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PEER REVIEWED ARTICLE

Anticipating urbanization-led land cover change and its impact on local climate using time series model: a study on Dhaka city

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Abstract:

Urbanization-led changes in natural landscape often result in environmental degradation and subsequently contribute to local climate variability. Therefore, apart from global climate change, Dhaka city's ongoing rapid urban growth may result in altering future local climate patterns significantly. This study explores transition relationships between urbanization (population), land cover, and climate (temperature) of Dhaka city beginning in 1975 through to forecast scenarios up to 2035. Satellite image, geographic, demographic, and climatic data were analyzed. Change in core urban land cover (area) was regarded as a function of population growth and was modeled using linear regression technique. The study developed and validated a time series (ARIMA) model for predicting mean maximum temperature change where (forecasted) land cover scenarios were regressors. Throughout the studied period, the city exhibited an increasing urbanization trend that indicated persistent growth of core urban land cover in future. As a result, the city's mean maximum temperature was found likely to increase by around 1.5-degree Celsius during 2016–2035 on average

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from that of observed 1996–2015 period. It is expected that findings of this study may help in recognizing urbanization-led climate change easily, which is crucial to effective climate change management actions and urban planning.

Keywords: urbanization; land cover; climate change; time series model; Dhaka city

1. Background

Urbanization is the process of growth in the proportion of a country's total urban population (Thomas, 2008). The majority of the global population currently live in urban areas, in 2018 this amounted to more than 4 billion people (UN DESA, 2019) and this number is growing at an annual rate of nearly 2% (World Bank, 2018). By 2050, proportion of the global urban population is likely to rise to 68% which will be mostly contributed by countries in Asia and Africa where the rate of urbanization is most rapid (UN DESA, 2019). Relevantly, it has been predicted that Dhaka will have more than 28 million people by 2030 (UN DESA, 2019). Dhaka is the capital of Bangladesh and the center of political, cultural and economic life. After liberation in 1971, the population of Dhaka started to rise sharply and since 1991 Dhaka has experienced remarkable urban growth (Rahman, et al., 2008). The previous annual population growth rate of Dhaka city of 4.2% (Biswas, et al., 2010) has recently shrunk to 3.48% (BBS, 2012). A study conducted by the World Bank revealed that sprawl intensity and coverage were increasing day by day within the Dhaka Statistical Metropolitan Area (World Bank, 2011). The probable reasons for this trend are population boom, very high land price in planned areas, development management inefficiency, etc. Therefore, historical change and urban growth pattern monitoring of Dhaka Metropolitan Area using remote sensing technologies (Ahmed, et al., 2013; Ahmed & Ahmed, 2012; Dewan & Yamaguchi, 2009a; Dewan & Yamaguchi, 2009b) have been of great interest to the scientific community.

Urbanization is always accompanied by several changes in socio-economic, cultural and demographic settings (Khoury, 1982). When characterized by rapid population growth, sprawl, poverty, etc., it creates stress in the urban environment, triggering environmental problems and risks for urban inhabitants (WHO, 2000). In this regard, Dhaka city is anticipated to be affected in two major ways; heat stress and flooding (multiplied by drainage congestion) as consequences of ongoing climate change (UN-HABITAT, 2008; Alam & Rabbani, 2007). A slight rise in sea level may engulf large parts of the city and negative consequences are likely to be felt by a large number of people; especially the urban poor who live in flood-prone and waterlogged areas (UN-HABITAT, 2008). Thus, the city needs to develop advanced knowledge of potential climate change, its impact and the mechanisms to overcome the situation.

Climate change has forced many rural people in Bangladesh to migrate to cities and this has caused a sharp rise in the slum population of Dhaka (Aulakh, 2013). Climate change is a global issue with great importance requiring adaptation and mitigation (United Nations, n.d.) otherwise a cascade of naturally triggered disasters will devastate the known forms of life on earth. "Climate change impacts and consequences can wipe out development gains and significantly reduce the standard of living" (Prasad, et al., 2009 p.10). Yet, cities can take active steps to minimize climate change induced or other natural disaster risks/impacts by improving planning, creating effective infrastructure and establishing disaster preparedness. In this regard, climate change prediction can help in developing local prevention, mitigation and adaptation strategies to minimize probable loss.

Due to urbanization, the increased demand for land for non-agricultural purposes (e.g. for urban residential and industrial use) is the main driver of land use and land cover[2] change (LULCC) (Coskun, et al., 2008). Evidence shows that LULCC has effects on climate change (Dale, 1997; Thompson, et al., 2011). As with the production of greenhouse gases, LULCC has significant effects on atmosphere, climate and sea level in both global and local systems (Meyer & Turner, 1992; Pielke, 2005; Hong Kong Observatory, 2012). Land cover change by new city elements and their surface materials alters energy, water exchanges and airflow. Urban climate also varies with these factors in a conjunction with direct anthropogenic emissions of heat, CO_2 and pollutants (Grimmond, 2007). For instance, "…small changes of 100 square kilometers in urban development or deforestation can change local rainfall patterns and trigger other climate disruptions" (Climate Future Group, 2006).

2 Land-use and land cover terms are often used interchangeably. However, the underlying difference between those is land-use stands for the particular use (e.g. residential / commercial etc.) of land whereas the land cover means the surface cover (e.g. urban area/ vegetation etc.) on the ground (Coffey, 2013).

From the above discussion, it is clear that Dhaka city is at risk of facing negative environmental consequences propelled by ongoing rapid urbanization. Migrating population, voluntary and forced (e.g. environmentally displaced), is adding pressure to the city at a significantly higher rate (6%) than the country's overall rate of internal migration (4.5%) (Xinhua, 2013; Khan, 2012). These migrants, typically unskilled and having lost their livelihoods, merge into the urban poor and often become even poorer than before migrating (Stojanov, 2005). They generally settle in low-lying flood prone areas in cities and gradually transform urban ecosystems and landscapes (UNU-IHDP, 2015) resulting in environmental degradation. Given predicted climatic vulnerability, it is necessary to anticipate urbanization-induced land cover change and associated future climate change so that proper adaptation and mitigation measures can be planned and initiated.

2. Objectives and scope

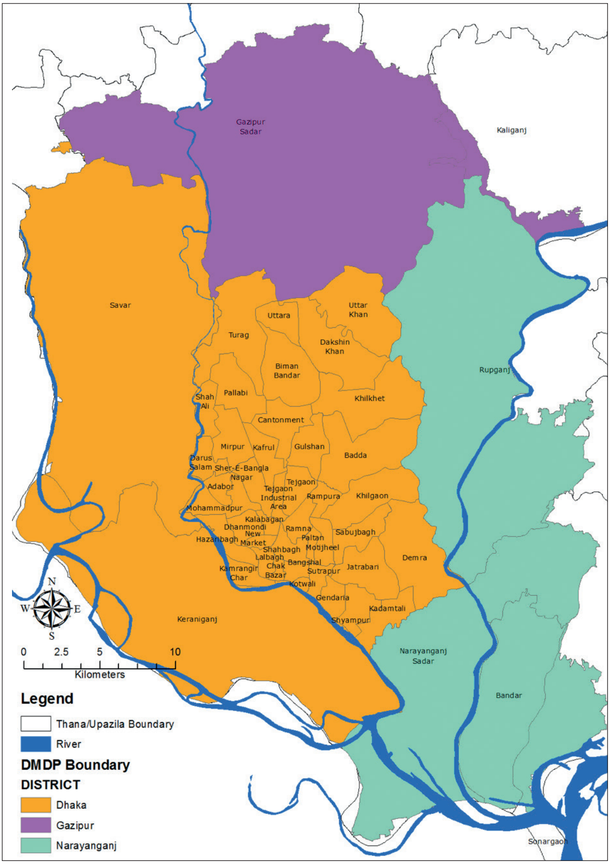
The objective of this study is to ascertain changes in future climate of Dhaka city in relation to the predicted land cover change using long term observational data. The study assumes that land cover change due to future urbanization is likely to bring changes on climate pattern of the study area. Hence, it targets to understand and explore the underlying relationships among urban population, land cover, and climatic parameter based on historical evidences. For performing the study, Dhaka Metropolitan Development Planning (DMDP) area is taken into consideration. It includes city corporation areas and other some peripheral urban centers and localities, which is governed by the *Rajdhani Unnayan Kartripakkha* (RAJUK) i.e. capital city development authority. The extent of the DMDP area is around 1439 km^2 (RAJUK, 2011) which is shown in Figure 1 along with local administrative Thana[3] and Upazila[4] boundaries.

Among different factors of urbanization economic growth, industrialization, exports, residential GNP per capita, agricultural productivity, size of total population, start date of modernization etc. are very dominant (Bairoch & Goertz, 1986). However, the study does not investigate the factors behind Dhaka's urbanization but examines its trends. The study recognizes change in urban population and land cover as the consequences of change in social, economic

3 Thana: administrative area/region in urban area controlled by a police station.

4 Upazila: the sub-division of a District, i.e. sub-district.

Figure 1: Administrative Map of the Study Area



and policy aspects as well as the management efficiency or inefficiency of the concerned authorities.

3. Method

Most commonly, remote sensing and Geographic Information System (GIS) are used to monitor and measure land-use changes. Numerous researchers have worked with multi-temporal digital satellite imagery and GIS database for comparing and assessing LULCC (Coskun, et al., 2008; Reis, 2008; The World Bank, 2012; Malaque & Yokohari, 2007; Gregorio & Jansen, 2005; Thompson, et al., 2011; Long, et al., 2007).

In climate change prediction/research, time series data and autoregressive integrated moving average (*ARIMA*) model has been frequently employed (Piwowar & Ledrew, 2002; Romilly, 2005; Ye, et al., 2013; Afrifa-Yamoah, 2015). This study has followed a similar method by developing a time series (1975–2015) database and ARIMA model with regressors for predicting climate change. Notably, regional climate change measurement accounts for maximum temperature trends only (Pielke, 2005). Therefore, the study attempts to predict change in mean maximum temperature of Dhaka city to ascertain probable climate change. This study's urban population, land cover, and maximum temperature predictions follow the timeframe (2016–2035) of the DMDP's second Structure Plan[5] (RAJUK, 2015). The study's detailed methodological aspects are described in the following sub-sections.

3.1 Land cover data

The study collected historical Landsat images (multispectral only) of the Dhaka region for 1975, 1989, 1999 & 2006 from the official data archive of the U.S. Geological Survey (USGS, n.d.). It worth mentioning that available images for 1975, 1989, and 1999 in the archive did not cover the DMDP (area of interest) entirely, consequently the next available years' data were collected (Table 1). The downloaded data, having less than 10% cloud coverage, were then projected to the Universal Transverse Mercator (UTM) – Zone 46 North with the World Geodetic System (WGS) – 1984 datum. Spatial resolution of these images was 30 × 30 meters except for 1975 images (Table 1) which were resampled to this specification. Apart from this, no further pre-processing was performed. Seasonality was ignored as all images were captured between November and March, which broadly falls in winter. As greeneries/vegetation, open space, and waterbodies contribute greatly in regulating local climate (Bolund & Hunhammar, 1999), the study has extracted land cover data under the following four categories:

1. Dense/Core Urban: densely developed urban lands areas within the study area.

2. Underdeveloped (Non-Urban & Agriculture): rural settlement, vacant/ open space, agricultural lands, services/ institutional area, proposed urban area, etc..

5 It is the long-term (20-year) strategic planning document of the DMDP area, which provides urban development strategies and planning proposals for the area.

3. Green/Reserved: homestead vegetation, forests, parks, restricted and reserved lands/ playgrounds, etc..

4. Waterbody: marshland, river, canal, pond, etc. areas.

Table 1: Particulars of collected Landsat images from the USGS archive

Data year (as regarded)	Acquisition Date	Path/ Row	Coverage of the study area	Sensor	Pixel size (meters)
1975	27-Mar-75	147/43	85%	MSS	60 x 60
	08-Feb-77	147/44	15%		
1989	04-Nov-89	137/44	85%	TM	30 x 30
	26-Nov-91	137/43	15%		
1999	24-Nov-99	137/44	85%	ETM+	30 x 30
	28-Feb-00	137/43	15%		
2006	27-Jan-06	137/43 and 137/44	100%	ETM+	30 x 30

Supervised Classification method, where user/analyst selects representative samples for each land cover category in the digital image, was applied during image analysis. To test accuracy of classified outputs, a total 100 stratified random samples were taken from four land cover classes. The Urban Area Plan (1995-2005) (RAJUK, 1995) and Detailed Area Plan[6] (DAP) (RAJUK, 2010) maps as well as high resolution Google Earth images were used while checking representativeness of actual land cover in the classification outputs. The overall accuracy of 1975, 1989, 1999, and 2006 classified images were 85%, 90%, 88%, and 91% with Kappa coefficients of 0.80, 0.86, 0.84, and 0.88 respectively. As the accuracy figures met the standard requirement for LULCC studies (Dewan & Yamaguchi, 2009a), no further actions to improve these classification outputs was taken. Total area under different land cover categories from the analyzed four image sets were calculated, summarized, and stored. Furthermore, recent land cover statistics from 2013 were extracted from generalized land use data used in the structure plan (RAJUK, 2015)

6 It is third and last tier of Development Plan for DMDP area, which provides further detailed urban planning proposals for specific sub-areas in the lights of the Structure Plan and the Urban Area Plan.

preparation work. At the end of this stage, land cover information of five different periods (1975, 1989, 1999, 2006 and 2013) were prepared and accumulated for further analyses.

3.2 Demographic data

The study has collected population census data from the years 1981 (BBS, 1981), 1991 (BBS, 1991), 2001 (BBS, 2001) and 2011 (BBS, 2012) for Dhaka, Gazipur and Narayanganj Districts (falling within the DMDP area). Here, enumerated population under corresponding Thanas and Upazilas (administrative regions) were considered. For calculating partial population at the periphery, overlying Upazila area (part) was multiplied by the gross population density of that particular Upazila as no other spatially distributed demographic data for that area were found.

3.3 Climatic information

Climatic information, recorded at Dhaka station, were collected from Bangladesh Meteorological Department (BMD, 2017) for the 1975–2015 period. Monthly maximum temperature values, in degree Celsius (°C), were arithmetically averaged to obtain the yearly mean maximum temperature (hereafter referred as temperature).

3.4 Time series database

At this stage, Underdeveloped (Non-Urban & Agriculture) and Green/Reserved land covers are aggregated into one category named 'Potential Urban' as lands under those categories are believed to be most suitable for urban functions and uses (Naab & Dogkubong, 2013). Finally, a time series database, starting from 1975, has been developed by combining three land cover (core urban, potential urban & waterbody) categories, population, and temperature data. To obtain in-between population and land cover figures of two base years, linear interpolation method was applied.

3.5 Forecasting method and ARIMA model

Population to the year of 2035 was projected using graphical method (FHWA, 2001). Moreover, exponential forecasting method (using F1 and F2) (George, et al., 2004) was applied since Dhaka experienced a near exponential growth trend in recent decades (Iqbal & Khan, 2005). The study compared those two outcomes and considered the lowest figure as the minimum probable population by the predicting year for further analyses.

Population of forecasted year $P_2 = P_1 \times e^{r*(t_2 - t_1)}$ (F1)

The study followed formula F2 for computing population growth rate where P_2 and P_1 were the population of last (t_2) and first (t_1) assessment year respectively.

Population growth rate $r = \frac{\ln P_2 - \ln P_1}{t_2 - t_1}$ (F2)

As the prepared land cover statistics were not originally time series (but sample) data, a linear regression model was applied to predict its future change. Here, population growth in the DMDP area has been viewed as a key contributor to core urban land cover change. Thus, forecasted population was used as the only regressor in building a linear model for core urban area prediction. Average annual gain/loss rate of waterbodies (land cover) has been used in forecasting their future status. Potential urban land cover area was calculated by deducting the sum of core urban and water-body areas from the total DMDP area. Land cover change rate(s) within the considered periods was assessed with the following formula F3 (Long, et al., 2007) where LC_2 and LC_1 were present and past land cover area respectively for a time interval (t).

Land cover change rate $LC_r = \frac{LC_2 - LC_1}{LC_1 \times t}$ (F3)

The study developed and applied an ARIMA (time series) model for predicting temperature change by the year of 2035. Before executing ARIMA, Augmented Dickey-Fuller test for unit root was performed on collected temperature records for a stationarity check of the time series. Since the temperature records were yearly data, seasonality test was not necessary. To identify the appropriate ARIMA model structure, Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) were tested. Finally, Akaike Information Criterion (*AIC*) and Bayesian Information Criterion (BIC) tests, where lower values signify the best-fitting model, were performed to determine goodness of fit of the tested ARIMA model(s). Notably, in the temperature change model, all (predicted) land cover categories were considered as regressors, since this study aimed to explore the impact of urban land cover change on the city's temperature by 2035.

Figure 2: Proportion and area (in km²) of different land-cover categories during collected data periods

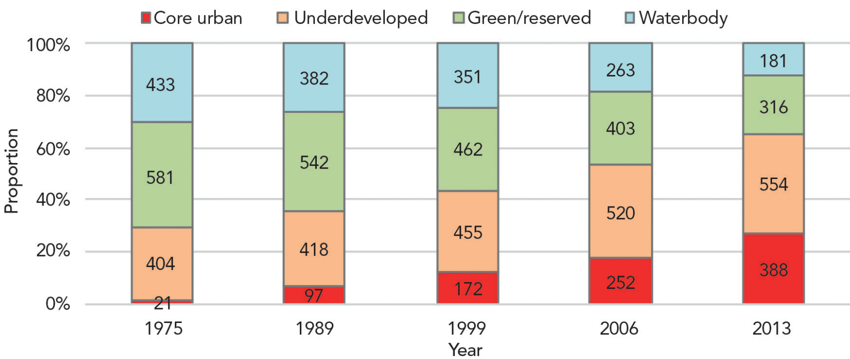


Table 2: Observed land-cover change rate over the periods

Land-cover category	1975–1989	1990–1999	2000–2006	2007–2013	Weighted Average
Core Urban	26.1%	7.7%	6.7%	7.7%	12.0%
Underdeveloped	0.2%	0.9%	2.1%	0.9%	1.0%
Green/ Reserved	-0.5%	-1.5%	-1.8%	-3.1%	-1.7%
Waterbody	-0.8%	-0.8%	-3.6%	-4.5%	-2.4%

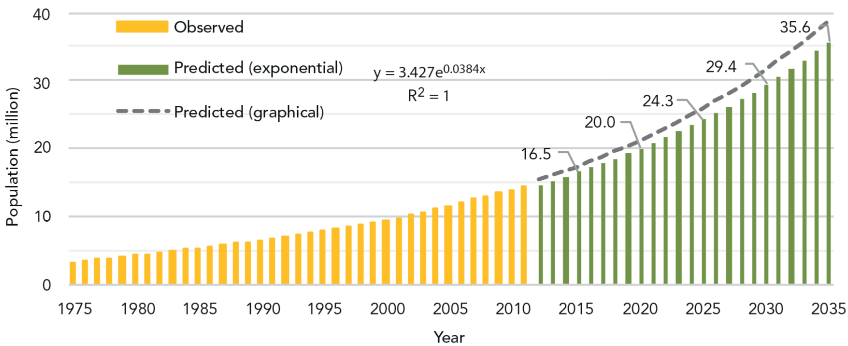
4. Results

Land cover statistics obtained from analyses are shown in Figure 2 from which change rates were calculated for different periods under corresponding land cover categories (Table 2). During the period 1975–2013, core urban and underdeveloped land covers were found growing annually at 12% and 1% rate respectively. However, in contrast, both green and waterbody land (cover) areas were found decreasing at around and above a rate of 2% per annum respectively. Total adjusted population of the study area in 2011 was found to be 14.2 million (Figure 3). During 2001–2011 period, population in Gazipur District was growing at nearly twice the rate (5.4%) per annum compared to the other two Districts. Interestingly, the population in the peripheral Districts was observed to be growing at a faster rate than central (below Dhaka District) region. With the help of forecasting methods discussed in section 3.5, probable population, land cover and temperature changes for the study area by 2035 (year) were estimated. The following sub-sections highlight different forecasted results.

4.1 Future population

The exponential method offered lower population figures than graphical method (Figure 3). While considering the lowest probable population, the model predicted the possibility of the study area having around 24.3 million inhabitants by the year 2025. Relevantly, it has been claimed that Dhaka city might have 23.6 million (Parvin, 2013) to 25 million (Davis, 2006) residents by 2025 which were close to the study's projection. Thus, the study considered forecasted population reliable and extended it to 2035, which resulted in an estimated population of above 35 million for the study area by that time.

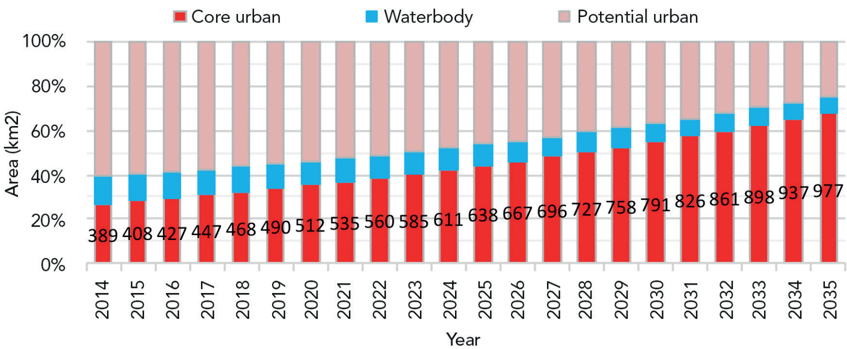
Figure 3: Observed and forecasted population of the study area



4.2 Imminent land cover change

Using liner regression model (see model summary in Appendix 1), core urban land cover of the study area by 2035 was approximated to be around 977 km^2 i.e. nearly 68% of the study area (Figure 4). Waterbody (land cover) area was estimated, using its annual average loss rate i.e. (-) 2.4% (see Table 2), to extend over only around 106 km^2 (7% of total) area. The remaining 25% (356 km^2) area was found likely to remain as potential urban space. In a related study, Ahmed and Bramley (2015) concluded that, in the absence any spatial development strategies, by 2025 more than 60% of total DMDP area would possibly be urbanized. However, they also observed that restrictions on reserved land may save around 15% from conversion into (core) urban land cover.

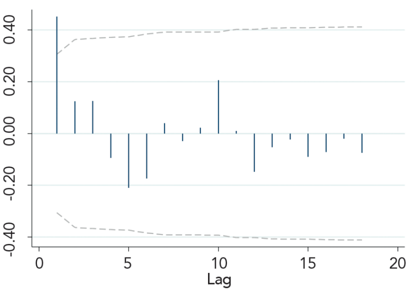
Figure 4: Predicted land cover scenario (using linear model) of the study area by 2035

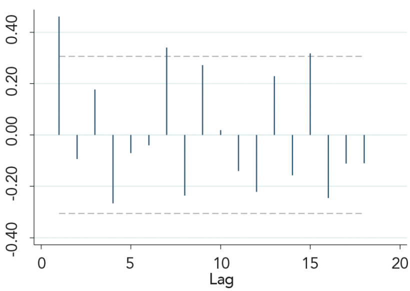


4.3 Probable temperature change

The Dickey-Fuller test, performed on collected temperature (1975–2015) records, found the time series stationary ($p = 0.0029$). Hence, ACF and PACF of temperature records were checked (Figure 5) to build an appropriate ARIMA model. The ACF graph set a clear indication of moving average (MA) and the model's suitability for temperature change assessment. Therefore, this study considered testing ARIMA(0,0,1) and $MA_{(1\ 10)}$ for lags 1 and 10 models with constant (series mean). Additionally, looking into the shape of PACF, an autoregressive $AR_{(1\ 7\ 15)}$ model for significant lags 1, 7 and 15 with constant (series mean) was also rendered.

Figure 5: ACF and PACF graphs of collected mean maximum temperature data



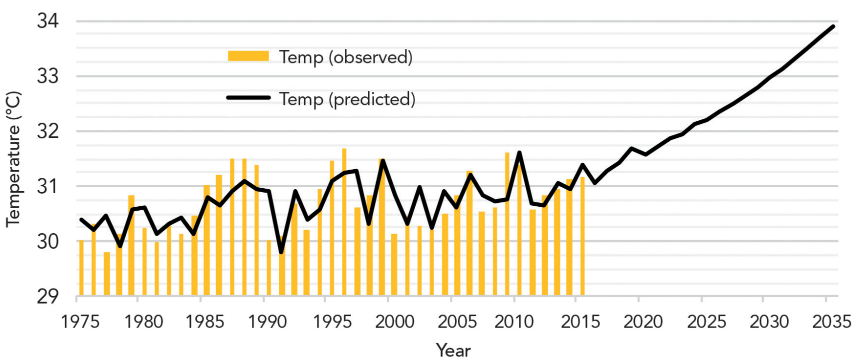


It was found that ARIMA(0,0,1) failed to pass probability test as its probability (> chi^2) value was above acceptable 0.05 (Table 3) range. From the remaining tests, $MA_{(1\ 10)}$ model was found to be the best fit for maintaining lower AIC and BIC values (Table 3). Later, the same $MA_{(1\ 10)}$ model (see model summary in Appendix 2) was applied to forecast temperature to the year 2035 where the previously predicted land covers were input as regressors. The resulting prediction (Figure 6) showed that between 2016 and 2035 the study area is likely to experience a nearly (+)1.52°C increase in mean maximum temperature compared to the 1996–2015 period.

Table 3: Test result of considered temperature (ARIMA) models

Summary	Temperature (1975–2015)		
	$AR_{(1\ 7\ 15)}$	ARIMA(0,0,1)	$MA_{(1\ 10)}$
Number of observations		41	
Probability > chi2	0.0093	0.517	0.0001
AIC	62.20853	55.44885	55.32161
BIC	75.91711	64.01671	67.31661

Figure 6: Observed and predicted temperature (using $MA_{(1\ 10)}$ model) of the study area



5. Discussion

The study area has exhibited a sharply increasing urbanization trend throughout the examined period resulting in rapid land use and land cover change (LULCC).

During 1981-2011 period, population in the Dhaka Metropolitan Development Planning (DMDP) area was found to be growing at an average annual rate of 3.84% as opposed to the country's overall rate of growth of 2.04% (World Bank, 2013) rate. Dhaka's population growth predominantly consists of migrants from rural areas attracted by the advantages of urban life (Hossain, 2008; Islam, 1999; Alam & Rabbani, 2007). In line with the general predictions relating to Dhaka city in respect of climate change vulnerabilities (UN-HABITAT, 2008; Alam & Rabbani, 2007), the study has revealed predicted increases in mean maximum temperature in the period 2016-2035. Such temperature rise may be the consequence of global and regional environmental change as well as local land cover change. To mitigate and adapt to the consequences of climate change or natural disasters, it is important to foresee the probable scenario. This study has communicated information relevant to such probable scenarios based on future urban population, probable land cover changes, and associated temperature (climate) change by 2035 for the DMDP area.

Considering the study's prediction, the expansion of core urban land cover in this area may significantly increase the volume of surface runoff while retentions and water channels (to retain and transfer rainwater to the surrounding outfalls (rivers)) were being depleted or insufficiently maintained. During monsoon (May to October), the level of surrounding rivers remains higher than the city's internal drainage level (Mowla & Islam, 2013). Consequently, the drainage capacity of those rivers reduces, and the city faces severe waterlogging from medium to high showers of rain. Over previous decades the city authority replaced many canals and low-lying runoff channels with roads and other infrastructure developments (Mowla & Islam, 2013). Moreover, illegal encroachment by influential people has led to the disconnection of many water drainage channels, drastically reducing their carrying capacity. Poor management of surface drainage network exacerbates waterlogging which may lead to flooding following prolonged rainfall.

In the light of the study's findings, it is apparent that urban (population) growth management can contribute to minimizing temperature increases in Dhaka city. Dhaka's inexorable growth is the reflection of extreme centralization of decision-making and political authority (Rahman, 2012). In this connection, '*smart growth*' principles (Corrigan, et al., 2004) like limiting outward expansion, encouraging higher density development, promoting mixed-use zoning, revitalizing older areas, etc. can be adopted. This study revealed a comparatively higher population growth rate in peripheral (fringe) areas characterized by sprawl development patterns (Rahman, et al., 2008). Improved governance with strict control and monitoring of the urban area plan, conservation and restoration of protected lands, etc. can reduce loss of climate control sinks e.g. greeneries, open space and waterbodies.

The urban system is a complex mosaic of climate, land use, biophysical, and socio-economic variables. In this study, land cover and climate change prediction work at city scale examined historic observational data and applied linear and time series model respectively. The study's considered parameters are very dynamic in nature and established models are not simple, precise, and always mathematical. Moreover, temperature (climate) change prediction used local parameters only where the impact of anticipated global/regional climate change (IPCC, 2014) on the study area was overlooked. However, it is commonly understood that the worst consequences of ongoing global climate change e.g. extreme weather conditions, seaward hazards, etc. would be felt by low-lying coastal cities like Dhaka (UNU-IHDP, 2015; UNFCCC, 2018). The study has analyzed five datasets to assemble 1975-2015 land cover scenarios, this can be improved by inputting more evidence from intermediate years. The observed mean annual degradation rate of waterbodies has been used in predicting future scenarios, which may vary in practice. Indeed, change in protected lands e.g. waterbodies and public spaces may not follow the observed pattern as their conservation greatly depends on the operational and management efficiency of the local government/authorities.

Urbanization is always accompanied by multiple changes in the socio-economic, cultural and demographic setting (Khoury, 1982). The relationship between socio-economic development and changes in land use that determines LULCC in both urban and rural areas is dynamic (Long, et al., 2007). This study has not evaluated social factors and their dynamics, investigation of these factors would form a valuable focus for future research. Setting aside these limitations, the predictions can still contribute in formulating development guidelines that are responsive to climate change. Concerned city planners and decision makers need to focus on managing the growth of both population and core urban land cover for climate change management of the DMDP area. The study's implications can be employed to mitigate and minimize climate change related negative externalities of Dhaka city notwithstanding any artificial or natural interventions large enough to alter the observed pattern. As a final point, this study may help to understand the underlying dynamism of similar contexts, as well as to quantify the future degree/level of change in maximum temperature for other urban areas.

Appendix 1: Summary of core urban land cover prediction model (linear regression)

Source	SS	df	MS
Model	407937.023	1	407937.023
Residual	1783.30564	37	48.1974497
Total	409720.329	38	10782.1139

Number of obs =	39
F(1, 37) =	8463.87
Prob > F =	0
R-squared =	0.9956
Adj R-squared =	0.9955
Root MSE =	6.9424

Core urban	Coef.	Std. Err.	t	P>t	[95% Conf. Interval]	
Population	29.77811	0.3236775	92	0	29.12227	30.43394
_cons	-84.8169	2.848425	-29.78	0	-90.58836	-79.04544

Appendix 2: Summary of $MA_{(1\ 10)}$ temperature prediction model (time series)

Sample: 1975 - 2015
Log likelihood = -20.6608

Number of obs =	41
Wald $chi^2(5)$ =	27
Prob > chi^2 =	0.0001

Temperature	Coef.	Std. Err.	z	P>z	[95% Conf. Interval]	
Urban_linear	0.0113777	0.031017	0.37	0.714	-0.0494146	0.07217
Potential_urban	0.0059544	0.0379652	0.16	0.875	-0.0684559	0.0803648
Waterbody	0.0111241	0.0295961	0.38	0.707	-0.0468833	0.0691314
_cons	19.49265	49.57308	0.39	0.694	-77.6688	116.6541
ARMA ma						
L1.	1.056285	0.2801433	3.77	0	0.5072141	1.605356
L10.	0.1880118	0.1236563	1.52	0.128	-0.05435	0.4303736
/sigma	0.3658156	0.0871539	4.2	0	0.1949971	0.5366341

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