A comparative study of street trees in two neighborhoods of Portland

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<table>
<thead>
<tr>
<th></th>
<th>USA</th>
<th>Iran</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population (million)</td>
<td>315</td>
<td>78</td>
</tr>
<tr>
<td>Area (Km²)</td>
<td>9,830,000</td>
<td>1,648,000</td>
</tr>
<tr>
<td>Forestlands (hectares)</td>
<td>305,000,000</td>
<td>12,000,000</td>
</tr>
<tr>
<td>Forest area (% of land area)</td>
<td>33.3</td>
<td>6.8</td>
</tr>
</tbody>
</table>
Middle east

(NASA)
Iran (Persia)

**Location**: South-western Asia (Middle East)
- 24° - 40° North Latitude
- 44° - 64° East Longitude

**Area**: 18th largest country in the world
(1,648,195 km² or 636,372 mi²)
- = UK + France + Spain + Germany or larger than state of Alaska

**Population**: 78 million
(70% under age of 30 - literacy rate is over 85%)

**Neighbors**: Russia, Turkey, Iraq, Afghanistan, and Pakistan.

**Energy**: 2nd in the world in natural gas reserves
3rd in the world in oil reserves
Climate

Annual mean temperature

Humid : 17 °C (63 °F)
Sub humid : 20 °C (68 °F)
Semi arid : 23° C (73 °F)
Saharian : 27° C (81 °F)
Arid > 35° C (95 °F)

Annual mean precipitation

Humid : 1400 mm (55 inch)
Sub humid : 1000 mm (40 inch)
Semi arid : 400 mm (16 inch)
Saharian : 150 mm (6 inch)
Arid < 100 mm (4 inch)
**Facts**

*Total forest area*: 12.4 million ha
(30,642,000 acres)
(7.4% of the total land area)

*Total desert area*: 34 million ha
(84,016,000 acres)
(20.6% of the total land area)

*Total rangeland area*: 90 million ha
(222,395,000 acres)
(54.6% of the total land area)

Low Forest Cover Country (LFCC)

*Per capita forest area* = 0.2 ha (0.5 acre)
(1/3 world average)

*Rich biodiversity*: 8000 plant species
History of Urban Forestry in ancient Persia

- The concept of phrase “urban forestry” was common among ancient Persians.
- As early as 4000 BC the idea of *earthly paradise* spread through Persian literature.
- Paradise (Persian language: *Pardis*) means urban garden or urban parks (forests).
- Pardis is a place in which existence is positive, harmonious, and timeless.
• Sunlight and water have been the main factors in designing urban parks (Pardis).

• Cypress was a sacred tree in Persia planted and well protected since 6000 years ago.

• The second oldest tree and the oldest cypress tree in the world—cypress of Abar-Kuh or Zoroastrian Sarv—is over 4000 years old and it is the oldest living thing in Asia. [www.wikipedia.org/wiki/Sarve_e_Abarkuh](http://www.wikipedia.org/wiki/Sarve_e_Abarkuh)
History of Urban Forestry in Europe and America

- Urban green spaces (botanical gardens) were cultivated during the Middle Ages.

- The term “arborist” was first recorded in 1578.

- In the 1800s, landscape design received more attention with street tree plantation in Avenue des Champs-Elysees.

- In 1700s, New England town squares were converted from pasture to park.
Urban forest’s benefits

- Urban forests in the U.S. contain about 3.8 billion trees with an structural asset value of $2.4 trillion (Nowak et al., 2002).
- Climate change- urban trees store 770 million tons of carbon (Nowak, 2002).
- Water flow and quality- urban trees can reduce runoff by 7 percent (Sanders, 1986).
- Noise abatement- planting of tall trees can reduce loudness by 50% (Cook, 1978).
- Local climate and energy use- urban trees in the US save about $2 billion annually in reduced energy costs (Akbari et al. 1988, 1992; Donovan, 2009).
• Air quality—urban trees in the US remove 784,000 tons of air pollution annually, with a value of $3.8 billion (Nowak et al., 2006).
• Real state and business—prices for goods purchased in Seattle were 11% higher in landscaped areas (Wolf, 1998).
• Individual well-being and public health—tree shade reduces UV radiation.
• Life and death (Donovan, 2011).
• The healing effects of urban forests—strengthen our immune system by increasing natural killer cells that destroy cancer cells (Karjalainen, 2010).
satellite image of Tehran’s urban green spaces

- Capital city of Iran
- Area: 686.3 Km²
- Population (2012): 12 million
- Green space: 70 Km² (4.11 %)
- Climate: Semi-arid
Tehran, the city of *Plane trees*

- Tehran is famous for its pomegranate orchards and plane trees (*Platanus orientalis*).
- Urban trees have been a part of Tehranians’ life for at least 200 years.
- The modern concept of urban forestry goes back to 45 years ago.
- Tehran municipality have achieved numerous international honors in terms of:
  - Monitoring urban forest health.
  - Increasing urban canopy cover.
  - Developing afforestation with native and exotic species.
  - Mitigating Urban Heat Island (UHI) effect.
  - Establishing green belts around city.
Main tree species in forest parks

- Eldar pine *(Pinus eldarica)*
- Arizona cypress *(Cupressus arizonica)*
- Locust tree *(Robinia pseudoacacia)*
- Judas tree *(Cercis griffithii)*
- Arbor vitae *(Thuja orientalis)*
- Pomegranate *(Punica granatum)*
- Mountain almond *(Amygdalus scoparia)*

Photographs:
- Saee urban park, Tehran
- Highways’ greenery project, Tehran
- Tehran
Main street tree species
Oriental plane (*Platanus orientalis*)

Vali-Aser’s street trees, Tehran

Plane trees
Urban forests’ management plan in Tehran

- Increasing canopy cover
- Selecting suitable sites for tree plantation
- Establishing green belts
- Afforestation and reforestation with native species
- Mitigating CO2 emissions
- Mitigating Urban Heated Island (UHI) effect
- Decreasing air pollution
- Decreasing sound pollution
- Decreasing Volatile Organic Compounds (VOCs) level
- Forest therapy
Oregon’s urban forests’ facts

• Average tree canopy cover: 28.5%
• Urban tree canopy cover: 15%
• Total number of trees in urban areas: 27.6 million.

Urban trees:

• Store 5.3 million metric tons of carbon ($120.8 million) annually.
• Remove 173,000 metric tons of carbon ($3.9 million) annually.
• Remove 4,090 metric tons of air pollution ($31.4 million) annually.

Portland’s urban forests facts

• Street tree population: 236,000 of 171 different types
• Park tree population: 1.2 million of 41 different types
• Broadleaf deciduous trees are dominant, 85% of street trees and 77% of park trees
• 90% of street and park trees are in fair condition
• Maples are dominant tree species
• Norway maple is the most important street tree
• The majority (60%) of street trees are native to Asia and Europe
• The majority (86%) of park trees are native to the Portland area
• Current canopy cover: 29.9%
• Canopy cover goal in 30 years: 47%
Urban forest’s challenges

- Insect and diseases
- Wildfire
- Natural catastrophic events
- Invasive plants
- Air pollution
- Additional development
- Planting strip size
- Overhead utility
Research questions

• Do site factors such as “strip size” and “overhead utility” have any effects on the health of street trees?

• Do street trees in different urbanized regions of the world follow similar structural patterns?

• What is the best index to study the relationship between street trees and people in different communities?
Objectives

- Finding the statistical relationship of tree dimensions, health, and site factors in different neighborhoods.

- Comparing the structural pattern of street trees in Portland and Tehran.

- Comparing different neighborhoods using basal area and canopy cover attributes.
Why did I do this research?
Because:

- Tree measurements such as dbh, total height, crown diameter and crown area can provide vital information on their own, as well as providing crucial data for other calculations such as leaf area and leaf biomass (Nowak 1996; Peper et al. 2001a; Peper et al. 2001b).

- Most of the environmental benefits associated with urban trees, such as CO2 sequestration (McPherson, 1998; McPherson and Simpson, 2000; Nowak and Crane, 2000), air pollution removal (Beckett et al., 1998; Nowak, 1994, 2006; Nowak et al., 2002; Donovan et al. 2005; Yang et al., 2005; Escobedo and Nowak, 2009), reduction of storm water runoff (Sanders, 1986; Xiao et al., 1998, 2000a,b), microclimate modification and reduction of the Urban Heat Island (UHI) through shading and evaporative cooling (Rosenfeld et al., 1998; Simpson, 1998; Akbari et al., 1998; Akbari, 2002; Donovan and Butry, 2009) are related to their size, and particularly to the size of their crowns.
Models (*predictive equations*) have been developed to assess costs and benefits of the existing urban forests and determine the best management practices to maximize the environmental benefits of urban trees (Nowak and Crane, 2000; Nowak and Dwyer, 2000; Nowak et al., 2008; McPherson et al. 1999, 2000).

Tree canopy cover is a critical measure of the urban and community forest resource (Nowak, 2009).

Studying urban forest attributes such as tree canopy cover per capita, total green space, canopy green space, and available green space is the most important goal of urban forest’s biometrics in any metropolitan city (Nowak, 2009).
Materials & methods
Study area- Portland’s satellite imagery
## Neighborhoods’ facts

<table>
<thead>
<tr>
<th>Neighborhood</th>
<th>Eastmoreland</th>
<th>Concordia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>SE Portland</td>
<td>NE Portland</td>
</tr>
<tr>
<td>Area</td>
<td>285 ha</td>
<td>345 ha</td>
</tr>
<tr>
<td>population</td>
<td>5007</td>
<td>9550</td>
</tr>
<tr>
<td>Population density</td>
<td>17.5 persons/ha</td>
<td>27.7 persons/ha</td>
</tr>
<tr>
<td>Median income</td>
<td>$63,364</td>
<td>$25,694</td>
</tr>
<tr>
<td>Below poverty level (%)</td>
<td>7 %</td>
<td>19 %</td>
</tr>
<tr>
<td>Total households</td>
<td>1543</td>
<td>3835</td>
</tr>
<tr>
<td>Crime density (Street robberies, 1995-2010)</td>
<td>Below average</td>
<td>Above average</td>
</tr>
</tbody>
</table>
Data collection

1- Quantitative and qualitative data(tree species, health condition, strip size and dbh) of 3316 and 4636 street trees in Eastmoreland and Concordia respectively.

2- Quantitative and qualitative data(dbh, crown diameter, tree height and health condition) of 60 Lindens (*Tilia americana*) in Eastmoreland.


4- Census data, and robbery maps of Portland in 2010.
Methods

- Statistical analyses of street trees’ attributes in Eastmoreland and Concordia.

- Modeling Lindens’ attributes using predictive equations in Eastmoreland.

- Comparison of canopy cover attributes in Eastmoreland and Concordia.
Statistical analyses of street trees’ attributes in Eastmoreland and Concordia

• Number of samples: 7952 trees (3316 trees in Eastmoreland and 4636 trees in Concordia).

• Tree factors: Dbh, strip size, tree location, health condition, and presence or absence of overhead utility.

• Type of analysis: (GLM) Generalized Linear Model
Modeling Linden’s attributes using predictive equations in Eastmoreland

➢ Tree measurement

Number of trees: 60 (in both sides of Reed college Blvd.)
Measured factors: Dbh, mean crown diameter, tree height, health condition.

➢ Regression analysis

a. Linear model
b. Non-linear exponential model
c. Logarithmic regression model
Comparison of urban forests’ attributes in Eastmoreland and Concordia

- Classifying two neighborhoods into four classes: Tree cover, water, pervious, and impervious surfaces using Feature Analyst extension in ArcGIS 10.

- Calculating urban canopy attributes
  - Canopy cover per capita
  - Canopy green space

- Calculating urban forest’s indexes
  - Trees per hectare
  - Total basal area
  - Basal area per hectare
  - Basal area per capita
Results

Statistical analyses of street trees’ quantitative factors in Eastmoreland and Concordia

Eastmoreland

<table>
<thead>
<tr>
<th>Paired factors</th>
<th>Omnibus test</th>
<th>Wald chi-square statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dbh-tree health</td>
<td>P&lt;0.05</td>
<td>800.850</td>
</tr>
<tr>
<td>Overhead utility -tree health</td>
<td>P&lt;0.05</td>
<td>56.191</td>
</tr>
<tr>
<td>Strip size-tree health</td>
<td>P&lt;0.05</td>
<td>28.586</td>
</tr>
</tbody>
</table>
### Concordia

<table>
<thead>
<tr>
<th>Paired factors</th>
<th>Omnibus test</th>
<th>Wald chi-square statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dbh-tree health</td>
<td>P&lt;0.05</td>
<td>223.515</td>
</tr>
<tr>
<td>Overhead utility – tree health</td>
<td>P&gt;0.05</td>
<td>---------------</td>
</tr>
<tr>
<td>Strip size-tree health</td>
<td>p&lt;0.05</td>
<td>183.499</td>
</tr>
</tbody>
</table>
Modeling Linden’s attributes using predictive equations in Eastmoreland

<table>
<thead>
<tr>
<th>Quantitative paired factors</th>
<th>Linear model</th>
<th>Nonlinear exponential model</th>
<th>Logarithmic regression model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$R^2$</td>
<td>$R^2$</td>
<td>$R^2$</td>
</tr>
<tr>
<td>Dbh vs. tree height</td>
<td>0.47</td>
<td>0.47</td>
<td>0.48</td>
</tr>
<tr>
<td>Dbh vs. mean crown diameter</td>
<td>0.08</td>
<td>0.18</td>
<td>0.06</td>
</tr>
<tr>
<td>Dbh vs. crown area</td>
<td>0.03</td>
<td>0.18</td>
<td>0.02</td>
</tr>
<tr>
<td>Dbh vs. tree health</td>
<td>0.02</td>
<td>0.00</td>
<td>0.02</td>
</tr>
<tr>
<td>Basal area vs. crown area</td>
<td>0.04</td>
<td>0.45</td>
<td>0.42</td>
</tr>
</tbody>
</table>

The Omnibus test for predicting tree health from dbh is not significant (p>0.05)

7/31/2013
Modeling oriental plane’s attributes using predictive equations in district 6 of Tehran

<table>
<thead>
<tr>
<th>Quantitative paired factors</th>
<th>Linear model $R^2$</th>
<th>Nonlinear exponential model $R^2$</th>
<th>Logarithmic regression model $R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dbh vs. tree height</td>
<td>0.49</td>
<td>0.50</td>
<td>0.46</td>
</tr>
<tr>
<td>Dbh vs. mean crown diameter</td>
<td>0.06</td>
<td>0.22</td>
<td>0.07</td>
</tr>
<tr>
<td>Dbh vs. crown area</td>
<td>0.23</td>
<td>0.25</td>
<td>0.21</td>
</tr>
<tr>
<td>Dbh vs. tree health</td>
<td>0.05</td>
<td>0.00</td>
<td>0.04</td>
</tr>
<tr>
<td>Basal area vs. crown area</td>
<td>0.03</td>
<td>0.48</td>
<td>0.44</td>
</tr>
</tbody>
</table>

The Omnibus test for predicting tree health from dbh is not significant ($p>0.05$)
Comparison of canopy cover attributes in Eastmoreland and Concordia

GIS-based classified map of Portland

Portland

Tree
Pervious
Impervious
Water

0 5,000 10,000 15,000 20,000 25,000 30,000 35,000 40,000 Feet

7/31/2013 35
GIS – based classified map of Eastmoreland
GIS-based classified map of Concordia
<table>
<thead>
<tr>
<th>Urban forests’ attributes and indexes</th>
<th>Eastmoreland</th>
<th>Concordia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total canopy cover (ha)</td>
<td>80.52</td>
<td>51.82</td>
</tr>
<tr>
<td>Impervious surfaces (ha)</td>
<td>44.34</td>
<td>149.87</td>
</tr>
<tr>
<td>Pervious surfaces (ha)</td>
<td><strong>73.67</strong></td>
<td><strong>117.79</strong></td>
</tr>
<tr>
<td>Water (ha)</td>
<td>5.28</td>
<td>-----------</td>
</tr>
<tr>
<td>Tree canopy cover per capita (m²/person)</td>
<td>160.81</td>
<td>54.26</td>
</tr>
<tr>
<td>Canopy green space (%)</td>
<td>1.09</td>
<td>0.43</td>
</tr>
<tr>
<td>Trees per hectare</td>
<td><strong>11.61</strong></td>
<td><strong>13.34</strong></td>
</tr>
<tr>
<td>Basal area per hectare (m²)</td>
<td>3.15</td>
<td>0.77</td>
</tr>
<tr>
<td>Basal area per capita (m²/person)</td>
<td>0.17</td>
<td>0.02</td>
</tr>
<tr>
<td>Total basal area (m²)</td>
<td><strong>899.5</strong></td>
<td><strong>267.24</strong></td>
</tr>
</tbody>
</table>
Discussion

• In both neighborhoods, trees’ health is mainly affected by increase in dbh size which is a factor of aging.

• Crown trimming and ongoing removal of interfering branches with overhead wires have significantly deteriorated the health condition of trees in Eastmoreland.

• Overhead utility does not have any effect on the health of street trees in Concordia.

• Strip size is the major health-induced factor for street trees in Concordia.

• In Eastmoreland, strip size does not have any effect on trees’ health.
• In Lindens, the relationship between dbh and tree height is the strongest but, between dbh and tree health the weakest.

• The relationship between dbh and health condition of Lindens is not significant.

• In Lindens, the relationship between dbh and crown area is very weak.

• Pervious and impervious surfaces in Concordia are 1.6 and 3.4 times more than Eastmoreland respectively.

• Basal area and canopy cover per capita in Eastmoreland are 8.5 and 3 times more than Concordia respectively.

• Basal area per capita is the most reliable index for studying the relationship between street trees and people.

• Street trees in different regions of the world have similar structural pattern.
Thank you