The Effect of Tree Planting Strategy On Canopy Cover in the City of Hartford

By Giles Lemmon

Introductions:

- Giles Lemmon (Me)
  - Student at Trinity College
  - Working with Jack and Grace, advised by Dr. Geiss
- Jack Hale
  - Tree Commission Head
- Grace Yi
  - Green Infrastructure Assistant
- Dr. Christoph Geiss
  - Program Director of Environmental Science at Trinity College

Introduction:

- The purpose of this exercise is to answer three main questions:
- 1) What would be the impact of planting 1000 trees per year?
- 2) How many trees would need to be planted to maintain the same canopy cover after 30 years?
- 3) How many trees would need to be planted to reach a canopy cover of 35% within the next 30 years?
- I would like to talk through the process by which I attempted to answer these questions

Background

- What is the current state of Hartford's canopy?
- Why are trees needed?
- Why is constant planting important?
- What has been the planting plan in the past?

What is the current state of Hartford's canopy?

- Hartford is a city in a forest
  - Hartford's urban forest makes it unique
- Hartford Currently has 568,000 trees (as of 2008)
- Around 26% of the city is covered by trees
- Canopy cover is the percentage of the land area that is covered by the canopy of trees
- Recently, the city has been beset by storms and pests
  - Storms necessitate large amounts of tree removals quickly
  - Disease and Pests are incredibly destructive
    - Emerald Ash Borer, Dutch Elm Disease, etc

Why are trees needed?

- Provide many vital uses
- Provide shade, which leads to lower AC bills
- Store carbon and absorb precipitation
- Remove pollutants from air
- Make neighborhoods much more pleasing

Why is constant planting important?

- The forest is rapidly aging
  - Trees with a diameter of more than 20 inches are 10% of total number of trees
  - These trees make up about 50% of the total canopy area
  - Majority of canopy cover comes from these old trees
  - When one old tree is removed, the canopy looses a large chunk of area
  - Not sufficient to simply plant one tree for every tree that is removed

What has been the plan for planting in the past?

- Plant as many trees as possible
  - Usually, this ends up being a few hundred per year
  - Recently, some years have had no new trees at all
  - Budget is very limiting
    - Significant amount of forestry money goes toward tree removals
  - Trees are expensive to plant
    - Once planted, however, last for a very long period of time

Why was this study undertaken?

- It is important to quantify impact of planting plans
- Important to have a basis to discuss planting targets
  - Very helpful for budgeting purposes
- Important to have a goal to aim for with regards to planting
- Recently, a new planting species mix has been planned out
  - Possible to see impact of that planting plan

Procedure

- What is iTree?
- What data was used in this study?
- How was canopy loss analyzed?
- What are the limitations of iTree?
- How were iTree limitations worked around?
- How was new growth calculated?

What is iTree?

- Developed in partnership with U.S. Forest Service
- Open source piece of software for modeling ecosystem services
- Designed for modeling different aspects of forests
- Data is input into iTree (species, DBH)
- This data is analyzed, and can be used to generate forecasts in response to different scenarios
  - In this case, ecosystem service of interest is canopy cover

What data was used in this study?

- In 2007, Knox Parks Foundation conducted a survey
  - UFORE (Urban FORest) analysis
  - 200 random locations throughout Hartford
  - Trees in each location were surveyed
- This data is the basis for this study
  - UFORE considers sampling method valid
  - UFORE study results backed up by satellite imagery

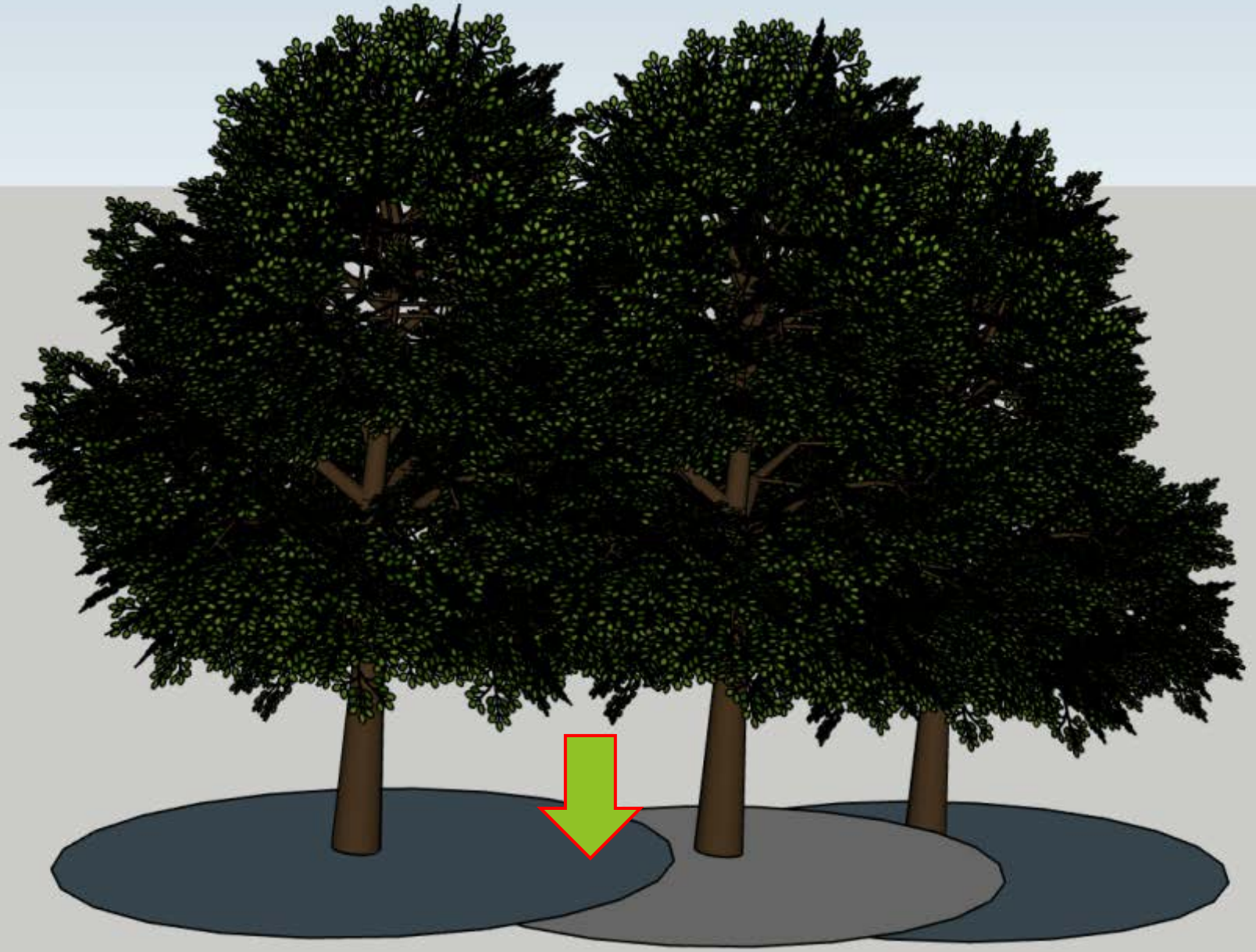
How was canopy loss analyzed?

- iTree eco v6.0 has the ability to forecast canopy growth over time
- 801 tree sample was put into iTree, and various parameters were adjusted
  - Mortality Rate: left at the default value of 2% loss per year
- The forecast model was run, and the results added to excel
- This forecast gives the number of acres that these representative 801 trees cover, assuming that 2% of them die each year and no new ones are planted.
- This number of acres is then scaled up as if the forest had 568,000 trees, with the assumption that this is a representative sample

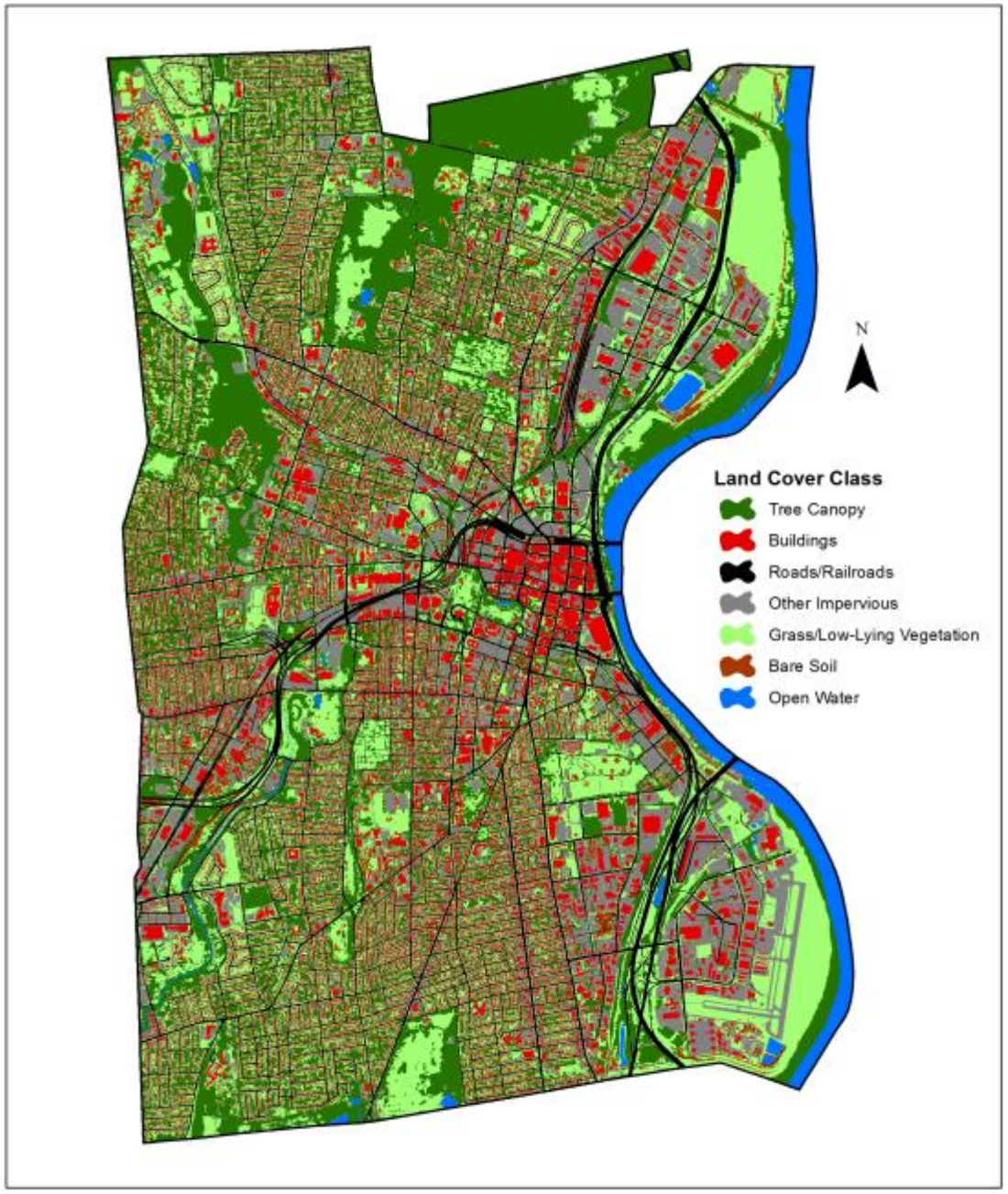
What are the limitations of iTree?

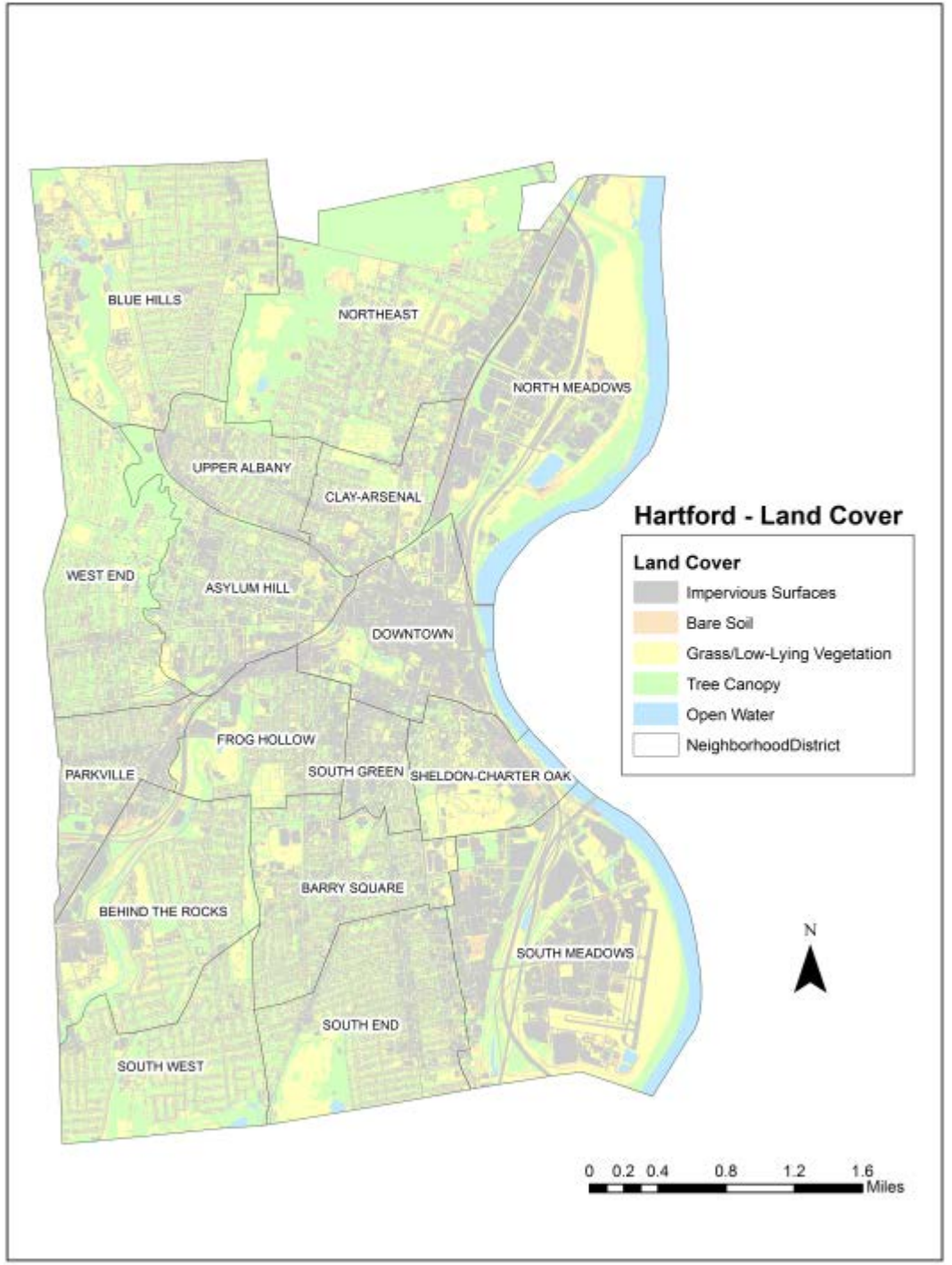
- iTree struggles with modeling trees in forested areas
- Hartford's urban canopy is a mixture of street trees and trees in more heavily forested areas
- iTree calculates canopy cover as if each tree has a distinct ground area.
- Individual trees in forests/parks are responsible for a smaller amount canopy cover
- Their closeness results in canopy overlap
- iTree tends to overestimate the total canopy cover

Trees in Forest (Note how canopy overlaps)



Urban Trees (Note distinct canopies)


N
Land Cover Class
Tree Canopy
Buildings
Roads/Railroads
Other Impervious
Grass/Low-Lying Vegetation
Bare Soil
Open Water


BLUE HILLS
NORTHEAST
NORTH MEADOWS
UPPER ALBANY
CLAY-ARSENAL
WEST END
ASYLUM HILL
DOWNTOWN
FROG HOLLOW
PARKVILLE
SOUTH GREEN
SHELDON-CHARTER OAK
BARRY SQUARE
BEHIND THE ROCKS
SOUTH MEADOWS
SOUTH END
SOUTH WEST
Hartford - Land Cover
Land Cover
Impervious Surfaces
Bare Soil
Grass/Low-Lying Vegetation
Tree Canopy
Open Water
NeighborhoodDistrict
N
0 0.2 0.4 0.8 1.2 1.6
Miles

How were iTree limitations worked around?

- Since this sample has 801 trees and Hartford had 568,000 trees, it should be possible to just multiply 801 by 402 (801 is 0.402% of 568,000) to scale it up, but the canopy iTree calculated for the sample is larger than it should be.
- It is possible to work backwards when looking at 2008 data
- 2008 UFORE study established that the canopy cover at that time was 26%
- The problem comes with extrapolating that 801 tree sample to the entire canopy.
- Since the actual canopy cover percentage is known, it is possible to work out a factor to multiply the 2008 sample by to scale it up
- (Canopy area of 801 tree representative sample) x ((Acres in 26% of Hartford)/(Canopy area of 801 tree sample))
- Basically, scaling up the canopy iTree has calculated in a different way
- When applied to 2008 sample, this resulted in a 26% canopy cover, as found by UFORE
- Applied to all years forecasted for the 2008 sample (canopy loss)

How was new growth calculated?

- iTree is capable of forecasting growth of a forest taking into account tree planting
- It is possible to modify various parameters that affect the new trees
- It is not possible to specify a mix of trees for planting
- iTree simply extrapolates the current mix of trees to each new “tree” that it models
- This leads to a number of difficulties
  - Hartford is in a unique situation
  - The mix of trees that we want to plant is different than the makeup of the forest
  - It is necessary to find a way to work around this problem

How was new growth calculated?

- Three new “forests” were created, one for small, medium, and large tree species
- Each of these forests were populated with species from the tree planting plan
- The growth of each forest was modeled for 40 years, with the number of trees to be planted in each forest being proportional to the mix specified in the planting plan
- “…..70-80% of trees planted should be large, 5-10% should be medium, and 20-30% should be small” (Tree Planting Plan)
- For my purposes I, I assumed 70% of new trees were large, 10% were medium, and 20% were small
- Canopy cover for each year of forecasted growth was added to a spreadsheet

How was new growth calculated?

- The area (in acres) of each year of growth for each size of tree was added to the calculated number of acres of the forest that had no planting (801 tree sample from earlier)
- The resulting land area was divided by the total area of Hartford, to produce the percentage of land area that was covered by trees
- This was repeated for each desired number of trees to plant (1000 trees, 3000 trees, etc)

Appendix A: Impact of Planting 1000 New Trees Per Year

Year	Itree Cover Calculated (2008 uFore) (Acres) (1)	Hartford Calculated Canopy Cover (No Regrowth) (Acres) (2)	Hartford No Planting Canopy Percentage (3)	Calculated/ Forecasted Small Tree Cover (Acres) (4)	Calculated/ forecasted Medium Tree Cover (Acres) (5)	Calculated/ forecasted Large Tree Cover (Acres) (6)	Calculated Total New Tree Cover (Acres) (7)	Total Hartford Canopy Cover Calculated (Acres) (8)	Canopy Cover Percentage (9)
2008	7.20	2892.03	26.00	0.00	0.00	0.00	0.00	2892.03	26.00

[Project: Combied Trees] [Series: Combined Trees] [Year: 2018] - i-Tree Eco v6.0.10

Reports | Forecast | Support

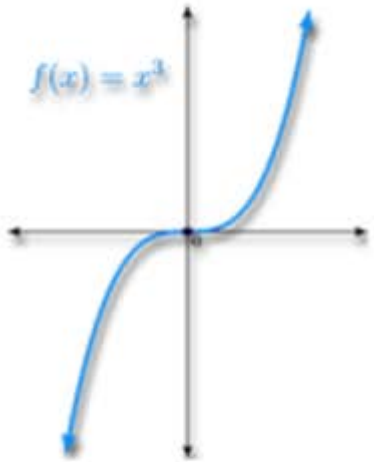
Trees to Plant | Extreme Events | Options

Active Configuration: Default | Rename | New | Duplicate | Delete | Restore Defaults | Configurations

Composition and Structure | Benefits | Reports

English | Metric | Units

Editing Mode: Off



Forecast is a separate component of i-Tree Eco that is run independently of the model. Utilizing Forecast is e
optional and will have no impact on your i-Tree Eco results (as seen on the **Reports** tab).

On this tab, you can run the Forecast component at a basic or advanced level. To estimate what your urban fo
look like in the future, Forecast uses the structural estimates (e.g., number of trees, species composition) ge
running the i-Tree Eco model along with anticipated growth and mortality rates. You can even include future
planting scenarios or possible adverse events, such as a storm or pest infestation, to predict their impact on
forest.

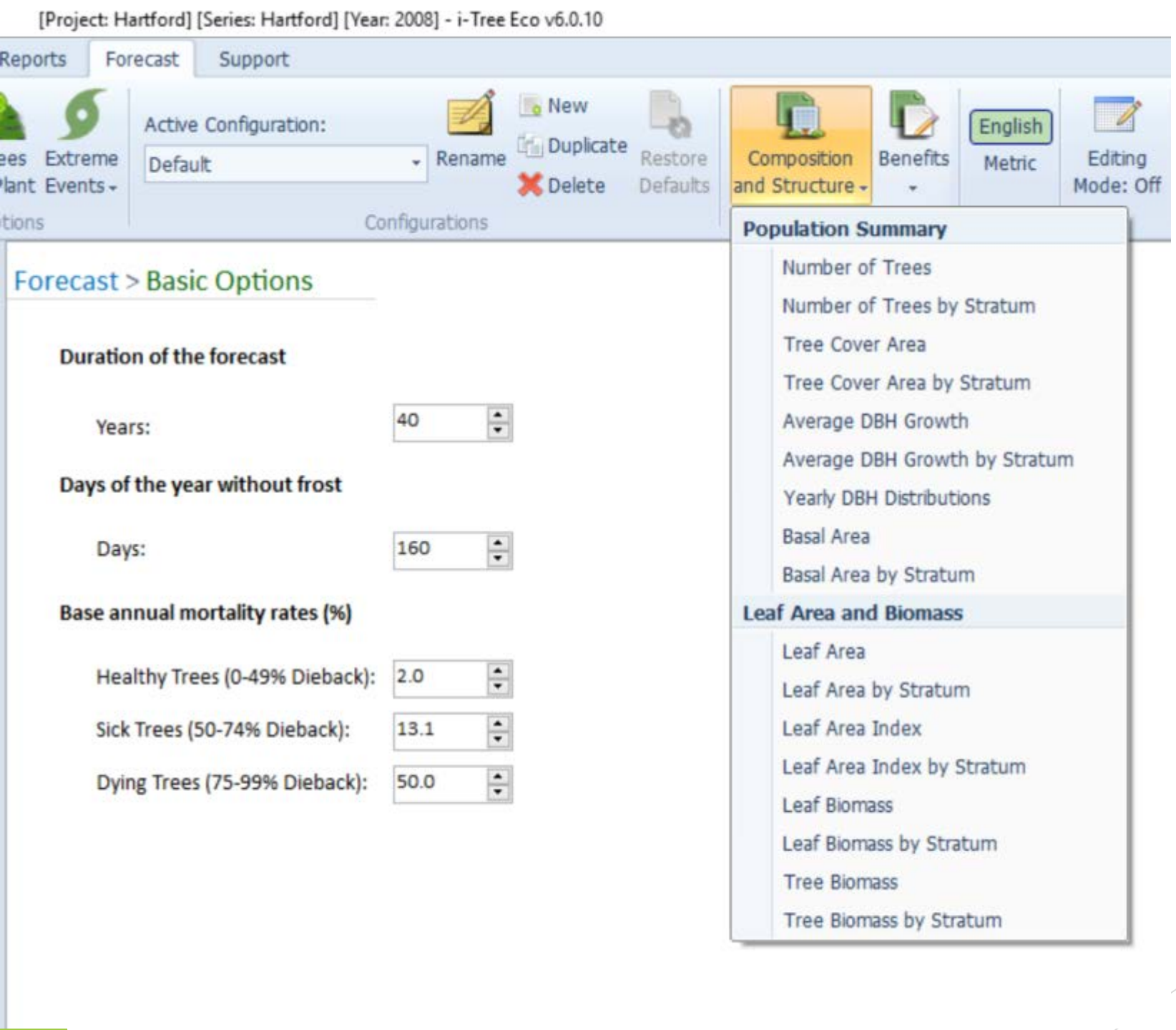
Forecast is designed to allow you to provide as little or as much information as you would like (see Notes be
most basic level, you could run Forecast using all of the defaults provided. To customize your Forecast result
change the default **Basic Options** to estimate your future urban forest based on local variables for the follow

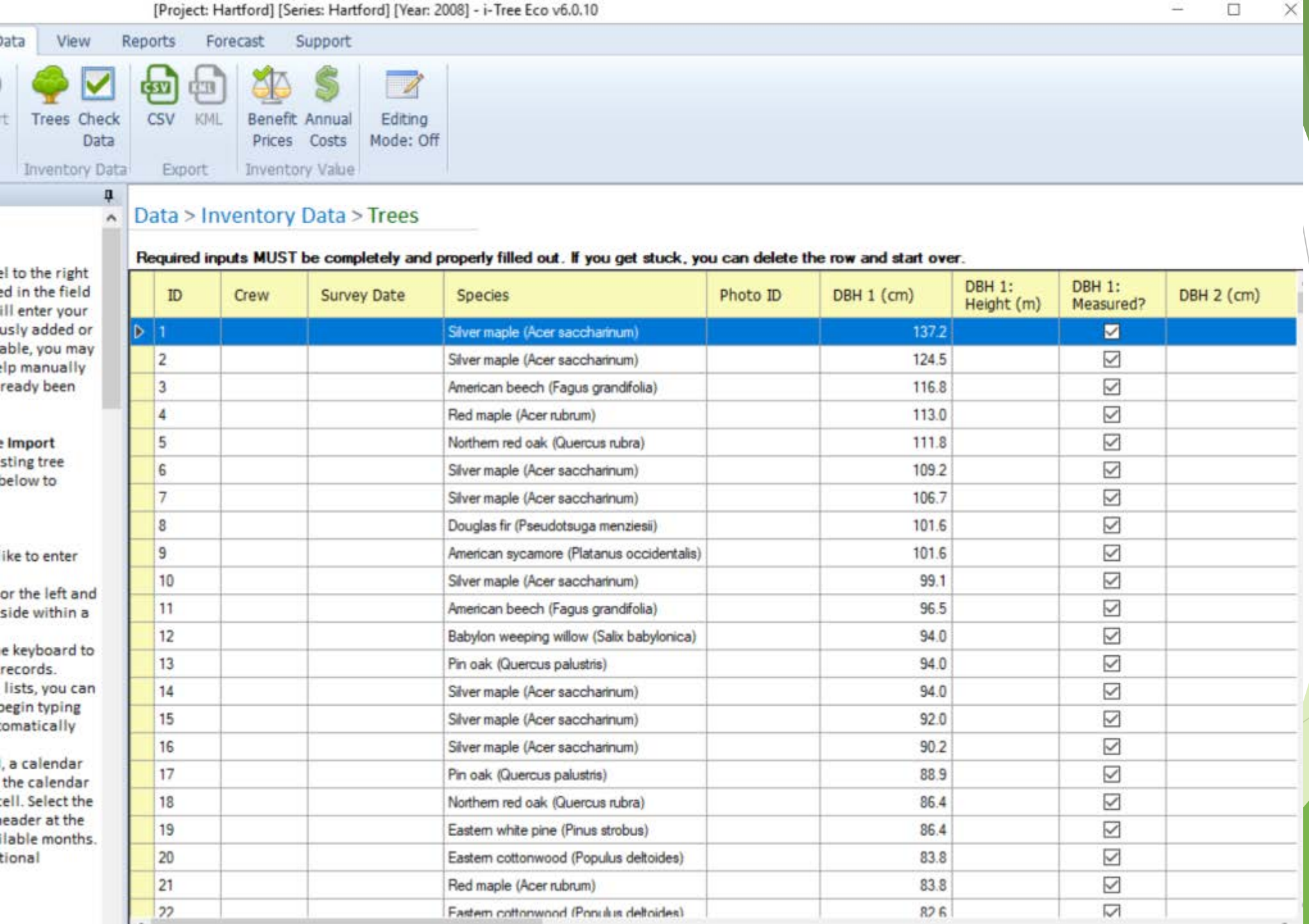
- Number of years to forecast
- Annual mortality rates
- Frost-free period (days)

For a more advanced Forecast run, you can choose to include the following occurrences in your estimates of
urban forest:

- Tree plantings
- Storm events
- Pest infestations

On the ribbon above, there are eight groups of available functions (see Notes below), including:

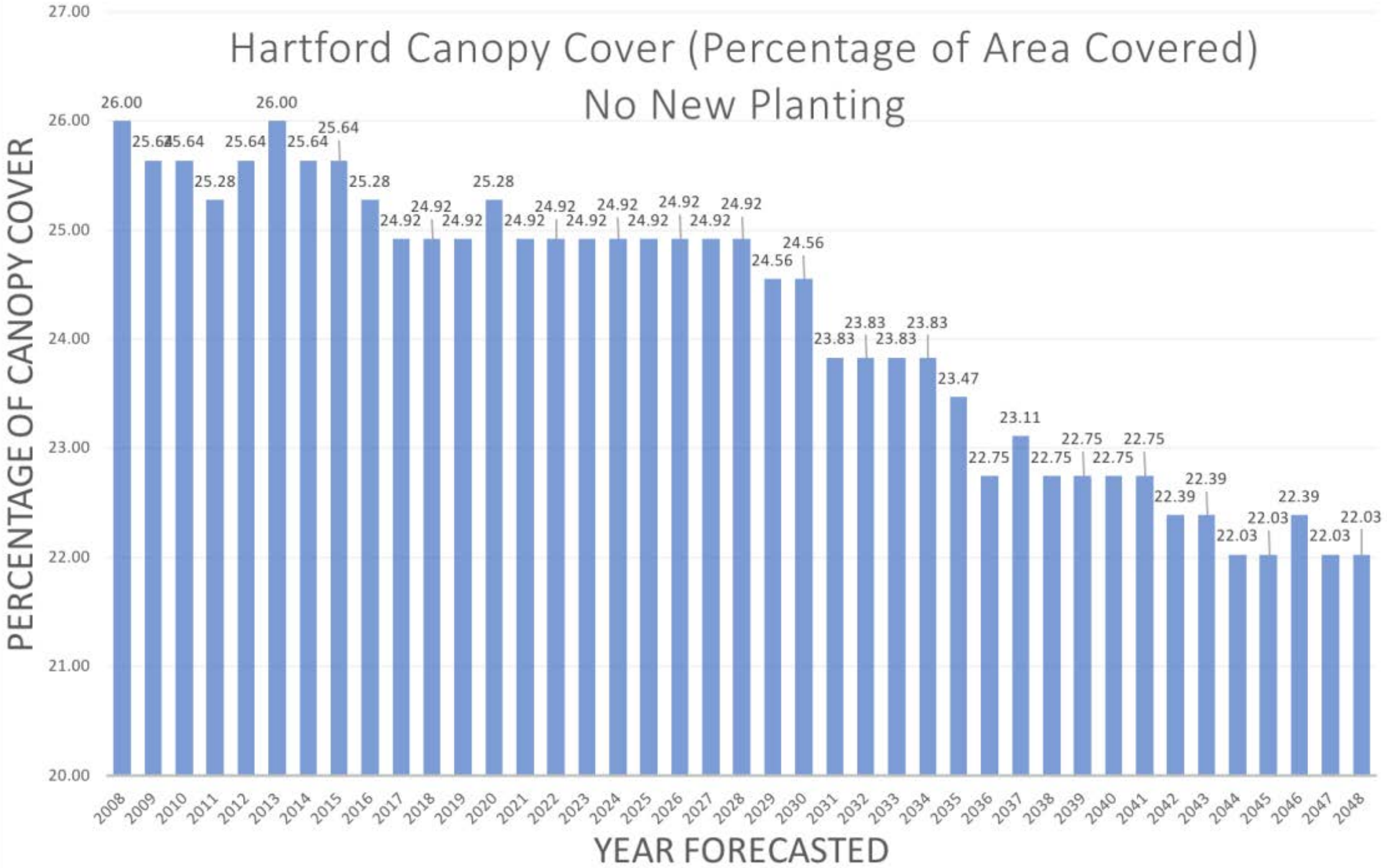

[Project: Hartford] [Series: Hartford] [Year: 2008] - i-Tree Eco v6.0.10
Reports
Forecast
Support
Extreme Events
Active Configuration:
Default
Rename
New
Duplicate
Delete
Restore Defaults
Configurations
Composition and Structure
Benefits
English
Metric
Editing Mode: Off
Forecast > Basic Options
Duration of the forecast
Years:
40
Days of the year without frost
Days:
160
Base annual mortality rates (%)
Healthy Trees (0-49% Dieback):
2.0
Sick Trees (50-74% Dieback):
13.1
Dying Trees (75-99% Dieback):
50.0
Population Summary
Number of Trees
Number of Trees by Stratum
Tree Cover Area
Tree Cover Area by Stratum
Average DBH Growth
Average DBH Growth by Stratum
Yearly DBH Distributions
Basal Area
Basal Area by Stratum
Leaf Area and Biomass
Leaf Area
Leaf Area by Stratum
Leaf Area Index
Leaf Area Index by Stratum
Leaf Biomass
Leaf Biomass by Stratum
Tree Biomass
Tree Biomass by Stratum

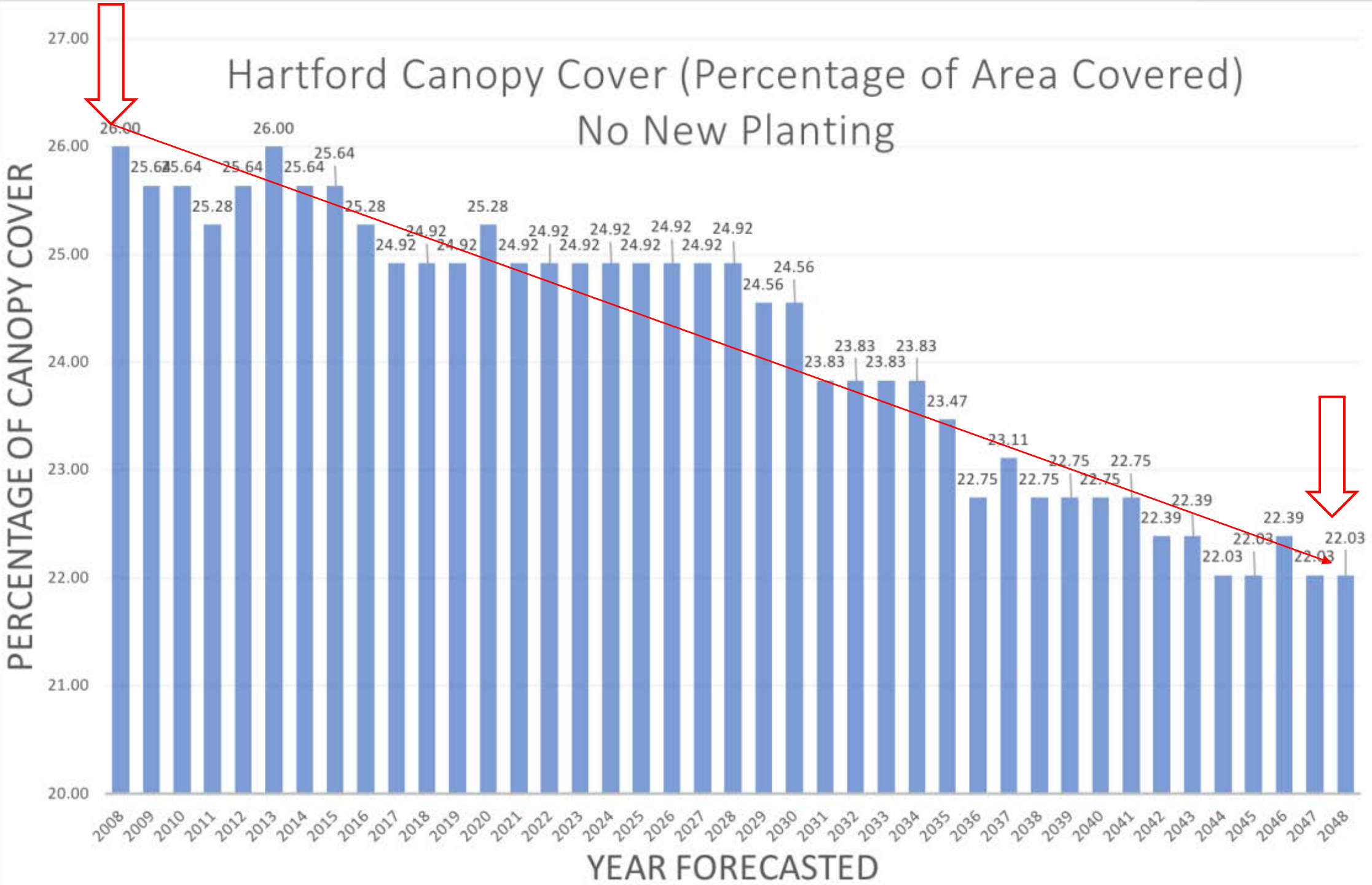

[Project: Hartford] [Series: Hartford] [Year: 2008] - i-Tree Eco v6.0.10
Data
View
Reports
Forecast
Support
Trees
Check Data
Inventory Data
CSV
KML
Export
Benefit Prices
Annual Costs
Inventory Value
Editing Mode: Off
Data > Inventory Data > Trees
Required inputs MUST be completely and properly filled out. If you get stuck, you can delete the row and start over.
ID
Crew
Survey Date
Species
Photo ID
DBH 1 (cm)
DBH 1: Height (m)
DBH 1: Measured?
DBH 2 (cm)
1 Silver maple (Acer saccharinum) 137.2
2 Silver maple (Acer saccharinum) 124.5
3 American beech (Fagus grandifolia) 116.8
4 Red maple (Acer rubrum) 113.0
5 Northern red oak (Quercus rubra) 111.8
6 Silver maple (Acer saccharinum) 109.2
7 Silver maple (Acer saccharinum) 106.7
8 Douglas fir (Pseudotsuga menziesii) 101.6
9 American sycamore (Platanus occidentalis) 101.6
10 Silver maple (Acer saccharinum) 99.1
11 American beech (Fagus grandifolia) 96.5
12 Babylon weeping willow (Salix babylonica) 94.0
13 Pin oak (Quercus palustris) 94.0
14 Silver maple (Acer saccharinum) 94.0
15 Silver maple (Acer saccharinum) 92.0
16 Silver maple (Acer saccharinum) 90.2
17 Pin oak (Quercus palustris) 88.9
18 Northern red oak (Quercus rubra) 86.4
19 Eastern white pine (Pinus strobus) 86.4
20 Eastern cottonwood (Populus deltoides) 83.8
21 Red maple (Acer rubrum) 83.8
22 Eastern cottonwood (Populus deltoides) 82.6

Results

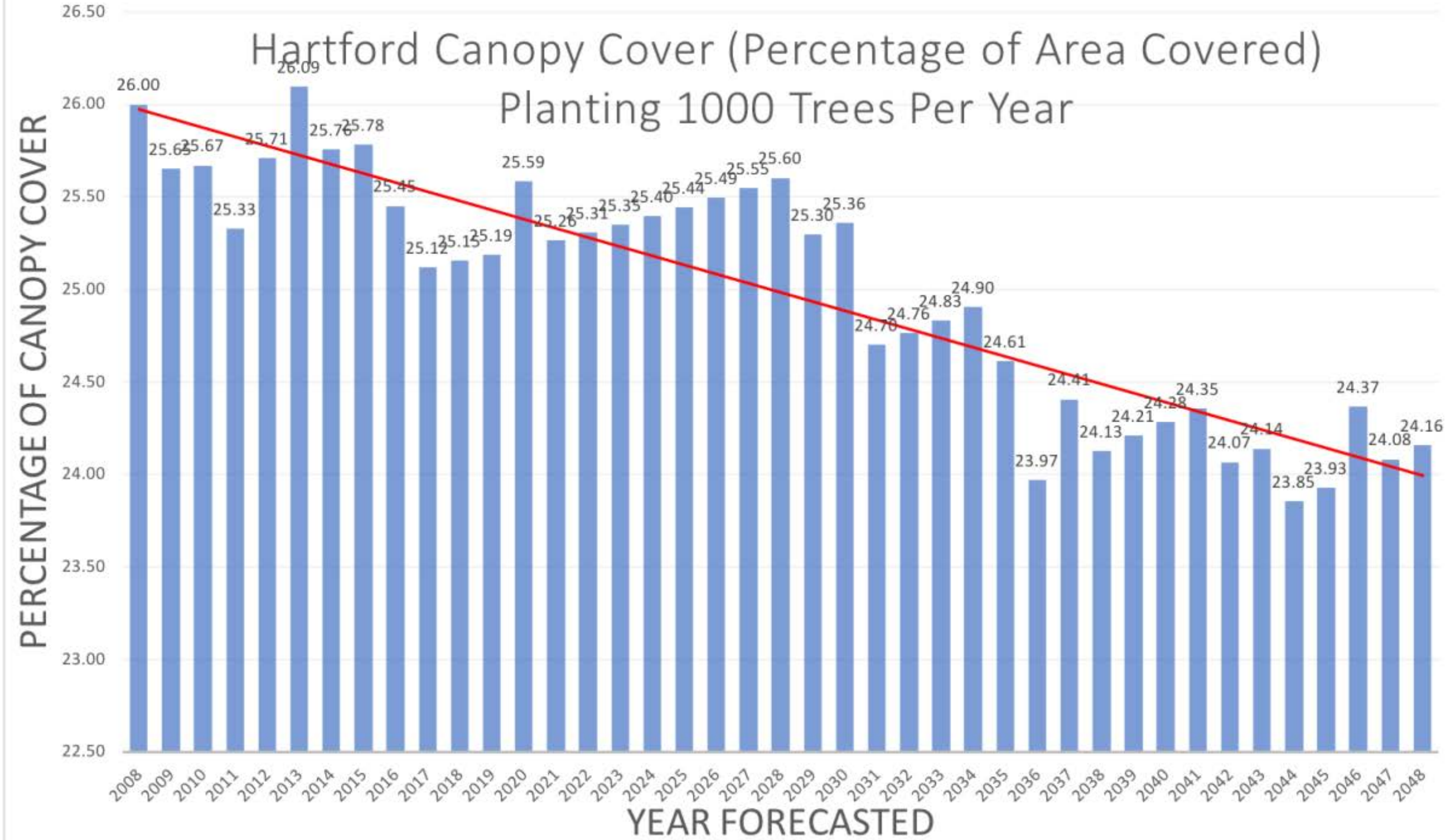
- What were to happen if no new planting were to occur? (Worst Case)
- What were to happen if 1000 trees were planted each year?
- What were to happen if 3000 trees were planted each year?
- How many trees would take to keep the same canopy cover in 30 years?
- How many trees would we have to plant to reach 35% canopy cover in 30 years?

What were to happen if no new planting were to occur?

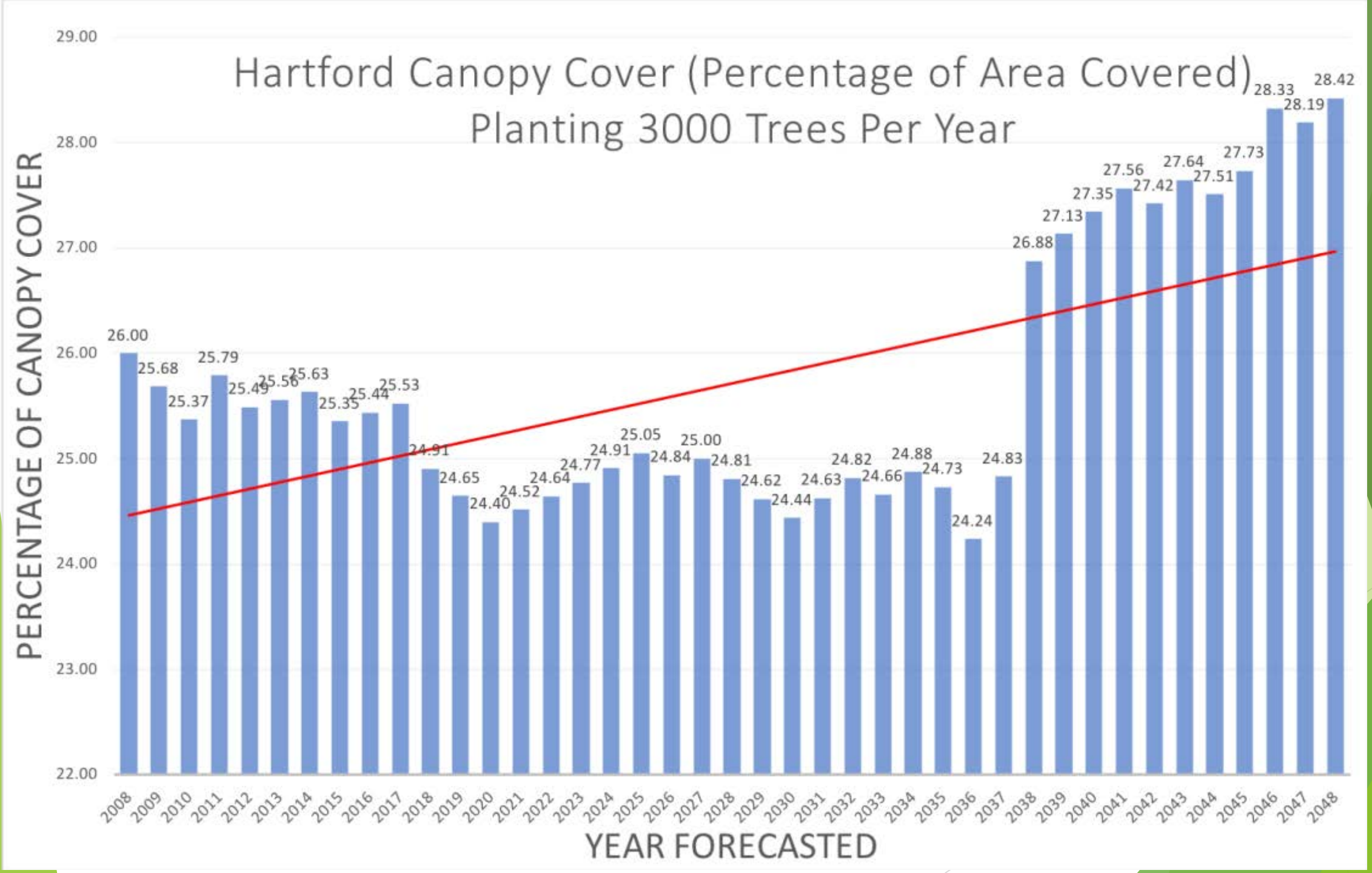

Hartford Canopy Cover (Percentage of Area Covered)
No New Planting
PERCENTAGE OF CANOPY COVER
YEAR FORECASTED
27.00
26.00
25.00
24.00
23.00
22.00
21.00
20.00
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048
26.00 25.64 25.64 25.28 25.64 26.00 25.64 25.64 25.28 24.92 24.92 24.92 25.28 24.92 24.92 24.92 24.92 24.92 24.92 24.92 24.56 24.56 23.83 23.83 23.83 23.83 23.47 22.75 23.11 22.75 22.75 22.75 22.75 22.39 22.39 22.03 22.03 22.39 22.03 22.03


Hartford Canopy Cover (Percentage of Area Covered)
No New Planting
PERCENTAGE OF CANOPY COVER
YEAR FORECASTED
27.00
26.00
25.00
24.00
23.00
22.00
21.00
20.00
26.00
25.64
25.64
25.28
25.64
26.00
25.64
25.64
25.28
24.92
24.92
24.92
25.28
24.92
24.92
24.92
24.92
24.92
24.92
24.56
24.56
23.83
23.83
23.83
23.83
23.47
22.75
23.11
22.75
22.75
22.75
22.75
22.39
22.39
22.03
22.03
22.39
22.03
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048

What were to happen if 1000 trees were planted each year?


Hartford Canopy Cover (Percentage of Area Covered)
Planting 1000 Trees Per Year
PERCENTAGE OF CANOPY COVER
YEAR FORECASTED
26.50
26.00
25.50
25.00
24.50
24.00
23.50
23.00
22.50
26.00
25.65
25.67
25.33
25.71
26.09
25.76
25.78
25.45
25.12
25.15
25.19
25.59
25.26
25.31
25.35
25.40
25.44
25.49
25.55
25.60
25.30
25.36
24.70
24.76
24.83
24.90
24.61
23.97
24.41
24.13
24.21
24.28
24.35
24.07
24.14
23.85
23.93
24.37
24.08
24.16
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048

What were to happen if 3000 trees were planted each year?


Hartford Canopy Cover (Percentage of Area Covered)
Planting 3000 Trees Per Year
PERCENTAGE OF CANOPY COVER
YEAR FORECASTED
29.00
28.00
27.00
26.00
25.00
24.00
23.00
22.00
26.00
25.68
25.37
25.79
25.49
25.56
25.63
25.35
25.44
25.53
24.91
24.65
24.40
24.52
24.64
24.77
24.91
25.05
24.84
25.00
24.81
24.62
24.44
24.63
24.82
24.66
24.88
24.73
24.24
24.83
26.88
27.13
27.35
27.56
27.42
27.64
27.51
27.73
28.33
28.19
28.42
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048

How many trees would take to keep the same canopy cover in 30 years?

How many trees would we have to plant to reach 35% canopy cover in 30 years?

- Would need to plant 6085 trees per year

- Seems like an incredible amount, but remember the forest is 568,000 trees!

Limitations

- Large variability in the forecasts
- This study may be used to guide thoughts on tree planting, but should not be taken as an absolute truth
- Underlying data sample is small
- Trees surveyed were only public trees
- Differences to real world
  - No pests, disease, unforeseen natural disasters
- Errors are generally on the conservative side
  - Tend to underestimate planting need
  - In reality, more trees are removed (due to natural disasters and unforeseen events)

Conclusions

- Hartford's urban forest is in a critical situation
- Trees can be thought of as a utility
  - Provide services as a result of investment
- To keep the current canopy cover, 1,465 trees must be planted each year
- 1000 trees would result in a canopy cover of 24.16%
- 3000 trees would result in a canopy cover of 28.42%
- To reach 35% in 30 years, 6085 trees must be planted annually
- It is important to invest in tree planting now
  - Improvements take a long time to assert them selves, but will last for a very long time

Thanks

- I would like to thank Grace Yi and Jack Hale for being so instrumental in completing this project. Their support has allowed me to create this study. I would also like to thank my advisor for this project, Dr. Christoph Geiss, for all the guidance along the way.