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A Study of Influence of Blue Landscapes in Outdoor Air Temperature: Case of Traditional Ponds of Kathmandu Valley

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Abstract

Anthropogenic climate change attributes to global temperature rise of 2ºC since 19th century till date. Urban areas are the first ones to experience first effects of climate change. Urban areas create a unique microclimate effecting variables like temperature and wind causing effects like urban heat island(UHI) where urban dense areas are warmer than its outskirts due to replacement of green areas with urban development which is intensified by climate change. The influence of blue landscapes for cooling effect on urban microclimate can make a positive impact on its thermal comfort. This research focuses on quantifying thermal effect of traditional ponds as blue landscapes in core urban area of Kathmandu valley.The quantitative data of the temperature has been studied through temperature measurement of two sites. One of the sites being in vicinity of an urban pond while the other being a urban residential location.Temperature data of 40 consecutive days had been studied. The temperature data showed a significant diurnal cooling effect of water body compared to other urban location.

Keywords

Blue landscapes, Traditional Ponds, Urban cool island, Urban blue landscape

1. Introduction

According to UN, 55.3% of total worlds population is living in cities [1]. Along with growth in population, the demand for various infrastructures in urban areas is rapidly growing which subjects to unplanned urbanization. Urbanization is also bringing major changes in land use, most land covers are hard land covers and green spaces are declining rapidly. The natural surfaces are being replaced by impervious surfaces causing higher temperature in urban core areas than nearby rural areas [2]. Given the severity of future climate change projections, and the increased risk of related impacts such as heatwaves and flooding [3], greater emphasis must be placed on adapting urban areas to the changing climate [4]. Urban cities are getting more compact thus loosing its traditional public spaces to housing and infrastructural purposes. The resources are diminishing but the demand is ever growing.

Water bodies have been used as cooling landscape elements through out the world. Water bodies absorbs radiation and provides evaporative cooling providing oasis effect decreasing nearby surface air temperature [5]. The physical phenomena like heat exchange , evapotranspiration, wind flow related to urban environment are influenced by water bodies. Evaporative cooling has been researched as one of the most effective methods of passive cooling in urban spaces and buildings [6]. The cooling influence of water bodies in urban context create urban cooling island. It negates the thermal impacts of Urban heat island and climate change.

1.1 Study area

Kathmandu valley is situated in the hilly region of Nepal, it lies between latitude of 27°, 32’ 13” and 27° 49’ 10” North and longitude of 85° 11’ 31” and 85° 31’ 38” East and is located at a mean elevation of about 1300 meters (4265 feet) above sea level. It is located in the middle section of the Himalayan range and is surrounded by Phulchowki Hill in South West, Shivapuri in North, Champa Devi in South west and Nagarjuna in west. There are two narrow river gorges in the South-West and North-West edges.

The climate of the Kathmandu valley is sub-tropical warm temperate with maximum of 19°C to 35.6°C ambient temperature in summer. The temperature in winter ranges between 2°C-20°C [7]. The average rainfall is 1400 mm where more than 80% rain fall occurs during June to August. Kathmandu has three main seasons : winter lies in the month of November to February; summer lies in the month of March to May; and rainy season during June to October [7]. The general wind direction is from South West to North East and exit through South East Sanga Hill.

Kathmandu is the city with highest population density in Nepal. It has the estimated population of 2.18 million with an annual growth rate of 5.2% [8].The city has expanded as much as 412%, with the majority of land converted from agricultural land, which has changed the valley's landscape considerably [9]. Various researches show a increasing temperature trend in Kathmandu valley. Temperature trends in the Kathmandu Valley based on data gathered from five weather stations from 1971-2011 indicates a continuous mean warming rate of 0.033°C per year, with the average maximum temperature increasing at 0.043°C per year and the minimum increasing at 0.02°C per year [10]Through the temperature increment trend in Kathmandu Valley it can be predicted that its impact can be severe if proper measures are not taken.

Traditional ponds built during Licchivi and Malla Periods [11]are scattered all over Kathmandu valley. These ponds are the integral part of ancient water supply system of the Kathmandu valley. Apart from its religious and recreational value these pond played a vital role in daily lives of the dwellers. These ponds collected storm water, recharged wells during dry seasons, cleaning and washing water, duck farming and animal husbandry [12]. For this research the thermal alteration made by Pimbahal Pond located in Lalitpur municipality as compared to settlement with similar urban characteristics on its surrounding shall be observed.

2. Objective

The main objective of this study is to quantify the thermal effect of traditional ponds as blue landscapes in core urban area of Kathmandu valley.

3. Literature Review

To improve urban climate, a number of policies have been recommended: higher albedo, more vegetation [13], or water bodies that favor the evaporative cooling [14]. Various studies have observed that water bodies is one of the most common ways of passive cooling. Water bodies are noted to be about the best absorbers of radiation. Four properties of water according to Oke, 1987 [15], which contribute to their cooler surface temperature are:

1. Penetration – since water allows short wave radiation transmission to considerable depths, energy absorption is diffused through a large volume;
2. Mixing – the existence of convection and mass transport by fluid motion also permits the heat gains/losses to be spread throughout a large volume;
3. Evaporation – unlimited water availability provides an efficient latent heat sink, and evaporative cooling tends to destabilize the surface layer and further enhance mixing; and
4. Thermal capacity – the thermal capacity of water is exceptionally large such that it requires about three times as much heat to raise a unit volume of water through the same temperature interval as most soil.

Previous studies have also found that the cooling effect of the blue-green space depends on the size, shape, connectivity, and complexity (composition and configuration) of the blue-green space, and the greenness of the green vegetation measured by the Normalized Difference Vegetation Index (NDVI) [16]. Study of Hathaway and Shaples [17]compared temperature of 12 locations close to a river with an urban location. Temperature variation of 0.25° C to 1.82° C was observed. Wong et al [6] conducted a study to have better understanding on the evaporative cooling performance of water bodies in humid climate and cooling ranged up to 1.8 ° C. Jin et. al. [18]'s research on effect of water body forms on microclimate of residential district using ENVI-met software for data stimulation. It was observed that centralized large water body was effective on regulating microclimate of residential district while scattered water can improve the uniformity of microclimate in the whole residential district. Zhang et. al. [19] studied Cooling Effect of Water Landscape in High-density Urban Built-up Area of Guangzhou, China. It was found that the high density built-up area around water bodies greatly increase the surrounding land surface temperature,resulting in stronger cooling intensity.

4. Research Methodology

There are various approaches to study cooling effect of water bodies on its surrounding. Field measurements , data from meteorological stations , land surface temperature from remote sensing devices or satellite imaging and model simulations are commonly used for retrieving temperature data. All of these methods have been used as per the requirement and reach of the researcher. For this research area of Pimbahal Pond in Lalitpur Municipality is being investigated compared to a residential area of Tapahiti 250 m away from the pond. This research is based of field measurements acquired over 40 day time period in two sites. The data samples were collected for twice a day i.e. 14.00 LST and 19:00 LST using calibrated thermometers. The data collected was then statically analyzed to determine correlation.

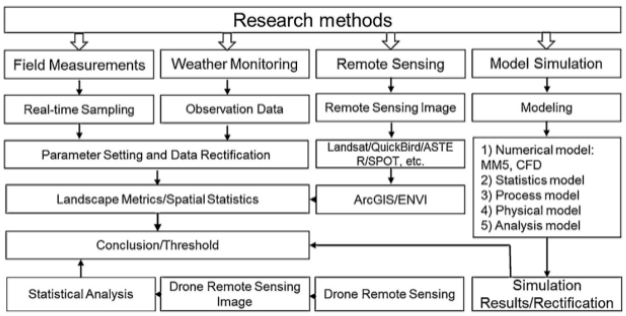

Figure 1: General Methods and techniques procedure of urban cooling effect studies

Among the given research methods the method of field measurement was used. However modifications were made in steps followed to reach the final output.

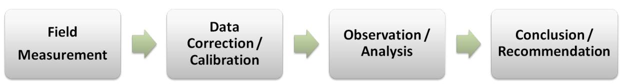

Figure 2: Modified research method

5. Data collection and observation

For collection of data two calibrated thermometers were placed in a louvered box selected sites. The apparatuses used for the measurement of temperatures at the two sites are Prana Air, C-AIR monitor and HTC-1. The Prana Air, C-Air monitor is placed at Pimbahal Pond and the HTC-1 is placed at the urban residential location at Tapahiti. The thermometer at Pimbahal was placed on a low balcony of a residential house and the thermometer at Tapahiti was placed on a small back yard of a residential house. To minimize inference of solar radiation and obtain accurate ambient air temperature and relative humidity the louvered box at height of 5 feet was used.

The field measurements were conducted during the period of 10 October 2020 to 18 November 2020 at two sites. Temperature reading at 14.00 LST and 19.00 LST was recorded during this time duration. The two sites represent similar urban characters with the difference being the presence of water body. Since the distance between both the sites is 250 m the variables like difference in weather conditions, variation speed of wind, direction of wind can be assumed as constant.

The temperature trends at Pimbahal and Tapahiti at 14.00 LST and 19.00 LST was compared as shown in Figure 3 and Figure 4 respectively. Since the temperature readings were taken in autumn season the temperature trend is seen to be decreasing as the valley was slowly getting closer to winter. Diurnal Temperature at Tapahiti is seen to be higher during 14.00 LST than Pimbahal from Figure 3. Significant cooling can be observed in the surrounding due to the presence of the Pimbahal Pond. Nocturnal temperature trend observed during 19.00 LST shows different temperature trend as seen in Figure 4. The temperature at Pimbahal is higher than that at Tapahiti. As per the literature the heat lost by air during the evening is balanced by heat lost by water causing rise in temperature during the evening in areas around the water body. This makes the surroundings with water body warmer as compared to areas without water bodies.

The average temperature of Pimbahal and Tapahiti at 14:00 LST was 26.02°C and 27.11°C . Difference of 1.09°C in the temperature of Pimbahal and Tapahiti was recorded. The cooling due to water body is observed.

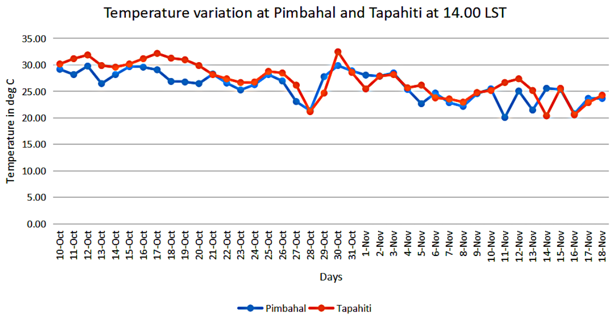

Figure 3: Daily temperature variation at Pimbahal and Tapahiti at 14:00 LST

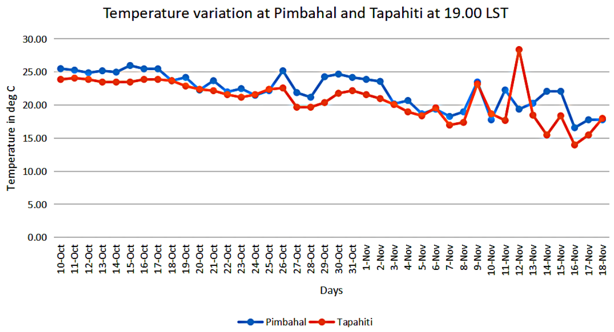

Figure 4: Daily temperature variation at Pimbahal and Tapahiti at 19:00 LST

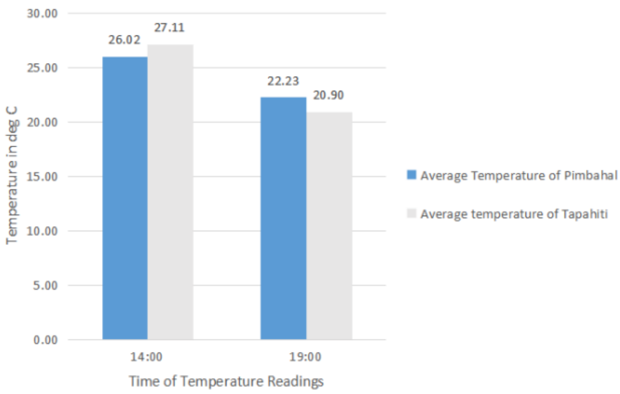

Figure 5: Average temperature readings of Pimbahal and Tapahiti at 14.00 LST and 19.00 LST.

During the evening the temperature trend observed differed from that during the day. The average temperature observed during the evening was at Pimbahal and Tapahiti was 22.23°C and 20.90°C respectively. As per the literature the heat lost by air during the evening is balanced by heat lost by water causing rise in temperature during the evening in areas around the water body. This makes the surroundings with water body warmer as compared to areas without water bodies.

6. Conclusion

Water bodies have different thermal characteristics as compared to air. Water bodies uses large amount of heat energy for vaporization cooling the air above it and the mixing of air cools its surrounding. The cooling from water bodies is significant closer to the water body.The cooling was observed more significant during hottest part of the day. During the day time it was observed that the water cooling island effect was 1.09°C. While during the evenings the surroundings of the water bodies was observed to be warmer. The latent heat of the water makes the surrounding of the water body warmer. The surrounding of water body was observed to be warmer by 1.33°C. Though the nocturnal temperature was warmer it was closer to the human comfort temperature during colder evenings as compared to areas farther from the water body.

7. Recommendation

As the study suggests some amount of diurnal cooling by water bodies in its surrounding it can be used as a means of passive cooling in future urban planning projects. Incorporating blue landscapes can provide more effective urban cooling. Effect of humidity on the apparent temperature should be studied for future researches.

8. Limitations

- Temperature recording was taken for only 40 days period.
- Due to limitation in time and resources the thermometers were placed only in two places.
- There were limited research studies on the topic.

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