Urban Driven Land Use Change Influence on Climate: The Case of Addis Ababa Ethiopia

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ABSTRACT

Detection of land use change is crucial in identifying its impact on urban scale climate and suggesting plausible interventions for sustainable land use management. Temperatures in the central parts of the city (both commercial and residential sectors) are found to be warmer than adjoining areas. The population density considerably influences the minimum temperature change. Future urban climate change projection of urban heat island under emission pathway of A2 and B2 scenario shows that, the nocturnal UHI will be intense in winter or dry season episodes in the city. Under RCP 8.5 scenario the highest urban warming will occur during October to December (0.5 ºC to 1.0 °C) in the 2050s and 2080s.

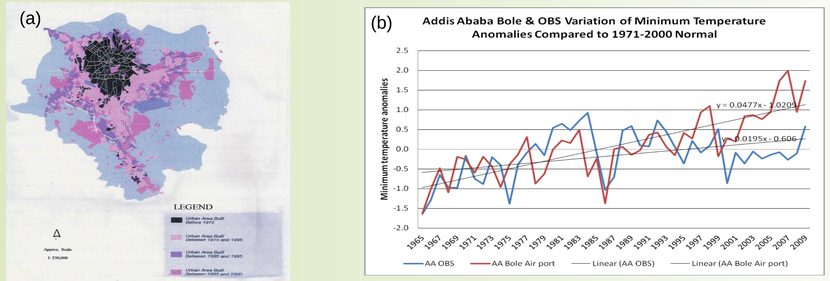

Figure 1: (a) Physical Expansion of Addis Ababa (ORAAMP, 2002) and (b) Minimum temperature anomalies compared to the 1971-2000 mean

Data and Methodologies

Three Land-sat images from Land-sat 5 Thematic Map (TM) were selected. The rate of change was calculated for each type of land use and land cover using the following formula (Carlson and Arthur, 2000):

$$Rate = \frac{(Re - Pr)}{Y}$$

where: *Re* = Recent area of land use and, or cover in km^2, *Pr* = Previous area of land use and, or cover in km^2 and *Y* = interval between *X* and Y in years.

Minimum temperature data from Addis Ababa observatory (OBS) and Bole International Airport (BOL) stations are used for UHI assessment. Wilby et al., (2002) used SDSM to predict future UHI for the city.

$$\Delta T_{u-r} = T_{min}\,OBS - T_{min}\,BOL$$

where, are the daily minimum temperature at the station Addis Ababa observatory (OBS) and Bole Airport (BOL), respectively.

The population density of Bole sub-city is about 2,753 and the corresponding density of OBS station area is about 23,900 inhabitants per square kilometer.

Result and Discussions

• Land Use Change

The built-up area was concentrated in the central part of the city. The 1999 and 2011 land cover maps show an expansion of built-up areas, shrinkage in the forest and agricultural lands in all direction of the city.

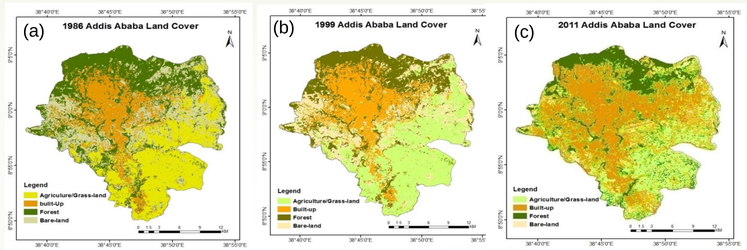

Figure 2. Ababa Land use/Land covers a) 1986, b) 1999 and c) 2011

• Climate and Urbanization

The comparison of the climate data between observed grid and HadGEM2-AO climate model shows generally similar spatial patterns despite difference in the magnitude of the climate variables.

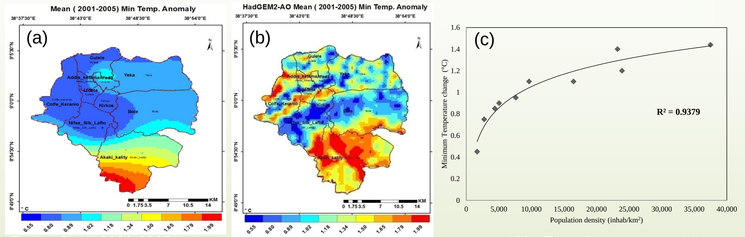

Figure 3 (a) (2001-2005) observed grid and (b) HadGEM2-AO mean annual Min Temp Anomalies and (c) The variation of average (2006–2010) Min Temp change of Addis Ababa (with respect to he base period (1981–2005) mean) with population density at ten sub-cities.

The minimum temperatures increases from 1.02 to 1.99 ºC in the sub-city of Arada, Addis Ketema, Kirkos, southern Gulele, Yeka and Bole). The strong correlation of UHI with population density as indicated in this analysis confirms earlier findings from Oke (1997) and this builds our confidence in the grid observation data.

• Projected change in Nocturnal UHI

Interestingly, weakening of the mean UHI intensity occurs in the rainy season. Also the mean annual future UHI under RCP 8.5 scenario will increase between 0.5 and 1 °C. The RCP 4.5 scenario shows an increase by about 0.2 to 0.5°C. The mean monthly nocturnal urban heat island (UHI) of Bole and OBS stations shows higher UHI in April and reaches 0.4°C

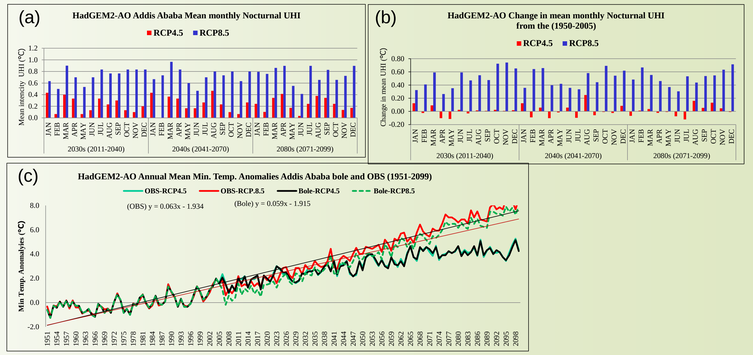

Figure 4 (a) downscaled UHI under RCP4.5 and RCP8.5 for the 2030s, 2050s and 2080s, and (b) change in UHI with respect to base period 1961–2000 c) Addis Ababa Bole and OBS annual mean minimum temperature anomalies (compared to 1951–2000 mean) for the period 1951–2099.

Conclusion

Built-up areas substantially expanded, while forest areas, vegetation covers and agricultural lands exhibited a sharp decline. The observed changes in land covers were largely attributed to urbanization, which also impact on the urban heat island effect. Projected nocturnal heat island shows that, the UHI will be intense in winter (dry seasons). This suggests the need for more urban greening by creating urban city parks and urban trees. The dry season has the highest frequency of hot conditions at both sites of Addis Ababa observatory station and Addis Ababa Bole Airport station, while the wet season recorded the lowest frequencies of hot condition.

References

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