plots).

	Mean	Mode	SE
Soil Organic Matter (g/kg)	128.280		22.608
Total Carbon (g/kg)	49.929		7.054
Total Nitrogen (g/kg)	2.596		0.329
C:N Ratio	20.259		1.453
Bulk Density (g/cm ³)	0.636		0.051
Microbial Biomass (µg/g)	94.969		23.012
Texture		Coarse Loamy Sand	
Clay Content	21.712		2.739

Table 7. Summary Soil Statistics for Lloyd District. Lloyd District-specific soil statistics (34 plots).

	Mean	Mode	SE
Soil Organic Matter (g/kg)	85.729		6.344
Total Carbon (g/kg)	46.049		3.106
Total Nitrogen (g/kg)	2.638		0.197
C:N Ratio	17.899		0.477
Bulk Density (g/cm ³)	0.478		0.048
Microbial Biomass (µg/g)	36.275		7.191
Texture		Coarse Loamy Sand	
Clay Content	10.500		0.000

Table 8. Summary Soil Statistics for Gateway. Gateway-specific soil statistics (19 plots).

	Mean	Mode	SE
Soil Organic Matter (g/kg)	77.521		4.916
Total Carbon (g/kg)	36.833		3.258
Total Nitrogen (g/kg)	2.798		0.256
C:N Ratio	13.205		0.179
Bulk Density (g/cm ³)	0.636		0.044
Microbial Biomass (µg/g)	67.395		6.096
Texture		Fine Clay	
Clay Content	56.833		3.871

Table 9. Summary Soil Statistics for Lents. Lents-specific soil statistics (53 plots).

Lents Soil	Mean	Mode	SE
Soil Organic Matter (g/kg)	95.412		8.525
Total Carbon (g/kg)	42.223		5.654
Total Nitrogen (g/kg)	3.233		0.449
C:N Ratio	13.934		0.873
Bulk Density (g/cm ³)	0.743		0.040
Microbial Biomass (µg/g)	52.978		8.796
Texture		Fine Silty Clay	
Clay Content	34.328		3.273

Table 10. Summary of Soil Statistics for Portland. Means and modes are averages and counts across all EcoDistricts (154 plots).

	Mean	Mode	SE
Total Carbon (g/kg)	47.872		3.524
Total Nitrogen (g/kg)	2.782		0.143
C:N Ratio	17.096		0.595
Bulk Density (g/cm3)	0.711		0.023
Microbial Biomass (µg/g)	74.659		6.240
Texture		Coarse Loamy Sand	
Clay Content	30.214		1.583

Table 11. Summary of Urban Statistics for Downtown. Downtown-specific urban statistics (48 plots).

	Mean	Mode Central Commercial	SE
Zoning			
Impervious Surface (%)	70.920		2.000
Distance to Urban Center (km)	1.094		0.203
Years Since Annexation	124.000		1.078
Years Since Development	50.940		6.653
Square Footage of Buildings on Adjacent Tax Lots	70,059		15,708
Footprint of Buildings on Adjacent Tax Lots (acres)	1.128		0.173
Total Value of Adjacent Tax Lots	\$10.45 M		\$2.03 M

Table 12. Summary of Urban Statistics for Lloyd District. Lloyd District-specific urban statistics (34 plots).

	Mean	Mode Central Commercial	SE
Zoning			
Impervious Surface (%)	75.240		1.975
Distance to Urban Center (km)	2.042		0.064
Years Since Annexation	101.200		0.728
Years Since Development	39.270		2.699
Square Footage of Buildings on Adjacent Tax Lots	75,863		23,401
Footprint of Buildings on Adjacent Tax Lots (acres)	2.058		0.511
Total Value of Adjacent Tax Lots	\$17.57 M		\$6.64 M

Table 13. Summary of Urban Statistics for Gateway. Gateway-specific urban statistics (19 plots).

Zoning	Mean	Mode Central Commercial / Institutional Residential	SE
Impervious Surface (%)	60.760		2.597
Distance to Urban Center (km)	9.397		0.060
Years Since Annexation	23.160		1.442
Years Since Development	43.800		2.619
Square Footage of Buildings on Adjacent Tax Lots	60,332		21,319
Footprint of Buildings on Adjacent Tax Lots (acres)	4.207		0.902
Total Value of Adjacent Tax Lots	\$13.47 M		\$618,519

Table 14. Summary of Urban Statistics for Lents. Lents-specific urban statistics (53 plots).

Zoning	Mean	Mode Open Space	SE
Impervious Surface (%)	51.100		2.125
Distance to Urban Center (km)	10.026		87.821
Years Since Annexation	61.700		5.212
Years Since Development	53.440		3.979
Square Footage of Buildings on Adjacent Tax Lots	4,219		1,687
Footprint of Buildings on Adjacent Tax Lots (acres)	3.547		1.689
Total Value of Adjacent Tax Lots	\$660,684		\$232,123

Table 15. Summary of Urban Statistics for Portland. Means and modes are averages and counts across all EcoDistricts (154 plots).

	Mean	Mode	SE
Zoning		Central Commercial	
Impervious Surface (%)	63.800		2.602
Distance to Urban Center (km)	2.721		0.655
Years Since Annexation	85.060		6.148
Years Since Development	31.900		5.253
Square Footage of Buildings on Adjacent Tax Lots	47,481		16,486
Footprint of Buildings on Adjacent Tax Lots (acres)	2.546		1.078
Total Value of Adjacent Tax Lots	\$9.03 M		\$3.94 M

Table 16. Principal Components Loadings of Urban Variables for Portland. PCA loadings show that each urban variable governs its own principal axis; values represent fractions of axes composed of the variance of each variable.

Portland PCA	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Total Value of Adjacent Tax Lots	1.000						
Years Since Annexation			0.967	-0.168	0.181		
Distance to Urban Center							0.994
Impervious Surface			0.176		-0.978		
Square Footage of Buildings on Adjacent Tax Lots		-1.000					
Years Since Development			-0.166	-0.986			
Footprint of Adjacent Tax Lots						0.994	

Table 17. Summary of Regression Analysis for Downtown. Soil organic matter in the Downtown EcoDistrict can be estimated from total carbon, total nitrogen and C:N ratio. Note that the intercept does not significantly contribute to the Downtown model, but is retained to limit the significant variables.

	Estimate	SE	t-value	P-value
Intercept	-63.360	48.930	-1.295	0.202
log(Total Carbon (g/kg))	-234.580	43.120	5.440	2.230×10^{-6}
log(Total Nitrogen (g/kg))	516.730	69.120	7.475	2.310×10^{-9}
sqrt(C:N Ratio)	98.070	21.590	4.543	4.290×10^{-5}

Table 18. Summary of Regression Analysis for Lloyd District. Soil organic matter in the Lloyd District EcoDistrict can be estimated only by measuring several variables, including soil, vegetation and urban parameters. Note that all variables significantly contribute to the Lloyd model.

	Estimate	SE	t-value	P-value
Intercept	13400.864	3767.269	3.557	1.677×10^{-3}
log(Total Carbon (g/kg))	-617.270	135.575	-4.553	1.420×10^{-4}
log(Total Nitrogen (g/kg))	928.345	179.804	5.163	3.120×10^{-5}
sqrt(C:N Ratio)	314.006	60.524	5.188	2.930×10^{-5}
Shannon Diversity Index	-36.808	9.822	-3.747	1.051×10^{-3}
Impervious Surface (%)	-1.720	0.538	-3.195	4.030×10^{-3}
log(Total Value of Adjacent Tax Lots)	4.370	1.360	3.214	3.843×10^{-3}
log(Day of Year Sampled)	-2312.449	649.331	-3.561	1.660×10^{-3}
Soil Temperature (°C)	-8.923	3.825	-2.333	2.876×10^{-2}
Bulk Density (g/cm ³)	-98.934	30.186	-3.277	3.305×10^{-3}
Soil Moisture (%)	3.503	0.997	3.515	1.859×10^{-3}

Table 19. Summary of Regression Analysis for Gateway. Soil organic matter in the Gateway EcoDistrict can be estimated from C:N ratio and Conifers/ha. Note that the Conifers/ha term does not significantly contribute to the Gateway model, but is retained to limit the significant variables.

	Estimate	SE	t-value	P-value
Intercept	-384.266	43.073	-8.921	1.310×10^{-7}
sqrt(C:N Ratio)	117.970	10.504	11.230	5.340×10^{-9}
sqrt(Conifers/ha)	0.979	0.984	0.995	0.335

Table 20. Summary of Regression Analysis for Lents. Soil organic matter in the Lents EcoDistrict can be estimated from total nitrogen, C:N ratio and Trees/ha. Note that the Trees/ha term does not significantly contribute to the Lents model, but is retained to limit the significant variables.

	Estimate	SE	t-value	P-value
Intercept	-154.948	20.825	-7.441	1.380×10^{-9}
log(Total Nitrogen (g/kg))	88.980	5.721	15.552	2.000×10^{-16}
sqrt(C:N Ratio)	35.611	4.200	8.479	3.570×10^{-11}
sqrt(Trees/ha)	-0.205	0.260	-0.788	0.434

Table 21. Summary of Regression Analysis for Portland. Soil organic matter in the Portland can be estimated from total carbon, total nitrogen, microbial biomass and bulk density.

	Estimate	SE	t-value	P-Value
log(Total Nitrogen (g/kg))	98.293	27.183	3.616	6.140×10^{-4}
log(Microbial Biomass ($\mu\text{g/g}$))	23.302	7.397	3.150	2.544×10^{-3}
Bulk Density (g/cm^3)	-109.443	33.442	-3.273	1.77×10^{-3}

Table 22. Publications Used to Compare Portland to Pacific Northwest Soil Organic Carbon. Where necessary, reported bulk density was used to convert between Mg/ha and g/kg. Only data from samples taken from the A horizon or superficial 30 cm were used. Soil organic carbon is calculated as 50% of SOM for use in comparison to studies that do not report loss-on-ignition (SOM).

Author	SOC (Mg/ha)	Year	Location
Griffiths et al	893	1998	HJA
Homann	720	2007	OR Coast
Griffiths et al	691	1994	HJA
Homann	559	2005	WA Coast
Homann	291	2007	OR Cascades
Sun et al	267	2004	Lookout Mt WA
Homann	256	2005	WA Cascades
Sun et al	247	2004	Mt. Jefferson
Sun et al	229	2004	Mill City S
Sun et al	201	2004	Battle Ax, OR
Klopatek	175	2002	WRCCRF
Klopatek	157	2002	WRCCRF
Sun et al	154	2004	Breitenbush
Sun et al	142	2004	HJA
Adams	105	2005	Eastern WA
Klopatek	97	2002	WRCCRF
Adams	35	2005	Eastern WA

Table 23. Comparison of Pacific Northwest Forest Soils to Portland Soils. Fewer, smaller trees, drier soils and less soil microbial biomass in Portland yields a comparable quantity of soil organic matter.

	Pacific Northwest Forest Soils	Portland Soils
Stem Density (trees/ha)	519.8 ¹	339.0
Mean DBH (cm)	33.9 ¹	28.5
Average Annual Precipitation (cm)	253.0 ¹	91.5 ²
Microbial Biomass (µg/g)	500.0 ³	69.6

¹ North et al., 2005

² NOAA, 2011

³ Chaer et al., 2009

Figures

Figure 1. Sampling Sites. Potential sites with 1:1 ratio of high structure to low structure vegetation were identified using a GIS. 154 sampling locations were chosen after considering accessibility: 48 Downtown, 34 in Lloyd District, 19 in Gateway and 53 in Lents.

Differences in Vegetation Structure Among EcoDistricts

Figure 2. Differences in Vegetation Structure Among EcoDistricts. Distributions of vegetation variables where significant differences exist between at least two EcoDistricts; letters represent significant differences ($\alpha = 0.05$).

Figure 3. ANOSIM of Bray-Curtis Distance Among EcoDistricts. Analysis of Similarity shows that significant differences in plant community composition exist for at least two EcoDistricts. ANOSIM between each pair of Ecodistricts demonstrates that significant differences exist between Downtown and Lents and Lloyd District and Lents ($\alpha = 0.05$); where notches do not overlap, statistically significant differences exist between medians.

Differences in Soil Properties Among EcoDistricts

Figure 4. Differences in Soil Properties Among EcoDistricts. Distributions of soil variables where significant differences exist between at least two EcoDistricts; letters represent significant differences ($\alpha = 0.05$).

Figure 5. Soil Organic Matter Among EcoDistricts. Distributions of soil organic matter in each EcoDistrict. No significant differences were found ($\alpha = 0.05$).

Figure 6. Map of Soil Organic Matter in Portland. Bubble size is proportional to soil organic matter at each sampling location. No spatial trends were discovered.

Distribution of SOM in Portland

Figure 7. Distribution of Soil Organic Matter in Portland. The distribution is normal with a slight right tail; bins were selected using the Freedman-Diaconis rule.

Differences in Urban Character Among EcoDistricts

Figure 8. Differences in Urban Characteristics Among EcoDistricts. Distributions of urban variables where significant differences exist between at least two EcoDistricts; letters represent significant differences ($\alpha = 0.05$).

Figure 9. Expected vs. Observed Soil Organic Matter Values for Portland. The regression model for Portland (Table 21, Equation 5) was used to generate expected soil organic matter values, which were plotted against observed values. Minima and maxima are displayed; dashed line is 1:1.

Soil Organic Carbon (Mg/ha)

Figure 10. Soil Organic Matter in Portland and the Pacific Northwest. No significant difference was found between the two data sets; error bars represent one standard error.

Figure 11. Soil Organic Matter in Temperate Cities. Where necessary, reported bulk density was used to convert between Mg/ha and g/kg. Only data from samples taken from the A horizon or superficial 30 cm were used. Soil organic carbon is calculated as 50% of SOM for use in comparison to studies that do not report loss-on-ignition (SOM). Portland can be found near the center of the figure.

Figure 12. Change in Soil Organic Matter with Urbanization in Temperate Cities.
 Values are as reported in each publication, no calculation was performed.

Mean Soil Organic Carbon (%) by Biome

Figure 13. Soil Organic Matter by Biome. Where necessary, reported bulk density was used to convert between Mg/ha and g/kg. Only data from samples taken from the A horizon or superficial 30 cm were used. Soil organic carbon is calculated as 50% of SOM for use in comparison to studies that do not report loss-on-ignition (SOM). Means of reported values by biome are shown.

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Appendix A. Genera Recorded at Each Site. Unknown stems are numbered per site ID.

Site ID	EcoDistrict	Genus
D10092301	Downtown	<i>Ailanthus</i>
D10092301	Downtown	<i>Ailanthus</i>
D10092301	Downtown	<i>Acer</i>
D10092302	Downtown	<i>Taxus</i>
D10092302	Downtown	<i>Taxus</i>
D10092302	Downtown	<i>Taxus</i>
D10092302	Downtown	<i>Taxus</i>
D10092302	Downtown	<i>Taxus</i>
D10092302	Downtown	<i>Chamaecyparis</i>
D10092302	Downtown	<i>Chamaecyparis</i>
D10092303	Downtown	<i>Acer</i>
D10092303	Downtown	<i>Acer</i>
D10092303	Downtown	<i>Acer</i>
D10092304	Downtown	<i>Ginkgo</i>
D10092304	Downtown	<i>Ginkgo</i>
D10092304	Downtown	<i>Ginkgo</i>
D10092304	Downtown	Unknown 1
D10092401	Downtown	<i>Photinia</i>
D10092401	Downtown	<i>Photinia</i>
D10092401	Downtown	<i>Photinia</i>
D10092401	Downtown	<i>Photinia</i>
D10092401	Downtown	<i>Salix</i>
D10092401	Downtown	<i>Ribes</i>
D10092401	Downtown	<i>Prunus</i>
D10092401	Downtown	<i>Laurus</i>
D10092401	Downtown	<i>Salvia</i>
D10092401	Downtown	<i>Ribes</i>
D10092401	Downtown	<i>Photinia</i>
D10092401	Downtown	<i>Pinus</i>
D10092401	Downtown	<i>Pinus</i>
D10092401	Downtown	<i>Photinia</i>
D10092401	Downtown	<i>Robinia</i>
D10092401	Downtown	<i>Mahonia</i>
D10092401	Downtown	<i>Ilex</i>
D10092401	Downtown	<i>Rhododendron</i>
D10092401	Downtown	<i>Rhododendron</i>
D10092401	Downtown	<i>Ribes</i>
D10092401	Downtown	<i>Syringa</i>
D10092401	Downtown	<i>Mahonia</i>
D10092401	Downtown	<i>Vitis</i>
D10092402	Downtown	<i>Acer</i>

D10092402	Downtown	<i>Sorbus</i>
D10092402	Downtown	<i>Acer</i>
D10092403	Downtown	<i>Rosa</i>
D10092403	Downtown	<i>Rosa</i>
D10092403	Downtown	<i>Styrax</i>
D10092403	Downtown	<i>Rosa</i>
D10092403	Downtown	<i>Rosa</i>
D10092403	Downtown	<i>Quercus</i>
D10092403	Downtown	<i>Quercus</i>
D10092403	Downtown	<i>Taxus</i>
D10092404	Downtown	<i>Acer</i>
D10092404	Downtown	<i>Acer</i>
D10092404	Downtown	<i>Acer</i>
D10092404	Downtown	<i>Acer</i>
D10092404	Downtown	<i>Tilia</i>
D10093001	Downtown	<i>Acer</i>
D10093001	Downtown	<i>Cotinus</i>
D10093001	Downtown	<i>Nandina</i>
D10093001	Downtown	<i>Nandina</i>
D10093001	Downtown	<i>Taxus</i>
D10093001	Downtown	<i>Taxus</i>
D10093001	Downtown	<i>Taxus</i>
D10093001	Downtown	<i>Viburnum</i>
D10093001	Downtown	<i>Viburnum</i>
D10093001	Downtown	<i>Panicum</i>
D10093001	Downtown	<i>Panicum</i>
D10093001	Downtown	<i>Eupatorium</i>
D10093001	Downtown	<i>Acer</i>
D10093001	Downtown	<i>Perovskia</i>
D10093001	Downtown	<i>Acer</i>
D10093001	Downtown	<i>Thuja</i>
D10093001	Downtown	<i>Taxus</i>
D10093001	Downtown	<i>Nandina</i>
D10100101	Downtown	<i>Ulmus</i>
D10100101	Downtown	<i>Ulmus</i>
D10100101	Downtown	<i>Ulmus</i>
D10100101	Downtown	<i>Tilia</i>
D10100101	Downtown	<i>Tilia</i>
D10100101	Downtown	<i>Tilia</i>
D10100101	Downtown	<i>Zelkova</i>
D10100101	Downtown	<i>Ulmus</i>
D10100101	Downtown	<i>Ulmus</i>
D10100102	Downtown	Unknown 5
D10100102	Downtown	Unknown 5
D10100102	Downtown	Unknown 5

D10100102	Downtown	Unknown 5
D10100102	Downtown	Unknown 5
D10100102	Downtown	<i>Ulmus</i>
D10100102	Downtown	<i>Prunus</i>
D10100102	Downtown	<i>Ilex</i>
D10100102	Downtown	<i>Pinus</i>
D10100102	Downtown	Unknown 3
D10100102	Downtown	<i>Populus</i>
D10100102	Downtown	<i>Populus</i>
D10100102	Downtown	<i>Populus</i>
D10100102	Downtown	<i>Populus</i>
D10100102	Downtown	<i>Populus</i>
D10100102	Downtown	<i>Populus</i>
D10100102	Downtown	<i>Populus</i>
D10100102	Downtown	Unknown 4
D10100102	Downtown	Unknown 5
D10100102	Downtown	Unknown 5
D10100102	Downtown	<i>Abelia</i>
D10100102	Downtown	<i>Mahonia</i>
D10100102	Downtown	<i>Viburnum</i>
D10100102	Downtown	<i>Abelia</i>
D10100102	Downtown	<i>Abelia</i>
D10100102	Downtown	<i>Rhododendron</i>
D10100102	Downtown	<i>Abelia</i>
D10100102	Downtown	<i>Rhododendron</i>
D10100102	Downtown	<i>Rhododendron</i>
D10100102	Downtown	<i>Rhododendron</i>
D10100102	Downtown	<i>Rhododendron</i>
D10100102	Downtown	<i>Abelia</i>
D10100102	Downtown	<i>Rhododendron</i>
D10100102	Downtown	<i>Ilex</i>
D10100102	Downtown	<i>NA</i>
D10100102	Downtown	<i>Rhododendron</i>
D10100102	Downtown	<i>Rhododendron</i>
D10100102	Downtown	<i>Rhododendron</i>
D10100102	Downtown	<i>Rhododendron</i>
D10100102	Downtown	<i>Magnolia</i>
D10100102	Downtown	<i>Magnolia</i>
D10100102	Downtown	<i>Rhododendron</i>
D10100102	Downtown	<i>Rhododendron</i>
D10100201	Downtown	<i>Acer</i>
D10100201	Downtown	<i>Acer</i>
D10100201	Downtown	<i>Acer</i>
D10100201	Downtown	<i>Euonymus</i>

D10100201	Downtown	<i>Euonymous</i>
D10100201	Downtown	<i>Euonymous</i>
D10100201	Downtown	<i>Acer</i>
D10100201	Downtown	<i>Acer</i>
D10100201	Downtown	<i>Acer</i>
D10100202	Downtown	<i>Buxus</i>
D10100202	Downtown	<i>Rhododendron</i>
D10100202	Downtown	<i>Rhododendron</i>
D10100202	Downtown	<i>Pieris</i>
D10100202	Downtown	<i>Pieris</i>
D10100202	Downtown	<i>Juniperus</i>
D10100202	Downtown	<i>Buxus</i>
D10100202	Downtown	<i>Cornus</i>
D10100202	Downtown	<i>Acer</i>
D10100202	Downtown	<i>Acer</i>
D10100202	Downtown	<i>Acer</i>
D10100203	Downtown	<i>Acer</i>
D10100203	Downtown	<i>Acer</i>
D10100203	Downtown	<i>Acer</i>
D10100203	Downtown	<i>Acer</i>
D10100203	Downtown	<i>Acer</i>
D10100203	Downtown	<i>Acer</i>
D10100204	Downtown	<i>Rhododendron</i>
D10100204	Downtown	<i>Rhododendron</i>
D10100204	Downtown	<i>Berberis</i>
D10100204	Downtown	<i>Camellia</i>
D10100204	Downtown	<i>Arbutus</i>
D10100204	Downtown	<i>Arbutus</i>
D10100204	Downtown	<i>Pinus</i>
D10100204	Downtown	<i>Rhododendron</i>
D10100204	Downtown	<i>Gaultheria</i>
D10100204	Downtown	<i>Pinus</i>
D10100204	Downtown	<i>Ulmus</i>
D10100204	Downtown	<i>Ulmus</i>
D10100204	Downtown	<i>Ulmus</i>
D10100801	Downtown	<i>Camellia</i>
D10100801	Downtown	<i>Buxus</i>
D10100801	Downtown	<i>Buxus</i>
D10100801	Downtown	<i>Nandina</i>
D10100801	Downtown	<i>Buxus</i>
D10100801	Downtown	<i>Buxus</i>
D10100801	Downtown	<i>Nandina</i>
D10100801	Downtown	<i>Camellia</i>
D10100801	Downtown	<i>Rhododendron</i>
D10100801	Downtown	<i>Buxus</i>

D10100802	Downtown	<i>Zelkova</i>
D10100802	Downtown	<i>Acer</i>
D10100802	Downtown	<i>Zelkova</i>
D10100802	Downtown	<i>Zelkova</i>
D10100803	Downtown	<i>Zelkova</i>
D10100803	Downtown	<i>Zelkova</i>
D10100803	Downtown	<i>Zelkova</i>
D10100803	Downtown	<i>Acer</i>
D10100804	Downtown	<i>Arbutus</i>
D10100804	Downtown	<i>Arbutus</i>
D10100804	Downtown	<i>Arbutus</i>
D10100804	Downtown	<i>Betula</i>
D10100804	Downtown	<i>Liriodendron</i>
D10100804	Downtown	<i>Liriodendron</i>
D10100804	Downtown	<i>Acer</i>
D10100804	Downtown	<i>Acer</i>
D10100804	Downtown	<i>Acer</i>
D10100804	Downtown	<i>Photinia</i>
D10100804	Downtown	<i>Ilex</i>
D10100804	Downtown	<i>Thuja</i>
D10100804	Downtown	<i>Thuja</i>
D10100804	Downtown	<i>Thuja</i>
D10100804	Downtown	<i>Thuja</i>
D10100804	Downtown	<i>Thuja</i>
D10100804	Downtown	<i>Ilex</i>
D10100804	Downtown	<i>Ilex</i>
D10100804	Downtown	<i>Spirea</i>
D10100804	Downtown	<i>Spirea</i>
D10100804	Downtown	<i>Spirea</i>
D10100805	Downtown	<i>Tilia</i>
D10100805	Downtown	<i>Tilia</i>
D10100805	Downtown	<i>Tilia</i>
D10100805	Downtown	<i>Tilia</i>
D10100805	Downtown	<i>Tilia</i>
D10100805	Downtown	<i>Acer</i>
D10100805	Downtown	<i>Photinia</i>
D10100805	Downtown	<i>Thuja</i>
D10100805	Downtown	<i>Photinia</i>
D10100805	Downtown	<i>Thuja</i>
D10100805	Downtown	<i>Photinia</i>
D10100901	Downtown	<i>Acer</i>
D10100901	Downtown	<i>Ulmus</i>
D10100901	Downtown	<i>Ulmus</i>
D10100901	Downtown	<i>Ulmus</i>
D10100901	Downtown	<i>Ulmus</i>

D10100901	Downtown	<i>Acer</i>
D10100901	Downtown	<i>Acer</i>
D10100901	Downtown	<i>Acer</i>
D10100901	Downtown	<i>Acer</i>
D10100902	Downtown	<i>Acer</i>
D10100902	Downtown	<i>Ulmus</i>
D10100902	Downtown	<i>Ulmus</i>
D10100902	Downtown	<i>Ulmus</i>
D10100902	Downtown	<i>Leucothoe</i>
D10100902	Downtown	<i>Ulmus</i>
D10100902	Downtown	<i>Acer</i>
D10100902	Downtown	<i>Acer</i>
D10100902	Downtown	<i>Acer</i>
D10100902	Downtown	<i>Leucothoe</i>
D10100902	Downtown	<i>Leucothoe</i>
D10100902	Downtown	<i>Leucothoe</i>
D10100902	Downtown	<i>Rhododendron</i>
D10100902	Downtown	<i>Leucothoe</i>
D10100902	Downtown	<i>Leucothoe</i>
D10100902	Downtown	<i>Leucothoe</i>
D10100902	Downtown	<i>Leucothoe</i>
D10100903	Downtown	<i>Acer</i>
D10100903	Downtown	<i>Acer</i>
D10100903	Downtown	<i>Acer</i>
D10100903	Downtown	<i>Viburnum</i>
D10100903	Downtown	<i>Viburnum</i>
D10100903	Downtown	<i>Viburnum</i>
D10100903	Downtown	<i>Viburnum</i>
D10100903	Downtown	<i>Acer</i>
D10100903	Downtown	<i>Viburnum</i>
D10100903	Downtown	<i>Viburnum</i>
D10100904	Downtown	<i>Cupressus</i>
D10100904	Downtown	<i>Juniperus</i>
D10100904	Downtown	<i>Photinia</i>
D10100904	Downtown	<i>Acer</i>
D10100904	Downtown	<i>Acer</i>
D10100904	Downtown	<i>Acer</i>
D10100904	Downtown	<i>Arctostaphylos</i>
D10100904	Downtown	<i>Acer</i>
D10100904	Downtown	<i>Acer</i>
D10100904	Downtown	<i>Acer</i>
D10100904	Downtown	<i>Arctostaphylos</i>
D10100905	Downtown	<i>Betula</i>
D10100905	Downtown	<i>Betula</i>
D10100905	Downtown	<i>Zelkova</i>

D10100905	Downtown	<i>Zelkova</i>
D10101401	Downtown	<i>Ulmus</i>
D10101401	Downtown	<i>Ulmus</i>
D10101401	Downtown	<i>Ulmus</i>
D10101401	Downtown	<i>Ulmus</i>
D10101401	Downtown	<i>Ulmus</i>
D10101401	Downtown	<i>Ulmus</i>
D10101401	Downtown	<i>Ulmus</i>
D10101401	Downtown	<i>Ulmus</i>
D10101402	Downtown	<i>Acer</i>
D10101402	Downtown	<i>Acer</i>
D10101402	Downtown	<i>Acer</i>
D10101402	Downtown	<i>Acer</i>
D10101402	Downtown	<i>Acer</i>
D10101403	Downtown	<i>Pinus</i>
D10101403	Downtown	<i>Ulmus</i>
D10101403	Downtown	<i>Pinus</i>
D10101403	Downtown	<i>Ginkgo</i>
D10101403	Downtown	<i>Mahonia</i>
D10101403	Downtown	<i>Mahonia</i>
D10101404	Downtown	<i>Platanus</i>
D10101404	Downtown	<i>Platanus</i>
D10101404	Downtown	<i>Platanus</i>
D10101405	Downtown	<i>Liquidambar</i>
D10101405	Downtown	<i>Liquidambar</i>
D10101405	Downtown	<i>Liquidambar</i>
D10101501	Downtown	<i>Ulmus</i>
D10101501	Downtown	<i>Tilia</i>
D10101501	Downtown	<i>Tilia</i>
D10101501	Downtown	<i>Ulmus</i>
D10101501	Downtown	<i>Rhododendron</i>
D10101501	Downtown	<i>Rhododendron</i>
D10101501	Downtown	<i>Rhododendron</i>
D10101501	Downtown	<i>Rhododendron</i>
D10101501	Downtown	<i>Acer</i>
D10101501	Downtown	<i>Rhododendron</i>
D10101501	Downtown	<i>Nandina</i>
D10101501	Downtown	<i>Nandina</i>
D10101501	Downtown	<i>Rhododendron</i>
D10101501	Downtown	<i>Rhododendron</i>
D10101501	Downtown	<i>Cotoneaster</i>
D10101501	Downtown	<i>Rhododendron</i>
D10101501	Downtown	<i>Cotoneaster</i>
D10101501	Downtown	<i>Ilex</i>
D10101501	Downtown	<i>Rhododendron</i>

D10101501	Downtown	<i>Nandina</i>
D10101501	Downtown	<i>Abelia</i>
D10101501	Downtown	<i>Pieris</i>
D10101502	Downtown	<i>Acer</i>
D10101503	Downtown	<i>Acer</i>
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D10101503	Downtown	<i>Pyrus</i>
D10101503	Downtown	<i>Pyrus</i>
D10101503	Downtown	<i>Thuja</i>
D10101503	Downtown	<i>Pyrus</i>
D10101503	Downtown	<i>Photinia</i>
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D10101503	Downtown	<i>Pyrus</i>
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D10101504	Downtown	<i>Acer</i>
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D10101504	Downtown	<i>Pinus</i>
D10101504	Downtown	<i>Pinus</i>
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D10101504	Downtown	<i>Ribes</i>
D10101504	Downtown	<i>Rhododendron</i>
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D10102101	Downtown	<i>Ilex</i>
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D10102101	Downtown	<i>Prunus</i>
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D10102202	Downtown	<i>Spirea</i>
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D10102202	Downtown	<i>Nandina</i>
D10102202	Downtown	<i>Nandina</i>
D10102203	Downtown	Unknown 1
D10102203	Downtown	Unknown 1
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D10102203	Downtown	<i>Quercus</i>
D10102203	Downtown	<i>Quercus</i>
D10102203	Downtown	<i>Quercus</i>
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D10102203	Downtown	<i>Acer</i>
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D10102203	Downtown	Unknown 2
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D10102203	Downtown	<i>Euonymus</i>

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D10102203	Downtown	<i>Berberis</i>
D10102203	Downtown	<i>Berberis</i>
D10102203	Downtown	<i>Prunus</i>
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D10102204	Downtown	<i>Photinia</i>
D10102204	Downtown	<i>Photinia</i>
D10102204	Downtown	<i>Abelia</i>
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D10102204	Downtown	<i>Abelia</i>
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D10102207	Downtown	<i>Robinia</i>
D10102207	Downtown	<i>Robinia</i>
D10102207	Downtown	<i>Calocedrus</i>
D10102207	Downtown	<i>Erica</i>

D10102207	Downtown	<i>Spirea</i>
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D10102207	Downtown	<i>Mahonia</i>
D10102207	Downtown	<i>Calocedrus</i>
G10082601	Gateway	<i>Pseudotsuga</i>
G10082601	Gateway	<i>Pseudotsuga</i>
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G10082601	Gateway	<i>Pseudotsuga</i>
G10082601	Gateway	<i>Pinus</i>
G10082601	Gateway	<i>Quercus</i>
G10082601	Gateway	<i>Acer</i>
G10082601	Gateway	<i>Acer</i>
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G10082601	Gateway	<i>Acer</i>
G10082601	Gateway	<i>Cornus</i>
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G10082602	Gateway	<i>Acer</i>
G10082602	Gateway	<i>Acer</i>
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G10082602	Gateway	<i>Pseudotsuga</i>
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G10082701	Gateway	<i>Quercus</i>
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G10082704	Gateway	<i>Ilex</i>
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G10083003	Gateway	<i>Thuja</i>
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G10083003	Gateway	<i>Pinus</i>
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G10083101	Gateway	<i>Daphne</i>
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G10090202	Gateway	<i>Fraxinus</i>
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G10090202	Gateway	<i>Thuja</i>
G10090202	Gateway	<i>Cornus</i>
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G10090602	Gateway	<i>Potentilla</i>
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L10090701	Lents	<i>Rhododendron</i>
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L10090701	Lents	<i>Pinus</i>
L10090701	Lents	<i>Pinus</i>
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L10090701	Lents	Unknown 2
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L10090701	Lents	<i>Cedrus</i>
L10090701	Lents	<i>Pinus</i>
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L10090702	Lents	<i>Acer</i>
L10090702	Lents	<i>Myrica</i>
L10090702	Lents	Unknown 1
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L10090702	Lents	<i>Abelia</i>
L10090702	Lents	<i>Abelia</i>
L10090702	Lents	<i>Abelia</i>
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L10090702	Lents	<i>Abelia</i>

L10090901	Lents	<i>Rosa</i>
L10090901	Lents	<i>Symphoricarpos</i>
L10090901	Lents	<i>Spirea</i>
L10090901	Lents	<i>Symphoricarpos</i>
L10090901	Lents	<i>Symphoricarpos</i>
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L10090901	Lents	<i>Cupressus</i>
L10090901	Lents	<i>Picea</i>
L10090901	Lents	<i>Rosa</i>
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L10090901	Lents	<i>Rosa</i>
L10090901	Lents	<i>Rosa</i>
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L10090902	Lents	<i>Pseudotsuga</i>
L10090902	Lents	<i>Pinus</i>
L10090902	Lents	<i>Juniperus</i>
L10090902	Lents	<i>Acer</i>
L10090902	Lents	<i>Prunus</i>
L10090902	Lents	<i>Abelia</i>
L10090903	Lents	<i>Sorbus</i>
L10090903	Lents	<i>Acer</i>
L10090903	Lents	<i>Pseudotsuga</i>
L10090903	Lents	<i>Pseudotsuga</i>
L10090903	Lents	<i>Pseudotsuga</i>
L10090903	Lents	<i>Prunus</i>
L10090903	Lents	<i>Prunus</i>
L10090903	Lents	<i>Prunus</i>
L10090903	Lents	<i>Prunus</i>
L10090903	Lents	<i>Prunus</i>

L10090903	Lents	<i>Prunus</i>
L10090903	Lents	<i>Pseudotsuga</i>
L10090903	Lents	<i>Agave</i>
L10090904	Lents	<i>Larix</i>
L10090904	Lents	<i>Pinus</i>
L10090904	Lents	<i>Acer</i>
L10090904	Lents	<i>Acer</i>
L10090904	Lents	<i>Acer</i>
L10090904	Lents	<i>Pinus</i>
L10090904	Lents	<i>Pinus</i>
L10090904	Lents	<i>Acer</i>
L10090904	Lents	<i>Pinus</i>
L10090904	Lents	<i>Acer</i>
L10090904	Lents	<i>Cotoneaster</i>
L10090904	Lents	<i>Acer</i>
L10090904	Lents	<i>Cotoneaster</i>
L10090904	Lents	<i>Pinus</i>
L10090904	Lents	<i>Pinus</i>
L10090904	Lents	<i>Salix</i>
L10090904	Lents	<i>Pyrus</i>
L10090904	Lents	<i>Cotoneaster</i>
L10090904	Lents	<i>Berberis</i>
L10090904	Lents	<i>Berberis</i>
L10090904	Lents	<i>Berberis</i>
L10090904	Lents	<i>Berberis</i>
L10090904	Lents	<i>Acer</i>
L10090904	Lents	<i>Pinus</i>
L10090904	Lents	<i>Pinus</i>
L10090904	Lents	<i>Jasminum</i>
L10091001	Lents	<i>Catalpa</i>
L10091001	Lents	<i>Acer</i>
L10091001	Lents	<i>Ulmus</i>
L10091001	Lents	<i>Ligustrum</i>
L10091001	Lents	<i>Ligustrum</i>
L10091001	Lents	<i>Ligustrum</i>
L10091001	Lents	<i>Ligustrum</i>
L10091001	Lents	<i>Ligustrum</i>
L10091001	Lents	<i>Ligustrum</i>
L10091001	Lents	<i>Acer</i>
L10091001	Lents	<i>Prunus</i>
L10091001	Lents	<i>Prunus</i>
L10091001	Lents	<i>Prunus</i>
L10091001	Lents	<i>Syringa</i>
L10091001	Lents	<i>Hydrangea</i>

L10091001	Lents	<i>Hydrangea</i>
L10091001	Lents	<i>Nandina</i>
L10091001	Lents	<i>Nandina</i>
L10091001	Lents	<i>Nandina</i>
L10091001	Lents	<i>Nandina</i>
L10091001	Lents	<i>Spirea</i>
L10091301	Lents	<i>Acer</i>
L10091301	Lents	<i>Acer</i>
L10091301	Lents	<i>Acer</i>
L10091301	Lents	<i>Acer</i>
L10091301	Lents	<i>Pseudotsuga</i>
L10091301	Lents	<i>Acer</i>
L10091301	Lents	<i>Pyrus</i>
L10091301	Lents	<i>Juniperus</i>
L10091301	Lents	<i>Acer</i>
L10091301	Lents	<i>Prunus</i>
L10091301	Lents	<i>Berberis</i>
L10091301	Lents	<i>Berberis</i>
L10091301	Lents	<i>Taxus</i>
L10091301	Lents	<i>Sciadopitys</i>
L10091301	Lents	<i>Acer</i>
L10091301	Lents	<i>Picea</i>
L10091301	Lents	<i>Picea</i>
L10091301	Lents	<i>Prunus</i>
L10091301	Lents	<i>Prunus</i>
L10091301	Lents	<i>Prunus</i>
L10091301	Lents	<i>Prunus</i>
L10091301	Lents	<i>Prunus</i>
L10091301	Lents	<i>Acer</i>
L10091301	Lents	<i>Fraxinus</i>
L10091301	Lents	<i>Acer</i>
L10091301	Lents	<i>Thuja</i>
L10091301	Lents	<i>Acer</i>
L10091301	Lents	<i>Juniperus</i>
L10091301	Lents	<i>Juniperus</i>
L10091302	Lents	<i>Malus</i>
L10091302	Lents	<i>Acer</i>
L10091302	Lents	<i>Cornus</i>
L10091302	Lents	<i>Malus</i>
L10091302	Lents	<i>Pyrus</i>
L10091302	Lents	<i>Abies</i>
L10091302	Lents	<i>Camellia</i>
L10091302	Lents	<i>Camellia</i>
L10091302	Lents	<i>Rosa</i>
L10091302	Lents	<i>Rosa</i>
L10091302	Lents	<i>Rhododendron</i>

L10091302	Lents	<i>Thuja</i>
L10091302	Lents	<i>Thuja</i>
L10091302	Lents	<i>Thuja</i>
L10091302	Lents	<i>Hydrangea</i>
L10091302	Lents	<i>Rosa</i>
L10091302	Lents	<i>Rosa</i>
L10091302	Lents	<i>Rosa</i>
L10091302	Lents	<i>Buxus</i>
L10091302	Lents	<i>Hibiscus</i>
L10091302	Lents	<i>Thuja</i>
L10091302	Lents	<i>Chamaecyparis</i>
L10091302	Lents	<i>Chamaecyparis</i>
L10091302	Lents	<i>Chamaecyparis</i>
L10091302	Lents	<i>Pinus</i>
L10091302	Lents	<i>Pinus</i>
L10091302	Lents	<i>Taxus</i>
L10091302	Lents	<i>Euonymous</i>
L10091302	Lents	<i>Rosa</i>
L10091302	Lents	<i>Rosa</i>
L10091302	Lents	<i>Rosa</i>
L10091302	Lents	<i>Acer</i>
L10091302	Lents	<i>Rosa</i>
L10091302	Lents	<i>Rosa</i>
L10091302	Lents	<i>Rhododendron</i>
L10091302	Lents	<i>Rosa</i>
L10091302	Lents	<i>Crataegus</i>
L10091302	Lents	<i>Rosa</i>
L10091302	Lents	<i>Rosa</i>
L10091303	Lents	<i>Prunus</i>
L10091303	Lents	<i>Prunus</i>
L10091303	Lents	<i>Prunus</i>
L10091303	Lents	<i>Pyrus</i>
L10091303	Lents	<i>Pyrus</i>
L10091303	Lents	<i>Thuja</i>
L10091303	Lents	<i>Rosmarinus</i>
L10091303	Lents	<i>Rosmarinus</i>
L10091303	Lents	<i>Hibiscus</i>
L10091303	Lents	<i>Acer</i>
L10091303	Lents	<i>Syringa</i>
L10091303	Lents	<i>Lavandula</i>
L10091303	Lents	<i>Euphorbia</i>
L10091303	Lents	<i>Salvia</i>
L10091303	Lents	<i>Rosa</i>
L10091303	Lents	<i>Rosa</i>
L10091303	Lents	<i>Rosa</i>

L10091303	Lents	<i>Vaccinium</i>
L10091303	Lents	<i>Rosa</i>
L10091303	Lents	<i>Hibiscus</i>
L10091303	Lents	<i>Rosa</i>
L10091303	Lents	<i>Rosmarinus</i>
L10091303	Lents	<i>Rosa</i>
L10091303	Lents	<i>Hibiscus</i>
L10091303	Lents	<i>Salvia</i>
L10091303	Lents	<i>Rosmarinus</i>
L10091303	Lents	<i>Lavandula</i>
L10091303	Lents	<i>Buxus</i>
L10091303	Lents	<i>Salvia</i>
L10091303	Lents	<i>Loropetalum</i>
L10091303	Lents	<i>Vaccinium</i>
L10091303	Lents	<i>Loropetalum</i>
L10091303	Lents	<i>Lavandula</i>
L10091303	Lents	<i>Forsythia</i>
L10091303	Lents	<i>Pseudotsuga</i>
L10091303	Lents	<i>Pinus</i>
L10091303	Lents	<i>Pinus</i>
L10091303	Lents	<i>Thuja</i>
L10091303	Lents	<i>Thuja</i>
L10091303	Lents	<i>Thuja</i>
L10091303	Lents	<i>Juglans</i>
L10091303	Lents	<i>Prunus</i>
L10091303	Lents	<i>Prunus</i>
L10091303	Lents	<i>Rosmarinus</i>
L10091303	Lents	<i>Salvia</i>
L10091401	Lents	<i>Quercus</i>
L10091401	Lents	<i>Abies</i>
L10091401	Lents	<i>Betula</i>
L10091401	Lents	<i>Betula</i>
L10091401	Lents	<i>Thuja</i>
L10091401	Lents	<i>Calocedrus</i>
L10091401	Lents	<i>Calocedrus</i>
L10091401	Lents	<i>Tilia</i>
L10091401	Lents	<i>Liriodendron</i>
L10091401	Lents	<i>Viburnum</i>
L10091401	Lents	<i>Viburnum</i>
L10091401	Lents	<i>Viburnum</i>
L10091401	Lents	<i>Arbutus</i>
L10091401	Lents	<i>Mahonia</i>
L10091401	Lents	<i>Mahonia</i>
L10091401	Lents	<i>Abelia</i>
L10091401	Lents	<i>Arbutus</i>

L10091402	Lents	<i>Sorbus</i>
L10091402	Lents	<i>Larix</i>
L10091402	Lents	<i>Ilex</i>
L10091402	Lents	<i>Ilex</i>
L10091402	Lents	<i>Ilex</i>
L10091402	Lents	<i>Weigela</i>
L10091402	Lents	<i>Spirea</i>
L10091402	Lents	<i>Forsythia</i>
L10091402	Lents	<i>Rosa</i>
L10091402	Lents	<i>Viburnum</i>
L10091402	Lents	<i>Syringa</i>
L10091402	Lents	<i>Thuja</i>
L10091402	Lents	<i>Ilex</i>
L10091402	Lents	<i>Spirea</i>
L10091402	Lents	<i>Acer</i>
L10091402	Lents	<i>Chamaecyparis</i>
L10091402	Lents	<i>Pinus</i>
L10091402	Lents	<i>Rosa</i>
L10091402	Lents	<i>Thuja</i>
L10091402	Lents	<i>Viburnum</i>
L10091402	Lents	<i>Cornus</i>
L10091402	Lents	<i>Syringa</i>
L10091402	Lents	<i>Pinus</i>
L10091402	Lents	<i>Mahonia</i>
L10091402	Lents	<i>Mahonia</i>
L10091402	Lents	<i>Pieris</i>
L10091402	Lents	<i>Spirea</i>
L10091402	Lents	<i>Cornus</i>
L10091402	Lents	<i>Cornus</i>
L10091402	Lents	<i>Sorbus</i>
L10091402	Lents	<i>Chamaecyparis</i>
L10091402	Lents	<i>Spirea</i>
L10091402	Lents	<i>Mahonia</i>
L10091402	Lents	<i>Ilex</i>
L10091402	Lents	<i>Magnolia</i>
L10091402	Lents	<i>Forsythia</i>
L10091402	Lents	<i>Cornus</i>
L10091402	Lents	<i>Mahonia</i>
L10091402	Lents	<i>Spirea</i>
L10091402	Lents	<i>Picea</i>
L10091402	Lents	<i>Vaccinium</i>
L10091402	Lents	<i>Vaccinium</i>
L10091402	Lents	<i>Mahonia</i>
L10091402	Lents	<i>Cotoneaster</i>
L10091402	Lents	<i>Mahonia</i>

L10091402	Lents	<i>Thuja</i>
L10091402	Lents	<i>Sarcococca</i>
L10091402	Lents	<i>Cornus</i>
L10091402	Lents	<i>Ilex</i>
L10091403	Lents	<i>Sorbus</i>
L10091403	Lents	<i>Abelia</i>
L10091403	Lents	<i>Juniperus</i>
L10091403	Lents	<i>Thuja</i>
L10091403	Lents	<i>Thuja</i>
L10091403	Lents	<i>Thuja</i>
L10091404	Lents	<i>Cotoneaster</i>
L10091404	Lents	<i>Rosa</i>
L10091404	Lents	<i>Tilia</i>
L10091404	Lents	<i>Tilia</i>
L10091404	Lents	<i>Tilia</i>
L10091404	Lents	<i>Cotoneaster</i>
L10091404	Lents	<i>Ilex</i>
L10091404	Lents	<i>Ilex</i>
L10091404	Lents	<i>Ilex</i>
L10091404	Lents	<i>Ilex</i>
L10091404	Lents	<i>Ilex</i>
L10091404	Lents	<i>Ilex</i>
L10091404	Lents	<i>Ilex</i>
L10091404	Lents	<i>Ilex</i>
L10091404	Lents	<i>Acer</i>
L10091404	Lents	<i>Juglans</i>
L10091404	Lents	<i>Acer</i>
L10091404	Lents	<i>Acer</i>
L10091404	Lents	<i>Acer</i>
L10091404	Lents	<i>Acer</i>
L10091701	Lents	<i>Tilia</i>
L10091701	Lents	<i>Tilia</i>
L10091701	Lents	<i>Tilia</i>
L10091701	Lents	<i>Tilia</i>
L10091701	Lents	<i>Cotoneaster</i>
L10091702	Lents	<i>Acer</i>
L10091702	Lents	<i>Acer</i>
L10091702	Lents	<i>Prunus</i>
L10091702	Lents	<i>Prunus</i>
L10091702	Lents	<i>Vaccinium</i>
L10091702	Lents	<i>Thuja</i>
L10091702	Lents	<i>Malus</i>
L10091702	Lents	<i>Prunus</i>
L10091702	Lents	<i>Prunus</i>

L10091702	Lents	<i>Sorbus</i>
L10091702	Lents	<i>Abies</i>
L10091702	Lents	<i>Pinus</i>
L10091702	Lents	<i>Pseudotsuga</i>
L10091702	Lents	<i>Prunus</i>
L10091702	Lents	<i>Prunus</i>
L10091702	Lents	<i>Prunus</i>
L10091702	Lents	<i>Rhododendron</i>
L10091702	Lents	<i>Symphoricarpos</i>
L10091702	Lents	<i>Rosa</i>
L10091702	Lents	<i>Rosa</i>
L10091702	Lents	<i>Vaccinium</i>
L10091702	Lents	<i>Juglans</i>
L10091703	Lents	<i>Crataegus</i>
L10091703	Lents	<i>Cornus</i>
L10091703	Lents	<i>Rhododendron</i>
L10091703	Lents	<i>Rhododendron</i>
L10091703	Lents	<i>Rhododendron</i>
L10091703	Lents	<i>Ilex</i>
L10091703	Lents	<i>Camellia</i>
L10091703	Lents	<i>Hydrangea</i>
L10091703	Lents	<i>Vaccinium</i>
L10091703	Lents	<i>Hydrangea</i>
L10091703	Lents	<i>Vaccinium</i>
L10091703	Lents	<i>Vaccinium</i>
L10091703	Lents	<i>Pinus</i>
L10091703	Lents	<i>Pinus</i>
L10091703	Lents	<i>Magnolia</i>
L10091703	Lents	<i>Rhododendron</i>
L10091703	Lents	<i>Rhododendron</i>
L10091703	Lents	<i>Rhododendron</i>
L10091703	Lents	<i>Abelia</i>
L10091703	Lents	<i>Abelia</i>
L10091704	Lents	<i>Prunus</i>
L10091704	Lents	<i>Magnolia</i>
L10091704	Lents	<i>Rhododendron</i>
L10091704	Lents	<i>Rhododendron</i>
L10091704	Lents	<i>Rosa</i>
L10091704	Lents	<i>Paeonia</i>
L10091704	Lents	<i>Prunus</i>
L10091704	Lents	<i>Juglans</i>
L10091704	Lents	<i>Catalpa</i>
L10091704	Lents	<i>Abelia</i>
L10091704	Lents	<i>Prunus</i>
L10091704	Lents	<i>Ulmus</i>

L10091704	Lents	<i>Rosa</i>
L10091704	Lents	<i>Rosa</i>
L10091704	Lents	<i>Rosa</i>
L10091704	Lents	<i>Rosa</i>
L10091704	Lents	<i>Ulmus</i>
L10091704	Lents	<i>Acer</i>
L10091704	Lents	<i>Acer</i>
L10091704	Lents	<i>Prunus</i>
L10091704	Lents	<i>Prunus</i>
L10091705	Lents	<i>Photinia</i>
L10091705	Lents	<i>Rhododendron</i>
L10091705	Lents	<i>Rhododendron</i>
L10091705	Lents	<i>Rhododendron</i>
L10091705	Lents	<i>Camellia</i>
L10091705	Lents	<i>Taxus</i>
L10091705	Lents	<i>Ilex</i>
L10091705	Lents	<i>Prunus</i>
L10091705	Lents	<i>Rhododendron</i>
L10092001	Lents	<i>Malus</i>
L10092001	Lents	<i>Malus</i>
L10092001	Lents	<i>Acer</i>
L10092001	Lents	<i>Rhododendron</i>
L10092001	Lents	<i>Rosa</i>
L10092001	Lents	<i>Rosa</i>
L10092001	Lents	<i>Syringa</i>
L10092001	Lents	<i>Lavandula</i>
L10092001	Lents	<i>Syringa</i>
L10092001	Lents	<i>Cornus</i>
L10092001	Lents	<i>Rosa</i>
L10092001	Lents	<i>Ilex</i>
L10092001	Lents	<i>Syringa</i>
L10092001	Lents	<i>Syringa</i>
L10092001	Lents	<i>Acer</i>
L10092001	Lents	<i>Acer</i>
L10092001	Lents	<i>Buddleja</i>
L10092001	Lents	<i>Populus</i>
L10092001	Lents	<i>Rhododendron</i>
L10092001	Lents	<i>Acer</i>
L10092001	Lents	<i>Acer</i>
L10092001	Lents	<i>Thuja</i>
L10092001	Lents	<i>Rosa</i>
L10092001	Lents	<i>Acer</i>
L10092001	Lents	<i>Juniperus</i>
L10092001	Lents	<i>Picea</i>
L10092001	Lents	<i>Picea</i>

L10092001	Lents	<i>Pseudotsuga</i>
L10092001	Lents	<i>Malus</i>
L10092001	Lents	<i>Malus</i>
L10092001	Lents	Unknown 3
L10092002	Lents	<i>Paeonia</i>
L10092002	Lents	<i>Rosa</i>
L10092002	Lents	<i>Paeonia</i>
L10092002	Lents	<i>Acer</i>
L10092002	Lents	<i>Rosa</i>
L10092002	Lents	<i>Rosa</i>
L10092002	Lents	<i>Rosa</i>
L10092002	Lents	<i>Rosa</i>
L10092002	Lents	<i>Hydrangea</i>
L10092002	Lents	<i>Acuba</i>
L10092002	Lents	<i>Paeonia</i>
L10092002	Lents	<i>Prunus</i>
L10092002	Lents	<i>Prunus</i>
L10092002	Lents	<i>Prunus</i>
L10092002	Lents	<i>Prunus</i>
L10092002	Lents	<i>Prunus</i>
L10092002	Lents	<i>Prunus</i>
L10092002	Lents	<i>Thuja</i>
L10092002	Lents	<i>Nandina</i>
L10092002	Lents	<i>Cupressus</i>
L10092002	Lents	<i>Thuja</i>
L10092002	Lents	<i>Cupressus</i>
L10092002	Lents	<i>Paeonia</i>
L10092002	Lents	<i>Buxus</i>
L10092002	Lents	<i>Paeonia</i>
L10092002	Lents	Unknown 3
L10092002	Lents	<i>Hydrangea</i>
L10092002	Lents	<i>Hydrangea</i>
L10092002	Lents	<i>Thuja</i>
L10092002	Lents	<i>Fuschia</i>
L10092002	Lents	<i>Hydrangea</i>
L10092002	Lents	<i>Cornus</i>
L10092002	Lents	<i>Acer</i>
L10092002	Lents	<i>Rhododendron</i>
L10092002	Lents	<i>Nandina</i>
L10092002	Lents	<i>Rhododendron</i>
L10092002	Lents	<i>Nandina</i>
L10092002	Lents	<i>Acer</i>
L10092002	Lents	<i>Euonymous</i>
L10092002	Lents	<i>Pseudotsuga</i>
L10092002	Lents	<i>Nandina</i>

L10092002	Lents	<i>Juniperus</i>
L10092002	Lents	<i>Picea</i>
L10092002	Lents	<i>Cornus</i>
L10092002	Lents	<i>Rhododendron</i>
L10092002	Lents	<i>Thuja</i>
L10092201	Lents	<i>Acer</i>
L10092201	Lents	<i>Pieris</i>
L10092201	Lents	<i>Pieris</i>
L10092201	Lents	<i>Acer</i>
L10092201	Lents	<i>Paeonia</i>
L10092201	Lents	<i>Prunus</i>
L10092201	Lents	<i>Acer</i>
L10092201	Lents	<i>Prunus</i>
L10092201	Lents	<i>Prunus</i>
L10092201	Lents	<i>Aralia</i>
L10092201	Lents	<i>Aralia</i>
L10092201	Lents	<i>Corylus</i>
L10092201	Lents	<i>Aralia</i>
L10092201	Lents	<i>Spirea</i>
L10092201	Lents	<i>Prunus</i>
L10092202	Lents	<i>Pseudotsuga</i>
L10092202	Lents	<i>Picea</i>
L10092202	Lents	<i>Buxus</i>
L10092202	Lents	<i>Thuja</i>
L10092202	Lents	<i>Acer</i>
L10092202	Lents	<i>Acer</i>
L10092202	Lents	<i>Spirea</i>
L10092202	Lents	<i>Rosa</i>
L10092202	Lents	<i>Rosa</i>
L10092202	Lents	<i>Rosa</i>
L10092202	Lents	<i>Hydrangea</i>
L10092202	Lents	<i>Juniperus</i>
L10092202	Lents	<i>Juglans</i>
L10092202	Lents	<i>Ailanthus</i>
L10092202	Lents	<i>Rhododendron</i>
L10092203	Lents	<i>Ailanthus</i>
L10092203	Lents	<i>Camellia</i>
L10092203	Lents	<i>Vitis</i>
L10092203	Lents	<i>Vitis</i>
L10092203	Lents	<i>Castanea</i>
L10092203	Lents	<i>Rosa</i>
L10092203	Lents	<i>Yucca</i>
L10092203	Lents	<i>Euphorbia</i>
L10092203	Lents	<i>Betula</i>
L10092203	Lents	<i>Calocedrus</i>

L10092203	Lents	<i>Rosa</i>
L10092203	Lents	<i>Rosa</i>
L10092203	Lents	<i>Rosa</i>
L10092203	Lents	<i>Rosa</i>
L10092203	Lents	<i>Rosa</i>
L10092203	Lents	<i>Rosa</i>
L10092203	Lents	<i>Rosmarinus</i>
L10092203	Lents	<i>Syringa</i>
L10092204	Lents	<i>Acer</i>
L10092204	Lents	<i>Quercus</i>
L10092204	Lents	<i>Quercus</i>
L10092204	Lents	<i>Quercus</i>
L10092204	Lents	<i>Acer</i>
L10092205	Lents	<i>Cydonia</i>
L10092205	Lents	<i>Quercus</i>
L10092205	Lents	<i>Acer</i>
L10092205	Lents	<i>Quercus</i>
L10092206	Lents	<i>Acer</i>
L10092206	Lents	<i>Rhododendron</i>
L10092206	Lents	<i>Camellia</i>
L10092206	Lents	<i>Syringa</i>
L10092206	Lents	Unknown 1
L10092206	Lents	Unknown 1
L10092206	Lents	<i>Acer</i>
L10112601	Lents	<i>Pyrus</i>
L10112601	Lents	<i>Acer</i>
L10112601	Lents	<i>Pyrus</i>
L10112601	Lents	<i>Pyrus</i>
L10112601	Lents	<i>Prunus</i>
L10112601	Lents	<i>Pseudotsuga</i>
L10112601	Lents	<i>Thuja</i>
L10112601	Lents	<i>Cupressus</i>
L10112601	Lents	Unknown 2
L10112601	Lents	<i>Putus</i>
L10112601	Lents	<i>Cupressus</i>
L10112601	Lents	<i>Rhododendron</i>
L10112601	Lents	<i>Rhododendron</i>
L10112601	Lents	<i>Rhododendron</i>
L10112601	Lents	<i>Rhododendron</i>
L10112601	Lents	<i>Weigela</i>
L10112601	Lents	<i>Rosa</i>
L10112601	Lents	<i>Lagerstromia</i>
L10112601	Lents	<i>Rosa</i>
L10112601	Lents	<i>Juniperus</i>
L10112601	Lents	<i>Juniperus</i>

L10112601	Lents	<i>Rhododendron</i>
L10112601	Lents	<i>Mahonia</i>
L10112601	Lents	<i>Spirea</i>
L10112601	Lents	<i>Nandina</i>
L10112601	Lents	<i>Rhododendron</i>
L10112601	Lents	<i>Rhododendron</i>
L10112601	Lents	<i>Mahonia</i>
L10112601	Lents	<i>Nandina</i>
L10112601	Lents	<i>Nandina</i>
L10112601	Lents	<i>Mahonia</i>
L10112601	Lents	<i>Rosa</i>
L10112601	Lents	<i>Rhododendron</i>
L10112601	Lents	<i>Rhododendron</i>
L10112601	Lents	<i>Mahonia</i>
L10112601	Lents	<i>Rosa</i>
L10112601	Lents	<i>Mahonia</i>
L10112601	Lents	<i>Buxus</i>
L10112602	Lents	<i>Pyrus</i>
L10112602	Lents	<i>Pyrus</i>
L10112602	Lents	<i>Malus</i>
L10112602	Lents	<i>Abies</i>
L10112602	Lents	<i>Juniperus</i>
L10112602	Lents	<i>Abies</i>
L10112602	Lents	<i>Acer</i>
L10112602	Lents	<i>Pinus</i>
L10112602	Lents	<i>Abies</i>
L10112602	Lents	<i>Pinus</i>
L10112602	Lents	<i>Pyrus</i>
L10112602	Lents	<i>Pyrus</i>
L10112602	Lents	<i>Rosa</i>
L10112602	Lents	<i>Rosa</i>
L10112602	Lents	<i>Rosa</i>
L10112602	Lents	<i>Rosa</i>
L10112602	Lents	<i>Rosa</i>
L10112602	Lents	<i>Rosa</i>
L10112602	Lents	<i>Camellia</i>
L10112602	Lents	<i>Nandina</i>
L10112602	Lents	Unknown 1
L10112602	Lents	Unknown 1
L10112602	Lents	<i>Buddleja</i>
L10112602	Lents	Unknown 3
L10112603	Lents	<i>Pyrus</i>
L10112603	Lents	<i>Pyrus</i>
L10112603	Lents	<i>Malus</i>
L10112603	Lents	<i>Abies</i>

L10112603	Lents	<i>Pyrus</i>
L10112603	Lents	<i>Pyrus</i>
L10112603	Lents	<i>Rosmarinus</i>
L10112603	Lents	<i>Rosa</i>
L10112603	Lents	<i>Pyracantha</i>
L10112603	Lents	<i>Juniperus</i>
L10112603	Lents	<i>Rosa</i>
L10112603	Lents	Unknown 2
L10112603	Lents	<i>Rosa</i>
L10112603	Lents	<i>Rosa</i>
L10112604	Lents	<i>Acer</i>
L10112604	Lents	<i>Cornus</i>
L10112604	Lents	<i>Pinus</i>
L10112604	Lents	<i>Abies</i>
L10112604	Lents	<i>Acer</i>
L10112604	Lents	<i>Rosa</i>
L10112604	Lents	<i>Thuja</i>
L10112604	Lents	<i>Hydrangea</i>
L10112604	Lents	<i>Hydrangea</i>
L10112604	Lents	<i>Viburnum</i>
L10112604	Lents	<i>Wisteria</i>
L10112604	Lents	<i>Rosa</i>
L10112605	Lents	<i>Acer</i>
L10112605	Lents	<i>Crataegus</i>
L10112605	Lents	<i>Crataegus</i>
L10112605	Lents	<i>Ilex</i>
L10112605	Lents	<i>Cornus</i>
L10112605	Lents	<i>Pinus</i>
L10112605	Lents	<i>Thuja</i>
L10112605	Lents	<i>Acer</i>
L10112605	Lents	<i>Rosa</i>
L10112605	Lents	<i>Rosa</i>
L10112605	Lents	<i>Thuja</i>
L10112605	Lents	<i>Hydrangea</i>
L10112605	Lents	<i>Hydrangea</i>
L10112605	Lents	<i>Viburnum</i>
L10112605	Lents	<i>Wisteria</i>
L10112606	Lents	<i>Prunus</i>
L10112606	Lents	<i>Prunus</i>
L10112606	Lents	<i>Prunus</i>
L10112606	Lents	<i>Malus</i>
L10112606	Lents	<i>Prunus</i>
L10112606	Lents	<i>Prunus</i>
L10112606	Lents	<i>Calocedrus</i>
L10112606	Lents	<i>Juniperus</i>

L10112606	Lents	<i>Rosa</i>
L10112606	Lents	<i>Juniperus</i>
L10112606	Lents	<i>Rhododendron</i>
L10112606	Lents	<i>Rhododendron</i>
L10112606	Lents	<i>Lavandula</i>
L10112606	Lents	<i>Viburnum</i>
L10112606	Lents	<i>Viburnum</i>
L10112606	Lents	<i>Buxus</i>
L10112606	Lents	<i>Thuja</i>
L10112606	Lents	<i>Buxus</i>
L10112606	Lents	<i>Buxus</i>
L10112606	Lents	<i>Juglans</i>
L10112701	Lents	<i>Larix</i>
L10112701	Lents	<i>Thuja</i>
L10112701	Lents	<i>Syringa</i>
L10112701	Lents	<i>Acer</i>
L10112701	Lents	<i>Juglans</i>
L10112701	Lents	<i>Cotinus</i>
L10112701	Lents	<i>Pieris</i>
L10112701	Lents	<i>Rosa</i>
L10112701	Lents	<i>Syringa</i>
L10112701	Lents	<i>Berberis</i>
L10112701	Lents	Unknown 1
L10112701	Lents	<i>Quercus</i>
L10112701	Lents	<i>Rosa</i>
L10112701	Lents	<i>Rosa</i>
L10112701	Lents	<i>Syringa</i>
L10112701	Lents	<i>Arbutus</i>
L10112702	Lents	<i>Picea</i>
L10112702	Lents	<i>Cupressus</i>
L10112702	Lents	<i>Buxus</i>
L10112702	Lents	Unknown 1
L10112702	Lents	<i>Buxus</i>
L10112702	Lents	<i>Ilex</i>
L10112702	Lents	<i>Rosa</i>
L10112702	Lents	Unknown 2
L10112702	Lents	Unknown 3
L10112702	Lents	<i>Buxus</i>
L10112703	Lents	<i>Carpinus</i>
L10112703	Lents	<i>Carpinus</i>
L10112703	Lents	<i>Castanea</i>
L10112703	Lents	<i>Cornus</i>
L10112703	Lents	<i>Thuja</i>
L10112703	Lents	<i>Thuja</i>
L10112703	Lents	<i>Prunus</i>

L10112704	Lents	<i>Betula</i>
L10112704	Lents	<i>Betula</i>
L10112704	Lents	<i>Betula</i>
L10112704	Lents	<i>Betula</i>
L10112704	Lents	<i>Betula</i>
L10112704	Lents	<i>Betula</i>
L10112704	Lents	<i>Corylus</i>
L10112704	Lents	<i>Betula</i>
L10112704	Lents	<i>Crataegus</i>
L10112704	Lents	<i>Crataegus</i>
L10112704	Lents	<i>Crataegus</i>
L10112704	Lents	<i>Crataegus</i>
L10112704	Lents	<i>Betula</i>
L10112704	Lents	<i>Betula</i>
L10112704	Lents	<i>Corylus</i>
L10112704	Lents	<i>Betula</i>
L10112704	Lents	<i>Betula</i>
L10112704	Lents	<i>Crataegus</i>
L10112704	Lents	<i>Corylus</i>
L10112704	Lents	<i>Betula</i>
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L10112704	Lents	<i>Betula</i>
L10112704	Lents	<i>Betula</i>
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L10112704	Lents	<i>Crataegus</i>
L10112704	Lents	<i>Mahonia</i>
L10112704	Lents	<i>Symphoricarpos</i>
L10112704	Lents	<i>Crataegus</i>
L10112704	Lents	<i>Mahonia</i>
L10112704	Lents	<i>Symphoricarpos</i>
L10112704	Lents	<i>Mahonia</i>
L10112704	Lents	Unknown 1
L10112704	Lents	Unknown 1
L10112704	Lents	Unknown 1
L10112704	Lents	<i>Acer</i>
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L10112704	Lents	<i>Acer</i>
L10112704	Lents	Unknown 2
L10112704	Lents	Unknown 3
L10112704	Lents	<i>Crataegus</i>
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L10112704	Lents	<i>Crataegus</i>
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L10112704	Lents	<i>Crataegus</i>
L10112704	Lents	<i>Cornus</i>
L10112704	Lents	<i>Crataegus</i>
L10112704	Lents	<i>Cornus</i>
L10112704	Lents	<i>Crataegus</i>
L10112704	Lents	<i>Crataegus</i>
L10112704	Lents	<i>Cornus</i>
L10112704	Lents	Unknown 5
L10112704	Lents	<i>Cornus</i>
L10112704	Lents	<i>Crataegus</i>
L10112704	Lents	<i>Crataegus</i>
L10112704	Lents	<i>Cornus</i>
L10112901	Lents	<i>NA</i>
L10112902	Lents	<i>Crataegus</i>
L10112902	Lents	<i>Crataegus</i>
L10112902	Lents	<i>Rhododendron</i>
L10112902	Lents	<i>Rosa</i>
L10112902	Lents	<i>Berberis</i>
L10112902	Lents	<i>Rhododendron</i>
L10112902	Lents	<i>Rosa</i>
L10112902	Lents	<i>Berberis</i>
L10112902	Lents	<i>Robinia</i>
L10112902	Lents	<i>Rosa</i>
L10112902	Lents	<i>Crataegus</i>
L10112902	Lents	<i>Magnolia</i>
L10113001	Lents	<i>Styrax</i>
L10113001	Lents	<i>Cupressus</i>
L10113001	Lents	<i>Malus</i>
L10113001	Lents	<i>Choisya</i>
L10113001	Lents	<i>Berberis</i>
L10113001	Lents	<i>Spirea</i>
L10113001	Lents	<i>Spirea</i>
L10113001	Lents	<i>Choisya</i>
L10113001	Lents	<i>Buxus</i>
L10113001	Lents	<i>Rosa</i>
L10113001	Lents	<i>Rosa</i>
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L10113001	Lents	<i>Rosa</i>
L10113001	Lents	<i>Camellia</i>
L10113001	Lents	<i>Camellia</i>
L10113001	Lents	<i>Camellia</i>
L10113001	Lents	<i>Conifer</i>
L10113001	Lents	<i>Hydrangea</i>
L10113001	Lents	<i>Acuba</i>
L10113001	Lents	<i>Acuba</i>

L10113001	Lents	<i>Rhododendron</i>
L10113002	Lents	<i>Crataegus</i>
L10113002	Lents	<i>Sorbus</i>
L10113002	Lents	<i>Acer</i>
L10113002	Lents	<i>Camellia</i>
L10113002	Lents	<i>Rosa</i>
L10113002	Lents	<i>Rosa</i>
L10113002	Lents	<i>Pinus</i>
L10113002	Lents	<i>Acuba</i>
L10113002	Lents	<i>Prunus</i>
L10113002	Lents	<i>Ilex</i>
L10113003	Lents	<i>Abies</i>
L10113003	Lents	<i>Juniperus</i>
L10113003	Lents	<i>Rosa</i>
L10113003	Lents	<i>Rosa</i>
L10113003	Lents	<i>Juniperus</i>
L10113003	Lents	<i>Juniperus</i>
L10113003	Lents	<i>Juniperus</i>
L10113003	Lents	<i>Rosa</i>
L10113003	Lents	<i>Rhododendron</i>
L10113004	Lents	<i>Pseudotsuga</i>
L10113004	Lents	<i>Arbutus</i>
L10113004	Lents	<i>Malus</i>
L10113004	Lents	<i>Symphoricarpos</i>
L10113004	Lents	<i>Ilex</i>
L10113004	Lents	<i>Mahonia</i>
L10113004	Lents	<i>Rhododendron</i>
L10113004	Lents	<i>Arborvitae</i>
L10113004	Lents	<i>Rhododendron</i>
L10113004	Lents	<i>Rhododendron</i>
L10113004	Lents	<i>Acer</i>
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L10113005	Lents	<i>Prunus</i>
L10113005	Lents	<i>Cedrus</i>
L10113005	Lents	<i>Acer</i>
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L10113005	Lents	<i>Acer</i>
L10113005	Lents	<i>Acer</i>
L10113005	Lents	<i>Acer</i>
L10113005	Lents	<i>Photinia</i>
L10113005	Lents	Unknown 1
L10113005	Lents	<i>Acer</i>
L10113005	Lents	<i>Acer</i>
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L10113005	Lents	<i>Acer</i>

L10113005	Lents	<i>Lavandula</i>
L10113005	Lents	<i>Viburnum</i>
L10113005	Lents	<i>Rosmarinus</i>
L10113005	Lents	<i>Rosmarinus</i>
L10113005	Lents	<i>Nandina</i>
L10113005	Lents	<i>Nandina</i>
L10113006	Lents	<i>Acer</i>
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L10113006	Lents	<i>Acer</i>
L10113006	Lents	<i>Prunus</i>
L10113006	Lents	<i>Acer</i>
L10113006	Lents	<i>Acer</i>
L10113006	Lents	<i>Rosa</i>
L10113006	Lents	<i>Acer</i>
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L10113006	Lents	<i>Acer</i>
L10113006	Lents	<i>Corylus</i>
L10113006	Lents	<i>Castanea</i>
L10113006	Lents	<i>Castanea</i>
L10113006	Lents	<i>Acer</i>
L10113006	Lents	<i>Acer</i>
L10113006	Lents	<i>Acer</i>
L10113006	Lents	<i>Acer</i>
L10113006	Lents	<i>Acer</i>
L10113006	Lents	<i>Acer</i>
L10113006	Lents	<i>Buxus</i>
L10113006	Lents	<i>Pieris</i>
L10113006	Lents	<i>Buddleja</i>
L10113006	Lents	<i>Buddleja</i>
L10113006	Lents	<i>Hypericum</i>
L10113006	Lents	<i>Salix</i>
L10113007	Lents	<i>Prunus</i>
L10113007	Lents	<i>Koelreuteria</i>
L10113007	Lents	<i>Acer</i>
L10113007	Lents	<i>Acer</i>
L10113007	Lents	<i>Catalpa</i>
L10113007	Lents	<i>Acer</i>
L10113007	Lents	<i>Koelreuteria</i>
L10113007	Lents	<i>Acer</i>
L10113007	Lents	<i>Buddleja</i>
L10113007	Lents	<i>Acer</i>
L10113007	Lents	<i>Acer</i>
L10113007	Lents	<i>Acer</i>
L10113007	Lents	<i>Acer</i>
L10113007	Lents	<i>Rosa</i>

L10113007	Lents	<i>Rosa</i>
L10113007	Lents	<i>Wisteria</i>
L10113007	Lents	<i>Rosa</i>
L10113007	Lents	<i>Rosa</i>
L10113008	Lents	<i>Acer</i>
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L10113008	Lents	<i>Acer</i>
L10113008	Lents	<i>Acer</i>
L10113008	Lents	<i>Cornus</i>
L10113008	Lents	<i>Rosa</i>
L10113008	Lents	<i>Rosa</i>
L10113008	Lents	<i>Rosa</i>
L10113008	Lents	<i>Lavandula</i>
L10113008	Lents	<i>Rosa</i>
L10113008	Lents	<i>Rosa</i>
L10113009	Lents	Unknown 1
L10113009	Lents	<i>Crataegus</i>
L10113009	Lents	<i>Salix</i>
L10113009	Lents	<i>Crataegus</i>
L10113009	Lents	<i>Crataegus</i>
L10113009	Lents	<i>Crataegus</i>
L10113009	Lents	<i>Salix</i>
L10113009	Lents	<i>Ash</i>
L10113009	Lents	<i>Acer</i>
L10113009	Lents	<i>Carpinus</i>
L10113009	Lents	<i>Alder</i>
L10113009	Lents	<i>Sorbus</i>
L10113009	Lents	<i>Alder</i>
L10113009	Lents	<i>Thuja</i>
L10113009	Lents	<i>Cedrus</i>
L10113009	Lents	Unknown 2
L10113009	Lents	<i>Thuja</i>
L10113009	Lents	<i>Cedrus</i>
L10113009	Lents	Unknown 2
L10113009	Lents	<i>Symphoricarpos</i>
L10113009	Lents	Unknown 3
L10113010	Lents	<i>Sorbus</i>
L10113010	Lents	<i>Sorbus</i>
L10113010	Lents	<i>Sorbus</i>
L10113010	Lents	<i>Pseudotsuga</i>
L10113010	Lents	<i>Sorbus</i>
L10113010	Lents	<i>Sorbus</i>
L10113010	Lents	<i>Sorbus</i>
L10113010	Lents	Unknown 1

L10113010	Lents	<i>Pseudotsuga</i>
L10113010	Lents	Unknown 2
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L10113010	Lents	<i>Pseudotsuga</i>
L10113010	Lents	<i>Pseudotsuga</i>
L10113010	Lents	<i>Crataegus</i>
L10113010	Lents	<i>Crataegus</i>
L10113010	Lents	<i>Alder</i>
L10113010	Lents	<i>Crataegus</i>
L10113010	Lents	<i>Crataegus</i>
L10113010	Lents	<i>Crataegus</i>
L10113010	Lents	<i>Crataegus</i>
L10113010	Lents	<i>Sorbus</i>
L10113010	Lents	<i>Sorbus</i>
L10113010	Lents	<i>Sorbus</i>
L10113010	Lents	<i>Alder</i>
L10113010	Lents	<i>Sorbus</i>
L10113010	Lents	<i>Sorbus</i>
L10113010	Lents	<i>Sorbus</i>
L10113010	Lents	<i>Alder</i>
L10113010	Lents	<i>Crataegus</i>
L10113010	Lents	<i>Sorbus</i>
L10113010	Lents	<i>Sorbus</i>
L10113010	Lents	<i>Pseudotsuga</i>
L10113010	Lents	<i>Pseudotsuga</i>
L10113010	Lents	<i>Mahonia</i>
L10120201	Lents	<i>Sorbus</i>
L10120201	Lents	<i>Sorbus</i>
L10120201	Lents	<i>Sorbus</i>
L10120201	Lents	<i>Sorbus</i>
L10120201	Lents	<i>Cercidiphyllum</i>
L10120201	Lents	<i>Cercidiphyllum</i>
L10120201	Lents	Unknown 1
L10120201	Lents	Unknown 1
L10120201	Lents	Unknown 2
L10120201	Lents	<i>Crataegus</i>
L10120201	Lents	Unknown 2
L10120201	Lents	Unknown 2
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L10120202	Lents	<i>Tsuga</i>

L10120202	Lents	<i>Tsuga</i>
L10120202	Lents	<i>Quercus</i>
L10120202	Lents	<i>Crataegus</i>
L10120202	Lents	<i>Crataegus</i>
L10120202	Lents	<i>Pseudotsuga</i>
L10120202	Lents	<i>Crataegus</i>
L10120202	Lents	<i>Pseudotsuga</i>
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L10110501	Lloyd	<i>Spirea</i>
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LL10110503	Lloyd	<i>Acer</i>
LL10110503	Lloyd	<i>Acer</i>
LL10110503	Lloyd	<i>Taxus</i>
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LL10110503	Lloyd	<i>Rhododendron</i>
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LL10110503	Lloyd	<i>Acer</i>

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LL10112003	Lloyd	<i>Quercus</i>
LL10112003	Lloyd	<i>Pieris</i>
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LL10112003	Lloyd	<i>Quercus</i>

LL10112003	Lloyd	<i>Pieris</i>
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LL10112004	Lloyd	<i>Tilia</i>
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LL10112004	Lloyd	<i>Berberis</i>
LL10112004	Lloyd	<i>Rhododendron</i>
LL10112004	Lloyd	<i>Rhododendron</i>
LL10112004	Lloyd	<i>Cotoneaster</i>
LL10112004	Lloyd	<i>Cotoneaster</i>
LL10112005	Lloyd	<i>Platanus</i>
LL10112005	Lloyd	<i>Platanus</i>
LL10112006	Lloyd	<i>Pyrus</i>
LL10112006	Lloyd	<i>Platanus</i>
LL10112006	Lloyd	<i>Platanus</i>
LL10112006	Lloyd	<i>Platanus</i>
LL10112006	Lloyd	<i>Pyrus</i>
LL10112007	Lloyd	<i>Liquidambar</i>
LL10112007	Lloyd	<i>Liquidambar</i>
LL10112007	Lloyd	<i>Liquidambar</i>
LL10112007	Lloyd	<i>Styrax</i>
LL10112007	Lloyd	<i>Styrax</i>

LL10112007	Lloyd	<i>Euonymous</i>
LL10112007	Lloyd	<i>Euonymous</i>
LL10112007	Lloyd	<i>Euonymous</i>
LL10112007	Lloyd	<i>Euonymous</i>
LL10112007	Lloyd	<i>Euonymous</i>
LL10112007	Lloyd	<i>Euonymous</i>
LL10112007	Lloyd	<i>Euonymous</i>
LL10112008	Lloyd	<i>Gleditsia</i>
LL10112008	Lloyd	<i>Gleditsia</i>
LL10112008	Lloyd	<i>Gleditsia</i>
LL10112008	Lloyd	<i>Acer</i>
LL10112008	Lloyd	<i>Acer</i>
LL10112008	Lloyd	<i>Pinus</i>
LL10112008	Lloyd	<i>Fraxinus</i>
LL10112008	Lloyd	<i>Thuja</i>
LL10112008	Lloyd	<i>Thuja</i>
LL10112008	Lloyd	<i>Thuja</i>
LL10112008	Lloyd	<i>Thuja</i>
LL10112008	Lloyd	<i>Thuja</i>
LL10112008	Lloyd	<i>Thuja</i>
LL10112008	Lloyd	<i>Thuja</i>
LL10112008	Lloyd	<i>Thuja</i>
LL10112008	Lloyd	<i>Thuja</i>
LL10112101	Lloyd	<i>NA</i>
LL10112102	Lloyd	<i>NA</i>
LL10112103	Lloyd	<i>Platanus</i>
LL10112103	Lloyd	<i>Platanus</i>
LL10112103	Lloyd	<i>Platanus</i>
LL10112103	Lloyd	<i>Platanus</i>
LL10112103	Lloyd	<i>Populus</i>
LL10112104	Lloyd	<i>Tilia</i>
LL10112104	Lloyd	<i>Tilia</i>
LL10112104	Lloyd	<i>Tilia</i>
LL10112104	Lloyd	<i>Tilia</i>
LL10112104	Lloyd	<i>Liriodendron</i>
LL10112104	Lloyd	<i>Tilia</i>
LL10112104	Lloyd	<i>Tilia</i>
LL10112104	Lloyd	<i>Acer</i>
LL10112104	Lloyd	Unknown 1
LL10112104	Lloyd	<i>Cornus</i>
LL10112104	Lloyd	<i>Magnolia</i>
LL10112104	Lloyd	<i>Magnolia</i>
LL10112104	Lloyd	<i>Pieris</i>
LL10112104	Lloyd	<i>Acer</i>
LL10112104	Lloyd	Unknown 2

LL10112104	Lloyd	<i>Berberis</i>
LL10112104	Lloyd	<i>Berberis</i>
LL10112104	Lloyd	<i>Berberis</i>
LL10112104	Lloyd	<i>Berberis</i>
LL10112104	Lloyd	<i>Ligustrum</i>
LL10112105	Lloyd	<i>Platanus</i>
LL10112105	Lloyd	<i>Platanus</i>
LL10112105	Lloyd	<i>Platanus</i>
LL10112106	Lloyd	<i>Acer</i>
LL10112106	Lloyd	<i>Acer</i>
LL10112106	Lloyd	<i>Taxus</i>
LL10112106	Lloyd	<i>Buxus</i>
LL10112106	Lloyd	<i>Ilex</i>
LL10112106	Lloyd	<i>Buxus</i>
LL10112106	Lloyd	<i>Taxus</i>
LL10112106	Lloyd	<i>Buxus</i>
LL10112107	Lloyd	<i>Acer</i>
LL10112107	Lloyd	<i>Acer</i>
LL10112107	Lloyd	<i>Acer</i>
LL10112107	Lloyd	<i>Acer</i>
LL10112107	Lloyd	<i>Euonymous</i>
LL10112107	Lloyd	<i>Berberis</i>
LL10112107	Lloyd	<i>Cotoneaster</i>
LL10112107	Lloyd	<i>Euonymous</i>
LL10112107	Lloyd	<i>Berberis</i>
LL10112107	Lloyd	<i>Cotoneaster</i>
LL10112108	Lloyd	<i>Euonymous</i>
LL10112108	Lloyd	<i>Berberis</i>
LL10112108	Lloyd	<i>Acer</i>
LL10112108	Lloyd	<i>Acer</i>
LL10112108	Lloyd	<i>Acer</i>
LL10112108	Lloyd	<i>Acer</i>
LL10112109	Lloyd	<i>Malus</i>
LL10112109	Lloyd	<i>Malus</i>
LL10112109	Lloyd	<i>Malus</i>
LL10112109	Lloyd	<i>Cedrus</i>
LL10112109	Lloyd	<i>Buxus</i>
LL10112109	Lloyd	<i>Quercus</i>
LL10112109	Lloyd	<i>Quercus</i>
LL10112109	Lloyd	<i>Quercus</i>
LL10112109	Lloyd	<i>Quercus</i>
LL10112109	Lloyd	<i>Acer</i>
LL10112109	Lloyd	<i>Buxus</i>
LL10112301	Lloyd	<i>Abies</i>
LL10112301	Lloyd	<i>Abies</i>

LL10112301	Lloyd	<i>Abies</i>
LL10112301	Lloyd	<i>Abies</i>
LL10112301	Lloyd	<i>Abies</i>
LL10112301	Lloyd	<i>Pinus</i>
LL10112301	Lloyd	<i>Pinus</i>
LL10112301	Lloyd	<i>Pinus</i>
LL10112301	Lloyd	<i>Pinus</i>
LL10112301	Lloyd	<i>Abies</i>
LL10112302	Lloyd	Unknown 1
LL10112303	Lloyd	<i>Populus</i>
LL10112303	Lloyd	<i>Populus</i>
LL10112304	Lloyd	<i>Cedrus</i>
LL10112304	Lloyd	<i>Prunus</i>
LL10112304	Lloyd	<i>Quercus</i>
LL10112304	Lloyd	<i>Populus</i>
LL10112304	Lloyd	<i>Acer</i>
LL10112304	Lloyd	<i>Populus</i>
LL10112304	Lloyd	<i>Populus</i>
LL10112304	Lloyd	<i>Prunus</i>
LL10112304	Lloyd	<i>Pseudotsuga</i>
LL10112304	Lloyd	<i>Prunus</i>
LL10112304	Lloyd	<i>Prunus</i>
LL10112304	Lloyd	<i>Quercus</i>
LL10112304	Lloyd	<i>Populus</i>
LL10112304	Lloyd	<i>Prunus</i>
LL10112305	Lloyd	<i>Acer</i>
LL10112305	Lloyd	<i>Acer</i>
LL10112305	Lloyd	<i>Acer</i>
LL10112305	Lloyd	<i>Acer</i>
LL10112305	Lloyd	<i>Ilex</i>
LL10112305	Lloyd	<i>Ilex</i>
LL10112305	Lloyd	<i>Ilex</i>
LL10112305	Lloyd	<i>Ilex</i>
LL10112305	Lloyd	<i>Ilex</i>
LL10112305	Lloyd	<i>Ilex</i>

Appendix B. Coordinates of Each Site. Decimal Degrees, GCS NAD 1983.

Site ID	Latitude	Longitude
D10092301	45.5180	-122.6850
D10092302	45.5178	-122.6856
D10092303	45.5194	-122.6847
D10092304	45.5233	-122.6853
D10092401	45.5130	-122.6880
D10092402	45.5135	-122.6860
D10092403	45.5150	-122.6860
D10092404	45.5158	-122.6860
D10093001	45.5122	-122.6860
D10100101	45.5108	-122.6860
D10100102	45.5123	-122.6840
D10100201	45.5139	-122.6831
D10100202	45.5128	-122.6830
D10100203	45.5122	-122.6830
D10100204	45.5107	-122.6850
D10100801	45.5105	-122.6840
D10100802	45.5102	-122.6830
D10100803	45.5098	-122.6840
D10100804	45.5101	-122.6850
D10100805	45.5096	-122.6850
D10100901	45.5081	-122.6800
D10100902	45.5093	-122.6800
D10100903	45.5082	-122.6820
D10100904	45.5075	-122.6830
D10100905	45.5102	-122.6820
D10101401	45.5232	-122.6790
D10101402	45.5230	-122.6760
D10101403	45.5211	-122.6800
D10101404	45.5211	-122.6830
D10101405	45.5171	-122.6870
D10101501	45.5191	-122.6830
D10101502	45.5160	-122.6730
D10101503	45.5134	-122.6760
D10101504	45.5130	-122.6790
D10101505	45.5129	-122.6790
D10101601	45.5085	-122.6790
D10101602	45.5076	-122.6790
D10101603	45.5035	-122.6790
D10101604	45.5079	-122.6780
D10102101	45.5086	-122.6730
D10102102	45.5163	-122.6840
D10102201	45.5154	-122.6820

D10102202	45.5091	-122.6730
D10102203	45.5097	-122.6750
D10102204	45.5083	-122.6750
D10102205	45.5081	-122.6750
D10102206	45.5072	-122.6760
D10102207	45.5071	-122.6760
G10082601	45.5133	-122.5660
G10082602	45.5132	-122.5660
G10082701	45.5125	-122.5640
G10082702	45.5132	-122.5640
G10082703	45.5112	-122.5610
G10082704	45.5117	-122.5610
G10083001	45.5139	-122.5560
G10083002	45.5169	-122.5540
G10083003	45.5191	-122.5510
G10083004	45.5196	-122.5540
G10083101	45.5210	-122.5590
G10090201	45.5225	-122.5560
G10090202	45.5281	-122.5580
G10090301	45.5159	-122.5640
G10090302	45.5262	-122.5670
G10090303	45.5276	-122.5620
G10090304	45.5341	-122.5590
G10090601	45.5308	-122.5560
G10090602	45.5345	-122.5520
L10090701	45.4937	-122.5670
L10090702	45.4949	-122.5670
L10090703	45.4967	-122.5720
L10090901	45.4918	-122.5690
L10090902	45.4908	-122.5670
L10090903	45.4857	-122.5690
L10090904	45.4851	-122.5690
L10091001	45.4892	-122.5720
L10091301	45.4846	-122.5710
L10091302	45.4834	-122.5570
L10091303	45.4841	-122.5560
L10091401	45.4960	-122.5610
L10091402	45.4953	-122.5560
L10091403	45.4949	-122.5540
L10091404	45.4949	-122.5490
L10091701	45.4949	-122.5500
L10091702	45.4933	-122.5560
L10091704	45.4925	-122.5530
L10091705	45.4933	-122.5530
L10092001	45.4925	-122.5570

L10092002	45.4916	-122.5480
L10092201	45.4915	-122.5540
L10092202	45.4916	-122.5570
L10092203	45.4871	-122.5510
L10092204	45.4849	-122.5560
L10092205	45.4849	-122.5590
L10092206	45.4853	-122.5590
L10112601	45.4814	-122.5700
L10112602	45.4769	-122.5690
L10112603	45.4767	-122.5690
L10112604	45.4759	-122.5750
L10112605	45.4759	-122.5740
L10112606	45.4756	-122.5760
L10112701	45.4749	-122.5710
L10112702	45.4706	-122.5780
L10112703	45.4716	-122.5750
L10112704	45.4692	-122.5710
L10112901	45.4791	-122.5660
L10112902	45.4748	-122.5670
L10113001	45.4789	-122.5630
L10113002	45.4821	-122.5640
L10113003	45.4806	-122.5620
L10113004	45.4796	-122.5600
L10113005	45.4811	-122.5570
L10113006	45.4805	-122.5560
L10113007	45.4799	-122.5560
L10113008	45.4796	-122.5560
L10113009	45.4779	-122.5490
L10113010	45.4741	-122.5480
L10120201	45.4683	-122.5510
L10120202	45.4685	-122.5670
L10120203	45.4662	-122.5760
L10120204	45.4739	-122.5630
LL10110501	45.5268	-122.6620
LL10110502	45.5330	-122.6610
LL10110503	45.5330	-122.6620
LL10110504	45.5338	-122.6600
LL10110505	45.5322	-122.6630
LL10111201	45.5315	-122.6650
LL10111301	45.5318	-122.6490
LL10111302	45.5316	-122.6490
LL10111601	45.5330	-122.6690
LL10111602	45.5328	-122.6700
LL10111603	45.5330	-122.6680
LL10111604	45.5343	-122.6680

LL10112001	45.5322	-122.6500
LL10112002	45.5330	-122.6500
LL10112003	45.5327	-122.6500
LL10112004	45.5310	-122.6490
LL10112005	45.5313	-122.6520
LL10112006	45.5304	-122.6520
LL10112007	45.5301	-122.6540
LL10112008	45.5303	-122.6570
LL10112101	45.5304	-122.6580
LL10112102	45.5304	-122.6580
LL10112103	45.5284	-122.6560
LL10112104	45.5287	-122.6570
LL10112105	45.5289	-122.6555
LL10112106	45.5305	-122.6640
LL10112107	45.5302	-122.6640
LL10112108	45.5301	-122.6630
LL10112109	45.5323	-122.6710
LL10112301	45.5294	-122.6660
LL10112302	45.5292	-122.6670
LL10112303	45.5326	-122.6710
LL10112304	45.5299	-122.6690
LL10112305	45.5313	-122.6690