

2015 Master Project

BASF Agricultural Solutions: Sustainability of Grounds and Landscaping at Durham, NC Facility

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Signed

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Executive Summary

The BASF Agricultural Solutions Headquarters occupies, the client of this project, has requested our team to examine the biological value, environmental value and economic value of its 100 acres corporate-owned forest which locates in Durham area as well as its storm water collection pond. There has been a significant construction project during the academic year 2013 and additional large projects are being considered for the near future. The goal of project is to help BASF conserve the natural aspects of the site in a manner that is consistent with its corporate sustainability strategy and messaging by understanding the values of the forest. Our client was also looking for a list of plants that they could introduce to the pond to make it a sustainable man-made wetland.

This project used methodologies such as field survey, literature research, secondary research, scenario analysis and modeling, covering the study area of forest cooling effect and monetary values, forest noise attenuation, carbon sequestration, animal inventory and plant inventory.

After the one-year study period, we found that forest reduces 15-20% of the baseline temperature and smoothens the temperature fluctuation. This effect equals approximately 57% of the cooling of BASF's current cost on cooling. The carbon storage of the forest is about 964.71 tons and the gross annual equals to about 31.59 ton/year. Additionally, trees have the effect of reducing five to fifteen decibel of noise with a 40 meters tree belt and have the effect of smoothening the strength of noise fluctuation, which contributing to create a more stable environment.

In the bio-diversity study, we have found 45 different species of trees and shrubs which were mostly common and widespread in South and Southeastern United States. We also observed 20 different species of birds and two mammals (White-tailed Deer and Virginia Opossum).

Recommendations are provided at the end part of the report for the company's environmental conservation team including plants recommendation for the storm water collection system, and forest conservation strategy, such as establishing educational tour, building an online platform to share newly observed animals and plants, and remarking the trail by installing tags.

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1 Introduction

1.1 Background of BASF

The business unit of agriculture solution of BASF targeted at providing crop protection at the highest level by offering a variety of chemicals and technologies that are applied to agriculture sector, including herbicides, fungicides, insecticides and seed treatment technologies. The corporate pursues in finding and inventing new agricultural products and technologies align with environmental-friendly purpose, thus it invests \$442 million annually on a global basis mainly in research and development, which is equivalent to more than \$2 million a day. Products and serviced delivered by BASF Crop Protection meet the demands of customers and contribute to the sustainability of agriculture.

The BASF Agricultural Solutions Headquarters locates at the Research Triangle Park, and occupies approximately 100 acres area, including company facilities, parking, greenhouses, turf grass, pond, landscaping and forest.

The natural community that BASF has contains living biotic factors and natural abiotic factors, such as plants and animals as well as soil and water. North Carolina is a state located within the temperate deciduous forest global biome (Luczkovich, 2001), and the ecoregion that Raleigh area is located in is the Northern Outer Piedmont (Pomona College, 2015). The type of the BASF forest is hardwood forest which consists of oaks, maples, hickories, and some pines with undisturbed gentle slopes on site (Luczkovich, 2001).

1.2 Benefits of Urban Forests

Urban forests have many functions and values, including removing air pollution and absorbing ultraviolet radiation, ameliorating air temperature and noise level, reducing building energy use, improving water quality, and improving physiological & psychological well-being (Nowak et al. 2007). Urban forests act as “reservoirs” for species by providing animal and plant habitats (ACTrees, 2011). Regarding this project, we focused on conducting quantifying the effect of air temperature reduction and noise attenuation, evaluating the carbon storage and gross sequestration by the forest per year as well as conducting on-site observations to create bio-inventory.

1.2.1 Air temperature reduction

Trees can shade buildings in summers and block winds in winters, ameliorating air temperature and thus contributing to energy conservation. However, how effective the trees could perform energy conservation is dependent on the distance of trees from buildings, the size and amount of foliage on the trees, and the regional climate and living environment (Nowak and John, 2007). The forest also plays different role in different season. For instance, trees that provide shadow for buildings in summer can reduce the demands of cooling, while can increase heating needs in winter. Nevertheless, forest has an overall effect of reducing energy consumption. Heisler's (1986) study demonstrated that energy consumption in a house surrounded by trees is lower than that house with same conditions but located in an open area by 20% to 25%. Approximately \$2 billion annually could be saved for residents in reducing energy use if 100 million trees are properly planted in communities in the United States (Akbari et al., 1988).

1.2.2 Carbon storage and sequestration

Trees can perform as a carbon sink that reduces atmospheric CO₂ as they grow. It has been estimated that large and healthy trees can annually sequester about 93 kg C, while small trees can sequester 1 kg C per year (Nowak, 1994a). In the current urban forest ecosystem in the domains of the United States, a total of 700 million metric tons of carbon (commensurate with a range of 335- 980 million tC) of \$14,300 million value is stored in the whole urban forest ecosystem, and the gross carbon sequestration rate of the ecosystem is 22.8 million Tc/year of the value of \$460 million/year (commensurate with a range of 13.7-25.9 million tC per year) (Nowak and Crane, 2002).

1.2.3 Noise Reduction

Field tests have proven that if designed and planted properly, trees can considerably mitigate noise. Aylor (1972) found that foliage and stems of trees can scatter the transmitted sound, while the ground acts as role of absorbing it. Wide belts (30m) of dense and tall trees coupled with soft ground surfaces significantly reduce 6 to 10 decibels, approximately 50% or more of the original loudness (Cook, 1978). Even for the narrow planting area (typically <3m wide), reduction of noise can be achieved by 3 to 5 decibels from dense belts of vegetation (Reethof and McDaniel, 1978). In addition to physically attenuating the soundness, trees can also generates its own noise that might increase sounds such as wind moving through trees or as birds flying across or staying and singing on the branches. These sounds enable people to filter unwantedly annoying noise yet focusing on more euphoria ones (Robinette, 1972). Whether the source of sounds could be seen or not is another important key to people's awareness of noise.

The existing tree visually blocking the sight of the sound source, and thus decrease perceptions of noise they actually receive (Anderson et al., 1984).

1.2.4 Biodiversity of Urban Forests

Compared with wild open forests, urban ecosystems have been traditionally regarded as areas where the biodiversity level is low and mainly embracing non-native species (Alvey, 2006). However, increasing studies suggests that urban and suburban forest ecosystem can contain comparatively higher biodiversity levels than natural forests (Balmford et al., 2001; Godefroid and Koedam, 2003). Biodiversity research on urban areas has revealed the correlation between the population density and high level of biodiversity. Araújo (2003) confirmed that urban areas across the Europe contain comparatively higher levels of biodiversity than non-city areas with no or little population, as the findings showed that an increasing human population density is associated with richness of mammal, reptile, amphibian and plant species throughout Europe. Many studies even demonstrated the role of urban forests harboring endangered species. In Sweden, it is estimated that two-thirds of red-listed species have been harbored by Stockholm County with high population (Colding et al., 2003).

Most city dwellers in United States have demonstrated that they adore and appreciate wildlife that appears around them (Shaw et al., 1985). 73% of residents in New York State were interested in attracting wild animals to their backyard and enjoying time with them (Brown et al., 1979). The main reason why residents show interests in feeding wildlife in backyards was the feelings of personal satisfaction and euphoria from helping and saving wildlife (Yeomans and Barclay, 1981). Urbanization can sometimes actually create and enhance the habitats of animals and plants, resulting in increases in biodiversity. In Oakland, California, for instance, diversity and richness of tree species have grown from an original Shannon-Weiner diversity index value of approximately 1.9 and 10 species in 1850 to the value of 5.1 and greater than 350 species in 1988 (Nowak, 1993). Urban ecosystems can also perform as refugees for threatened animal and tree species. A total of 20 threatened and endangered species as well as 130 plant species are hosted in Cook County with highest population in Chicago (Howenstine, 1993).

2 Methodologies

2.1 Forest value evaluation

2.1.1 Forest monetary cooling effect

Equipment, appliances and software: Continuous temperature recorder, Excel

Methods: field data collecting, data searching and quantitative analysis

Temperature was recorded in (i.e. under the cover of trees and leaves) and out of (i.e. on parking area) the forest using continuous temperature recorders. Data was collected in August, September and October, 7 days per month, on a 24-hour base. After data was retrieved, we calculated the average temperature difference in and out of the forest from 7:30 am to 7:30 pm, which was assumed to be the period when air-conditioners were turning on. We converted the unit of collected data (i.e. Celsius degree) into the amount of electricity that air-conditioners demanded to result in the same amount of cooling effect in (kWh). Subsequently, we used the current electricity price (\$/kWh) to quantify the exact value of cooling effect of the forest (the electricity cost needed to make the same temperature reduction).

We have set four temperature recorders in the forest and in main campus at BASF from August 28, 2014 to September 6, 2014 to continuously run recording. One was hung on a STOP sign on parking area (dry area), where the recorder could accept directly sunlight without any shade (No.1).

The second temperature recorder (No.2) has been placed near the pond, where it could accept directly sunlight without any shade as well, but was run in wet environment.

The third temperature recorded (No.3) located in the forest, surrounded by trees, leaves and brunches. The shade prevented this recorder from being directly radiated from the sunlight, and provided a comparatively stable working ambient.

The last temperature recorder (No.4) was set at the edge of the forest, where it could receive sunlight radiation at some time period and also possesses the shade to be cooled down.

The energy needed for cooling would be:

$$\text{Energy needed for cooling} = 24(h/d) \times UA_{total}(Btu/h \cdot ^\circ F) \times CDD(^{\circ}F \cdot d/y) \quad (4)$$

Notes:

UA_{total}: energy consumption (Btu) used by the cooling appliances to reduce 1 degree Fahrenheit in an hour;

CDD (cooling degree days): the production of temperature reduction and days need cooling per year ($^{\circ}F \cdot d/y$).

We assumed that if the average outdoor temperature exceeded 65 °F, that day would be a CDD. We found the daily average temperature in Durham area from 1981 to 2010 from National Weather Service Forecast Office, and identified that the average CDD during those years were 153 (°F · d/y) by using IF function in Excel. We assumed that the temperature could be reduced by 15% with the presence of forest as identified previously. Then we calculated the new daily average temperature by reducing 15% of each value, and derived that the new CDD was 78 (°F · d/y) if the environment was covered by trees. Thus,

$$\frac{\text{Energy saved for cooling}}{\text{Energy needed for cooling}} = \frac{CDD_{original} - CDD_{new}}{CDD_{original}}$$

We have also assumed that the electricity price would keep the same rate.

2.1.2 Carbon sequestration

Equipment, appliances and software: Excel

Methods: data searching and quantitative calculation

Trees can serve as a CO₂ sink through excess carbon storage as biomass and carbon fix during photosynthesis. The total storage of carbon in U.S. forests is up to 152,236 MMT CO₂e, accounting for 2 percent of global terrestrial carbon stores. Wood products that are both in use and in landfills are attributable to an additional 8,781 MMT CO₂e (EPA, 2007). However, the dynamic of net CO₂ source/sink that forests perform in a long term is linked with trees growth status. Additionally, human activities also influence on forests including emitting gases from fossil fuel and reaping biomass. From 1969 to 1994, urban areas have doubled in the lower 48 United States due to urbanization (Nowak et al., 2001). Because of the expansion of city and urban areas, urban forests are effective in combating increasing carbon dioxide in atmosphere through sequestering CO₂ and affecting the CO₂ emissions from urban areas.

Not much research has been conducted on carbon storage by urban forests. Nowak team (Nowak, 1993) first estimated national carbon storage stored by urban ecosystems with a range of 250 to 750 million tonnes dependent on carbon data extrapolated from Oakland, CA. In Nowak's later assessment, he updated the national carbon storage in the basis of data extracted from another eight cities combining with data of national urban tree cover, and the results of carbon storage and sequestration stored and taken up by urban trees were estimated at three different levels, national, regional and state (Nowak and Crane, 2002).

We gathered the area of the forest from BASF by interviewing the client. We then searched average soil carbon storage in Durham area from online database. Subsequently, we used carbon sequestration function (equation 1 and 2), which is correlated with the space of trees coverage and soil carbon sequestration capacity to calculate how much carbon could be sequestered by the forest (since the carbon inspiration and expiration of trees are almost balanced, we did not consider photosynthesis reaction at this point).

For this project, we extracted carbon data of carbon storage as well as gross annual sequestration from urban forests of North Caroline in Nowak and Crane’s paper, which are 39.7 t/ha and 1.3 t/ha/year respectively. The BASF Agricultural Solutions Headquarters occupies approximately 100 acres including buildings, parking, greenhouses, pond, landscaping and forest. Deducting spaces for buildings and others, forest accounts for about 60 acres. Therefore, the carbon storage and gross annual sequestration from the forest were estimated as follows:

$$\textit{The carbon storage} = a \times S \quad (1)$$

$$\textit{The gross annual sequestration} = b \times S \quad (2)$$

Notes:

a: the coefficient of tons of carbon storage per ha forest in this region, 39.7 ton per ha in Durham area;

S: area covered by the BASF’s forest, which is 60 acres in this case;

b: the coefficient of tons of carbon storage per ha forest per year in this region, where we applied 1.3 ton/ha per year here.

2.1.3 Noise reduction

Equipment, appliances and software: Decibel Recorder, Excel

Methods: field data collection and quantitative calculation

We collected the strength of noise alongside the freeway beside BASF (D1), in the forest and in the main campus of BASF (D2). The distance (r1) between sampling point of D1 the highway, and the distance (r2) between the sampling point of D2 and the highway was recorded. The differences (i.e. D1-D2) were used to represent the noise mitigation ability of the forest. D3 were defined as the theoretical decibel that should be recorded at distance r2, using the Distance Function (Sengpielaudio, 2015):

$$D_3 = D_2 - \left| 20 * \log\left(\frac{r_1}{r_2}\right) \right| \quad (3)$$

Notes:

D₂: the decibel (dB) acquired at the sampling point where is r₁ away from the highway;

D₃: the theoretical decibel (dB) in the point where is r₂ away from the highway without any obstacles;

r₁: distance between the sampling point near the highway and the highway (m);

r₂: distance between the sampling point in the forest and the highway (m).

The difference of the noise strength (D₂-D₃) is the noise reduction ability of the forest.

We chose a weekday (January.30, 2015) at 9:00 am to conduct the field survey. By using the cellphone app named “Decibel 10th”, we recorded two serious of data of D₁ (at where r₁ equals 5 m) and D₂ (at where r₂ equals to 45 m) simultaneously for a continuous four-minute period, with interval of 0.1 second. The two sets of data were recorded by both of the two team-members, Wenjia and Wenting, holding the same type of cellphone (i.e. iPhone 5) on the same height (1 m) to minimize the experiment error. We then used Excel to calculate the corresponded D₃ values according to function (3) and the raw dataset of D₁, and subsequently created figure of instantaneous noise change during that period.

2.2 Biological value

2.2.1 Selection of sampling areas

Equipment, appliances and software: Google earth, USDA soils on-line

Methods: Random Sampling

The sampling areas were selected based on the different soil type and geographic characteristic. Shown as Figure.1, the forest is divided by different regions according to soil type. We stratified the sampling based of the soil type to select suitable sampling areas where there was water assessable for our camera recording and observation research, because animals need water to survive, and they were more likely to show up at where there was water for drinking. In addition, the project was focused on studying the permanent natural area, which is located in south of the main campus, and a wetland in north of the main campus.

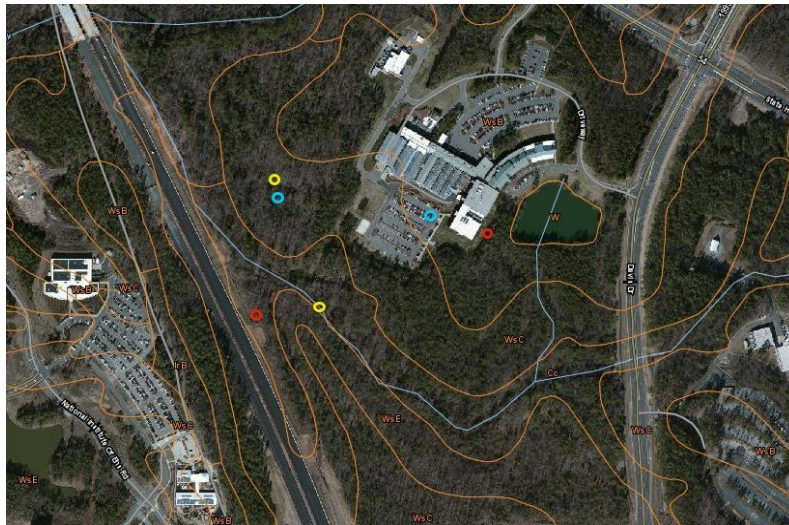


Figure.1 (Yellow circle: camera trap; red circle: noise record; blue circle: temperature record)

Sampling points were chosen where there was water available, such as creek and pond, in open area. The cameras were set on tree trucks, three to four feet high, which provided best vision to record the animals. The sampling points were changed if few or no photo of animals were taken by the cameras.

2.2.2 Birds

Methods: Sound Identification

Nicolette L. Cagle, Ph.D., an expert in ecology and also the advisor of this project, attended three field trips with the team. The time for bird survey is selected in early morning (i.e. 7:00 – 8:30 am) to be in accordance with the activity of the birds. Additionally, because birds migrate with the season change, we conducted field survey in different months and season in July, September and late October. We identified and differentiated the birds according to their singing as well as their appearance by hearing and using telescope.

To confirm that we have identified most of the bird species, we used “Accumulation Curve” to estimate the chance of new species. When the trend of newly found species get close to horizontal (i.e. little or no difference), we may have got most of the bird species, as Figure.2 shows.

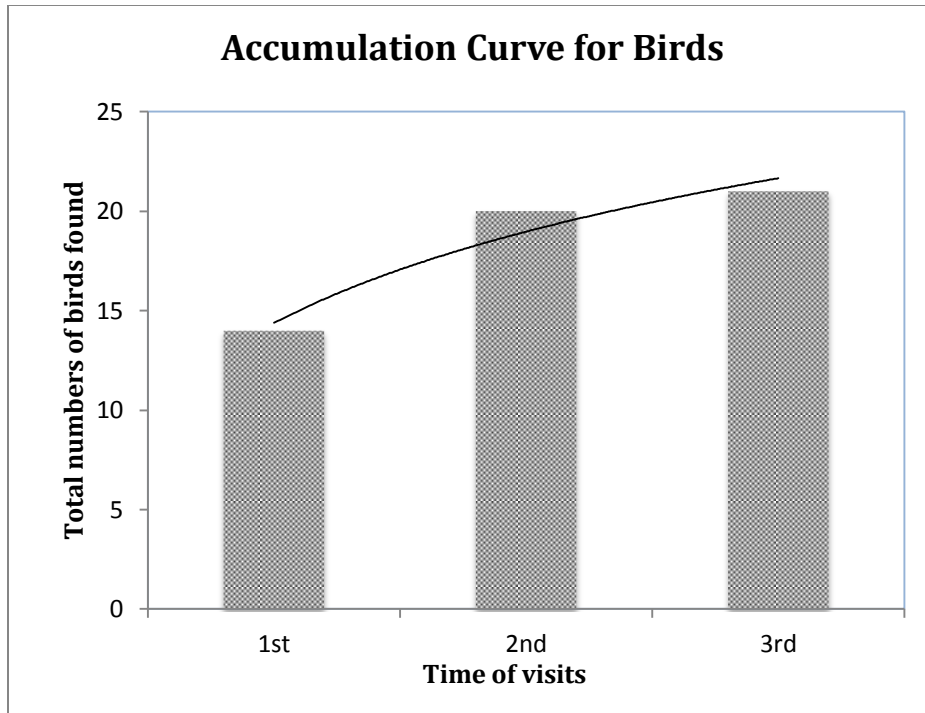


Figure.2 Birds Accumulation Curve

2.2.3 Amphibian

Methods: Sound Identification

One of the typical amphibians in the forest is frog. Frogs can be differentiated by their calls. We conducted field trips and differentiate frogs by sound around the wetland and pond. Sometimes there were frogs existed alongside the trail. We also used cameras to record the photo of the animal.

2.2.4 Mammals and reptile

Equipment, appliances and software: Camera

Methods: Camera recording

Cameras had been set up on the selected sampling area for recording the appearance of mammals and reptiles. The camera automatically ran on 24-hour base and lasted for three to four days for observation. We replied the photo to find out the evidence of reptiles. Snakes

were commonly seen in midsummer while mammals could be seen in most of the warm days, and therefore, we started the camera research during July and August, September and October in 2014. The cameras were set about two to three feet above the ground to execute recording. We also observed the footprints and bite stamps so as to distinguish mammals

2.2.5 Trees

Equipment, appliances and software: Cameras

Methods: Visual Identification

Tree surveys were also taken in July, September and October in 2014, one day per month in case there are species missed. Trees were identified and differentiated by trunks, leaves, flowers and fruits. Some leaves can also be tasted to support the result.

Same as the way to confirm that we have identified most of the bird species, we also used "Accumulation Curve" to estimate the competence of tree survey. When the trend of newly found species gets close to horizontal (i.e. little or no difference), we might have got most of the tree species.

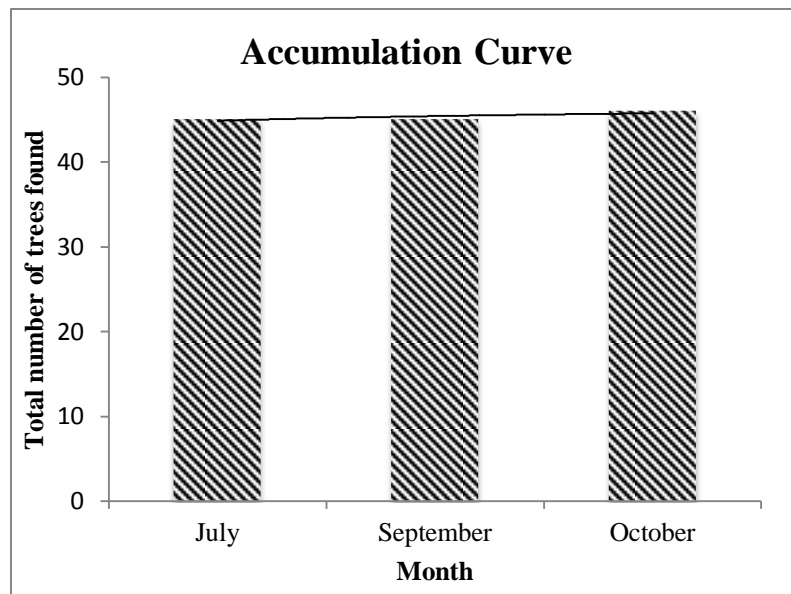


Figure.3 Animal Accumulation Curve

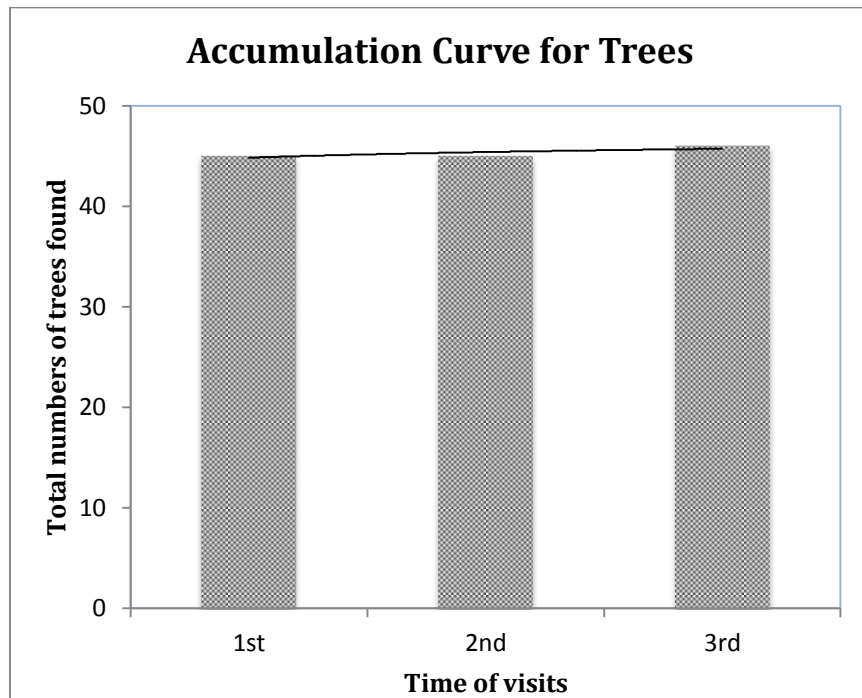


Figure.4 Tree Accumulation Curve

2.3 Plant recommendation for storm water collection system

Requested from our client, we also made a list of native plants that are suitable for their rainwater garden. Three main principles have been considered for an appropriate list with plant options. First, plants should be native rather than invasive that would not lead to threat to local vegetation. Second, it should not be time- and labor-consuming for BASF staffs to take care of these plants, which means that they are vital and easy to grow. Third, these plants should also have recreational and beauty values. During the last summer, we visited rainwater garden in the preserve of Catawba College, and consulted their management staffs. The Elizabeth Stanback Wildlife Garden was designed as a “naturalistic wildlife garden”, hosting more than 160 native plant species that reflects the area’s native ecology. These native plants helps promotes resource and environmental conservation and eliminates resource-robbing lawn turf while only requiring low maintenance. Therefore, based on their successful experience, we first looked at potential choices from the BASF forest, combined suggestions from professionals, and then generated a recommendation list of native plants for BASF rainwater garden.

3 Results

3.1 Cooling effect

3.1.1 Temperature reduction

After running the steps as indicated in methods, we recorded the temperatures at the four sampling points from August 28, 2014 to September 6, 2014, and exported the temperature curves as shown in Figure.4, 5, 6 and 7. The four figures copied the data from Recorder No.1, Recorder No.2, Recorder No.3 and Recorder No.4 respectively.

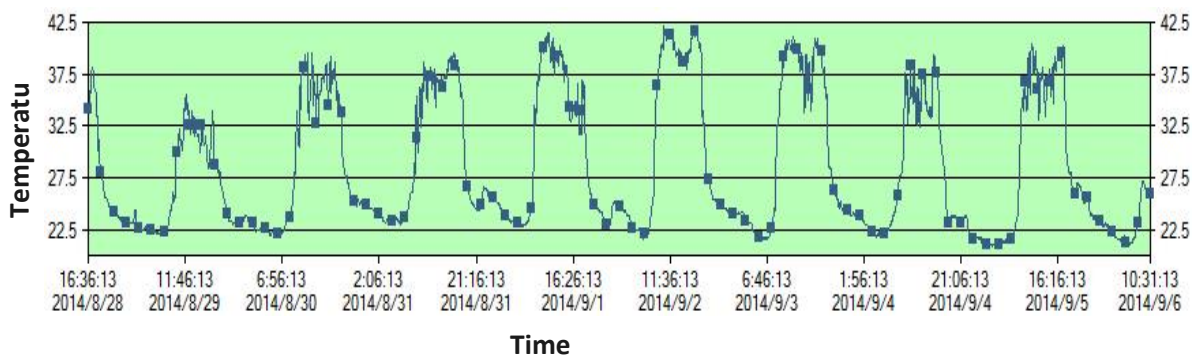


Figure.5 Temperature curve of the recorder located in parking area

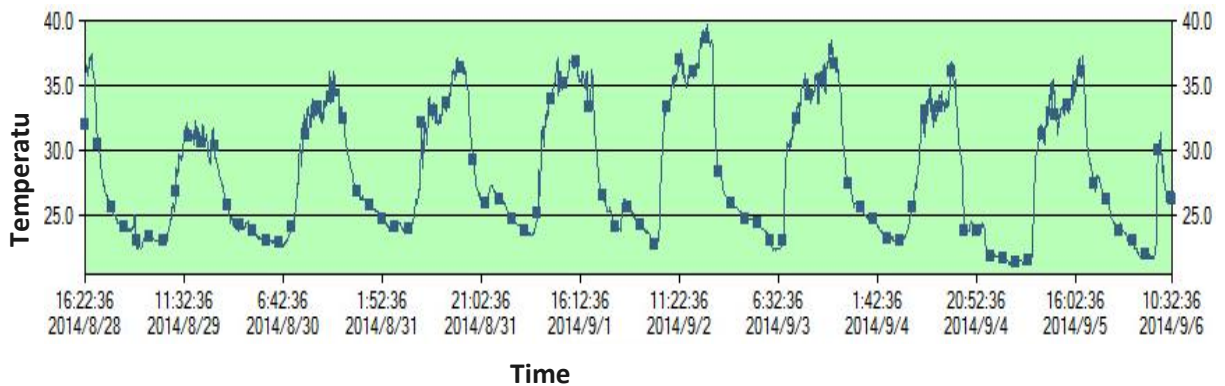


Figure.6 Temperature curve of the recorder near the pond

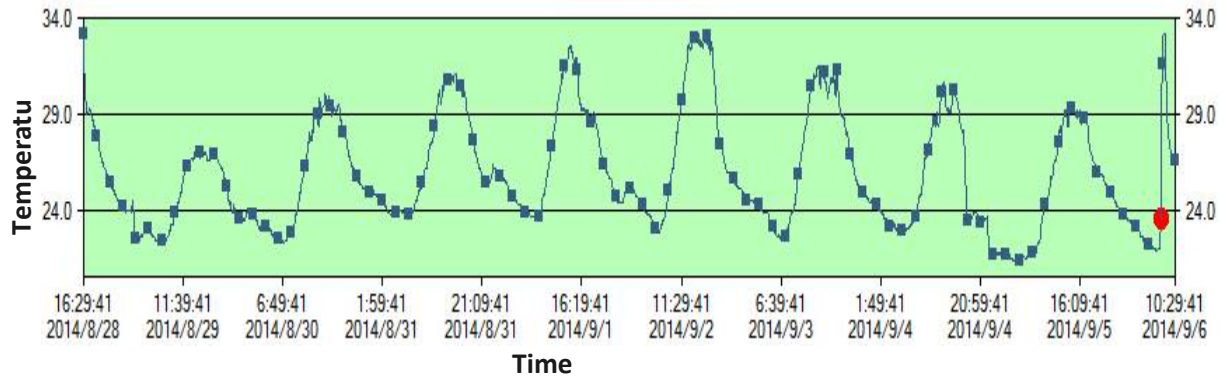


Figure.7 Temperature curve of the recorder placed in the forest

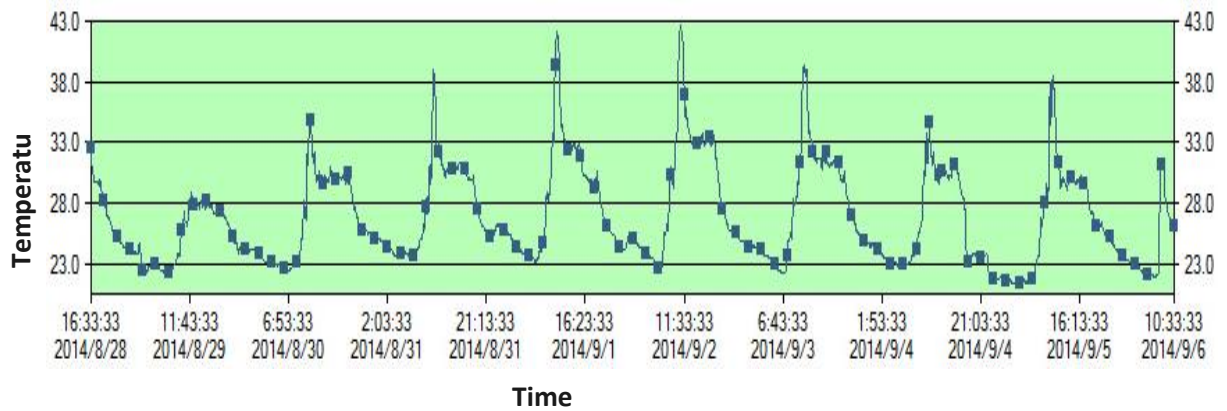


Figure.8 Temperature curve of the recorder placed at the edge of the forest

Then, we compiled all the datasets into a comprehensive figure of Temperature curve comparison at the four locations as shown in Figure.9.

The data collected by field survey shows that, trees command the ability to reduce temperature. In day time, the difference between the temperature at the parking area and in the forest was approximately five to seven degrees (i.e. Figure.4 and Figure.6), 15-20% reduction of the baseline temperature, which is paralleled to the result we derived from previous study that trees help reduce the surrounding environment by 20-25%. In the evening, the forest also has the effect of keep energy and withholds the temperature, as we can see that the lowest temperature of a specific day we recorded from the parking lot is lower than the lowest temperature we retrieved in the forest (Figure.4 and Figure.6). In other words, the forest has the effect of smoothing the temperature fluctuation and stabilizing the environment.

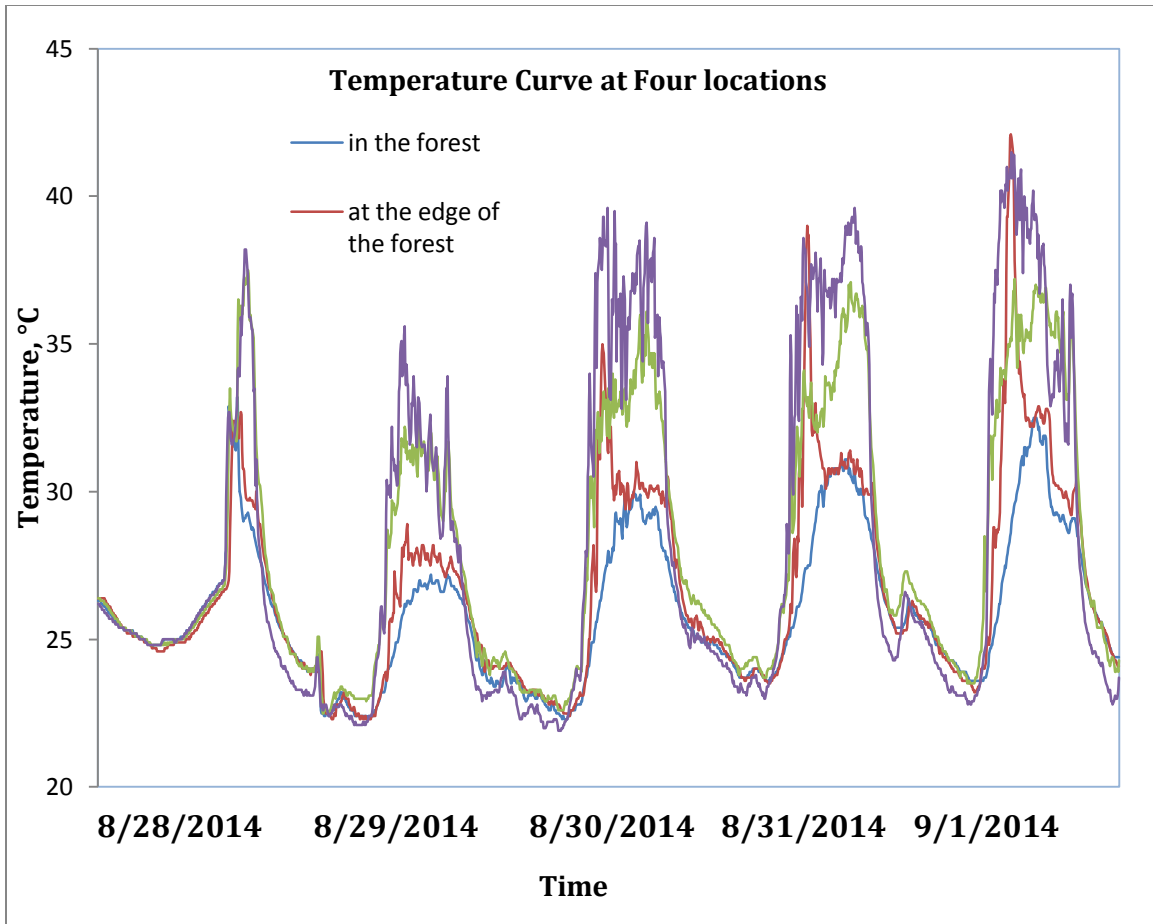


Figure.9 Temperature curve at the four sampling points

3.1.2 Monetary value of cooling effect

According to the energy saving function of:

$$\frac{\text{Energy saved for cooling}}{\text{Energy needed for cooling}} = \frac{CDD_{original} - CDD_{new}}{CDD_{original}}$$

$$\frac{\text{Energy saved for cooling}}{\text{Energy needed for cooling}} = \frac{\text{Degrees} * 153\text{days/year} - 0.85\text{Degrees} * 78\text{days/year}}{\text{Degrees} * 153\text{days/year}}$$

$$= 56.7\%$$

Thus, we conclude that the monetary value of the forest’s cooling effect equals to approximately 56.7% of the cost on cooling.

3.2 Carbon offset

The carbon storage and gross annual sequestration from the forest were estimated as follows:

$$\text{The carbon storage} = 39.7 \frac{t}{ha} \times 60 \text{ acres} \times 0.405 \frac{ha}{acre} = 964.71 t$$

$$\text{The gross annual sequestration} = \frac{1.3 \frac{t}{ha}}{year} \times 60 \text{ acres} \times 0.405 \frac{ha}{acre} = 31.59 t/year$$

If the land was still forest without BASF facilities, then the carbon storage and the gross annual sequestration would be 1,607.85 t and 52.65 t/year. Under this condition, the space is 100 acres.

3.3 Noise reduction

After we exported the data from “Decibel 10th”, we cleaned useful data (data that were occasionally failed to be recorded) and selected the data that started from the same time period. We created Figure.8 and Figure. 9 for the peak and average decibel comparison.

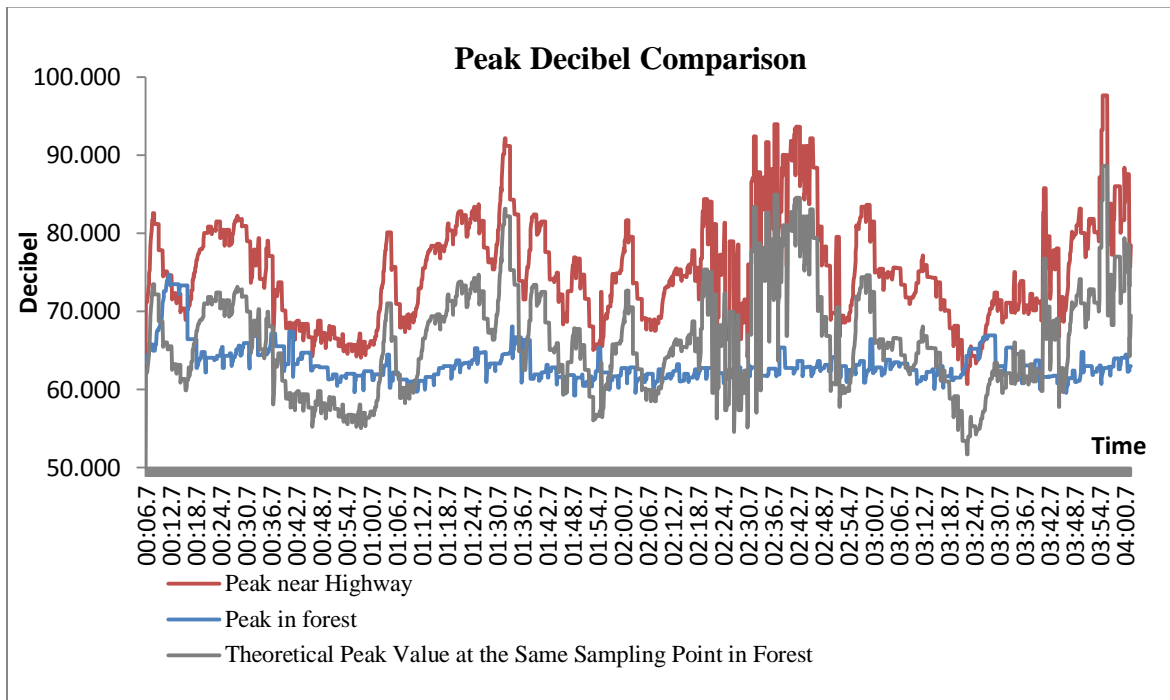


Figure. 8 Peak Decibel Comparison

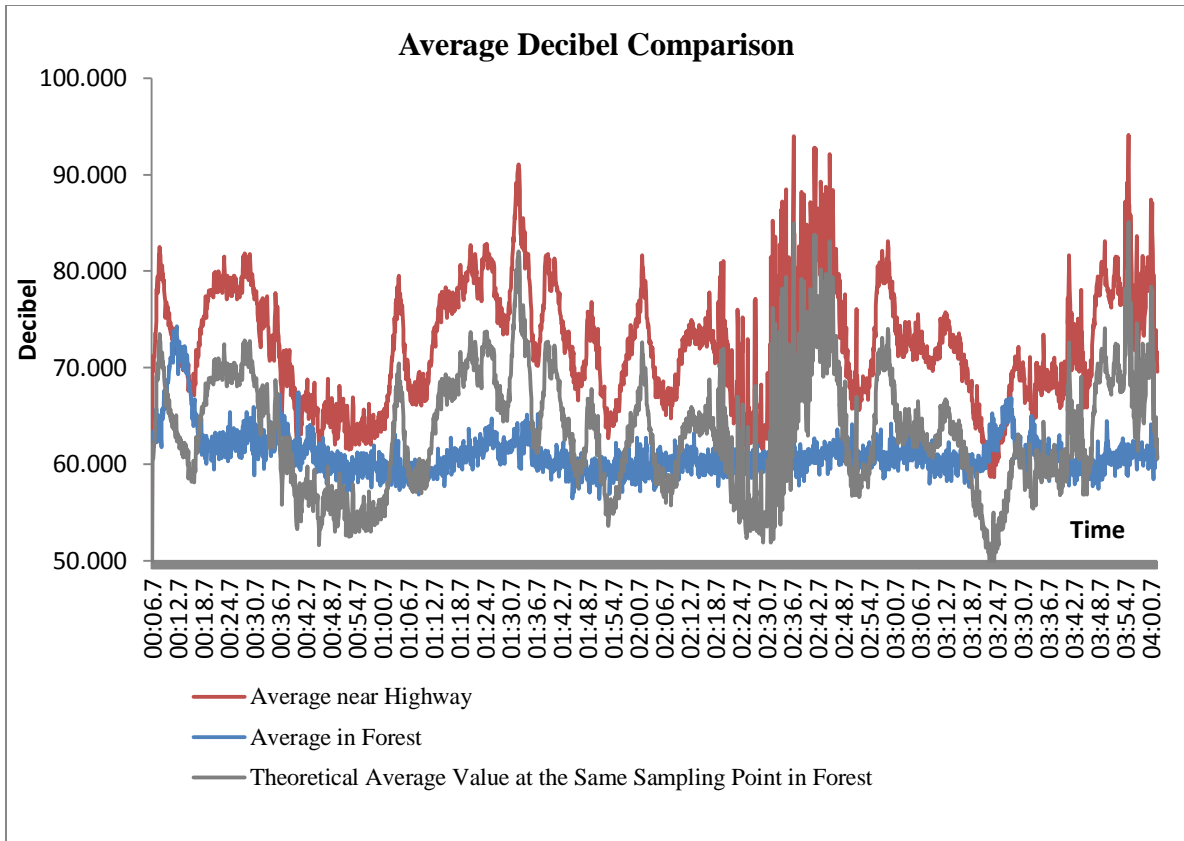


Figure.9 Average Decibel Comparison

Figure.8 shows the peak decibel values alongside the highway (i.e. 5 meters away), 45 meters away from the highway in the forest, and the theoretical decibel values at 45 meters away from the highway. The peak values reveal the highest decibel during the intervals (i.e. 0.1 second). Similarly, Figure.9 exhibits the average decibels in the two sampling points as well as the theoretical values, and the average values is the average strength of noise during the 0.1-second interval. Most of the recorded decibels are five to fifteen dB less than the theoretical values, which indicate that the decibel in the forest is smaller than the decibel at the position without trees and other plants. In other words, the forest has the effect of reducing noise. As mentioned in the introduction section, trees have the effect of reducing three to five decibel of noise with a 30 meters tree belt, and this value is close to our recorded values.

Another finding is that, as shown in both of the peak and average decibel comparison figures, the curve of recorded noise is much smoother in the forest than the theoretical values, making the surrounding a more stable environment.

3.4 Biodiversity of BASF forest

After conducting several on-site observations, we have identified 45 different species of trees and shrubs (See Table.1). Most of the plants are common and widespread in South and Southeastern United States; however, two invasive species have been found, one is Japanese Holly and the other is Japanese Honeysuckle. Both of these two plants are original from Asia, and the native range is mainly in Japan and Korea. The Japanese Holly Fern is popularly planted by residents in their gardens throughout the South and Southeastern parts of the United States, and has been extensively planted since the 1800s. This fern can grow under different light conditions and suit in humid soils, thus it is suitable for coastal areas. No obvious threaten has been detected for this plant, therefore not much information is presented about removing Holly Fern (National Park Service, 2012). The Japanese Honeysuckle, however, has more ecological threat to the local plants and thus need to be controlled. In North America, Japanese Honeysuckle spread widely due to few natural enemies, and it can out-compete natural native plants because of its characteristics. The vine of this plant can climb on the native shrubs and trees and wrap them that prevent water flowing through them (National Park Service, 2005). Japanese Honeysuckle is a fast-growing climber with vigorous root system. While it gets older, it develops a comparatively thick, wood stem that is not easily broken, which helps them spread and displace neighboring native vegetation (FCPS, 2015). Thus Japanese Honeysuckle should be monitored and removed where they could become an added ecological threat. Many chemical and non-chemical methods of removal and control are available under different extent of infestation with varied consumption of time and labor.

Referring to animals, 20 birds and two mammals have been differentiated based on sound identification and camera setting. Animals are barely seen in the daytime, except for the hearings from birds. White-tailed Deer and Virginia Opossum were detected from photos captured by cameras at night.

Table.1 Bio-inventory

Trees			
<i>Parthenocissus quinquefolia</i> (Virginia Creeper)	<i>Vitis rotundifolia</i> (Muscadine Grape)	<i>Toxicodendron radicans</i> (Poison Ivy)	<i>Rhus coriaria</i> (Sumac)
<i>Pinus taeda</i>	<i>Quercus falcate</i>	<i>Cornus florida</i>	<i>Liquidambar</i>

(Loblolly Pine)	(Southern Red Oak)	(Flowering Dogwood)	(Sweetgum)
<i>Viburnum dentatum</i> (Arrowwood Viburnum)	<i>Carya tomentosa</i> (Hickory)	<i>Quercus stellata</i> (Post Oak)	<i>Acer rubrum</i> (Red Maple)
<i>Quercus alba</i> (White Oak)	<i>Juniperus virginiana</i> (Eastern Red Cedar)	<i>Ulmus rubra</i> (Slippery Elm)	<i>Carya tomentosa</i> (Mockernut Hickory)
<i>Ilex decidua</i> (Deciduous Holly)	<i>Oxydendrum arboreum</i> (Sourwood)	<i>Ilex crenata*</i> (Japanese Holly*)	<i>Ilwz vomiroeia</i> (Yaupon Holly)
<i>Quercus virginiana</i> (Southern Oak)	<i>Saccharum officinarum</i> (Sugar Cane)	<i>Betula nigra</i> (River Birch)	<i>Solanum dulcamara</i> (Nightshade)
<i>Quercus rubra</i> (Northern Red Oak)	<i>Usnea austral</i> (Old Man's Beard)	<i>Myrica gale</i> (Wax Myrtle)	<i>Saururus cernuus</i> (Lizard's Tail)
<i>Rubus argutus</i> (Sawtooth Blackberry)	<i>Morus rubra</i> (Red Mulberry)	<i>Cercis canadensis</i> (Eastern Redbud)	<i>Microstegium vimineum</i> (Japanese Stiltgrass)
<i>Platanus occidentalis</i> (American Sycamore)	<i>Ulmus alata</i> (Winged Elm)	<i>Morus alba</i> (White Mulberry)	<i>Dichanthelium clandestinum</i> (Deer-tongue Witchgrass)
<i>Lonicera japonica</i> (Japanese Honeysuckle*)	<i>Smilax rotundifolia</i> (Greenbrier)	<i>Carya illinoensis</i> (Pecan)	<i>Viburnum acerifolium</i> (Mapleleaf Viburnum)
<i>Quercus phellos</i> (Willow Oak)	<i>Liriodendron tulipifera</i> (Tulip Tree)	<i>Abies fraseri</i> (Christmas Fir)	<i>Eunonymus americanus</i> (Hearts a Bustin')

<i>Carpinus caroliniana</i> (Muscle Wood)			
Birds			
<i>Branta canadensis</i> (Canada Geese)	<i>Thryothorus ludovicianus</i> (Carolina Wren)	<i>Corvus brachyrhynchos</i> (American Crow)	<i>Zenaida macroura</i> (Mourning Dove)
<i>Poecile carolinensis</i> (Carolina Chickadee)	<i>Baeolophus bicolor</i> (Tufted Titmouse)	<i>Piranga rubra</i> (Summer Tanager)	<i>Cardinalis cardinalis</i> (Northern Cardinal)
<i>Setophaga pinus</i> (Pine Warblers)	<i>Seiurus aurocapilla</i> (Ovenbird)	<i>Cyanocitta cristata</i> (Blue Jay)	<i>Picoides pubescens</i> (Downy Woodpecker)
<i>Falco columbarius</i> (Merlin)	<i>Regulus calendula</i> (Ruby-crowned Kinglet)	<i>Sitta carolinensis</i> (White Breasted Nuthatch)	<i>Corvus corax</i> (Common Raven)
<i>Turdus migratorius</i> (Robin)	<i>Mimus polyglottos</i> (Northern Mockingbird)	<i>Spizella passerina</i> (Chipping Sparrow)	<i>Sphyrapicus varius</i> (Yellow-bellied Sapsucker)
Mammals			
<i>Odocoileus virginianus</i> (White-tailed Deer)	<i>Didelphis virginiana</i> (Virginia Opossum)		

4 Discussion

4.1 Cooling effect

One of the reasons that forest possesses the ability to smooth the temperature fluctuation and stabilize the environment might be that forest possesses higher humidity than the parking area, and water has a good ability of storing energy. At daytime, water in the forest stored solar energy, preventing the environment to be heated rapidly. At night, the stored energy in water was release into the atmosphere, warming the surroundings. This guess could be proved by the curve comparison between Figure.4 and Figure.5, which have been derived at the two places (i.e. the parking area and the sampling point near the pond). The largest temperature difference within one day (September 2) at the parking reached 20 degrees while the difference near the pond was about 17 degree at that day.

The temperature recorder placed at the edge of the forest is used to further identify the cooling effect the trees. As can be seen in Figure.7, the shape of temperature curve is similar to the shape of temperature curve in Figure.6, except that there are high peaks in each sampling day around noon. That is the time period that the recorder can be directly radiated by the sunlight. This finding also proves that shade of tree has an obvious effect of cooling the atmosphere.

4.2 Carbon offset

As stated, the carbon storage and gross annual sequestration from the forest were estimated to be 964.71 t and 31.59 t/year respectively. If all of the BASF agriculture headquarter land was still forest, then the carbon storage is 1,607.85 t. The carbon storage of the forest has already decreased by 643.14 t due to the establishment of BASF facilities. However, the existed forest helps remove atmospheric CO₂ from local fixed emission sources such as power plants, and mobile emission sources from traffic, mainly the highway nearby the forest. It is expected that in the future carbon offset market, BASF could offset its emissions from office building by the carbon storage and sequestration effects from the forest.

4.3 Noise reduction

As Figure.8 and Figure.9 show, some of the recorded data in the forest were greater than the theoretical values. One of the reasons might be that there was noise interruption around this area. For example, the birds in the forest might contribute to the noise at this sampling point. There is also a path pass by this sampling point, where trucks passed by occasionally. The noise generated by the engine of the truck further added the values of the noise there.

4.4 Biodiversity of BASF forest

The BASF forest hosts many local plants and provides habitats for animals. In our study, up to 45 different species of trees and shrubs, 20 birds and 2 mammals have been identified. According to the Identification Curves, we have almost covered all the species for vegetation along the trail and differentiated all the birds based on their sounds. However, not many mammals have been found due to several reasons: first, in daytime, animals are less willing to come outside searching for food because of disturbance from human activities, which reduced our chances to see and observe them when we conducted field survey. Second, although we set up cameras to capture their images, we didn't have adequate equipment that could support us to cover more sample areas. Given the limitation, we would suggest our client to get more cameras as well as ensure that those cameras could last for a longer time. If our client is interested in animal species and want to obtain more detailed information, more types of animals should be considered such as amphibians. Moreover, more experiments should be applied such as capture and observation, which requires certificate application and elaborate study plan.

5 Conclusions

The forest of BASF has a distinct effect on hosting native plants and animals, reducing noise and air temperature, as well as sequestering and storing carbon from atmosphere. In many cities throughout the United States, it is common to discover that the tree species planted in neighborhoods are the same with low level of diversity in street tree species. Referring to cities, only a few street tree species would be found to be planted over and over again. In Oakland, CA, for instance, 49 percent, nearly a half of tree population of the urban ecosystem can be categorized into four tree species (Nowak, 1993), while in Chicago, IL, more than half of the population is made up by six species or genera (Nowak, 1994b). The lower species diversity would lead to detrimental problems, best demonstrated by a classic example of problems associated with extensive of American elm when it has been largely planted in the cities of United States as an urban tree after World War II. In Minneapolis, MN, for example, American elm contributed ninety-five percent of all urban trees population in cities and towns which is equivalent to 200,000 elms in total (Price, 1993). However, a fungus that leads to Dutch elm disease happened in the late 1960's. The disease was spread by bark beetles and caused elms begin wilting and die, and thus killed almost all American elms mainly in Minneapolis area and throughout the United States. In addition to loss in resilience to extraneous disease and environmental changes, this low level of biodiversity also worsened the situation by removing and disposing killed trees in expensive and time-consuming ways. Therefore, higher level of

biodiversity in tree species decreases the vulnerability of the forest as well as improves the aesthetic values. The forest also shows various well-established layers of vegetation including canopy, subcanopy, shrub layer, as well as ground cover along with the appearance of dead logs and dead standing trees (snags). Retaining natural structure and developing high level of diversity is significant for forest ecosystem to perform function of hosting different wildlife in the forest. The BASF forest has logs and snags, not only providing habitat for animals such as mammals, amphibians and reptiles as well as serving as food for many native insects and fungi. These insects and fungi turn out to be food for birds, and therefore, the forest hosts many native and migrating birds.

Referring to noise reduction, the BASF forest absorbs approximately 5 decibels of noise from traffic, and provides a more stable environment for BASF employees to work. The reasons why it achieves effective noise reduction are as follows: first, the total width of the vegetation area is more than 5m, and these plants grow perpendicular to the noise transmitted direction (alongside the road). Second, these trees and shrubs are close to each other with distances that are appropriate for their growing. Third, the vegetation groups are a combination of various plants at different heights. In addition to ameliorating the traffic noise, the forest has an apparent effect on energy conservation. In theory, trees, especially deciduous trees which are the trees that lose all their foliage at falls could save energy bills in summer time by shading and blocking buildings and air conditioners from direct sunshine. Although the results of BASF forest demonstrated that it has an effective role of cooling the air temperature and thus decreasing energy use, it does not directly influence the energy use of BASF office building, as there is a distance between the forest and the building and the trees can neither shade the building nor the air-conditioners. However, these trees might help reduce the consumption of energy by preventing coming cold winds in winters. Since these trees surround the building and keep much foliage, they help prevent winds entering that bring way heat from the outer surfaces of buildings.

The atmospheric carbon dioxide can be captured by the BASF forest in two ways: taken up and absorbed by living trees and other plants through photosynthesis as well as stored as carbon in biomass (i.e. trunks, branches, leaves, and roots) and ground soils. The carbon offset value of BASF forest could become monetary value in the future, as the voluntary “retail” market is growing and more and more individuals and entities are engaged to seek for purchasing carbon offsets to reduce their greenhouse gas footprint or become “carbon neutral”.

6 Recommendations

6.1 Plants selection for BASF’s Wetland Garden

As mentioned in previous section, we have three principles for the wetland plants selection: native, easy-growing and good-looking. After conducting on-site observation of rainwater garden in Catawba College and consulting from the biological professionals, we generated a recommendation list of native plants for BASF rainwater garden (See Table.2).

Table.2 Recommended Plants for BASF’s Wetland

Recommended Plants for Rainwater Garden				
Cephalanthus occidentalis (Buttonbush)	Saururus cernuus (Lizard’s Tail)	Lobelia cardinalis (Cardinal Flower)	Equisetum (Horsetail)	Chasmanthium latifolium (Wood oats)
Chionanthus virginicus (White Fringetree)	Sagittaria Lancifolia (Duck Potato)	Lobelia Siphilitica (Great Blue Lobelia)	Typha Latifolia (Bulrush)	Lilium Candidum (Lily)

Some of the plants in the table can be found in the forests, while others are recommended to grow to increase the biodiversity and recreational value. All of these plants favor humid condition, easily grown in medium to wet soils type with full direct sunshine to part shade. Flowering plants such as Cardinal Flower, Lobelia Siphilitica and Lily feature with flowers of different colors. Cardinal Flower is red, Lobelia Siphilitica is blue and Lily is white, which creates more colors in the wetland, and attracts employees to visit and rest. Additionally, these plants seeds are commonly available in flower market and online, and prices are acceptable.

6.2 Educational tour for BASF’s forest

We want to further extract the value of the BASF’s forest and convey the importance of the forest to the local residents. The forest could be used as an educational resource to increase the residents’ environmental awareness, and educate students about biodiversity and other effects of the forest. Based on the existing trail, we suggest our client design and provide forest tour to public school students. Tours should be conducted in springs and falls, when the forest is more

vigorous with varied plants and migratory birds. Our appendix could be used as educational material or handouts that help students differentiate plants. The Cornell Lab of Ornithology “All About Birds” is a useful website to play different birds’ sounds and learn how to identify them based on these sounds. Our bird inventory could also help that provide potential species to choose from.

In order to realize the forest tour, our clients might have to make efforts in several aspects:

- Build an online platform to share newly observed animals and plants
In the first place, our client would like to see whether there is a fox or other small mammals in their forest, as some employees reported witness foxes in the forest. Unfortunately, during our study, we didn’t observe foxes or capture an image of them. To instantly share observation experiences and continuously update bio inventory, an online communication system should be developed through forest website or emailing system.
- Remark the trail by installing tags
Currently, the trail in the forest remains natural and open while marked by the colorful ribbons hanging on the trees. It might be confusing for those first-time visitors that they would easily get lost rather than keep on the right track. The tags of trees are aged with blurry words, and some tags are covered by newly grown plants. Therefore, new tags should be designed and installed. They would not only introduce the trees and shrubs, but also indicate the trail. The materials that used for tags should be durable, and environmental-friendly.
- Establish rainwater garden
The rainwater collection system is located at the end of the forest trail. After planting different types of native plants, the garden would increase the recreational value of the tour and might become a new habitat for more insects and small animals. However, gardeners should be hired or experienced employees should take the responsibility to take care of the garden ideally at least once per week.

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