Biodiversity in Reclamation Treatments at the Lehigh Hanson Sand and Gravel Quarry

Phase 1: Vegetation Diversity

Draft Report

Submitted to SYLVIS Environmental

September 20, 2014

Emily Mason
Dr Sue Grayston
Dr Cindy Prescott
Department of Forest and Conservation Sciences
University of British Columbia
2424 Main Mall
Vancouver B.C. V6T 1Z4

Table of Contents

Abstract

The area of land that is affected by the mining industry continues to grow, making effective land reclamation techniques increasingly important. Revegetation is an essential aspect of mine reclamation, but adverse soil characteristics often make it challenging. Many reclamation methods, including biosolids amendment, are proposed to effectively restore a healthy plant community to such areas. This report presents vegetation biodiversity results from the Lehigh Hanson Materials' Sechelt sand and gravel quarry, comparing reclaimed mine sites, planted to poplars, conifers, grasses or unplanted and either un-amended or amended with biosolids, with adjacent natural forested areas. We found generally that unamended sites had higher Shannon diversity indices; consistent with previous studies (Canadian Institute for Environmental Law, 2008), although amended poplar plantations had high above-ground biodiversity. Future work will include biomass sampling to assess differences in productivity between the different treatments, as well as assessment of the richness and abundance of the soil macro- and meso- fauna and microorganisms in the sites that are responsible for nutrient cycling processes.

Introduction

With the area of land affected by resource extraction constantly expanding, the search for effective reclamation methods has become increasingly important. In any surface mining operation the overlying materials, which include vegetation and soil, must be removed before the desired minerals can be extracted. This often leaves the remaining substrate with low nutrient and water availability (Wong, 2003; Van Ham, Lee, & McLean, 2000; Polster, 2012). Biosolids have been used in agriculture, forestry, and reclamation for many years. Biosolids are a byproduct of the wastewater treatment process that contain high concentrations of nutrients and are treated to minimize pathogens (Canadian Institute for Environmental Law and Policy, 2008). Among their many beneficial properties, biosolids can increase soil organic matter, water-holding capacity, carbon sequestration, and stabilize soil pH (Canadian Institute for Environmental Law and Policy, 2008). This study aims to explore the above and belowground biodiversity of several reclamation areas at Lehigh Hanson Materials' sand and gravel mine in Sechelt, BC and explore the relationships between biodiversity, vegetation, and soil treatment. The results of this study will augment our understanding of the effects of municipal biosolids on biodiversity and ecosystem functionality.

Objectives

The objectives of our project consist of two elements: biodiversity and education. First, the above and belowground biodiversity will be assessed by measuring the richness, abundance, and evenness of the soil macro- and meso- fauna and plant communities in various areas of the mine. The relationships between these communities, the different vegetation covers and soil treatments will be explored. We will also assess the correlation between the biodiversity at each site and long-term soil data collected by SYLVIS Environmental, who have managed the reclamation program at the mine since 1998.

Our educational objectives include organizing a bioblitz day at the mine involving the Sechelt Indian Band and local high-school students. The students will collect soil samples from various areas of the mine, create their own Berlese funnels, and identify the soil fauna they extract. The results of the bioblitz will be featured on Soil4Youth, an online resource that promotes soil science education for high school students across Canada. We would also like to incorporate the project findings into several undergraduate courses at the University of British Columbia. The findings will potentially be used to develop a problem-based case study for Sustainable Soil Management (APBI 402/ SOIL 502), and the data would be used in Soil Processes (APBI 401/ SOIL 501). We also propose our research site as a field trip location for Field and Laboratory Methods in Soil Science (APBI 403/SOIL 503) and a new course in Ecological Restoration (FRST 4XX).

Background

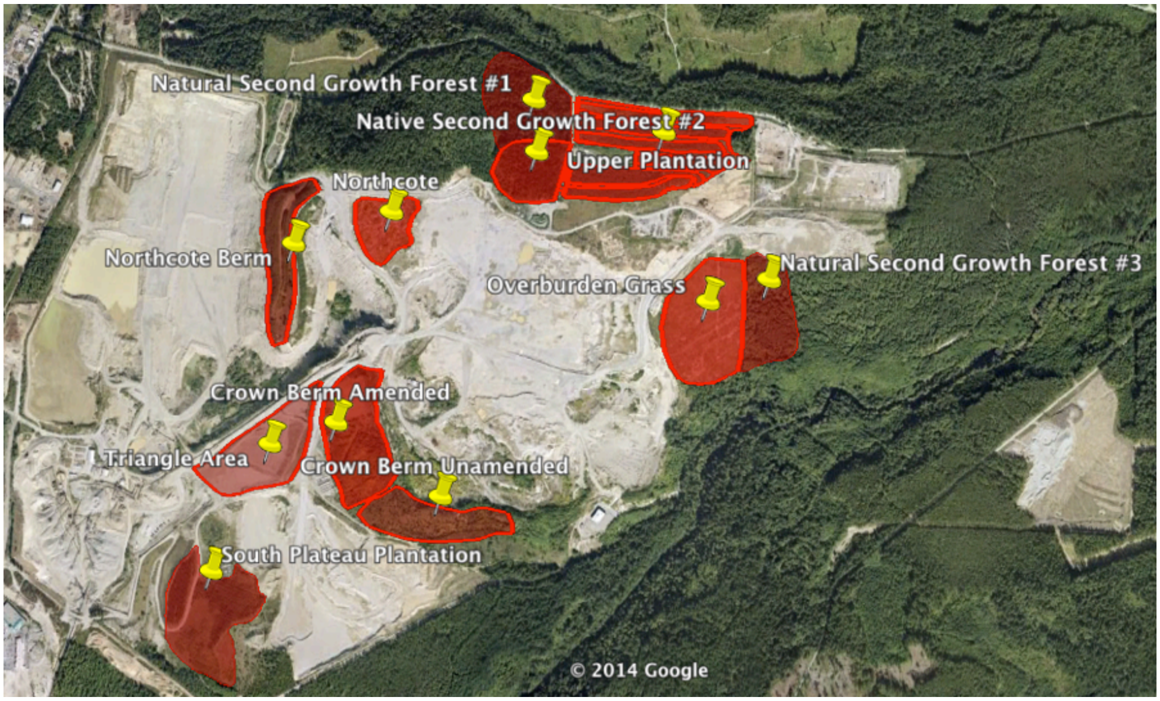
The Lehigh Hanson Materials sand and gravel mine (Sechelt Mine) is located in Sechelt, BC (49.4742° N, 123.7542° W). Sechelt is located within a coastal temperate rainforest. It has a mean annual temperature of 9.9°C. The highest monthly average of 17.4°C occurs in July and August and the lowest monthly average is 3.4°C in December. The mean annual precipitation is 1611mm with 53mm falling as snow. August has the lowest mean precipitation while the highest is in November (Wang, Hamann, & Spittlehouse, 2013). The mine is located in the Coastal Western Hemlock biogeoclimatic zone where the dominant tree species are *Tsuga heterophylla* (Raf.) Sarg., *Thuja plicata* (Donn ex. D. Don) and *Pseudotsuga menziesii* (Mirb.). *Pinus monticola* (Douglas ex. D. Don) is also evident in the natural second-growth forests. The reclamation project at the Sechelt mine began in 1998. Municipal biosolids from the District of Sechelt, the City of Powell River, the Town of Gibsons and BC Ferries, along with pulp and paper residuals, have been applied by SYLVIS Environmental to amend the mine soils and assist the reclamation process. Pulp and paper residuals were applied to the Northcote Berm (NCB) in 1998 and the South Plateau plantation (SP) and 1998 and 2002. Municipal biosolids and liquid biosolids account for the remaining amendments (Table 1). Poplar trees were planted at the Northcote Berm, the South Plateau plantation and the Upper Plantation (UP) in 2001, 2004, and 2005 respectively and the Northcote berm, which has a significant west-facing slope, was also seeded with grasses. The biosolid-amended poplar plantations were established with the intention of enhancing nutrient cycling and building soil organic matter and water holding capacity, after harvesting, the areas will be seeded with native species. The two remaining amended sites are the Upper Crown berm (CBA) and the Triangle area (TA). The Crown Berm has been amended with liquid biosolids while the Triangle area has received dewatered biosolids.

Year	Northcote Berm	Crown Berm	Northcote Road	South Plateau	Triangle Area	Upper Plantation
Area of Site	4.9 ha	2.3 ha	0.5 ha	7.6 ha	7.2 ha	9.2 ha
1998	P			P		
1999	X					
2000		X	P			
2001			X	X		
2002			X	P		
2003			X			
2004				X		
2005				X		X
2006						X
2007				X		X
2008		X		X		X
2009		X	X	X	X	
2010		X	X	X	X	X
2011		X	X	X	X	X
2012		X	X	X	X	X
2013		X	X	X	X	X

Table 1: Amendments applied to the six reclamation sites from 1998-2013. Pulp and paper sludge (P) was applied to several sites; the other amendments (X) are municipal biosolids from various sources.

Site	Soil treatment	Planting/seeding	Age	Canopy open or closed?	Aspect
UP	B	P	9	C	-
SP	B	P	10	C	-
NCB	B	P/G	13	C	W
NC	N	N	-	O	NW
OG	N	N	-	O	-
CBU	N	C	15	O	S
CBA	B	G	17	O	S
TA	B	G	5	O	SW
N1	N	N	-	C	-
N2	N	N	-	C	-
N3	N	N	-	C	-

Table 2: Site variables: soil treatments (N: no amendment, B: biosolids), Planting/seeding (P: Poplar, G: grass, N: none, C: conifers, T: trees), age, Canopy closure, and aspect.



Google earth V. 7.1.2.2041.(9/11/2009). Sechelt, B.C., Canada. 49°29'12.14" N 123°41'44.99" W. Eye alt 3.56km. Google earth. [September 10, 2014].

Figure 1: Aerial view of the quarry, with the study sites highlighted. Adapted from a version prepared by SYLVIS environmental.

Methods

Eleven areas of varying vegetation cover, age and treatment were selected from the mine site (Table 2). There are three natural second-growth forests (N1, N2, N3); three poplar plantations- the Upper Plantation (UP), the South Plateau plantation (SP), and the Northcote Berm plantation (NCB)- which receive annual biosolids applications; two areas which have been seeded with grasses and receive annual biosolids applications (TA, CBA); two overburden deposits that have received no subsequent treatment (NC, OG); and one overburden deposit that was planted with conifers in 1999 (CBU). Refer to appendix for images of the study sites. In each area five transects of 10 meters were laid down and seven plots of 0.5 by 0.5 meters were placed evenly along these transects. In the plantations, transects were oriented to include the poplar rows as well as the tracks made by the equipment during biosolids applications as this would provide a better representation of the entire site. The percent cover of the species found within each plot was then estimated. Additionally, the point-centered quarter method was implemented to estimate tree density. The distances from the beginning of each transect to the closest tree in each quadrant and their diameters at breast height were measured. The Shannon diversity index was used to compare the vegetation at each site; this index is commonly used for ecological analysis, it sums the proportions of each species to calculate diversity, which measures both richness and evenness. The life forms found at each site were analyzed using PC-ORD, multivariate analysis software, specializing in the analysis of ecological data.

Soil samples were taken for subsequent analysis. Five cores of the top 10 centimeters were taken from three locations in each site and refrigerated. These samples will undergo microbial community analysis in the future.

Results

Trees

Basal area and density (stems/ha) at each site were measured to provide an indication of site productivity (Table 3). The highest densities were found in two of the naturally regenerating sites, NC and OG. The trees in these sites are mostly *Pseudotsuga mensiezii* (Mirb.) and *Pinus contorta* (Dougl.). The natural second growth areas N1, N2, and N3 had the next highest densities, followed by the poplar plantations (SP, UP, and NBC) and finally another naturally regenerated site (CBU). The grassland sites (TA and CBA) contained too few trees to measure density.

The highest basal areas per tree were found in two of the three natural second-growth sites (N1 and N2), while the lowest was found at the CBU site. Many of the trees at the NC and OG sites had not reached an adequate size to measure DBH and the basal areas could not be calculated.

The natural sites (N1, N2, and N3) also had the highest basal area per hectare, followed by the poplar plantations (UP, NCB, SP) and finally CBU.

SITE	DENSITY (TREES/HA)	BASAL AREA (CM^2/TREES)	BASAL AREA (CM^2/HA)
CBA	-	-	-
TA	-	-	-
NC	2776.56	-	-
OG	2428.24	-	-
N1	1643.78	0.02	169.73
N2	1519.76	0.01	113.47
N3	2691.19	0.01	76.78
UP	1000.59	0.01	49.63
NCB	1166.78	0.01	39.72
SP	950.38	0.01	27.44
CBU	434.95	0.00	5.63

Table 3: Density(trees/ha), basal area per tree, and basal area per hectare of the trees in each site. The values shown are the average of the five transects at each site.

Understory vegetation

Percent cover

Understory vegetation cover and number of species were measured as indicators of site productivity and diversity (Table 4). The percent cover of the understory vegetation in the naturally regenerating areas (OG, NC, and CBU) was higher than the biosolids-treated grasslands (TA and CBA).

Number of life forms and species

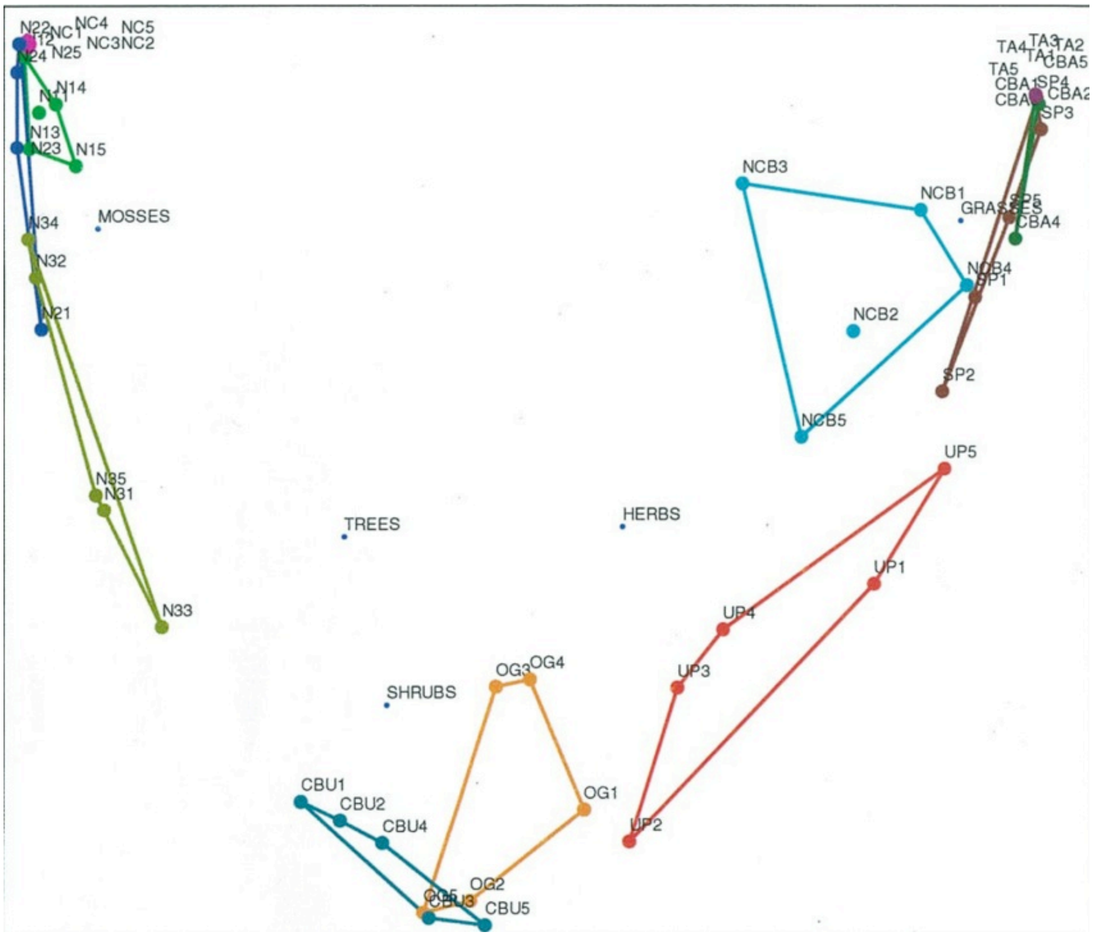
On average the naturally regenerating areas (OG and CBU) had the highest number of plant life forms per plot, while the grassland areas (TA and CBA) had the lowest (Figure 2). The highest number of species was found in OG, followed by two of the poplar plantations (UP and NCB). The lowest number of species was found in the grassland areas (TA and CBA).

Shannon diversity index and species evenness

The grassland sites (TA and CBA) and the natural sites (N1, N2, N3) had the lowest Shannon diversity index, while the naturally regenerating overburden sites (OG, NC, and CBU) and the poplar plantations (UP, NCB, SP) had the highest Shannon diversity indices. Species evenness was correlated with Shannon diversity.

SITE	PERCENT COVER	NUMBER OF LIFE FORMS	NUMBER OF SPECIES	SHANNON INDEX	SPECIES EVENNESS
OG	117.7	4.6	12.2	1.944	0.776
UP	84.0	3.2	10.6	1.802	0.766
NCB	98.9	3.2	10.4	1.666	0.718
NC	85.8	3	9.8	1.356	0.766
CBU	117.8	3.8	8.4	1.293	0.615
SP	39.4	2.4	5.6	1.253	0.740
N3	136.7	3	6	1.168	0.673
CBA	81.6	1.6	5.6	0.950	0.428
N1	84.8	3.2	8.4	0.902	0.432
N2	72.7	2.2	6.4	0.737	0.397
TA	83.3	1.2	4.8	0.717	0.460

Table 4: Variables of understory vegetation. The values shown are averages of the 35 plots in each area. The species found at each site were categorized into 5 life forms: mosses and lichens, herbaceous plants, graminoids, shrubs, and tree seedlings.



McCune, B. and M. J. Mefford. 2011. PC-ORD. Multivariate Analysis of Ecological Data. Version 6.15. MjM Software, Gleneden Beach, Oregon, U.S.A.

Figure 2: a visual representation of the similarities between each site in terms of life forms.

Legend

Site Code	Site Name	Site Description
N1	Natural second-growth #1	Natural second-growth forest
N2	Natural second-growth #2	Natural second-growth forest
N3	Natural second-growth #3	Natural second-growth forest
UP	Upper Plantation	Biosolid-amended poplar plantation
NCB	Northcote Berm	Biosolid-amended poplar plantation
SP	South Plateau Plantation	Biosolid-amended poplar plantation
TA	Triangle Area	Biosolid-amended grassland
CBA	Crown Berm Amended	Biosolid-amended grassland
CBU	Crown Berm Unamended	Naturally regenerating site
NC	Northcote	Naturally regenerating site
OG	Overburden Grass	Naturally regenerating site

Discussion

Generally, the highest diversity was observed in the naturally regenerating overburden sites and the poplar plantations. The diversity was highest in the naturally regenerating overburden sites; however, the poplar plantations also had relatively high basal areas per hectare indicating that they are both diverse and productive sites. The grassland areas displayed neither high diversity nor productivity. Thus it appears that seeding to grass reduces the plant diversity of biosolids-amended sites.The reduction of diversity on these sites may be attributed to the seed selection combined with autoecological characteristics of the species selected.

Trees

Pseudotsuga menziesii (Mirb.) and *Pinus contorta* (Dougl.) dominate the Northcote (NC) and overburden grass (OG) areas. These pioneer species are part of the initial cohort established in the post-disturbance conditions. Because of their size, these young trees require very little space, however once they reach a larger size, limited resources (including space) will likely result in stem exclusion and the site will no longer be able to support such a high density of stems. Thus, the density of this site is likely a result of its age and therefore does not necessarily indicate higher productivity. The highest basal area per hectare was found in the natural sites; however, the natural sites are much older than the poplar plantations, which are between 13 and 9 years old. Thus the higher basal area per hectare in the natural forests is a result of age and does not indicate that they are more productive than the poplar plantations.

Understory vegetation

The three sites with the highest vegetative cover (N3, CBU, OG) were also the only sites that supported a relatively homogenous shrub layer. The lowest cover was found in the South Plateau plantation (SP); however, this site had recently received its annual biosolids application. The application and disking of the biosolids disturbed the vegetation between the poplar rows, which would have contributed to its low diversity and cover. One of the natural second-growth sites (N2) also had a low understory vegetation cover, but it appeared to be heavily browsed by deer and elk. It has been suggested that seeding reclamation sites with mixtures of grasses and legumes can limit the establishment of other plants, especially woody shrubs and trees, and as a result biodiversity can be reduced (Polster, 2012). This is consistent with our findings in the biosolids-amended grasslands (TA and CBA). Interestingly, the natural sites had low Shannon diversity indices that were closer to the biosolids-amended grassland sites than the unamended sites. This can be attributed to the older trees in the natural forests (~80 years) and the stand being in the late stem exclusion stage when conditions are too shaded for most understory plant species. The highest numbers of plant species were found in the unamended sites. This could be related to the more heterogeneous topography in the unamended sites, which promotes plant diversity (Polster, 2012). It could also be attributable to the unamended sites not being seeded, unlike several of the biosolids-amended sites. Seeding with grasses and legumes has been shown to limit the establishment of other plants, and therefore limit biodiversity (Polster, 2012). Other studies have suggested that although diversity may be higher in unamended plots, biomass is higher in plots amended with sewage sludge (Moreno, Peñaranda, Lloret, & Alcañiz, 2004). Biomass was not sampled in this study, however our sites could display similar characteristics as the vegetation in most of the amended plots appeared to be more continuous from the ground to the maximum height, whereas the unamended sites often had distinct layers; for example distinct layers of moss and salal. This is apparent in the Crown Berm sites (CBA and CBU). These sites have similar characteristics such as underlying material, aspect and little to no canopy cover. The unamended site had a higher Shannon diversity index, and although biomass was not measured, the amended site appeared to have much greater biomass.

Future work

It would be valuable to broaden our understanding of the effects of biosolids on the ecosystem as a whole through plant biomass and soil faunal and microbial community analysis. This would provide more insight into the trade-off between biodiversity and productivity, which is an area that requires further research, for example, long-term observation of reclaimed areas under different treatments, and comparison of biodiversity and biomass throughout a longer time frame.

Our educational objectives were stalled by the early closure of schools due to job action by teachers in British Columbia as well as difficulties reaching students during the summer holidays. We plan to present our results to schools and communities on the Sunshine Coast in order to generate interest in educational events such as a bioblitz for youth at the quarry and to promote awareness of ecological restoration at the Lehigh Hanson Materials Sechelt mine.

Literature Cited

Canadian Institute for Environmental Law. (2008). Biosolids in mine reclamation? a review of the literature. Canadian Institute for Environmental Land and Policy

Moreno-Peñaranda, R., Lloret, F., & Alcañiz, J. M. (2004). Effects of Sewage Sludge on Plant Community Composition in Restored Limestone Quarries. Restoration Ecology , 12 (2), 290-296.

.Polster, D. (2012). A New Paradigm fo the Restoration of Drastically Disturbed Sites. Polster Environmental Services Ltd., Duncan, BC.

Van Ham, M., Lee, K., & McLean, B. (2000). Pit to park: gravel mine reclamation using biosolids. British Columbia Mine Reclamation Symposium 2000, (pp. 38-51). Williams Lake.

Wang, T., Hamann, A., & Spittlehouse, D. (2013). *ClimateBC_Map- A Interactive Platform for Visualization and Data Access*. Retrieved 07 24, 2014 from http://climatemodels.forestry.ubc.ca/climatebc/

Wong, M. H. (2003). Ecological restoration of mine degraded soils, with emphasis on metal contaminated soils. Chemosphere , 50 (6), 775-780.

Appendix


Photos 1 and 2: The Northcote (NC) and Overburden grass (OG) sites.


Photo 3 and 4: The amended Crown Berm (CBA) and Triangle area (TA) sites.

Photos 5 and 6: Natural site #1 (N1).

Photos 7 and 8: Upper plantation (UP) Northcote berm (NCB)

Photo 9: The South Plateau Plantation (SP).