Storm-Water Mitigation using Urban Forest Management

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E522 Urban Forest Ecology

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Introduction:

Stormwater management is an important component in city planning, especially as urbanization increases. With more of the population moving from rural to urban areas, cities are accommodating the influx by developing more infrastructure and impervious surfaces (i.e. roofs, roads, large areas of pavement, and asphalt parking lots) and decreasing vegetation cover (pervious surface). The more impervious surfaces reduce the water infiltration leading to an increase in stormwater runoff, which occurs when rainwater or melted snow flows over the streets, lawns and other sites creating negative economic and environmental impacts within the cities.

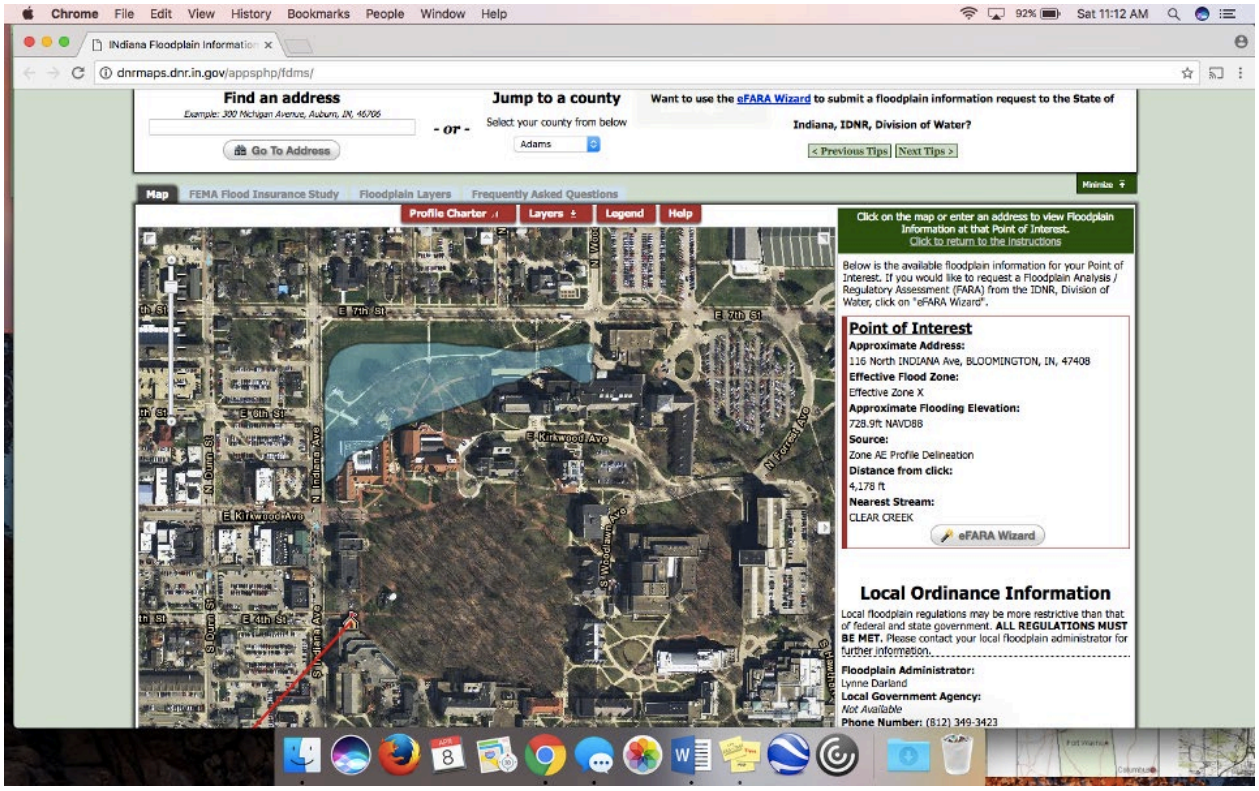
Cities have utilized different management techniques to address stormwater runoff. One of the techniques is the use of urban trees. Trees reduce stormwater runoff by capturing and storing rainfall in their canopy and have been shown to help reduce surface water runoff by as much as 60% compared to asphalt [i].

In this study, we identified the flooding zones in Bloomington and of those areas, we examined one specific block in Bloomington - Indiana between 7th and Kirkwood. The purpose of the study was to (1) re-inventory the current tree cover (2) assess and evaluate the tree cover and potential areas for implementing stormwater management tools.

Methods:

For our study, we used the Indiana Floodplain maps of Monroe County to identify specific areas in Bloomington impacted by flooding. The street- Indiana Avenue between 7th and Kirkwood was selected for the case study because of the sizable amount of flooding that occurs in that area (Figure 1).

Figure 1. Floodplain information for street of Indiana Avenue between 7th and Kirkwood.



After the area was selected we did a re-inventory of the street trees on both sides of Indiana Avenue between 7th and Kirkwood. For our re-inventory, we cataloged the existing trees' diameter at breast height (DBH), species, condition, maintenance requirements, and age. This information was then cross examined with the existing 2007 and 2012 tree inventory to identify the tree change over time. We then used this data with direct observations to construct stormwater management recommendations.

Results:

Rainfall interception is a function of a trees lifetime. As a trees lifetime increases, the amount of rainfall intercepted is seen to increase. This is because more surface area is related to more evapotranspiration. However, a lot of places plant trees too close together causing them not to meet their full rainwater interception potential. Dunn meadow does not have moderate canopy cover compared to the surrounding area (Figure 1). To the south is Dunn's Wood with larger tree cover but to the north is the downtown core of Bloomington where

street cover varies and in most places, is less. An updated inventory of the street trees on the outskirts of Dunn Meadow (7th street and N. Indiana Avenue) was taken April 8, 2017 and compared to 2007 and 2012 Bloomington street tree inventories.

Since trees provide the most benefit when they are mature, each tree inventories are categorized into immature, semi-mature, mature, or senescent. The two main trees inventoried are Maple (Maple, Red and Sugar) and Oak, where a mature maple is between 40-50' and a mature oak (Oak, Pin) is 25-40'. Planting spaces are counted in the immature category since when the tree is first planted no benefits are usually provided. Additionally, the 2012 inventory shows Ash, Green and Elm, American located on N. Indiana Avenue. These trees are found to be removed but are included for comparison since some of the trees have been replaced. Ash, Green is found to be at maturity at 25' and Elm, American at 35-45'.

As briefly mentioned, 2007 and 2012 had four main street tree species: Maple, Ash, Elm, and Oak. Each species was broken up into immature, semi-mature, mature, and senescent. Since the Maple is considered mature around 40', immature is 0-20', semi-mature is 21-39', mature is 40-50' and senescent is 50'+. An oak tree is assigned immature if 0-10', semi-mature if 11-24', mature if 25-39' and senescent if 40'+. The ash trees are assigned immature values of 0-5', semi-mature 6-10', mature 11-25', and senescent 25'+. Finally, the Elm is considered immature 0-5', semi-mature 6-19', mature 20-35' and senescent 45'+. A decrease in immature trees and increase in semi-mature trees is seen from 2007/2012 inventories to present day data collected (Appendix B and D).

Analysis:

Storm-water is urban areas poses many environmental issues with one of the main ones being washing harmful chemicals and substances into waterways. These waterways could be streams, rivers, or even into potential drinking water sources. Trees are able to intercept this rainwater through two main mechanisms: canopy cover and root systems. Tree roots grow near the surface since that is where the majority of the nutrients lie. The roots are able to soak up and store more of the rainwater and prevent it from flushing chemicals into unwanted places and preventing soil erosion. The leaves, branches, and bark will also catch the rainfall reducing the overall amount of runoff. The street we examined - Indiana and 7th has had issues with flooding during the 2007 floods and 2012 floods in the city to Bloomington.

While conducting the street tree inventory, we also were analysing the layout of the street. The street had a few new maple trees have been planted next to and in Dunn Meadows. On the left side of the street, Maple trees were planted uniformly and on the right side of the street, Oaks were planted. The tree diversity was restricted to these two species of trees.

Many of the young trees were well maintained and required regular pruning a few of them had root collars and vertical supports. A couple of trees were marked. There was a tree with a small portion of the trunk was removed. There were a couple of spots in the tree lawn that could be used for planting new trees. We saw a few trees which were surrounded with mulch. This poses a serious problem in identifying girdling roots. We had identified two car parks on the street which are covered with impervious material.

The street trees surrounding Dunn Meadow flood plain are seen to be majority immature and semi mature. This does not change much between years and demonstrates that trees from 2007 and 2012 were healthy enough to transition into the semi-mature or mature

category for their species. The difference between semi-mature and mature can be sectioned into how many benefits the tree is contributing to the surrounding area. Once a tree is considered mature, it is providing the maximum amount of benefits available to the community. When semi-mature, the trees benefits are linearly related to its growth rate increase. As the tree approaches maturity, the benefits of the semi-mature tree will increase. Once mature, the benefits will level out and begin to decrease once the tree becomes senescent. This process differs for each tree. A mature Sugar Maple (40-50') is able to intercept 7,358 gallons of storm water runoff a year when near a park or vacant lot (Dunn Meadow).[ii] Table 1 shows how each tree seen in the most recent inventory (2017) can provide between 3,000-5,000 more rainfall interception once full maturity is reached.

One factor that may influence the amount of rainfall intercepted besides maturity is the type of surface surrounding the trees. Generally, the more impermeable the surface the faster the water is able to contribute to runoff. Surrounding Dunn Meadow is concrete pavement and Dunn Meadow itself is a grassy field. The street trees closer to Dunn Meadow will have a better chance of intersecting more rainfall than the trees on the other side of the road since they are closer to the permeable grassy field and the other trees are surrounded mainly by impermeable concrete. By making the surrounding area more permeable, the chance of a flood is less likely to happen because the trees are enabled to intercept more rainwater.

Table 1. Tree Species and Water Infiltration[iii]

Tree	Semi-Mature (gallons/year)	Mature (gallons/year)
Sugar Maple	5,619 (21')	7,358 (40')
Red Maple	5,720 (21')	7,607 (40')
Pin Oak	2,569 (11')	7,353 (25')

RECOMMENDATIONS:

CONDITIONS THAT LIMIT TREE GROWTH IN URBAN AREAS:

Urban areas are high stress areas for the normal growth of trees. There is a need for human intervention to enable a healthy growth for trees in the urban setup. Limited Soil volumes, pollution, increase in surface temperatures due to heat island effect, reduced quantity of water are some of the common problems that urban trees suffer[iv].

1. INCREASING THE TREE COVER:

Trees absorb 30 % of most precipitation, a further 30%of the precipitation is absorbed by the round and held by the roots of the trees which are again transpired into the air. Trees drastically reduce the quantity of storm water runoffs and potential flooding of urban areas.[v] The wider the canopy cover the more rainwater the tree will be able to absorb thus reducing a lot of costs in building sewerage treatment plants. The city of Seattle did a cost benefit analysis of increasing the canopy cover from 18% to 38% and the results suggested that it would double the storm water retention capacity by more than $41 million[vi]. Dunn Meadows has a lot of vacant space where a lot of trees can be planted. These trees can limit the quantity of storm water run off .

Figure 2. Recommendation for planting trees on Dunn Meadow[vii]:

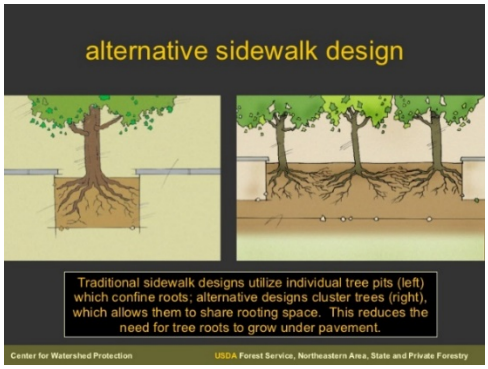
2. ADD MORE VARIETY AND DIVERSITY:

The entire block has either Maples or Oaks. It is really important that there should be a diversity in the species of trees planted in the street, as it will help in the preserving the tree canopy cover in case a specific species of tree is affected by disease. Considering the existing Emerald Ash Borer problem[viii] affecting the Oaks in America it is important that there should be a variety in the species of trees to ensure continuation of the tree cover and will reduce the risk of exposure and potential loss in the event of exposure to pest and disease. It is recommended that limiting planting to a 10%-20%-30% [ix]diversity mix would be pragmatic solution to ensure the continuation of the tree canopy cover.

3.CONVERSION OF IMPERMIABLE SURFACES TO PERMIABLE SURFACE:

The city of Bloomington has had its own share of floods. When the ground is covered with impervious material in form of roads, carparks, walkways the rainwater is diverted to drains which open into the sewerage system and when they reach their maximum capacity flooding happens.[x] There was a computer modelling done which shows that for every 1% of impermeable land which is transformed into woodland , the runoff would be reduced by 0.5%.[xi]. Tress which are planted as part of "sustainable urban drainage System schemes[xii]" have been proved to be effective in controlling flooding in urban areas. On the same times if the carparks identified in picture () are covered with permeable material, and the walkways and sidewalks are re-laid in permeable material there was is a lot of reduction in storm water runoff.

Figure 3: Alternative Street Designs to help Increase Tree Cover[xiii]:



4.CREATING TREE WELLS AND CURB EXTENSIONS:

The block - Indiana and 7th is right off an urban Commercial Center because of this there are geographical limitations in planting a lot of trees due to limited availability of space. Creating tree wells and curb extensions could be a solution this problem. Tree wells do not take up space[xiv], in addition to providing ecological services, they also provide shade to the vehicles parked under them and reduce the quantity of Hydrocarbons and suspended particulate matter in the air (Figure 4).

Figure 4. Curb extensions can be useful in reducing storm water runoffs[xv]:

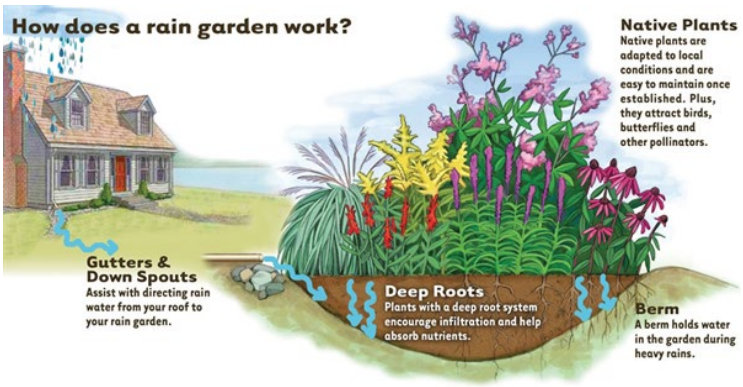
5.INVOLVING THE COMMUNITY MEMBERS:

While conducting a street tree inventory we observed that a lot of private trees are well maintained and are much healthy in comparison than the public trees. A few of the trees that

we observed had some structural damage and showed signs of abuse. If members of a community are educated about the benefits of trees and are taught how to maintain them and take care of them they can form a team with the city forest department in taking care of trees in their locality and help in creating a sustainable tree cover.

6.CREATIG ARTIFICIAL RAIN GARDENS AND TREE ISLANDS:

Figure 5. How Raingardens Work.[xvi]



Many of the tree lawn and areas that have a lot of utility lines can be converted into rain-gardens patches with native trees and plants. These rain gardens reduce storm water runoffs. In addition to reducing the quantity of storm water run-offs they add aesthetic value to the property, they are easy to maintain and they also keep the water clean.[xvii]

7.CREATE PARTNERSHIP BETWEEN THE CITY FORESTER, THE STORMWATER/CITY PLANNER/ENGINEER AND COMMUNITY MEMBERS:

The block - Indiana between 7th and Kirkwood is a busy with a lot of traffic thoroughfare. The current situation warrants a joint effort between the forester, the city engineer and the members of the community to devise ways which incorporate city planning and forest management practices to provide solutions for cost effective storm management techniques.

With increasing urbanizations and rapid deforestation it is the need of the hour to work jointly in ameliorating the damages and ensure a better quality of living.

Figure 6. Collaboration of Forestry Practices and Sewerage Construction[xviii]

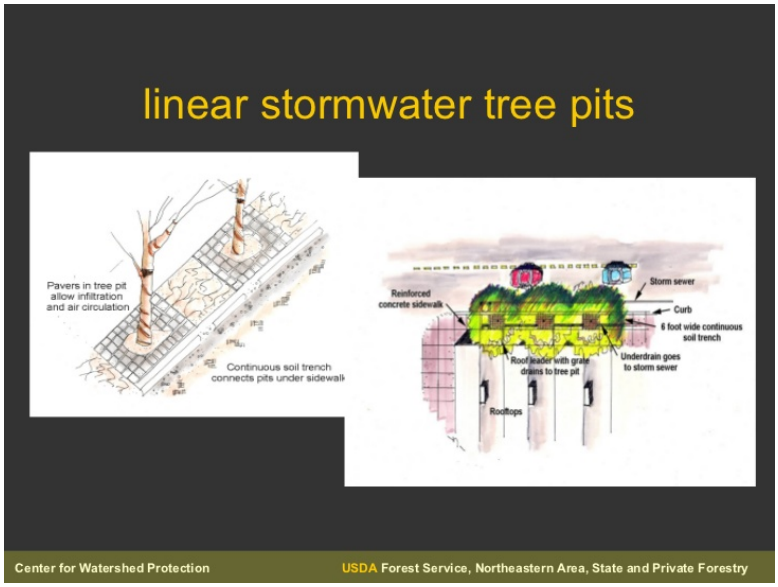


Figure 7. Permeable Surfaces to Mitigate Stormwater [xix]

IDENTIFIED SPOTS WHERE TREES CAN BE PLANTED TO INCREASE THE TREE CANOPY COVER:

1. Parking lot at the corner of Indiana and Kirkwood
2. Home lawns with cooperation with the owners
3. Dunn meadows.
4. Street lawns on the right- side of Indiana and 7th heading toward Kirkwood.

Conclusion

As the climate is rapidly altering, the likelihood of flooding events will also increase. The City of Bloomington with its history of flooding is therefore more susceptible to future flooding and needs a strong and initiative storm-water management plan to mitigate the environmental and economic impacts associated with flooding. Our re- inventory of the street trees and analysis of the block Indiana Avenue between 7th and Kirkwood provides the City of Bloomington with specific recommendations, such as increasing the tree cover, converting impermeable surfaces, and implementing raingarden to mitigate future flooding and use it as a template to expand it into a city-wide management plan.

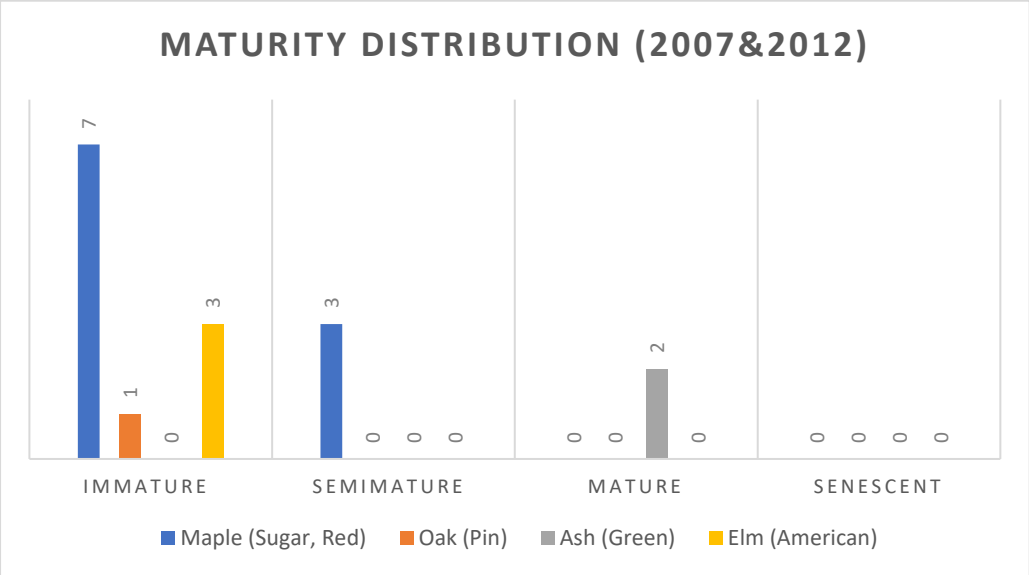
[i] Environmental Protection Agency (EPA). 2013. "Stormwater to Street Trees." https://www.epa.gov/sites/production/files/2015-11/documents/stormwater2streettrees.pdf

[ii] National Benefit Calculator. http://www.treebenefits.com/calculator/.
[iii] Arbor Day Foundation. 2017. "Tree Details." https://www.arborday.org/trees/treeguide/TreeDetail.cfm?Itemid=879.
[iv] https://www.slideshare.net/watershedprotection/using-trees-to-reduce-stormwater-runoff-formatted-presentation?type=powerpoint
[v] Dan Burden "urban street trees: 22 benefits specific applications"
[vi] http://ufmptoolkit.net/wp-content/uploads/2016/03/LongBeachUFMP.pdf

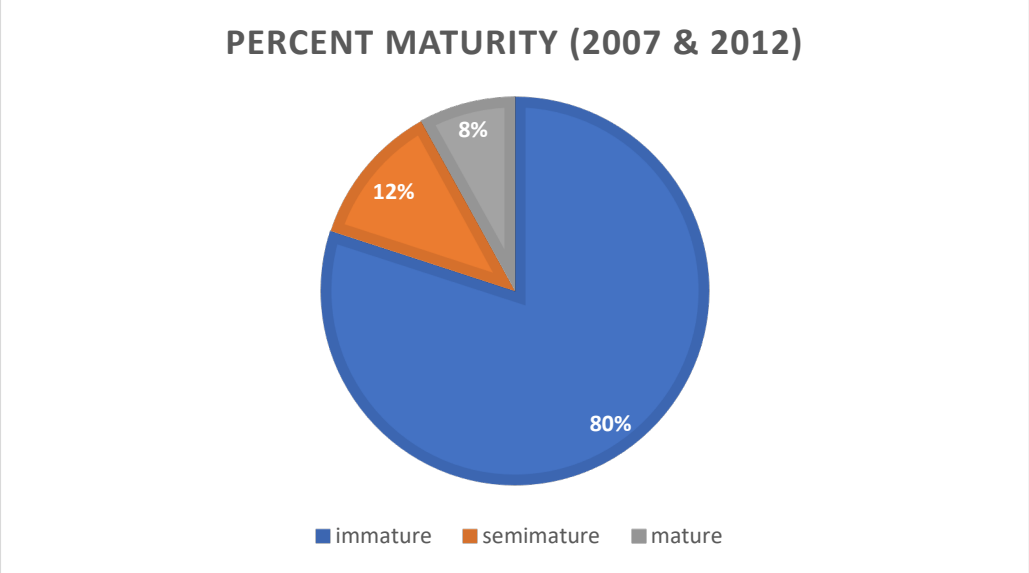
[vii] https://www.slideshare.net/watershedprotection/using-trees-to-reduce-stormwater-runoff-formatted-presentation?type=powerpoint
[viii] John Ball and Sarah Tyo "Diversity of the Urban Forest: We need more genera not species"
[ix] John Ball and Sarah Tyo "Diversity of the Urban Forest: We need more genera not species"
[x] http://theconversation.com/can-we-really-prevent-floods-by-planting-more-trees-52160
[xi] http://theconversation.com/can-we-really-prevent-floods-by-planting-more-trees-52160
[xii] https://www.sepa.org.uk/regulations/water/diffuse-pollution/diffuse-pollution-in-the-urban-environment/
[xiii] https://www.slideshare.net/watershedprotection/using-trees-to-reduce-stormwater-runoff-formatted-presentation?type=powerpoint
[xiv xiv] Dan Burden "urban street trees: 22 benefits specific applications"
[xv] https://www.slideshare.net/watershedprotection/using-trees-to-reduce-stormwater-runoff-formatted-presentation?type=powerpoint
[xvi] https://www.google.com/url?sa=i&rct=j&q=&esrc=s&source=imgres&cd=&ved=0ahUKEwif-8SEhLnTAhVDyoMKHXuuABgQjRwIBw&url=http%3A%2F%2Fwww.lsrca.on.ca%2Fpermits%2Frainscaping%2Fbuild-a-rain-garden&psig=AFQjCNFBBAqlKo3V18fystOSAHhfkWOxZw&ust=1492983742792371
[xvii] http://www.lsrca.on.ca/permits/rainscaping/build-a-rain-garden
[xviii] https://www.slideshare.net/watershedprotection/using-trees-to-reduce-stormwater-runoff-formatted-presentation?type=powerpoint
[xix] https://www.slideshare.net/watershedprotection/using-trees-to-reduce-stormwater-runoff-formatted-presentation?type=powerpoint

Appendix:

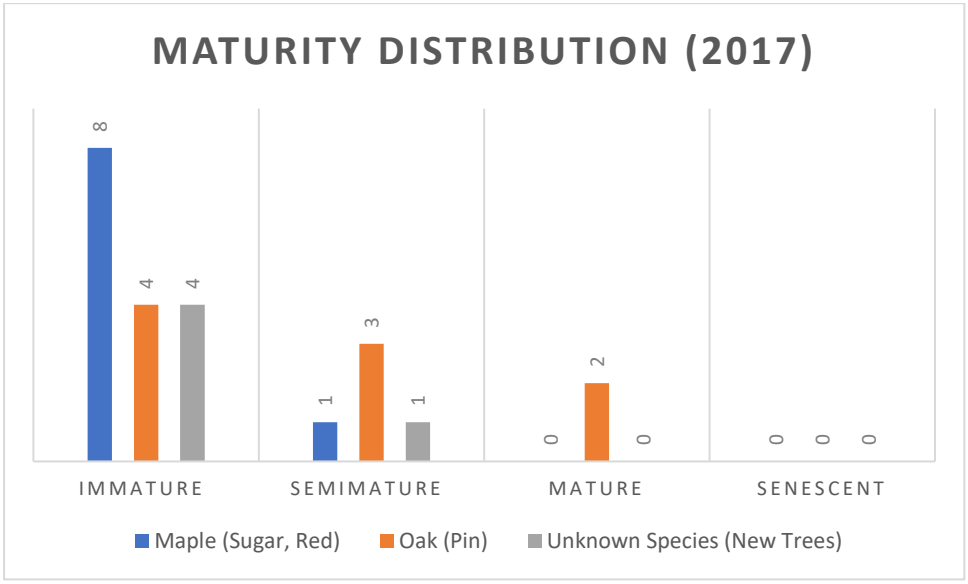
Appendix A. Maturity Distribution of the Street Trees on Indiana and 7th from 2007 and 2012.



Appendix B. Maturity Percent of the Street Trees of Indiana and 7th from 2007 and 2012..



Appendix C. Maturity Distribution of the Street Trees of Indiana and 7th from 2017.



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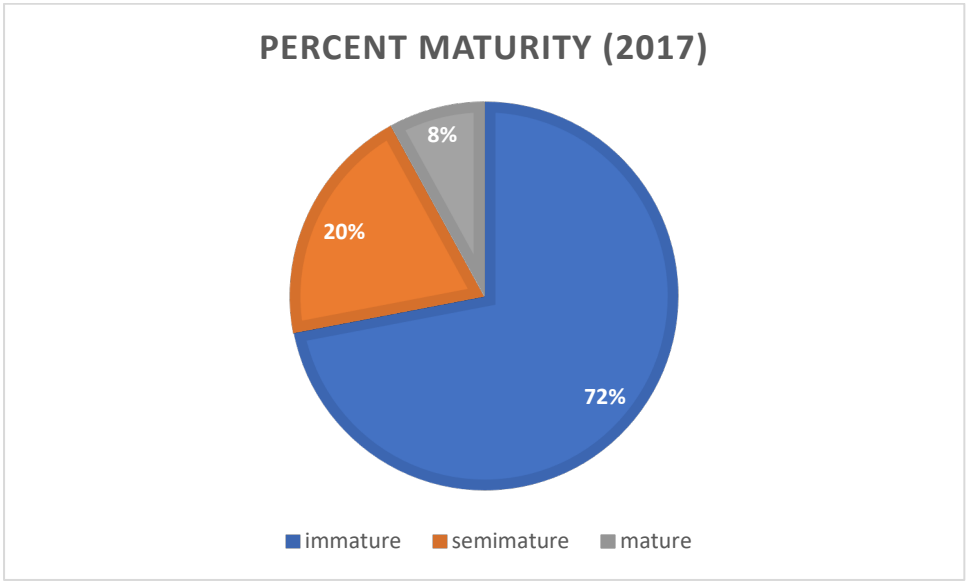
Appendix D. Maturity Percent of the Street Trees of Indiana and 7th from 2017.



Appendix E. Updated Street Tree Inventory of Indiana and 7th

ADDRESS_	STREET	LOCATION	LOC_NUM	SPECIES	DATE_	SURVEYOR	CONDITIO	DBH	LAWN	MAINNANEN	WIRE	Notes
528	07TH STE	F	1	OAK, SPECIES	12-Dec-06	MIS	FAIR	2	7	TRAIN	NO	
528	07TH STE	F	1	OAK, SPECIES	08-APR-17	AC/RK/JN	fair	5	7	ROUTINE SM		some damage to trunk, and at intersection
528	07TH STE	F	1	PLANTING SITE LARGE	12-Dec-06	MIS	MA	0	7	PLANT	NO	
528	07TH STE	F	1	still same	08-APR-17	AC/RK/JN		0	7			
601	07TH STE	F	3	PLANTING SITE MEDIUM	12-Dec-06	MIS	MA	0	6	PLANT	NO	
601	07TH STE	F	3	No longer here	08-APR-17	AC/RK/JN		0	6			
601	07TH STE	F	4	MAPLE, SUGAR	12-Dec-06	MIS	FAIR	22	6	ROUTINE LG	NO	
601	07TH STE	F	4	Maple, sugar	08-APR-17	AC/RK/JN	fair	26	6	ROUTINE LG	no	ivy growing on tree, also next to stop sign
601	07TH STE	F	5	PLANTING SITE MEDIUM	12-Dec-06	MIS		0	7	PLANT	NO	
601	07TH STE	F	5	New tree --unknown spec	08-APR-17	AC/RK/JN	fair	11	7	ROUTINE SM	no	forked and girdling root
601	07TH STE	F	6	PLANTING SITE MEDIUM	12-Dec-06	MIS		0	7	PLANT	NO	
601	07TH STE	F	6	New tree --unknown spec	08-APR-17	AC/RK/JN	fair	4	7	ROUTINE SM	NO	
215	INDIANA AVE N	F	1	MAPLE, SUGAR	02-Jan-07	MIS	GOOD	22	5	ROUTINE LG	NO	
215	INDIANA AVE N	F	1	maple was removed and an oak was pl	AC/RK/JN		good	4	5	ROUTINE SM	yes	
100	INDIANA AVE N	F	1	Sugar Maple	2012	MEM	poor	7	>6	PRIORITY 3	yes	
100	INDIANA AVE N	F	1		08-APR-17	AC/RK/JN						
100	INDIANA AVE N	F	2	Green Ash	2012	MEM	good	25	>6	ROUTINE LG	yes	
100	INDIANA AVE N	F	2		08-APR-17	AC/RK/JN						
100	INDIANA AVE N	F	2	Green Ash	2012	MEM	good	21	>6	ROUTINE LG	yes	
100	INDIANA AVE N	F	2		08-APR-17	AC/RK/JN						
100	INDIANA AVE N	F	3	American Elm	2012	MEM	good	5	>6	None	no	
100	INDIANA AVE N	F	3		08-APR-17	AC/RK/JN						
114	INDIANA AVE N	S	2	American Elm	2012	MEM	good	5	NA	None	no	
114	INDIANA AVE N	S	2		08-APR-17	AC/RK/JN						
114	INDIANA AVE N	S	1	American Elm	2012	MEM	good	5	NA	None	no	
114	INDIANA AVE N	S	1		08-APR-17	AC/RK/JN						
114	INDIANA AVE N	F	1	Sugar Maple	2012	MEM	good	7	> 6	ROUTINE SM	yes	
114	INDIANA AVE N	F	1		08-APR-17	AC/RK/JN						
201	INDIANA AVE N	F	2	Planting Space Small	2012	MEM	NA		5	PLANT	yes	
201	INDIANA AVE N	F	1	Oak	08-APR-17	AC/RK/JN	fair	4	5	ROUTINE SM	yes	too much mulch
201	INDIANA AVE N	F	1	Sugar Maple	2012	MEM	poor	19	5	PRIORITY 2	yes	removed
201	INDIANA AVE N	F	1	Oak	08-APR-17	AC/RK/JN	fair	4	5	ROUTINE SM	yes	structural damage
201	INDIANA AVE N	F	3	Planting Space Small	2012	MEM	NA		5	PLANT	yes	
201	INDIANA AVE N	F	4	Planting Space Small	2012	MEM	NA		5	PLANT	yes	
601	KIRKWOOD E	S	6	Red Maple	2012	MEM	poor	13	5	ROUTINE LG	no	removed
601	KIRKWOOD E	S	6	Maple	08-APR-17	AC/RK/JN	fair	4	5	ROUTINE SM	no	already pruned once
601	KIRKWOOD E	S	3	planting space medium	2012	MEM	NA		5	PLANT	no	
601	KIRKWOOD E	S	3	Maple	08-APR-17	AC/RK/JN	fair	3	5	ROUTINE SM	no	mulching is awful, bark coming off
601	KIRKWOOD E	S	8	planting space medium	2012	MEM	NA		5	PLANT	no	
601	KIRKWOOD E	S	8	Maple	08-APR-17	AC/RK/JN	good	5	5	ROUTINE SM	no	bark removed, structural damage
601	KIRKWOOD E	S	2	Red Maple	2012	MEM	good	9	5	ROUTINE SM	no	
601	KIRKWOOD E	S	2	Maple	08-APR-17	AC/RK/JN	fair	13	5	ROUTINE LG	no	intense pruning, damage
601	KIRKWOOD E	S	4	Red Maple	2012	MEM	fair	11	5	ROUTINE LG	no	
601	KIRKWOOD E	S	4	Maple	08-APR-17	AC/RK/JN	fair	15	5	ROUTINE LG	no	dead branches, mulching over roots
601	KIRKWOOD E	S	5	Red Maple	2012	MEM	fair	14	5	ROUTINE LG	no	
601	KIRKWOOD E	S	5	Maple	08-APR-17	AC/RK/JN	fair	15	5	ROUTINE LG	no	damaged/dead limbs
601	KIRKWOOD E	S	1	Sugar Maple	2012	MEM	poor	25	5	PRIORITY 1	no	removed
601	KIRKWOOD E	S	1	Maple	08-APR-17	AC/RK/JN	good	2	5	TRAIN	no	
observations: young street trees. Older private trees												
red = 2007 inventory												
black = our inventory												
blue = 2012 inventory												

Appendix F. Part 2 of Updated Street Tree Inventory of Indiana and 7th.

ADDRESS_	STREET	LOCATION	LOC_NUM	SPECIES	DATE_	SURVEYOR	CONDITIO	DBH	LAWN	MAINANEN	WIRE	Notes
In front of parking lot	INDIANA AVE N	F		Oak	05-APR-17	AC/HE/JM	FAIR	20		ROUTINE LG	Yes	dead branches/ has marker tag (351)
In front of parking lot	INDIANA AVE N	F		Oak	05-APR-17	AC/HE/JM	FAIR	9		ROUTINE SM	Yes	structural damage
In front of parking lot	INDIANA AVE N	F		Oak	05-APR-17	AC/HE/JM	FAIR	6		ROUTINE SM	Yes	structural damage; bark coming off
In front of parking lot	INDIANA AVE N	F		Oak	05-APR-17	AC/HE/JM	POOR	26		PRIORITY 3	Yes	random prunin; topping; fungi
In front of parking lot	INDIANA AVE N	F		Oak	05-APR-17	AC/HE/JM	FAIR	6		ROUTINE SM	Yes	fungi, moss, root girdling
Across from 210, in front of DM	INDIANA AVE N	F		Maple	05-APR-17	AC/HE/JM	GOOD	4		ROUTINE SM	No	
Across from 210, in front of DM	INDIANA AVE N	F		New Tree	05-APR-17	AC/HE/JM	FAIR	1-2		Train	No	protective guard around roots
Across from 210, in front of DM	INDIANA AVE N	F		New Tree	05-APR-17	AC/HE/JM	FAIR	1-2		Train	No	protective guard around roots
Across from 210, in front of DM	INDIANA AVE N	F		New Tree	05-APR-17	AC/HE/JM	FAIR	1-2		Train	No	protective guard around roots