Journal of
Geography & Natural Disasters

ISSN: 2167-0587

Short Communication

Is there a relationship between land surface temperature and ground water availability in the kumasi metropolis?

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Abstract:

Rise in urban temperature due to infrastructure development may require some cool offs that can be attained when trees are present in cities or when water is available for use to cool buildings and human systems. Water availability is therefore important for reliable water supply as a measure to deal with urban heat. Water availability determines the extent to which borehole can be constructed in developing countries such as Ghana. In this study, the Land Surface Temperature of Kumasi Metropolis has been studied over a period of 10 years (2009 to 2019) in comparison to the extent of water availability given the decline in green vegetation cover of the city due to infrastructure development. The objectives of the study were to determine temperature levels in the Kumasi Metropolis from 2009 to 2019 and determine whether there is any correlation between Land Surface Temperature (LST) and water availability. Methods applied to the study were to convert the digital numbers of Landsat 2009, 2015 and 2019 images to radiance, top of brightness temperature and at-sensor brightness temperature. Normalized Difference Water Index (NDWI) was calculated by subtracting the green band of Landsat data from the red band divided by addition of the green band to the red band. Results of the study show rise in temperature over a period of 10 years where parts of the city that had high temperatures of 31°C and other parts had medium to low temperatures of 18° C. NDWI result show high water levels exist at places of high surface temperatures while low water availability exist at places of low temperatures. The correlation between LST and NDWI show a positive relationship. The study concludes that the positive correlation result was not expected as such further research is needed to understand the nature of result obtained.

Keywords: Temperature, water availability, urban, heat, water index

Introduction

MLand surface temperature (LST), is defined as the skin temperature of the land Jeevalakshmi, (2017; Khandelwal et al., (2017) an important parameter for determining atmospheric surface relations and energy fluxes between the ground and the atmosphere. (Bonafoni et al., 2017; Khandelwal et al., 2017). Measurement of LST is done using satellite data or ground based equipments to measure emitted radiations using sensors (Alemu, 2019). Satellite data based LST calculations help explain the relationship between surface temperature on one hand and deforestation, urbanization and desertification on the other hand as there is a close relation between temperature and these end state conditions (Batista et al., 2013). The thermal bands of Landsat TM, ETM+ and Landsat 8 are commonly used data for such environmental analysis (NASA 2015). Although, there are other remote sensing data sources such as MODIS, NOAA- 17/AVHRR and Meteosat-9) the choice of data depends on the benefit to the user (Jakub, et al, 2016). Landsat has been a preferred data for many researchers because of its free availability and relatively moderate spatial resolution that make it possible to investigate land surface temperature patterns and its relationship to different land use types (Jakub et al, 2016).

Not many researches have been done to estimate and monitor environmental and ecological processes such as variations in land surface temperature and its effect on hydrology (Khan, 2015). The Normalized Difference Water Index (NDWI) is an index for determining water availability from Near-Infrared (NIR) and Short Wave Infrared (SWIR) channels of the electromagnetic spectrum that measure vegetation water content and the spongy vegetation canopy (Gao, 1996). The Normalized Difference Water Index (NDWI) is also a method for determining open water features as the presence of water is enhanced in specific spectrums of satellite imageries for analysis (Mcfeeters 1996). The NDWI index has strong absorption ability and low radiation in the visible and infrared range of the electromagnetic spectrum (https://www.sentinel-hub.com/eoproducts/ndwi-normalized-difference-water-index). The measurement of reflected near-infrared radiation and visible green light in the electromagnetic wavelength makes it possible to eliminate soil and terrestrial vegetation features that are not needed for such analysis (Mcfeeters 1996). In other instances physical properties of soil influence soil moisture conditions and extent of water stress depending on whether there is a vegetation cover or not (Gao, 1996). Detection and monitoring of the moisture condition of vegetation canopies over large areas are effectively done using water indicators such as NDWI (Delbart et al. 2005, Jackson et al. 2004).

Deforestation along water bodies such as rivers, streams, dams, lakes and brooks intensify evaporation (Rost, Gerten, & Heyder, 2008). The presence of trees however prevent the sun rays from directly hitting water surfaces to heat up water bodies at high temperature leading to evaporation (Ramachandra et al 2012).

Methodology

Calculation of Land Surface Temperature and NDWI were done by downloading the 2009, 2015 and 2019 images from the website of the United States Geological Survey (USGS) (Table 1). The three images were geometrically and radiometrically corrected Figure 2. These corrected images were sub setted using the shapefile of the Kumasi Metropolitan area and converted to top of atmosphere reflectance and to sensor brightness values.

The theoretical framework for estimating land surface temperature and determination of water availability was done using downloaded Landsat 2009, Landsat 8 Operational Land Imager (OLI) 2015 and 2019 images. The downloaded images were geometrically corrected to reverse displaced pixels that have occurred as a result of variations in sensor positions as the sensors observed the earth due to earth curvature and terrain effects which include relief displacements. The three images were radiometrically corrected by recalibrating pixel values to eliminate errors of sun azimuth, elevation and atmospheric conditions at the time the images were being captured which are considered as noise in the images. Reflected solar energy captured by satellite sensors were converted to radiance for purposes of calculating land surface temperature using the inverse square law. Radiometric re-scalling coefficients provided in the metadata files that came with the images were used to rescale the data to top of atmosphere reflectance. The top of atmosphere brightness temperature was calculated by using the thermal constants contained in the metadata file of the images. The Normalized Difference vegetation Index was calculated using the method of McFeeters, (1996).

Results

Analysis of land surface temperature for Landsat 2009 (Figure 3) show areas of high, moderate and low temperatures. Most of the built up areas have moderate Land surface Temperatures such as KNUST and Anwomaso. Areas of high Land Surface Temperature include Atonsu, Suame, Afrancho, Ohwimase. High land surface temperature exist among settlements along tarred roads and pavements that act as black bodies that absorb much heat and reflects less heat. Low temperature areas are the Agricultural College and Frampong that have lot of tree cover compared to the moderate and high temperature areas.

Discussion

Land surface temperature in 2009 was high for most built up areas such as Suame and Atonsu as there was a steep rise in temperature in 2015 but most parts of the metropolis had moderate Land Surface Temperature over the 10 years period such as KNUST and Agriculture College. Earlier studies in the metropolis using satellite data show evidence of urbanization leading to loss of the city vegetation cover to build up/bare land and concrete surfaces as the city expands, as a result, the LST in 2002 was 24°C which increased to 53°C in 2008 (Appiah, Forkuo, and Bugri, 2017).

Analysis of Normalized Difference Water Index show high water index for areas such as Suame, Atonsu and Kwadaso which were earlier identified as areas of high Land Surface Temperature. There has been an appreciable increase in the water index from 2009 to 2015 but the extent of increase was marginal.

Conclusion

In conclusion the study result showed a study rise in Land Surface Temperature from 2009 to 2015 and a slight increase in temperature from 2015 to 2019 which has contributed to rise in the city temperature. Analysis of correlation between Land Surface Temperature and Normalized Difference Water Index for the period showed a positive correlation result of high land surface temperature over places that have more water index compared to low Land Surface Temperature at areas that are associated with low water index.