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AN ELEVEN YEARS ANALYSIS OF THE SEASONAL DYNAMICS OF URBAN HEAT ISLAND (UHI) INTENSITY (2004-2014)

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ABSTRACT

Urban heat island (UHI) intensity is the characteristic warmth of both the atmosphere and lithosphere in urban areas compared to its rural surrounding areas. This study observed the seasonal dynamics of UHI in Coventry city. ArcGIS was used to collect the land surface temperature (LST) of different seasons; summer, autumn, spring and fall using the peak month to represent each season. These data was collected during the night times to avoid cloud cover and limit other impeding factors for accurate data collection and results. The data was collected for a period of 11years that is 2004-2014. The study revealed that there was no regular pattern of UHI across the four seasons, however, it was discovered that there was a marginal increase in temperature in some regions during the seasons. To mitigate UHI effects this study recommends the planting of trees to moderate the microclimate as well as the use of green roofs to absorb more of CO_2 thereby modifying and regulating the climate.

Contribution/Originality: This study contributes to the existing literature on urban heat Island Intensity. Using ArcGIS and land surface temperature, the study observed the seasonal dynamics of UHI intensity in Coventry City with a marginal increase in temperature in some seasons; it therefore recommends the planting of trees to moderate the climate.

1. INTRODUCTION

Urban heat island (UHI) was first described in the 19th century by Luke Howard in the 1810s to be precise, he defined UHI as a change and increase in temperature in the urban area over its surrounding areas (Howard, 1818). According to Stewart and Oke (2012) the term urban heat island was first coined in the 1940s (Balchin & Pye, 1947). Urban areas are growing rapidly of which half of the world's population has migrated to live in urban areas due to quest for a better living, although a city occupies just 2% of the earth's surface (United Nations (UN)-Habitat, 2007). Land surfaces that were once moist and permeable have now become dry and impervious, thereby making the urban areas warmer than its surrounding areas (Voogt, 2004). With the rapid increase in population, under optimal environmental conditions, UHI may attain a high temperature of 10-15°C (Oke, 1973). The following cities around the globe documented the impact and effect of UHI.

In the USA, between year 1951-2000 the UHI has been 0.05°C (Environmental Protection Agency, 2016). According to EPA many US cities have air temperature of about 5.6°C warmer than the surrounding natural land

cover. Findings by Debbage and Shepherd (2015) estimated the UHI of the 50 most populous cities in USA. Their findings indicated a 10% increase of urban spatial contiguity which might increase UHI intensity by 0.3 and 0.4°C.

The UHI of Brussels the capital of Belgium was examined by Lauwaet et al. (2015) for 2000-2009 and projected 2060-2069, results obtained shows that UHI has impact on temperature especially during the night as the mean night time UHI of Brussels is accounted to 3.15° C between 2000-2019 and it is expected to be more frequent in the future although with a small change in magnitude.

A great city called Stuttgart in Germany a city located at 240m above sea level with surrounding hills of about 500m. This topography worsens the UHI effect as well as the quality. The city is prominently known for industrialisation as a result faced with the challenge of air quality. Study by Climate- ADAPT (2015) projected that the mean temperature will be increased by 2° C by 2071-2100 and by 2100; the great Stuttgart region will experience more than 30days heat stress. To curtail this, Environmental Protection Agency (2016) highlighted cold production systems; the most important cold production green infrastructure area is located near the western part of Stuttgart with a surface area of about 1000 ha. One important role of this climate buffer is that it is connected to the cities of Leonberg, Sindelfingen, Vaihingen and Boblingen.

According to Kershaw, Sanderson, Coley, and Eames (2010) the UHI effect in the UK cities is estimated to have large UHIs in the summer although not in every city. Small cities like Leicester and York, the UHIs are small and do not vary in seasons. The annual average UHIs for different cities in the UK ranges between 0.1-1.9 ° C whereas in the summer period between 0.1 and 2.0 ° C. in London for instance since the 1960's, UHI in spring and summer season, has increased approximately 0.12 ° C per decade and it is projected to increase by 0.26 ° C by 2080 (Wilby, 2003).

In the urban areas, materials like roofs and impervious surfaces can be about 27-50 ° C warmer than air temperature in the dry sunny days, while in the rural areas where it is shaded and moist it can remain close to air temperature (Sailor, 2002). Furthermore, Sailor (2002) stated that air temperature in urban areas can be as high as 12°C warmer than its surrounding areas or rural areas. Oke. (1982) observed, UHI displays a paradox diurnal behaviour although increase in air temperature is more evident at night. Skin temperature which is referred to the temperature of the outermost surface of the body is said to be higher during the day but lower at night while air temperature is said to be higher at night but lower during the day (Huang, Li, Zhao, & Zhu, 2008). Unger, Sümeghy, and Zoboki (2001) identified that temperature has been the main climatic parameter to distinguish between the micro climate of an urban area and its neighbouring surroundings or rural surroundings which was agreed by Shashua-Bar and Hoffman (2002) that this phenomenon has been well studied and was found to be the typical thing around the world.

According to Quattrochi et al. (2004) UHI develops when natural and moist surfaces are being replaced with impervious urban materials that absorb solar radiation during the day time and re-emits during the night times. As cities grow, they tend to convert the natural habitat to urban habitat by cutting down of trees for building, the innovations of new technologies such as cars, phones etc. electricity generation thus results to increase in air temperature. The increase demand of energy to run these technologies emits greenhouse gases which are known to be contributors to global warming and climate change. Studying Coventry City, this paper aims to analyse the seasonal variation of UHI over 11years in order to ascertain the pattern that exists in this city as it runs through four major seasons that is spring, autumn, winter and fall.

2. METHODS AND DATA COLLECTION

Coventry city is located at the south-eastern corner of the west midland, United Kingdom as shown in figure 1.0. It has a land area 98.64km² and its geographic position is latitude N52.4 and a longitude of W -1.5 (Met Office, 2015). Coventry has a population of about 308,313 people and is surrounded by the west midlands. This has inhibited Coventry from expanding into the administrative region of Warwickshire and the municipality of Solihull.

Coventry has a maritime climate with mild winters. The extreme temperature documented in Coventry ranges from − 18.2ºC in February 1947 to 35.1ºC in august 1990m while the lowest temperature recorded lately was − 10.8ºC in December 2010 (Met Office 2015).
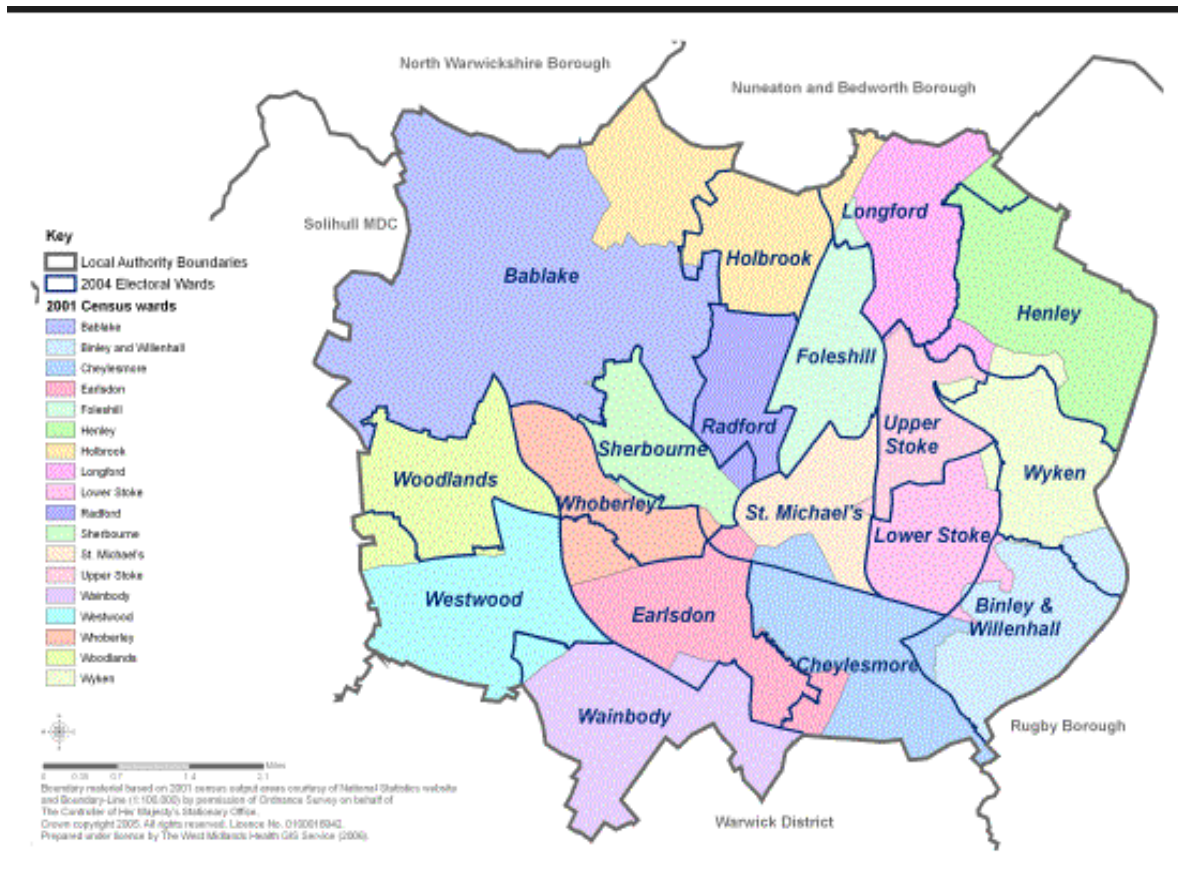
2.1. Study Area

Figure-1. Showing the map of Coventry city.

Source: DPHE Birmingham (2004).

2.2. Data Collection

MODIS/TERRA Land Surface Temperature/Emissivity Daily level 3 global 1km SIN Grid 005 product was employed in this research. MOD11A1 (005) which comprises of 1km pixel generates daily products through the spilt-window LST algorithm. Spit-window LST algorithm was applied to separate atmospheric column water and the air surface temperature into controllable sub-ranges. Data collection was made from Reverb/Echo platform a component of National Aeronautics and Space Administration (NASA) and System Data and Information System (EOSDIS). MOD11A1 v005 version was selected for this study compared to other versions such as v004 and v041, v005 products is refined and has led to improved spatial analysis as well, has enhanced precision and stability of MODIS LST products as agreed by Peng and Li (2009) study and it is further illustrated in Figure 2.

Figure-2. Illustrates bounding box of Coventry on reverb/echo platform.
Source: Reverb/Echo (2015).

The HDF format of MOD11A1 data was downloaded from the NASA platform and was uploaded into ArcGIS for data processing. ArcGIS, a software in the geographic information system (GIS) software used for creating and analysing maps, data processing and data analysis, data acquisition (Esri, 2015). This software was used in this study because of its ability to display HDF File and the conversion of raster data to the American Standard Code for information interchange (ASCII) data. The LST data was collected between 22:00:00 to 23:00:00 from year 2004 t0 2014. The time interval was selected because UHI effect is stronger at the night times (Oke., 1982) especially between the hours of 3 to 5hours after sunset (UCAR, 2015). Four selected months of the different seasons in Coventry was used. The selected months were April (spring), July (summer), September (autumn) and December (winter). In addition, Karl, Diaz, and Kukla (1988) suggested that night-time LST data is acquired during the absence of solar radiation and interaction at night.

2.3. Data Processing

The downloaded HDF data from Reverb/Echo platform was transferred to ArcGIS for data processing. ArcGIS divided the HDF data to eleven sub datasets. The sub dataset 4(1200 x1200) LST night 1km MODIS Grid Daily 1km LST was selected because of it is in 16bits and was recorded at night.

Figure-3. Showing Sub dataset 4 of the HDF data on July 15th, 2006.
Source: Reverb/Echo (2015).

To discern the cloud cover in Coventry City, an outline image of Coventry City as superimposed in the Figure 3 shows that there is the presence of cloud as the white part indicates the presence of cloud. Figure 4 deduced that individual pixel value can be derived from the imagery by clicking on each pixel and recording the value, in this study Arc Toolbox was used to convert the raster data to ASCII data, and the data was copied to excel spread sheet for analysis.
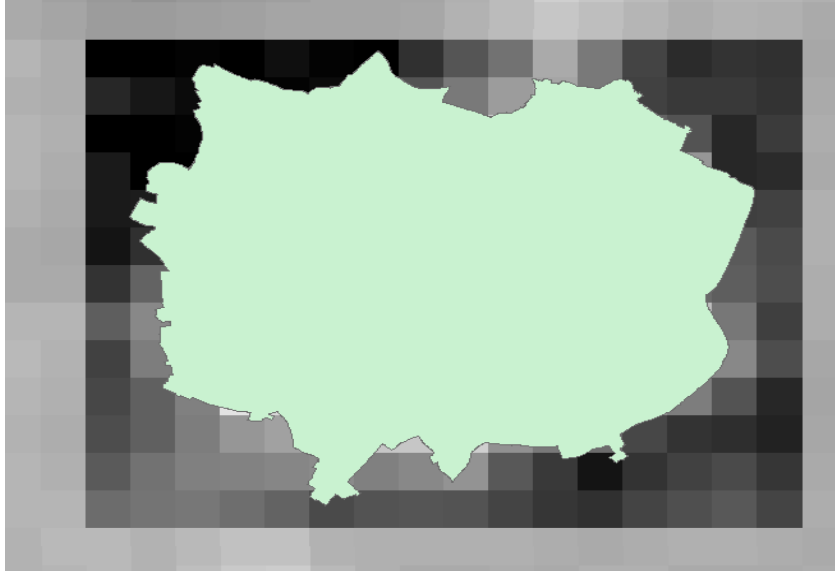

Figure-4. Pixels of the Coventry outline after the clipping process.
Source: Reverb/Echo (2015).

2.4. Data Analysis

Each cell in the excel spread sheet represents a pixel as shown in Figure 4. To convert pixel values to kelvin, it was multiplied by scale factor of 0.2. This is because data was collected in the time.

SDS Name	Long Name	Number Type	Unit	Valid Range	Fill Value	scale factor	add offset
LST_Day_1km	Daily daytime 1km grid Land-surface Temperature	uint16	K	7500-65535	0	0.02	0.0
QC_Day	Quality control for daytime LST and emissivity	uint8	none	0-255	0	NA	NA
Day_view_time	(local solar) Time of daytime Land-surface Temperature observation	uint8	hrs	0-240	0	0.1	0
Day_view_angle	View zenith angle of daytime Land-surface Temperature	uint8	deg	0-130	255	1.0	-65.0
LST_Night_1km	Daily nighttime 1km grid Land-surface Temperature	uint16	K	7500-65535	0	0.02	0.0
QC_Night	Quality control for nighttime LST and emissivity	uint8	none	0-255	0	NA	NA
Night_view_time	(local solar) Time of nighttime Land-surface Temperature observation	uint8	hrs	0-240	0	0.1	0

Figure-5. Showing SDS datasets and their corresponding scale factors.
Source: Wan (2006).

For the four seasons, from 2004 to 2014 the average of each pixel was calculated. The UHI intensity was calculated by subtracting the mean value from the pixel values of the eleven years. The conditional formatting tool of excel was used to convert the spread sheet to a heat map. A heat map is a two-dimensional presentation of data; it uses colours to display relationships in a set of data thereby making it easier to visualize patterns. The colour scale

used in this study was yellow, green and red. Where yellow represents mild or moderate areas, green represents colder areas and red represents the hotter areas. Further analysis was made where a cross-sectional graph was plotted in order to understand the pixel value trend across each season and year. Mid-section values in each heat up were represented on the graph. For better analysis, all individual yearly graphs for each season were super-imposed to one graph. After cross-sectional analysis and heat map, observations shows from the heat maps that some pixel values were high across all seasons. For clearer investigation, the shape outline of Coventry and a MOD11A1 HDF file were uploaded into ArcGIS platform. The use of Google earth was employed to identify the area that displays some marginal increase and Google earth was used to examine some historical images of the place this was done to identify the surface characteristic and to determine if there is a correlation between land surface features and a margin in temperature change either increasingly or decreasingly.

2.5. Results and Discussions

For clearer analysis, results were analysed separately using heat maps and cross-sectional line graphs. As mentioned in fig 2.4, data was obtained from Reverb/Echo platform a component of National Aeronautics and Space Administration (NASA) and System Data and Information System (EOSDIS). MOD11A1 v005 version was selected for this study compared to other versions such as v004 and v041, v005 products is refined and has led to improved spatial analysis.

Heat Maps Analysis for the Spring Season

5.867273	5.66	5.630909	5.134545	5.185455	5.563636	5.629091	5.627273	5.030909	4.96	5.885455	5.725455	5.309091	6.18	6.547273	6.621818
6.189091	6	5.463636	5.267273	5.403636	5.889091	5.530909	5.761818	5.812727	5.992727	5.934545	5.68	5.572727	5.265455	5.5	5.554545
5.572727	5.26	4.845455	5.165455	4.874545	5.383636	5.185455	5.854545	6.312727	6.572727	6.245455	6.012727	5.905455	5.174545	6.481818	5.378182
5.743636	5.218182	4.778182	5.214545	4.978182	5.063636	5.458182	5.710909	6.230909	6.514545	6.501818	5.976364	5.790909	5.792727	5.730909	5.036364
5.305455	4.972727	5.087273	5.034545	4.852727	4.62	4.658182	5.845455	6.043636	6.36	6.234545	5.469091	5.298182	5.427273	5.183636	4.594545
5.434545	4.925455	4.749091	5.032727	5.1	5.076364	5.501818	5.850909	6.312727	6.347273	6.236364	5.656364	5.46	5.234545	4.938182	4.736364
5.341818	5.12354	5.334545	5.587273	5.54	5.396364	5.176364	5.723636	6.238182	6.318182	6.263636	6.234545	5.965455	5.338182	5.092727	5.16
5.123636	4.894545	5.765455	5.749091	5.438182	5.152727	5.194545	5.861818	6.06	6.038182	5.961818	6.116364	6.045455	5.703636	3.607273	5.074545
4.616364	4.229091	4.767273	5.076364	4.976364	4.772727	5.021818	5.683636	5.652727	5.627273	5.589091	5.48	5.683636	6.107273	5.698182	5.298182
4.510909	4.187273	4.461818	4.985455	5.050909	4.703636	5.187273	5.658182	6.065455	5.849091	5.427273	5.4	5.705455	6.016364	5.492727	5.405455
4.212727	4.329091	4.54	4.385455	5.029091	4.701818	5.123636	5.074545	5.174545	5.141818	4.716364	4.965455	4.769091	4.583636	4.941818	5.32
4.352727	4.643636	4.507273	4.32	4.369091	4.694545	4.776364	4.556364	4.598182	4.858182	4.818182	5.116364	4.8	5.185455	5.2	5.194545
4.38	4.205455	4.189091	4.429091	4.354545	4.196364	4.68	4.58	5.043636	5.347273	5.245455	4.969091	4.625455	5.089091	5.649091	5.452727

Figure-6. Showing the heat map for April 2004.

Source: Reverb/Echo (2015).

As observed in Figure 6, it shows that April 2004 had the highest temperature over the period of 11years; with 6.57 kelvin being the maximum pixel value above temperature for the season. Between the year 2005 and 2006, there was a significant drop in temperature with the value of 0.84 as the highest value within the period of two years. In the following year as shown in Figure 7 there was an instantaneous increase in temperature with a maximum pixel value of 6.24 in 2007. The next 3years that is 2008, 2009 and 2010 experienced cooler temperatures having a pixel values as low as -5.67 in the year 2008. The year 2011 had a pixel value as high as 4.08 kelvin while 2012 had a cool pixel value as low as -8.21 which was the lowest temperature of the 11 years. This led to a drop of 14.21 kelvin between the highest pixel (6.57) in 2004 and the lowest pixel value (-8.21) in 2014. Figure 6 deduced that the spring season over the 11year period is undulating in pattern. This is as a result of a rapid decline and increase in pixel value with the interval of 2-3years.

4.147273	3.82	4.350909	4.454545	4.665455	4.403636	4.589091	4.807273	5.050909	5.2	5.205455	4.945455	5.069091	6.08	6.247273	6.041818
4.929091	4.1	4.343636	4.547273	4.583636	4.709091	4.710909	5.001818	5.212727	5.552727	5.194545	4.74	5.512727	5.545455	5.24	4.994545
5.272727	4.74	4.845455	4.805455	4.714545	4.763636	4.905455	5.094545	4.932727	5.152727	5.225455	4.672727	5.305455	4.794545	6.121818	4.758182
5.043636	5.078182	5.058182	4.994545	4.758182	4.783636	5.098182	4.670909	4.790909	4.874545	4.901818	4.916364	5.050909	4.632727	4.810909	4.376364
5.085455	4.872727	4.887273	4.954545	4.692727	4.6	4.838182	4.645455	4.563636	4.6	4.554545	4.809091	4.918182	4.927273	4.623636	4.734545
5.534545	5.205455	5.049091	4.832727	4.66	4.756364	4.761818	4.570909	4.352727	4.327273	4.216364	4.496364	4.72	4.674545	4.438182	4.756364
5.901818	5.897621	4.974545	5.027273	4.72	4.416364	4.676364	4.823636	4.398182	4.318182	4.463636	4.554545	4.565455	4.198182	4.372727	4.62
5.263636	5.734545	5.305455	4.869091	4.678182	4.592727	4.754545	4.741818	4.56	4.658182	4.781818	4.576364	4.665455	4.103636	2.627273	4.634545
5.116364	5.189091	5.327273	4.976364	4.736364	4.572727	4.861818	4.803636	4.752727	4.687273	4.909091	4.98	5.183636	4.767273	4.798182	4.638182
5.210909	4.887273	5.261818	4.845455	4.610909	4.343636	4.787273	4.878182	4.665455	4.669091	4.707273	5.04	5.405455	5.116364	5.232727	5.305455
4.872727	4.689091	4.86	4.785455	4.689091	4.401818	4.683636	4.434545	4.634545	5.101818	5.096364	4.965455	5.089091	5.183636	4.941818	4.24
4.632727	4.523636	4.567273	4.72	4.469091	4.274545	4.516364	4.656364	4.398182	4.638182	4.958182	4.916364	4.58	4.545455	4.36	3.954545
4.42	4.305455	4.129091	4.429091	4.314545	4.236364	4.14	4.26	4.103636	4.187273	4.225455	4.289091	4.125455	4.049091	3.869091	3.772727

Figure-7. Showing heat map for April 2007 spring.

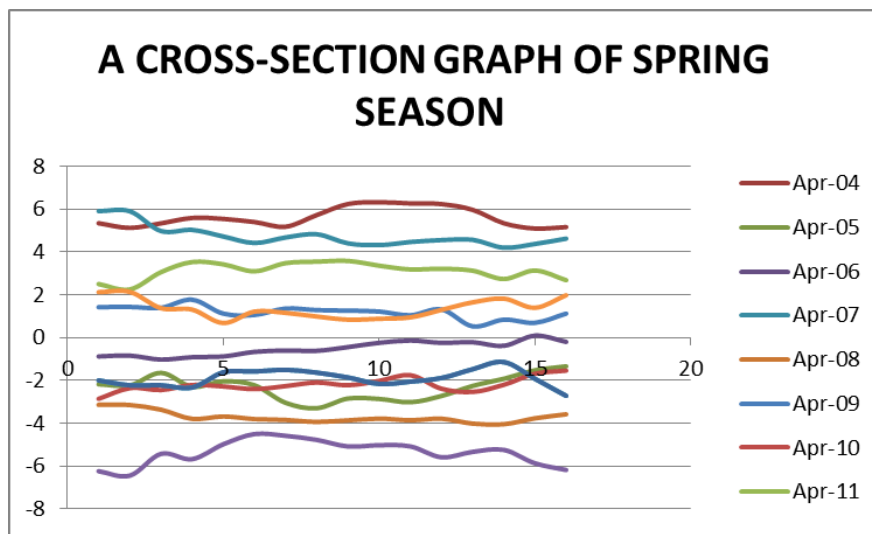**Figure-8.** Showing the cross-section graph for spring season.

As illustrated in Figure 8, the dominance of lower values over 2005 shows that although it had lower values, the coldest year was 2004 as shown in Figure 9. It was also observed that 2012 had the coldest spring season while 2006 had a moderate temperature due to its proximity on the neutral line on the graph. The year 2009, 2011 and 2014 had temperature value of 0-4 and the year 2005, 2006, 2010, 2011 and 2013 had a temperature value between 0 and -4.

Heat Maps for The Summer Season

-1.09273	-1.29091	-1.57273	-1.41455	-0.83455	-0.92727	-1.03091	-2.92727	-3.31636	-3.48727	-3.96364	-4.10182	-3.83455	-2.26364	-2.26727	-2.04727
-1.14182	-1.07455	-1.52	-1.30727	-1.62	-2.25455	-2.58364	-3.06182	-3.47636	-3.61455	-3.77091	-3.69818	-2.82545	-2.58909	-2.45091	-2.29273
-1.07636	-1.18	-1.28	-2.01636	-2.74364	-2.54364	-2.79455	-3.43636	-3.75818	-3.70727	-4.01818	-3.49455	-3.04	-2.44182	-2.08	-2.05636
-1.22727	-1.26727	-1.25636	-2.78727	-2.68545	-2.43636	-2.76727	-3.48909	-4.04545	-3.98545	-3.68	-3.20182	-3.13636	-2.83455	-2.10182	-1.64545
-0.74182	-2.81091	-2.83273	-3.05273	-2.73818	-2.62	-3.31818	-3.96909	-3.42727	-3.19818	-2.91818	-2.53091	-2.68909	-2.45636	-1.77273	-1.11091
-0.67091	-0.76909	-1.42364	-1.83455	-1.98545	-2.01455	-2.41818	-2.84182	-2.14545	-1.93818	-1.76545	-1.68727	-2.15091	-1.86727	-1.28364	-0.83455
-0.71455	-0.55455	-2.01455	-2.45455	-2.51636	-2.48909	-2.64182	-2.83636	-2.31091	-1.92182	-1.68727	-1.38727	-2.02545	-2.03818	-1.61091	-1.02727
-0.48	-0.76364	-0.33091	-2.16182	-2.24364	-2.60182	-2.60545	-2.88364	-2.35455	-1.82727	-1.52727	-1.28364	-2.15455	-2.08	-1.27818	-0.76182
-3.29273	-2.98545	-3.24364	-3.85455	-3.97273	-3.80909	-3.90364	-4.46545	-3.29818	-2.67455	-2.33091	-2.19636	-2.12182	-2.21636	-1.4	-1.09818
-3.27091	-3.33273	-3.63636	-4.12545	-4.00364	-4.12545	-2.54727	-2.57636	-2.67636	-2.54182	-1.93636	-1.65818	-1.80364	-1.60909	-1.09091	-0.85091
-3.67818	-3.45455	-3.30364	-3.54727	-3.77636	-3.58545	-2.82909	-2.9	-3.07273	-2.68545	-2.23091	-2.14	-1.79091	-1.52727	-1.16727	-0.99818
-3.32727	-3.17818	-3.23273	-3.35455	-1.79455	-1.93818	-2.01273	-1.91091	-2.28182	-2.06545	-1.72909	-1.56909	-1.30727	-1.36364	-1.11091	-0.94
-3.06364	-2.96182	-3.15091	-3.23455	-3.32909	-3.26	-2.73636	-1.73455	-1.90727	-1.88727	-1.57455	-1.52545	-1.45273	-1.59273	-1.35818	-1.09818

Figure-9. Heat map for summer season July 2004.

2.5.1. Heat Maps for the Summer Season

In the year 2004, the temperature during the summer seasons was as low as -4.46 kelvin and was recorded at its smallest pixel value. In 2005 and 2006 there was a gradual increase in temperature in the earth surface. Although in 2007 there was a decrease in temperature and 2008 there was an upsurge in its pixel values. For the next three years, there was a decline in temperature with 2010 being the coldest as it recorded -9.5 being the lowest pixel value. In 2011 a slight rise in temperature was observed with a continuing trend until 2014, bearing in mind that an increase in temperature occurred between year 2005 and 2006.
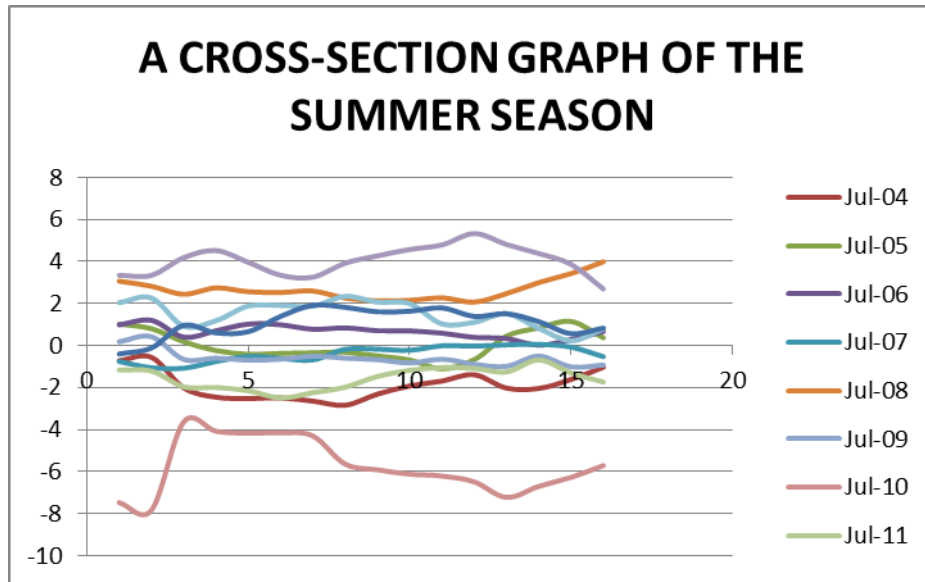
Figure-10. Showing cross-section graph for the summer season.
Source: Reverb/Echo (2015).

As shown in Figure 10, the year 2010 was the coldest summer as there was an increase from -7.4k to -5.7k. In 2008 there was a slight increase while in 2004 the temperature was fluctuating in pattern. A steady pattern was observed in the years 2005, 2006, 2007, 2009, 2011 and 2012. Over the period of years, it was deduced that the warmest summer was in 2012 because of its high pixel values in temperature.

Heat Maps of the Autumn Season

Figure-11. Showing September 2004 heat map for the autumn season.
Source: Reverb/Echo (2015).

The heat map shows a drop in temperature between 2004 and 2005. From 2006 to 2008 there was a decreasing trend change and an increase in pixel values. In 2009, LST values reduced and increased in 2010 although no major increase in 2011. There was a consistent increase in the pixel values from 2012-2014 respectively. It can therefore be said that, autumn season displayed an inter-annual fluctuation meaning an increase and decrease in the LST

values. Between 2005 and 2006, this trend was observed between 2005 and 2006 and it was more obvious from 2012 to 2014. In the year 2008, it was seen to experience the warmest autumn among other years while 2005 experienced the coldest autumn. This is as a result of the dominance of high pixels values and low pixel values in the two years respectively.
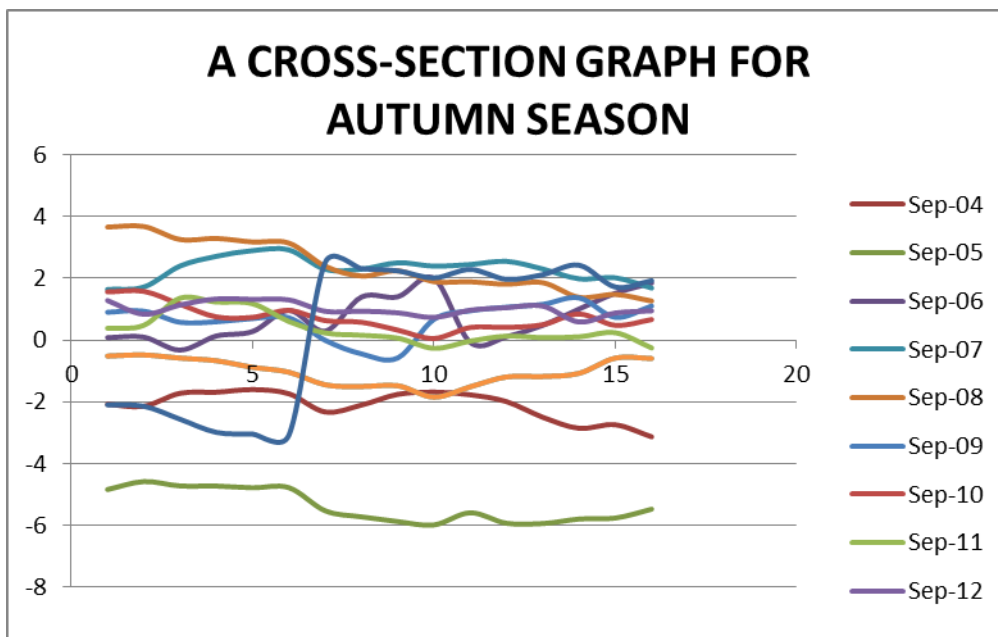

Figure-12. Cross-section for the autumn season.

Source: Reverb/Echo (2015).

A sharp rise in temperature in the year 2014 was observed as shown in Figure 12 with a temperature of about -3.07 to 2.5kelvin with a slight decline to 1.9k. In the year 2005, it was observed to be the coldest; there was a further decline in the pixel values. 2008 was the hottest year experiencing a slight drop in temperature with no significant change in 2013 with its fluctuating pattern. There was a slight drop in temperature in 2004 and a great change observed from 2009 to 2012 respectively.

Heat Maps for the Winter Season

-0.11636	-0.20909	-0.42364	-0.78909	-0.62182	-0.61636	-0.86364	-0.88909	-1.31818	-1.28364	-1.24182	-1.20182	-1.48727	-1.46727	-1.79818	-1.41273
0.16	0.174545	-0.06364	-0.57818	-0.34545	-0.53273	-0.81636	-0.92727	-1.02	-1.45455	-1.32182	-1.15636	-1.56727	-1.48182	-1.48727	-1.58364
-0.04545	-0.55636	-0.66727	-0.62182	-0.50909	-0.40909	-0.60727	-0.81636	-0.81091	-0.63091	-0.54545	-0.45273	-1.57818	-1.25636	-1.46182	-1.65273
-0.2	-0.71636	-1.09455	-0.96545	-0.84364	-0.41818	-0.60727	-0.90727	-0.74727	-0.42182	-0.32545	0	-0.90364	-0.92182	-1.36545	-1.45818
-0.23636	-0.90727	-1.06727	-1.08764	-0.97455	-0.75091	-0.76909	-0.86364	-0.51273	-0.61636	-0.63818	-0.10727	-0.63818	-0.80727	-0.61818	-0.99091
-0.92545	-0.80909	-1.12182	-1.48182	-1.25818	-0.91636	-0.90909	-1.04545	-1.10182	-1.11818	-1.09818	-0.8	-1.22909	-0.83636	-0.70727	-0.99455
-0.92727	-0.97636	-1.18	-1.14727	-1.24727	-0.98545	-1.24364	-1.12909	-0.90727	-1.46182	-1.89091	-1.83636	-1.61273	-1.16	-1.15273	-1.66545
-1.43818	-1.68545	-1.25818	-1.29636	-1.18182	-1.06727	-1.00364	-1.27455	-1.12182	-1.02182	-1.06909	-1.46545	-1.60909	-1.46364	-1.30182	-1.42182
-1.71273	-1.92364	-1.74	-1.64909	-2.24727	-1.36727	-1.17455	-1.2	-1.16364	-0.88545	-1.08909	-1.09091	-1.12	-1.43273	-1.26727	-1.35818
-1.84	-1.98727	-1.74182	-1.63091	-1.93091	-1.80545	-1.94	-1.95636	-1.97818	-1.93818	-1.54545	-1.48364	-1.19818	-1.17818	-1.12182	-1.09636
-1.86182	-1.88364	-1.77091	-1.63091	-1.87091	-1.83455	-2.35636	-2.20909	-2.27091	-2.16727	-1.39273	-1.52545	-1.24545	-1.21818	-1.18727	-1.05455
-1.79818	-1.83455	-1.75273	-1.74182	-1.79273	-1.35091	-1.51273	-1.42	-1.77273	-2.35818	-2.24545	-2.32727	-2.29455	-2.10545	-1.3	-1.21455
-0.99636	-1.03455	-1.19818	-1.3	-0.78909	-0.73455	-0.64364	-0.27273	-0.69273	-1.52182	-1.50727	-1.43818	-1.29091	-1.28	-1.08364	-1.39455

Figure-13. Showing heat map for the winter season December 2004.

Source: Reverb/Echo (2015).

As illustrated in Figure 13, there was a steady increase in temperature from 2004-2007. Figure 5 shows a significant drop in temperature because of the high negative pixel indicates which was as low as -10 in year 2008. In the year 2009 an increase in temperature was experienced while the year 2010 experienced a decline in temperature. In 2011 there was slight increase in temperature; December 2012 had a unique distribution of pixel value in the

sense that the southern-western Coventry had high pixel values as high as 4.0 while the north-eastern part had a low pixel value. The year 2008 experienced the coldest winter while the year 2013 had the warmest winter. The 11years period, the winter temperature experienced as an undulating trend.

-7.43636	-7.06909	-5.98364	-6.14909	-6.22182	-6.49636	-6.26364	-6.12909	-6.59818	-6.64364	-6.58182	-4.78182	-6.30727	-6.28727	-6.63818	-6.65273
-7.42	-7.04545	-7.32364	-7.61818	-8.24545	-8.99273	-9.23636	-9.34727	-9.48	-6.87455	-6.62182	-6.49636	-6.38727	-6.30182	-6.30727	-6.72364
-7.08545	-7.53636	-7.36727	-7.26182	-8.96909	-8.98909	-9.24727	-9.47636	-9.59091	-6.97091	-6.70545	-6.57273	-6.47818	-6.15636	-6.36182	-6.45273
-6.78	-7.07636	-6.97455	-6.98545	-8.94364	-8.99818	-9.30727	-9.60727	-9.62727	-9.76182	-9.56545	-9.24	-9.24364	-9.46182	-6.44545	-6.37818
-6.45636	-6.96727	-7.00727	-7.65432	-9.33455	-9.37091	-9.44909	-9.54364	-9.33273	-9.53636	-9.49818	-9.20727	-9.25818	-9.24727	-8.97818	-8.31091
-7.04545	-6.94909	-7.12182	-7.42182	-9.65818	-9.59636	-9.70909	-9.84545	-8.02182	-7.95818	-7.81818	-9.46	-7.48909	-7.05636	-7.02727	-7.15455
-7.06727	-7.15636	-7.82	-8.12727	-8.28727	-8.04545	-8.58364	-8.46909	-8.38727	-8.20182	-8.29091	-8.23636	-7.85273	-7.68	-7.67273	-5.64545
-7.61818	-7.84545	-7.91818	-7.73636	-7.02182	-6.90727	-7.22364	-7.53455	-9.40182	-8.86182	-8.74909	-6.26545	-6.28909	-6.40364	-5.56182	-5.56182
-7.59273	-7.36364	-6.82	-7.02909	-7.62727	-7.02727	-8.41455	-8.44	-8.72364	-8.78545	-9.18909	-10.0109	-9.88	-5.71273	-5.54727	-5.45818
-6.74	-6.76727	-6.74182	-6.99091	-7.37091	-7.38545	-7.56	-8.87636	-8.93818	-9.21818	-9.76545	-9.68364	-9.31818	-9.17818	-9.04182	-8.97636
-6.98182	-6.68364	-6.85091	-6.99091	-7.25091	-7.37455	-7.41636	-9.04909	-9.05091	-8.90727	-9.35273	-9.48545	-9.16545	-9.17818	-9.04727	-8.85455
-7.01818	-6.91455	-6.97273	-7.12182	-7.17273	-6.81091	-6.77273	-6.62	-7.07273	-7.13818	-6.48545	-6.54727	-6.43455	-6.36545	-6.52	-6.29455
-7.21636	-7.13455	-7.13818	-7.14	-6.72909	-6.71455	-6.58364	-9.37273	-9.75273	-9.58182	-8.90727	-9.07818	-9.11091	-9.12	-9.20364	-9.15455

Figure-14. Showing heat map December 2008.
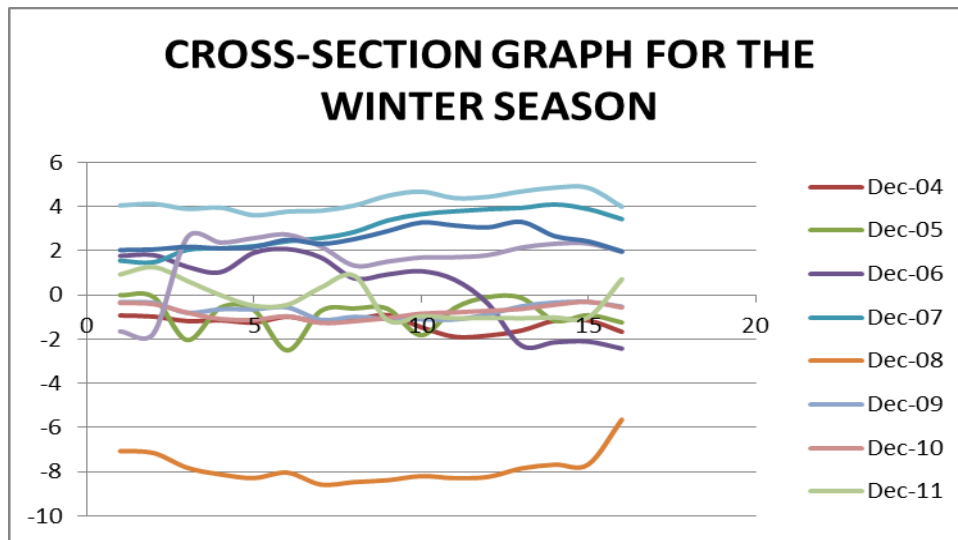
Source: Reverb/Echo (2015).

Figure-15. Cross-section Graph for the winter season.

Source: Reverb/Echo (2015).

As shown in Figure 15, the year 2008 was the coldest winter, however, there was a cross- sectional increase in pixel values from -7 to -5.5 in 2006, there was a decline in temperature from 1.8-2.4 in the year 2012 there was a significant increase from approximately -1.7 to 2.6. In 2014, there was no change but a fluctuating temperature trend. The year 2004, 2005, 2010 and 2011 also had fluctuating values with a slight increase in 2007. There was no regular trend in the seasonal variation of UHI intensity.

Based on the study conducted, Table 1 summarises the warmest years across all seasons. Investigation carried for those years shows no specific factors that could cause those warm years. Observation indicates that there was no regular trend in the seasonal variation of UHI intensity.

Table-1. Showing the warmest year of all seasons.

Season	Year	Average UHI Intensity
Spring	2004	5.39
Summer	2012	3.85
Autumn	2008	2.28
Winter	2013	4.11

Source: Researcher's Data.

Using Google earth tool, it was discovered that there was increasingly warm pixels leading to a rise in temperature, this was as a result of land cover alteration as seen in Figure 16.

Figure-16. Primrose hill street of Coventry in 2006.

Source: ArC GIS NASA.

Figure-17. Primose Hillstreet of Coventry 2014.

Source: ArC GIS NASA.

From Figure 16 and 17, showing the land cover change it can then be agreed that the slight rise in temperature within the area is as a result of land cover change. Voogt (2004) affirms that urban areas get warmer when moist and permeable land surfaces are replaced by dry and imperious surfaces. There was no much vegetation loss in 2014, other factors like construction materials and roof cover could influence the increase in temperature. According to Coutts, Beringer, and Tapper (2006) construction materials such as concrete replaces vegetative land and have low albedo thus, leading to high absorption of solar radiation. Building walls and dark roof could attain

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high temperature of 60-65ºC when exposed to direct sunlight (Doick & Hutchings, 2013). The conversion of vegetation to car parks and other impervious surface may have cause an increase in temperature, the use of synthetic grass in the football field thereby making surface non-permeable. Furthermore study like (Bounoua et al., 2015) agreed that when non-permeable surfaces are at 1%, it results to a rise in temperature of about 1.3ºC. Temperature remains constant despite an increase in impervious surfaces but when the surface exceeds 35% of the land area, temperature increases. As observed in Figure 18, temperature can be 1.6ºC warmer when 65% of the land surface is covered by impermeable surfaces.
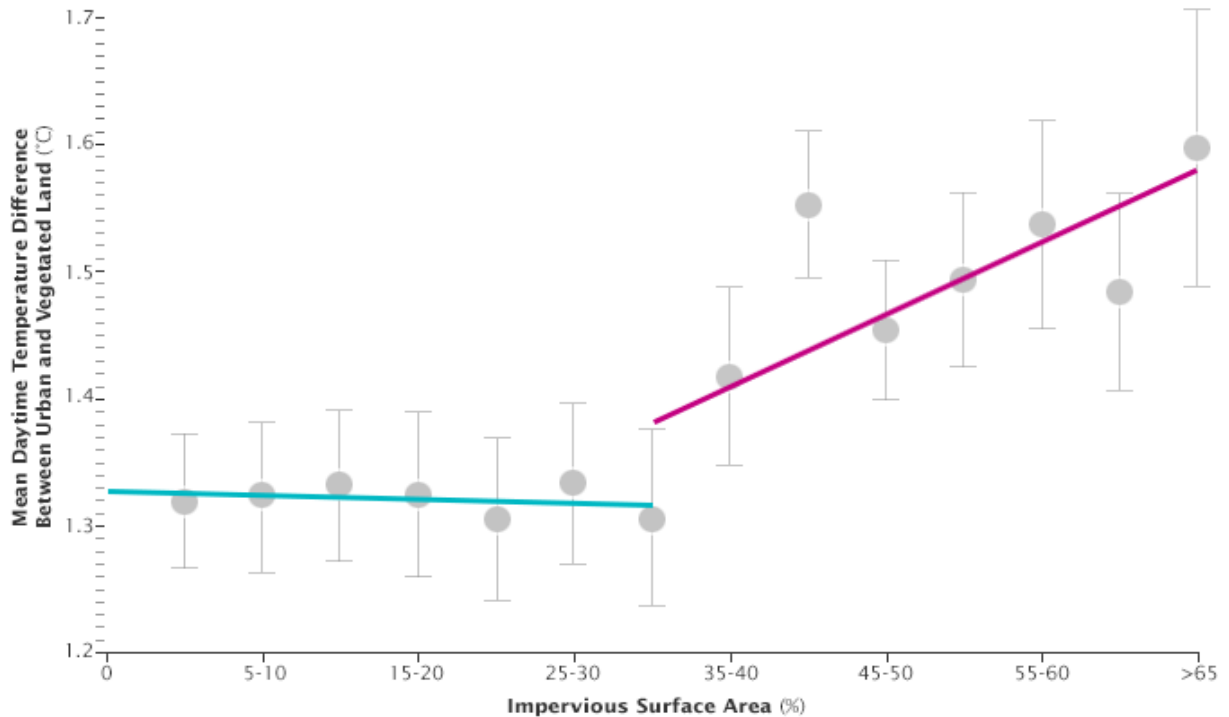

Figure-18. Showing the mean daytime between urban and vegetated land.
Source: National Aeronautics and Space Administration (NASA) (2015).

In 2006, most of the land surface was bare, the higher pixel values may be as result of the recent developments which could absorb water and reduce runoffs which also increase cooling through evaporation and reflectivity (Davies, Steadman, & Oreszczyn, 2008). Another factor responsible for the increase in temperature could be anthropogenic heat from vehicles, energy for heating and cooling as well as increase in population. This is because development attracts human presence therefore leading to increase in population and human activities.

Study by Shahmohamadi, Che-Ani, Maulud, Tawil, and Abdullah (2011) agreed that human and animal metabolism increases artificial heat which warms up the ambient temperature through convection, conduction and radiation. Also, emission from vehicles and machineries may lead to rise in pollution dome; this will prevent the re-emission of the long wave radiation. However, it was observed that some pixels had a marginal reduction in values. Figure 19 and 20 illustrates land surface characteristics; for better comparism, three places were highlighted, the highlighted part tiled point A in 2004 as shown in figure 19, had a bare surface with few structures and vehicles, indicating the presence of human activities. In the year 2014 as illustrated in figure 20, the land was covered with vegetation. While at Point B and C as seen in figure 19, in the year 2004 sparse vegetation is seen but as at 2012 vegetation was denser compared to 2004. Therefore, it can be concluded that the marginal increase and decrease in pixel values can be associated with vegetation cover.

Figure-19. Showing Arden Park 2004.

Source: Google earth.

Figure-20. Showing Arden park 2014.

Source: Google Earth.

3. CONCLUSION AND RECOMMENDATION

In summary, over the period of 11years, there was no significant increase in temperature however; this study recommends the following measures:

- Green roofs provide evaporative cooling thus modify the microclimate. They also manage storm water by reducing run-off to drains. According to Mentens, Raes, and Hermy (2006) in Brussels the annual rainfall run-off could be reduced by 2.7% if 10% of the roofs in the city are replaced with green roofs. Susca, Gaffin, and Dell'Osso (2011) study stated that 38kg of CO_2e (Carbon IV Oxide equivalent) savings could be achieved if black roofs are replaced with green roofs. The use of urban surfaces such as building walls with high albedo and pavements have the capacity to reduce UHI, yet most cities in the UK have not fully adopted it (Mills, 2005). Also Spronken-Smith and Oke (1998) deduced that water bodies have substantial cooling effect on leeward side. As a result of reflective surface, the increase percentage of energy is used in evaporative cooling rather than warming the air.

Another good example of sustainable cities using green roofs in buildings and busses is the city of Stuttgart which demonstrates clear environmental friendly public transportation and also maximizes environmental benefit to reduce carbon foot print in the transport system. Green roofs might be cost and maintenance intensive, however they clean the air and buildings with little or no experience of summer heat, as it maintains a cooler indoor temperature and most importantly it removes greenhouse effect (The New Green Spaces, 2011). Green roofs, green walls are essential part in constructions to help cool cities.

- The use of green infrastructures such as green ventilation and corridor. Stuttgart city is said to be a forerunner in the protection of green spaces, using green ventilation corridors in protecting its climate with winds to impede UHI. This has improved air quality and increased resilience against global warming. Green infrastructure can be used to combat the effect of UHI. In the case of Stuttgart, the Neckar river cycle route is an important path for commuters as well as tourists which is been considered as one of the green investment in the city. This new route allows green, safe and efficient transportation between industrial and commercial centres, residential and leisure centres (Esslingen & Nurtingen, 2015). Stuttgart is known to be one of Germany's greenest city which is based on the principle of cool city (Inhabitat, 2010).

- Planting of trees and vegetation enables evaporation and evapotranspiration which would have huge impact on UHI. Asaeda and Abu (1998) affirmed that 60 hectares of park may reduce mid-day air temperature by up to 1.5°C for about 1km distance. It is therefore recommended that green park should not be 300meteres away from each other for optimum cooling. According to Asaeda and Abu (1998) a 100 meter Green Park cools to a distance of 300meters. Also, vegetation and trees provides shade from direct sunlight radiation. It is imperative to mitigate UHI effects, in order to protect humans from direct solar radiation which could cause some discomfort leading to sickness (Emmanuel, 2005). Also, there is reduction of solar intensity as a result of shading thus, lowering efficiencies of solar photovoltaic cells. Meanwhile, Stuttgart city has more than 60% of green area with 65,000 trees in parks and 35,000 along the streets. In the 1970's the city integrated green areas into a large "U" shape connecting the park to the gardens to the forest and the city edges (Environmental Protection Agency, 2013).

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