HOW URBAN AGRICULTURE CAN MITIGATE URBAN HEAT ISLAND EFFECTS (UHI)

By

AGSA MIRIUM SHAJI

FACULTY OF NATURAL RESOURCES MANAGEMENT

LAKEHEAD UNIVERSITY

THUNDER BAY, ONTARIO

APRIL 27, 2023

HOW URBAN AGRICULTURE CAN MITIGATE URBAN HEAT ISLAND EFFECTS (UHI)

By

Agsa Mirium Shaji

An undergraduate thesis submitted on the partial fulfillment of the requirements for the degree of Bachelor of Environmental Management

Faculty of Natural Resource Management
Lakehead University

April 27 2023

____________________ ____________________

Major Advisor Second Reader

LIBRARY RIGHTS STATEMENT

A CAUTION TO THE READER

ABSTRACT

Shaji, A. 2023. How urban agriculture can mitigate urban heat island effects. 35 pp.

Keywords: Urban agriculture, the heat island effect, albedo, city planning, heat waves, evapotranspiration, solar radiation, aquaponics, green roofs, sustainability, microclimate, urbanization, greenhouse gas, community gardens, urban farming, and climate change.

This thesis explores the efficiency of urban agriculture (UA) to mitigate the effects of the urban heat island UHI) effect. The thesis examines the causes and impacts of UHI and how UA may help to lessen some of its and the different types of UA that can be practiced in cities, which include rooftop vegetation vertical farming, hydroponics, aeroponics and community gardens. The research was conducted by reviewing existing literature on these topics and found that UA can help improve an area's urban microclimates through multiple environmental mechanisms. In addition, various economical and social benefits of UA are also presented and synthesized.

TABLE OF CONTENTS

FIGURES

ACKNOWLEDGMENTS

I would like to thank my thesis supervisor Ms. Keri Pidgen Welyki, for her guidance and support throughout the project and my second reader Dr. Nathan Basiliko for his feedback and review. I would also like to thank my friends and my family for their continuous support and prayers.

INTRODUCTION

Metropolitan areas have warmer air temperatures than the nearby rural countryside (Laden et al., 2022). This Urban Heat Island (UHI) phenomenon is recognized as the most typical and well-documented example of climatic change during a time of rapid urbanization (Laden et al., 2022). More than natural landscapes like forests and water bodies, city infrastructures release longwave radiation, and it depends on the material the structures are made up of. For example, materials like asphalt which is used to build roads absorb solar heat which increases the surface temperature of cities (Kakoniti et al., 2016) and infrastructures like windows reflect the solar heat and this reflectivity is based on the glass materials the windows are made up of and some structures like buildings, absorb and reflect a certain amount of solar heat (Jelle 2013).

Green spaces are known to have a positive impact on regional microclimates and thus, build climatically resilient cities and mitigate UHI. Urban agriculture (UA) which encompasses activities including horticulture, animal husbandry, aquaculture, and other methods for generating fresh food or other agricultural goods, refers to agricultural activities in urban centres and their surrounding territories (Tornaghi 2014). UA is considered an effective way to mitigate UHI as it incorporates various micro- and meso-scale land uses that tend to maintain a moderate temperature in the area relative to sealed soil and building infrastructure, as well as contribute to the social and economic development of cities. This includes mitigating health issues in humans by providing quality food sources, reducing impacts of climate change, providing space for protocol development and creating job opportunities among people. UA promotes to the economic development of a country at different scales by providing incomes or at least offsetting food costs to households who practise UA (Ilieva et al., 2022).

In addition to providing food, urban farming has been used in cities to meet the shifting requirements of urban residents' lives by providing them access to fresh food locally, employment opportunities, educational opportunities (Audate et al., 2019).

Investigating the potential of urban farming to reduce urban heat island intensities in our cities and provide green infrastructure in addition to food crops is urgently needed as the UHI significantly and increasingly impacts humans and the environment.

Humans struggle to physiologically adapt to their surroundings in extreme temperatures (Gronlund et al., 2018). For example, heat waves may negatively impact human health once the temperature reaches the upper tolerance level, increasing the incidence of stress, disease and death (Tian et al., 2021). The UHI effect can further exacerbate health effects by altering rainfall patterns, combining with, and worsening air pollution, raising the risk of flooding, and lowering water quality (Heaviside et al., 2017). There is an urgent need to take action to mitigate the UHI, and numerous studies have been conducted on urban agriculture and its effects on urban heat islands.

The objective of this research is to examine the causes and effects of urban heat islands, and to show how urban agriculture can be used to mitigate some of these effects. I hope that this thesis will raise public awareness of the value of urban agriculture and its potential to make cities more resilient to temperature extremes while providing numerous other benefits.

METHODOLOGY

The research was based on published studies on the efficiency of urban agriculture in reducing the effects of the urban heat island brought on by climate change. Online literature databases including Google Scholar, Web of Science, JSTOR, and Lakehead OMNI were used to find relevant publications. Search phrases used included: Urban agriculture, the heat island effect, albedo, city planning, heat waves, evapotranspiration, solar radiation, aquaponics, green roofs, sustainability, microclimate, urbanization, greenhouse gas, community gardens, urban farming, and climate change.

A case study analyzing the vegetation and temperature difference around Thunder Bay International Airport weather station in Ontario was conducted. The temperature data of the weather station were collected from the Environment Canada website. Google Earth Pro was used to classify the areas into polygons to identify the relative vegetation and other surfaces covered like asphalt and concrete within a distance of 1-km radius of the station.

LITERATURE REVIEW

Climate change is a major cotemporary global threat. Although climate change from long-term cyclical changes in solar radiative forcing and biophysical feedbacks is natural, anthropogenic changes to the global climate and atmospheric composition has caused unprecedented, fast changes in global temperatures and regional climates. Climate change is a long-term alteration of a region's normal or average weather. The main source of these variations in climate is the emission of greenhouse gases due to human activities, principally fossil fuel, mining, and combustion and also cement production and land use changes (Stocker, 2014). Over the past few decades, increases in industrial and human activity have sped up these changes, including an average, rise in the average global surface temperature of ~ 1 C since 1880, which is equivalent to an extra 3 watts of energy per m^2 over then entire earth’s surface (Santos & Bakhshoodeh, 2021).

Urbanization accelerates warming in by producing urban heat islands and local-scale aerosol- based radiative forcing (Kumar, 2021). The difference between the radiation entering the Earth's atmosphere and the radiation that is absorbed or reflected by atmospheric particles is known as aerosol radiative forcing. It has a variety of effects on the climate since all aerosols—aside from dust—interfere with solar radiation Positive radiative forcing occurs when aerosols absorb sunlight, causes the atmosphere to warm. This is because the energy that is absorbed is then released as heat, warming the air around it. (Chung 2012).

By the middle of the twenty-first century, the effects of interactions between climate change, the urban heat island effect, and air pollution are predicted to make it more likely that people will experience poor health in urban areas around the world (Kumar, 2021). Urban dwellers experience high levels of thermal stress due to the UHI effect, and those who live in polluted areas may experience respiratory problems, heat stroke, and skin diseases. When these two effects combine, however, vulnerable urban dwellers experience more environmental pressures, which may worsen their physical discomfort (Yuanyuan et al.,2021).

Additionally, heat waves have the capability to deteriorate the building components, and it is reported that by 2050, intense and recurrent heat waves will be occurring in most cities around the globe (O'Neill and Ebi, 2009).

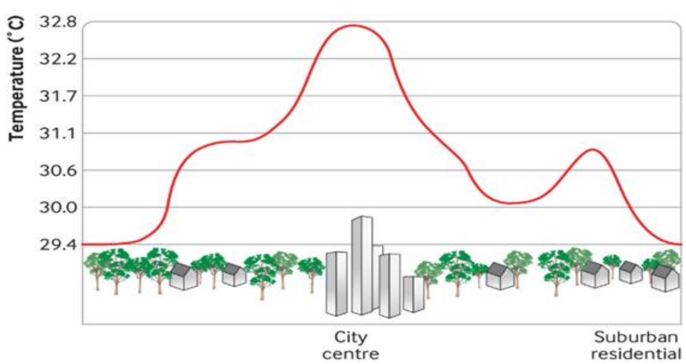

Fig 1: Illustrative profile of UHI in city and suburban areas (Tong et al., 2021).

In Fig 2, the study conducted by Tong et al., (2021) demonstrates that the temperature in the city of London center is 32.8 degree Celsius and the sub-urban residential area temperature is around two degrees less than the city centre with a temperature of 30.8 degree Celsius as it has more vegetation. The sub residential areas had more street trees. These trees provide shading effect and cools the air through evapotranspiration in plants thus reducing surrounding temperature (i.e, solar energy is converted to latent rather than sensible heat) in every city, and the characteristics of the heat island effect are heavily influenced by the regional climate in which the city is situated (Chakraborty & Lee 2019), as well as the size of the design of the city itself (Laden et al., 2022).

Researchers have found that green spaces can significantly reduce the effects of climate change-induced heat waves. Practising UA can create cities that are environmentally resilient. Vertical farming, community gardens, hydroponics and aquaponics are some easy and cost-effective methods UA methods that can be practised in cities (Laden et al., 2022). Increasing the quantity of land used for urban agriculture has several benefits in addition to perhaps being a successful urban heat island mitigation approach. It has social benefits because it fosters community and re-connects people with food production and the environment by enabling them to establish local and self-sufficient food systems. The substantial increase in consumer demand for organic goods creates considerable price premiums and profitable investment opportunities for manufacturers. Urban gardens are located close to consumers and within urban areas, which reduces the harmful environmental consequences related to transportation.

According to estimates, more than one- third of the waste that is dumped in municipal landfills is made up of food waste, including food packaging (Pothukuchi & Kaufman 2000). Due to short transit distances and the potential to compost food waste for urban agricultural output, a large portion of this garbage might be kept out of landfills. Also, by increasing the quantity of pervious surface in the city and protecting open space by converting them to green space, it will reduce the effects of noise and air pollution in cities. (Smith & Nasr 1992).

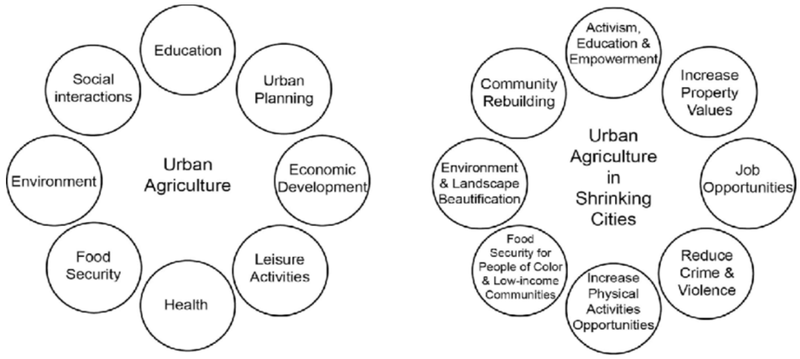

Fig 2: Various social, ecological, and economical benefits of UA (Paddeu 2017).

1. HEAT ISLAND EFFECT

UHI is acknowledged as being the most overt aspect of metropolitan climate (Yang et al. 2016). Once covered with natural vegetation, areas are cleared to build cities and accommodate the needs of the growing human population thus generating adverse heat effects.

The isotherm patterns of near-surface air temperatures resemble the outlines of an island, and these patterns are used to define the heat island based on temperature disparities between urban and rural areas (Roth 2012). Surface urban heat islands and air temperature urban heat islands are the two UHI forms that are most frequently evaluated as both demonstrate the temperature difference between surface land (ground) and air temperature by which UHI can be assessed. The temperature rise can be assessed at ground level as a result of solar radiation absorption and reflection as well as warm stagnant air is observed in the atmosphere due to urban canyons (i.e., rows of building creating long channels over roadways) by which air temperature UHI can be observed.

Elevated temperatures that are observed on urban surfaces, including roadways, walkways, and building envelopes, are known as surface UHIs (Hayes et al., 2022). The thermal properties of urban surfaces above the structure are significantly influenced by SUHI. It is important to note that a sizeable portion of solar radiation, which typically consists of 43% of light, 52% near-infrared light, and 5% ultraviolet light, is absorbed by asphalt surfaces (Golden & Kaloush 2006; Mohajerani et al., 2017) which is a major component of road infrastructures in the cities.

Radiant heat at night is mainly emitted by anthropogenic structures and daytime heat that has been stored. Although the expansion of SUHIs is frequently linked to urban sprawl and rising industrial and human activity, its formation is also significantly influenced by factors such as geographic location, meteorological conditions, urban materials, seasons, and time of day and night (Haashemi et al., 2016). SUHIs can occur at any time of day, although during the summer they are most severe 3-4 hours before sunset as the sun is low enough in the sky. While surface UHIs typically differ most in their patterns during the day, air temperature UHIs are typically greater and show the most spatial variation at night. (Buyantuyev and Wu 2010).

Albedo is the amount of reflectivity, materials with higher albedo reflect more shortwave and store less longwave energy and materials with low albedo retains more heat and causes thermal discomfort. While air temperature is the term used to describe the elevated ambient temperatures that are present in metropolitan areas because of the release of thermal energy from anthropogenic sources such as air conditioning, vehicles, etc. (Hayes et al., 2022). The most crucial component in determining the daytime and night temperature of a city is the surface albedo (Kolokotroni & Giridharan 2008), that is further discussed in the section 2.

2. CAUSES OF URBAN HEAT ISLAND EFFECT

The main causes of the heat island effect are the increase of concrete and other, heat-absorbing surfaces (pavement surfaces), the structural density of modern cities (Urban topography), and urban sprawl. All these factors occupy a large area of space and vegetation is being cleared in cities and thus interrupting the healthy ecological interaction with vegetation and environment. (Mohajerani et al., 2017). The materials of man-made structures in cities have characteristics such as reduced urban albedo, increased thermal mass per area, increasing city roughness, greater anthropogenic heat produced from buildings and cars, and reduced evaporative areas. This increases the UHI in cities (Ryu & Baik 2012). Urban materials absorb and hold more solar radiation than rural soils and vegetation because they have a higher heat capacity. Under optimum weather conditions, the heat island intensity fluctuates in a noticeable manner throughout the day. In contrast to rural surfaces, which lose heat quickly at night, urban surfaces release their stored heat slowly. As a result, many hours after sunset, when rural surfaces have cooled but urban surfaces are still warm, the intensity of the urban heat island rises (Shahmohammadi et al., 2010).

2.1 Heat-Absorbing Surfaces (Pavements):

Pavements significantly contribute to the UHI. This is caused by two factors: the dark pavement surface's relatively low albedo (Mohajerani et al., 2017) and the huge geographic area of pavements in modern cities. These surfaces absorb more solar energy, thus causing increased heat in the area (Santamouris 2013). The temperature profile of pavements is determined by physical characteristics, including the material used, surface texture, and colour of the pavements, as well as interactive thermal properties of pavement materials like thermal conductivity, heat capacity, albedo, thermal emissivity, capacitance, and permeability. Although concrete and cement directly raise UHI, they are the most often used raw materials in pavement construction because of their dependability, adaptability, and affordability (Senevirathne et al., 2021).

Albedo or reflectivity is a measure of how much solar radiation the Earth's surface reflects and absorbs, is a key factor in controlling the Earth's surface temperature and climate (Kumar et al., 2021). Variations in a city's albedo can be attributed to a number of things, including surface orientation heterogeneity, the materials used for the pavement and rooftops, and more (Nuruzzaman 2015).

The surface of conventional impermeable pavements is dark, and they have a high heat inertia. They often absorb and retain solar energy throughout the summer but counteract evaporative cooling, which aids in the buildup of UHI (Qin 2015). Depending on how its surfaces are arranged, a city's albedo can directly affect its microclimate development. Low-albedo urban surfaces will store more solar energy and be more heterogeneous in their orientation and choice of materials for pavements, rooftops, and other surfaces. Low urban surface albedo will result in the development of a microclimate with an elevated urban temperature (Nuruzzaman 2015).

The solar reflectance of common pavement materials like asphalt and concrete ranges from 5 to 40% (Wijeyesekera et al., 2012). This implies that they absorb between 95% and 60% of the solar energy that is directed at them. This leads to an increase in temperature through emission from pavements. New asphalt concrete has an albedo of 5%, which means that it absorbs about 95% of sunlight.

In comparison to other surfaces with lighter colours, asphalt pavements and other black pavements reflect less heat and absorb more heat. According to the study done by Senevirathne et al., 2021 pavement has the ability to retain high temperature for a long time and its ability to reach very high temperatures. In summer time, conventional pavements can heat up to 48 degrees Celsius to 67 degree Celsius (EPA n.d). The reason is that black colour has the potential to absorb all the wavelengths within the visible light range. The amount of energy the pavement will store depends on its thickness. Those that are thicker will store more heat than those that are thinner (Wijeyesekera et al., 2012).

According to the research conducted by Akbari et al., (2009), approximately 40% of today's urban settings in cities are covered in pavement, and pavements are potent emitters of heat radiation, as demonstrated by numerous studies using mesoscale imaging from satellites of infrared and thermal activities in cities. One such study was done by observing and assessing surface UHI data from eight different big cities in Asia by using thermal remote sensing at 1km resolution and it was found that satellite-based surface UHIs are observed higher in the day-time with a maximum in areas of large buildings or paved surfaces (Tran et al., 2006). Akbari et al., (2009) state that roof surfaces and pavements together constitute nearly 60% of the urban surfaces. These structures together with other man-made structures is the main component of modern cities and urbanization.

2.2 Structural Density of Modern Cities

The physical and spatial characteristics of urban areas, such as building height, floor area ratio, and population density, are referred to as the structural density of cities. It is a way to assess how densely and intensively land is used in a city, and it has an impact on a number of urban phenomena like the UHI (Hien et al., 2011). The word "urban canyon" refers to the network of streets and alleys that are encircled by the walls, roofs, and buildings that constitute an urban setting. The intersection of the roadways and the buildings results in structures that resemble canyons and are frequently reflected (Shahmohammadi et al., 2010). Within these canyons, numerous structures and street surfaces not only absorb and re-emit radiation but also produce infrared radiation. Buildings cover a portion of view of sky with considerably warmer surfaces (buildings), which absorb a significant proportion of the infrared heat released from the ground and radiate even more of it back into space. The amount of radiation that reaches street level and escapes back into the atmosphere will vary depending on the geometry of an urban canyon (Santamouris 2015). Tall buildings and winding streets create an urban canyon that traps heat and restricts airflow.

The most significant human-made factor affecting the properties of wind flow through an urban zone is urban geometry (Mohajerani et al., 2017). By increasing the friction caused by rough urban surface, horizontal airflow is reduced in the city, the complex geometry of urban surfaces raises the air temperature. Without air circulation, warm air stagnates in urban canyons. In cities with lower wind speeds, evaporative cooling is also hindered.

Second, the intricate geometry of the urban surface radiation. Vertical canyon walls capture short-wave radiation during the day. Due to the reduced sky view, infrared energy losses at night are also delayed. As opposed to complicated urban surfaces, rural surfaces are smoother and hence undergo more nocturnal radiative flux divergence (Shahmohamadi et al., 2010).

A more noticeable UHI effect can result from urban canyons' tendency to retain energy and result in a greater temperature at night. Open built-up regions get more direct solar energy and are subject to more unfavourable temperature conditions. Hence, when evaluating the effects of regional climate conditions on the canopy layer UHI, the urban morphology has a substantial impact on the urban microclimate (Liu et al., 2020). As more areas built up in cities and its boundaries, long- term and short-term patterns of temperature variations can be observed (Singh and Kalota 2019).

2.3 Urban Sprawl

Urban sprawl was defined by Basawaraja et al. (2011), as the process of unplanned urban growth, unequal utilisation, and growth in built-up regions along urban and rural edges. The existence of urban heat islands has been identified in the built-up areas of Ludhiana city, where more and more expansion has been noted towards its southeastern regions, according to a study done in the city of Ludhiana in India. Pollution is produced as a result of industrial development and a growth in the number of vehicles, which exacerbates the effects of temperature (Singh and Kalota 2019).

Air pollution and the UHI effect are the two most noticeable environmental issues because of the high increase in urban population, which has also caused a significant shift in the urban land cover and a sharp rise in energy consumption Sprawl creates car-dependent neighborhoods which are known to have an impact on air quality given the emission of carbon (Ciu et al., 2016).

Future difficulties to sustainable development will be faced by cities, especially those in nations that are developing. Despite occupying less than 2% of the planet's area, cities consume 78% of the world's energy, and more than 60% of the greenhouse gas emissions are produced there. Additionally, this has increased the degree and frequency of extreme high-temperature weather as well as the trend of global warming. Physical, social, neighbourhood, land-use regulation, and urban planning elements all have an impact on urban expansion, and their effects vary depending on the location and the development process (Chen et al., 2020).

3. URBAN AGRICULTURE

One of the effective measures that can mitigate UHI is urban agriculture (UA). Plants can reduce the ambient air temperature in the cities, thus cooling the area (Eom et al., 2012). There have been severe changes in temperature which affect human comfort as well as raised environmental concerns due to UHI, and this is mainly due to the lack of green spaces in urban settings.

Prior to the industrial revolution, all agriculture was local due to the impossibility of transporting food over larger distances, which forced the confinement of production to the fringes of cities. Agriculture was purposefully separated from cities during the 19th and 20th centuries while societies pursued industrialization, urbanization, and 'progress'; urban agriculture was at best ignored and more frequently outlawed and suppressed (Mougeot 1994). This may be due to the belief that agriculture is incompatible with the contemporary urban lifestyle and that nature must somehow be subdued for modern cities to function. This change was not viewed as significant because a wide range of foods were still offered at reasonable costs even though nearby agriculture was diminishing. But the shift to a worldwide industrial food system has had enormous and far-reaching long-term effects. It can be argued that the current food system contributes to health issues, environmental degradation, social inequity, international conflict, and now perhaps most importantly climate change (Mougeot 1994).

It is reported that cities with higher population density and per capita GDP have higher NO2 pollution concentrations, while cities closer to the ocean, with higher vegetation coverage and higher elevation, have lower air pollutant concentrations (Yuanyuan et al.,2021). Takebayashi and Moriyama (2012) evaluated the properties of asphalt concrete pavements and grass surfaces and showed that the average daily temperature of AC pavements is up to 20 °C higher than the grass surface. This substantial rise has a negative impact on the environment. Moreover, the lack of green spaces in urban dwellings has significantly affected normal ecosystem functions such as water and air filtration, cooling, evapotranspiration etc. Urban farming frequently use water more efficiently as it will be in very limited supply in cities which leads to the wise use of natural resources (Laden et al., 2022).

In order to lessen the severity of the problem in the first place and increase the effectiveness of the adaptation measures, a strong climate change adaptation strategy must also include a mitigation component. Urban agriculture may influence temperatures in many ways due to differing moisture (evapotranspiration), aerodynamic, and thermal qualities of vegetation and urban materials (Eom et al., 2012). By enhancing the overall chemical processes that produce ground-level ozone, UHI may be a key factor in the increased ozone levels. Ozone layer captures infrared rays emitted from the ground surfaces and increases heat in the troposphere. When the air temperature rises above 90 degrees, sunlight and intense heat can photochemically heat up the ozone and causes its depletion. But by effective implementation and management of urban infrastructures, and according to scientists, these levels can be maintained at a level which is not harmful to humans and the environment that could improve ozone layer as vegetation could tackle green house gas emissions to some extent (Maurice et al., 2003).

Temperature drops of up to 2°C were seen in some parts of a regional simulation model using 50% green spaces covering evenly dispersed throughout Toronto (Bass et al. 2002). By tackling the transportation problem, changing the production and waste management methods now used, and addressing the areas that are biologically productive as well as acting as carbon sinks, UA has the potential to make a significant difference in mitigating climate change. The concepts related to urban agriculture include city farming, edible urban landscapes, and productive planting.

4. TYPES OF URBAN AGRICULTURE

About 20–25% of the urban surface is made up of roofs. Their conversion to green spaces could result in numerous advantages for the city, including improvements to UHI, air quality, storm-water management, biodiversity, and urban amenities (Susca et al., 2011). In cities, lowering the surface temperature of rooftops may be crucial to improving the microclimate of the region.

This objective can be achieved by replacing conventional roof surfaces with spaces that offer much lower summertime temperatures to improve their thermal performance and lessen solar radiation absorption (Akbari et al., 2015) and one way to do this is through practising rooftop gardening which is the farming practice done on the very top level of commercial, industrial, and residential structures (Wong et al., 2003). Through this, buildings are protected from solar radiation by vegetation, thus preventing solar radiation absorption by the buildings. The building beneath them will therefore be cooler as a result.

A rooftop garden with 6% vegetation coverage can result in a reduction of 1 to 2°C (Susca et al., 2011). They improve evapotranspiration, minimize heat convection to the air above, and as a result, use less energy for cooling.

In addition, the plants in the rooftop garden take up carbon from local infrastructure emissions and use it as a fuel for photosynthesis, thus combating climate change on a larger scale. The plants lower air pollution by eliminating particulate matter and polluting gases like carbon monoxide, nitrogen oxides, and sulphur dioxide. Plants absorb carbon from the atmosphere and use it for photosynthesis and evapotranspiration which is the release of water from a plant as a vapour into the atmosphere, is a significant factor that contributes to cooling effect.

Similar to rooftop gardening, vertical farming is a UA method that can be practised on rooftops at small-scale and large-scale levels. It is a method where plants are stacked in different layers and each plant has its own plot thus reducing competition for resources. The most cost-effective and easy types of vertical farming include hydroponics and aeroponics (Garg and Balodi 2014). Hydroponics is a system where plants use water nutrient solution rather than soil as a growing medium and it will make rational use of water. It is possible to grow vegetables hydroponically both outdoors and indoors. It is found that the hydroponic system on an external vertical wall in buildings reduces the total energy consumption used by up to 23 % and reduces the air conditioning consumption by up to 20 % (Birkby 2016) Aeroponics is the method of growing plants without using soil or a substrate culture. where there is artificial support helping the plant grow in the air and no soil or substrate is needed to support the plant and this can be done in places with limited space (Lakhiar et al., 2018).

Another type of UA that can improve microclimate and UHI in cities is community gardening. Community gardens are areas of land where people living in cities grow food and have limited access to their own property to grow food as each plot is allocated to an individual or group of people. Community gardens are bottom-up, community-based, cooperative initiatives to grow food, as opposed to top-down attempts by government groups to establish green spaces (Okvat and Zautra 2011). By carbon sequestration, community gardening could help in the effort to moderate climate change. When plants absorb CO_2, they separate the carbon from the oxygen. As the carbon is absorbed in the soil and released as oxygen, soil fertility is increased, and atmospheric carbon is decreased (Armstrong 2000). One of the key strategies for reducing greenhouse gas emissions, according to the Intergovernmental Panel on Climate Change, is the sequestration of carbon in soils (Okvat and Zautra 2011). By doing this, the effects of emissions from anthropogenic sources can be reduced, which will enhance the microclimate in cities.

Fresh food can be produced near to the city through urban gardening techniques, which saves energy on transportation, cooling, storage, and packaging. Additionally, since urban wastewater can be used in urban agriculture, it enables the productive reuse of organic wastes, which lowers greenhouse gas emissions from wastewater treatment and landfill methane emissions. It also makes fresh water available for higher-value uses and reduces energy use in the production of fertilizers (Dubbeling et al., 2019).

5. CASE STUDY

Fig 3: View of Thunder Bay International Airport from google earth pro with classified mowed, concrete, and vegetated areas.

The Thunder Bay International airport is situated on the downtown side of the city which is a developed area with lots of residential, commercial, and industrial buildings. The land cover of 2802357m^2 within a 1km radius of the airport was assessed with the help of Google Earth Pro. The lands were classified into concrete, vegetation, and mowed lands. The mowed land constitutes 50% of the land, vegetation constitutes 15.99% and 33.63% concreted and developed areas of around 7% (houses, trees, and streetways).

From the weather temperature data, the maximum temperature here recorded for the month of July 2019 was 34 degrees Celsius and the lowest recorded was 19.5 degree Celsius. When compared to the previous 2018 weather data, an increase in the microclimate of the region has been noted. There is very less green space and more developed structures are occupying this area because of urbanization. The mowed land has grasses and soil, and the concrete areas have low albedo which creates a rise in temperature in the region. Since the airport area doesn't support the growth of trees with large canopies in the area as it could block the pilot's view on the ground, it is advised that gardens could be maintained at the side of the main entrance and a vertical greenery system can also be practised.

In the area, there are approximately 40 houses. People can practise rooftop gardening or community gardening and providing them with seedlings for suitable plants like lettuce, tomato, strawberries etc and giving them incentives to start this could raise their interest in this matter.

According to Skelhorn et al., adding 5% more green space with new shrubs or trees shaded the ground, lowered the temperature by about 0.5 °C. It is recommended that shrub trees be planted because they can create a cooler environment than grass can, and because shrubs can lower the temperature of the soil's surface.

When planning cities, areas that can be effective places for practising UA should be identified and proper instructions and incentives should be given to people so that people become more proficient and responsible to practise UA. It will also be useful to monitor the native species in the area as they can adapt more to changing local conditions.

When relating to the general topography of Thunder Bay, the area where the airport is located is an industrial area. Most of the lands are open space with very little vegetation. Thunder Bay is a city that is facing urban sprawl as there are lot of immigrants choosing Thunder Bay because of its scenic beauty, job opportunities and educational institutions. Urbanization to some extent is a foreseeable factor of the city. It will be necessary to include more green spaces in the city in order to balance the effects on temperature.

CONCLUSION

The location of the city, together with the topography and regional climate traits, all affect how urban agriculture affects the UHI. Therefore, city planners should consider all these factors when planning to develop resilient cities towards the effects of climate change. Urban agriculture can contribute to the comfort of residents by enhancing the macroclimate if it is properly designed and incorporated into urban architecture. Green areas around apartment buildings and homes, as well as unused areas of the city, contribute to a more favourable physical environment because the vegetation can lower temperatures, enhance humidity, break wind, and block solar radiation, thereby providing shades and natural areas. There are several more methods for reducing the heat island, including raising the city's albedo, adding more shading both artificial and natural, like by growing trees), preserving current vegetation, and creating ventilation channels to maintain temperature balance. It would be wise to pick drought-tolerant types for additional planting, yet it is crucial that enough water be made available to facilitate evapotranspiration. Including all these considerations when city planning and developing appropriate policies will help in maintaining climatic conditions and could also help to give comfort to the human population in urban settings.

LITERATURE CITED

Akbari, H., Menon, S., & Rosenfeld, A. 2009. Global cooling: increasing world-wide urban albedos to offset CO2. Climatic change, 94(3), 275-286.

Armstrong, D. 2000. A survey of community gardens in upstate New York: Implications for health promotion and community development. Health & place, 6(4), 319-327.

Audate, P. P., Fernandez, M. A., Cloutier, G., & Lebel, A. 2019. Scoping review of the impacts of urban agriculture on the determinants of health. BMC Public Health, 19, 1-14.

Basawaraja, R., Chari, K. B., Mise, S. R., & Chetti, S. B. 2011. Analysis of the impact of urban sprawl in altering the land-use, land-cover pattern of Raichur City, India, using geospatial technologies. Journal of Geography and Regional Planning, 4(8), 455.

Bass, B., Krayenhoff, E. S., Martilli, A., Stull, R. B., & Auld, H. 2003. The impact of green roofs on Toronto's urban heat island. Pp 1.

Birkby, J. 2016. Vertical farming. ATTRA sustainable agriculture, 2, 1-12.

Buyantuyev, A., & Wu, J. 2010. Urban heat islands and landscape heterogeneity: linking spatiotemporal variations in surface temperatures to land-cover and socioeconomic patterns. Landscape ecology, 25, 17-33.

Chakraborty. T, Lee, X. 2019. A simplified urban-extent algorithm to characterize surface urban heat islands on a global scale and examine vegetation control on their spatiotemporal variability. International Journal of Applied Earth Observation and Geoinformation. Vol 74. 269-280.

Chung, C. E.2012. Aerosol direct radiative forcing: a review. Atmospheric aerosols—regional characteristics—chemistry and physics, 379-394.

Chen, M., Zhou, Y., Hu, M., & Zhou, Y. (2020). Influence of urban scale and urban expansion on the urban heat island effect in metropolitan areas: Case study of Beijing–Tianjin–Hebei urban agglomeration. Remote Sensing, 12(21), 3491.

Currie, B. A., Bass, B. 2008. Estimates of air pollution, mitigation with green plants and green roofs using the UFORE model. Urban Ecosystem, 409-422.

Dubbeling, M., van Veenhuizen, R., & Halliday, J. 2019. Urban agriculture as a climate change and disaster risk reduction strategy. Field Actions Science Reports. The Journal of Field Actions, (Special Issue 20), 32-39.

[EPA] United Nations Environmental Protection Agency. Using cool pavements to reduce heat islands.

Hien, W. N., Kardinal Jusuf, S., Samsudin, R., Eliza, A., & Ignatius, M. 2011. A climatic responsive urban planning model for high density city: Singapore's commercial district. International Journal of Sustainable Building Technology and Urban Development, 2(4), 323-330.

Eom, K. C., Jung, P. K., Park, S. H., Yoo, S. Y., & Kim, T. W. 2012. Evaluation of the Effect of Urban- agriculture on Urban Heat Island Mitigation. Korean Journal of Soil Science and Fertilizer, 45(5), 848-852.

Garg, A., & Balodi, R. 2014. Recent trends in agriculture: vertical farming and organic farming. Adv Plants Agric Res, 1(4), 00023.

Gronlund, C. J., Sullivan, K. P., Kefelegn, Y., Cameron, L., & O'Neill, M. S. 2018. Climate change and temperature extremes: A review of heat-and cold-related morbidity and mortality concerns of municipalities. Maturitas, 114, 54-59.

Haashemi, S., Weng, Q., Darvishi, A., & Alavipanah, S. K. 2016. Seasonal variations of the surface urban heat island in a semi-arid city. Remote Sensing, 8(4), 352.

Hayes, A. T., Jandaghian, Z., Lacasse, M. A., Gaur, A., Lu, H., Laouadi, A., GE. H., & Wang, L. 2022. Nature-Based Solution to Mitigate Urban Heat Island (UHI) Effects in Canadian Cities. Buildings, 12(7), 925.

Heaviside, C., Macintyre, H., & Vardoulakis, S. 2017. The urban heat island: implications for health in a changing environment. Current environmental health reports, 4(3), 296-305.

Jelle, B. P. 2013. Solar radiation glazing factors for window panes, glass structures and electrochromic windows in buildings—Measurement and calculation. Solar Energy Materials and Solar Cells, 116, 291-323.

Kakoniti, A., Georgiou, G., Marakkos, K., Kumar, P., & Neophytou, M. K. A. 2016. The role of materials selection in the urban heat island effect in dry mid-latitude climates. Environmental fluid mechanics, 16, 347-371.

Kumar N.K. H., M. Murali, H.V. Girish, S. Chandrashekar, K.N. Amruthesh, M.Y. Sreenivasa, Shobha Jagannath. 2021. Impact of climate change on biodiversity and shift in major biomes. Editor(s): Suruchi Singh, Pardeep Singh, S. Rangabhashiyam, K.K. Srivastava, Global Climate Change. Elsevier. Pages 33-44, ISBN 9780128229286.

Kolokotroni, M., & Giridharan, R. 2008. Urban heat island intensity in London: An investigation of the impact of physical characteristics on changes in outdoor air temperature during summer. Solar energy, 82(11), 986-998.

Ladan, T. A., Ibrahim, M. H., Ali, S. S. B. S., & Saputra, A. 2022. A geographical review of urban farming and urban heat island in developing countries. IOP Conference Series. Earth and Environmental Science, 986(1), 12071.

Lakhiar, I. A., Gao, J., Syed, T. N., Chandio, F. A., & Buttar, N. A. 2018. Modern plant cultivation technologies in agriculture under controlled environment: A review on aeroponics. Journal of plant interactions, 13(1), 338-352.

Liu, Y., Li, Q., Yang, L., Mu, K., Zhang, M., & Liu, J. 2020. Urban heat island effects of various urban morphologies under regional climate conditions. Science of the total environment, 743, 140589.

Maurice. E. J, Maurice. G & Dale. Q & Elizabeth.S. 2003. The Urban Heat Island Phenomenon: How Its Effects Can Influence Environmental Decision Making in Your Community. Pp 10.

Mohajerani. A, J. Bakaric, T.J. Bailey. 2017. The urban heat island effect, its causes, and mitigation, with reference to the thermal properties of asphalt concrete. Journal of Environmental Management.197. 522-538.

Mougeot, L. J. A. 1994. Urban food production: evolution, official support and significance. Cities Feeding People Report 8. Ottawa, International Development Research Centre.

Nuruzzaman, M. 2015. Urban heat island: causes, effects and mitigation measures-a review. International Journal of Environmental Monitoring and Analysis, 3(2), 67-73.

Nugent, R. A.1999. Measuring the sustainability of urban agriculture. For hunger-proof cities. Sustainable urban food systems, 95-99.

Okvat, H. A., & Zautra, A. J. 2011. Community gardening: A parsimonious path to individual, community, and environmental resilience. American journal of community psychology, 47, 374-387.

O'Neill, M. S, Ebi, KL. 2009. Temperature extremes and health: impacts of climate variability and change in the United States. Journal of occupational and environmental medicine. 51(1):13-25.

Paddeu, Flaminia.2017. Legalising urban agriculture in Detroit: A contested way of planning for decline. Town Planning Review. 88. 109-129.

Pothukuchi, K., & Kaufman, J. L. 2000. The food system: A stranger to the planning field. Journal of the American planning association, 66(2), 113-124.

Qin. Y. 2015. A review on the development of cool pavements to mitigate urban heat island effect. Renewable and Sustainable Energy Reviews. 52. 445-459.

Roth, M. 2012. Urban Heat Islands. In Handbook of Environmental Fluid Dynamics. CRC press Vol 2. Pp. 162-181.

Ryu, Y.-H., & Baik, J.-J. 2012. Quantitative Analysis of Factors Contributing to Urban Heat Island Intensity. Journal of Applied Meteorology and Climatology, 51(5), 842–854.

Santamouris, M. 2013. Using cool pavements as a mitigation strategy to fight urban heat island—A review of the actual developments. Renewable and Sustainable Energy Reviews, 26, 224-240.

Santamouris, M. 2015. Analyzing the heat island magnitude and characteristics in one hundred Asian and Australian cities and regions. Science of the Total Environment, 512, 582-598.

Santos. R.M, Bakhshoodeh. R. 2021. Climate change/global warming/climate emergency versus general climate research: comparative bibliometric trends of publications. Heliyon. 7 (11).

Shahidan, M. 2011. The potential optimum cooling effect of vegetation with ground surface physical properties modification in mitigating the urban heat island effect in Malaysia (Doctoral dissertation, Cardiff University).

Shahmohamadi, P., Che-Ani, A. I., Ramly, A., Maulud, K. N. A., & Mohd-Nor, M. F. I. 2010. Reducing urban heat island effects: A systematic review to achieve energy consumption balance. International Journal of Physical Sciences, 5(6), 626-636.

Singh, R., & Kalota, D. 2019. Urban sprawl and its impact on generation of urban heat island: A case study of Ludhiana city. Journal of the Indian society of remote sensing, 47(9), 1567-1576.

Skelhorn, C., Lindley, S., & Levermore, G. 2014. The impact of vegetation types on air and surface temperatures in a temperate city: A fine scale assessment in Manchester, UK. Landscape and Urban Planning, 121, 129-140.

Smit, J., & Nasr, J.1992. Urban agriculture for sustainable cities: using wastes and idle land and water bodies as resources. Environment and urbanization, 4(2), 141-152.

Stocker, T. (Ed.). 2014. Climate change 2013: the physical science basis: Working Group I contribution to the Fifth assessment report of the Intergovernmental Panel on Climate Change. Cambridge university press.

Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley. 2013.IPCC. "Summary for policymakers," in Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, eds. Cambridge, New York, NY: Cambridge University Press.

Susca, T., Gaffin, S. R., & Dell'Osso, G. R. 2011. Positive effects of vegetation: Urban heat island and green roofs. Environmental pollution, 159(8-9), 2119-2126.

Takebayashi, H., & Moriyama, M. 2012. Study on surface heat budget of various pavements for urban heat island mitigation. Advances in Materials Science and Engineering, 2012.

Tian, L., Lu, J., Li, Y., Bu, D., Liao, Y., & Wang, J. 2021. Temporal characteristics of urban heat island and its response to heat waves and energy consumption in the mountainous Chongqing, China. Sustainable Cities and Society, 75, 103260.

Tong, S., Prior, J., McGregor, G., Shi, X., & Kinney, P. 2021. Urban heat: an increasing threat to global health. 375.

Tornaghi, C. 2014. Critical geography of urban agriculture. Progress in Human Geography, 38(4), 551-567.

Tran, H., Uchihama, D., Ochi, S., & Yasuoka, Y. 2006. Assessment with satellite data of the urban heat island effects in Asian mega cities. International journal of applied Earth observation and Geoinformation, 8(1), 34-48.

Wang, X., Dallimer, M., Scott, C. E., Shi, W., & Gao, J. 2021. Tree species richness and diversity predicts the magnitude of urban heat island mitigation effects of greenspaces. Science of The Total Environment, 770, 145211.

Wijeyesekera, D., Mohamad Nazari, N. A., Lim, S., Masirin, M., Zainorabidin, A., & Walsh, J. 2012. Investigation into the urban heat island effects from asphalt pavements. OIDA International Journal of Sustainable Development, 5(6), 97-118.

Wong N H, Chen Y, Ong C L, Sia A. 2003. Investigation of thermal benefits of rooftop garden in the tropical environment. Building and Environment, 38, 261-270.

Yang. L, Qian. F, Song. D.X, Zheng. K. J. 2016. Research on urban heat island effect. Procedia Engineering, 169. 11-18.

Yuanyuan Wang., Zhongyang Guo., Ji Han. 2021. The relationship between urban heat island and air pollutants and them with influencing factors in the Yangtze River Delta, China. Ecological Indicators. Vol 129. 107976.