Organics Trailblazer Project

Lambton Former Coke Works

Final report monitoring 2008-2009

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Soil Environment Services

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1 Introduction

1.1 Background

This report details the final findings of a monitoring programme at the former Lambton coke works site which originally accommodated the Lambton Trailblazer project.

Monitoring covers the period May 2008 to August 2009. The works consists of soil sampling and testing for the following parameters: pH, electrical conductivity, available N, P, K, potentially toxic elements, organic matter and aggregate stability, soil structure assessment, tree height assessment, gas measurements and soil moisture assessment.

1.2 Trial design

Trial plots were constructed in May 2007 in the north west of the Lambton former coke works site (Figure 1, Trial layout).

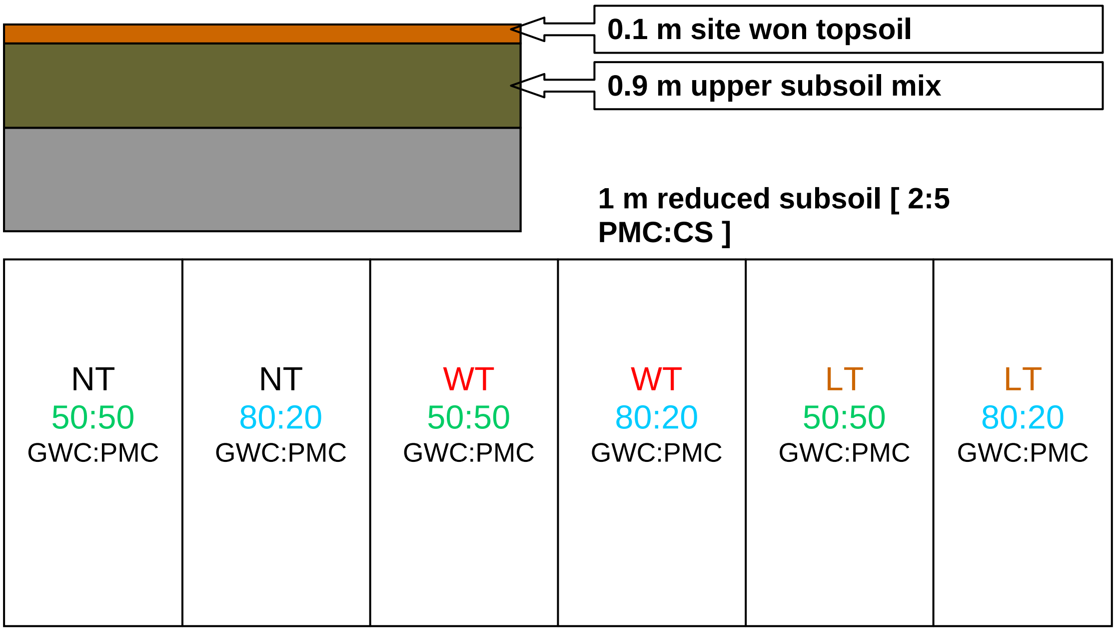

Figure 1: Trial layout

1.3 Trial monitoring

1.3.1 Soil physical parameters

- **Soil aggregate stability.** Aggregate stability is assessed by a wet sieving technique on 0.25 to 2 mm sized aggregates.

- **Structural development.** This is assessed by profile observation and penetration resistance. The date of assessment is timed to avoid confusion introduced by dry soil and therefore penetration resistance is measured with the soil at field capacity and profile structural examination scheduled for the end of the periods.

1.3.2 Soil chemical parameters

- **N transformations.** Plant available nitrogen concentrations (NO_3 and NH_4,) were measured in soil samples from 50 cm depth.

- **Other macronutrients and key chemical properties.** Potassium, phosphorus, soil electrical conductivity (salinity) and pH were measured in soil samples from 50 cm depth.

- **Phytotoxins (Bo, Cu, Ni and Zn).** These metals are common in soils at Lambton and although uncontaminated materials have been specified for the construction of the trial, measurements were undertaken as a check should any unexplained plant deaths occur. Levels were measured in soil samples from 50 cm depth.

1.3.3 Soil gas composition

Permanent gas wells (vented HDPE pipes and gravel backfill) were installed to depths of 50 cm and 150 cm in each plot in May 2007, and monitoring of all gas parameters was conducted on three occasions in August 2008, February 2009 and August 2009.

- **Carbon dioxide.** This provides an indication of microbial activity (aerobic respiration) within the soil.

- **Oxygen.** Oxygen concentrations are linked to rates of microbial respiration (CO_2 , CH_4) and may indicate rates of gas diffusion through subsurface soil layers.

- **Methane.** Methane production occurs due to microbial digestion under anaerobic conditions and is harmful to plant growth.

1.3.4 Plant growth

- **Tree height.** Four trees of two species (oak and alder) were randomly selected in each plot and their height measured from the base of the trunk to the top of the leading shoot.

- **General observations on plant health.** Visual assessment of selected trees was made on a monthly basis to monitor signs of disease.

- **Tree root development.** Qualitative assessment of root profiles of randomly selected trees from each of the treatments was undertaken by excavating a section in a soil pit in February 2009 and August 2009.

2.0 Results

2.1 Soil physical parameters

2.1.1 Aggregate Stability

Land Preparation	Compost:PMC	Sample date Aug-08	Feb-09	Aug-09
Loose tipped	**50:50**	64.3	79.4	62.7
	80:20	58.3	80.4	67.4
Wide track	**50:50**	65.0	78.8	69.4
	80:20	62.7	78.8	43.8
Narrow track	**50:50**	59.3	77.8	69.5
	80:20	65.0	78.2	67.1

Table 1: Soil aggregate stability

No significant differences in aggregate stability were observed between treatments. This can largely be attributed to difficulties in applying this test in highly stony artificial soil-forming materials.

2.1.2 Structural development

Qualitative assessment of the soil structural development conducted in February and August 2008, and August 2009 demonstrated that topsoil emplacement with bulldozers resulted in a much greater concentration of compaction, and a reduced degree of structural integrity, with poorly structured topsoil (site-won clay loam) and heavily compacted subsoil material. In marked contrast, loose tip emplaced plots displayed a much reduced degree of structural damage to the topsoil, with retention of natural soil structures, and a much less compacted underlying subsoil (see Photos 1 and 2).

Soil emplacement method: Loose tipped	Bulldozer
0 – 15cm Moderately stony coarse-Medium sub-angular blocky clay.	0 – 5 cm Moderately stony coarse – medium sub-angular blocky clay.
	5 – 15 cm Compacted poorly structured, moderately stony clay forming very coarse clods or platy aggregates.
15 – 50 cm Loose structureless colliery shale.	
	25 – 50 cm Very compacted structureless colliery shale.

Generalised soil profiles to 50 cm depth

Photo 1: root profile narrow track bulldozer plot August 2009

Photo 2: Root profile loose tipped plot August 2009

2.1.3 Penetrometer resistance

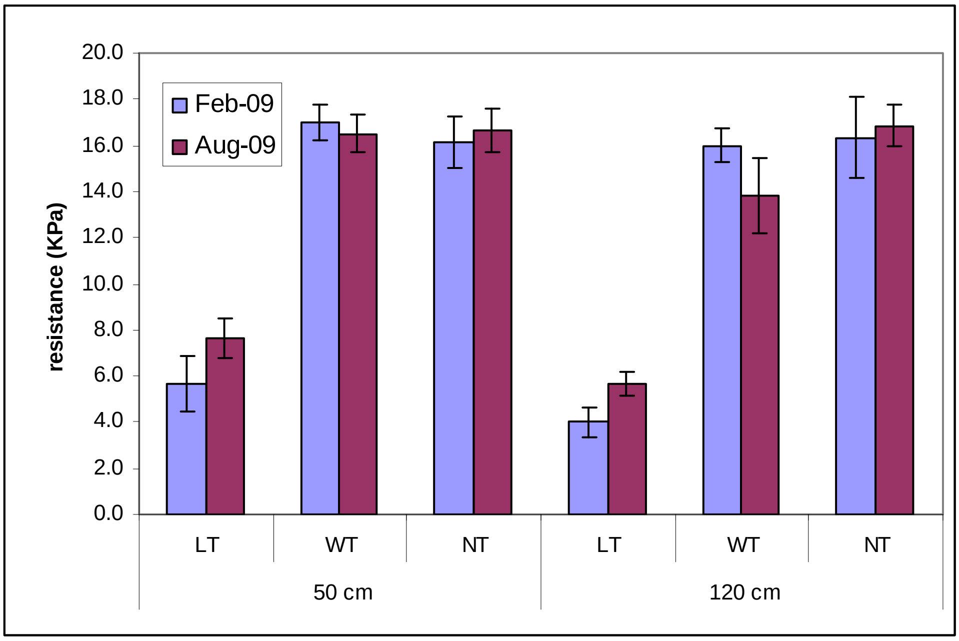

Figure 2: Soil penetrometer resistance

2.2 Soil chemical parameters

2.2.1 Nitrogen

Loose tip plots exhibited relatively high levels of soil nitrate but low ammonium, whereas the opposite was true on bulldozer prepared plots (Figure 3). There was also a significant interaction between land preparation method and organic amendment; when the higher application of paper mill crumb was applied in combination with bulldozer land preparation, a major increase in soil ammonia concentration occurred relative to the loose tip prepared plots. This increase did not occur when plots were prepared using the higher ratio of compost:paper mill crumb.

This pattern, also observed in previous monitoring indicates that the bulldozer prepared plots experience prolonged periods of anaerobism during the plant growing season. The absence of nitrifying soil bacteria (which only operate in aerobic conditions) likely explains the accumulation of ammonium in the bulldozer prepared plots. The difference in ammonium accumulation between organic treatments was also previously observed, and can be explained by the higher active nitrogen pool in the paper mill crumb compared with the PAS 100 compost. This suggests that green waste compost may be more suitable as a subsoil amendment, where a stable material would be preferable to one which will rapidly decompose.

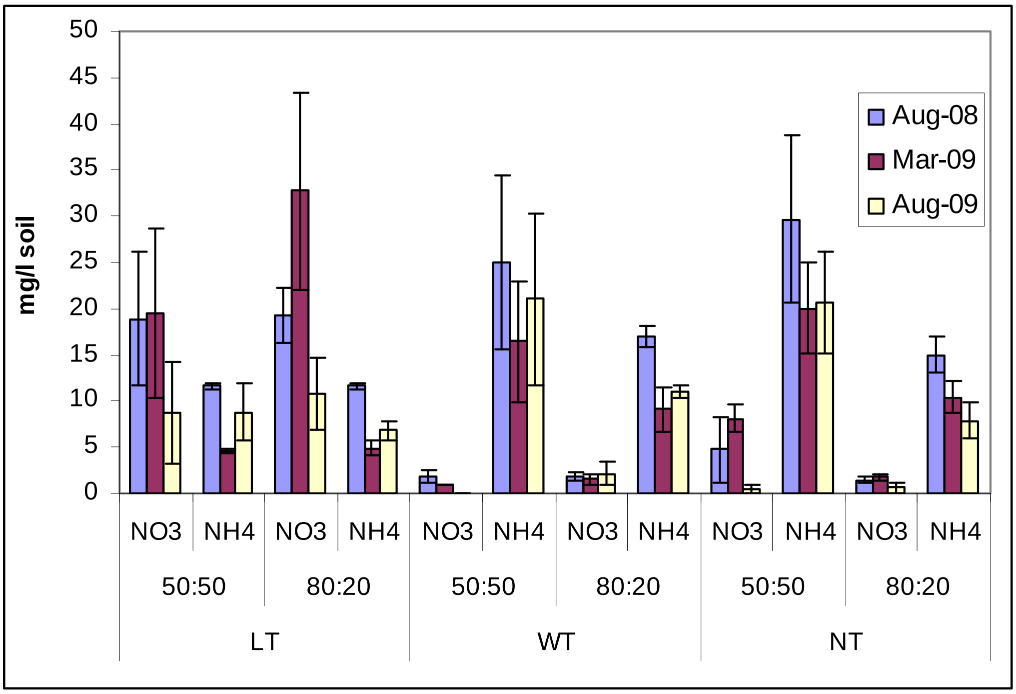

Figure 3: Soil available nitrogen concentrations

2.2.2 Nutrients and phytotoxins

Land preparation	Compost:PMC	NO3	NH4	P	K	Cu	Ni	Zn	Bo	EC(uS/cm)	pH	OM%
						Aug-2008						
Narrow track	50:50	4.7	25.0	17.0	830	82.0	19.3	136	1.1	1600	7.9	
	80:20	1.4	17.0	9.3	680	60.3	16.0	98	1.0	1467	7.8	
Wide track	50:50	1.8	29.7	13.3	840	57.7	17.7	133	1.3	1800	7.7	
	80:20	1.8	15.0	13.3	820	61.3	17.3	103	1.2	1367	7.8	
Loose tipped	50:50	18.9	11.7	22.0	707	61.3	17.7	116	1.5	1443	7.7	
	80:20	19.3	11.7	14.0	540	71.0	17.7	106	1.2	1433	7.7	
						Feb-2009						
Narrow track	50:50	8.1	20.0	6.3	387	61.0	18.7	128	0.9	2067	8.7	
	80:20	1.7	10.4	4.7	257	68.3	18.3	116	0.9	1766	8.4	
Wide track	50:50	1.0	16.4	8.3	327	63.0	21.0	130	1.3	1800	8.3	
	80:20	1.5	9.1	5.3	233	66.0	18.0	123	1.0	1666	8.5	
Loose tipped	50:50	19.5	5.6	13.0	340	76.3	23.0	140	1.4	1566	8.4	
	80:20	32.7	4.9	8.3	150	85.7	21.3	120	1.4	1633	8.4	
						Aug-2009						
Narrow track	50/50	1.0	21.3	10.7	830	52.7	16.3	96	0.9	1700	7.6	19.3
	80/20	0.6	7.9	9.4	663	55.7	14.7	127	0.7	1667	7.6	18.7
Wide track	50/50	0.0	21.0	27.3	987	55.3	15.7	107	1.3	1733	7.6	21.0
	80/20	2.1	11.1	13.0	697	54.3	15.0	87	0.7	1833	7.6	18.0
Loose tipped	50/50	8.7	8.8	21.3	533	55.0	17.3	96	1.2	1333	7.5	16.7
	80/20	10.8	6.8	21.3	350	55.7	18.7	99	1.0	1567	7.6	16.3

Table 2: Soil chemical properties

Addition of the higher rate of paper mill crumb resulted in a higher concentration of potassium and boron at all three sample dates (Table 2). Zinc levels were also higher with the 50:50 treatment at the first two sampling dates (in agreement with previous observations), although this pattern is not evident in the latest monitoring.

2.3 Soil gas concentrations

Concentrations of methane were found to be significantly higher in bulldozer prepared plots at both sample depths in August 2008 and February 2009 (Table 3). This suggests anaerobic conditions are generated in the compacted bulldozer prepared subsoils, through a combination of poor drainage (leading to waterlogging) and low oxygen diffusion rates. However, by the final sampling date, methane levels were very low in all plots, indicating a slowing of decomposition of organic material. There was no consistently observed difference between organic treatments effects.

Carbon dioxide concentrations were greater in the bulldozer prepared plots than the loose tipped plots, while the opposite was true of oxygen levels. This indicates a continuation of the trend observed in previous monitoring whereby gas diffusion rates in the loose tipped plots allow dissipation of CO_2 and exchange with atmospheric O_2.. This indicates healthier soil conditions in the loose tipped plots.

Land preparation	Compost:PMC	CH_4		CO_2		O_2	
		Aug-08					
		50 cm	**150 cm**	**50 cm**	**150 cm**	**50 cm**	**150 cm**
Loose tipped	50/50	0.1	7.2	0.0	5.7	12.3	14.7
	80/20	0.0	6.4	0.0	9.2	12.9	10.9
Wide track	50/50	14.9	12.2	21.3	24.3	9.7	10.1
	80/20	9.3	10.1	4.5	7.6	13.5	15.7
Narrow track	50/50	19.4	10.1	3.2	8.5	10.1	15.5
	80/20	10.4	11.9	14.3	24.4	14.1	10.6
		Feb-09					
Loose tipped	50/50	0.0	0.0	1.4	1.2	17.4	18
	80/20	0.0	0.0	0.8	3.9	17.9	15.8
Wide track	50/50	1.4	1.9	6.9	4.2	14.0	16.0
	80/20	6.2	8.0	4.0	13.8	15.7	8.4
Narrow track	50/50	5.5	13.8	0.7	14.1	18.8	10.4
	80/20	3.2	17.1	13.1	22.6	9.3	7.2
		Aug-09					
Loose tipped	50/50	0.0	0.0	0.0	8.1	20.8	14.4
	80/20	0.0	0.0	1.7	4.6	20.1	17.1
Wide track	50/50	0.0	0.2	2.3	2.9	18.8	19.1
	80/20	0.0	0.0	3.8	9.2	17.6	15.4
Narrow track	50/50	0.0	2.0	5.3	17.4	16.6	12.8
	80/20	0.0	0.3	5.8	16.2	16.2	10.2

Table 3: Soil gas concentrations

2.4 Plant growth

Both oak and alder trees grown on the loose tipped plots were significantly taller than those on either of the bulldozer treatments. However, over the monitoring period, growth rate of oak trees did not differ between treatments (Figure 3), with treatment differences being due to differential growth in the previous monitoring period (included in the Trailblazer project report). Growth of alder trees however, continued to be greater on the loose tipped plots than those prepared with a bulldozer. Alder are recognized to be well adapted to woodland creation on reclaimed sites, being rapidly establishing pioneers, able to fix atmospheric nitrogen to encourage nutrient cycling. In contrast oak is a relatively slow growing species not well adapted to sub-optimal soil conditions. This is reflected in the differences in tree heights between the two species.

Tree growth rates did not differ significantly between organic treatments. The main limitation to tree growth was the restricted rooting depth caused by the compacted subsoil in the bulldozer prepared plots. This limits plant access to water and nutrients to an extremely thin layer, and will be expected to persist as resistance levels have not dissipated over the monitoring period to levels allowing normal tree rooting.

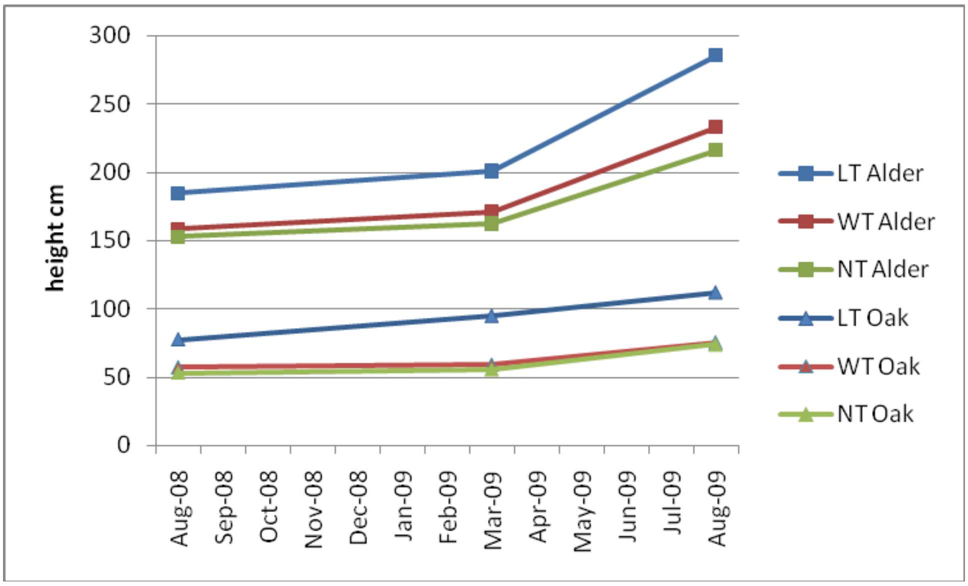

Figure 3: Tree growth rates 2008-2009.

2.4.1 General visual observations on plant health

No significant visual differences in chlorosis were noted. Trees on the bulldozer emplaced soils appear stunted in comparison to those on the loose tipped plots (Plate 1).

Plate 1: Wide tracked plot in the foreground with a loose tip in the mid-ground (Aug 09)

3.0 Conclusions and recommendations

The use of PAS 100 compost as a soil improver has shown demonstrable benefits in tree establishment. The combination of the 80:20 mix of compost to paper mill crumb with the loose tip emplacement method was shown to be the most effective means of woodland establishment.

The loose tip method is an important technique for successful woodland establishment; bulldozer land preparation should not be used. The use of a wide track bulldozer did not reduce problems of soil compaction relative to a conventional bulldozer.

Paper mill crumb has been shown to decompose relatively rapidly. This may make it useful as a topsoil amendment to supply plant nutrients, but it is less well suited as an additive to subsoil profiles, leading to relatively high levels of ammonium and methane production.

The study has also shown that choice of tree species is an important consideration in woodland establishment on sites lacking natural soil resources, particularly where rate of establishment is an important consideration. A significant proportion of “pioneer” species such as alder and birch is recommended.