Soil Quality Analysis - Chemistry Case Study
"Sustainability Street"

Introduction

Sustainability Street is located on the University of British Columbia (UBC) campus. It lies in between Main Mall and West Mall. Phase 1 has been completed and phases 2 and 3 will be completed by 2009 (see map in Appendix 1). Sustainability Street is in an urban location and the microclimate is influenced by adjacent buildings and asphalt roads. Phase 1 consists of landscaped vegetation and a channel and a pond as part of a proposed storm water drainage project (contained by an impermeable bentonite clay medium – see Appendix 2). Phases 2 and 3 are yet to be developed and the area is mainly asphalt and lawn with several mature trees.

Sustainability Street is being developed by UBC Campus Planning who have identified and attempted to include multiple stakeholders in its planning and development (http://www.sustain.ubc.ca/sustainabilitystreet/). Its aims are aligned to those of the UBC Sustainability Strategy (http://www.sustain.ubc.ca/) and the involvement of AGRO 402/ SOIL 502 partially fulfills its educational principle (Space2Place Phase 1 Report).

The functions of the soil at the site have not been formally defined, but from discussions with David Grigg, Brenda Sawada, Jeff Nulty and Grazyna Rougeau we have identified two primary functions:

1. For use as a suitable growth medium for the species of vegetation designated in the landscape plans;
2. For use as a suitable medium for inclusion in the storm drainage project plans.

Soil Genesis

Bertrand and Wood (1991), Luttmerding (1981) and the Soil Web website were used in researching the following section.

According to the Canadian System of Soil Classification the soils in this area are represented by the Podzolic Order, and more specifically form part of the Bose Soil Management Group. These soils are derived from glacial till which consists of glacio-fluvial deposits of gravel, boulders and sand. The unsorted material was deposited during the retreat of glaciers around ten thousand years ago. The material is coarse-textured and prone to compaction, therefore poor water-retention capacity in the A horizon should be considered.

The soils are usually found between 10 and 100 m above sea level, with gentle to steeply sloping topography. The regional climate type is wet temperate and in excess of 2000 mm of precipitation falls annually (usually as rain). The combination of high levels of precipitation and the coarse-textured parent material leads to leaching of iron, aluminum and humified organic material from the A horizon into the B horizon, often leaving a characteristic A_e horizon. The B horizon may show signs of oxidation and gleying or mottling. The deeper IIC horizon is composed of compact or cemented clay material, which forms an impermeable layer. Lateral seepage may occur at times of intense precipitation.

The original climax vegetation would have been western red cedar and Douglas fir forest. These forests are generally accepted as being nutrient-poor and especially nitrogen deficient. The forest floor is generally acidic (3.5 – 5) with a limited decomposer community dominated by fungi.

Any remnants of native soil at the Sustainability Street site would be expected to exhibit properties as outlined above, and in this case previous chemical analysis from the UBC

Farm (which is also on the Bose Soils Management Group) will be useful in diagnosing management issues at this site.

History of Site

Urban soils can be expected to exhibit properties relating to compaction, contamination, removal of native soils and vegetation, and addition of fabricated materials (Sæbø and Ferrini, 2006). Since the site was deforested it has been used as grazing land, has had an orchard planted on it, and has been developed for building. Proximity to storage for chemical fertilizers and pesticides, and use by vehicular traffic are all considerations for potential soils contamination. According to UBC Plant Operations the Phase 1 (developed) site has had additions of fabricated growth medium (from Fraser Richmond Soil and Fiber) as well as top-dressing in the form of compost from the UBC in-vessel composter and Plant Operations' own compost.

Sampling Strategy

Our group used the Ministry of Agriculture and Lands guidelines (http://www.agf.gov.bc.ca/resmgt/publist/Soil.htm) and recommendations from Carter (1993) to formulate our sampling strategy. We sampled strategically (without replication) from Phase 1, Phase 1 sloped site, and from the undeveloped site (Phase 2 and 3) to a depth of between 20-30 cm (see map in Appendix 1). We composited samples and have sent them (after storing them at 4ºC) to Pacific Soil Analysis Incorporated (PSAI) for analysis.

Our field observations suggest that there is little influence of native soil in the rooting zone, but compaction (measured with a cone penetrometer) at depths of 20-30 cm may be due to a compacted C horizon, remnant of the native podsol, or may be an artifact of urban development. There is some sign of channel erosion of the growth medium on un-vegetated slopes and some slumping of growth medium into gullies (recorded using depth measurements down the soil catena). We obtained chemical analysis results for the fabricated growth medium and the UBC in-vessel compost to aid in our analysis (see Appendix 3 and 4).

Chemical indicators of soil quality and sustainability

Neufeld (1980), Carter (1993), and the USDA soils assessment websites were used to interpret existing data and make predictions for our own soil analyses.

Organic Matter (OM) plays a role in developing soil structure, maintaining soil biological health and cation exchange capacity (CEC) and so maintaining levels of nutrient mineralization. The OM content of the native soils at this site is expected to be low, with associated poor retention of nutrients, poor water-holding capacity, and low biological activity. However, the growth medium prior to site application has an OM of 17.7% which is fairly high. The compost has an OM of around 70% (with an anomalous reading of 17.1% for one of the samples). The values for compost are predictably high and this should be considered when assessing the need for soil amendments, as a build-up of OM may alter the C:N ratio of the soil (see below) and tie up available nutrients in soil organism biomass.

The **Carbon:Nitrogen (C:N)** ratio is another broad indicator of the soil's ability to mineralize nutrients and provide labile carbon for soil organism metabolism. If the C:N ratio is too high then available N will be quickly immobilized by soil organisms as they metabolize labile C sources. If the C:N ratio is too low there is potential for N leaching from the soil (as nitrate). In this case, leaching of N from the soil/growth medium could lead to eutrophication of the drainage channel and storm water storage pond. The growth medium C:N ratio is 28.4 and the compost is between 12 and 30. Sources quote an ideal C:N range between 20-35 which suggests that these levels are adequate.

Soil pH is a key property when analyzing soil quality. pH affects the availability of soil nutrients and other chemical compounds in the soil, and most (if not all) soil chemical and biological reactions are influenced by the soil pH. Knowledge of soil pH (either measured in water or in dilute salt solution) is required for interpretation of other soil chemical data. Podzolic soils under native vegetation would be expected to have a low pH, but in this case, with limited native soil in the rooting zone the pH of the growth medium is of more importance. The growth medium has a pH of 6.0 and the pH of the compost ranges from 5.0 to 7.5. Liming was not recommended by PSAI. Compost generally increases soil pH (Cogger, 2005), and this should be considered in the management plans for the site as if soil pH becomes too high N can be lost through volatilization of ammonia.

Salt concentration or **Total Electrical Conductivity (TEC)** should be monitored as the accumulation of soluble salts in the soil profile alters plant osmotic potential and can induce specific ion toxicities or nutrient imbalances. The compost CEC values on average exceeded 20 meq/100g. Composts can induce high salt concentrations in soil, depending on the feed material (Cogger, 2005) and a soil chemical monitoring plan should consider this. The TEC for the growth medium is excessive at 4.8 mmhos/cm and the laboratory suggests several hours of leaching by rainfall before vegetation is planted. We were not able to establish whether this had been carried out.

Nitrogen (N) is essential for plant growth and generally limiting in podzolic soils. Total N is the default test in the PSAI analysis and should be interpreted in the context of OM and C:N ratio values. The growth medium exhibited total N of 0.36% which was declared moderate by PSAI and they suggested fertilization including N in April, June and August. Available N is dynamic and difficult to interpret due to the complex nature of the N cycle. Timing of sampling should be considered when testing for available N (especially total N). The compost was tested for nitrate levels and these results were predictably highly variable and ranged from less than 1 ppm to over 600 ppm.

Available Phosphorus (P) is also important for plant growth and growth medium levels were high (316 ppm). This may have implications for leaching (and eutrophication). P levels in the compost at around 60 ppm were not excessive.

The growth medium was also tested for **available Potassium (K), Calcium (Ca) and Magnesium (Mg)**. K (1440 ppm) and Mg (525 ppm) levels were shown to be high and leaching *in situ* under rainfall for several hours before planting was recommended. Ca levels were acceptable (1375 ppm). K was also high in the compost (>600 ppm) this should be considered when deciding on soil amendments. Other nutrients such as the micro-nutrient Manganese (Mn) can also be tested for but the extent of testing will depend on time and financial constraints.

Soil chemical results from our sampling of the site will indicate to us how the chemical indicators have altered since application and whether compost amendments have positively or negatively affected the soil growth medium. This will enable us to provide detailed recommendations for management.

Potential Contamination of Site

Campus Planning asked us to sample for possible soil contaminants which may directly affect water quality in the proposed storm drainage system. Our research into past land use and data from a Cantest analysis report on another urban soil suggests that we should test for light and heavy extractable hydrocarbons and strong acid leachable metals (although the limited amount of clay in the native soil and growth medium indicates a low CEC and therefore low retention of heavy metals). We would also suggest further testing for Poly-chloro biphenyls and Volatile Organic Compounds if there is the financial capacity. Both sets of compounds can be derived from materials which may have been stored at the site or which may be in the run-off which has been channeled into the area (e.g. fuel additives, paint, printer ink etc).

Fraser Richmond Soil and Fiber have requested that UBC provide them with specifications for their growth medium in relation to this function. They can then confirm whether or not their fabricated material is suitable for use within the drainage catchment.

We sampled soil for analysis as described in the above section. The Ministry of Water, Land and Air Protection has detailed guidelines on sampling and testing soil in potentially contaminated land. Our sampling method is not rigorous enough to fulfill these criteria, so if contamination was suggested by the results from our sampling a full sampling strategy should be put in place. This would include site-specific background contaminant sampling, replication, and data submission to the Ministry as outlined under Protocol 4 (http://www.env.gov.bc.ca/epd/epdpa/contam_sites/guidance/).

Recommendations and Conclusion

- During sampling we found little native soil remaining at the Sustainability Street site and therefore suggest management practices which relate mainly to the properties of the growth medium and amendments.
- However, initial sampling suggests the presence a compaction layer may be due to a compacted C horizon from the original podsol. This has implications for rooting depth and lateral water flow into the drainage channel and pond, and we suggest that the physical case study group looks into this further.
- The chemical analysis from the fabricated medium suggests no need for immediate compost amendments, except for possible N addition. However, this can be confirmed once the *in situ* chemical analysis results are interpreted.
- There does appear to be an issue with high soluble salt, K and P levels in the growth medium, and compost additions may exacerbate this. Our *in situ* analysis should confirm whether leaching over the winter has decreased these concentrations.
- There appears to be some confusion over the vegetation landscaping philosophy and the functional role of the planting (see Appendix 5 for species list and map). We recommend Campus Planning and Space2Place Landscape Design hold further discussions with Plant Operations maintenance crews over the sustainability of site management. We believe that the vegetation should be re-considered in light of the soil analysis results and the microclimate of the site

(including elevated water temperatures resulting from the proposed lateral heat exchange system in an adjacent building) (see Craul, 1999).

- We recommend the biological case study group conduct a soil meso-fauna survey as an indicator study of soil biological health.
- We believe a closed-loop management system pilot project should be initiated (maybe in conjunction with a directed studies project) which could suggest ways to reduce energy consumption from maintenance and reduce inputs to the site. This system should include UBC in-vessel compost but also include retention of in-site organic matter inputs. This would tie in with Sustainability Street goals.
- Enhanced communication between stakeholders would increase the sustainability of the project.
- The project leaders should set up an annual or bi-annual soil monitoring scheme. The scheme should be realistic and fit in with financial and time constraints. Data should be made available to all stakeholders, and the creation of a soil quality data base could be used as a basis for other on-campus soil monitoring projects.

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Space2Place Phase 1 Report for Sustainability Street – supplied by Jeff Cutler of Space2Place Landscape Design

http://www.sustain.ubc.ca/sustainabilitystreet/ Sustainability Street website

http://www.sustain.ubc.ca UBC Sustainability Goals

http://www.landfood.ubc.ca/soil200/ Soils Web online teaching and learning tool

http://www.agf.gov.bc.ca/resmgt/publist/Soil.htm British Columbia Ministry of Agriculture and Lands soil sampling protocols

http://www.env.gov.bc.ca/epd/epdpa/contam_sites/guidance/ BC Waste Management guidelines for contaminated sites

http://soils.usda.gov/sqi/assessment/assessment.html US Dept. Agriculture site on soil testing

http://soils.usda.gov/sqi/assessment/test_kit.html US Dept. Agriculture site on soil testing

Case Study 2 - Biological Indicators at Sustainability Street

Introduction

Urban soils, such as those at Sustainability Street, often have unique characteristics which need to be considered when evaluating a site in the context of soil quality indicators. In comparison with natural soils, urban soils frequently exhibit higher spatial variability in chemical and biological properties (Lorenz and Kandeler, 2005).

In our study we specifically considered the role of the native Bose soil in modifying the soil biological parameters, along with the type and amount of site disturbance, the proposed function of the site and its soils, and the potential for soil biota colonization once the site has been established.

Biological Indicators and Soil Quality

Soil Quality reflects the capacity of a specific kind of soil to function within natural or managed ecosystem, to sustain plant or animal productivity (Sojka and Upchurch, 1999).

Soil Condition is the ability of the soil to perform according to its potential. This ability changes over time due to human use and management or due to unusual natural events (Sojka and Upchurch, 1999).

Despite the development of strategies for testing, surveying and evaluating soil chemical indicators in various systems, no generally accepted strategies exist for determining soil biological indicators and for evaluating the ability of the soil to function as a habitat for microorganisms (Kördel and Römbke, 2001).

Sojka and Upchurch (1999) believe that the concept of soil quality is "contextual, value-laden and outcome driven". They argue that the soil quality paradigm has emerged conforming to a narrow vision of an ideal. Within this concept, they argue, soil indicators are given either a positive or negative score. For example, Soil Organic Matter (or SOM) is generally perceived only as positive factor. SOM does play an integral role in the biological health of soil. Humic material stabilizes extra-cellular enzymes, contributes to soil structure and water-holding capacity, enhances litter decomposition and nutrient mineralization, and so can increase plant available nutrients. However, “excess” SOM can immobilize nutrients in the short-term (Fox, 2003).

Sustainability Street has an SOM content of between 18% (growth medium at source) and 13% (after application). In healthy agricultural soils SOM is usually between 5-10%, so this value is a little high and should be monitored. However, very recalcitrant materials, especially those left on the soil surface, contribute to a mulch effect which protects soils from erosive forces (Fox); the mulching effect of any compost amendments at Sustainability Street may prevent the erosion of the newly disturbed soils.

In agricultural soils the ideal C:N ratio range is 15-30; above this ratio the immobilization of available nitrogen (and other essential nutrients) by microorganisms whilst catabolizing available carbon may actually reduce the availability of nutrients in the short-term (Fox, 2003; Tomlin and Fox, 2003). The C:N ratio value at Sustainability Street is at the high end of this range, and should be monitored.

Some of the plant species at Sustainability Street have the potential to form mycorrhizal associations. However, over time natural mycorrhizal colonization may be limited by the high potassium and phosphorous levels at the site. This confounding factor may decrease with time as excess nutrients are leached from the site (along with excess salinity). For example, over the past five months potassium concentration has been reduced by approximately 50%.

The pH values of the soil under native vegetation in the area range from 3 to 5, which would encourage a fungal-dominated system and earthworms would be absent. The higher pH at Sustainability Street is suitable for earthworms and would select for a different assemblage of soil biota. However, the complex nature of soil biological food webs and the plethora of species and operational taxonomic units make it difficult to predict the potential community at ‘equilibrium’.

Soil Fauna and Microorganisms

Soil fauna increase decomposition of organic matter and the turnover of nutrients in a system. The extent to which these processes will have a beneficial effect on soil composition is determined by how well and in what way populations respond to stressors arising from environmental and anthropogenic impacts on the soil system.

We carried out an earthworm survey at the site. Earthworms contribute to soil physical, chemical and biological processes such as soil structure formation and organic matter dynamics through nutrient cycling, and soil pore water dynamics through their burrowing activities, which provide soil pores for aeration and water infiltration. The presence of earthworms under the turf at the undeveloped site leads us to recommend that the existing soil is left on the site during development.

Earthworm species may change their behaviour greatly when transferred from one soil environment to another, even if soil environments are similar (Edwards, 2004). There are no specific behaviour patterns at the species level or within ecological niches (Edwards, 2004). We predict native earthworm colonization of Sustainability Street from existing undisturbed reservoirs as native earthworms through adaptation to the new soil conditions.

Dr Grayston (personal communication) suggested a survey to identify the presence or absence of meso-faunal niche groups. In combination with chemical analyses and techniques such as evaluation of total microbial carbon or microbial respiration (which could be carried out in Forestry or out-sourced), mycorrhizal colonisation studies, litter bag incubations and treatments which examined the benefits of soil biota inoculations, a base-line data set could be developed over time which would be of use in monitoring other sites on campus. Sustainability Street is an ideal place to carry out such research.

Weed Seed Banks

Dr. Upadhyaya (personal communication) suggested that as the fabricated growth medium has been applied to an average depth of 30cm, the native soil seed bank will probably remain dormant, but if the soil is disturbed the seed bank could be quantified by simply counting the seed in a specified amount of soil. The growth medium has been sterilized (Fraser Richmond Soil personal communication) so Dr Upadhyaya suggested incubation of the growth medium through out establishment to assess the rate of weed colonization in the high-nutrient growth medium.

Carbon Sequestration

Some extrapolation can be made for the restoration of degraded land through preventing soil erosion and careful vegetation species selection (IPCC, 2007). This can improve carbon sequestration by 0.25 tons of carbon per hectare per year over the course of 30 years (IPCC, 2007). We recommend planting trees and the introduction of perennial species to increase the capacity of the site to sequester carbon. Tillage reduction is not an issue as mulching and light weeding are the current maintenance regimes. Increased diversity of species are recommended provided they are appropriate for the site conditions and do not require increased maintenance. Reduction of inputs could be achieved through more of a closed-loop management system.

Other Case Studies

- UBC Farm – this case study identified similar issues regarding best way to manage soil for fauna and colonization of beneficial soil biota. However, management of pest species (especially wire worms) is not an issue at Sustainability Street.
- Landfill – both studies deal with fabricated growth medium and have to address weed seed bank issues.
- Forestry – brought up interesting ideas relating to base-line biological indicator data bases and how to monitor for soil biological quality. Such ideas could be adapted for an urban context.

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