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The Environmental, Social, and Economic Benefits of Blue Green Infrastructure in an Urbanized Area

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The Environmental, Social, and Economic Benefits of Blue Green Infrastructure in an Urbanized Area

Joseph L. Oguns

Thesis submitted to

Davis College of Agriculture, Natural Resources and Design

In partial fulfillment of the requirements for the degree of

Master of Landscape Architecture

In

Landscape Architecture Department

Davis College of Agriculture, Natural Resources and Design

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Morgantown, West Virginia

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**Keywords: Blue – Green Infrastructure; non-point source pollution; Co2 emission;
air pollution; park; total suspended solids; watershed; surface water runoff; water
quality; Pittsburgh**

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Abstract

The Environmental, Social, and Economic Benefits of Blue Green Infrastructure in an Urbanized Area

Joseph L. Oguns

At present, it is evident that there is a shift from rural to an urban settlement which results in high demand for residential buildings and other urban infrastructure. Blue – Green Infrastructure (BGI) is a system of using blue (water) and green (nature) to address urban and environmental challenges. The purpose of this study is to evaluate the environmental, social, and economic benefits of blue-green infrastructure in an urbanized area in Pittsburgh, Pennsylvania, USA. The study involves the utilization of Geographic Information System (GIS) to determine water quality level resulting from nonpoint source pollution through acquiring elevation data; watershed; and processing the elevation data through performing appropriate watershed delineation for the study area. Different landscape models (i-Tree Design, i-Tree Landscape) were explored to determine the different benefits attached to BGI Infrastructure aside aesthetic and refuge benefits from the Landscape Performance Series database. The i-Tree Landscape gives one an idea of areas where particulate matter and atmospheric gases exist, and areas to prioritize planting of trees. A pilot scale-site was chosen from the discovered areas to prioritize plantation with the help of some selected criteria. Five design patterns (Green Parks, Riverfront, Activity Nodes, Green Parking, and Green Streets) were adapted, an i-Tree Design model was used to get the pre and post environmental and economic benefits of trees on a 10-yr. expectation plan. The water quality model, I discovered areas that have high total suspended solids (TSS) level giving one an idea on the water quality of the area. The areas pointed out as areas to prioritize planting by the i- Tree Landscape model also has high TSS level from the GIS delineation to further justify the outcomes of the two models used. Sustainable design concepts were provided on how to practice/ incorporate blue-green infrastructure in areas that need interventions towards creating a balance between the built and natural environment.

Dedication

I wish to dedicate this thesis project to my late father and to every committed youth.

Acknowledgement

All achievements in life is a function of great ideas, lessons, theories, gifts, knowledge and talents of individuals who have in one way or the other added value to one's life, this thesis is not an exemption.

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CHAPTER 1

Introduction

1.1. General Background for the Study

The World Health Organization forecasted that there will be a 60% increase of the world's population of people that will be living in an urban settlement in 2030 and a possible increase of about 70% by 2050 (WHO, 2014). Such a move can lead to urban sprawl, which will affect human health because it will lead to loss of green and nature (Bell et al., 2010). Because of human activities (use of fertilizers on farms, transportation facilities, impervious surfaces, oil spills, buildings) there tend to be environmental, social, and climatic challenges in the urban areas which need to be attended to by her residents and the government, and it can be achieved through the continuous dissemination of research findings to stakeholders. Nonpoint pollution source (NPS) is the major cause of water pollution in the US (EPA, 2007). Discharges from NPS go into surfaces and ground waters in a diffuse manner. Before pollutants reach surface water or infiltrate into groundwater, it moves over an extensive land area. Land and runoff management practices are the best ways to reduce NPS pollution rather than focusing on effluent treatment.

1.2. Purpose of the Study

The purpose of this study is to evaluate the environmental, social and economic benefits of blue (water) – green (nature) infrastructure in an urbanized area in Pittsburgh, PA a postindustrial city. This study includes the use of Geographic Information System (GIS) to determine the water quality from the watershed and processing of the digital elevation model of the area using GIS tools, to use other landscape models (i-Tree Design, i-Tree Landscape) from Landscape Performance Series database to further determine environmental activities which affect air, water, land, and health. The various spatial tools that will be used in this project will help one to determine the best area to prioritize blue green infrastructure, and other benefits (social and economic), which one can derive from blue green infrastructures that are beyond aesthetic and shade from the canopies which are the quick benefits to think about. Sustainable Design concept particularly on the area

that need to prioritize blue -green infrastructure from the i-Tree Landscape result was provided.

1.3. Research Questions

How to set up a process in determining where to prioritize blue green infrastructure in an urbanized area?

What are the environmental, social, and economic benefits of blue green infrastructures?

How can blue green Infrastructure improve urban sustainability and public health?

1.4. Scope of the Study Area

The study area is in Pittsburgh City, with a population of 305,704 residents within the city boundary (2017) it is the 63rd- largest city in the US. Categorized as a postindustrial city. It is known as the “Steel City” with about 300 steel-based businesses and as the “City of Bridges”. After World War II, the city launched a project known as “Renaissance” cleaning up the air and rivers and a focus on cultural and neighborhood development during “Renaissance II”. The city is now the center of Leadership in Energy and Environmental Design. Pittsburgh is the county seat of Allegheny County, in southwest PA; which has a population of about 1,225,365 (Census 2010). It is categorized as the second largest county in the state with a total of 745 sq. mi (1939 km²). The elevation ranges from 208.3 m to 424.82 m.

Figure 1: Pittsburgh Neighborhood Map

1.5. Significance of the Study

Green Infrastructure has a significant importance in enabling the social life of neighborhoods and creating a sense of community (Kim and Kaplan, 2004). There is a positive link between social life and health (Nieminen et al., 2010). People living in a region with high a percentage of green infrastructure have the tendency of lowering levels of stress (Grahn and Stigsdotter, 2003; Ward Thompson et al., 2012). Research has shown a reduction in risk of mortality from cardio – respiratory disease in urban areas having access to natural environment by 5 to 10 percent to areas with poor access (Mitchell and Pophan, 2008; Richardson and Mitchell, 2010). Water is an important part of the landscape in therapeutic landscape (Williams, 2010, p. 19637). Water is a symbol of purity being expressed in the mental and spiritual life of man. Non-point source pollution

is a major cause of water quality degradation in America which makes it challenging to meet water quality standards for lakes, rivers, streams, and estuaries, most Appalachian states utilizes surface water for drinking and other purposes.

This study will help to guide the government and residents of areas at health risk because of the water quality level, determine the water quality of the areas to know areas at risk and take positive steps, also determining areas with SO₂, O₃, and CO presence in the air, it will help to determine areas to prioritize planting of trees and blue infrastructure, total area of impervious surfaces, the rate at which carbon storage/sequestration can be achieved with green infrastructure. The approach can be applied to any State in the United states or other countries with access to similar data.

1.5. Methodology

Flow chart of Methodology

Figure 2: Flow Chart of Methodology

CHAPTER 2

Literature Review

2.1. History of Green Blue Infrastructure

There is less concentration on sustainability, green blue infrastructure projects in the urban context, rather other areas of development were concentrated on; economic and consumerist expansion took over urban life which led to the subsidence of the urban system, resulting in massive setbacks in many cities. The quest for making cities more resilient, livable dynamic to a monofunctional lifeless system began (Dreiseitl, 2012). To make the city an engaging one by creating places for children to play and socializing among families and groups. Projects on the use of rainwater making, to be visualized and not hidden under the ground were employed; buffering of the rainwater after cloud – bursts, cleaning of runoff from the road, feeding of the nearby streams and not polluting them. These projects were done at a different scale from the one done in the villages in Switzerland to larger scale projects in Berlin's

Potsdamer Platz (urban hydrology project); Bishan – Ang Mo Kio Park (blue-green and social infrastructure project) and Kallang Riverfront (rain and stormwater management project) in Singapore.

The World Health Organization forecasts that there will be a 60% increase of the world's population of people that will be living in an urban settlement in 2030 and a possible increase of about 70% by 2050 (WHO, 2014). Such a move can lead to urban sprawl, which will affect human health because it will lead to a loss of green space and nature (Bell et al., 2010).

Historically, from the mid-nineteenth century, the industrial growth and the migration of people into large cities in American Northeast and Midwest led to a reform in the urban landscape.

2.2. Green Infrastructure

Green Infrastructure (GI) can be traced to the nineteenth century (Benedict and McMahon, 2002). The sudden growth in urban areas affected many areas due to anthropogenic activities; poor sewer system; water contamination; pollution, communicable diseases; poor living conditions and the breakdown of physical infrastructures. These challenges brought about the advocacy of public parks in Europe called Birkenhead Park (Liverpool) and Victoria Park in the East End of London in the 1830s and 1840s to boost the health of workers in the urban settlements (Ward Thompson, 2011). It helped to bring a change in North America, Frederick Law Olmstead when appointed as general of the sanitary commission in Riverside, Chicago, he utilized the public health facility (Szczygiel and Hewitt, 2000). He came out with his theories and plan on health, well-being and nature. It was discovered that mental, social and physical health risk is affected by industrialized urban settlement (Eisenman, 2013). Olmstead contributed to practical planning of natural system for health benefits using green infrastructure in the planning and development of cities. He further advocated for the provision of physical exercise in Buffalo Park (Taylor, 1999). He created a balance between users (health, recreation, and social bond) and nature (ecological function).

Patrick Geddes (1915) a biologist and a city planner, and Ian McHarg (1971) looked at green infrastructure and sustainability in city development through nature connecting with people and place and creating a connection between human habitats and nature respectively (Hough, 2007 p54).

2.3. The role of Green Infrastructure on Health

The term 'health' is defined by WHO as the complete state of physical, mental, and social wellbeing and not only the absence of illness (WHO, 1948). There is a large body of research done in health and the environment in the past that studied on the negative side of the environment as it relates to public health including water-borne diseases, harmful chemicals that cause cancer and other illnesses (Frumkin, 2001). Recently, the focus has changed researchers now study on the positive sides of human health on different areas of physical and social environment, focusing on air quality, public transportation, urban and rural settlement, and green space. People's access to green infrastructure, housing,

health, and education are categorized as the requirement for an excellent quality of life (CABE, 2010). Research has shown a reduction in risk of mortality from cardiorespiratory disease in urban areas having access to the natural environment by 5 to 10 percent to areas with poor access (Mitchell and Pophan, 2008; Richardson and Mitchell, 2010).

Four proposed health benefits of accessing nature were outlined (Hartig et al., 2014); Physical activity restorative value of nature; Social bond, and air quality improvement through green infrastructure.

Physical activity has both curative and preventive effects (Ward, Thompson, 2011). Lack of observance of physical activity has cost the UK economy more than £5 to £8 billion a year (Bird, 2007). Blood pressure can be reduced by access to the walkable green corridor (Ortega – Smith et al., 2004). Walking in a forest can as well assist cardiovascular relaxation and decreases bad physiological symptoms (Lee et al., 2014). Adults and children with more access to parks are prone to have a lower Body Mass Index (BMI) level (Wolch et al., 2011).

There is a lot of evidence on mental health advantages related to nature and green space. Exposure to nature can be curative (Hartig et al., 1991). People living in a region with green infrastructure have the tendency of lowering levels of stress (Grahn and Stigsdotter, 2003; Ward Thompson et al., 2012). More so, people having more than 1 km away from green infrastructure are tending to have higher levels of stress to those living close (Stigsdotter et al., 2010). The quality of a park is mostly studied recently and has more advantages on mental health to the number of public open spaces in the neighborhood (Francis et al., 2012). Residence with trees and grass that can be seen from the apartment buildings reduces mental stress and aggression level in comparison with the apartment where trees and grasses are not seen (Kuo and Sullivan, 2001). Overgrown or unmanaged green spaces is possible to increase the level of anxiety due to fear of crime (Kuo et al., 1998).

2.4. The role of Green Infrastructure on Social Bond

Green Infrastructure has significant importance in enabling the social life of neighborhoods and creating a sense of community (Kim and Kaplan, 2004). There is a

positive relationship between social life and health (Nieminen et al., 2010), also with green infrastructure availability and health (De Vries et al., 2013). The urban green infrastructure in Switzerland helped in creating a social network among friends: children and young people from different demography (Seeland et al., 2009).

2.5. The role of Green Infrastructure on Air Quality

Regardless of the allergies gotten from the release of pollen, they also have positive effects. Air pollutants (particulate matter and gases) can be improved with trees and vegetation to enhance urban air quality (Nowak et al., 2006). Trees can be used as a refuge during summer to guide against excess heat and reduce the demand for air conditioning and relieves heat stress (Lafortezza et al., 2009).

2.6. Blue Infrastructure

Blue (water) Infrastructure is a unique element in a landscape that beautifies the environment. Several corporate developments depend on water (Kaplan and Kaplan, 1989). People are attracted to an environment that has water (lakes, coasts, rivers) (Nasar and Li, 2004).

2.7. The Role of Blue Infrastructure on Wellness

Water is an important part of the landscape in a therapeutic landscape (Williams, 2010, p. 19637). Holy walls of Ireland are sites of indigenous health (Foley, 2011, p. 477). Likewise, Lourdes Spring in South France is a healing center (Gesler, 1996, p. 101). It is seen as a serene and relaxing place (Ulrich, 1993). On the other hand, because of flooding, which is a potential hazard which can have a negative mental effect (Mell, 2008). Green and blue infrastructure have links that contribute positively to human health. Current studies have shown the restorative benefits to it (White et al., 2010; Volker and Kistemann, 2011, 2013). Blue spaces and coastal regions were seen to be more restorative to green nature scenes (White et al., 2013). The sense of place is key to well being of people. Water is seen as a natural mirror, displaying blurring images that are not as visible as normal mirror (Burmil et al., 1999, p. 101; Nasar and Li, 2004, p. 236). Water is seen as a symbol of purity which is being expressed in the mental and spiritual life of man. The idea behind seeing water as a holy thing is found in religious places like Lourdes

in France (Nouwen, 1990, p. 8, cited by Gesler, 1996, p. 100), and at St. Anne de Beaupre in Quebec, Canada were people where people use water for healing, fertility and miraculous powers (Williams, 2010, p. 1637). Water is seen to have more influence on emotional well – being compared to other environments (Felsten, 2009, p. 166; Ulrich, 1981, p. 548).

2.8. The Role of Blue Infrastructure on Economy

Non-governmental business owners find it appealing to have businesses in blue spaces (Luttik, 2000). Benches for short relaxation and personal safety for bathing activities help support recreation activities (Asakawa et al., 2004 p. 177; Burmil et al., 1999, p. 104; Smith et al., 1995b, pp. 42-43). Recreation that is characterized by a higher further motion (kinetic recreation) on water e.g., canoeing or cycling at the water edge (Yabes et al., 1997, p. 182; Yamashita, 2002, p. 9). There are other forms of recreation done at a point example swimming, walking, and social meetings are called situation – based recreational experience (Smith et al., 1995b, Pp. 33-35; Yabes et al., 1997 Pp. 182 – 183; Yamashata, 2002, p. 9).

2.9. Nonpoint Source Pollution

Nonpoint Source Pollution NPS means a pattern of pollution or diffused source pollution where the source nor the size of the specific emissions can be seen with accuracy. It happens because of snowmelt and rainfall moving through or over the ground. It is seen as a cause of impaired water quality in America which makes it challenging to meet water quality standards for lakes, rivers, streams, and estuaries. The sources of NPS pollution are urban activity, industry, transportation, and agriculture. Generally, NPS pollution comes from runoff, infiltration, drainage, seepage, precipitation, hydrologic modifications, or atmospheric deposition. When the snow melts and rain falls, it transports natural pollutants and pollutants from human activities then into the groundwater, coastal waters, wetlands, lakes, and rivers (EPA 2003 chapter 1, pp. 1-3). Urban pollution comes mostly from urban runoff (McLeod et al., 2006). More Total Suspended Solids (TSS) and total Kjeldahl nitrogen (TKN) load are seen in urban runoff to two local point sources.

2.10. Economic Benefits of Improving Water Quality

A study was made on the Tar – Pamlico River the fourth largest in North Carolina. There were issues of algae blooms, diseases in fish, reduction in fish harvest, shellfish bed and underwater grass losses, 30% of the Tar- Pamlico River affected by pollution, 67% is because of agricultural NPS pollution (North Carolina Division of Environmental Management, 1988). Surface water quality is affected by agricultural NPS pollution thus it reduces the efficiency of these activities; boating, swimming, fishing, and others. Best management practices (BMPS's) are effective avenue for abating NPS pollution using holding ponds or buffer strips because they are cost-effective. The government of North Carolina State and North Carolina Agricultural Cost – Share Program (ACSP) recently compensates organizations or the use of BMP's.

2.11. How Green Blue Infrastructure can be executed

There is a need for policy makers to consider public health and the physical environment. Green space should take places in urban planning not as a luxury, but as a necessity (Maas et al., 2006). Connectivity (housing and transportation) in landscapes can be provided by creating and management of green infrastructures. It will also promote restoration, social bonds, exercise. Housing choice is also a function of green and blue infrastructure (Hartig et al., 2003b). There should be good designs and proper selection of urban vegetation, and maintenance to have a positive influence on water and air quality and do not affect human health, it will also reduce crime rate level (Kuo and Sullivan, 2001). Open views along pedestrian paths and oversight or near buildings can make people feel safe, particularly the women (Krenichyn, 2004).

CHAPTER 3

Research Methods

The research methods observed in this study involves the use of Geographic Information System (GIS) to perform water quality analysis by determining the pollutant concentration in kg/yr of the entire study area, using of two landscape models; i-Tree landscape model to determine the air pollutants gases spatial location and areas to prioritize blue infrastructure, and i-Tree design model to find out the stormwater, carbon dioxide removal and avoided, air quality, and economic benefits the individual and collective trees. Lastly case studies were studied to look at existing projects that have similar applications to my study area.

The study area is in Pittsburgh City in Allegheny County, southwest of the U.S. Pennsylvania (PA). It has a population of about 1,225,365. It is categorized as the second largest county in the state with a total of 745 sq. mi (1939 km²). The elevation ranges from 0 m to 254 m.

Figure 3: Study area Map

Figure 4: Hillshade of Pittsburgh City

3.1. Data Sources and Processing

To understand how the flow direction works the data and processes shown in figure 6 below were carried out.

Flow Chart

Figure 5: Flow Charts of Water Analysis Steps

This process includes acquiring elevation data for the Allegheny watershed, processing the elevation data, and performing appropriate watershed delineation for the study area. The first step is to get the digital elevation model of the study area from nationalmap.gov (HU– 8 Sub basin). Digital elevation model (DEM) is a 3-Dimensional terrain analysis derived from interpolated surface of topography.

After downloading, the 1/3 arc-second USGS NED n41w081 dataset, it was extracted to the desired folder. The cell size was changed to 10, 10 (X, Y) cell size from 9.259 e -005, then projected by choosing UTM NAD - 1983 Zone 17N, and applied Int. from the Math tool. The boundary of the Allegheny Watershed was added, and a buffer of 200 meters was applied on the boundary to get a new shapefile Allegheny Boundary, the Deml

dataset was extracted by mask and the hill shade was also processed to give the maps below. The next step is to get the line work for the streams (watershed) also called basin or catchment referred to an area where rainfall and streams are drain to an outlet or points on stream channels. It can be lakes, streams, wetlands, groundwater and surface water. Accessed from nhd.usgs.gov on NHD Data pre-staged sub regions in GDB and High Resolution, select download and extract the appropriate HUC 8 for the watershed 05020005 Lower Monongahela, 05020006 Youghiogheny, 05010009 Lower Allegheny, 05030101 Upper Ohio, and 05030105 Connoquenessing. The flowline was added and clipped to the watershed boundary as seen below.

Figure 6: Watershed Distribution Map

These processes were employed with the aid of the Spatial Analyst Tool (Hydrology) on the study Dem to get the Fill Dem, Flow Direction using Fill Dem as the input raster, then the Flow Accumulation using the Flow Direction as input and changing the output data as an integer. The output maps are seen below:

Figure 7: Flow Accumulation Map

The next step was on working on the vector versus the raster grid, using the flow accumulation and reclassifying it to 2 classes from the legend properties, to get the raster stream grid. The flow accumulation was queried using 2000 fac units 10m cell size that corresponds to fifty acres. The Thin Command was used to get rid of the raster cells next

to each other. Reclassify tool was further used using Thin streams as input and naming 0 as NoData and 1 as 1 to get an output called watergrid. The maps are shown below:

Figure 8: The vector and Raster Streams Comparism

Figure 9: Thin, Streamgrid and Watergrid Result Map

The elevation was raised by 100m using the Raster Calculator (“filldem” + 100) to get an output dem100. Then the focal mean values of the dem for the raster streams were processed using the Focal Statistics tool. In addition, the Con tool was used using watergrid as the input conditional raster and the focalmin as the input true raster or constant value and strmelev as the output.

The Raster Calculator was used to multiply dem100 and Is Null_Strme1 to get an output step1, after which the Con tool was used to get an output burndem using step1 as input conditional raster and dem 100 as input true raster. Using the burndem as an input surface raster, the filldem2; flow direction2 flow accumulation2 were processed from the Hydrology tool. Fac2 was queried using “fac2” >= 2000 to get watergrid2 with the Raster Calculator tool.

3.2. Determining the Water Quality

GIS model was used in this analysis, DEM, Watershed, Precipitation, and the Land Cover of the focus area were used in the process. TSS (Total Suspended Solids) mg/L values were assigned to the NLCD 2011.

2011 Land Cover Value	Land Cover Types	Mg/ L of TSS
11	Open Water	3
21	Developed, Open Space	19
22	Developed, Low Intensity	20
23	Developed, Medium Intensity	25
24	Developed, High Intensity	35
31	Barren Land (Rocks/Sand/Clay)	30
41	Deciduous forest	16
42	Coniferous forest	14
43	Mixed forest	15
52	Dwarf Scrub	22
71	Grassland/Herbaceous	19
81	Pasture/ Hay	27
82	Cultivated Crops	27
90	Woody Wetlands	8
95	Emergent Herbaceous Wetlands	8

Table 1: Total Suspended Solids (TSS) Values Versus NLCD 2011

The reclassified NLCD 2011 was given an output emc_tss, the map is seen below.

Figure 10: Expected Mean Concentration Map

To estimate Annual loadings throughout the watershed, the pollutant mass contribution that each cell makes to downstream pollutant loading was calculated by taking the product of the expected mean concentration and runoff associated with the cell or

Load (mass/ time) = Expected mean Concentration EMC (Mass / Volume) * Q (Volume / time)

$$L = K * Q * EMC * A$$

K = Constant = 10^{-6} kg – m – L / mg – mm – m³ (Converting the units)

Q = Units in mm/yr.

EMC = in mg/liter A = Area of one grid cell

L = in kg/yr. (Loading)

To determine the cell-based loading grid raster calculator tool was used to multiply the runoff with the reclassified emc_tss. The precipitation data (Climate Prism Raster 1981 - 2010 Annual Average Maximum Precipitation by state) was downloaded from gdg.sc.egov.usda.gov. The 30-yr. annual depth of stream flow of 0.655474mm was used and multiplied with the annual precipitation total in mm to give the runoff. The cell load was gotten by multiplying the runoff with emc_tss.

Figure 11: Cell Based Loading Grid Map

The cumulative load output in kg/yr. for both in streams and out streams cells were gotten with flow accumulation tool using the flow direction 2 (fdr2) to get an output Part A and multiplying it with 0.0001.

Figure 12: Cumulative Load Output Map in Kg/yr.

To create a grid of concentration this equation was used

$$C \text{ (mg/L)} = L \text{ (kg/yr.)} / Q \text{ (m}^3\text{/yr.)} \times .001 \text{ m}^3\text{/L}$$

From the model this query was used

("tss_load" / "Cu_runoff2") * 1000 to get the tss_conc.

It helps to determine the pollutant concentrations within the area.

Figure 13: Cumulative Load Output in Kg/yr with Base Map.

From the water quality model, one can identify areas that have high TSS level which gives an idea on the water quality of the area, Total Suspended Solids are parameters used in determining water quality suspended in water. TSS can be because of surface runoff, decaying plants and animals, and soil erosion. The areas pointed out as areas to prioritize planting by the i- Tree Landscape model also among the area having high TSS level from the figure 12 above. High concentrations of suspended solids can cause many problems for stream health and aquatic life.

The Limitations of the water quality model

It does not consider infiltration, interflow, or groundwater flow additions; It uses mean annual runoff and flow measures with one-time water quality sampling data; It does not include atmospheric conditions such as evapotranspiration or temperature.

Advantages of the water quality Model

The results include surface runoff from point and non – point sources.

It is a landscape, GIS/ watershed model and not a receiving water model.

It is a deterministic simulation model.

It is easy to analyze the output and query functions from results

3.3. The i- Tree Models

3.3.1. i-Tree Landscape

i-Tree Landscape is a landscape model that gives other tree benefits which is different from physical benefits of beauty and refuge. The benefits include: enhancing water quality reducing urban heat island, stormwater mitigation, air pollution (ozone, sulfur dioxide, nitrogen dioxide, and particulate matter) spatial location, and areas to prioritize tree planting in a study area. This model uses canopy cover data National Land Cover Database (NLCD) 2011 and new high-resolution urban tree canopy data in partnership with U.S. Forest Service, Society of Municipal Arborists, Arbor Day Foundation, Casey Trees, Environmental Science and Forestry, and International Society of Arboriculture.

It is a five steps process:

1. Find Location/s to be studied by selecting area/s of interest with the control panel at the top right of the interface which has Map Layers, Canopy, and Land Layers, and Base Maps dataset to explore.
2. Explore Location Data to view data in English or Metric units, chart or table format. It gives one an idea of the impervious and canopy cover, land cover, U.S. Census, human health risk data, and forest data.
3. Tree Benefits of the selected area is seen in metric or English units under the map in chart or table format beneath the map.
4. Prioritize Tree Planting; areas to prioritize tree planting can be seen at this stage for sustainable practice and benefits. It can be weighed on a scale of 1 and 100 with the chosen method equals 100.

- Generating Results is the final stage where one can see the overall report and choose the output format desired by clicking on the done button. The sections to be seen includes location information, prioritization, and tree benefits.

i-Tree Landscape Findings

Figure 14: Map of the Study area (i-Tree Landscape)

Canopy & Impervious	Area		Canopy		Impervious		Plantable Space	
	Acre	Percentage	Acre	Percentage	Acre	Percentage	Acre	Percentage
Selection Total	37,899.8	100.00	15,963.0	44.43	14,703.9	40.89	5352.9	14.90

Table 2: Canopy, Impervious, and Plantable Spaces Table

Canopy & Impervious	Carbon Storage		Carbon Sequestration		CO ₂ Equivalent Storage		CO ₂ Equivalent Sequestration	
	\$	Short Ton	\$/yr	t/yr	\$	Short Ton	\$/yr.	t/yr.
Selection Total	63,281,109	370,922.6	1,241,224	7,277.8	63,261,109	1,360,049.3	1,241,224	26,685.1

Table 3: Carbon and CO₂ Storage and Sequestration

Air Pollution Removal	\$/yr	lb/yr	Health Incidence	Emergency Room Visits	Hospital Admissions	Acute Respiratory System	Asthma Exacerbation	Mortality	School Loss Days	Hospital Admissions, Cardiovascular	Acute Bronchitis	Upper Respiratory Symptoms	Lower Respiratory Symptoms	Work Loss Days
Selection Total	7,345,840	1,091,598.4	1184	0.03	0.22	907.52	185	0.34	59.82	0.01	0.02	2.08	2.50	26.16

Table 4: Total Air Pollution Removal

Figure 15: CO Areas in Pittsburgh City

Figure 16: Ozone O₃ Maximum Areas in Pittsburgh

Figure 17: Particulate Matter 2.5 Average Areas in Pittsburgh

EPA Impaired Waters

Impaired
Not Impaired

Dataset showing NHD (National Hydrography Dataset) Watercourses that are classified as impaired

Figure 18: EPA Impaired Waters in Pittsburgh

Legend

Minimum to Maximum

Figure 18: Areas to Prioritize Plantation

The i-tree landscape gives one a good understanding of the impervious and canopy area sizes, air pollution removal, human health risk information and forest data via exploring Pittsburgh neighborhoods. It also gave areas to prioritize planting of trees, the watercourses of National Hydrology Database that are impaired according to the Environmental Protection Agency (EPA). A location will be determined from the areas where tree plantation is majorly required based on some certain criteria.

3.4. Determining the Focus Area

The i-Tree landscape model result in figure 19 above gave one an idea of places to prioritize green infrastructure. For me to determine the right place to focus my design proposal and evaluations, I randomly chose two neighborhoods from the maximum areas where tree planting is required. I used the i-Tree Landscape model to further analyze the two neighborhoods: North Oakland (Area A) and Lawrenceville (Area B) with some criteria to concentrate on one.

Selection Criteria	Area A	Area B
50% Impervious	✓	
Areas above 500 acres	✓	
30% Tree Cover Per Capita	✓	✓
40% Population Density	✓	✓
30% Tree Stocking Level	✓	✓

Table 5: Selection criteria for design focus area

Figure 20: Lawrenceville PA (Area A)

Canopy & Impervious	Area		Canopy		Impervious		Plantable Space	
	Acre	Percentage	Acre	Percentage	Acre	Percentage	Acre	Percentage
Selection Total	986.5	100.00	266.0	30.40	445.9	50.96	165.5	18.91

Table 6: Canopy, Impervious, and Plantable Spaces for Lawrenceville

Canopy & Impervious	Carbon Storage		Carbon Sequestration		Co ₂ Equivalent Storage		Co ₂ Equivalent Sequestration	
	\$	Short Ton	\$/yr.	t/yr.	\$	Short Ton	\$/yr.	t/yr.
Selection Total	954,855	5,598.6	15,642	91.7	954,804	20,528.5	15,642	336.3

Table 7: Carbon and CO₂ Storage and Sequestration for Lawrenceville

Legend: Min. to Max.

Figure 21: Areas to Prioritize Plantation in Lawrenceville, PA

Second Option: North Oakland

Figure 22: North Oakland Map

Canopy & Impervious	Area		Canopy		Impervious		Plantable Space	
	Acre	Percentage	Acre	Percentage	Acre	Percentage	Acre	Percentage
Selection Total	319.3	100.00	88.5	27.71	206.3	64.61	24.5	7.68

Table 8: Canopy, Impervious, and Plantable Spaces Table for North Oakland

Canopy & Impervious	Carbon Storage		Carbon Sequestration		CO ₂ Equivalent Storage		CO ₂ Equivalent Sequestration	
	\$	Short Ton	\$/yr.	t/yr.	\$	Short Ton	\$/yr.	t/yr.
Selection Total	216,584	1,269.9	6,422	37.7	216,573	4,656.4	6,422	138.0

Table 9: Carbon Results of North Oakland

Legend: Min. to Max.

Figure 23: Areas to Prioritize Plantation in North Oakland

Finally, Area A was chosen as the site to propose design intervention and analysis over Area B because Lawrenceville passed all the selection criteria set for decision making (50% Impervious, Areas above 500 acres, 30% Tree Cover Per Capita, 40% Population Density, 30% Tree Stocking Level). More so, Lawrenceville has more room for growth and development without much design constraints. Lawrenceville is divided into 3 upper Lawrenceville, Central Lawrenceville, and Lower Lawrenceville, though it is seen as an entity. I further chose the Upper Lawrenceville as a pilot project for the whole Lawrenceville, the whole boundary of Upper Lawrenceville was used though not completely highlighted by the i-Tree Landscape result in figure 21 but it was added to address the flood zone challenge as mapped in figure 34 below.

3.5. i-Tree Design Model

i-Tree Design is a model that guide anyone in determining the tree benefits which includes air quality enhancement, stormwater interference, economic, and green gas reduction, through inserting the set location, tree species, conditions, and tree size. The model is used by directly placing the selected specie/s of tree/s to the exact spatial location to get the overall tree benefits (stormwater, air quality, and CO₂) for 2 to 99 years.

After having an idea on the area to focus on prioritizing tree planting, i-Tree Design v6.0 was used as the third model to get an estimation of the different benefits of the individual trees, by also making a pre and post comparism of the existing condition and my 5 design patterns which include Parks, Waterfront, Activity Nodes, Green Streets, and Green Parking looking at a 10-year plan benefits of the both conditions. Different trees samples; Red elm (*Ulmus rubra*), American Mountain ash (*Sorbus Americana*), Eastern Hemlock (*Tsuga canadensis*), Balsam fir (*Albies balsamea*), Ironwood (*Ostrya virginiana*), and Hickory trees were used in the design model. It was done through these processes:

1. Entering a street address of sample area among the areas to prioritize plantation with a choice of determining areas where trees have an effect on heating and cooling utility on a building.
2. Placing the trees by describing the tree species, diameter or circumference, tree condition, tree exposure to sunlight and finally dragging the trees in the areas that need intervention by zooming in and out.
3. Lastly estimating the benefits of the trees planted by entering the number of years from 2 to 99 to calculate overall benefits on the amount of money to be saved on stormwater, air quality and CO₂; stormwater – the amount of gallons of stormwater to intercept; energy - ; air quality – on the chart showing the absorbing pollutants, intercepting particulate; and carbon Dioxide – the pounds of carbon dioxide those trees will reduce.

i-Tree Design Model Results

The results for the five design patterns were explored according to their location and provided below to have a good understanding about stormwater runoff savings, air quality improvement savings, number of gallons of rainfall intercepted, and carbon dioxide reduction savings provided below.

Address: 27 51st St. Pittsburgh, PA, 15201, USA

Trees Evaluated = 60

Current Year 2019 i-Tree Design Benefits	Total 10 – Year Benefits (2029)
\$1,287.20 of stormwater runoff savings by intercepting 160,903 gallons of rainfall.	\$70,856 of stormwater runoff savings by intercepting 8,856,730 gallons of rainfall.
\$164.17 of air quality improvement savings	\$9,333 of air quality improvement savings
\$169.26 of carbon dioxide reduction savings	\$8,837 of carbon dioxide reduction savings

Table 10: Pre- Condition Results of Upper Lawrenceville Park Site

Trees Evaluated = 279

Current Year 2019 i-Tree Design Benefits	Total 10 – Year Benefits (2029)
\$6,013.43 of stormwater runoff savings by intercepting 751,671 gallons of rainfall.	\$275,290 of stormwater runoff savings by intercepting 34,410,361 gallons of rainfall.
\$829.25 of air quality improvement savings	\$41,719 of air quality improvement savings
\$949.69 of carbon dioxide reduction savings	\$34,155 of carbon dioxide reduction savings

Table 11: 10-Year Post Benefits Results of Upper Lawrenceville Park

Address: 5125 Holmes St. Pittsburgh, PA 15201, USA

Trees Evaluated = 44

Current Year 2019 i-Tree Design Benefits	Total 10 – Year Benefits (2029)
\$900.68 of stormwater runoff savings by intercepting 112,580 gallons of rainfall.	\$34,287 of stormwater runoff savings by intercepting 4,285,983 gallons of rainfall.
\$106.32 of air quality improvement savings	\$4,023 of air quality improvement savings
\$131.76 of carbon dioxide reduction savings	\$5,078 of carbon dioxide reduction savings

Table 12: Pre- Condition Results of Recreational Park Site

Trees Evaluated = 232

Current Year 2019 i-Tree Design Benefits	Total 10 – Year Benefits (2029)
\$3,657.62 of stormwater runoff savings by intercepting 457,170 gallons of rainfall.	\$134,471 of stormwater runoff savings by intercepting 16,808,751 gallons of rainfall.
\$657.08 of air quality improvement savings	\$24,168 of air quality improvement savings
\$425.64 of carbon dioxide reduction savings	\$18,062 of carbon dioxide reduction savings

Table 13: 10-Year Post Benefits Results of Recreational Park

Address: 6111 Butler St. Pittsburgh, PA 15201, USA

Trees Evaluated = 40

Current Year 2019 i-Tree Design Benefits	Total 10 – Year Benefits (2029)
\$869.04 of stormwater runoff savings by intercepting 108,617 gallons of rainfall.	\$45,375 of stormwater runoff savings by intercepting 5,671,910 gallons of rainfall.
\$105.88 of air quality improvement savings	\$5,599 of air quality improvement savings
\$113.40 of carbon dioxide reduction savings	\$5,279 of carbon dioxide reduction savings

Table 14: Pre- Condition Results of Outdoor Event Center.

Trees Evaluated = 602

Current Year 2019 i-Tree Design Benefits	Total 10 – Year Benefits (2029)
\$15,022.57 of stormwater runoff savings by intercepting 1,877,937 gallons of rainfall.	\$954,263 of stormwater runoff savings by intercepting 119,280,974 gallons of rainfall.
\$2,275.51 of air quality improvement savings	\$155,322 of air quality improvement savings
\$1,731.39 of carbon dioxide reduction savings	\$84,536 of carbon dioxide reduction savings

Table 15: 10-Year Post Benefits Results of Outdoor Event Center

Address: 520 McCandless Ave. Pittsburgh, PA 15201, USA

Trees Evaluated = 11 each for the 3 Nodes

Current Year 2019 i-Tree Design Benefits	Total 10 – Year Benefits (2019)
\$629.31 of stormwater runoff savings by intercepting 78,663 gallons of rainfall.	\$25,425 of stormwater runoff savings by intercepting 3,178,104 gallons of rainfall.
\$75.9 of air quality improvement savings	\$2,880 of air quality improvement savings
\$69.15 of carbon dioxide reduction savings	\$3,159 of carbon dioxide reduction savings

Table 16: Pre- Condition Results of the 3 Activity Nodes

Trees Evaluated = 40 for Each of the 3 Nodes

Current Year 2019 i-Tree Design Benefits	Total 10 – Year Benefits (2029)
\$1,838.64 of stormwater runoff savings by intercepting 283,533 gallons of rainfall.	\$39,597 of stormwater runoff savings by intercepting 4,949,757 gallons of rainfall.
\$502.56 of air quality improvement savings	\$48,510 of air quality improvement savings
\$349.71 of carbon dioxide reduction savings	\$7,890 of carbon dioxide reduction savings

Table17: 10-Year Post Benefits Results for the 3 Activity Nodes

Address: 5629 Harrison St. Pittsburgh, PA 15201, USA

Trees Evaluated = 100

Current Year 2019 i-Tree Design Benefits	Total 10 – Year Benefits (2029)
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\$1,569.16 of stormwater runoff savings by intercepting 196,105 gallons of rainfall.	\$99,985 of stormwater runoff savings by intercepting 12,497,786 gallons of rainfall.
\$222.16 of air quality improvement savings	\$14,602 of air quality improvement savings
\$107.92 of carbon dioxide reduction savings	\$6,916 of carbon dioxide reduction savings

Table 18: Pre- Condition Results of Green Parking

Trees Evaluated = 341

Current Year 2019 i-Tree Design Benefits	Total 10 – Year Benefits (2029)
\$6,835.96 of stormwater runoff savings by intercepting 854,494 gallons of rainfall.	\$413,965 of stormwater runoff savings by intercepting 51,744,402 gallons of rainfall.
\$1,047.65 of air quality improvement savings	\$66,031 of air quality improvement savings
\$1,247.12 of carbon dioxide reduction savings	\$65,224 of carbon dioxide reduction savings

Tables 19: 10-Year Post Benefits Results of Green Parking

Address: 5147 Keystone St. Pittsburgh, PA 15201, USA

Trees Evaluated = 8 each for 30 Streets

Current Year 2019 i-Tree Design Benefits	Total 10 – Year Benefits (2029)
\$2,946.9 of stormwater runoff savings by intercepting 368,280 gallons of rainfall.	\$235,590 of stormwater runoff savings by intercepting 2,944,785 gallons of rainfall.
\$575.7 of air quality improvement savings	\$44,460 of air quality improvement savings

\$180.9 of carbon dioxide reduction savings	\$22230 of carbon dioxide reduction savings
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Table 20: Pre- Condition Results of 30 Green Streets

Trees Evaluated = 40 each for 30 streets

Current Year 2019 i-Tree Design Benefits	Total 10 – Year Benefits (2029)
\$22,682.40 of stormwater runoff savings by intercepting 2,835,330 gallons of rainfall.	\$2,370,330 of stormwater runoff savings by intercepting 296,290,770 gallons of rainfall.
\$5025.60 of air quality improvement savings	\$485,100 of air quality improvement savings
\$1516.8 of carbon dioxide reduction savings	\$173,730 of carbon dioxide reduction savings

Tables 21: 10-Year Post Benefits Results of 30 Green Streets

Address: 5629 Harrison St. Pittsburgh, PA 15201, USA

Trees Evaluated = 100

Current Year 2019 i-Tree Design Benefits	Total 10 – Year Benefits (2029)
\$1,569.16 of stormwater runoff savings by intercepting 196,105 gallons of rainfall.	\$99,985 of stormwater runoff savings by intercepting 12,497,786 gallons of rainfall.
\$222.16 of air quality improvement savings	\$14,602 of air quality improvement savings
\$107.92 of carbon dioxide reduction savings	\$6,916 of carbon dioxide reduction savings

Table 22: Pre- Condition Results of Riverfront

Trees Evaluated =226

Current Year 2019 i-Tree Design Benefits	Total 10 – Year Benefits (2029)
\$3,434.11 of stormwater runoff savings by intercepting 429,202 gallons of rainfall.	\$283,434 of stormwater runoff savings by intercepting 34,427,948 gallons of rainfall.
\$512.63 of air quality improvement savings	\$43,781 of air quality improvement savings
\$339.29 of carbon dioxide reduction savings	\$19,460 of carbon dioxide reduction savings

Tables 23: 10-Year Post Benefits Results of Riverfront

The i-Tree Design model exposes one to the economic and environmental benefits that can be maximized if the interventions are applied. The pre (existing) and post (10 years) evaluations were processed to see the benefits one can derive. The tree counting of the existing trees were made by aerial view of the site. To summarize the overall benefits of the interventions we will be looking at them under 5 patterns: Green Parks, Activity Nodes, Green Parking, Green Streets and Riverfront and the pre and post conditions as seen in the tables below.

S/N	Patterns	Total # of Trees	Tree Benefits	2019	2029
1.	Green Parks	144	Stormwater runoff savings	\$3056.92	\$150,518
			Galloons Intercepted	382,100	18,814,623
			Air quality improvement savings	\$376.37	\$18,955
			CO ₂ reduction savings	\$414.42	\$19,194
2.	Activity Nodes	33	Stormwater runoff savings	\$629.31	\$45,375
			Galloons Intercepted	78,663	3,178,104

			Air quality improvement savings	\$75.9	\$960
			CO ₂ reduction savings	\$69.15	\$3,157
3.	Green Parking	100	Stormwater runoff savings	\$1569.16	\$99,985
			Galloons Intercepted	96,105	12,497,786
			Air quality improvement savings	\$222.16	\$14,602
			CO ₂ reduction savings	\$107.92	\$6,916
4.	Green Street	240	Stormwater runoff savings	\$2946.9	\$235,590
			Galloons Intercepted	368,280	235,590
			Air quality improvement savings	\$575.7	\$44,460
			CO ₂ reduction savings	\$180.9	\$22,230
5.	Riverfront	100	Stormwater runoff savings	\$1569.16	\$99,985
			Galloons Intercepted	196,105	12,469,786
			Air quality improvement savings	\$222.16	\$14,602
			CO ₂ reduction savings	\$107.92	\$6,916

Table 24: Pre-Condition Table of the 5 Design Patterns

S/N	Patterns	Total # of Trees	Tree Benefits	2019	2029
1.	Green Parks	1,113	Stormwater runoff savings	\$24,693.62	\$1,364,024
			Galloons Intercepted	3,086,778	170,500,086
			Air quality improvement savings	\$3,761.84	\$221,209
			CO ₂ reduction savings	\$3,106.72	\$136,753

2.	Activity Nodes	120	Stormwater runoff savings	\$1,838.64	\$39,597
			Galloons Intercepted	283,533	4,949,757
			Air quality improvement savings	\$502.56	\$48,510
			CO ₂ reduction savings	\$349.71	\$7,890
3.	Green Parking	341	Stormwater runoff savings	\$6,835.96	\$413,965
			Galloons Intercepted	854,494	51,744,402
			Air quality improvement savings	\$1,047.65	\$65,224
			CO ₂ reduction savings	\$1,247.12	\$65,224
4.	Green Street	1200	Stormwater runoff savings	\$22,682.40	\$2,370,330
			Galloons Intercepted	2,835,330	296,290,770
			Air quality improvement savings	\$5,025.60	\$485,100
			CO ₂ reduction savings	\$1,516.80	\$173,730
5.	Riverfront	226	Stormwater runoff savings	\$3,434.11	\$283,434
			Galloons Intercepted	429,202	34,427,948
			Air quality improvement savings	\$512.63	\$43,781
			CO ₂ reduction savings	\$339.29	\$19,460

Table 25: Post-Condition Table of the 5 Design Patterns

CHAPTER 4

Site Inventory

4.1. Present Condition

Figure 24: A1 – Transit Inc

Figure 25: Existing Rail Track

Figure 26: Art All Night Event Area

Figure 27: Industrial Area

Figure 28: Sunoco Company

Figure 29: Vacant Pervious Land

Figure 30: Children Lots Shuttle

Figure 31: Allegheny River

Figure 32: Butler Street

Figure 33: 62nd Bridge

Google Images

4.2. Inventory Analysis

Figure 34: Flood Map of Upper Lawrenceville

Figure 35: Figure Ground

Topography

Legend

- Topography
- Street Edges
- Street
- Building Footprint
- Site Boundary

Joseph Oguns

Figure 36: Topography

Figure 37: Soil Mapping of Upper Lawrenceville

Proposed Zoning

Figure 38: Proposed Zoning

Guiding Values

Existing Parks

232928.2977 sq. ft

Area of Existing Building

324958.0222 ft²

Overall Length of Street

65262.9815 ft

Street Edges Length

105181.6271 ft

Railway Length

28229.5703 ft

Upper Lawrenceville Boundary

260.349 acres

CHAPTER 5

Case Study

Smartínský Park, Playground

Slovenia

Design Year: 2015 -2016

Year of Construction: 2015 -2016

Area: 11 ha

Budget: £1,000,000

Following to the municipal spatial planning, the park site was stated to be a green space and an infrastructural corridor, meanwhile, it is a place surrounded by sheds, garden bed, and main power lines across. As at 2007, it was used as a wedge between the city's cemetery, and the major road which caused much of reaction. In the spirit of management and new urban development, there was an announcement from the municipal and mayor's office to clear the sheds and gardening beds. It brought a concern to gardeners in the city and the future of the site. The trees were shielded, and a gardening policy was announced through the intervention of the allotment gardeners and the mayor on site. It brought about the rehabilitation of the site and reduction in the intervention. In the first season, flowering lawn mixture was planted, and the public was given access to the site as the planning and designing commence. The local stakeholders suggested the need for a park and playground. The gradual transformation of the site commences since 2007 because of its size (11 ha), and it reached its zenith in 2015. It was named Smartinski Park having a similar name with a closed road. It is seen as the biggest playground in the city.

Source: Smartinski Park, Playground

There was a popular demand for a playground, at first, it sounded strange because of having a playground in the front of a cemetery. Lots prefer a playground incorporated into

the park. The erection of walkthrough paths (2), planting big trees and the landform reshaping was the first phase of development of the park aside the existing fruit trees. It took them time to design the playground. The designers used their experience with nursery kids' involvement in play as a foundation for their design concept. The park design has water features with sand, playing landforms, vegetation, play equipment and enough space. It attracted many from far and near the city. There were lots of suggestions as people continue to use the park. The suggestions included having a scooter ride, a circular path, softly curved hills, water play pumps, tea house and soon.

Figure 39-46: Smartinski Park, Playground, Slovenia

Source: Smartinski Park, Playground

Tom Hanafan River's Edge Park, Phase 1

Iowa

Budget: \$11.5 million

Size: 85 acres

Project type: Waterfront redevelopment

Completion Date: 2013

The project Tom Hanafan River's edge park is in Council Bluffs, Iowa. It is a floodplain area along the Missouri River lacking public access. The great flood in Missouri River 2011 has affected the area; the ecological value of the woodland reduced because of the invasive plants. Invasive plants removal and reforestation of the Ton Hanafan River Edge were the strategies used to revive the ecology and operations of the site. To mitigate the floodplain challenges, bioswales and meadow planting were used to increase the floodplain storage capacity. A 2,000-seater amphitheater was designed on top of an existing levee bordering a 20 acre of native meadow.

There was a cost comparison and it was discovered that there is going to be savings on maintenance to installing the meadow, and it will help the park to save \$4,700 annually. The cost of maintaining a meadow is however 3.85 times lesser to the traditional mown lawn.

Figure 47-52: Tom Hanafan River's Edge Park, Phase 1, Iowa

Source: Tom Hanafan River's Edge Park, Phase 1

The sustainable features of the project include the 4 acres great lawn that improves filtration process during flooding and rain, the outdoor amphitheater that accommodate 2,000 users, flood tolerant species (biofiltration plants), 3 infiltration (biofiltration) basins in the parking lots to mitigate lot runoff and checkmate stormwater, walk along the riverfront (Missouri River), regional trail system through the eastern landing, native plant materials.

Garden of Seven Moments

Switzerland

Design Year: 2013

Year built: 2014 -2015

The garden was divided into seven interconnected moments, it is featured by sun and wind exposure, terrain conditions and the complexity of vegetation. The moments are divided linked to the landscape surrounding via trails or views. The sloping shade garden of the house surroundings defines the links of the entrance floor to the terraced areas. There is a secret bamboo canal; the second moments that confuse transient to lead them to a paly of light. The sound of water from the rock fountain at the end leafy axis. The border of the shrub and the Mediterranean perennial connects to a long black wall on property edge and the bottom through a grassy ramp as the third moment. The fourth moment is the seasonal changes where the little maintained flowering perennials and a mixed edge of herbaceous are celebrated. The growing of fruit trees on a meadow terrain (terraced slope) which is formerly part of the extended vineyard is dedicated to the fifth moment. The sixth moment is centered on giving her users pleasure. It is located around a pergola sown with wisteria and perfumed Jasmine near the swimming pools. The last moment is centered on a reflection of specific views to give room for meditation along the way.

The project helped to bring in new intervention to the garden which brought a change in perspective of the entire landscape and the inhabitation. Native and non-native plants (grass and shrubs) were used to design on the sloppy topography which gave the garden a unique description of 'combining topography and vegetation'.

Figure 53-58: Garden of Seven Moments, Switzerland

Source: Garden of Seven Moments

Drapers Field

London

Commissioned: 2010

Construction Completed: June 2014

Budget: £4.3m for 3 sites

Drapers field the first Olympic park in east London. The park was contracted to Kinnear Landscape Architecture (KLA) from the available fund (Olympic section 106 funds) by the borough of Waltham Forest. Drapers Park, location is a connection to the communities in east London through the KLA designed Temple Mill Lane, the new East village projects and the Olympic park. Draper's field was mainly a football arena not used efficiently by the people of the community. A client before KLA proposed interventions on the play area, pavilion, and the sports facilities. The idea brought about having a bigger Olympic park that will accommodate children, youth for the current and new communities into sports and other informal activities. The park will also encourage sports and play along the route to Chobham Academy near the Olympic village. KLA designed the school exterior and the landscape with creative interventions and provided good sports facilities. The creative design of the landscape enhances cycling and cycling training and other forms of play. Other elements that make the place the Olympic park an attractive and enjoyable place are the corrugated forms made up of concrete and grass; water play implanted into the corrugated forms that produce splash ponds for children to control the water's flow; obstacle bike track along the school route; the enhanced pavilion for community café and hub.

Figure 59 – 64: Draper's Field, London

Source: Drapers field

CHAPTER 6

Design

Designing a User Friendly Upper Lawrenceville

As established in the preliminary chapters of this thesis project. The movement of people is increasing across the world, which is bringing imbalance by cities and rural areas. However, the ecosystem is passing through stress in areas like housing, living density, flooding, air pollution and lots more. The fact remains that people living in cities need to be in contact with the rural life to maintain their root. At present it is becoming a challenge for people living to have a touch of their rural life.

This design proposal is centered on creating a health friendly upper Lawrenceville, to also be an attraction to other neighborhoods and visitors from other regions. Through sustainable interventions that will foster development, economy, connections; pedestrian circulations, and water connection from upper Lawrenceville to Etna, Public green and blue infrastructure, creating a community and lots more. A prototype of the design concept can also be reproduced in areas that plantations are prioritized from the i-Tree Landscape model used in this study.

Figure 65: Composite Analysis Map

Opportunities

Streetscape

Activity Nodes

Parks

Green Parking

Waterfront

Constraints

Zoning and regulations

Flood zones

Railroad

Construction along the riverfront

|

Master Plan of the Site

Figure 66: Master plan of the site

Masterplan Description

Figure 67: Masterplan Description of the site

A - Upper Lawrenceville Park B – Trail C – Green Parking
D – Riverfront/Garden E – Outdoor Events Center. F – Green Streets
G – Activity Nodes H- Recreational Park / Meditation Garden

Program Description

Public Green should be distributed at 1500-foot interval

“The human body does not wear out with use. On the contrary, it wears out when it is not used” (Alexander C. et al., 1977)

0 0.5 1 1.5 Kilometers

Figure 68: Upper Lawrenceville Park

Today, water is pushed down not seen by people to sit besides, swim in, or use their legs to flag. What we see is pave all-around cities. I am advocating that water should be an element in building or parks in a city. Children are enthralled by water in motion, you can see them play around it forever. There should be places in the community where people can effectively use both their body and mind to work by using the blue green infrastructures in the environment and the working environment. Part of the solution to this is to encourage physical activities close to houses and places of work. There should pool (for swimming) and still water (example pond, lake...) in every neighborhood. The pool should be designed where the main entrance be shallow with a depth of 1 to 2 inches and expands gradually. The proposed Upper Lawrenceville Park is centered towards promoting these objectives. It has a clay play area for children to play by molding with their hands with the water coming from the four-water pumps, playground, swings, swimming pool, seating areas, lawn tennis, basket ball court and plaza.

There should be reduction of pave most especially in flood plain areas

“There is too much hot hard asphalt in the world. A local road, it only gives access to buildings, needs a few stones for the wheels of the cars; nothing more. Most of it can still be green”
(Alexander C. et al., 1977)

0 0.5 1 1.5 Kilometers

Figure 69: Green Parking

Green parking is proposed in this region to reduce flooding and as a means of incorporating green infrastructure to the location that is mainly used as the children hospital shuttle lots. The runoff from the parking lots can be channeled to wetlands, and

green recreational sites that are close. It further improves the quality of the water through filtration of pollutants. It has the potential of reducing runoff from 50 to 80 percent.

Buildings should not be used as focal point in outdoor spaces

“People use open space if it is sunny, and do not use it if otherwise, in all but desert climates” (Alexander C. et al.,

Figure 70: Outdoor Activities Center

There should be a form of enclosure in an outdoor space and it should be in areas that have good access to sunlight. People tend to use the sunny side of the outdoor space. However, there need to be a balance between the sun and shade. People need the trees in the outdoor space to sit and rest on. The proposed outdoor space is located near the riverfront which will give the people a good view of the activities that take place by the riverfront, the water feature on the middle serves as the focal point of the outdoor space

with walk areas for people to move and interact and seating areas and plaza to buy things. The lawn spaces are free for other forms of outdoor games by the users. The proposed program at the riverfront will provide boating activities, fishing, seating, and garden to the neighborhood and provide a link of connection to the Etna neighborhood.

Every Community and Neighborhood should have a place for individual and collective sport, and located in place that will attract tourists.

“If children are not allowed to utilize the whole of the adult world around them they cannot become adults. The Modern society are so dangerous that children cannot be allowed to utilize them freely” (Alexander C. etal., 1977)

Figure 71: Recreational Park

Doing and copying are two platform's children used to learn. They need a space to make it a reality, but as it is, children are not safe to play around cities because of the fear of being hit by cars or trucks. The recreational park proposed will give them the environment to have a safe and enjoyable experience. Biking is another activity that is good for the environment and not expensive to acquire, however the design of the environment does not make it to work. Bike paths should be designated with a unique color or symbol to create awareness to the road or park users, especially where bike paths are shared by pedestrians. The recreational park proposed in the above figure has a designated place for biking activities.

There should always be a place free from noise and protected from buildings that is in walkable distance in busy areas of the city, where people can use during lunch time and other free times to meditate and feel the beauty of nature. A garden is designed in the proposed recreational park where visitors will have a feel of nature.

The graph below gives an understanding of the benefits one can get from engaging in exercises.

Figure 72: Exercise and Death Rate Graph

Activity Nodes should be distributed in the Neighborhood at walkable Interval

Subcultures need to have a center for its public life, a place where people can go to see people and to be seen” (Alexander C. et al., 1977)

Figure 73: The 3 Activity Nodes

One can identify hot spots areas and use it as a bearing for designing other activity nodes through the paths to create a network. The activity nodes should be a place to connect people like having a public square that will promote night activities like street theaters. People tend to use places that are not too far from them. The activity nodes should be like 10 minutes walk from each other and the paths leading to those nodes should be full

of activities like carnivals, shopping arena, ice cream shops, coffee shops, churches, and movie centers. The path networks should be properly lighted to encourage high pedestrian density in the day and night. It is believed that busy pedestrian paths most especially in the night tend to reduce the rate of crime. Activity nodes will reduce the use of cars most especially when taking short trips and bike racks should be positioned there. Residents will be encouraged to use their bikes, foot to move within their neighborhood as a lifestyle, it will also further reduce the problem (noise, ill health, air pollution, eyesore) brought by the use of cars.

There should be layout of foot Paths, Bike Paths and Green Street in the neighborhood

“The simple social intercourse created when people rub their shoulders in public is one of the most essential kind of social glue in society” (Alexander C. et al., 1977)

Figure 74: Circulations

Indoor and lobby movements have taken over the social mix that we get from pedestrian movement. The indoor movement cannot be compared with the outdoor movement because people have a feel of the environment through later means. Because of the comfort (privacy, flexibility) people get from using their cars they tend to use them regardless of the distance of travel. London and Paris have one of the best urban public transportation but still experience low turnout of riders every year. Alexander C. et al., 1977 gave two proposal which they believe will tend towards a healthy environment. Buildings should be layout in a pattern that will form pedestrians' green streets. The bike paths should be designated with a unique color or symbol to create awareness to the road users. Where bike paths are shared with pedestrians there should be a distinction on the path to create a balance. The proposed long trail along the Upper Lawrenceville Park will serve as a bike and pedestrian trail to help boost the number of users of the proposed program and encourage a healthy lifestyle. There a lot of impervious surfaces around the sites; green street will help reduces the impervious surfaces, reduce pollution, and encourage pedestrian and bike circulations.

6.1. Perspective Views / Sections

Perspective Views

Figure75-78: Perspective views of the outdoor space and Riverfront

Sectional View

0 0.5 1 1.5 Kilometers

Figure79: Green Parking Section

0 0.5 1 1.5 Kilometers

 A horizontal scale bar with alternating black and white segments, representing a distance of 0 to 1.5 kilometers.

Figure 80: The Recreational Park Section

0 0.5 1 1.5 Kilometers

Figure 81: The Riverfront Section

0 0.5 1 1.5 Kilometers

Figure 81: Upper Lawrenceville Park Section

CHAPTER 7

Discussion/ Conclusions

The results gotten from the first model using the GIS model to access the water quality of the entire Pittsburgh city and the pilot scale site helped me to identify areas with high Total suspended solids which gives one an idea of areas with water quality issue. The result of the i-Tree landscape model showing EPA impaired waters areas have a similarity with the GIS model. It further suggests that there is need for Upper Lawrenceville to take the issue of surface runoff and nonpoint source pollution serious by adapting the interventions proposed and other sustainable practices. The i-Tree Landscape is also instrumental in the analysis of this thesis by guiding me on areas with impervious and canopy areas, air pollution removal, human health risk data, EPA impaired waters area and places to prioritize plantation. The i-Tree Design model majorly helped me to explore how any site location in the USA can maximize the environmental and economic benefits of blue infrastructures and managing surface runoff. The results comparing the 10-year plan benefits of the pre and post conditions of the 5 patterns interventions proposed showed 83% (3000 trees) increase on the number of trees against 17% (617 trees) of the existing trees, there is a 99.56% (\$4,471,350) increase of stormwater runoff savings of the post condition against 0.46% (\$9,771.45) of existing condition, 99.6% (557,912,963) increase in the amount of gallons of rainfall water to be intercepted to 0.04% (1,121,253) of the existing condition, Air quality improvement savings of 99.6% (\$863,824) of the post condition against 0.04% (\$1,472.29) of the existing condition, and Carbon dioxide reduction savings of 99.2% (\$229,327) of the post condition against 0.08% (\$880.31) of the existing condition. The design programs proposed will help to address the social life of Upper Lawrenceville and encourage sustainability.

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