EVALUATING THE IMPORTANCE OF URBAN WETLANDS IN MONITORING MICROCLIMATIC ENVIRONMENT; A STUDY IN BOLGODA LAKE IN SRI LANKA AND ITS SURROUNDING

Y.M.P.Samarasinghe1 and N.D.K.Dayawansa2

1 Post Graduate Institute of Agriculture, University of Peradeniya, Peradeniya.

Email: priya.samare@gmail.com

2 Department of Agricultural Engineering, Faculty of Agriculture, University of Peradeniya, Peradeniya.

Email: ndkdayawansa@yahoo.com

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ABSTRACT: Urban heat island effect is one of the serious environmental consequences which alter the microclimatic environment of urbanized areas by resulting relatively high air temperature compared to the surrounding non-urbanized areas. Wetlands within urban territory play an important role by regulating the microclimatic environment. This study was conducted in Bolgoda Lake and surrounding Divisional Secretariat Divisions (DSD) located in Colombo District, Western Province of Sri Lanka to identify the land use changes, Urban Heat Island (UHI) distribution, Microclimatic effect of UHIs and the relationship between population distribution pattern and the UHI distribution in 2001, 2005 and 2014. Landsat ETM+ (2001), Landsat TM (2005) and Landsat OLI/TIRS (2014) satellite imageries and population statistics (2001 and 2011) were analyzed with Remote Sensing and GIS techniques. Land use change detection revealed that area covered by paddy and other vegetation have reduced by 30% from 2001 to 2014 whereas densely urban/ construction sites have increased by 60%. A good relationship was identified between urbanization pattern and urban heat island (UHI) distribution while an expansion of heat islands was noticed in 2001, 2005 and 2014. Western side of the Bolgoda Lake and the coastal belt are critically affected by UHI effect resulted by elevated urbanization. It was observed that the land surface temperature (LST) is less closed to the wetland and increases with the distance from the wetland indicating the microclimatic regulation effect of wetlands. Low mean LST values were identified in water bodies and paddy/other vegetation land use classes whereas highest was reported for densely urban/construction sites. The study identified that the population density is increasing over time and the pattern of population density distribution follows the pattern of UHI distribution. Comprehensive analysis of satellite derived LST can be used to demonstrate the impact of urban wetlands on regulation of microclimatic environment and to encourage the protection of wetlands in urban areas.

1. INTRODUCTION

Urban areas are high in solar radiation absorption, thermal capacity and conductivity due to impervious surfaces (Weng and Yang, 2004). This leads to modify the thermal environment that is warmer than the surrounding nun-urbanized areas (Voogt and Oke, 2003) and the resultant area of high air temperature is defined as urban heat island (UHI) (Liu and Zhang, 2011; Prasad, 2012). The UHI effect is noticeably identified at nighttime compared to daytime due to the absorption of a greater amount of shortwave solar radiation at daytime and re-radiation of long waves at nighttime by urban materials such as bricks and concrete (Solecki *et al.*, 2005). Urban Heat Islands create critical environmental consequences such as accelerated pollution levels, modified precipitation patterns and unfavourable microclimatic conditions (Yuan and Bauer, 2007; Thaha, 1997; www.epa.gov). Advancement of thermal remote sensing techniques exposes more opportunities for studies of UHI and urban modifications (Voogt and Oke, 2003).

Urban wetlands provide a range of ancillary benefits to city dwellers; air filtration, micro-climate stabilization, flood and storm protection, groundwater recharge, water purification and recreation (Boyer and Polasky, 2004). Bolgoda Lake and associated vegetation located within the Colombo District of Sri Lanka can be considered as a vital wetland ecosystem which can play a significant role to compensate the UHI effect. This study was conducted with the objective of assessing and mapping the effect of Bolgoda Lake and associated vegetation for compensating urban heat of the surrounding environment.

2. MATERIALS AND METHODS

2.1 Study Area

The study area (Figure 1) includes the surrounding four DS divisions (Dehiwala, Kesbewa, Rathmalana, Moratuwa) of Bolgoda Lake and associated wetland complex.

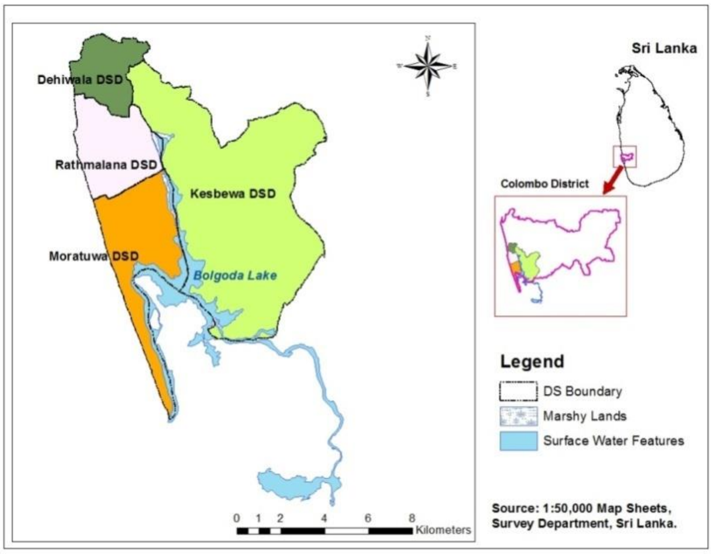

Figure 1: Study Area; Bolgoda Lake and Four DS Divisions (Dehiwala, Rathmalana, Kesbewa, Moratuwa)

2.2 Land Use Classification and Change Detection

Landsat ETM+ (2001), Landsat TM (2005) and Landsat OLI/TIRS (2014) images and population statistics at Grama Niladhari level were used as the data. ERDAS IMAGINE and ArcGIS 10.1 software were used for the data analysis. Land use change assessment was conducted from 2001 to 2014 using classification of remotely sensed data. A combination of Normalized Difference Vegetation Index (NDVI), Normalized Difference Built-up Index (NDBI) and Supervised Classification was used to classify the images.

2.3 Derivation of Land Surface Temperature and Extraction of UHI

In deriving land surface temperature, the at satellite temperature was calculated using equations given in the Landsat 7 Science Data Users Handbook for Landsat TM, ETM+ and OLI/TIRS data. Subsequently, Land Surface Temperature was derived using Equations proposed by Artis and Carnahan (1982) and Weng and Yang (2004). Land surface temperature values were normalized and then the values which are above 0.6 were considered as UHI (Zhao-ming *et al.* (Undated), Ukwattage and Dayawansa (2012)).

2.4 Microclimatic Impact of Wetlands

Multiple buffer zones (50 m) were created for water, paddy and other vegetation to identify the temperature variation with increasing distance from the wetland ecosystem. Surface temperature variation of different land use types was also studied to identify the impact of land use on land surface temperature.

2.5 Comparison of Population Density with UHI

GN division based population density variation pattern was compared with UHI distribution pattern since densely populated areas normally have high building density which can positively contribute to high land surface temperature. 2001 population data was compared with 2001 UHI and 2011 population data was compared with 2014 UHI due to unavailability of same time data for comparison.

3. RESULTS AND DISCUSSION

Wetlands associated with Lakes are fallen in to the group of Lacustrine whereas wetlands along rivers and streams are under the category of Riverine. Paddy lands also can be regarded as a substitute for natural wetland ecosystems due to its ecological service (Natuhara, 2013). Considering above facts, Bolgoda Lake and associated vegetation features and few scattered paddy lands can be considered as wetlands presence in the study area.

3.1 Land Use Change from 2001 to 2014

Figure 2 illustrates the land use of the study area in 2001, 2005 and 2014. Six land use categories were identified namely water, paddy and other vegetation, open vegetation, abandoned paddy/exposed soil, urban and densely urban/ construction sites.

The Western side of the Bolgoda Lake up to the coastline (Dehiwala, Ratmalana and Moratuwa DS Divisions) exhibit a higher degree of urbanization compared to the Eastern side of the lake (KesbewaDS Division) during 2001 to 2014. Kesbewa DS Division is also covered with a considerable extent of constructions and urban land uses in 2014. Expansion of urban area is noticeable along the transportation networks and around cities due to high access for facilities and services.

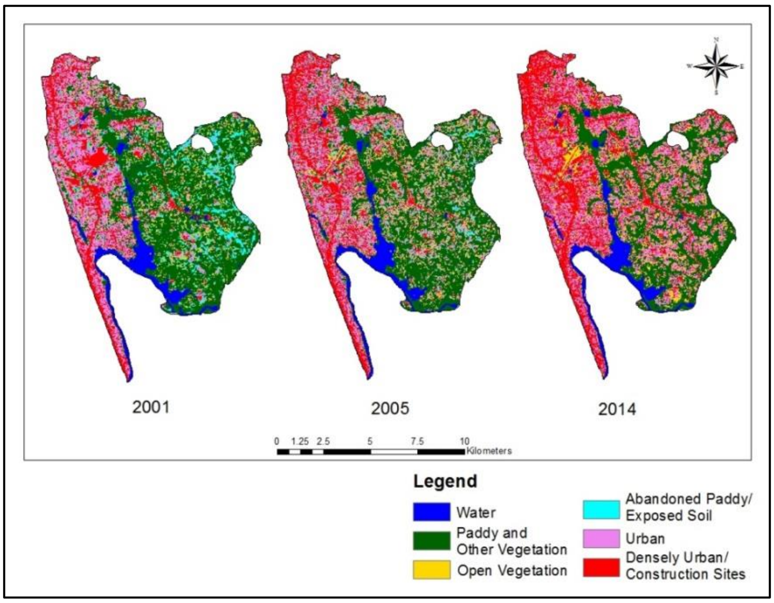

Figure 2: Land Use Distribution of the Study Area (2001, 2005 and 2014)

Figure 3 summarizes the land use changes of the area. Area covered with paddy and other vegetation has reduced by 30% from 2001 to 2014 whereas surface water features are more or less constant. Expansion of highly urban/ construction sites (60%) and urban areas (35%) were identified from 2001 to 2014 (Figure 4). Although abandoned paddy lands can be seen in 2001 and 2005, they have been disappeared in the year 2014 possibly due to restarting of paddy cultivation. Extent of open vegetation class has also increased possibly due to removal of large vegetation. Expansion of densely urban/ construction sites and urban land use collectively can be considered as an indicator of urbanization. The extents of above land use classes have increased by 20% and 58% from 2001 to 2005 and 2014 respectively. Extent of Water, Paddy and Other Vegetation which were collectively considered as the wetland has decreased by 20% and 27% from 2001 to 2005 and 2014 respectively. Figure 5 clearly visualize the changes of urban wetlands from 2001 to 2014.

It is apparent that increasing trend of urbanization and decreasing trend of wetland ecosystems are associated with possible environmental, social and economic uncertainties in the future.

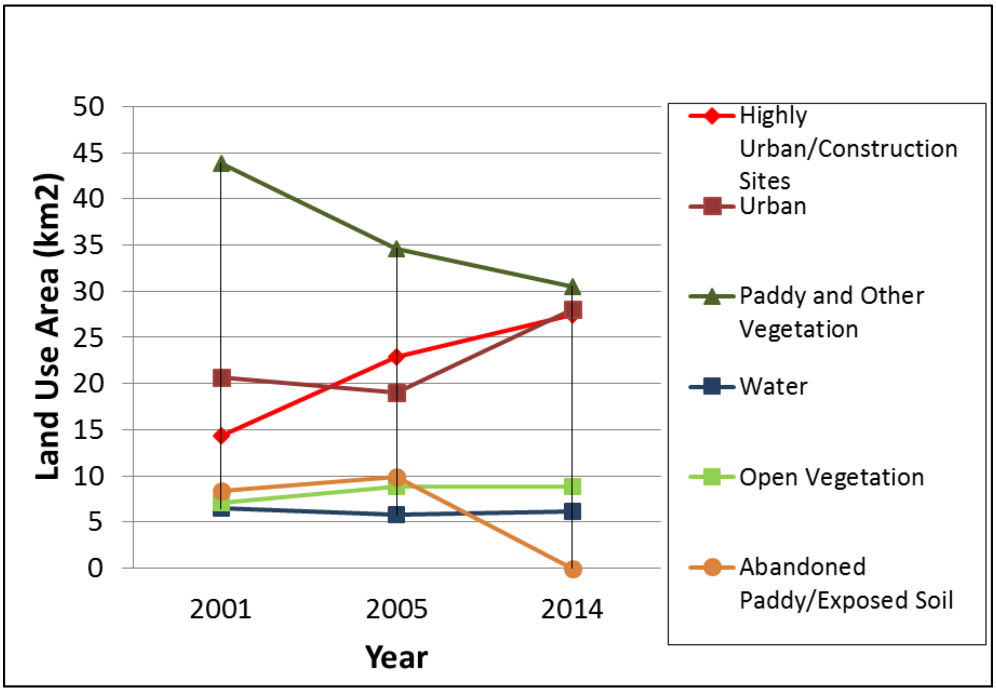

Figure 3: Summary of the Land Use Change (2001, 2005 and 2014)

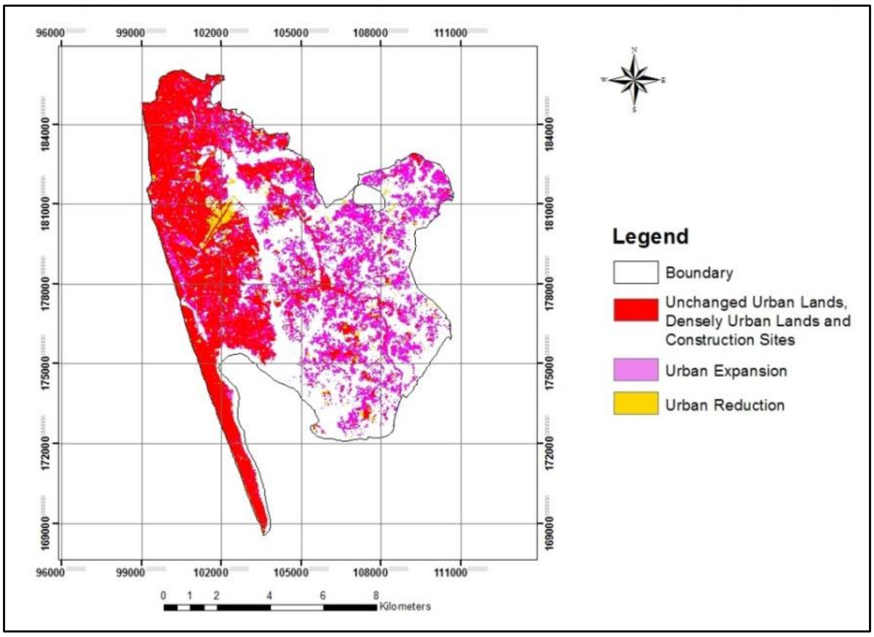

Figure 4: Changes of Urban and Densely Urban Lands/Construction Sites from 2001 to 2014

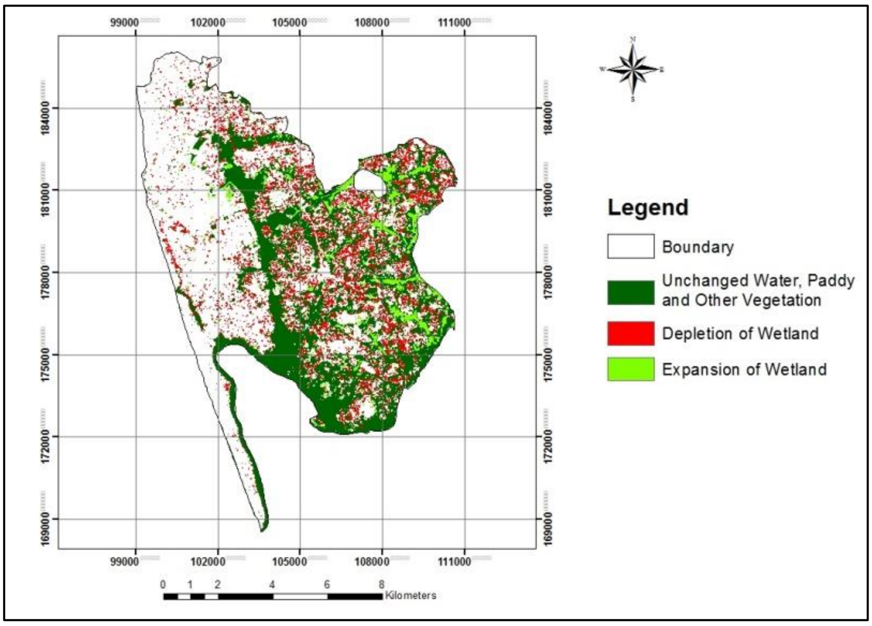

Figure 5: Changes of Water, Paddy and Other Vegetation from 2001 to 2014

3.2 Urban Heat Island (UHI) Distribution

Figure 6 presents the UHI distribution in the study area. Landsat TM, ETM+ and TIRS sensors have varying spatial resolutions of 120, 60 and 100 meters respectively in the Thermal Infra-Red Band which limits the capability of area wise comparison of heat islands. Also the different dates of image acquisition restrict UHI comparison. The pattern of UHI distribution similar to the pattern of urbanization implies that UHIs are correlated with the urbanization. UHI effect is less in the Eastern side of the Bolgoda Lake which belongs to Kesbewa DSD while the western side is critically affected by UHIs. In addition, signs of future expansion of UHIs in the Eastern side are also evident. Rathmalana airport area (A: Kandawala, Attidiya South, Katukurunduwatta and Piriwena GN divisions) is having a comparatively widespread heat islands in 2001 and 2005 due to areas with heavy built up. Though, the condition has changed in 2014 where the heat islands have shrunk possibly due to urban landscaping. Coastal areas also consist with UHIs as a result of high degree of urbanization in all three years. South-Eastern side of Moratuwa Divisional Secretariat Division (B; Villorawatta East, Villorawatta West, Moratumulla North, Moratumulla East, Moratumulla West,Indibedda West, Indibedda East andMolpe GN divisions) exhibits an expansion of heat islands over 2001, 2005 and 2014.

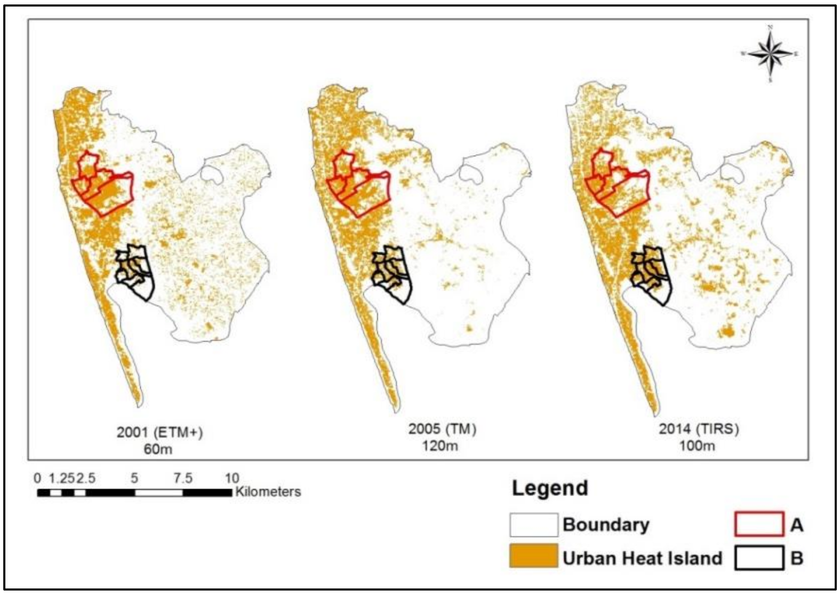

Figure 6: Urban Heat Island Distribution in 2001, 2005 and 2014

This increasing trend of UHI tells that it will make people more discomfort and necessary actions should be taken to compensate the urban heat. High urban temperature also increases the energy demand for air conditioning (Weng and Yang, 2004) which will create an unnecessary economic burden.

3.3 Micro Climatic Effect of Urban Wetlands

For all three years, it was observed that the mean Land Surface Temperature (LST) increases when the distance from the wetland increases. Figure 7 visualizes the above condition based on western and eastern sides of the wetland.
It is an indication that wetlands play an important role in regulating microclimatic environment of urban areas.

Figure 7 clearly illustrates the change of temperature with the distance to the wetland. According to Figure 8 (a) and (b) the temperature of the western and eastern sides of the wetland has become more or less similar after 200m distance. This implies that, when the distance from the wetland exceeds a certain limit the cooling effect resulted by the wetland is neutralized. This is a good indication to encourage the protection of urban wetlands since they can make people more comfortable by regulating micro climatic environment in addition to their common benefits such as flood protection.

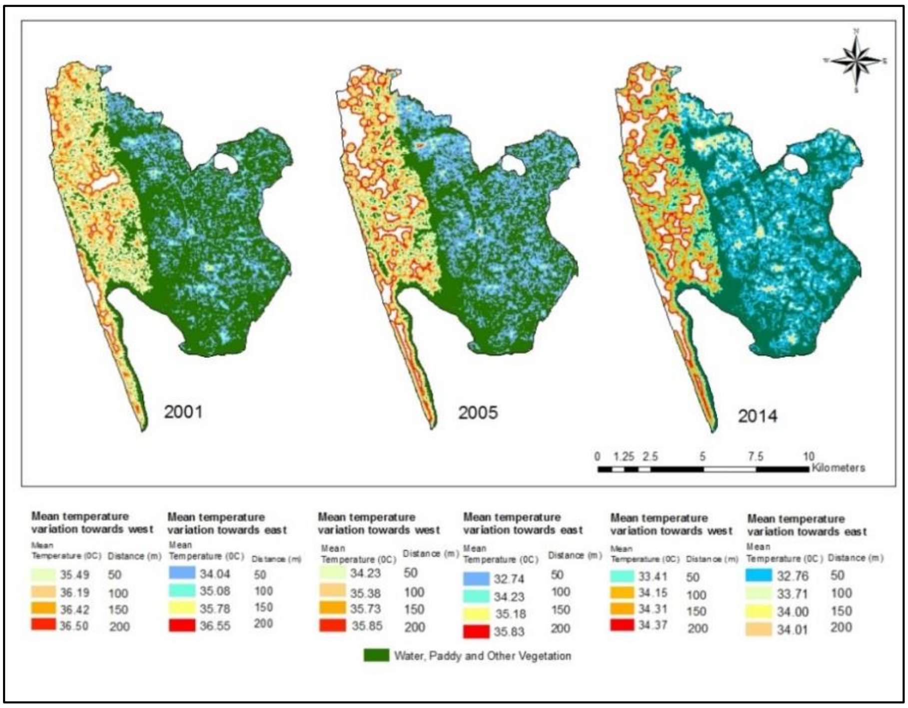

Figure 7: Microclimatic Impact of Urban Wetlands

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3.4 Land Surface Temperature Variation with Land Use

Figure 9 illustrates the mean temperature variation by the land use type. Highly urban/ construction sites account for the highest mean LST which is followed by urban lands and open vegetation. This provides evidence that urbanization and removal of vegetation cover contribute to increase land surface temperature.
Water surfaces account for the lowest mean LST. Second lowest temperature is reported from the paddy fields and other vegetation in year 2005 and 2014. The second lowest temperature for 2001 was identified from abandoned paddy fields possibly due to presence of water. This implies that water and associated wetlands perform a considerable role for the air-conditioning and make urban environment comfortable.

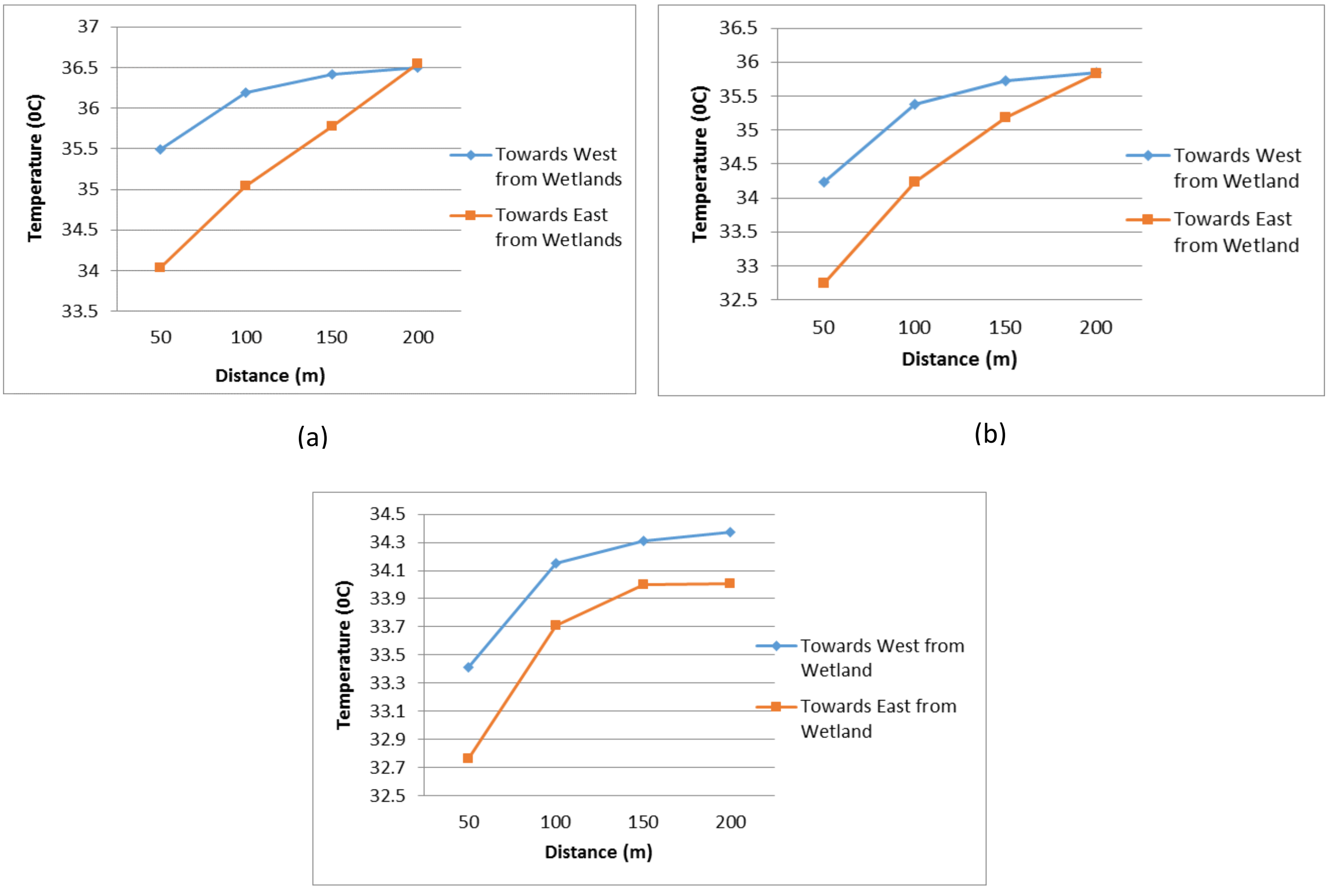

Figure 8: Mean Temperature Variation towards West and East from the Wetland; (a) 2001, (b) 2005, (c) 2014

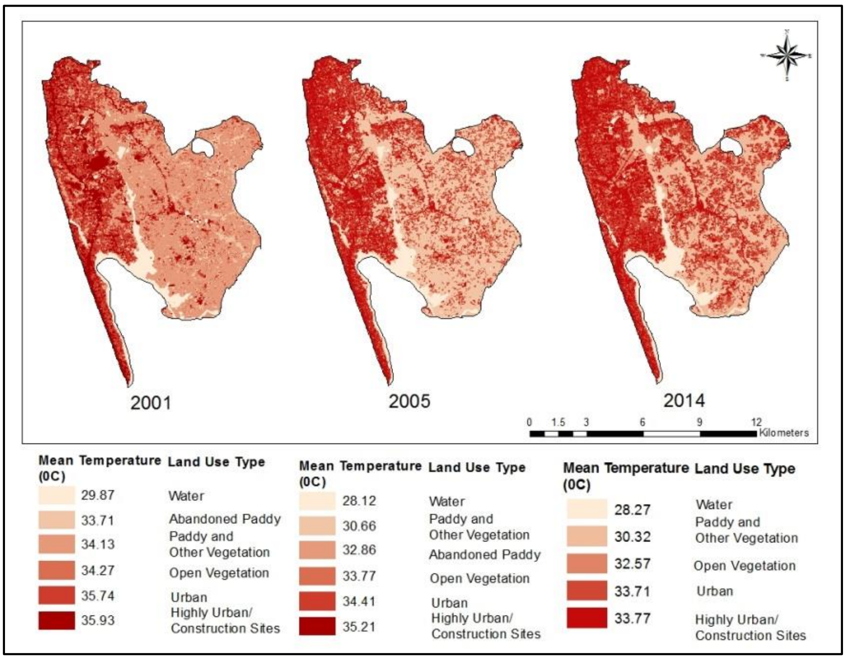

Figure 9: Mean Temperature Variation with the Land Use Type

3.5 Comparison of population density variation with UHI

Figures 10 and 11 depict the population distribution and the distribution of urban heat islands. Both population density and UHIs follow a similar distribution pattern showing a strong correlation between heavy urbanization and condensation of population.

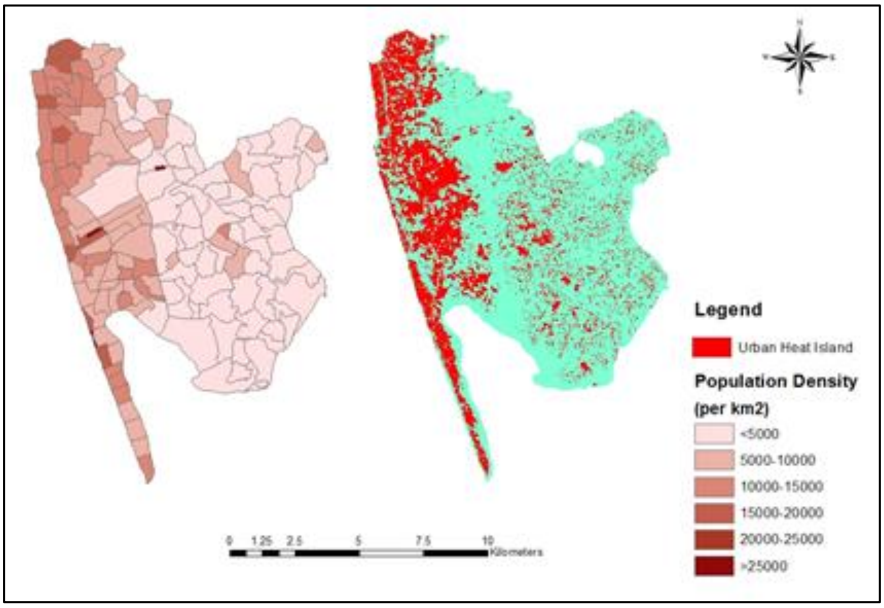

Figure 10: Population Density Urban Heat Island Distribution in 2001

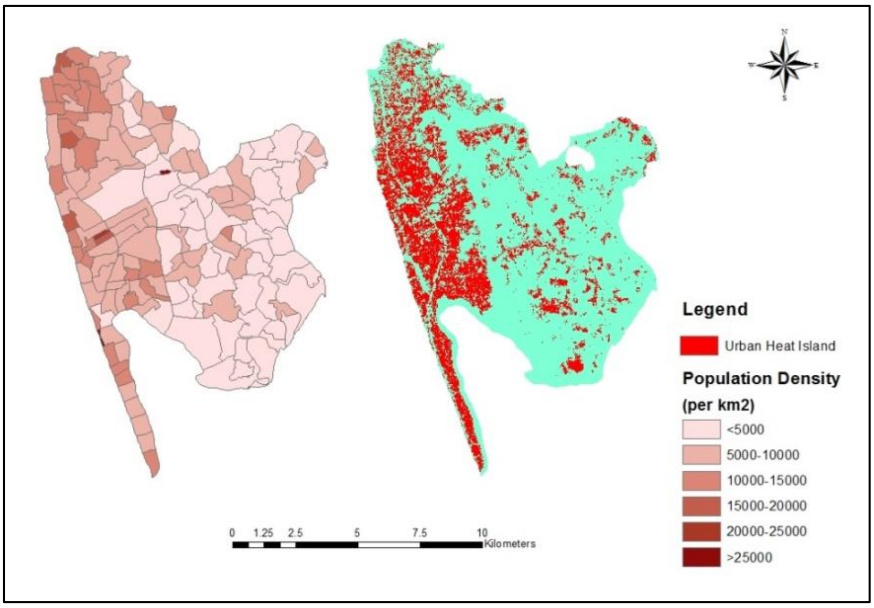

Figure 11: Population Density Urban Heat Island Distribution in 2014

4. CONCLUSION

The study area, Bolgoda Lake and four surrounding DS divisions show an increasing trend of urbanization from 2001 to 2014. According to the land use change assessment in this study area, highly urbanized/construction sites and urban land uses have increased by 58% whereas urban wetlands have decreased by 27% from 2001 to 2014. As a result of urban expansion and reduction of wetlands, Growth of UHI was also examined. Although the western side from the wetland system is severely affected by UHIs, the study identified a trend of expansion of UHIs in the eastern side of the wetland as well. This study revealed that the land surface temperature increases with the distance from the wetland indicating the cooling effect of urban wetlands. The study also identified the temperature variation over land use types where water and vegetation features cause to have lower LSTcomparative to urban land uses. Since, urban wetlands act as air-conditioners by controlling the microclimatic environment, conservation of wetlands is important by imposing strict rules and regulations.

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