vineland

RESEARCH & INNOVATION CENTRE




Alberta Highways Final Report

Soil Health and Tree Performance Five Years Post Remediation

Darby McGrath, PhD
Senior Research Scientist, Environmental Horticulture
darby.mcgrath@vinelandresearch.com

Ryan Munroe, MFC
Senior Research Technician, Environmental Horticulture
ryan.munroe@vinelandresearch.com

Charlene Williams, MFC
Research Technician, Environmental Horticulture
charlene.williams@vinelandresearch.com

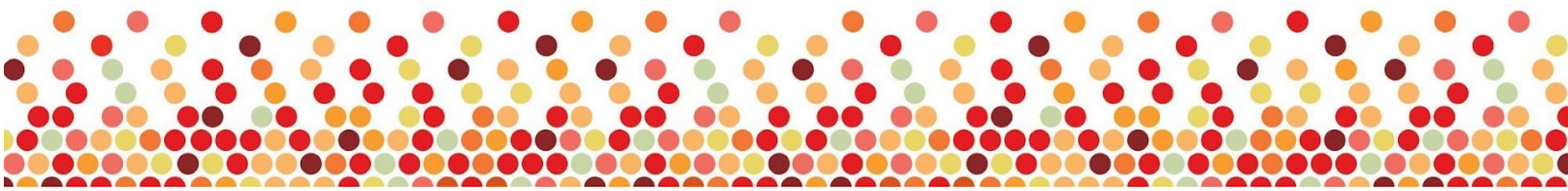


Table of Contents

Executive Summary

This report covers activities related to the soil assessment and tree monitoring conducted across two Alberta Highway Planting Trial sites by Vineland Research and Innovation Centre (Vineland) between August 2016 and August 2021. While the original trial included three testing sites, Calgary, Airdrie and Edmonton, this report covers the results of two sites with pre-restoration soil conditions more typical of urban and/or roadside conditions, Calgary and Airdrie respectively. Findings from Edmonton (2016 to 2019) were presented in the previous Greening Canada's Highways Report (p. 50-59), the summary results of which can be found in Appendix A. Vineland identified, collected and analyzed soil samples, prepared maps and corresponding soil health reports as well as designed and conducted follow up monitoring on the 96 trial trees located across the Airdrie and Calgary trial sites.

The Alberta Highway Planting Trial was designed to compare tree establishment and survival between the standard planting specification implemented by the Cities of Airdrie and Calgary and soil restoration treatments outlined by Vineland for highway roadside plantings. The trial consists of (i) pulp & paper residual and (ii) compost amendment treatments, (iii) a mechanical decompaction treatment and (iv) a standard planting practice 'control' treatment. All restoration treatments (decompaction, pulp and paper and compost amended beds) were implemented at both trial sites prior to planting in Spring 2016. Vineland's organic amendment soil restoration treatments were expected to improve tree establishment and growth by reducing soil compaction and increasing soil organic matter, soil permeability, water-holding capacity and overall soil health as compared to the 'control' standard planting specification used for highway roadside planting in Alberta. Based on previous research, the mechanical decompaction treatment was expected to provide moderate improvements to soil compaction and tree establishment.

Within this report, Vineland presents the results pertaining to:

- Airdrie and Calgary trial site soil health five years post- restoration (August 2021)
- Post-planting tree performance (August 2016- August 2021)

In the summer of 2017, 2019 and 2021, Vineland team members visited the Airdrie and Calgary trial sites to collect soil samples characterizing soil conditions throughout the five years following soil restoration. Post-planting tree assessments were conducted alongside soil sampling to characterize the performance of *Ulmus americana* 'Brandon' and *Fraxinus pennsylvanica* (multiple varieties) installed at both highway roadside planting sites.

NB. The current report builds on findings from 2016 and constitutes a continuation of the initial research conducted by Vineland on highway roadside plantings in Alberta. Full information related to the the design and implementation of soil restoration as well as initial post-planting tree performance is presented in the Greening Canada's Highways Report.

Soil Health and Tree Performance

Soil health refers to the capacity of soil to function as a complete ecosystem capable of supporting the myriad of organisms that live in the soil and by extension sustain plant, animal, and human life. Soil health is assessed using a set of indicators that encompass physical, chemical, and biological soil properties. Healthy soils provide regulating and supporting ecosystem functions such as nutrient cycling, water infiltration and retention, gas exchange, pest and disease regulation, biodiversity, and storage of carbon, many of which have notable impact on tree health, growth and establishment.

Tree performance refers to the overall vigor and productivity of a tree. Tree performance is evaluated at the individual level, where both quantitative and qualitative measures are used to assess tree health. Key indicators of tree performance, including caliper/diameter at breast height (DBH), height and canopy dieback, provide insight into a tree's response to its environment and can be used to evaluate potential for establishment and future growth.

Soil is the foundation that underlies tree performance. Understanding the relationship between soil health and tree performance is fundamental to improving tree establishment and growth. Where soil must have sufficient function to support such large and long lived organisms as trees, soil restoration, management and monitoring to build and maintain soil health are integral to the ongoing establishment and growth of trees in the landscape.

The degradation of soil health, resulting from management activities including the compaction and removal of topsoil associated with road construction, strips away soil organic matter and decreases the porosity of soil. Soil restoration works to address these basic, yet fundamental soil properties, supporting the successful establishment and growth of landscape trees, even in the harshest planting conditions.

Alberta Highway Planting Trial Design

Pre-restoration samples were collected in 2014 to capture the range of baseline soil conditions at Airdrie and Calgary highway roadside planting sites. Soil samples were analyzed by Vineland to assess bulk density, organic matter content and texture, whereby results were used to inform subsequent soil restoration planning and implementation. Four soil treatments were designed to evaluate the impact of various soil restoration strategies on tree establishment under the harsh growing conditions characteristic of highway and roadside plantings. The aforementioned soil treatments are outlined in **Table 1**, below.

Table 1. Overview of soil treatments implemented at Airdrie and Calgary highway roadside planting sites.

Treatment	Description
Pulp & Paper	Deep ripping +amendment with composted Pulp & Paper Residuals (15% v/v) + tilling
Compost	Deep ripping + amendment with municipal compost (15% v/v) + tilling
Decompaction	Deep ripping + tilling
Control	Excavate planting hole 2 times the size of root ball and install imported raw topsoil (requires disposal of excavated soil off-site)

Soil treatments were applied locally at both Airdrie and Calgary sites, resulting in four distinct treatment beds. A total of 24 trees were planted into each treatment to assess the impacts of soil restoration on tree performance and growth. 12 *Ulmus americana* 'Brandon' and 12 *Fraxinus pennsylvanica* (multiple varieties) were installed into each of the four soil treatments and monitored annually to track performance over time (**Figure 1**).

Figure 1. Overview of tree species installed into each of the four soil treatments at both Airdrie and Calgary trial sites.

The municipal compost used for the 'Compost' treatment met most compost quality standards within Canada in 2016. Best practices for the application of organic amendments on roadside planting suggest that lower sodium content is preferred, although compost quality is limited by the relevant composting process and feedstock used. The Pulp & Paper Residuals used for the 'Pulp & Paper' treatment met all relevant land application requirements. For full amendment details see **Tables 2A.** and **2B.**, below.

Table 2. Results of Compost Analyses conducted in 2016 for Pulp & Paper Residuals (**A**) and Compost (**B**) used to amend treatment beds at both Airdrie and Calgary trial sites. Results in green fall within the recommended range, whereas those in red refer to parameters exceeding the recommended range for soil restoration.

A. Pulp and Paper Residuals Analysis (2016)

Parameter	Result
pH	6.6
OM	100%
Moisture	81.6%
C:N ratio	22:1
Soluble Salts	1.77 mS/cm
CO_2 Respiration	Not reported
Total N	2.3%
P (ppm)	3330
K (ppm)	601
Available Na	338 ppm, 3.0 % Na+ base saturation
Texture	Not reported

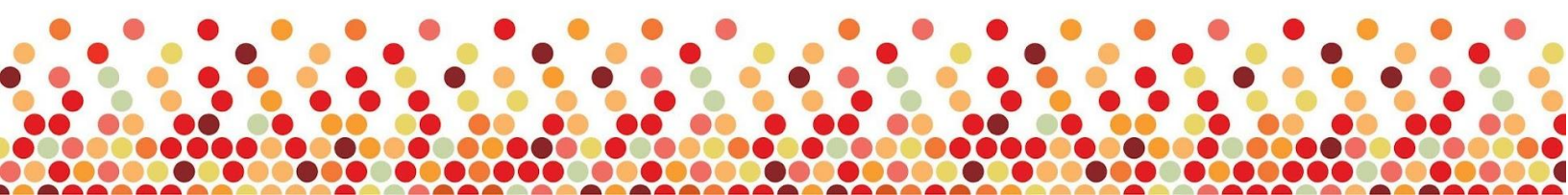
B. Compost Analysis (2016)

Parameter	Result
pH	8.1
OM	39%
Moisture	35%
C:N ratio	17:1
Soluble Salts	2.4 ms/cm
CO_2 Respiration	Stable and mature (8/9)
Total N	1.3%
P (ppm)	511
K (ppm)	3135
Available Na	262 ppm, 2.3 % Na+ base saturation
Texture	Fine texture (90% passing through ¼ inch sieve)

Soil Sampling

Soil samples were collected in late Summer of 2016, 2017, 2019 and 2021 to monitor changes over time in the 'Pulp & Paper', 'Compost', 'Decompaction' and 'Control' planting beds. Soil samples were not collected in the Summer of 2018 due to a gap in funding for the project, or in 2020 due to travel restrictions related to the COVID-19 pandemic.

A total of 12 localized samples were collected across 0-10cm and 20-30cm depths for all four soil treatments at both Airdrie and Calgary highway roadside planting sites. One composite sample was collected across the 0-30cm range from all treatment beds. Each composite sample was comprised of six sub samples and is intended to be representative of soil conditions within a given planting bed. Soil samples were processed and analyzed in-lab, where results are presented in the sections titled 'Airdrie' and 'Calgary', below.



Tree Monitoring

Post planting tree assessments were also conducted in late Summer of 2016, 2017, 2019 and 2021 and captured tree survival, height, caliper, DBH, canopy dieback and shoot extension for all 96 trees planted at both Airdrie and Calgary highway roadside sites. Tree assessments were not completed in the Summer of 2018 due to a gap in funding for the project, or in 2020 due to travel restrictions related to the COVID-19 pandemic. Post planting tree performance data is summarized for each site in the sections titled 'Airdrie' and 'Calgary', below.

Overview of Monitoring Approach

Trial Sites

Airdrie

- Ball and burlap caliper trees planted Spring 2016
- Located on the north east cloverleaf at Veterans Boulevard and Highway 2
- Treatment beds oriented east to west
- History of tree planting failure
- Highly compacted, low organic matter content, poor quality soil

Calgary

- Ball and burlap caliper trees planted Spring 2016
- Located on the north east cloverleaf at Blackfoot Trail and Glenmore Road
- Treatment beds oriented east to west
- Large mature poplar on-site, indicating sufficient soil quality to support trees
- Moderately compacted, medium organic matter content, good quality soil

Figure 2. The tracked piece of equipment used to spread organic amendment evenly on the Pulp and Paper Residuals and Compost planting beds (left). Right: three rear-mounted tines (60 cm depth) were also used on all three trial sites to perform deep ripping. This was performed on all treatment beds except the 'control' beds.

Figure 3. Airdrie trial site before treatment beds were created (top left), just after treatment beds were installed (2015) and soon after trees were transplanted (Spring 2016).

Figure 4. Calgary trial site before treatment beds were created (top left), just after treatment beds were installed (2015) and soon after trees were transplanted (Spring 2016).

Understanding Key Performance Indicators

Soil Health

Soil Compaction

Soil compaction breaks down the soil structure and subsequently restricts the movement of air, water and nutrients, while physically restricting root development. Construction activities often involve the complete removal of a friable high quality topsoil, the compaction of subsoil by heavy machinery and the addition of a thin layer of low quality topsoil. This type of soil will go through cycles of flooding and drought, and will provide only limited oxygen levels to tree roots. Compacted soils offer a difficult rooting environment because of their decreased pore space, due to lack of both macropores and micropores**.**

Soil Organic Matter

Soil organic matter (OM) is a term used to encompass the various organic constituents of soils, including living organisms and plant residues, as well as detritus and the more stable form of organic matter, called humus. Soil health is understood to be closely related to soils having enough soil organic matter to provide a range of physical, chemical and biological functions. These include: adequate water retention and infiltration, soil aeration, nutrient retention and availability, and diverse and robust soil microorganism communities. Low levels of OM results in reductions in water holding capacity of soils. Further, increasing SOM is an important strategy for reducing compaction as OM is essential to create soil aggregates and increase soil pore space.

Tree Performance

Caliper/ DBH

Caliper, DBH and other above ground properties are largely influenced by soil condition, via the soil-root interface. Key soil properties including pH, EC and the concentration of macro and micro nutrients are known to affect tree growth and development.

Height

Tree height measures the total height of the tree from the base of the stem to the top of the highest branch. Tree height is similarly influenced by soil condition by way of root development and growth. Key soil properties including texture, bulk density and compaction are known to affect root growth, either permitting or limiting the roots ability to extend across the soil profile to extract the resources required to support growth.

Canopy Dieback

Canopy dieback refers to the progressive death of twigs, shoots and branches from the terminal end moving downward toward the central stem of the tree and is an indicator of decline. Key soil properties such as soil OM content are known to influence canopy growth and productivity over time.

Airdrie

Soil Health and Tree Performance 5 Years Post-Remediation

Soil Health Report - Airdrie													
		Pulp & Paper			Compost			Decompaction			Control		
		0-10cm	20-30cm		0-10cm	20-30cm		0-10cm	20-30cm		0-10cm	20-30cm	
Physical	Soil Texture	Sandy Clay Loam			Sandy Clay Loam			Sandy Clay Loam			Sandy Loam		
	Bulk Density	1.25	1.53	Optimal	1.22	1.45	Optimal	1.75	1.72	High	1.69	1.79	Moderate
	Coarse Material (%)	3.4	3.3		7.7	6.5		4	3.8		4.7	2.5	
	Soil Compaction (psi)	85.34	168.31	Low	196.75	412.47	Moderate	177.79	327.13	High	244.16	457.51	High
Biological	Soil Organic Matter (%)	8.96	4.67	Optimal	10.55	3.23	Optimal	3.58	1.73	Low	4.10	2.63	Moderate/Low
Chemical	pH	8.4		High	8.4		High	8.5		Very High	8.6		Very High
	Electrical Conductivity (mS/m)	2.68		High	2.9		High	2.36		High	2.87		High

- Improved physical and biological performance in treatments with Pulp & Paper and Compost amendments
- Poor soil health associated with mechanical decompaction, including low soil OM as well as root limiting bulk density and compaction
- Moderate to poor soil health associated with replacement of planting hole soil with imported topsoil material (Control)
- Consistently high pH and electrical conductivity (EC) across all treatments, likely representative of the broader site condition (as opposed to the individual treatments)
    - High pH and EC are often associated with highway and other roadside sites given the runoff and the accumulation of road salt in soil
- **Improved soil health associated with Pulp & Paper and Compost as compared to Control demonstrates the continued impact of pre-planting soil restoration or soil physical, biological and chemical properties, five years post restoration and six years post planting**

Soil health is integral to establishment and growth, particularly that of newly planted trees. At the time of planting, transplanted trees need to build and re-establish their root systems in order to extract water and nutrients from the new soil environment. The building and re-establishment of a tree's root system, requires root extension and growth, which is largely impacted by key soil properties such as soil compaction and bulk density. **Figure 5** shows the relative root penetration through soil according to treatment as influenced by soil compaction measured five years post-restoration. Note that compaction results should be applied toward understanding differences between soil treatment where measurements only reflect soil compaction at the particular point in time at which measurements were taken (Summer 2021).

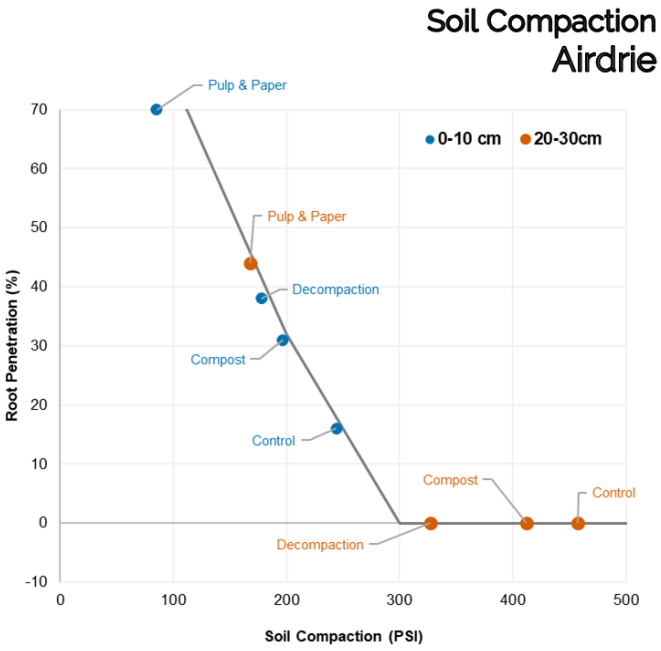


Figure 5. Root penetration as influenced by soil compaction, presented according to treatment at the Airdrie trial site.

- Pulp & Paper is the only soil treatment allowing for root penetration and growth across the entire rooting zone(0-30cm)
- 0% root penetration through soil beyond 20cm depth for Compost, Decompaction and Control treatments

Organic matter is needed to support the soil physical, biological and chemical conditions required for tree growth and establishment. **Figure 6** presents the percentage of soil organic matter in each treatment bed at the Airdrie trial site.

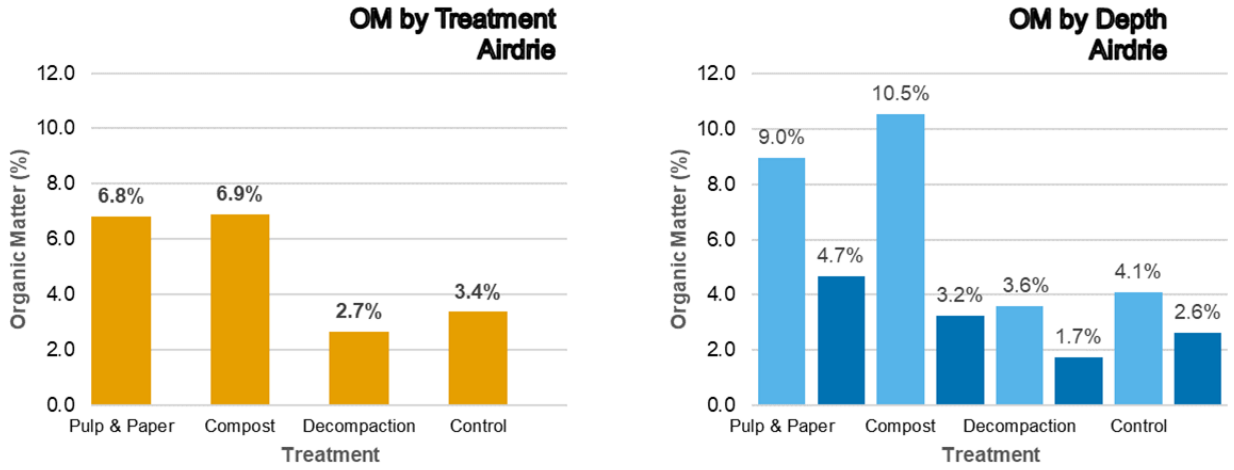


Figure 6. Soil organic matter, by treatment as well as by treatment and depth at the Airdrie trial site.

- Increased soil organic matter associated with soil restoration that includes the incorporation of organic amendments (Pulp & Paper and Compost)
- Lower soil organic matter in Decompaction treatment as compared to Control condition, demonstrating that soil disruption for the purposes of decompaction without associated addition of an amendment can contribute toward the overall loss of organic matter

- Soil organic matter is generally observed to decrease with increasing soil depth, although treatment level trends are maintained across both 0-10cm and 20-30cm depths. The tillage equipment used to prepare the Pulp & Paper and Compost beds was not very effective at incorporating organic amendments deeper than 20 cm.

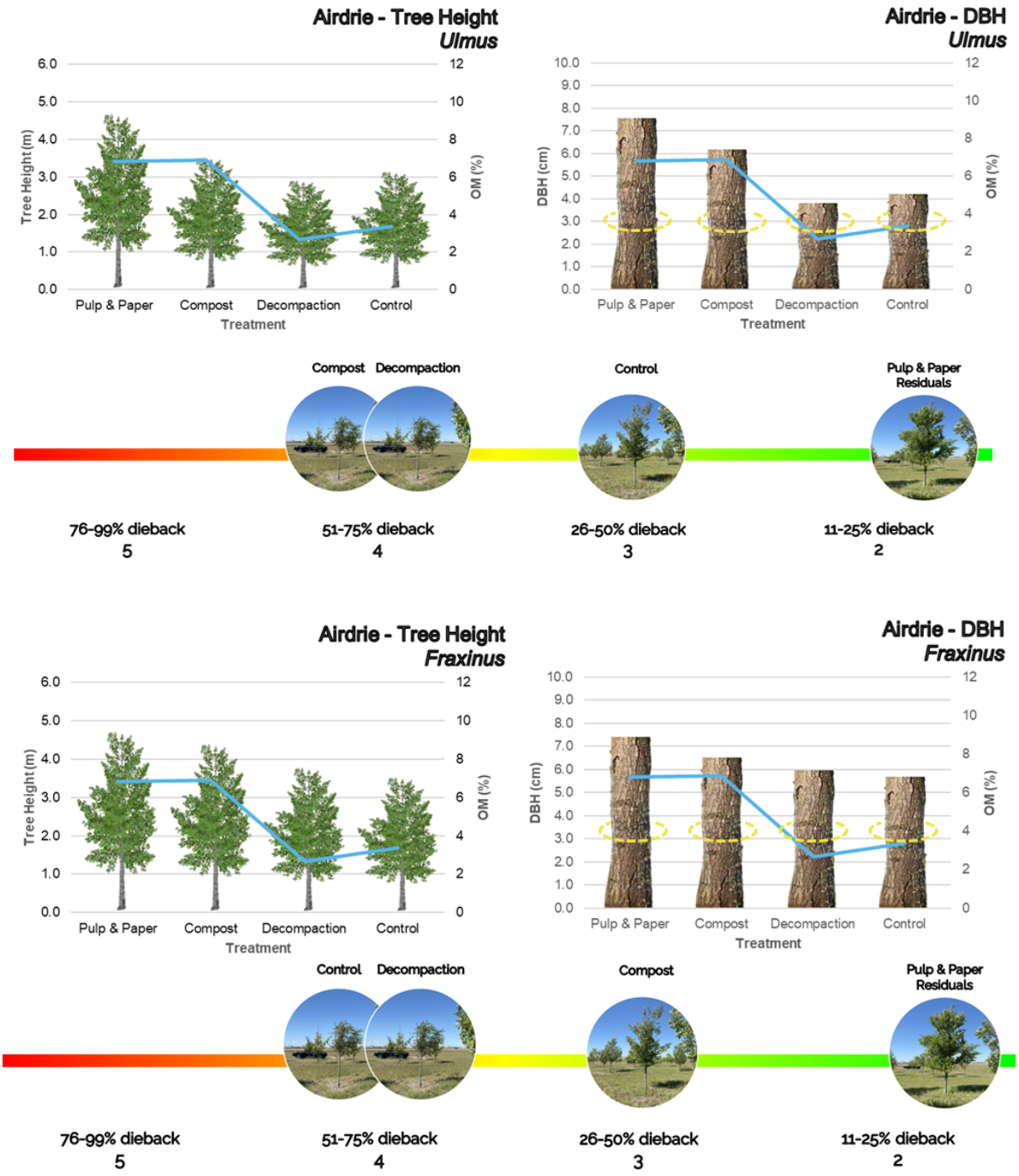


Figure 7. Summary of tree performance (height, stem growth (DBH) and canopy dieback) for *Ulmus* and *Fraxinus* trees according to treatment for the Airdrie trial site.

- Increased soil organic matter is associated with greater tree height and stem growth as well as reduced canopy dieback for both *Ulmus* and *Fraxinus* trees
- *Ulmus* and *Fraxinus* trees in planting beds amended with Pulp & Paper Residuals demonstrated improved overall performance as compared to their Compost, Decompaction and Control counterparts
    - Improved performance is consistent with the high soil health associated with the Pulp & Paper treatment
- **Notable increase in performance between Pulp & Paper and Control demonstrates the impact of soil restoration, particularly restoration using an organic amendment on tree establishment and growth, six years post planting**

Calgary

Soil Health and Tree Performance 5 Years Post-Remediation

Soil Health Report - Calgary

		Pulp & Paper			Compost			Decompaction			Control		
		0-10cm	20-30cm		0-10cm	20-30cm		0-10cm	20-30cm		0-10cm	20-30cm	
Physical	Soil Texture	Sandy Loam			Sandy Clay Loam			Sandy Clay Loam			Sandy Loam		
	Bulk Density	1.01	1.45	Optimal	1.43	1.63	Moderate	1.56	1.58	Moderate	1.54	1.66	Moderate
	Coarse Material (%)	5.71	1.5		3.65	1.74		3.5	1.26		1.92	6.06	
	Soil Compaction (psi)	177.79	379.28	Moderate	292.05	474.34	High	277.35	450.40	High	265.50	495.43	High
Biological	Soil Organic Matter (%)	9.47	4.17	Optimal	8.15	4.23	Optimal	6.57	3.83	Optimal	6.37	2.93	Optimal
Chemical	pH	7.8		High	7.9		High	8.0		High	8.0		High
	Electrical Conductivity (mS/m)	2.74		High	2.86		High	2.18		High	1.77		High

- Optimal soil OM across all treatments at 0-10cm depth contrasted by consistently moderate levels of OM at the 20-30cm depth
- Notably greater OM in treatments amended with Pulp & Paper and Compost
- Reduced bulk density and soil compaction associated with Pulp & Paper amendment as compared to all other treatments
- Consistently high pH and electrical conductivity (EC) across all treatments, likely representative of the larger site condition (as opposed to the individual treatments)
    - High pH and EC are often associated with highway and other roadside sites given the runoff and the accumulation of road salt in soil
- **Improved soil health associated with Pulp & Paper as compared to Control demonstrates the continued impact of pre-planting soil restoration on soil physical, biological and chemical properties, five years post restoration and six years post planting, despite relatively good soil conditions at the time of planting**

The post-planting development of a tree's root system is largely affected by soil compaction. **Figure 8** shows the relative root penetration through soil according to treatment at the Calgary trial site as influenced by soil compaction measured five years post-restoration.

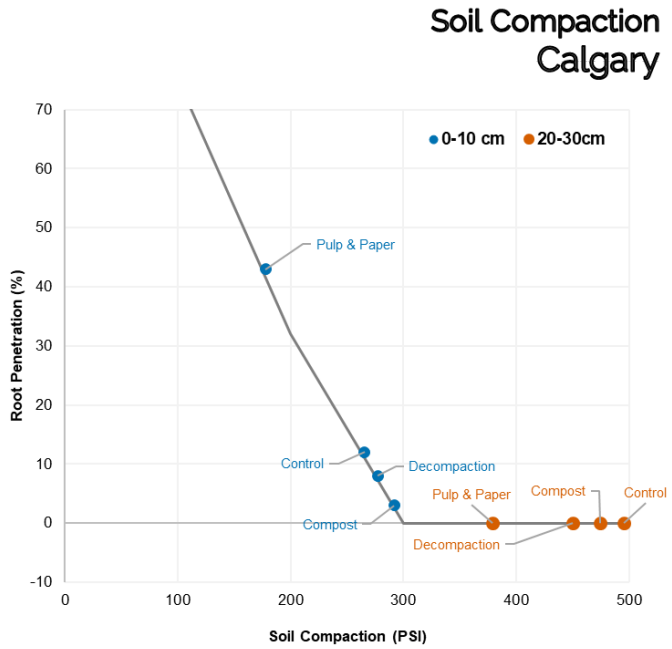


Figure 8. Root penetration as influenced by soil compaction, presented according to treatment at the Calgary trial site.

- Greatest root growth potential in Pulp & Paper treatment
- < 20% root penetration through soil between 0 and 10cm for Compost, Decompaction and Control treatments
- 0% root penetration through soil beyond 20cm depth for all treatments

Note that compaction results should be applied toward understanding differences between soil treatment where measurements only reflect soil compaction at the particular point in time at which measurements were taken (Summer 2021).
Organic matter is needed to support the soil physical, biological and chemical conditions required for tree growth and establishment. **Figure 9** presents the percentage of soil organic matter in each treatment bed at the Calgary trial site.

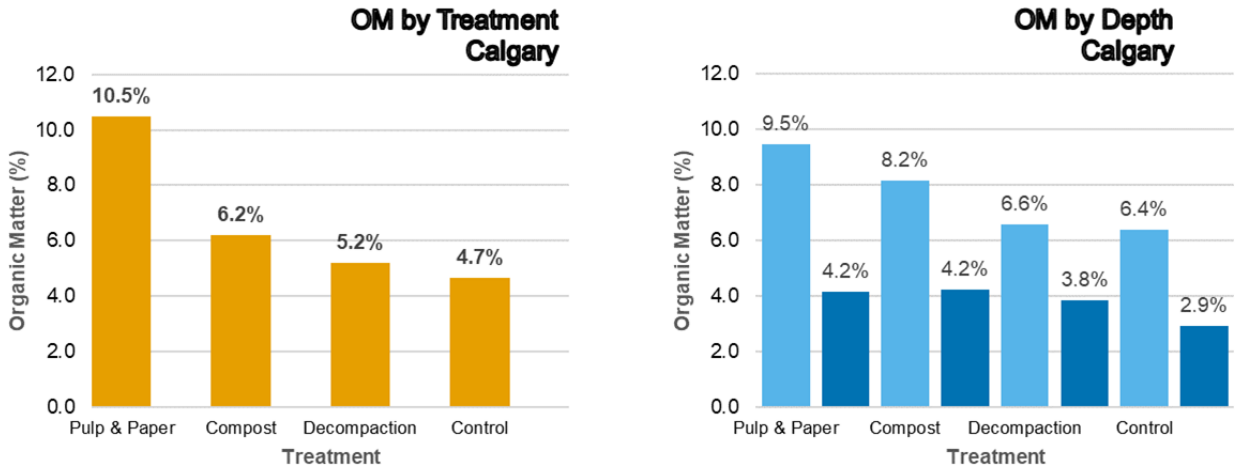


Figure 9. Soil organic matter, by treatment as well as by treatment and depth corresponding to the Airdrie trial site.

- Increased soil organic matter associated with soil restoration that includes the incorporation of organic amendments
- Soil organic matter is generally observed to decrease with increasing soil depth, although treatment level trends are maintained across both 0-10cm and 20-30cm depths

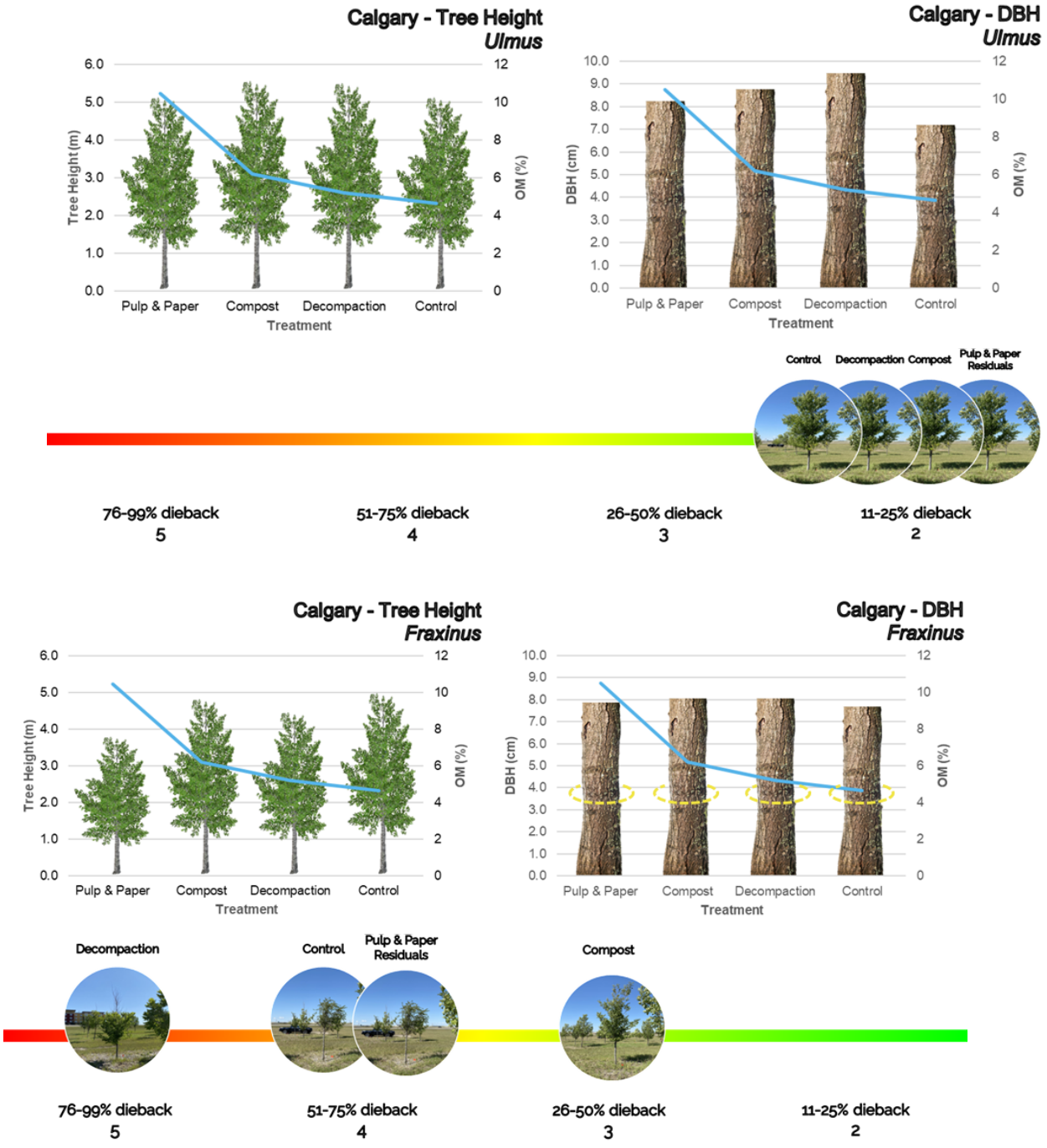
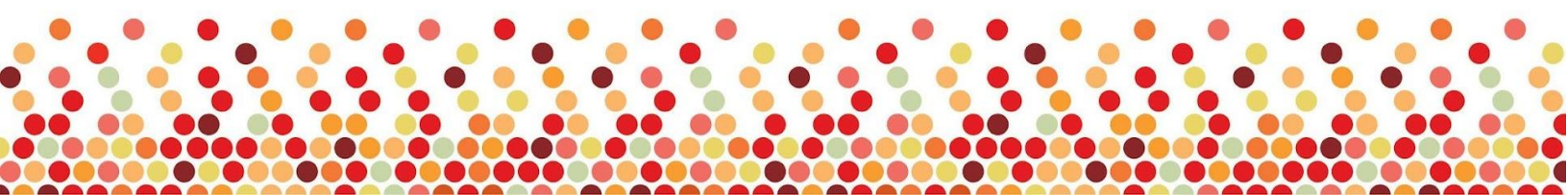


Figure 10. Summary of tree performance (height, stem growth (DBH) and canopy dieback) for *Ulmus* and *Fraxinus* trees according to treatment for the Calgary trial site.

- Tree assessments showed consistent height, stem growth and minimal canopy dieback regardless of soil treatment for *Ulmus* trees
    - Results suggest 'no impact' associated with soil restoration on overall tree performance for *Ulmus* at the Calgary trial site
    - Soil sampling conducted prior to planting showed baseline soil conditions that were inherently more favorable for tree establishment and growth. The subsequent soil restoration conducted on these 'healthier' soils contributed toward additional increases to soil quality. Tree performance for *Ulmus* is uniformly high across all four trial treatments given the comparatively high soil health occuring at the site level.
- Lesser height and increased canopy dieback was observed for *Fraxinus* trees in planting beds amended with Pulp & Paper Residuals
    - The reduced performance of *Fraxinus* contrasts with the positive findings for the same Pulp & Paper treatment at the Airdrie trial site. Soil conditions prior to planting were found to be more favorable for tree establishment and growth in Calgary as compared to Airdrie. The pulp and paper residuals amendment potentially impeded drainage through excessive water holding capacity and reduced actual water availability, in part due to insufficient depth of incorporation with the soil when the planting beds were established. Phosphorus and sodium levels were also excessive, which can pose problems for the establishment of beneficial mycorrhizal fungi, and for water uptake, respectively.
    - High organic matter in soil is known to support the increased growth and productivity of not just trees, but all vegetation, which in the case of the Calgary trial site included grass and ground vegetation surrounding planted trees. Increased frequency of mowing and other maintenance activities is likely to have contributed toward the stem damage observed across the Calgary trial site. Stem damage is known to negatively impact tree growth and performance and may account for the reduced performance of *Fraxinus* in Pulp & Paper planting beds.
- **The lack of enhanced tree performance associated with soil restoration treatments in Calgary supports the practice of baseline soil testing, which should then be used to determine whether an organic amendment is needed to improve soil health and tree establishment, and if so, the appropriate quantity and quality of organic amendment to use.**



Key Takeaways on Soil Health and Tree Performance

The results of the Alberta Highway Planting trials demonstrate that soil health and tree performance are inherently linked. It is critical to measure and monitor both soil and tree health to better understand the establishment and growth of trees in the landscape. Key takeaways, derived through 7 years of follow up monitoring and analysis of the Alberta Highways Planting Trial are summarized below and can be used to inform best practices for highway roadside plantings in the future.

- Moderate amounts of mature, stable, high-quality organic amendments can generate sustained improvements to highway roadside soil health and, in turn, tree establishment.
- Simply reporting tree survival alone does not tell us anything about the actual contribution of trees to canopy cover increases, which is the stated goal of most urban forest management plans.
- Soil restoration with a Pulp & Paper based organic amendment is associated with improved soil health (as was measured in this study) at both Airdrie and Calgary highway trial sites.
- Soil health was generally positively associated with improved tree performance as characterized by tree height, stem growth (caliper and DBH) and canopy dieback.
- Moderation is key to the improvement of soil health, particularly as it pertains to tree growth and establishment. Where soil conditions are already favorable for tree establishment and growth, soil restoration involving the addition of organic amendments can contribute toward increases to soil organic matter that exceed the range of what is optimal, which in turn can be detrimental for tree establishment and growth

Tree Performance Photo Monitoring by Treatment (2016-2021)

Airdrie - *Ulmus*

2016 (early September)


Pulp & Paper


Compost


Decompaction


Control

2017 (early September)


Pulp & Paper


Compost


Decompaction


Control

2019 (late August)

Pulp & Paper

Compost

Decompaction

Control

2021 (late August)

Pulp & Paper

Compost

Decompaction

Control

Airdrie - *Fraxinus*

2016 (early September)

Pulp & Paper

Compost

Decompaction

Control

2017 (early September)

Pulp & Paper

Compost

Decompaction

Control

2019 (late August)

Pulp & Paper

Compost

Decompaction

Control

2021 (late August)

Pulp & Paper

Compost

Decompaction

Control

Airdrie Site – Elm, Treatment 1 – Pulp and Paper, Tree 11

2016 2017 2019 2021

Airdrie Site – Elm, Treatment 2 – Compost, Tree 11

2016 2017 2019 2021

Airdrie Site – Elm, Treatment 3 – Deep-rip, Tree 11

2016 2017 2019 2021

Airdrie Site – Elm, Treatment 4 – Control, Tree 11

2016 2017 2019 2021

Airdrie Site – Ash, Treatment 1 – Pulp and Paper, Tree 2

2016 2017 2019 2021

Airdrie Site – Ash, Treatment 2 – Compost, Tree 2

2016 2017 2019 2021

Airdrie Site – Ash, Treatment 3 – Deep-rip, Tree 2

2016 2017 2019 2021

Airdrie Site – Ash, Treatment 4 – Control, Tree 2

2016 2017 2019 2021

Calgary - *Ulmus*

2016 (early September)


Pulp & Paper


Compost


Decompaction


Control

2017 (early September)


Pulp & Paper


Compost


Decompaction


Control

2019 (late August)

Pulp & Paper

Compost

Decompaction

Control

2021 (late August)

Pulp & Paper

Compost

Decompaction

Control

Calgary - *Fraxinus*

2016 (early September)

Pulp & Paper

Compost

Decompaction

Control

2017 (early September)

Pulp & Paper

Compost

Decompaction

Control

2019 (late August)


Pulp & Paper


Compost


Decompaction


Control

2021 (late August)


Pulp & Paper


Compost


Decompaction


Control

Recommended Organic Amendments

Compost quality analysis was conducted on all amendments used across Ontario and Alberta Highways Planting Trial sites between 2014 and 2016. Results are summarized below and can be used to inform best practices for soil restoration related to highway roadside plantings in the future.

	Alberta Airdrie and Calgary Sites		Ontario Site #1	Ontario Site #2
	Pulp & Paper Residuals	Compost	Compost	Compost
pH	6.6	8.1	7.6	6.3
OM	100%	39%	51.5	43.8
Moisture	82%	35%	Not Reported	Not Reported
C:N	22:1	17:1	12:01	13:01
Soluble Salts	1.8	2.4	Not Reported	Not Reported
CO2 Respiration	Not Reported	Stable and mature (8/9)	Not Reported	Not Reported
Total N	2.3%	1.3%	2.5%	2.2%
P (ppm)	3330	511	868	740
K (ppm)	301	3135	4581	3211
Available Na	338, 3% Na+ base saturation	262, 22.3% Na+ base saturation	Not Reported	Not Reported
Texture	Not Reported	Fine texture (90% passing through 1/4 inch sieve)	Not Reported	Not Reported

Appendix A: Edmonton Highway Planting Trial

Edmonton Highway Trial Site

Site Description

- Ball and burlap caliper trees planted Spring 2016
- The testing site is located south of Anthony Henday Dr. (west side of 17th street)
- Former agricultural field without a legacy of construction
- Pre-restoration soil quality was high; largely uncompacted with high organic matter content

Notes on Treatment Beds

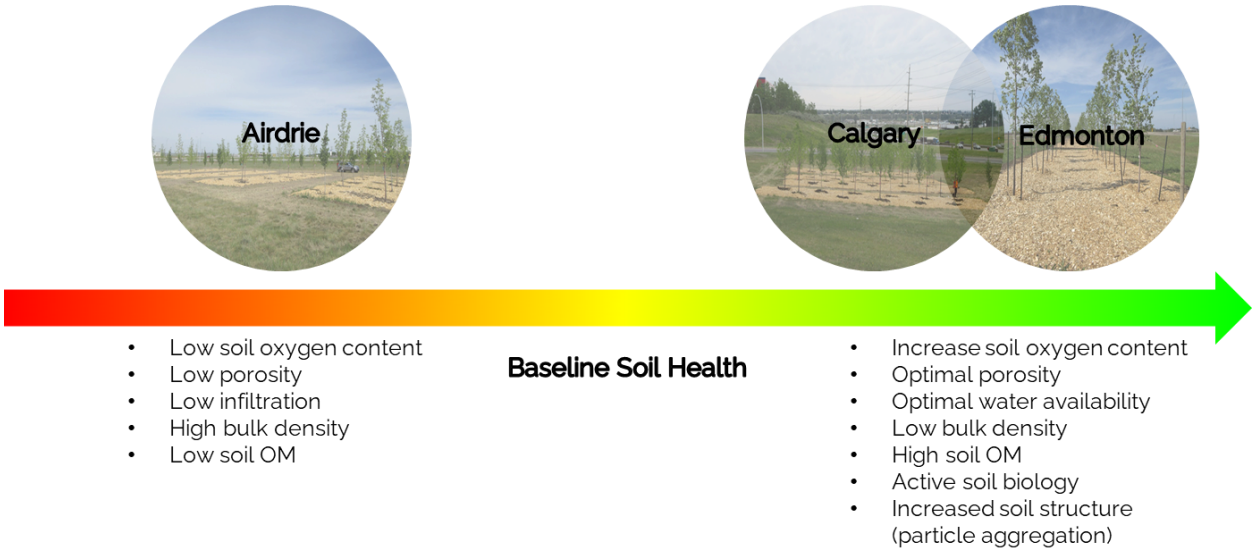
- Treatment beds oriented south to north
- Quality of the compost added to the 'compost treatment bed' was determined to be of low quality (high soluble salts)

2019 Tree Performance

- 100 % survival in all treatments
    - With the exception of *Ulmus* planted into beds amended with Pulp & Paper which demonstrated only 33 % survival
    - 40-60% canopy dieback in *Ulmus* across all other tree treatment beds
- 40-75% canopy dieback in *Fraxinus* planted into beds amended with Pulp & Paper and Compost
- 20% canopy dieback for *Fraxinus* planted into Decompaction and Control beds

Summary of Results

- The high quality pre-restoration soil (un-compacted, high organic matter soil with no major construction legacy) did not make this site a good testing site for urban roadside conditions
- Given that the post-restoration soil quality was already quite high, the addition of organic amendments did not provide additional benefits to the trees
    - This impeded drainage through excessive water holding capacity and reduced actual water availability through creation of 'peat-like' soil. Phosphorus and sodium levels were also excessive.
- The compost quality was poor and had high quality soluble salts; the ranges are likely to have exceeded the range of what is optimal for tree establishment.
- For these reasons, the Edmonton site was removed from the 2 additional years (2019 and 2021) of site monitoring



Baseline soil health across the three identified Alberta Highway Planting Trial sites. High bulk density and low soil organic matter are associated with poor soil health, whereas low bulk density and high soil organic matter is associated with optimal soil health, in this case prior to soil remediation. High baseline soil health at Edmonton made this site a poor test site for urban roadside conditions.

Tree Performance Photo Monitoring by Treatment (2016-2019)

Edmonton - *Ulmus*

2016 (early September)

Pulp & Paper | Compost | Decompaction | Control

2017 (early September)

Pulp & Paper | Compost | Decompaction | Control

2019 (late August)

Pulp & Paper | Compost | Decompaction | Control

Edmonton - *Fraxinus*

2016 (early September)

Pulp & Paper Compost Decompaction Control

2017 (early September)

Pulp & Paper Compost Decompaction Control

2019 (late August)

Pulp & Paper

Compost

Decompaction

Control

Vineland Research and Innovation Centre
4890 Victoria Avenue North, Box 4000
Vineland Station, ON L0R 2E0

tel: 905.562.0320

vinelandresearch.com

CANADIAN AGRICULTURAL PARTNERSHIP

Ontario

Canada