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Original article

Crown reaction and acclimation to cyclical V-trimming of city trees: An analysis using terrestrial laser scanning

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ABSTRACT

Trimming is an important practice for reducing potential contact between trees and power lines. V-trimming occurs when a tree is located directly under the electrical wires and results in the formation of a bilateral crown, but not much is known about a tree's reaction and acclimation to such a repeated stress in an urban context.

Using Terrestrial Laser Scanning (TLS), we present a study that focuses on documenting (i) short term effect of V-trimming on the tree structure, through the quantification and analysis of the dispersion of trimming induced branch loss and subsequent growth reaction, and, (ii) long term acclimation (i.e. changes in biomass location) of tree structure to repeated unidirectional trimming. A voxelisation method was used to derive space exploration metrics from TLS data based on explored volume quantification and voxels dispersion within the tree crown.

Our results show that V-trimming induces a significant decrease in explored crown space volume (12.8% on average) but that this loss is regained by trimmed trees within only 1 year following trimming thanks to a rapid regrowth rate. This was supported by an analysis of radial growth that showed that the growth of trimmed trees was greater than non-trimmed trees although this tendency was not statistically significant. In our study this regrowth was achieved without suckering; instead the regrowth mainly occurred within the crown periphery. We also observed that trimming had a significant influence on the way trees explore space with their crowns. While non-trimmed trees explored space preferentially toward a South direction, trimmed trees explored space in directions perpendicular to the wires (East and West). We also observed that crown biomass was located more in the extreme crown periphery in trimmed trees compared to non-trimmed trees.

1. Introduction

In urban areas, maintenance of power lines requires regular tree trimming that involves removing branches growing within a specific distance from the wires (Dupras et al., 2016). V-trimming occurs when trees are located directly under the power lines and results in a bilateral crown, creating a gap within which the wires can be free of any surrounding branches (Millet and Bouchard, 2003). After trimming, trees present a strong growth reaction in the form of fully reiterated branches emerging from epicormic bud dormancy release, usually called suckers (Millet and Bouchard, 2003, note that other studies may refer to suckers as watersprouts). Due to a high growth rate, suckers require regular removal in order to respect clearance standards. In this way, pruning interventions are cyclic, every 3 years for the city of Montreal.

In unidirectional pruning, such as V-trimming, the proportion of tree crown composed of suckers increases with pruning intensity (Millet and Bouchard, 2003). Suckers also exhibit a polyarchic organization plan (Millet and Bouchard, 2003) resulting in a higher growth rate compared to non-pruned trees (Marquier and Balandier, 2000; Millet and Bouchard, 2003) or non-pruned branches within a single tree (Millet and Bouchard, 2003; Follett et al., 2016). Sucker initiation has been extensively studied in the context of timber production (see Meier et al., 2012 for an extensive review). Epicormic release has been shown to positively correlate with multiple factors such as an increase in light availability (Howell and Nix, 2002; Gordon et al., 2006; Colin et al., 2010), bark temperature (Wignall and Browning, 1988), hormonal control release (Wilson, 2000; Cline and Dong-il, 2002), and slow tree growth (Colin et al., 2008). Although light is not necessarily the main factor leading to suckering, multiple studies have previously noted that it may increase sucker survival and/or growth rate (Wignall and Browning, 1988; Deal et al., 2003; Colin et al., 2008). Some studies have also highlighted the potential role of hydraulic architecture on

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sucker initiation and growth (Morisset et al., 2012; Gehring et al., 2015). Initiation and growth of suckers are thus influenced by many (above mentioned) factors which consequently control the ability of suckers to compensate for losses caused by pruning (in branch number, biomass and structure dimension). While individual sucker growth is well known (Goodfellow et al., 1987), the capacity of suckers to compensate for losses relative to the whole tree crown has never been quantified..

After tree pruning, increased net photosynthesis in residual leaves has been observed (Nowak and Caldwell, 1984; Pinkard et al., 1998; Medhurst et al., 2006; Maurin and DesRochers, 2013; Lisboa et al., 2014). This reaction, known as compensatory photosynthesis, increases carbon fixation in the remaining crown and can be sufficient to maintain tree productivity under a certain pruning intensity (Pinkard and Beadle, 1998a; Maurin and DesRochers, 2013). However, compensatory photosynthesis is limited by stomatal conductance capacity (Pinkard et al., 1998; Medhurst et al., 2006) resulting in tree growth reduction above a certain level of removal (O'Hara, 1991; Pinkard and Beadle, 1998b; Neilsen and Pinkard, 2003; Maurin and DesRochers, 2013). In urban areas, arborists generally state that not more than 25% to 30% of the foliage should be removed in a single pruning. However, quantifying branch losses in situ for large trees is a challenge due to the difficulties of using controlled pruning intensity (e.g. Pinkard et al., 1998) or allometries (Grabosky et al., 2007) to quantify the relative biomass loss. In order to investigate if there is a removal threshold using V-trimming which results in a reduction in tree growth, a tool to accurately quantify the relative losses and growth is thus required.

Most research that has looked at understanding tree reaction to pruning has taken place in a timber production context where pruning was used to improve wood quality. However, V-trimming in the urban setting differs from pruning in the forest in two main ways: (i) pruning in the forest involves removing lower branches, usually at the time of canopy closure, while V-trimming involves removing branches located in the crown where there is relatively good light exposure, and, (ii) V-trimming is cyclical and usually involves the repeated removal of branches at the same location in the crown. This may result in some level of tree crown acclimation over time. Such an acclimation may be seen at the branch level and at the crown level in the distribution and density of branches in the explored space (Millet and Bouchard, 2003), although changes occurring at the tree scale do not necessarily suggest changes at the branch scale (Barbeito et al., 2014).

To document tree reaction to trimming, it is essential to assess metrics that may accurately describe the whole tree crown structure, volume and biomass distribution. Terrestrial Laser Scanner (TLS) provides the capacity to collect accurate data in order to describe tree architectural characteristics at various scales, from the branch level to the whole crown level (Dassot et al., 2011). TLS data processing should however take into account that some limitation, such as occlusion and noise phenomena (Bucksch et al., 2010; Dassot et al., 2011) may affect metrics assessment capabilities. This limits the applicability of woody structure reconstruction methods to small sized trees (Delagrange et al., 2014) or may require allometric modeling of the smallest branches to accurately estimate tree biomass (Hackenberg et al., 2015). Some methods are however more robust in eliminating noise and occlusion (e.g. Raumonen et al., 2013; Hackenberg et al., 2015) but validations would require extensive work for large sized trees. Other methods have looked at quantifying tree functions metrics such as leaf area without reconstructing the tree structure (e.g. Van der Zande et al., 2010; Beland et al., 2011). Such methods are usually based on voxels to locally sample the TLS point cloud enabling the calculation of traits at a smaller scale than the tree scale. Other methods enable one to assess metrics that describe the whole crown form and space occupancy in relation to the tree environment (Martin-Ducup et al., 2016). However, these methods are not well suited to analyzing changes occurring at scales smaller than the tree scale as they do not take into account within crown biomass partitioning. A novel voxel based approach for describing tree space exploration has been recently introduced (Lecigne et al., 2014, 2017). The space exploration concept is based on the hypothesis that a voxel can be viewed as a portion of space containing a part of the point cloud, i.e. a part of the tree. The dispersion of the voxels in the 3D space is assumed to represent the way a tree occupies space so is well suited for comparing trees with different architectural traits or growing in different conditions (Lecigne et al., 2014, 2017). This method would thus be useful for analyzing changes occurring within the tree crown along power lines as the cohabitation between the power lines and trees can be viewed as a conflict in aerial space occupancy.

Using the space exploration concept, this study presents an assessment of the short- and long-term reactions and acclimation to V-trimming of urban trees using TLS data. The three main objectives of the study were: (i) to quantify and (ii) analyze the dispersion of branch loss at the moment of trimming and the subsequent tree growth, as well as (iii) assess potential acclimation, by evaluating the changes in the biomass dispersion within the crown of trimmed trees compared to non-trimmed trees.

To fulfill the first objective, we compared the total volume of voxel clouds for both trimmed and non-trimmed trees. We then used an algorithm to isolate the changes occurring in TLS point clouds of two subsequent time frames (Fig. 1: c, d and e, for example) to analyze the dispersion of branch loss and subsequent tree growth. We have developed two metrics to assess the biomass dispersion within the tree crown. The first metric identifies changes in the preferential growth direction of trees resulting from the bilateral crown constitution and is based on the analyses of voxel radial dispersion relative to the trunk (Fig. 1: f and g). The second metric verifies if the crown of trimmed trees accumulates biomass away from the wires rather than near the wires. This was achieved through the computation of the distance of voxels from the crown center (Fig. 1: h and i).A list of the variables and their abbreviations is available in Table 1.

2. Material and methods

2.1. Study site and sampled trees

The study site was located on two contiguous streets oriented in a North/West direction in a residential area of the Ahuntsic district of Montreal (Québec, Canada). This area was selected in collaboration with the local electricity supplier (Hydro Québec) and based on their planned trimming campaign during the study period. The average height of the electric wires was 11.3 m and corresponded to medium voltage conductors similar to 1W in Millet and Bouchard (2003).

Ten silver maples (Acer saccharinum) were selected with a similar diameter at breast height (DBH = 60.73 cm ± 6.8). Trees were located, on average, at 6 m from a building and at 3 m from the street. Five trimmed trees (T, DBH = 60.27 cm ± 10.3) were located under electric wires and five non-trimmed trees (N, DBH = 61.1 cm ± 3.5) were wire free and were located on the opposite side of the street. Note that one tree was removed from the T category due to observed partial crown death (i.e. N = 4 for T-trees).

The trees of this study were estimated to be 40–54 years-old based on radial measurements. Most of the buildings on the streets where the study took place were built between 1950 and 1975, with the oldest building being built in 1915 (Radio Canada, 2017). We thus assume that the trees were planted at the same time or shortly after installation of the electrical network in the area. We also believe that the trees have been trimmed in a V-shape since the beginning. Although we do not have any documentation to support this, visual inspection of the trees does not indicate any trace of another tree management technique. We did not observe a large proportion of the crown composed of old suckers as would be expected in the tree crown when converting trees from round over (Dahle et al., 2006a) or possibly from lateral trimming (Millet and Bouchard, 2003) to V-trimming. Also, the trees did not show