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# Evolving Green Areas Planning Strategies as A Means of Mitigating Urban Heat Island in Lafia Town, Nasarawa State, Nigeria

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**Abstract:** City planning with regard to green areas development can significantly offer a low cost and simple remedy to the impact of climate change in urban areas. This study examines green areas planning strategies as a means of mitigating urban heat island in Lafia town. The study discovered deficiencies in the development of green areas considering different land uses in Lafia town. The research used both primary and secondary data. Data deployed were used to calculate Normalized Difference Vegetation Index (NDVI); and the TIRS data were also used to derive LST. The boundaries of the urban area of Lafia town and the landscape indicators were interpreted and quantified based on high-resolution Google Earth images through manual interpretation based on the map of present land use. It is therefore recommended that green space should not be 300metres away from each other for optimum cooling. Also, vegetation and trees provides shade from direct sunlight radiation. The study further proposed a strategic base map of green areas planning to resolve the deficiencies and also made useful recommendations to stakeholders, policy makers and urban planners which when followed will provide green areas in Lafia town to enhance better health, a beautiful environment and urban heat island mitigation.

**Key words:** Green areas, Urban heat island, Planning strategies, Land uses, Mitigation

## I. Background of the study

The proportion of the world's population living in cities has increased from about one-third in 1950 to more than half in 2008 (Grimm et al., 2008), and is projected to increase to two-thirds by 2050 (UN-habitat, 2005, United Nations, 2019). Growth and expansion of our towns and cities entails the construction of infrastructures and other human activities to accommodate growing population and in turned leading to the tempering with the natural vegetation and landscape with consequential meteorological impacts causing urban heat. In developing countries, for instance, one of the main problems in our towns and cities today is uncontrolled and haphazard development. As towns and cities developed, paved areas surface and buildings substitute the natural landscape. Gloomy surface like parking lots, roofs and roads attracts the greatest amount of heat.

The urban heat island (UHI) is a well-known negative effect of urbanization resulting in higher air temperatures in urban centres than in the surrounding rural areas (Li et al, (2019). The International Panel on Climate Change predicts a global surface air temperature increase between 1.1 and 5.4 °C and higher extreme temperatures and more frequent heat waves (Lee et al. (2021). Urban heat island is an area that is significantly warmer than its surrounding rural areas due to human activities. Urban heat island is a well-known negative effect of urbanisation resulting in higher air temperatures in urban centres than in the surrounding rural areas. The temperature difference is usually larger at night than during the day, and is mist apparent when winds are weak (Li et tal, 2019).

The superposition of the preexisting urban heat island effect and climate change is expected to lead to more frequent and intense heat waves in urban areas worldwide (Corburn, 2009; Li and Bou-Zeid, 2013), especially in South Asia (Ullah et al., 2022). Against this backdrop, potential adaptation and mitigation strategies to counteract the urban heat island effect have attracted global interest as urban areas expand, urban populations concentrate and extreme climate events increase in frequency and intensity in a warming world.

The relationship between land cover, land use types and the urban thermal environment, and associated green area planning strategies to mitigate the urban heat island effect have been continuously studied. Numerous studies have related the type of land

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cover to its impacts on the Earth's surface temperature (Fu et al., 2022). For instance, Guerri et al. (2022) showed that >50 % of industrial buildings in the Florence metropolitan area were characterized as hot-spot areas, and replacing 10 % of impervious surfaces with planted areas can reduce LST by 2 °C in summer. The study by Morabito et al. (2021) have demonstrated that an increase in impervious surfaces combined with a low density of tree cover would increase the surface UHI intensity, and an increase in tree cover density can effectively enhance the cooling effect in 10 major Italian cities on the peninsula. Meanwhile, According to Bilgili (2009), green spaces are ecological based requirement and it has become an indispensable element of ecological, aesthetic and recreational value within an urban setting. Green areas in cities include (for purpose of this research) parks, woodlots, cemeteries, scenic areas and so on.

The importance of green areas in urban planning can be summarized as follows: A park-like area consisting of grass and sparse stands of trees appears to be the best means of avoiding temperature and moisture extremes, and yet maintaining a certain amount of ventilation. Studies show that green areas provide a wide range of benefits including social, aesthetic, environmental and economic (Tryvainen, Pauleit, Seeland and Vries, 2005; Grahn and Stigsdotter, 2003; Kaplan & Kaplan, 1988).

Urban green area planning was widely regarded as an effective nature-based solution to mitigate the urban heat island effect, therefore, developing landscape strategies to enhance its cooling intensity is crucial (Zhou et al., 2023). The most effective strategy for the mitigation of urban heat islands and even for global warming threat is to improve the local environment condition (Brontowiyono et tal, 2013). The use of green areas is a major planning technique by which city planners and landscape architects can prevent or reduce adverse effect of climate change. In recent years, the impact of urban heat island has become an issue due to urbanization (Smoyer, Rainham and Hewko, 2000).

The use of vegetation, particularly trees, constitutes one of the most effective strategies in contrasting the phenomenon (Wang et al., 2021). It is widely recognized that an increase in vegetation cover is very effective in reducing surface and air temperature (Weng and Schubring, 2004; Yuan and Bauer, 2007). For example, Kong et al. (2014) argued that a 10% increase in forest cover can result in a decrease in the Earth's surface temperature of approximately 0.83 °C. Similarly, Marando et al. (2022) suggested that a minimum 16 % increase in tree cover leads to a 1 °C decrease in urban temperature.

Lafia town, being an administrative centre in the State has attracted population increase and urban growth especially since in the 2000s. Migration of people has been the primary contributing factor for unplanned urban growth and is becoming a burden on the existing green areas. This is as result of increase in development and physical expansion in Lafia town over the years with no recourse to green space areas. Infrastructures and other construction have resulted in the removal of natural vegetation. The trend of urbanization is increasing heat intensity and contributing significantly as one of the reasons of likely urban heat island. The land on the region of Lafia is low and sandy, and the climate is hot and humid due to temperature rise in the environment from the hot sun heat reflection on the sand and its subsequent radiation at night has increased heat intensity thereby contributing significantly as one of the reasons of the likely urban heat island (Ebuga, Angbo & Bashayi, 2021). Research conducted by Ebuga, Angbo & Bashayi, (2021) on impact of heat island on human comfort in Lafia urban area revealed that temperature increase was observed from 1-2°C compare to other surrounding region with vegetation cover and the study suggested evolving green space planning strategies as a mitigation of the effect of urban heat island in Lafia town.

Review of extant literature shows contention as to green areas as a mitigation of heat island. Zhou et al., (2017) reported that the relationship between the spatial configuration of urban green areas and the thermal environment is contradictory in many cases. Many studies have claimed that patch density of urban green area was negatively correlated with the land surface temperature in many cities (Dugord et al., 2014; Zhou et al., 2019), but some studies conducted in other cities hold the opposite view (Li et al., 2013; Li et al., 2012). Since most of these studies are case or city based, it remains uncertain whether these inconsistencies are due to the different climatic conditions in each city. This study therefore seeks to identify deficiencies and evolve green areas planning strategies as mitigation of urban heat in Lafia town.

## II. Methodology

### 2.1 The Study Area

The present research is focused on Lafia urban area the capital of Nasarawa State and the administrative headquarters of Lafia Local Government Area is located at the south – west part of the state on latitude $8^{o}$ 30" N and longitude $8^{o}$ 31"E. Its location at the junction of regional roads confers on it good linkage with Makurdi (the capital of Benue state) to the south, Nassarawa Eggon, Akwanga, Keffi and Abuja to its North – west and Jos (the capital of Plateau state) to its North – East.Lafia urban area covers a total land area of 82.90 $km^2$. The population of Lafia urban area by 1991 census was 87,352 inhabitants and by projection to 269,958 to 2022.

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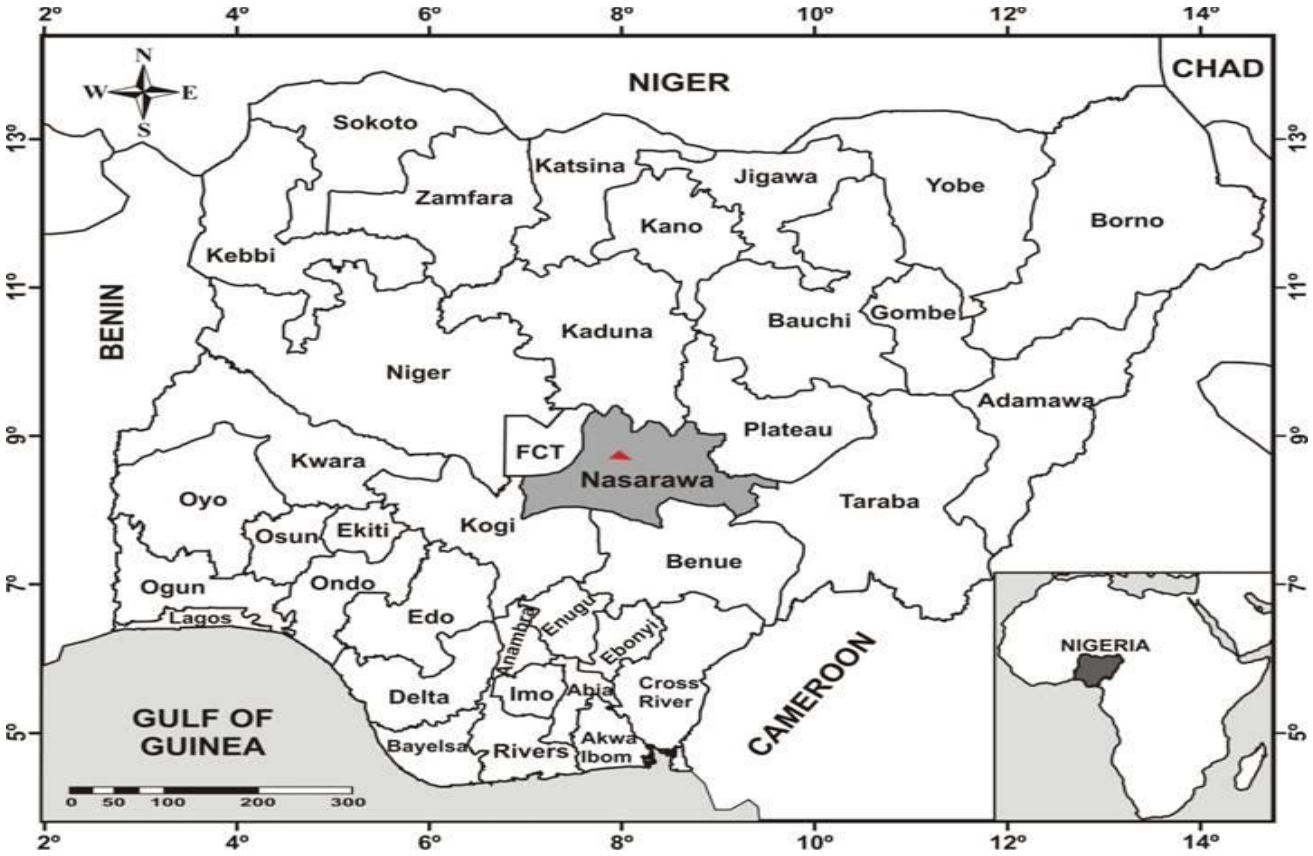
Figure 1: Map of Nigeria showing Nasarawa State




Source: Greater Lafia master plan, 1998

Figure 2: Map of Nasarawa State Showing Lafia

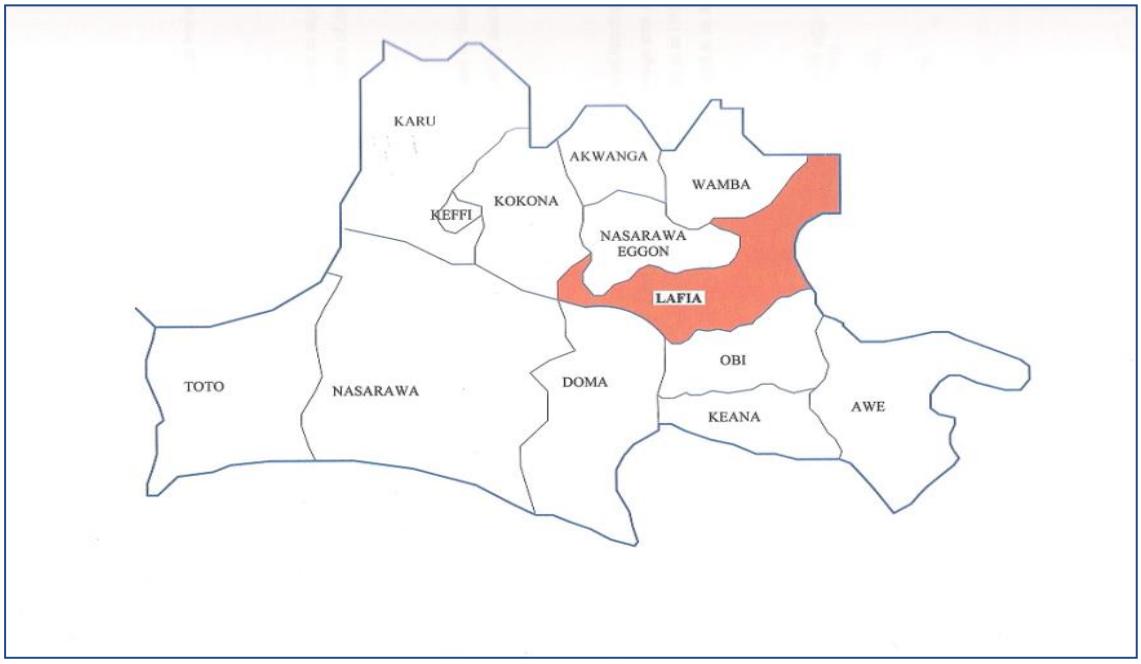


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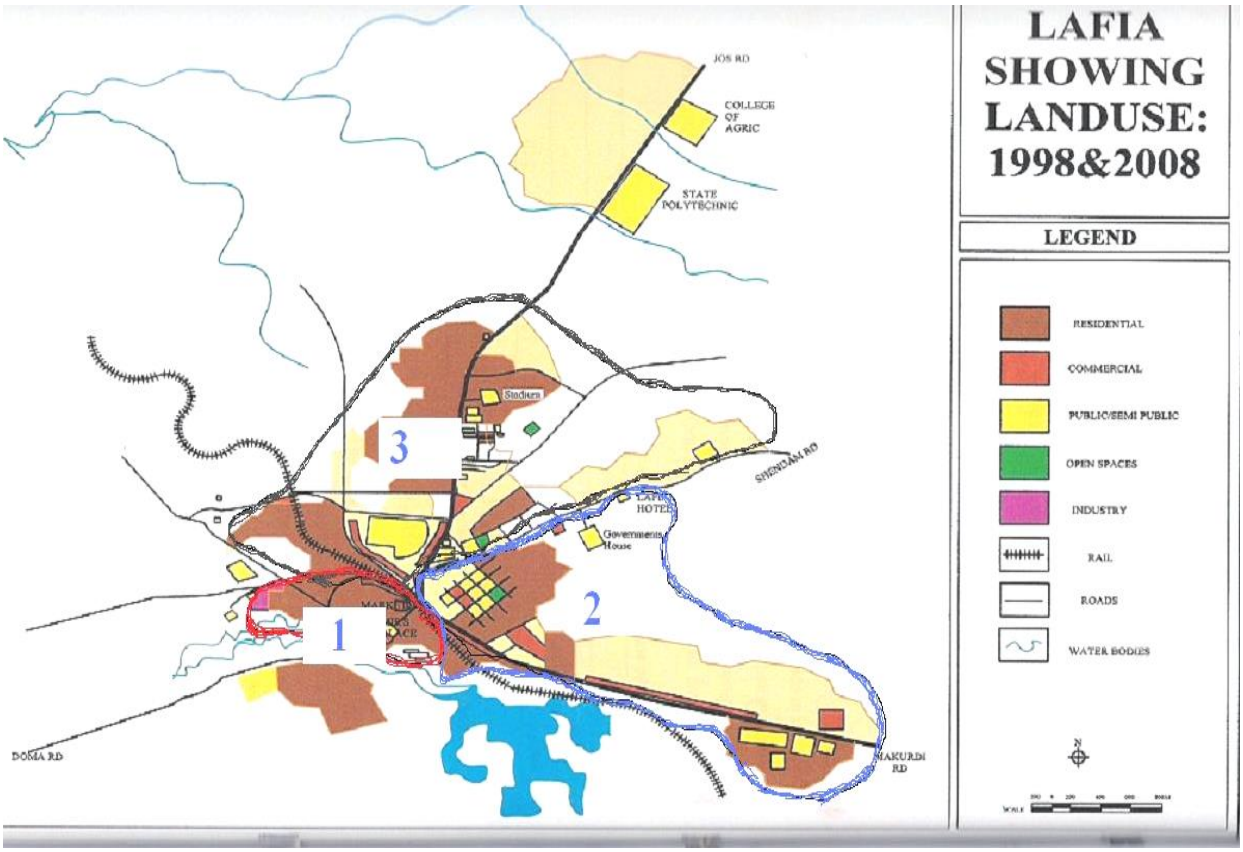
Figure 3.0 Existing Structure of Lafia town




1. Old Town 2. Sabon Pegi Area 3. Bukan Sidi And Tudun Gwandara Area

**2.2 Satellite data description and processing**

The data used in this study includes four cloud-free Landsat 8 OLI/TIRS images (Fig. 1 (b)) and high-resolution Google Earth images. The Landsat 8 OLI/TIRS data were acquired from the United States Geological Survey (https://glovis.usgs.gov/) and detailed information were shown in Table 1.0 Four Landsat 8 images were all acquired including remote sensing datasets of the year 2010, 2013 and 2020 from National Centre for Remote Sensing (NCRS) in Jos, Plateau State were used for this study. The OLI data were used to calculate Normalized Difference Vegetation Index (NDVI); and the TIRS data were used to derive LST. The boundaries of the urban area of Lafia town and the landscape indicators were interpreted and quantified based on high-resolution Google Earth images through manual interpretation based on the map of present land use. The LST maps were derived using radiative transfer equation (RTE) method and results were shown in Figure 4-8

Table 1.0 Characteristics of data used

| Data | Source | Scale | Format | Date of Acquisition |
|---|---|---|---|---|
| Landsat TM (2010) | www.landsat.org | 30m resolution | GeoTIFF | 13th November, 2020. |
| Landsat ETM+ (2013) | www.landsat.org | 30m resolution | GeoTIFF | 13th November, 2020. |
| Landsat ETM+ (2020) | www.landsat.org | 30m resolution | GeoTIFF | 13th December, 2020. |
| Nigeria Sat – X | NCRS Jos | 30m resolution | IMG | 2020 |

TM: Thematic mapper

ETM+: Enhanced thematic mapper plus

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## III. Results

### 3.1 Analysis of Urban Growth of Lafia Town

**Satellite Images Showing Urbanization Trend**

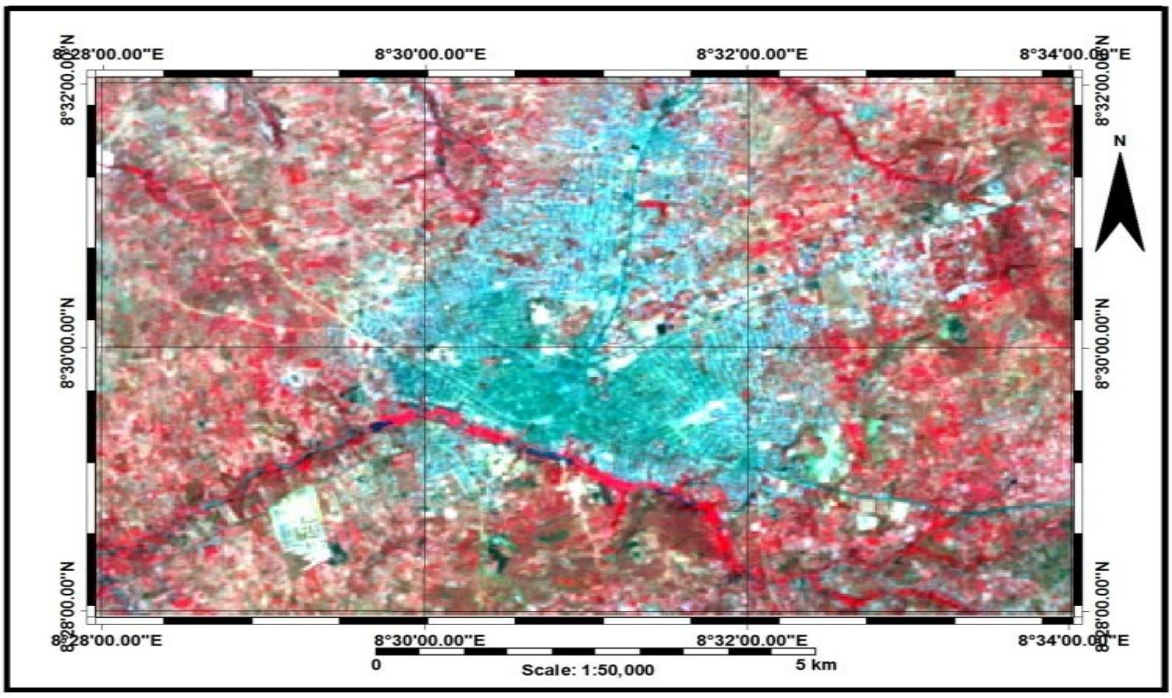


Fig 4: False color composite (bands 4, 3 and 2) of Lafia metropolis 2010

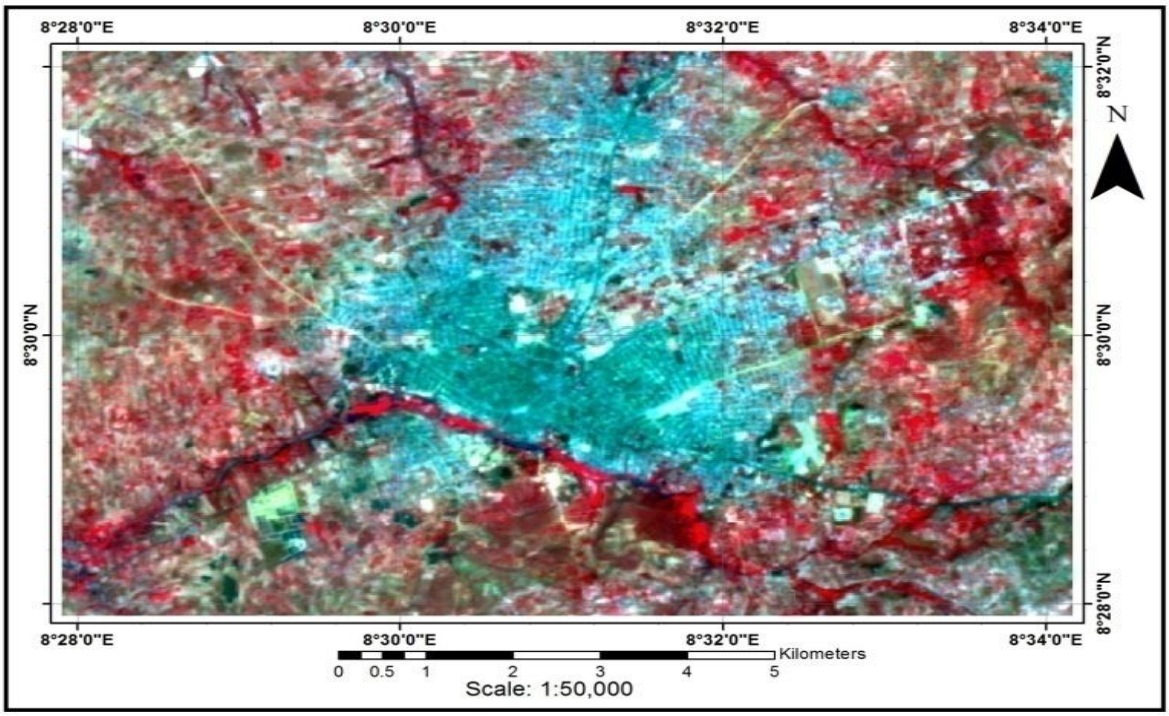


Fig 5: Nigeria Sat X image of Lafia urban area, 2013

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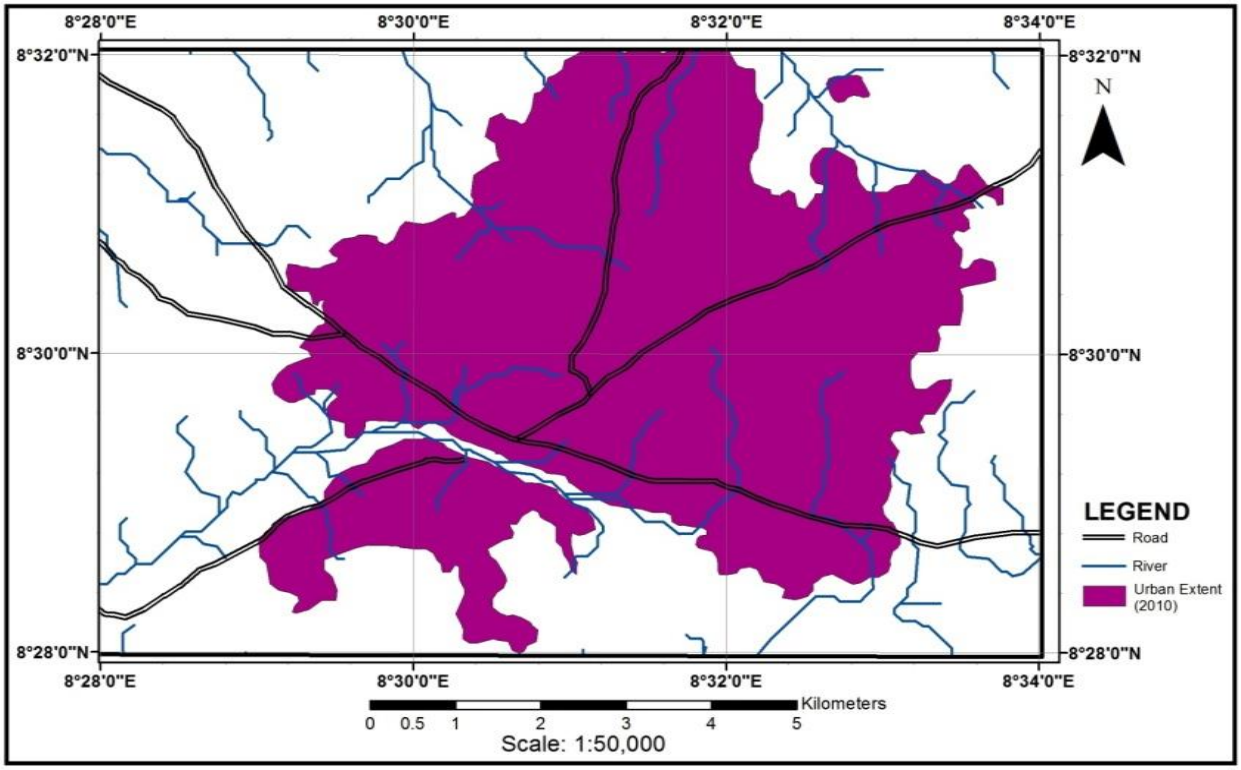


Fig 6: Map showing Lafia urbanization in 2010

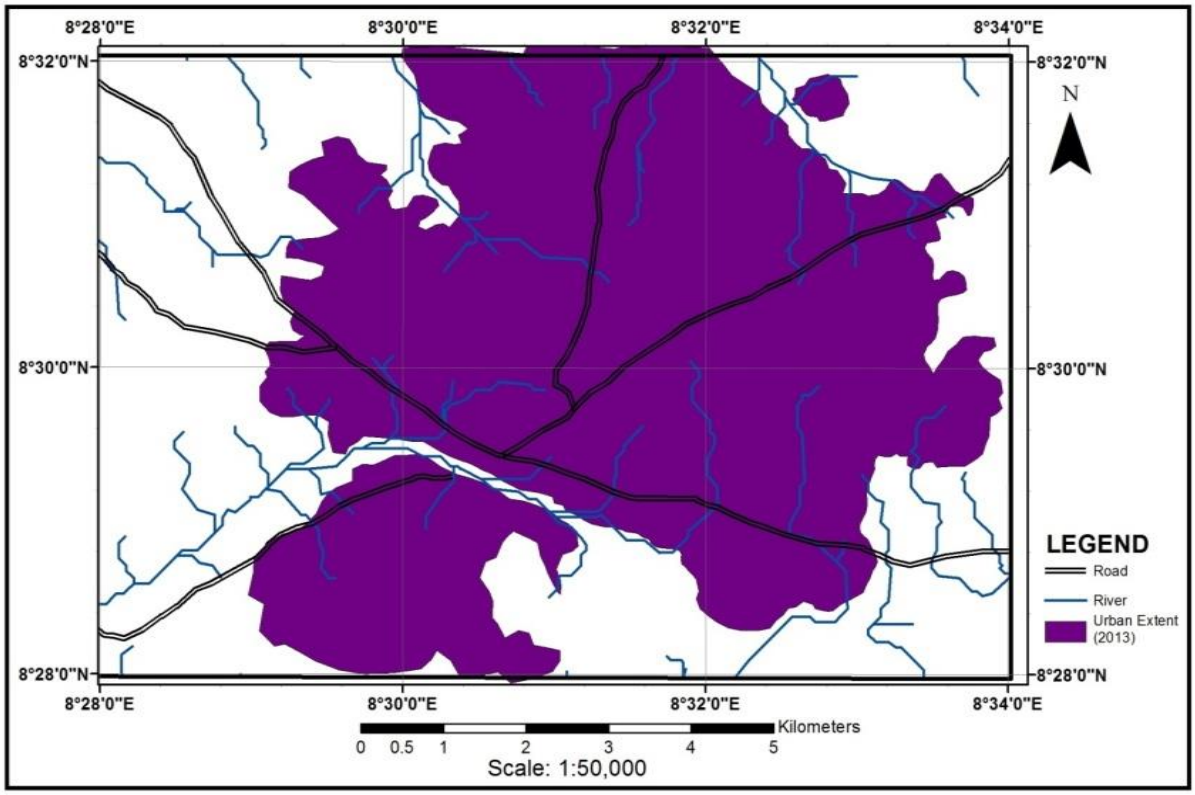


Fig 7: Map showing Lafia urbanization in 2013

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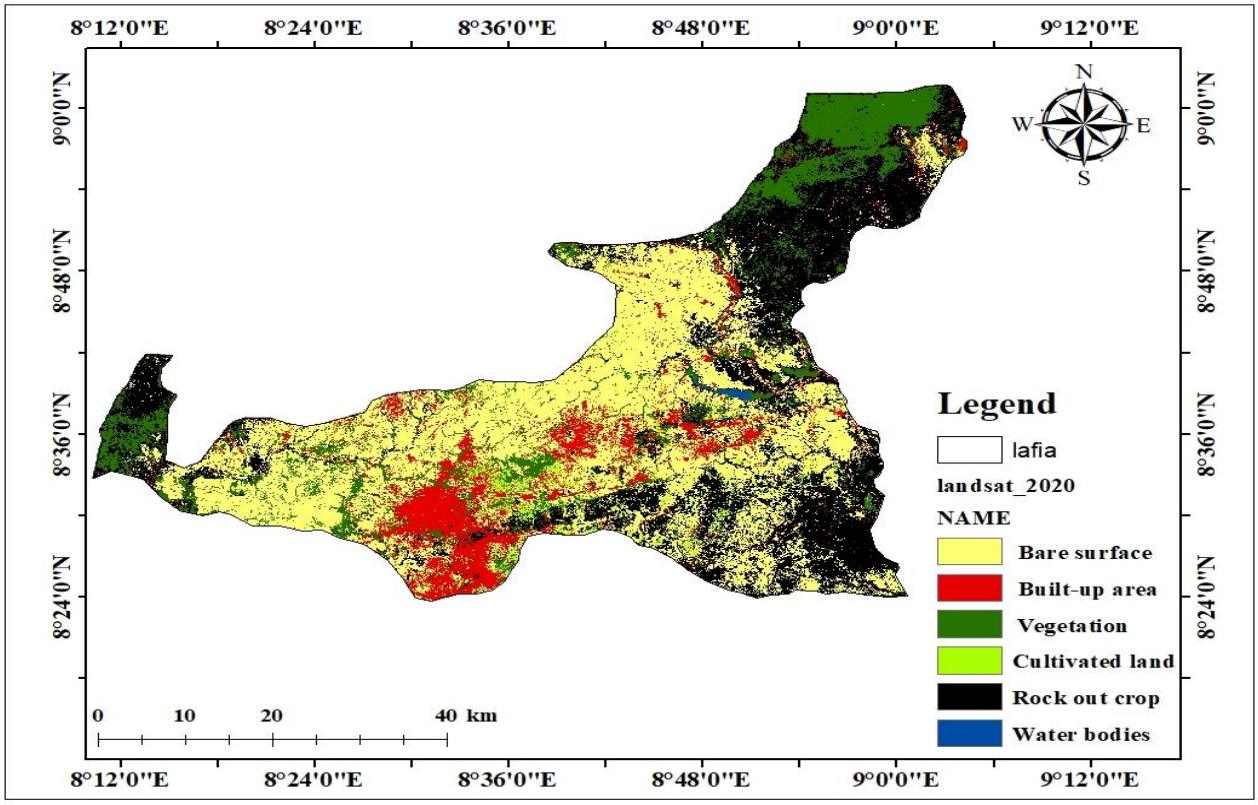


Figure 8: land use/land cover (LULC) Map of Lafia Urban Area Classification for 2020.

Table 2.0 This analysis is from the satellite imageries shown above

| S/No | Year | Total Land Area ($Km^2$) | Built – Up Area ($Km^2$) | % Built–Up Area | Absolute Growth ($Km^2$) |
|---|---|---|---|---|---|
| 1 | 2010 | 82.90 | 37.21 | 44.89 | 14.99 |
| 2 | 2013 | 82.90 | 46.54 | 56.14 | 9.33 |
| 3 | 2020 | 82.90 | 56.20 | 67.79 | 17.68 |

Table 2.0 Rate of Growth in Lafia Metropolis between the periods 2010 - 2020

*Note

$$\% \text{ Built – Up Area (2010)} = \frac{37.21 \times 100\%}{82.90} = 44.89\%$$

$$\% \text{ Built – Up Area (2013)} = \frac{46.54 \times 100\%}{82.90} = 56.14\%$$

$$\% \text{ Built – Up Area (2020)} = \frac{56.20 \times 100\%}{82.90} = 67.79\%$$

Absolute Growth ($Km^2$) = Change difference in Built – Up Area ($Km^2$) over a period of time

2010 – 2013 >>>> 9.33 = 46.54 – 37.21

2013 - 2020 >>>> 10.23 = 56.20 – 46.54

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Table 3.0 Land use changes in the Lafia town between 2010 - 2020

| S/N | Land use/cover | 2010 | | 2013 | | 2020 | |
|---|---|---|---|---|---|---|---|
| | | Area ($km^2$) | % | Area ($km^2$) | % | Area ($Km^2$) | % |
| 1 | Built-up | 37.21 | 44.89 | 46.54 | 56.14 | 56.20 | 67.79 |
| 2 | Vegetation/Nature | 15.06 | 18.17 | 13.10 | 15.80 | 10.10 | 12.18 |
| 3 | Agriculture | 25.03 | 30.19 | 19.06 | 22.99 | 11.50 | 13.87 |
| 3 | Open spaces | 5.60 | 6.76 | 4.20 | 5.07 | 5.10 | 6.15 |
| | Total | 82.90 | 100 | 82.90 | 100 | 82.90 | 100 |

Table 4.0 Summary of table 3.0

| Period | Vegetation/Nature | Agriculture | Open spaces/Vacant land | Built- up |
|---|---|---|---|---|
| 2010 | 15.06 | 25.03 | 5.6 | 37.21 |
| 2013 | 13.10 | 19.06 | 4.2 | 46.54 |
| 2020 | 10.10 | 11.50 | 5.10 | 56.20 |

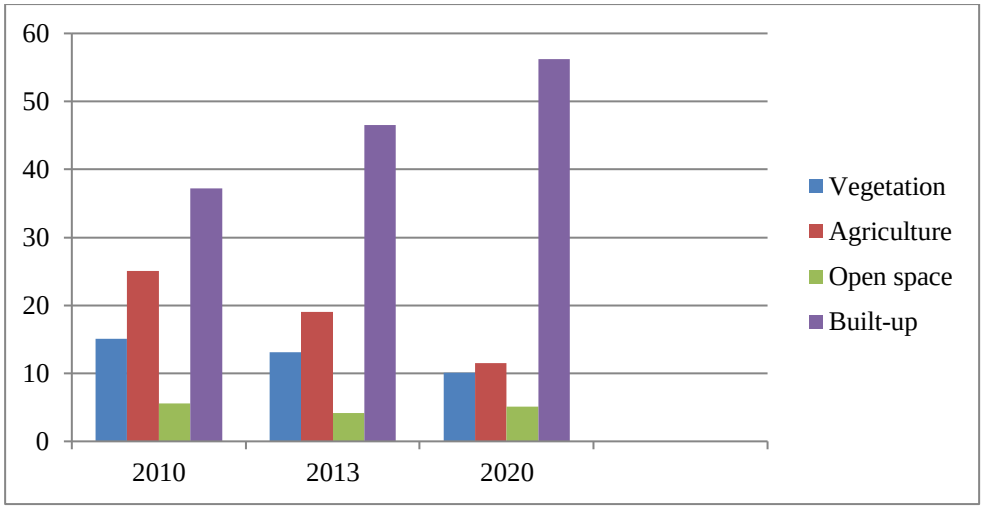


Fig. 9: Land use changes in the Lafia town between 2010 to 2020.

## IV. Discussion

The classified LandSat ETM imagery as shown in Table 1.0 indicated that the town area has a total 82.9 km² land area and also shows the land use/cover changes of the period 2010-2020. Changes have occurred over these years taken away agricultural land/vegetation covers and replacing it with buildings as a result of urbanization. It was reveals that built-up area in 2010 shows an increase of 44.89% while in 2013 shows increase of 56.14% and 2020 shows an increase of 67.79% which is more than half of the land space for urban area of Lafia town. This trend has affected the morphology of the urban system in Lafia town thereby increased the air temperature. The increase is as result of human activities through constructions coupled with the nature of the soil which trapped heat when sun hit the ground leading to urban heat in Lafia town.

This study found that urban green space can produce a cooling effect and significantly mitigate urban heat island, which has been confirmed by many studies (Yu, Yao, Yang, Wang, Vejre, 2019; Yu, Gao, Wang, Vejre, 2019). However, it is worth noting that

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the cooling effect of green space is related to the distance from the green space boundary. That is, with the increase of the distance, the change of the effect becomes lower and lower. When the turning point of distance appears, the cooling effect changes to zero. It showed that the cooling range of green space is not infinite, which is consistent with other research results (Peng, Dan, Qiao, Liu, Wu, 2021).

The rate and intensity of the urban heat island can be remarkably decreased by using appropriate urban space design methods, tools and planning directives. According to the results of this research urban water and green surfaces have the greatest ability in reducing the urban heat island, which surfaces can basically be found in open spaces (excepting green roofs). Besides, usually more than 50% of the total urban area consists typically of open spaces, thus, the appropriate design of these can significantly decrease the urban heat. Tree stands with closed crown canopy layers and developed stand climate are the most efficient cooing surfaces.

**V. Evolving Green Area Planning in Lafia town**

This study has evolved a green area planning as strategies of mitigation the effect of urban heat island in Lafia town. The green area planning design was done for landscaping of Lafia town to ensure the plants absorb the heat that may warm houses at night. Most of the roads were proposed with trees along roads to reduce surface heat. According to this research, the examined distant effect of such cool surfaces is not significant, thus it is practical to rather design green surfaces covered by water surfaces and closed tree stands with a high rate of closed crown canopy layers and consisting of eurytopic tree species capable of high transpiration. It is also very important to develop urban green networks instead of closed and isolated blocks of urban green areas, which mean that the planting and sustaining of linear urban green elements (allées, street tree rows) must be more emphasized (Figure 10 – 11

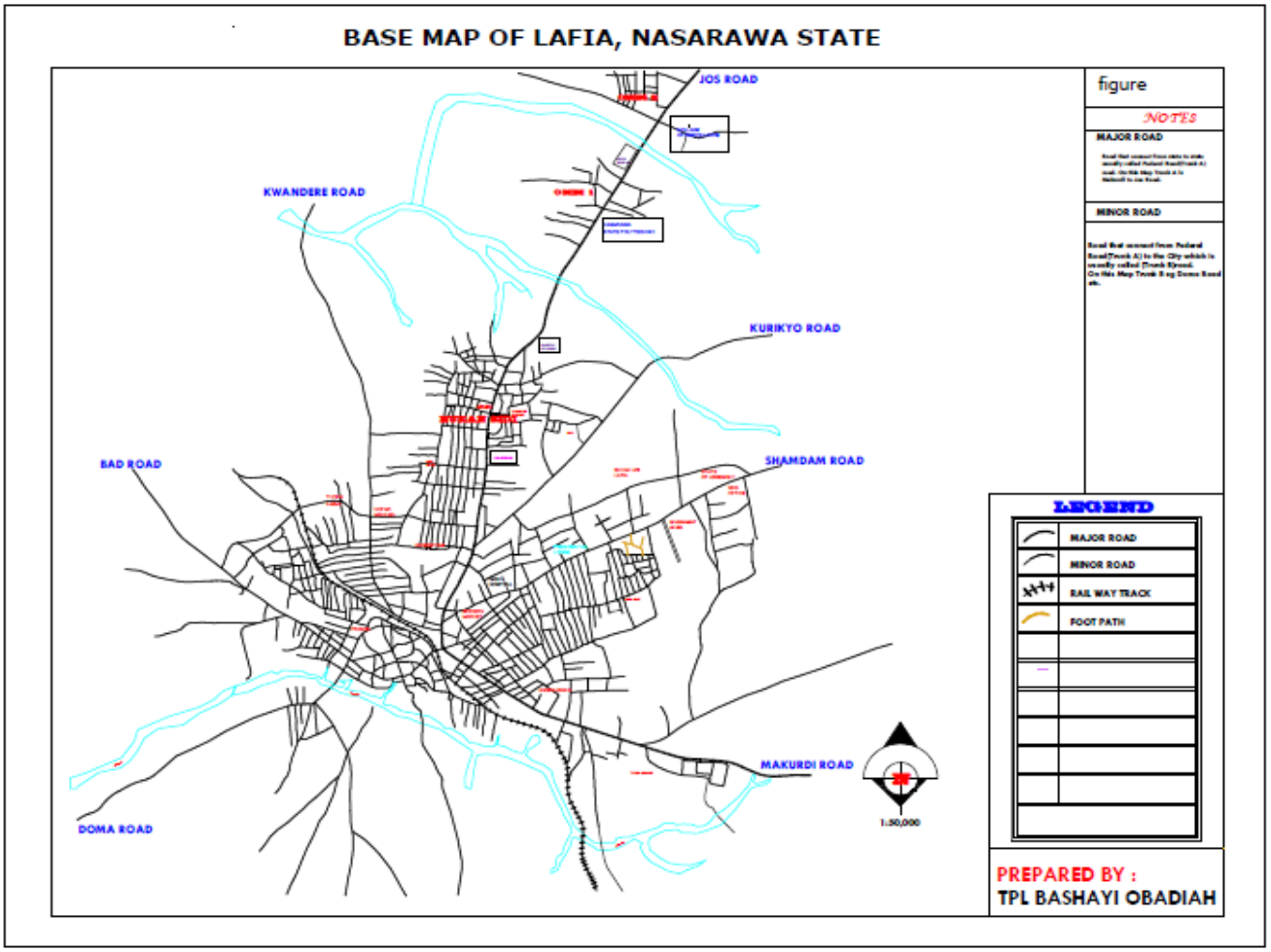


Figure 10. Based Map of Lafia Town

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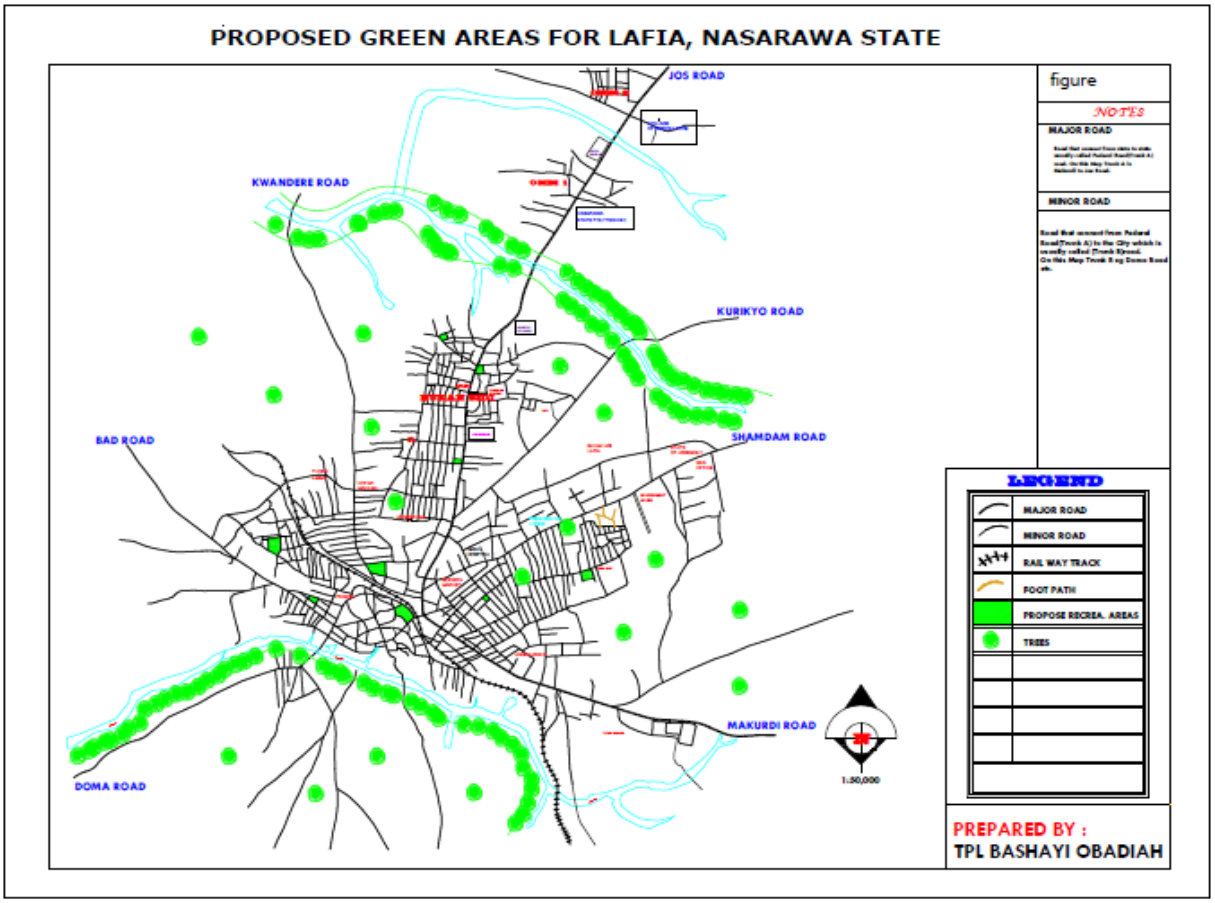


Figure 11: Proposed Green Areas as a Mitigation of Heat Island in Lafia Town

### 5.1 Strategies of Green Space Planning

- Car parks areas should comply with a minimum of 50% shade requirement by plantation of trees or/and at least low level bushes.
- There should be preparation of landscape master plan for urban centre. The implementation of such plan will restore lost aesthetic glory of the town. There should be a regulation applicable to individual developer to stipulate the percentage of the land that must be reserved for landscape and tree planting
- Roads should be shaded with trees enclosed by earth wall with shrubs to reduce the effect impose by direct sunrays and wind. The green areas of parks will moderate adverse climatic air hygiene effects by cooling oppressive summer days, reducing gusting winds and hot weather.
- Green areas and buffer strips of shrubs and trees can insulate residential areas from heat effective. The trees will serve as buffer against the sunrays and winds. Open spaces can be made an integral part of a sustainable and healthy environment in Lafia town through landscape planning and management. Open space when observed in building should be landscape with green flower or grasses.

## VI. Conclusion

The green area planning is one of the most effective strategies to counteract the urban heat island phenomenon. More greenery in public spaces has a relatively low cost compared to other mitigation solutions and provides other important ecosystem services. This study will helps guide the green space planning in urban areas to a certain extent and allows the government and planners to deeply understand the actual situation of the cooling effect of green spaces and their cooling contribution to the communities.

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## VII. Recommendations

This research discussed and recommended three strategies that might be used by Political Leaders, Policy Makers, Urban Planners and Engineers to mitigate urban heat of the city below:

### 7.1 Land Management and Plant Cover:

- Large green areas definitely have positive effect on the temperature of the city. Areas with fewer plants always have higher temperature. On the other hand, the Central Business District area has the highest temperature due to high density and high rise development. Tree planting programs should be reinforced in the urban area and incentives and subsidies should be part of the long term planning for Lafia town. Therefore, a well planned tree-planting program is the main strategy to ameliorate this unbearable heat. The use of sufficient and properly spaced parks would also help to ameliorate conditions there. The creation of as many cities parks as possible will improve the situation and help significantly in reducing the intensity of the urban heat island of the town.
- Moreover, tree planting programs should be introduced for all housing estates. Incentives and subsidies should be part of the long term planning.
- Herbicide should not be applied on grasses rather it should be trimmed in order to maintain a green environment

### 7.2 Urban Planning Recommendations

The existing pattern of land use allocation in Lafia should be adjusted in order to accommodate more open space for green areas. The average land use allocation for urban development in Lafia should be 30% of the total city area be given to residential. The next largest share (26%) is reserved for open space, primarily green areas as broadly defined above. Streets cover more than 20% of the city area. Community facilities and industrial and commercial land should share approximately 20% as been practice in America cities and other places of the world.

For the future urban development in Lafia town, the 26% of the open space should be distributed fairly well over the city. About 40% of the open area should consist of parks, playground, and golf courses for recreational purposes. The remaining 60% is undeveloped land that is bare land or woodlot.

The 30% of the residential development should also be distributed fairly over the city. Where 55% of the space should be plots layout and the current practice of the housing plot size should be adjusted in order to have enough plot size for building and green areas (landscaping) within the residential plot.

### 7.3 Green Open Space Planning Recommendations

The following is recommended for reducing urban heat:

- Planning authority should make sure that building plans include site plan that has detail landscaping and should be monitored to ensure compliance during plot development.
- Adequate and proper setbacks should be observed in building construction and room standard size should be adopted to ensure air circulation around and within building.
- Green space should not be 300metres away from each other for optimum cooling. According to Asaeda and Abu (1998) a 100metres green space cools to a distance of 300metres. Also, vegetation and trees provides shade from direct sunlight radiation.

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