WIND DAMAGE ON TREES FOLLOWING HURRICANE SANDY AND IMPLICATIONS FOR CITY LANDSCAPING: GLEN RIDGE – MONTCLAIR TOWNS, NEW JERSEY

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Abstract
Glen Ridge is a small municipality in the Northern New Jersey with a significant number of huge trees lining majority of its streets. The trees have been subject to a wide range of natural and artificial stresses, one being the strong wind associated with superstorm Sandy. On 29th October 2012, a windstorm of extreme intensity struck the Tristate region and brought havoc to the tree population including those in Glen Ridge. A survey was conducted immediately after the storm to collect quantitative information on fallen tree population. The study aimed at understanding the spatial extent of wind damage on trees with reference to location, trunk diameter and soil characteristics. A total of 51 fallen trees with a mean trunk diameter of 100.4 centimetres along streets in study area were surveyed. High damage was noted on trees in Glen Ridge (29 trees) while streets transitioning to Montclair had 22 fallen trees. Majority of the surveyed trees were found on USBOO soils (49%), which are characterised as disturbed urban soils with Boonton substratum-Boonton complexes. BowrB soils had 27.5%, Boob 13.7%, BowrC 7.8% and US-DUNB 2.0% of fallen trees. A need for city wide tree inventorying and species mapping is identified as a management implication to further enhance the historical value of the city. Other measures are discussed with a view of engaging appropriate local management partnerships and coordination frameworks to play a role in protecting the remaining large trees.

Keywords: hurricane, Sandy, trees, damage, city

1. Introduction

Decline and loss of large trees is a matter of global concern due to the substantial impacts on biodiversity and forest ecology (Laurance, 2012; Lindenmayer et al. 2012). They face a dull future given the continued changes in climate and occurring extreme events.

The super storm Sandy that hit New Jersey and the Tristate region on October 29th left an unimaginable number of trees down (NOAA, 2012). Trees fell onto houses, utility lines and poles causing loss of power, lives, property damage to name a few consequences. The Staten Island, the Rockaway peninsula in Queens, Long Island and the Jersey Shore were hardest-hit (Langan, 2012). The intensity of the storm was one the region had not experienced in decades. Driving through majority of towns became a nightmare, with many obstacles of all nature on ground.

As climate changes (IPCC, 2007; Paris et al. 2012), it is affecting how our Earth systems functions. It is suggested that more frequent storms accompanied by gusty winds, torrential rains, frequent flood events, rising sea level and storm surges will occur (Paris et al. 2012). Strong winds can cause trees to fall (Runkle, 1998; Gale, 2000). This is besides edaphic conditions, biological factors, climatic forces (Robert, 2003; Matelson et al. 1995) and diseases and pest invasion (McPherson, 2005). Of concern are the large tall urban and sub urban trees, established for over hundred years and continuously cleaning the air of pollutants such as sulfur dioxide (SO_2), nitrogen monoxides (NO_x), carbon monoxide (CO) and other particulates (Jim and Chen, 2008). Trees sequester and store Carbon dioxide (Lutz et al. 2012) from the atmosphere, hence current campaign by cities in the U.S.A and around the world gear towards nurturing more trees (Brown, 2008; McPherson et al. 2008), better forest conservation and management in order to reduce green house gas emissions.

In urban landscapes, the air cleansing capacity of urban trees is not for granted. The trees offer an alternative approach where the built urban environments can be improved and sustainably managed (Nowak et al. 2006; Randolp, 2004). Trees provide nesting grounds for birds, insects, and rodents, providing food like seeds, nuts, flowers, nectar, and leaves. More so, trees recycle soil nutrients creating rich patches for other species to thrive (Lindenmayer et al., 2012). While trees play important roles in ecosystem, large trees are experiencing an alarming increase in death rate, in many of the world's forests, woodlands, savannahs, farming areas and even in cities (Lindenmayer et al. 2012). Trees in urban-suburban setups are fewer in numbers relative to forest environments. Findings by Lutz et al. (2012) indicate that big trees, a meter or more in diameter accounted for nearly half the biomass recorded at a site in Yosemite National Park, yet represented only 1% of the trees growing there. Their results show that large trees, even if few, are critical to ecosystems but could be in verge of wipe out from increased death rate. Besides, tree falls some which are perpetuated by gusty record breaking winds as seen in hurricane Sandy pose threats.

Given the changing climate and increase in extreme events (IPCC, 2007), it is of great value to better manage trees in the urban – sub urban landscapes. Extreme events damaging urban trees and other properties could be infrequent. However, it is critical to document such damages besides establishing tree inventory designed to indicate spatial extent of trees within cities, their number, trunk sizes, stature approximate age, species and other attribute of interest as can be defined in a database. Differences in species and growth characteristics can dictate whether or not they are susceptible to high winds. Existing variation in arrangement of plant vessels the amount of fiber in tree trunk (Bejan et al. 2008) can allow some trees to bend with the winds, reducing overall falls and damage.

Urban trees are found in disturbed environments mainly along pavements and sidewalks (Jim, et al. 1997) unlike forest growing trees. They are often spaced out in planting to replicate certain city design models; and form little or no continuous canopy that could help minimize tree fall. They also face certain challenges e.g. when planted too close to buildings, they may fail to form perfectly, often growing crooked and eventually forming one-sided roots (Renwald, 2003). They lack sufficient sunlight, growing in a lopsided as they strain to grab sunlight. This ruins their natural symmetrical shape and hence become more susceptible to fall. Tree trimming by utility companies present a unique challenge identified as another hazard that hurt the tree canopy and overall tree balance (Gregory, 2011). Trees in the urban environment are continuously recovering from damages by lawn mowers, weed whips, construction damage, grade changes, de-icing salts and animal damage (Saebo et al. 2003).

The research idea of the current study was conceived while driving through Glen Ridge borough, a small town (3.88sq. kms) whose boundaries are shared with Montclair and three other towns. It was noted that many trees within less than a meter from the sidewalks and paved surfaces had fallen. Some streets had more fallen trees than others a likely indication of common underlying conditions. Majority of the fallen trees had roots extending widely from the trunk, and shallowly into the soil horizon (15.34 to 76. 2 cm) below ground, a zone where oxygen and most of the soil moisture and nutrients are located). Trees near pavements had fallen off with the concrete slabs, exposing shallow depth of rooting network.

The overall goal of the study was to assess the spatial distribution of fallen trees with the study area, determining their size and underlying soil characteristics. To meet the goal, specific objectives were to I) identify and map fallen trees along street and avenues in study area; II) measure diameter at point of cut using a measuring tape, III) Determine soil characteristics in location of tree fall noting any common trend.

The following section of the study is divided into material and methods followed in data collection, its analysis and result presentation, discussions, conclusion and recommendations put forward.

2. Methods

2.1. Study region

Glen Ridge borough is located 40° 48′ 17″ N 74° 12′ 16″ W 40.804798°N 74.204569°W in Essex County in Northern New Jersey (Fig.1.). It is a small town about 3.88sq. kms and with ~ 7,527 people (USCB, 2010). It is bordered by Bloomfield, Montclair, Orange and East Orange. The borough is divided into 9 zones: one family, two family, townhouse and professional office, Professional and office; nursing homes; public and private schools; municipal buildings and libraries, Commercial and professional office, Open space, Historic, Planned residential development and Business-residential overlay. It was the first municipality in New Jersey to establish a zoning ordinance (Roll, 2010).

In effort to protect trees, Glen Ridge has several ordinances e.g. ordinance Ord. 1226 § 1, 1993 that indicates "No person or corporation shall, without the written permit of the department of public works, cut, break, climb, injure or remove any living tree in a public highway, or any tree or plant in a public park; or cut, disturb or interfere with the roots of any such tree or plant; or injure, misuse or remove any device placed to protect such tree or plant ; Ord. 1226 § 2, 1993, that indicates "No shade or ornamental tree shall be planted in any of the public highways of the borough until such tree shall have been first approved and the place where it is to be planted designated by the department of public works, and a permit granted therefore (http://www.glenridgenj.org/).

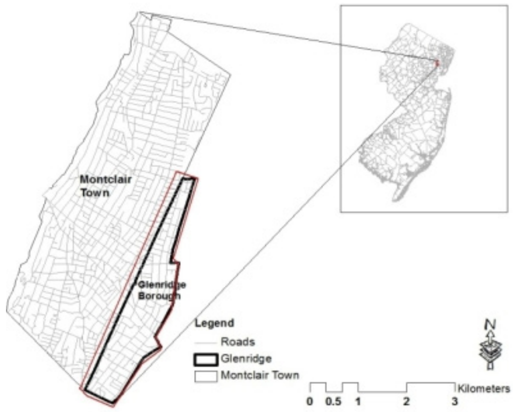

Fig.1. Study Area in Glen Ridge Borough and a small section of Montclair, New Jersey.

2.2 Data collection & Analysis

Data collection was done between November 17th and December 1St 2012. In order to identify and map fallen trees along street and avenues in study area, a street map was prepared using a road layer downloaded from NJDEP GIS database.

These enabled identification of streets within the study region. However, due to the immediate transition of streets from Glen Ridge to Montclair, some trees within the transition were also counted. Geographical coordinate point locations of fallen trees were obtained using a GPS – Trimble 6000 series HX data logger. Pictures of fallen trees, stumps and other useful observations for example health of trunk were also taken.

To measure diameter at base/point of cut, a tape measure was used taking measurement as close to the stump as possible). During the field work, some trees were still on ground while others had been removed since clean up was underway

Attributes of tree stump, location and other useful observed attributes for example condition of exposed roots, rotting trunks were noted down in a manner easy to reconcile with the GPS location.

In order to determine soil characteristics in location of tree falls, a soil data layer for Essex County (the county where the study area belongs) was obtained from (http://soildatamart.nrcs.usda.gov/) and overlaid to the towns Municipal layers – Glen Ridge and Montclair (Fig. 1.). This was further overlaid with the mapped fallen trees data points to enable assessment of tree fall in different soil types. This processing was done using ArcGIS© 10 for mapping and query development purposes.

Data analysis was also carried out in Microsoft Excel, for charting, tabulation and derivation of descriptive statistics. In the field, 33 tree stump diameters were actually measured, while the data for other point locations with fallen trees were logged into the GPS. This was due to the fact that clean up was underway and some stumps had been removed, while other were in process of removal. So there was need to move quickly to acquire correct locations while stumps were still in place, leaving out measuring the remainder of diameters. Also, since some stumps had been plugged out by the time data was taken in some locations, presence of disturbed soils, missing concrete slabs or damaged roofs next to disturbed area was a sign that the missing stump was from a tree that fell onto the facility and has been removed.

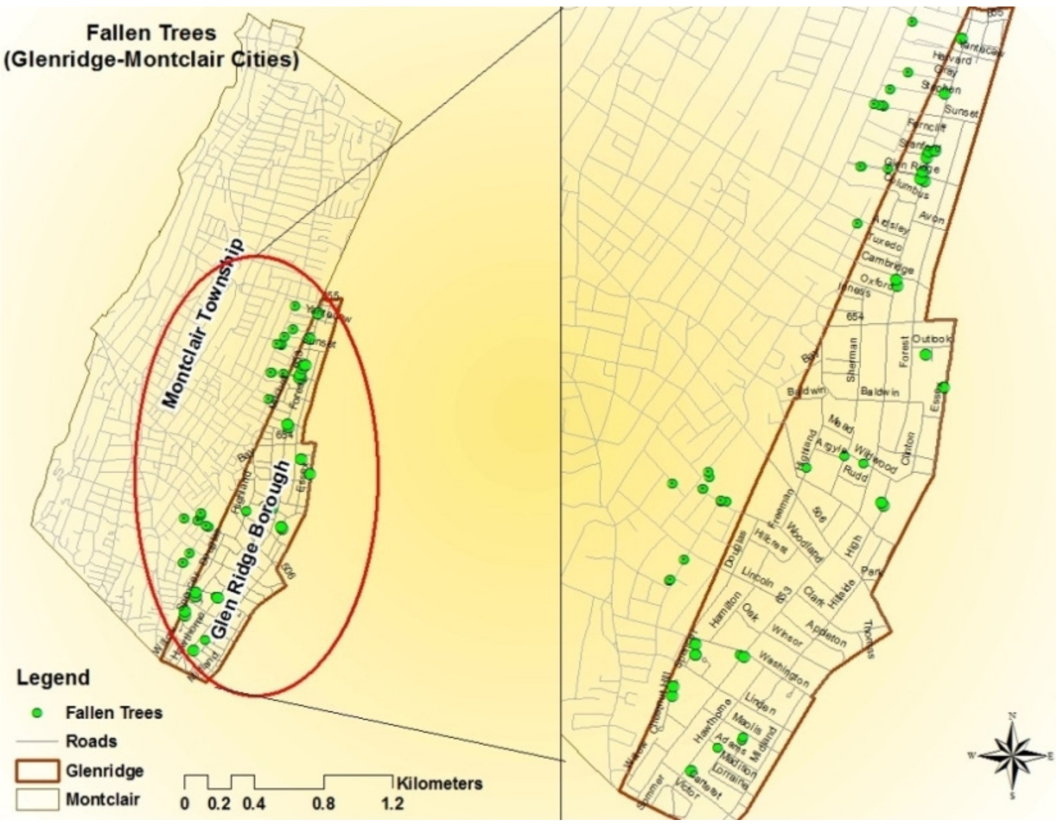

Fig. 2. Surveyed spatial distribution of fallen trees in Glen Ridge borough extending into Montclair Township

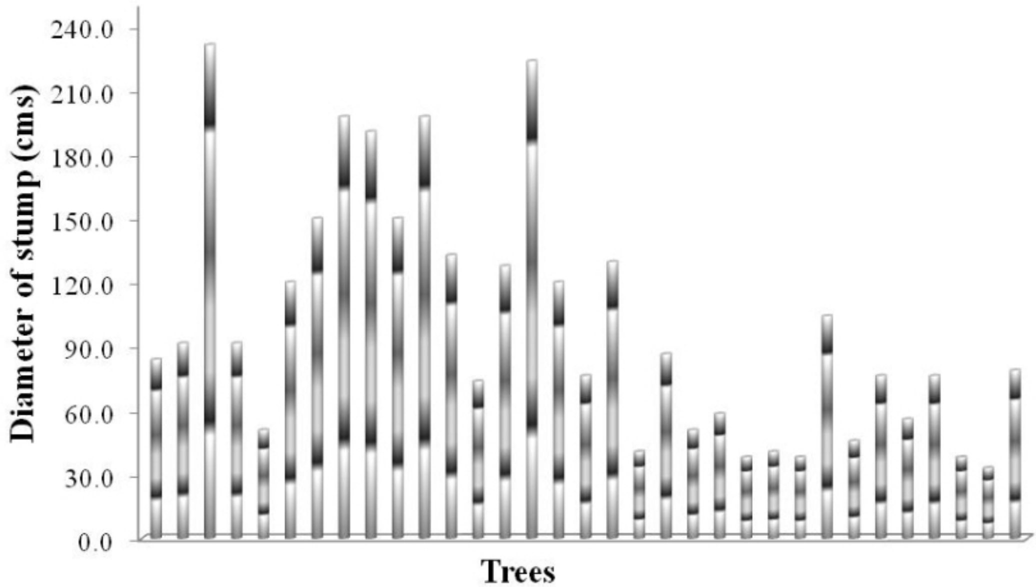

Fig. 3. Diameters (cms) of surveyed fallen trees

One challenge in the field was inability to accurately identify all fallen tree species either by leaves (due to mix-up of leaves on ground) and failure to obtain barks of the fallen trees (before city clean up) that could aid species identification. However, this had been attempted, collecting very little species information not sufficient for accurate study conclusion.

3. Results

3.1 Number and spatial extent of fallen trees

Overall, a total of 51 trees were mapped, of which 29 were in Glen Ridge, and 21 in Montclair at the transition border line (Fig. 2.). More damage was observed on Ridgewood Avenue (11 trees) unlike other streets where the number of observed falls was minimal per particular avenue but spread out within the study area. The avenue runs from one end of the Township to the other end connecting into Montclair.

Observed damage along streets transitioning into Montclair was not concentrated in particular street or avenues as it observed in Glen Ridge.

Table 1. Descriptive statistics of diameters (cms)

Measure	cms
Mean	100,9
Standard error	10,3
Mode	76,2
Smalles diameter	33,0
Largest diameter	231,1
Total No. of count (measured)	33

3.3 Soil characteristics in location of tree falls

Surveyed fallen trees were found on 5 major soil types (Fig. 5.). Majority of trees were found on USBOO soils (49%), followed by BowrB (27.5%), Boob (13.7%), BowrC (7.8%) and (USDUNB (2.0%). USDUNB class of soils, though occurring at a slope of 0-8% like USBOO and BowrC soils, it is of different characteristics originating from Dunellen Substratum-Dunellen Complexes (see Table 2.).

Fig. 4. a-k: Picture observations made in the field. a-c shows fallen trees with exposed shallow rooting in proximity to residential houses, d-e; shows pith trunk decay and hollowed trees, i-k; stumps of fallen trees less than one meter away from the pavement.

Table 2. A simplified description of soil characteristics found in study area (Source: http://soildamart.nrcs.usda.gov/)

Soil type	Description
BooB	Boonton silt loam, red sandstone lowland, on 3-8% slope
USBOO	Urban land, Boonton substratum-Boonton complex, red sandstone lowland on 0-8%
USDUND	Urban land, Dunellen Substratum-Dunellen Complex, on 0-8% slopes,, anthopogenic feature of urban land
BowrC	Boonton-urban land, boonton substratum complex, red sandstone lowland, on 8-15% slopes
BowrB	Boonton-urban land, boonton substratum complex, red sandstone, lowland on 0-8 %

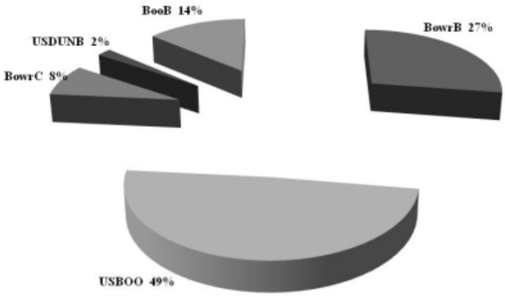

Fig. 5. Fallen trees on different soil types: BooB, USBOO, USDUNB, BowrC, BowrB (http://soildatamart.nrcs.usda.gov/)

4. Discussion

The study was an assessment to find how many trees fell in Glen Ridge borough into Montclair borderline following hurricane Sandy. The main goal was to map spatial distribution of fallen trees and measure attributes of diameter, identifying underlying soil characteristics in those localities.

4.1 Number and spatial extent of fallen trees

The survey assessment identified a total of 51 trees that fell within study area following hurricane Sandy. Glen Ridge Township lost 29 trees, while Montclair lost 21. The trees were mainly located less than two metres off the sidewalks and proximate to residential buildings. Foster et al. (1988), highlight that trees growing in such areas are highly likely affected by changes in their environment such as construction of pavements or buildings causing root injuries . Besides, such changes may affect the ability of trees to anchor strongly thereby making them vulnerable to wind fall. Observations taken in the field support allegations of poor taproot anchorage as observed where tree stumps uprooted the concrete slabs (Fig. 4. a-c). Generally, trees can have extended roots beyond reach of branches. However, for urban growing trees such extension is often interrupted by construction work which may injure or limit space for further growth.

A different notion by Searle et al. (2012) indicate that trees in urban setups are growing much faster than their kin's in forests, attributing the observation to a changing climate. In fact , their work indicate that the common native red oak seedlings can grow 8 times faster in New York's Central Park than in the Hudson Valley and Catskill Mountains, areas considered cooler and rural. Fast growing trees can attain wide diameters within a short duration than previously documented. Whether this rapid growth is accompanied by a well-established, deep penetrating root network that can enable strong anchorage is an area yet to be explored.

4.2 Stump trunk diameter

Results show the average diameter of fallen trees was 100.4cms; the smallest was 33 cms and the largest 231 cms (Table 1.). These findings indicate that huge trees achieving diameters of ~ 1 m were susceptible to the gusty winds experienced during the hurricane Sandy (>85 mph). While the study may not rule out myriad other factors that can contribute to fall (Matelson et al. 1995; McPherson, 2005), ability of urban trees to attain wider diameters faster than those growing in forest may have facilitated more damage. This is because equalities in rate of root growth versus upper trunk may be a factor that could lender huge urban growing trees unstable to resist strong winds. Moreover, roots pushing through limited growth space around building and sidewalk walks may perhaps suffer injuries, hindering proper development and functionality.

Mayor and Roda, (1994) indicate that irrigation of holm oak (Quercus ilex L.) trees increased the stem diameter growth of large trees than in smaller ones, enhancing inequalities in their growth rates. In the current study area, irrigation of lawns is a common practice that can highly benefit trees due to additional moisture availability. Nevertheless, not all homeowners irrigate lawns, a factor that may likely explain the observed variation in stump diameter within a small scale study. The study could not accurately explain the connection between location and species stump sizes, data that could offer further insights of species growth characteristics.

Studies also show that some species for example Red Oaks (which coincidentally dominate New Jersey) USDA, http://plants.usda.gov/plantguide/pdf/cs_quru.pdf) are more susceptible to rot and decay than the white oaks. The observation is attributed to a presence of water-tight vessels in White Oaks, which gives them an increased resistance to rot and decay. Further work in event of such storms should seek to accurately infer species types of fallen trees compared to those left standing. This aspect could not be conclusively verified in current work, even though species identification is key to better evaluations.

Now, within a city's scale, the current findings become even more important since huge urban trees are countable, and their function is undeniable. Glen Ridge is a small town and the observed rate of tree loss is alarming, and if repeated often as often as extreme weather is predicted, then it can be vulnerable. Current work identifies an urgent need to inventory trees in the borough, specifying spatial location, sizes, and growing conditions and soil characteristics in the event that the unknown of climate variation occurs. For the falling trees, a close assessment to identify other likely causes of fall other that wind could help tailor solutions to mitigate or reduce the number of trees falling. Loss of huge trees that have dominated urban landscapes for over century is not a trivial issue, replanting is achievable but replacing their roles is difficult.

4.3 Soil characteristics in location of tree falls

Our assessment of the type of soils in location with fallen trees indicate that trees growing on disturbed USBOO (49%) soils were more affected by the storm, followed by BowrB, Boob, BowrC, USDUNB soils (27.5%, 13.7%, 7.8%, and 2.0% respectively (Fig. 2b). Literature indicate that soils in urban and sur-urban areas are highly disturbed (NRCS, 2006), often showing great variability in horizonation where original horizons might have been mixed up or removed during such activities like construction of pavement, patios, driveways.

Urban disturbed soils contain little additions of natural organic matter. Falling leaves are collected and disposed-off limiting nutrient recycling, insect and earthworm, activity which speed up material decomposition. Debris resulting from human activities can affect soil chemical and physical attributes, more so taking up rooting volume or water and nutrient storage space. This greatly hampers tree growth in such an environment, predisposing them to sudden falls incase of strong winds. From our findings, >70% of fallen were found USBOO and BowrB soils, characterized as disturbed Boonton Complexes on slopes of 0-8%. This suggests that highly disturbed urban soil complexes in the study area may not support huge trees, in event of strong winds as seen in hurricane Sandy.

Tree fall orientation is strongly related to the direction of the slope (Gale, 2000; Robert, 2003). Trees are more likely to fall in the direction of an increasing slope (Sickle and Gregory, 1989). In this study, as the slope increased to 3-8% and 8-15%, fewer fallen trees were observed. However, the direction of fall was not assessed in this work, which might have offered substantiating highlights. Results show that USDUNB soils also had a slope of 0-8% like the USBOO and BowrB soils, but, lost a single tree. However, looking at the soil characteristic, the USDUNB complexes were different. Slope seem of little role as a factor facilitating falls in this study unlike soil characteristics.

The implication of this finding is that increased disturbances via land use alterations and progressive modification of urban-sub-urban landscapes will continue impacting soils, and weaken their ability to provide strong anchorage to existing large trees.

The constant de-icing of roads in winter also affects root growth, with excess sodium shown to limit the uptake of other elements e.g. K, Ca, Mg useful to plants.

This has significant implications to city's landscaping managers. Designing of activities like tree pruning, utility line installations and other projects that may affect tree development (roots, canopy, and crowns) should be keenly evaluated. There is an urgent need to identify where these large trees occurs. The city can also establish appropriate partnerships and local management coordination frameworks especially when determining areas that need careful evaluation before cutting trees , or other activities that might interfere with tree growth, activities between different actors, both public and private, utility employees, road construction, house modellers, etc all need to play a role in protecting the remaining large trees.

5. Conclusion

It is evident that hurricane Sandy did not only destroy human life, property, roads, but also invaluable years of carbon stock locked in the large trees that fell in Glen Ridge - Montclair. As cities strive to cut down greenhouse gas emissions and become more sustainable, they are faced with a challenge to integrate and frame urban-suburban heritage conservation strategies within the larger picture of overall sustainable development. Preserving large trees historically present in urban spaces can be one way of enhancing such integration, improving the quality of the human environment. A need is identified to look at the city landscape as whole, identifying present physical forms, their spatial organization and connection, their social, cultural and economic values and then choose the best way to preserve and manage them.

6. Recommendation

A need for urgent city-wide investigation to inventory and assess the extent of big tree loss, identifying areas where big trees have a better chance of survival. This can be via comprehensive surveys and mapping exercise.

Into the future, it would be important for the city to first evaluate the soil type and characteristics in areas of proposed tree landscaping. These may ensure that chosen landscaping trees are planted in soils capable of withstanding such highly disturbed urban soils.

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