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Evaluation of the spatial growth of Bauchi metropolis using remote sensing and geographic information systems (GIS) techniques

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Mohammed Aliyu Modibbo [1,2,*], Mohammed Arif Shahidah [1], Isah Funtua Abdulkadir [2], Umar Wali [2]

[1] Department of Geoinformatics, Faculty of Geoinformation and Real Estate Universiti Teknologi Malaysia, 81310 Skudai Johor, Malaysia
[2] Department of Surveying and Geoinformatics, Faculty of Environmental Technology, Abubakar Tafawa Balewa University, Bauchi, Bauchi, Nigeria

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ABSTRACT

This paper has evaluated the spatial growth of Bauchi Metropolis from 1976 to 2015 through the application of Remote Sensing and GIS techniques. Various satellite imageries of the metropolis (Landsat MSS of 1976, TM of 1986, 1996 and ETM+ of 2006 and 2015) were integrated; processed and classified using ERDAS imagine 9.1. The results showed an increase in area from 11.68km^2 in 1976 to 12.51km^2 in 1986 to 32.44km^2 in 1996, to 49.66km^2 in 2006 and finally to 89.23km^2 in 2015. It is recommended that government should provide the required capacities for the use of Remote Sensing and GIS in planning for the growth of the town.

1. introduction

Urban growth can be defined as a change in traditional physical texture of a rural landscape in to an urban form [1]. The demography of the world suggests a continuous increase in population and the proportion of the population living in urban areas [2]. For instance, the population of the world increased from 2.5 billion in 1950 to 6 billion in the year 2000 and, is projected to reach 8 billion in 2030. By the same token, the proportion of the population living in urban areas increased from 29.1% in 1950 to 47.1% in 2000. Projections to 2050 suggest that 66.67% of the world population of 9.3 billion will reside in towns [3]. These demographic trends have implications on land and its use. As the populations of cities grow, the need for land to support the use needs of the population also increases. For instance, the weekly need for urban land in developing countries between 2006 and 2036 is estimated at a quantity that will accommodate one million people [4]. Another estimate put

* *Corresponding author.*
E-mail address: modibboma@gmail.com (M. A. Modibbo)

the global urban residential land need as that required to construct 96,150 housing units per day [5]. In Dhaka, Bangladesh, at least 100,000 housing units are required annually to house the added population [5]. The capital of Thailand, Bangkok, requires 40,000 new parcels every year to keep pace with the demand for land [6]. In the same vein, the need in Auckland is 13,000 [7] while Bamako in Mali 5,200 hectares of land should be added by 2020 [8].

The consequence of the increased demand for land is the rapid spatial growth of cities whose magnitude differs from one country to another depending on the productivity, availability of the land resources, land administration and development mechanisms [9]. There are various factors that are responsible for the rapid urban growth which includes rate of mortality is low in the urban centres compared to their counterparts in the rural areas. Also considering the attention being given to the urban centres in terms of health care facilities, death rate seems to be lower compare to the rural areas. In the present days, cities are growing twice faster in terms of land area as compare to population [9]. The built up urban land areas in developing countries, presently at the frontline of urbanization, is expected to increase from the present 200,000km^2 to 600,000 km^2 in 2030. This 400,000km^2 increase will be equal to the world`s total combined urban area in 2004 [10]. Progression in urbanization is considered as the most prominent driver of land cover changes in the history of human civilization [11, 12].

Contemporary urbanization rates suggest that among the continents of the world, Africa has the highest rate of urbanization. For instance, six out of the ten countries with the highest urbanization rates in the world in 2013 are in sub Saharan Africa [13]. Also, from 1975, the continent has been urbanizing at an average the rate of 5% per annum. High rates of natural population increase and in migration to the cities are responsible this trend. Nigeria has the 9th largest urban population in the world and is the most urbanized African country [14]. As at 2010, 50% of Nigerians were urban dwellers, a proportion expected to reach 65% by 2020. The annual rate of urban population growth is thought to be 5.5%, roughly twice the national population growth rate of 2.9% [15]. Expectedly, the physical expansion of cities in the country has been remarkable. A shortlist of local examples of the physical expansion of cities include: Ibadan whose areal extent increased from 36km^2 in 1951 to > 400km^2 in 2000; Enugu, from 72.52km^2 in 1963 to 204 km^2 in 1985 [16]; Port Harcourt, from 17.4km^2 in 1975 to 236km^2 in 2006 [17,18].

Among other implications, the expansion of cities necessitates dynamic and responsive urban land policies and administration. Such policies should deal with the multifaceted process of handling and regulating rights, use and value of land [19], directed at achieving the overall objectives of ensuring the adequate provision of land, its guidance and control for the orderly growth of cities and their efficient functioning [20, 21]. For these objectives to be achieved, determination of the average rates of city growth is essential in planning for the provision of the right quantum of land for various uses.

Because studies about the physical expansion of cities involve temporal spatial change detection and analysis, Remote Sensing (RS) and Geographic Information System (GIS) tools are effective for this purpose [22, 23]. For example, Mishra et al. [24] used RS and GIS to analyzed urban growth and land use changes in Bhubaneswar city of India from 2000-2005, [25] investigated the pattern and urban expansion of Madurai city from 1991-2006, [26] quantified urban sprawl in China from 1980-2003, [27] estimated the loss in agricultural lands in the greater Cairo region of Egypt from 1972-2005 while [9] examined the sprawl of Lokoja town, North-Central Nigeria from 1987-2007.

In spite of being an urban area for long, Bauchi, North East Nigeria appears to be relegated in discourse about urban issues in the country. Yet, it appears that in recent years, the town has expanded significantly within a short time. This is attributable to the fact that since 2000, the town has been the destination of several people displaced by ethno religious conflicts and the *Boko Haram*

insurgency in neighboring states. To assist physical planning and land administration cope with this influx and its associated spatial implications, there is the need to provide temporal estimates of the physical growth of the town. This is the purpose of this study which employed RS and GIS techniques.

2. Methodology

The method to use will depend on the purpose of the study. The study made use of Landsat MSS of 1976, Landsat TM, 1986, 1996, and ETM+ of 2006 and 2015 satellite imageries respectively. The satellite images were obtained from the United State Geological Survey website (USGS; www.usgsearthexplorar.com). The MSS and TM imageries were of 32m resolution while the ETM+ imagery had a resolution of 15m.The rows and columns of the images were 186/053. These image used were radiometrically and geometrically corrected. The subsets of Bauchi Township were extracted from the full scene of the satellite imageries of 1976, 1986, 1996, 2006 and 2015. Both images were rectified and georeferenced to the UTM map projection system (ZONE 32), WGS84 Minna datum Nigeria. The georeferencing was carried out using the coordinates of 24 Ground Control Points (GCPs) obtained using hand held GPS, (78X) instrument. A total of 6 points out of the 24 GCPs, were used as check points for assessment of the transformation.

2.1. Study area

The location of the study is Bauchi town (latitude $10^0 19' 55''$ N and $10^0 20' 58''$N; longitude 9^0 $50'$ $50''$E and 9^0 $51'$ $29''$ E), north east Nigeria (Fig. 1). The town was founded in 1809 by Yakubu, one of the disciples of Sheik Usman Danfodio that established the Sokoto caliphate in northern Nigeria. Yakubu built a wall of about 10.5 km circumference around the town and administered the Bauchi emirate from the town. British colonialists occupied the town in 1902 and made it a provincial capital in 1926. In 1976, it became the capital of Bauchi State and Bauchi local government. The railway was extended to the town in 1961. The tertiary institutions in the town (Abubakar Tafawa Balewa University, Federal and State polytechnics) are sited at the outskirts of the town and have encouraged the development of satellite towns around them. The industries in the town (though most are moribund) includes an asbestos company, Steyr vehicle assembly plant, meat products processing company, fertilizer blending company, Alind electrical cable company, etc. The state Government have built an International Airport and the Nigerian Air Force Base is presently under construction at 22km along the University permanent site. Also the Bauchi State University as at present is constructing its permanent site at 10km along Maiduguri road. All these are making the town to growth faster as satellites towns are being established near all these new projects.

The 1963 population of the town was 38,014. This grew to 283,638 in 1991and was expected to grow at 2.53% per annum [28]. The establishment of zonal headquarters of Federal Government agencies for the North eastern part of the country in Bauchi was another factor responsible for the influx people. These agencies usually built housing accommodation for their staff which has also contributed towards the growth of the city. The 2004 population estimate was given as 316, 149 making the town the 22nd populous town in Nigeria [28]. The 2006 census gave the population of Bauchi Local Government as 493, 810 (the census figures were not disaggregated to town and village levels). It is expected that the bulk of this population reside in Bauchi town. At the national population growth rate of 2.79%, the population of the town is expected to be about 633,580 in 2015. This figure is likely to be much higher in view of the fact that the town has been a destination for many persons displaced by ethno religious conflicts in Plateau State and Boko haram insurgency in other states of

the north east geopolitical zone of the country. Bauchi town is considered as one of the fastest growing city in the Northern part of the country.

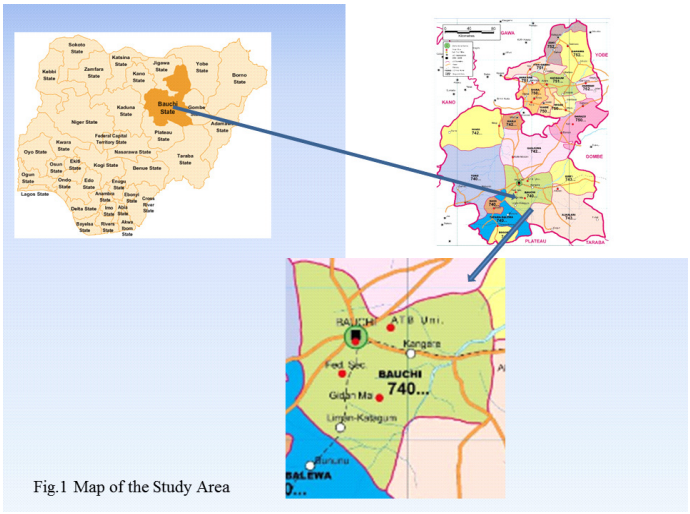

Fig. 1. Map of the study area. *Source:* Bauchi state Min. of Land &Survey, 2015.

2.2. Data processing

ERDAS imagine software was used for image processing while ArcGIS 10.1 was used in map making and analysis. Atmospheric correction was performed because the images were acquired at visible and near infrared wavelengths which are susceptible to absorption and scattering. The root means square error (RMSE) was computed as ±0.437 which is the measure of performance of the classifier. The final map element which includes the date on the map, the North arrow, Grid, Scale, Tittle etc. were exported in TIFF format.

Supervised classification using maximum likelihood algorithm was used. The images were later enhanced and classified in to various land cover types. The used of this algorithms were due to the fact that the author is well familiar with the study area. After the classification process, the three different images were then overlaid to determine the change in land use/land cover over the period of the study. The image statistics provided the information on the rate of changes within the study period.

3. Results and discussion

The results from the analyzed images shows that the area covered by the study area has expanded at various rates within the time frame of the study. In 1976 when the town was made a State capital, the built up area was 11.68km^2 (Fig. 2). This area increased only by 0.83km^2 to 12.51km^2 in 1986 (Fig. 3). This translates into an average annual growth of 0.083km^2. This is rather sluggish. By 1996, the areal extent of the town was found to be 32.44km^2 (Fig. 4). This means that the town increased in size by 19.83km^2. The expansion in the 1986-1996 decade was at an annual average of 1.983km^2. It can be observed that the rate of expansion from 1986-1996 decade was more than twice of that of the preceding decade (1976-1986). In 2006, the built up area covered 49.66km^2 (Fig. 5); an increase of 17.22km^2. The average annual increase was 1.722km^2. Between 2006 and 2015 the town expanded by 39.57km^2 to have a size of 89.23km^2 (Fig. 6).

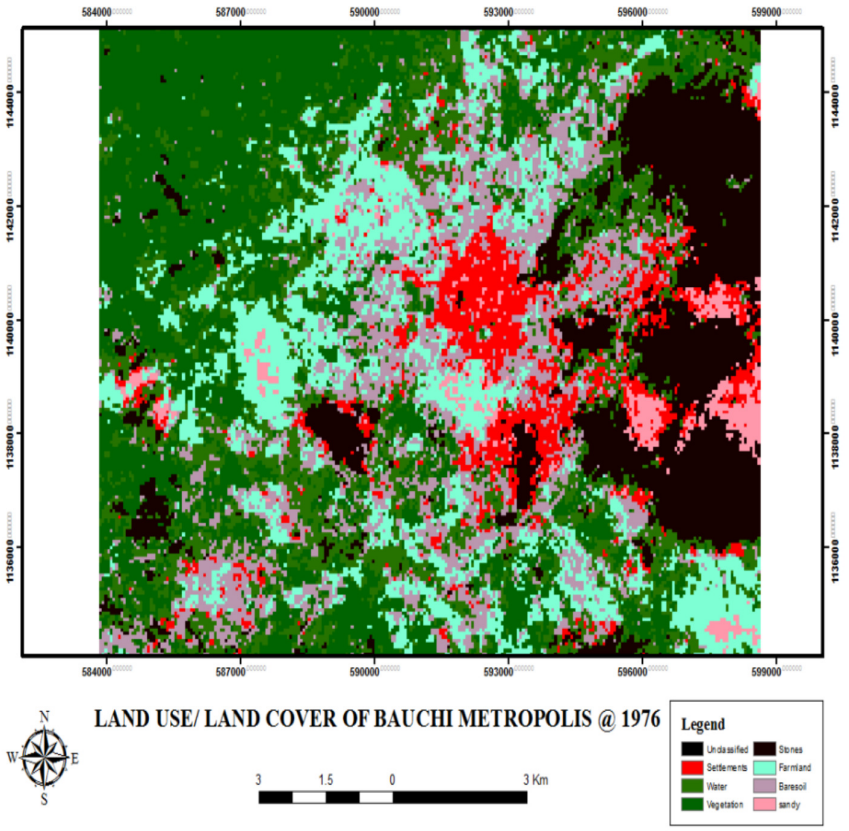

Fig. 2. Land use/Land cover of Bauchi Metropolis 1976

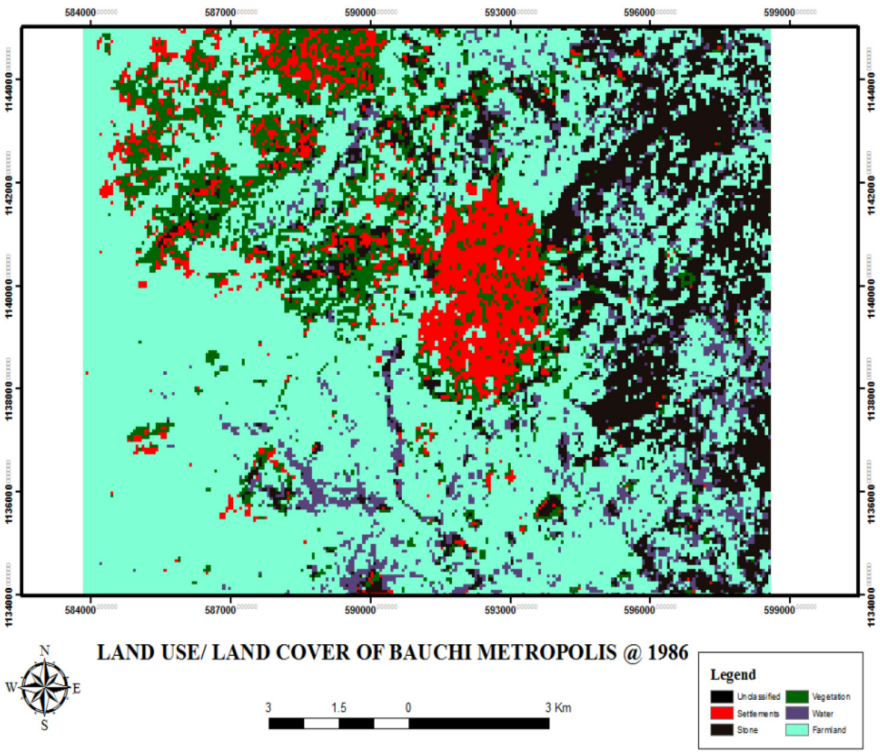

Fig. 3. Land use/Land cover of Bauchi Metropolis 1986

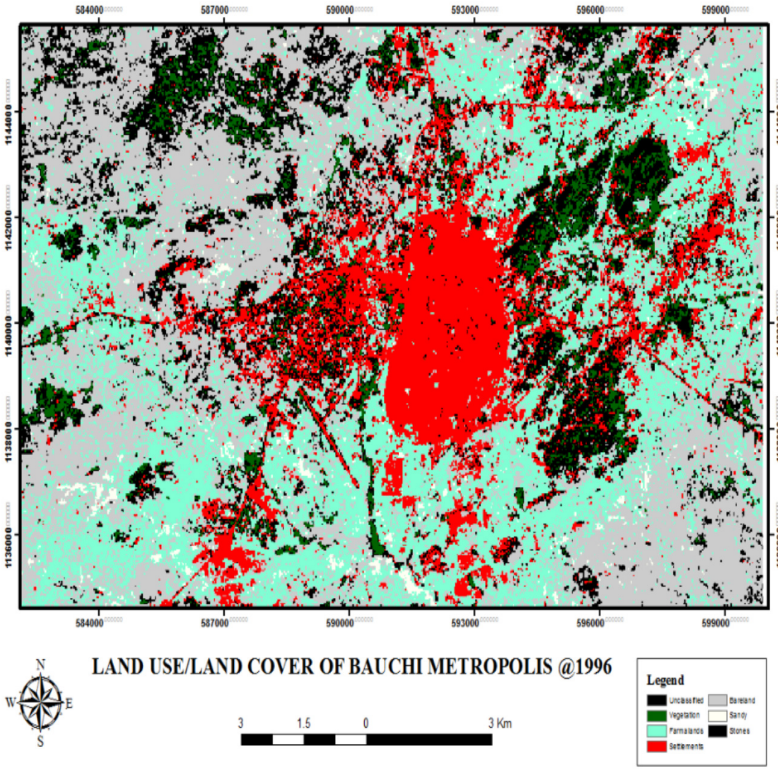

Fig. 4. Land use/ land cover of Bauchi Metropolis 1996

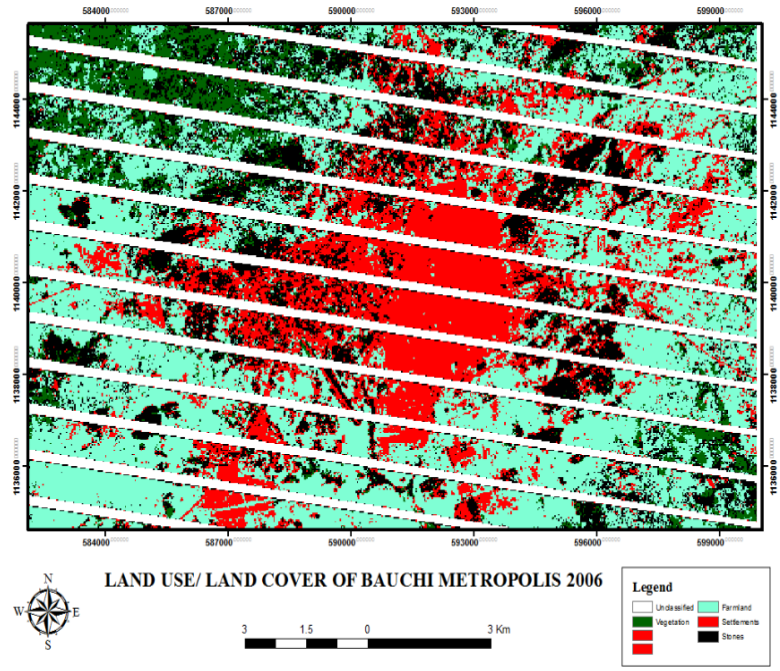

Fig. 5. Land use/ land cover of Bauchi Metropolis 2006

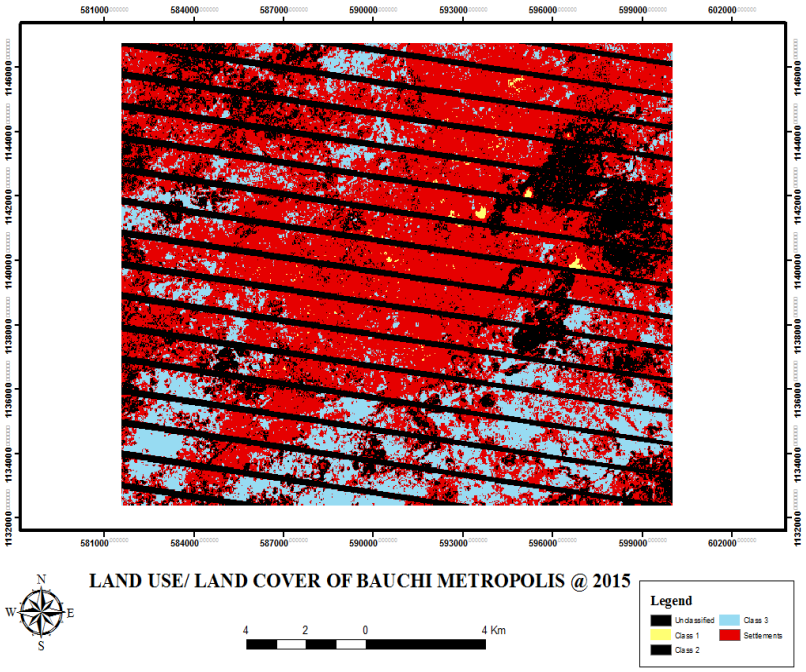

Fig. 6. Land use/land cover Bauchi Metropolis, 2015

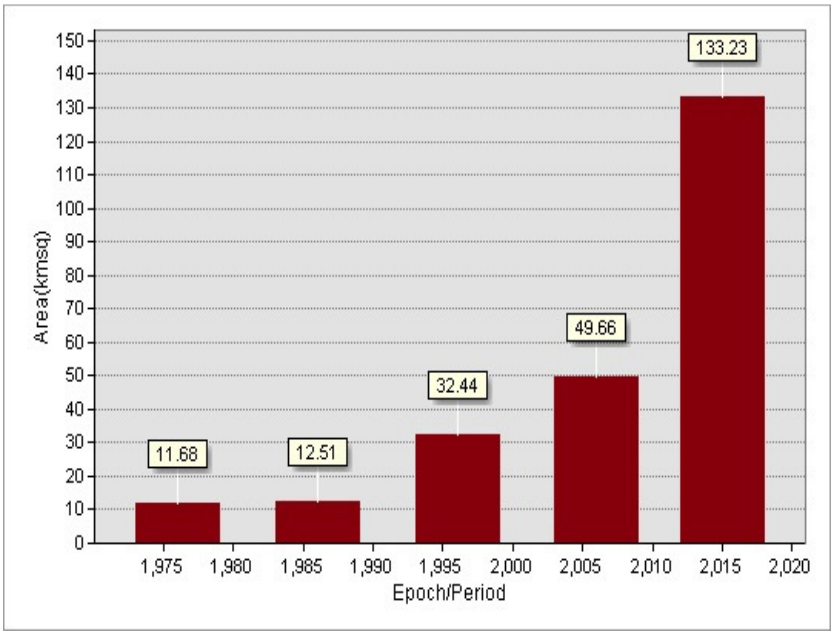

Fig. 7. Bar-chart showing increase in area (km^2) against the time

Thus, the town experienced the largest expansion between 2006 and 2015. The annual increase from 2006-2015 was 4.40km^2 for a period of 9 years. So take this rate and do the projection to 2030 which is 15years (15 multiply by 4.40= 66.00km^2). Then we add this with the area obtained in 2015 which is 89.23km^2 will give an area of 155.23km^2. This can be attributed to the influx of persons that sought refuge in the town as a result of violent conflicts from the adjoining states. The bar chart represented in Fig. 7 is based on recent growth trends, it can be estimated that by 2030, the size of the town will be 155.23km^2. As the city is experiencing rapid urbanization, it has brought some socio-

economic problems such as, greenhouse warming, overcrowding, air and pollution, slums etc. This growth may be attributed to the improvement in the economy between 1999 and 2015 when the country returns to democratic rule after a long military misruled. The influx of rural to urban migration is another reason for the rapid expansion of the city. The city has experienced rapid population growth and even identified as the most rapidly expanding city in the North east sub-region of the country. The effect of this spatial growth is the loss of biodiversity and environmental resources through the loss of vegetation cover. We also know that loss of vegetation decreases the amount of oxygen and increase the amount of carbon dioxide. This rapid spatial growth has also resulted in the increase waste generation and refuse damp that usually come from domestic and commercial places causing heaps of uncollected waste as used to be seen along some major streets. This is a challenge to physical planners, policy makers and land administrators to plan and ensure that infrastructures such as roads, pipe born water, electricity hospitals, and schools are provided and availed at a rate that is adequate for the anticipated growth.

4. Conclusion

The study has demonstrated the use of Remote Sensing and GIS techniques in assessing spatial urban growth. It has demonstrated its uniqueness for that purpose by providing temporal spatial data for the study area. It was also observed that Bauchi metropolis have witnessed a tremendous growth since the town was made a state headquarters in 1976.Even at present the town is going through some developmental projects as stated above. These ongoing projects will go a long way in increasing the amount of growth of the city in some years to come. These techniques should be embraced by Government agencies that are responsible for physical planning and land administration. The needed capacities in hardware, software and personnel to deploy remote sensing and GIS tools in the management of our towns and cities should be priotized. More attention should be given to the areas of space technology in our higher institutions of learning.

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