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Project Proposal: The Urban Heat Island Effect in New York City

Urban environments have impacts on the environment as a whole. These effects are continuously increasing as urban environments become more populated. Urban ecology research is also growing to improve the understanding of the effects of urbanization (Niemela, 1). One of the effects of urbanization that this term project will explore is referred to as the "urban heat island effect". The urban heat island effect is defined as an increase in urban air temperature as compared to the surrounding suburban and rural temperature (Rosenzweig, 1). The creation of an urban heat island is mainly due to urban construction of buildings and roads that absorb solar radiation and re-radiate it to the surroundings, increasing temperatures (Nyuk, 547). An urban heat island is created when naturally vegetated surfaces, such as grass and trees, are replaced with non-reflective, water resistant surfaces that absorb a high percentage of solar radiation (Rosenzweig). As cities develop, more vegetation is lost as surfaces are paved or covered with buildings. This results in less shade and moisture to keep urban areas cool (Soltani). Even during night time, the surface temperatures of urban surfaces are higher compared to rural ones. This is because during the day, the heat is stored in the urban construction material and is released at night (Niemela). Built-up areas also evaporate less water, which contributes to elevated surface and air temperatures. Properties of urban materials such as solar reflectance also influence the development of urban heat islands because they determine how much the sun's energy is reflected and absorbed ("Reducing Urban Heat Islands"). The addition of heat and pollutants from power plants, industrial processes, and vehicles into the city atmosphere all contribute to the intensity of the urban heat island effect (Rosenzweig). Heat islands can affect communities by increasing air conditioning costs, greenhouse gas emissions, heat-related illnesses, etc. There is a potential rising threat of mortality due to the heat load stress of urban residents caused by the warmer air temperature produced by urban heat island increases (Li). Now more than ever, due to the continuous population growth in urban areas, it is important to implement strategies to mitigate the urban heat island effect.

My project will explore different strategies to mitigate the urban heat island effect, specifically in New York City. The three main strategies I will focus on include: planting more street trees, creating green roofs, and developing dark surfaces into lighter surfaces. In cities like New York City, where there is less nature and more buildings and surfaces that trap the heat, planting more trees can help to mitigate this effect. There is a strong correlation between the appearance of large green areas in the city and the decrease of temperature (Nyuk). In urban areas where there is a low surface area covered by vegetation, the potential for surface cooling is very low. Trees provide shade which helps lower surface temperatures because it blocks the sun from being absorbed by the surface below the tree. About 10 to 30 percent of the sun's energy reaches the area below a tree, with the remainder being absorbed by leaves and used for photosynthesis, and some being reflected back into the atmosphere. Trees also provide shade for houses and office buildings. This reduces the need for air conditioning which reduces the amount of fossil fuels burned to produce electricity. They also help reduce air temperatures through a process called evapotranspiration, in which plants release water to the surrounding air, getting rid

of ambient heat. Lastly, trees absorb CO2 through photosynthesis which helps cool the atmosphere because CO2 blocks heat from escaping the atmosphere. Planting more street trees that are in close proximity to cars can help mitigate the heat island effect because they can reduce the evaporative emissions from parked vehicles through absorption. The combination of CO2 removal from the atmosphere and the shading of surfaces makes trees extremely efficient tools in fighting the heat island effect. ("Reducing Urban Heat Islands")

Similar to planting more street trees, green roofs are another strategy that New York City can mitigate the heat island effect. A green roof is a vegetative layer grown on a rooftop. Using green roofs in New York City where there is a built environment with limited vegetation, can moderate the heat island effect. They could be the best option in neighborhoods with limited redevelopment opportunities (Rosenzweig, 4). Green roof temperatures can be 30–40°F lower than non-green roofs and can reduce city-wide ambient temperatures by up to 5°F. In addition, green roofs can reduce building energy use by 0.7%, reducing electricity demand ("Reducing Urban Heat Islands"). Green roofs provide shade, remove heat from the air, and reduce temperatures of the roof surface. The plants of a green roof block sunlight from reaching the underlying roof. Shading reduces surface temperatures below the plants. These cooler surfaces, in turn, reduce the heat transmitted into buildings or re-emitted into the atmosphere. Reduced surface temperatures help buildings stay cooler because less heat flows through the roof and into the building which results in less need for air conditioning which also helps to reduce the heat island effect. In addition, lower green roof temperatures result in less heat transfer to the air above the roof, which can help keep urban air temperatures lower as well. The green roof not only cools the roof's surface and provides shade, it also cools the surrounding air. It achieves this through the processes of evaporation and transpiration which are referred to as evapotranspiration. Evapotranspiration cools the air by using heat from the air to evaporate water. Both processes release moisture into the air. During evaporation, water is converted from liquid to vapor. During transpiration, water that was drawn up through the soil by the roots evaporates from the leaves. As trees release water into the atmosphere from their leaves via transpiration, the surrounding air is cooled as water goes from liquid to a vapor. in trees, water moves into the tree's roots from the soil and travels through the tree's water-conducting system, eventually being transpired from the leaves. The water that is released in its gas vapor form has a cooling effect on the surrounding air. These two mechanisms reduce temperatures of the roof surface and the surrounding air. The surface of a vegetated rooftop can be cooler than the ambient air, whereas conventional rooftop surfaces can exceed ambient air temperatures by up to 90°F. The outdoor cooling provided by trees also reduces the energy used inside a home or office. ("Reducing Urban Heat Islands")

Another strategy to mitigate the urban heat island effect is by developing dark, low albedo surfaces into lighter, more reflective surfaces. A material's color and shade affects the amount of light it absorbs or reflects. Dark colors reflect less light to the eye, so therefore they absorb more light. Since they absorb more light, they are hotter than lighter surfaces that do not absorb as much solar heat. For example, a matte black material would absorb the most solar energy. The term "albedo" describes the percentage of solar radiation reflected back into space by an object or surface. A perfectly black surface has an albedo of 0, where all radiation is absorbed. A perfectly white surface has an albedo of 1.0, where all radiation is reflected; therefore, surfaces that are lighter and higher albedo will reflect the sun instead of absorbing the heat ("Reducing Urban Heat Islands"). Urban areas typically have surface materials, such as roofing and paving, which have a lower albedo than those in rural settings. As a result, built up

cities generally reflect less and absorb more of the sun's energy. This absorbed heat increases surface temperatures and contributes to the formation of surface and atmospheric urban heat islands. Traditional pavements in the United States are concrete and asphalt, which can reach summertime surface temperatures of 120–150°F. These surfaces can transfer heat downward to be stored in the pavement subsurface, where it is re-released as heat at night. The warmer daytime surface temperatures also can heat storm water as it runs off the pavement into local waterways. These effects all contribute to urban heat islands. If the darker, lower albedo surfaces in New York City were developed into lighter, higher albedo surfaces, there would be less solar absorption and therefore would lower surface temperatures and help mitigate the heat island effect. ("Reducing Urban Heat Islands")

A way I can incorporate these scientific ideas into my creative work would be to create a digital photo book. It would be comprised of a series of digital photos that I take. Each photo would advance the narrative of a short story that I create. The story could be about a character who lives in New York City. The beginning would be the character feeling very hot, due to the heat island effect, and decides to use air conditioning. I can "draw" different illustrations on the photos to show that the air conditioning worsens the heat island effect by burning fossil fuels needed to produce electricity. The middle section of the story will show different factors that contribute to the heat island effect such as dark surfaces that absorb the solar heat and buildings that re-radiate solar heat into the atmosphere. For example, one photo could show the character next to a dark surface, and the drawn illustrations could be orange and red flames. Then, the character will have an "idea" to help reduce the heat island effect. The end of the story will show the character by a tree, a higher albedo surface, and a green roof. I will digitally "draw" illustrations showing how the vegetation provides shade and absorbs CO2 and how the lighter surface reflects solar heat instead of absorbing it.

Another idea for my creative work would be to create a mini documentary at a local green roof, showing its positive effects in mitigating the urban heat island effect. The visuals would be the green roof itself, and the scientific ideas would be incorporated through voiceover and visual effects. The scientific ideas that would be incorporated include: how green roofs provide shade which cools the building and lessens the need for air conditioning which contributes to the heat, and how the greenery absorbs CO2 which is a gas that traps heat from escaping the atmosphere. The potential audience for both of these creative works would be people who live in urban areas since they would be directly affected by the urban heat island effect. Both the photo story and the documentary are visual, and therefore could be enjoyed by all ages.

Project Table

Street trees provide shade which helps lower surface temperatures because it blocks the sun from being absorbed by the surface below the tree. They also absorb CO2 emissions from nearby cars through photosynthesis which removes it from the air which helps cool the air because CO2 traps heat from escaping the atmosphere.	This idea could be incorporated through a digital photo story. At the end of the story when the character thinks of ways to cool the air, the character could "plant" a tree which would show the shade it provides and I could digitally illustrate the CO2 that it absorbs.
Development of New York City's dark surfaces into lighter, higher albedo surfaces can cool surface temperatures because lighter surfaces reflect more light and absorb less solar energy and therefore do not store as much heat as the darker surfaces.	This idea could be incorporated through a digital photo story as well. The character could be next to a dark, matte surface and I can digitally "draw" illustrations showing visually that the dark surface is absorbing solar heat. Conversely, I can illustrate the reflection of light for the lighter surfaces.
Green roofs can cool air temperature through evapotranspiration, and they provide shade which reduce temperatures of the roof and leads to less demand for air conditioning which all helps mitigate the heat island effect.	This idea could be incorporated as a mini documentary at a local green roof, providing information on its positive effects.

Annotated Bibliography

Reducing Urban Heat Islands: Compendium of Strategies. U.S. Environmental Protection Agency. 2008. Print. "Heat Island Compendium." EPA, Environmental Protection Agency, 9 May 2017. Web.

- The surface of a vegetated rooftop can be cooler than the ambient air, whereas conventional rooftop surfaces can exceed ambient air temperatures by up to 90°F. Evapotranspiration cools the air by using heat from the air to evaporate water. Both processes release moisture into the air. During evaporation, water is converted from liquid to vapor. During transpiration, water that was drawn up through the soil by the roots evaporates from the leaves.

Li, Huidong. "A New Method to Quantify Surface Urban Heat Island Intensity." *Science of The Total Environment*, vol. 624, 2018, pp. 262-272. Science Direct. Web. 25 Feb. 2019.

- There is a potential rising threat of mortality due to the heat load stress of urban residents caused by the warmer air temperature produced by urban heat island increases. The higher air temperature increases energy consumption and greenhouse gas emissions due to the increased use in air conditioning.

Niemela, Jari. *Urban Ecology: Patterns, Processes, and Applications*. New York: Oxford University Press, 2011. Print.

- The effect of the urban heat island is highly dependent on the different construction types of buildings and the use of air conditioning. It is influenced by the three-dimensional shape of the city such as the width of the streets, height and type of the buildings, type and size of urban greens, etc.

Nyuk Hien, and Chen Yu. "Study of Green Areas and Urban Heat Island in a Tropical City." *Habitat International*, vol. 29, no. 3, 2005, pp. 547-558. Science Direct. Web. 25 Feb. 2019.

- The primary cause of the heat island effect in cities is due to the absorption of solar radiation by buildings, roads, and other hard surfaces. That heat is re-radiated to the surroundings which increases temperatures.

Price, John C. "Assessment of the Urban Heat Island Effect Through the Use of Satellite Data." *Monthly Weather Review*, vol. 107, no. 11, 22 June 1979, pp. 1554-1557. AMS. Web. 25 Feb. 2019.

- The increase in air temperature in cities is usually accompanied by elevated concentrations of CO2. An indirect effect is altered flow patterns and vertical convection in urban areas. Changes in flow patterns can cause local cloudiness, dispersion of urban air mass, and rainfall. This effect may be due to the trapping of energy within the "urban canyon"

Rosenzweig, Cynthia. "Mitigating New York City's Heat Island with Urban Forestry, Living Roofs, and Light Surfaces." 30 Jan. 2006. Semantic Scholar. Web. 25 Feb. 2019.

- Urban Heat Island Effect is defined as an increase in urban air temperature compared to the surrounding suburban and rural temperature. Heat Islands have regional-scale impacts

on energy demand, air quality, and public health. It was revealed that vegetation cools surfaces effectively and the most effective mitigation strategy is curbside planting.

Soltani, Ali, and Ehsan Sharifi. "Daily Variation of Urban Heat Island Effect and Its Correlations to Urban Greenery: A Case Study of Adelaide." *Frontiers of Architectural Research*, vol. 6, no. 4, Dec. 2017, pp. 529-538. Science Direct. Web. 25 Feb. 2019

- Urban structures affect the shadow patterns and heat exchange in the built environment. In urban areas where there is a low surface area covered by vegetation, the potential for surface cooling is very low. Distribution and intensity of urban greenery also affect local wind patterns.