1. Abstract

The city of Addis Ababa was founded by Emperor Menilik in the year 1886. Since then Addis Ababa remained the capital city of the nations because of its location, hygienic conditions and material convenience. Addis Ababa is one of the fastest growing metropolitan areas in Ethiopia. The rapid urban growth the city saw in the last century resulted in tremendous land cover change dynamics within the metropolitan region. Particularly within the last 15 years rapid urbanization has consumed vast acreage's of land adjacent to the city.

The urban heat island (UHI) effect in a large city, with a population of 2.42 million, examine on the influence of temperature, in central Ethiopia (Addis Ababa). UHI is related to the population of a town and have been studied extensively via direct observation. A direct warming of the air can result from various combustion processes such as those involved with vehicles, air conditioning and heating.

Antropogenically induced changes in the energy balance in urban centers have a significant effect on temperature, which has been termed the Urban Heat Island (UHI) effect. The energy balance can also change as a result of land surface changes that included variations in the albedo, thermal aerodynamic properties, hydrology and morphology of the surface.

The purpose of this investigation is to examine the current trends of urban heat island and its effects on the weather of Addis Ababa. The aim of the paper is to evaluate the potential impacts of urban growth on the temperature characteristics of the city.

1.1 Data and Study area

Historical daily dry bulb temperature data, measured at the height of 1.5 meters is used in this study. The mean annual maximum temperatures of selected years were also compared with population parameters to examine the correlation between population growth and temperature. The stations for the measurement of air temperature are located at different altitudes in the urban and rural parts of the city. The station representing the rural part of the city is situated near Bole International airport, while stations in the central parts of the city are found at the head quarters of the observatory and International Research for Livestock Institute ILRI (Shola). Direct temperature measurements were made on November 29, 1999 and November 29, 2000, to investigate the behavior of the UHI in Addis Ababa. Afterwards, the data was subjected to simple statistical investigation for analysis. The attitude and the local topography of the city, located in the high plateaus of the central Ethiopian highlands could have considerable effect on the diurnal character of the UHI.
1.2 Locations and Climate of Addis Ababa

Addis Ababa is situated in the high plateaus of central Ethiopia in the North-South oriented mountain systems neighboring the Rift-Valley. It is located at latitude 09° 02’ and longitude 38° 44’. The stations in the relatively low altitude parts of the city, around Bole International airport is 2408 meters, while the elevation in Entoto mountain, north of the city is more than 2444 meters. The city is overlooked by mount Yarer to the east having approximately the same height as mount Entoto and mount Wochecha to the west, which is approximately 3361 ft above sea level. Not far from Addis Ababa there are a number of small crater lakes distributed in the east west direction, many of them around in Debre Zeit about 40 Kilometers east of the city.

The average annual temperature is between 16-18 °C. The highest temperature ever recorded 32 °C in October 1957, and the lowest temperature ever recorded is -0.5 °C in January 1960. Addis Ababa receives an average of 1255.2 mm rainfall per year. The highest monthly rainfall ever recorded (424.7 mm) occurs in August 1970 and the lowest rainfall (62.3 mm) was recorded in November 1976.
1.2.1 Population Growth

During the past century, the population of Addis Ababa increased significantly. The population of the city during the era of emperor Menelik was estimated about 100,000. Within the span of 100 years the population of the city increased dramatically. According to the 1994 national population and housing census carried out by the Central Statistical Authority of Ethiopia, the size of the city’s population was 2,112,737. Compared to the 1984 census, the 1994 population size has shown a 3.26% increase. This change had occurred due to not only natural increase and migration but also reclassification of area. It must be notified that area size of Addis Ababa had increased from 222.04 km$^2$ in 1984 to 530.21 km$^2$ in 1994.

The Urban-rural distribution of population in Addis Ababa indicates that the overwhelming majority of the population is living in urban areas. The population density of Addis Ababa is 3984 persons per km$^2$. The densities of population in urban and rural sectors of the city are 7008 and 121 persons per Km$^2$ respectively. The highest population density is concentrated over northeast and central parts of the city. Nearly 56.1% of the urban population is living in area of 297.48 km$^2$. Only 1.3% of the population is living in rural areas, which covers 232.73 km$^2$.

The rapid growth of the urban population has accelerated the process of slum formation in Addis Ababa. The formation of slums in developing countries in general is largely influenced by the rate of cityward migration as well as by the rate of absorption and assimilation of migration who hold to their traditional attitudes and values. The cityward migrations have given rise to the worst slum conditions in Addis Ababa. The congested areas of high gross residential density have very often more than 200 person per acre with attached houses built in an extremely haphazard manner without regard to lack of sanitary toilets, inadequate surface drainage and open drains. This result for air-pollution and solar energy is absorbed from slums rooftops, resulting surface temperature of urban structure higher than the ambient air temperature.

Addis Ababa is the largest center of commercial and industrial establishments in Ethiopia. The main industrial area of the city is found in Akaki over Southeastern parts where the biggest factories are located. The majority of the industries are government owned. Recently some small scales private factories are also flourishing in the area congesting the residential neighborhoods. Zone 1 covers the areas Northwest of the central observatory station and Zone 5 is situated in the main commercial center of the city where most of privately owned business enterprises are found.
1.2.3 Fuel Types used in Addis Ababa

Most of the housing units (60.6%) in the city are using dung / manure as fuel material, while 35.2 housing units use firewood and leaves for fuel consumption. Nearly 0.8% of the housing units use no fuel. Zone 6 has higher proportion of housing units that use dung / manure and lower proportion of housing units that use firewood / leaves (16%). The use of kerosene in rural area of Addis Ababa accounted for 2%. About 37.3% of housing units used combination of electricity with other types of fuels.

1.3 HEAT ISLAND

One of the fundamental components that set a city apart from its rural surroundings is the climate that prevails over urban environment. In urban areas, buildings and paved surfaces have gradually replaced preexisting natural land escape, As a result, solar energy is absorbed into roads and rooftops, causing the surface temperature of urban structures to become up to 11°C higher than the ambient air temperature (Taha, Akbari & Sallor 1992).

The image shows albedo values for various urban surfaces. The albedo is a measure of amount of solar energy reflected by the surface. As such, low albedo implies higher surface temperature since the large amounts of energy are absorbed. As surface throughout an entire community or city become hotter overall ambient air temperature increase. This phenomenon is known as Urban Heat Island (UHI). Air temperature in a city could rise by about 3°C or higher because of the effects of UHI. The resulting higher temperature caused by the urban heat island had the effect of increasing the demand for cooling energy in commercial and residential buildings in some large cities.

2.0 Results and discussion

Both Minimum and Maximum temperature trends examined together with urban population increase during the period between late 1960s and 2000. The total population increase in the eighteen years (1967-1984) was 739,581 and the annual mean maximum temperature in the same period became warmer by 1.7°C. The annual mean maximum temperature attained its pick in the year 2000. It is interesting to observe that the urban population was also highest in the same year.

A transect observation taken on 29 November 1999. The value of dry-bulb temperature measured at 0600 UTC in rural parts of the city (Bole Airport) is smaller than the values observed in urban areas of the city at the central observatory by 3 °C. Similar observations were made at 0900 UTC also show the same result. However, at this time the gap between dry bulb temperatures between the two stations is 1°C.
At 1200 UTC air temperature was 22°C at Bole, while 23.4°C was recorded at the central station, which means the urban center is warmer by about 1.4 °C. The UHI at 1500 UTC was 2.2°C. This confirms the existence of UHI throughout the day although it attained its pick value during early morning. It is apparent from this study that the UHI phenomena became the feature of the weather of Addis Ababa partly in association with the increase in population. It is expected that as the city expands further the magnitude of the UHI would become stronger affecting the living condition of the urban population.

3.0 Conclusions and Recommendations

It is evident from this study the UHI phenomena is becoming the character of the urban weather in Addis Ababa. The diurnal magnitude of the UHI was increased due to the year-to-year influx of rural population to the city attracted by a better living and working conditions. With the expected increase in the urban population in the next two decades the UHI would also be expected to increase further. Additional empirical and quantitative studies are required to investigate the overall impact of the increase in UHI on the local weather of the city. Particularly studies should focus to analyze the impact and the evolvement of UHI in relation to land-use, forest cover and the gradual growth of heavy industries, and the resulting air-pollution. The results of this preliminary study more elaborate if a large of network of stations would have been used. Thus there is a need to increase the network of stations in the city. Moreover, regular monitoring of the environment should be conducted to evaluate the impact of the UHI by installing mobile stations. Hence financial support is essential for purchasing equipment and accessories.
Figure 7 Observation Of The Temperature At Addis Ababa Observatory, Bole Air-Port and ILRI
On 29 November 2000

Figure 8 Observations Of The Temperature Addis Ababa Observatory, Bole Airport and ILRI
On 29 November 1999