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Augmenting Blue Land Uses: An adaptation approach for Climate Change in Urban Areas. A case study of Janakpur Municipalities, Nepal

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Abstract

Climate change has emerged as a major challenge to human kind in the 21st century and Nepal is no exception. The challenges are even more severe in the context of urban areas where most wealth and population is concentrated. Greening an area is a major strategy for adapting to climate change; however, with blue land use a major source of evaporation can act as another activity to aid the adaption to climate change, where ponds are traditionally present within a city but are often abandoned. The present research has been carried out in the city of Janakpur situated in the central southern flatland of Nepal along its Southern border with India. The research outlines the relation of blue land use and its cooling capacity in an urban area. The research adopts both qualitative and quantitative research methods, showing that blue land use does have positive a correlation with the cooling of the surrounding area. The research in Janakpur, a pond city with more than 200 ponds within the urban fabric reveals that during summer the houses along the ponds will experience temperatures 2 °C lower than houses situated more than 100 m away from the ponds.

1. Introduction

Climate change has emerged as a major challenge to human kind in the 21st century and Nepal is no exception. Although Nepal does not emit a high quantity of greenhouse gases compared to developed and industrialized economies, it is facing several consequences of climate change, where changes are also raising temperatures in the country. Over-dependency on the country's natural resources and unregulated use of ecosystem services with a growing population has led to food and water scarcity, increased pollution and poverty and reductions in habitat for wildlife and biodiversity. Within such circumstances climate change represents an additional stress which has multiple consequences, such as extreme climate events including floods, draughts, heat waves, cold streams, etc. The challenges are even more severe in the context of urban areas where most wealth and population is concentrated. Urban areas are among the most profoundly altered landscapes away from natural ecosystems and processes **[1]**. Urbanization and subsequent construction and land use changes disturb the ecological balance in cities. It is not surprising that cities have altered microclimates with, among other effects, significantly elevated surface and air temperatures. The elevation in temperatures is most generally explained in terms of the basic surface energy balance processes of shortwave and longwave radiation exchange, latent, sensible and conductive heat flows **[2]**.

Nepal does not have a long history of urbanization, though its urban population has increased from 3.6 % in 1961 to 17 % in 2011 **[3]**. The urban population growth rate was measured at 3.38 % in 2011, illustrating that it is one of the fastest urbanizing countries in the world. In 2014, the level of urbanization was 18.2 %, with an urban population of 5,130,000 within 58 municipalities, with a rate of urbanization of 3 % **[4]**. However, the share of the urban population has increased to 38.2 % within 217 municipalities in 2016. For the period 2016-2050, Nepal will remain amongst the top ten fastest urbanizing countries in the world, with a projected annual urbanization rate of 1.9 %. In Nepal, urban areas and their surroundings contribute to more than 60 % of the GDP **[5]**, illustrating that the higher level of concentration of health and wealth in cities of Nepal.

Data from 45 weather stations across Nepal for the period 1976-2005 indicate consistent warming in maximum temperatures at an annual rate of 0.04 °C/yr **[6]**. The warming seems to be consistent and continuous after the mid-1970s. The average warming in annual temperature between 1977 and 1994 was 0.06 ºC/yr **[7]**. The warming is found to be more pronounced in the high altitude regions of Nepal such as the Middle Mountains and the High Himalaya, while the warming is significantly lower or even lacking in the Terai and Siwalik regions (**Figure 1**).

Extraction of natural resources to meet the demands of an ever increasing population has led to increased environmental pollution, declining water quality and quantity, land pollution, and other environmental problems in the cities of Nepal **[8]**.

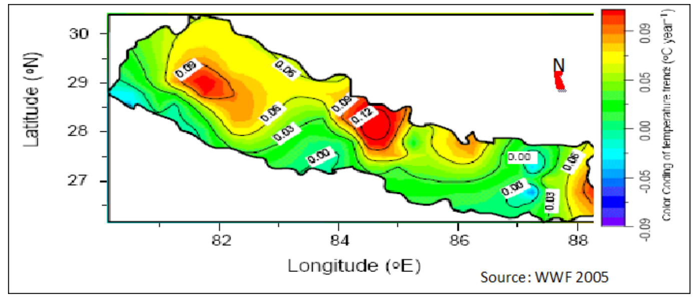

Figure 1: Spatial variation of annual mean temperature in Nepal 1976 – 2005 (°C/yr)

Within these circumstances, climate change represents an additional stress with multiple consequences such as extreme climate events including floods, draughts, heat waves, cold streams, etc. These events will further increase the stress on already stressed urban environments leading to degraded quality of life and of environment and increased exposure to risks.

Climate change has emerged as one of the greatest challenges to cities in the future. Most research prescribes incorporating urban green space to counter the rise in temperature and ensure against public health hazards. Urban blue spaces, defined as all surface waters within a city, are regarded as a possible factor for temperature mitigation **[9]**, but their effects have not been quantified and so they remain underrepresented in research, recommendations for action and in planning. In this context, the present study has been conceptualized to understand the implications of blue land uses and its possible policy outcome for adaptation to Climate Change.

2. Study Area

The Janakpur municipality houses 98,446 inhabitants **[10]** and is a medieval, historical and religious town with 59 ponds (excluding fish ponds) within its jurisdiction **[10]** under the responsibility of Ram Mandir (temple), Janaki Mandir Guthi. Guthi is an institution which manages the affairs of socio-cultural activities. It is a kind of trust created by act that manages the properties and activities of temples. Despite the disappearing and shrinking ponds with increasing population density, the city of Janakpur still has 3.8 percent of its total area within its jurisdiction under blue land use. This suggests that Janakpur is an ideal case to study the implications of blue land use within a city. With the changing climate, Janakpur is experiencing heat waves and extended droughts from very intense summers. The ponds in the city can have a cooling effect resulting in temperatures almost 1 to 2 °C lower than the surrounding settlements. The local perceptions confirm this statement. Besides adaptation to climate change, increased blue land use will add value to religious, socio-economic and recreational dimensions of the city. Janakpur Municipality, the pond city, is located in the Dhanusha district of Central Nepal about 24 km south of the East West highway and 20

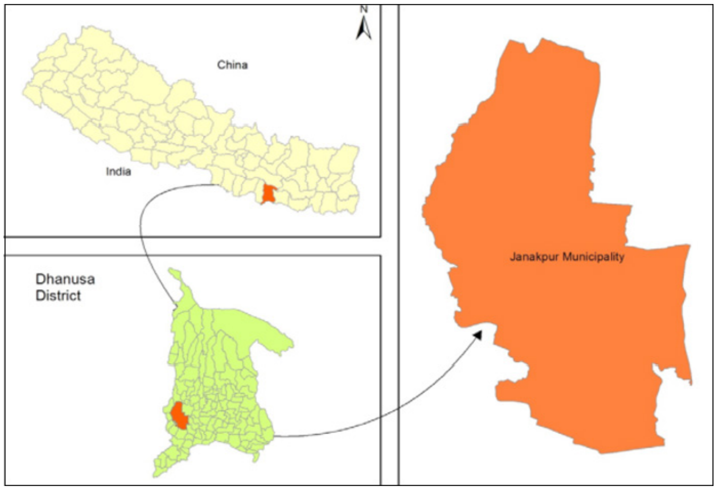

Figure 2: Location map of Janakpur Municipality (Map Source: Topographical Map 1992, Department of Survey).

km north of the Indian boarder. It is one of the oldest municipalities in Nepal established in 1962 A. D. The municipality covers an area of 26.9373 km^2 and lies between Latitudes 26°41'48" and 26°46'30" North and Longitudes 85°54'0" and 85°57'14" East, at an average elevation of 76 m MSL (max. elevation of 85 m and min. elevation of 67 m above MSL **[11]**.

On 24th November 2015, the minister of the council upgraded the Janakpur Municipality to a sub-metropolitan city encompassing the surrounding VDCs of Benga, Shivapur, Mahuwa, and Lohana in the East, Devpura, Rupaitha, and Basahiya in the South and Bindi, Basbiti and Kurtha in the West. The sub-metropolitan city comprises 15.4 % of the district population and 1.8 % of the national urban population. The population of the sub-metropolitan city has increased to 169,287 with estimated population density of 1700 per km^2 after the addition of the surrounding VDCs **[11]**.

However, the present study is confined to the Janakpur Municipal Area (**Figure 2**). According to the 2011 census there were 19,195 households in Janakpur with an average household size of 5.13. Total population of 98,446 was recorded in the national census of 2011 with 52,481 males and 45,965 females.

3. Methodology

This research is based on both primary and secondary information. The existing theories and literature are analyzed along with data from secondary sources to hypothesize and observe the phenomena at ground level and test its validity. The qualitative data collected from door to door and key informant surveys are triangulated. The methodology is comprised of sample design and data collection, data analysis and inference drawing. The findings from both qualitative and quantitative information analysis are discussed and logical links are established through argument.

The past data for 4 Terai towns situated at similar elevations with similar urban characteristics (Birgunj, Janakpur, Rajbiraj and Biratnagar) have been collected from DHM, however in the case of Rajbiraj too much data is missing, giving a misleading outcome, and it was therefore discarded during analysis. Temperatures were analyzed using linear regression. A time series analysis was done to understand the past rainfall pattern to help future projections and planning using the past and present data. Among many components of the time series, the secular trend method was used to comprehend the general tendency of the time series data to increase, decrease or stagnate during a long period of time. For future projections, a Statistical Downscaling Model (SDSM) 4.2 **[12]** was used.

3.1 Case Study Area and Sampling

To study blue land use and its implications on climate change in a city, 3 clusters have been identified to represent the city evenly. Three different clusters, namely wards 5, 6 and 8, have been identified to represent the city core, inner fringe and outer fringe, respectively. Furthermore, each cluster has a specific characterization from a blue land use point-of-view. Therefore, cluster I (ward No 5) has settlements with a pond at one corner, cluster II (ward No 6) has settlements around the pond. Cluster III does not have a pond within its dense settlements (**Figure 3**). The clusters have been selected in such a way that the socioeconomic conditions of the people living in those areas are similar. Households in buildings with a similar number of stories and possessing similar electrical appliances were treated as having a similar socioeconomic level.

Under probability samples, stratified random sampling was used to select the sample households in the case study clusters. The study population has been stratified using indicators such as houses near the pond and away from the pond. A purposive random sampling technique was used in which the sample size is calculated for a 95 % confidence level in each cluster. The total number of households in each cluster is around 500 to 600 and the sample size is 200 with a margin of error of 5.6 %. The sample size was calculated using an online sample size calculator (http://www.raosoft.com/samplesize.html). The sample size calculated in this way is about 30 % of the population in each cluster. In a case study research, several sources of data, such as documents, observations, interviews are used to get a deep understanding of the case **[13]**.

Key Informant Survey (KIS)

In each cluster/ward 3 key informants were identified, including a former holder of office in the municipality, a present office bearer of the ward and a local social worker. In case of ward number 5 and 6 ex-mayor, ward secretary and a school head master were selected as key informants. Similarly, in ward number 8, an ex-ward chairman, ward secretary and school head master were interviewed as the key informants. An open ended questionnaire was used for conducting the KIS.

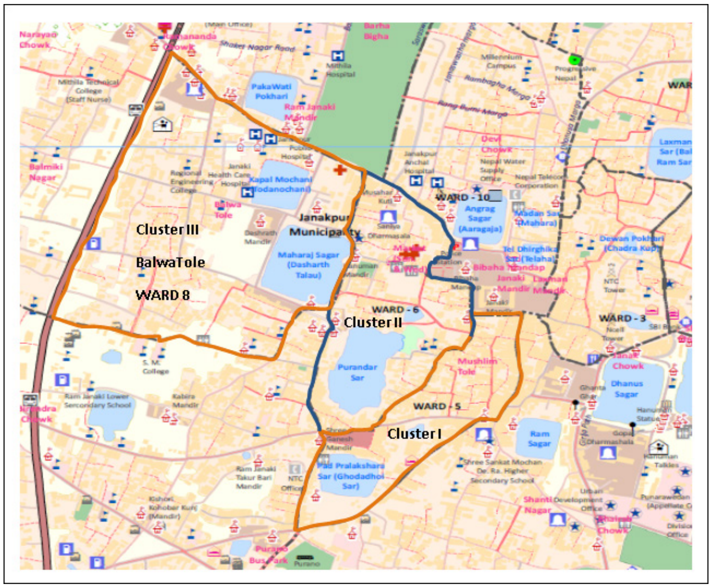

Figure 3: Case Study Areas Cluster I, II and III (Ward No 5, 6 and 8 Respectively) Source: Janakpur Municipality (2012)

Focus Group Discussion: One focus group discussion was carried out in each ward. About 30 to 50 participants were included. The participants were inhabitants of the ward with more than 50 yr of age. About 60 % or more participants were women. The questionnaire used for key informants was used for the focus group discussion also.

4. Analysis

The Janakpur Municipality, with a population 98,446, is comprised of 19,195 households (HH) spread over 2,693.73 ha in 16 wards. The sample area selected is 8 % of the total area with 20 % of buildings as illustrated in **Table 1.**

Table 1: Buildings, Road Network (Km) and Area by Ward

Ward no.	No. of HH	Road Length (Km)	Ward Area (Ha)	Remarks
5	503	1.66	9.56	Core
6	591	3.23	13.3	Inner Fringe
8	2785	27.62	193.55	Outer fringe
Muni	19195	272.75	2693.72	

Source: **[10]**

The building typology as illustrated in **Table 2** suggests that about 45 % of the buildings within the municipality are Reinforced Cement Concrete (RCC) while in the case study area this composition varies from 50 % in cluster III to 60 % in cluster I.

Table 2: Number of Buildings in wards by Construction type

Ward No	Cement Masonry	Mud Masonry	Others	RCC	Temporary	Wooden Wall	Total	RCC/Total
5	161	7	4	309	16	6	508	0.61
6	212	7	8	332	22	10	597	0.56
8	1112	125	35	1344	115	19	2758	0.49
Muni	10368	1006	360	11542	1442	1121	25839	0.45

Source: **[10]**

Table 3: Land Use in the Janakpur Municipality

S . No	Land Use	Municipality		Ward 5		Ward 6		Ward 8	
		Area in Ha	%	Area in Ha	%	Area in Ha	%	Area in Ha	%
1	Built up	637.77	23.68	7.36	76.99	9.86	74.14	76.63	39.59
2	Cultivation	1806.41	67.06		0		0	91.26	47.15
3	ENV Sensi. Area	7.47	0.28		0		0		0
4	Forest	59.23	2.2		0	0.23	1.73	5.01	2.59
5	Open Space	3.83	0.14	0.32	3.35	0.02	0.15		0
6	Recreational	15.95	0.59		0	0.12	0.9		0
7	Water Body	103.88	3.86	1.18	12.34	2.19	16.47	13.74	7.1
8	Road	59.2	2.2	0.7	7.32	0.88	6.62	6.91	3.57
	Total	*2693.74*	*100*	*9.56*	*100*	*13.3*	*100*	*193.55*	*100*

Source: Author (Analysis of updated base Map 2016)

The updated base map of the municipality reveals that about 4 % of land within the municipality is under water bodies. Other dominant land uses are Cultivation and Built up areas which cover 67 % and 24 %, respectively (**Table 3**). **Table 3** illustrates the land use of the three different clusters in this study. The blue land use covers about 12, 16 and 7 % of the land in wards 5, 6 and 8, respectively, which is much higher than the municipality itself. The built up areas are similar in the case of wards 5 and 6, with 77 and 74 %, respectively, which is higher than ward 8 (40 %) and the municipality as a whole (23.7 %). Wards 5 and 6 have hardly any open space, forests or recreation spaces. Ponds and their surroundings provide the services of open spaces and recreation spaces. Ward 8, which extends from inner fringe to the suburbs, is still under development with about 47 percent of land under agricultural uses.

The analysis of **Table 1**-**Table 3** illustrates that wards 5 and 6 are of same level of development with similar kinds of construction and higher density. In ward 8, by virtue of its location, the density is low for both buildings and roads. The types of construction indicate the similar socioeconomic level of the population in these wards. The household sampling was carried out in proportion with building typology.

5. Results

5.1 Climate Change Blue Land Use Interface

The eco-city study of Manchester city concludes that increases in green landscape could significantly ameliorate rising temperatures associated with climate change and the urban heat island effect resulting in an increase in human thermal comfort and quality of life, and reducing energy bills **[14]**. Cooling is mainly due to evapotranspiration and the shading of leaves. Water bodies are also supposed to assist in cooling down the air around them via evaporation and convection **[2]**. Open water bodies offer a source of moisture, creating the oasis effect during the day in urban environments **[15][16]**.

Blue land use can positively influence the microclimate of the surroundings in a city fabric on hot summer days due to natural cooling coming from evaporation. Water bodies are believed to be the best radiation absorbers, while they also provide a very small thermal response **[17]**. The blue mass provides an effective latent heat sink, and evaporation assists in cooling air just above the water surface and further improves the mixing.

A cooler surface leads to a cooler air temperature. The breeze continuously replaces the cool air with hot and the process continues. These characteristics result in the surface temperatures of the water bodies being cooler than those on land **[18]**. Enriched evaporation is capable of lowering air temperature and hence mitigates the process of UHI and increases the inhabitants' thermal comfort.

Studies often find that temperatures close to and downwind from water bodies are reduced by about 1 °C to 2 °C in comparison with surrounding areas, with the highest amount of temperature reduction observed throughout the day **[16]**. A study by Saaroni and Ziv showed a cooling pond effect of 1.6 °C at mid-day over the warmest part of a day as the surface of the lake was somehow cooler than the grass cover of the surrounding park and hence the daytime cooling influences were clearly obviously due to blue land use **[16]**.

Murakawa **[19]**, in Hiroshima, Japan, found that downwind cooling influences from the Ota River are present for at least a few hundred meters. The temperature of the air around the 270 m wide river was about 3-5 °C cooler (between 12-5 PM) than the surrounding region. An extra local cooling from the river believed to be more widespread occurred where building density was lower and streets were wider **[17][19]**.

Similarly, the literature-based research of Volker **[9]** revealed that ΔT (ΔT= T urban – T blue) was usually positive indicating that urban blue areas were relatively cooler during the day around the highest ambient temperatures of the city, and negative revealing that urban blue areas were relatively warm during the night. This is due to the specific heat, which is greater for water than for any other material, so that water cools more slowly during the night than other urban materials like concrete **[20][21]**.

The ΔT for each study ranged from 0.4 °C (minimum) to 5.6 °C (maximum) (**Table 4**). According to Volker, ponds with fountains showed the highest temperature difference of 4.7 °C in comparison with the park. If it is compared with urban built-up areas, the difference can go up to 6 °C. The lowest difference was seen in the case of a pond with a park compared to the park itself (ΔT= 0.4 °C). However, this proves that blue land use has higher capacity to lower midday temperatures.

Table 4: Temperature comparison with and without ponds in Urban Fabric

S. No	Description of Blue Land Use	Compared With	ΔT in °C
1	Fish Pond	Urban Built Up Area	2.6
2	Pond	Urban Built Up Area	1.3
3	Pond in Park	Park	0.4
4	Pond with Park	Residential Area	1.16
5	Pond with Fountain	Park	4.7
6	Pond without Fountain	Park	1.8
7	Urban Water Front	In land Sites	5.4

Source: **[9]**

5.2 Climate Data, Present Trend and Future Perspective

The analysis of the temperature data from three stations located in Biratnagar, Janakpur and Birgunj reveals that the temperature has a rising trend (**Figure 4**). The average annual maximum temperature in Biratnagar and Birgunj has been rising at a rate of 0.019 °C and 0.007 °C per annum while Janakpur's annual average maximum temperature is rising at the rate of 0.001 °C. Similarly the annual average minimum temperature of Biratnagar, Janakpur and Birgunj is increasing at the rate of 0.027 °C, 0.044 °C and 0.030 °C, respectively. The equation in each time series graph shows how the temperature (*y*) varies with time (*x*). The temperature graph is a straight line with $y=mx+c$. The positive coefficient of *x* represents the increasing trend per annum while the constant represent the base year value of temperature i.e. 1975 in this case. The magnitude of m provides the quantum through which the temperature is rising per annum.

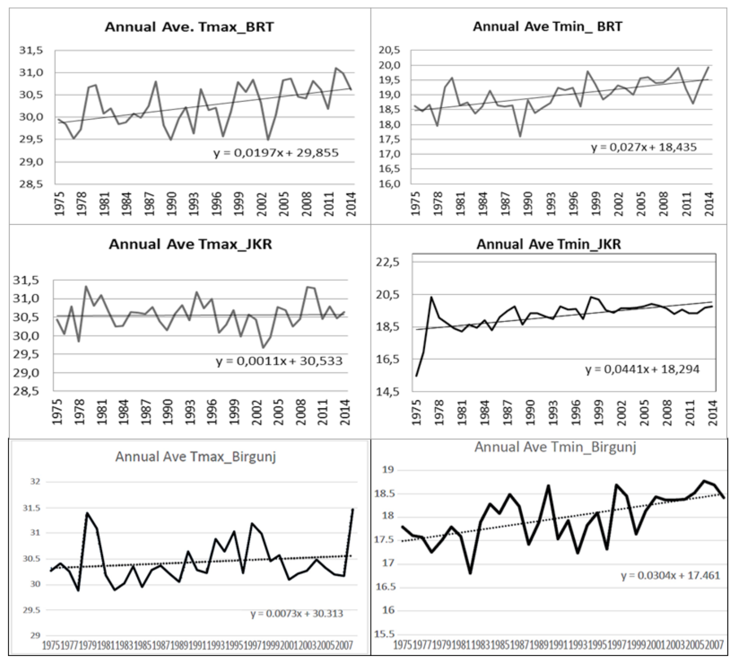

Figure 4: Past Trend of Temperature in Terai Towns (Annual average maximum and minimum temperature in Biratnagar, Janakpur and Birgunj) Note: Formats are different from each other mainly because the graphs are generated by statistical model (SDSM) 4.2 **[12]** used to carry out the trend analysis. Source: Author (Data from DoHM).

The annual average maximum temperature in Janakpur is increasing at a very slow pace in comparison with Birgunj and Biratnagar, although Janakpur is situation between the two Terai towns and has a similar topography, form and socio-economic level. Similarly, the average minimum temperature is increasing with a higher pace in Janakpur than in the other two cities. Why is Janakpur warming up more slowly in summer and faster in winter compared to other similar towns with similar topography and socio economic condition? The phenomenon is explained by the existence of numerous ponds within the city of Janakpur.

This indicates the cooling effect of Blue Land Use (ponds) in summer and heating in winter. This is due to the high heat holding capacity (thermal capacity) of water. Blue land use holds large amount of heat during summer resulting in the slow temperature rises in Janakpur. During winter, the high thermal capacity of the water allows it to release heat for longer periods resulting in the higher pace of warming during winter in Janakpur.

The future trends of temperatures in the three cities have been developed using the statistical downscale model (SSDM) version 4.2 **[12]**. The future projections show that the trend of temperature rises in summer is 0.037 °C, 0.026 °C and 0.022 °C in Birgunj, Janakpur and Biratnagar, respectively. Similarly, the average annual minimum temperature will increase by 0.081 °C, 0.017 °C and 0.055 °C per annum in Birgunj, Janakpur and Biratnagar, respectively (**Figure 5**). The trend indicates the active implication of the water bodies in the Janakpur Municipality.

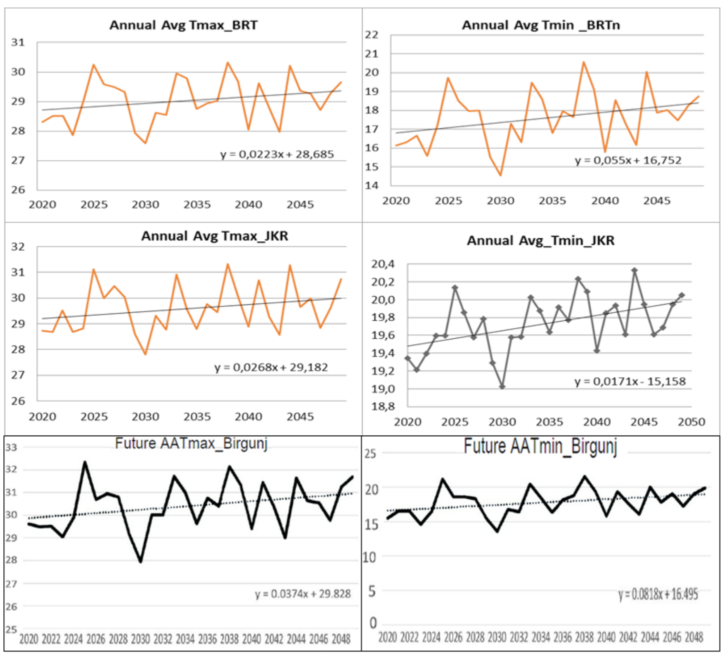

Figure 5: Future Trend of Temperatures in 3 Terai Towns (Annual average maximum and minimum temperature in Biratnagar, Janakpur and Birgunj) Note: Formats are different from each other mainly because the graphs are generated by statistical model (SDSM) 4.2 **[12]** used to carry out the trend analysis. Source: Author (Data from DHM).

5.3 Impact of Blue Land Use in Janakpur

An experiment was carried out in Janakpur Municipality on 27, 28 and 29th of April 2016 in three different wards (6, 7 and 8) to measure the temperature difference near the pond and inside the built-up urban sectors. In each ward temperatures were measured near the pond, about 35 m away from the pond and 75 m away from the pond in the built-up area. In ward 5, temperatures were recorded at 12.30 PM. Similarly, temperatures in wards 6 and 8 were recorded at 1.30 PM and 2.30 PM. Simple room temperature measuring air thermometers (3 Nos) were used over the three days. The results are shown in **Table 5**.

Table 5: Temperature Difference near and away from Blue Land Use

Date	Ward No 5			Temp Diff ΔT in °C	
	Bank of the Pond	35m away from the pond	75m Away from the pond	35m away from the pond	75m Away from the pond
27-Apr	35.6	36.1	37.4	0.5	1.8
28-Apr	33.8	34.4	35.8	0.6	2
29-Apr	37.2	37.8	39.6	0.6	2.4
Date	Ward No 6			Temp Diff ΔT in °C	
	Bank of the Pond	35m away from the pond	75m Away from the pond	35m away from the pond	75m Away from the pond
27-Apr	35.6	35.8	37.7	0.2	2.1
28-Apr	34	34.5	35.8	0.5	1.8
29-Apr	37.5	37.9	39.7	0.4	2.2
Date	Ward No 8			Temp Diff ΔT in °C	
	Bank of the Pond	35m away from the pond	75m Away from the pond	35m away from the pond	75m Away from the pond
27-Apr	35.6	36.1	37.1	0.5	1.5
28-Apr	34.2	34.2	35.6	0	1.4
29-Apr	37.3	37.8	39.5	0.5	2.2

Source: Author (field Investigation)

The observation confirms that the urban blue land use has a cooling effect on temperatures within city fabric. The temperatures near to the urban ponds were found to be considerably lower than in urban built-up sectors. The maximum ΔT was found on April 29th when the temperature of the city was highest i.e. 39.6 °C. It implies that the higher the temperature the greater the cooling effect of the urban blue areas. Similarly, the table illustrates that the ΔT or the cooling effect diminishes with the distance from the pond. The observations confirms the findings of other researchers, notably Murakawa, Volker, Wong and others **[9][18][19]**.

The cooling impact of the pond on city fabric depends on the density and building height along with the road width through which the cold air is carried out to the city **[22]**. The result from the study carried out by Nindyani **[22]** interestingly illustrates that the wider river width did not result in a significantly greater cooling effect. The spatial analysis (refer **Figure 6**, **Figure 7** and **Figure 8**) shows that about 50 % of houses are under the influence of ponds in these wards. In ward 5, 11 % of HH are within a 25 m buffer of pondsm while the 50 m and 100 m buffers encompass 32 % and 35 % of total HH in the ward, respectively (**Figure 6**). In case of ward 6, 22 % of HH are within 25 m of the pond while the 50 m and 100 m buffers encompass 40 % and 58 % of HH in the ward, respectively (**Figure 7**). Similarly in the ward 8, 9 % of HH reside within 25 m of the pond while the 50 m and 100 m buffers encompass 31% and 48 % of HH, respectively (**Figure 8**).

The household survey and key informant surveys carried out in wards 5, 6 and 8 revealed that the temperature has increased over the years across the city. About 83, 86 and 87 % of the HH survey respondents from wards 5, 6 and 8, respectively, verified that the city has become

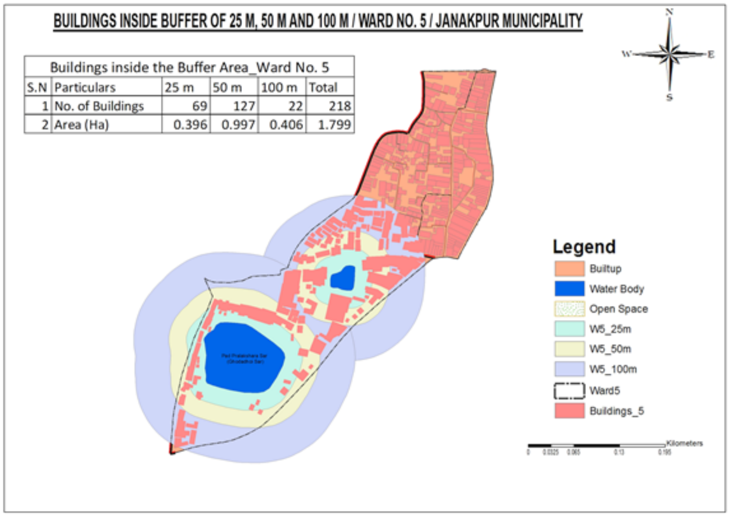

Figure 6: Buildings inside buffers of 25, 50 and 100 M from the pond

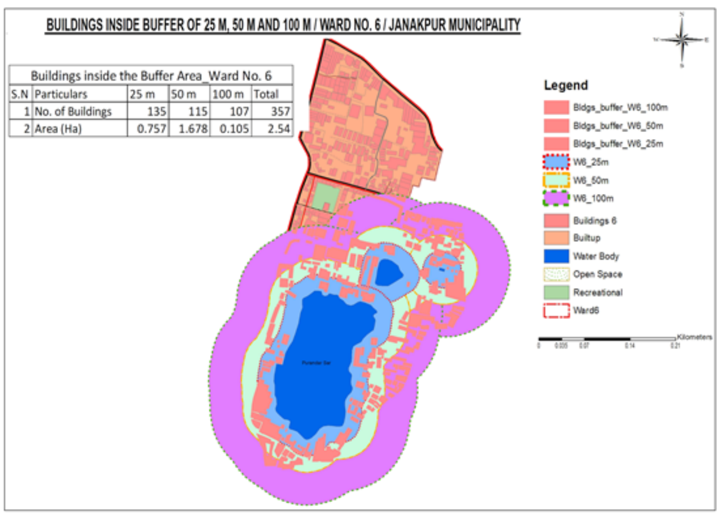

Figure 7: Buildings inside buffers of 25, 50 and 100M from the pond

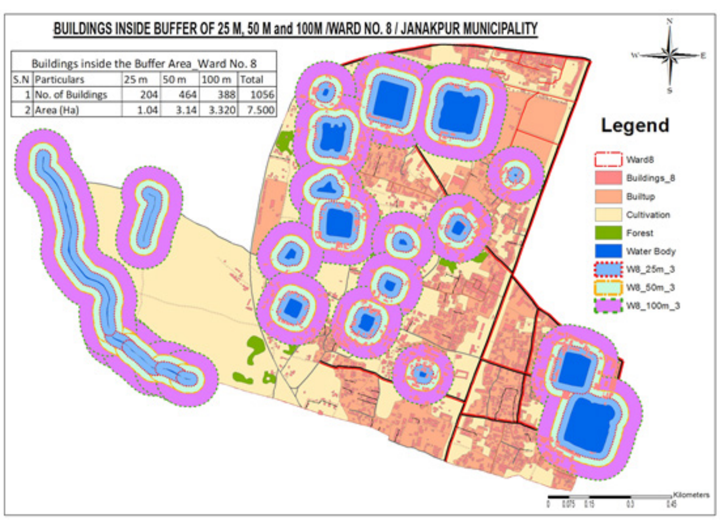

Figure 8: Buildings inside buffers of 25, 50 and 100M from the pond

warmer and the temperature is increasing annually. Similarly, 72, 76 and 64 % of respondents to the HH survey in wards 5, 6 and 8, respectively, expressed that winter is shorter but it is severe, taking tolls on people's lives every year. This confirms the data from desinventar (web based database portal of UNISDR). This was further confirmed with key informants and group discussion surveys. More than 90 % of respondents on all the three types of survey confirmed that the areas surrounding the ponds are cooler during scorching heat and therefore, people flock to the Pipal Chutari (a seating platform around a Pipal tree) at the bank of these ponds. Eighty % of HH respondents and two key informants (former mayors) revealed that people living near the ponds are running fans for fewer hours for cooling as they generally switch off in the morning for 5 hrs (3 to 8 AM). Similarly, the electricity tariff analysis reveals that it increases as we move away from the ponds, with some exceptions. The group discussions in each ward with local people confirmed the observations and analysis.

6. Discussion

A space or an area can be cooled by passive evaporation, a process where evaporation occurs naturally from standing or moving water (such as ponds, basins or fountains). The evaporation and transfer of sensible heat result in lowering air temperature around the water bodies **[23]**. In the process of evaporation, the heat is stored without increasing the temperature. Evaporation decreases air temperature due to the latent heat of absorption and increased specific humidity. Meanwhile, the transfer of sensible heat between air and the underlying water (the water is cooler than the air) also reduces air temperature, especially under hot weather conditions. In terms of the potential cooling effect brought about by the different ground covers, usually lawns and woods or shade from trees contribute significant cooling effects during both day and night **[22]**. In addition, water bodies were shown to be cooler than concrete areas in the day, but the study also showed the probability of these large water areas contributing heat at night and, in some instances, being even warmer than the concrete surfaces by about 0.4 °C to 1.0 °C **[24]**.

In 2013, Volker **[9]** illustrated that blue bodies have a cooling impact on urban fabric. The cooling impacts of ponds in different contexts reveal that it ranges from 4.7 °C in the case of ponds with fountains to 1.3 °C in the case of other ponds, in comparison with urban built-up sectors. The cooling impact diminishes while moving away from the water body; however, the extent through which the cooling effect prevails depends on the density and height of buildings, along with the width of roads and open spaces around the water body. Temperature of similar towns situated on either side (east and west) of Janakpur demonstrated that since 1975, the trend of annual average maximum temperature rise is slower than both the cities of Biratnagar in the east and Birgunj in the west. Similarly the trend of annual average minimum temperature rise is faster (0.047 °C) than that of Biratnagar and Birgunj. The outcome could be explained by presence of such a huge number of ponds in the city fabric and their cooling effect. The ponds in Janakpur provide cooling effects in summer. The three day temperature recordings at various distances from the urban blue areas in Janakpur further substantiate this fact. They revealed that the cooling effect decreases with the distance away from the water bodies and it goes up to 75 m. The meandering narrow streets undermine these effects. The temperature records show that the cooling effect is stronger nearer the ponds. The key informants and participants of the focus group discussions confirmed the phenomena and expressed that the ponds provide a soothing environment to city dwellers in the scorching summer when even the city power supply or even the moving fans fails to do so. People from surrounding areas gather at the Pipal Chautharis developed in the vicinity of ponds.

7. Conclusion

Evaporative cooling from the water bodies is suitable for areas with a high air temperature and low air humidity. In a high air humidity climate, evaporative cooling might be less applicable if it is not supported with increased air flow. The benefits of such a climate model are useful in urban planning in extreme hot and humid climates. Based on the past and future temperature trend analysis and temperature records taken at different distances from the pond in the Janakpur municipality some empirical relationships related to water evaporation and its cooling effect can be outlined. Water bodies absorb heat from their surroundings when they evaporate and produce a cooling effect. In the process they act as a temperature sink and adapt the increasing heat due to climate change and other process. The literature, field measurement and experiences of key informants indicated that the cooling effect seems to depend on extreme temperatures . The wind increases the amount of evaporation as it carries the released vapor from the water bodies to reduce humidity. The occurrence of wind is caused by differences in air pressure, sending air to the lower pressure area. Increasing the wind speed increases the cooling effect from the water bodies, cooling the environment for a longer distance.

However, wind speeds in Janakpur are very limited and it generally flows from east to west or vice versa. The streets with east west direction can take the cooling effect of the ponds well into the city fabric. The measurement result is enhanced if the ponds are fitted with fountains and the surrounding area is covered by trees and green land uses as the fountain keeps bringing cooler water to the surface increasing the pace of the cooling process of the air just above the water bodies. Furthermore, the width of a river and size of a lake does not result in a significantly greater cooling effect. The uniformly distributed ponds in the city of Janakpur are in a position to contribute in adapting to climate change throughout the city. The inhabitants of Janakpur City are fortunate enough to have numerous ponds in their vicinity which can contribute to adaptation to climate change, one of the most pressing issues of the 21st century. An area for further research is the relationship between blue land use and the extent of the cooling effect.

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