TEST Engineering & Management

November-December 2019
ISSN: 0193-4120 Page No. 3284- 3291

Modelling of Population Density in Urban Cities using VIIRS Night Time Light Data

Siti Noratiqah Mohamad Deros[#1], Norashidah Md Din[#2], Syamimi Norzeli[#3], Azmira Mohd Sukri[#4], Mohd Zafri Bin Baharuddin[+5]

[#1]*Institute of Energy Infrastructure, Universiti Tenaga Nasional (UNITEN),43000 Kajang, Selangor, Malaysia*
[1]siti.noratiqah@uniten.edu.my,[2]*norashidah@uniten.edu.my*,[3]*MNsyamimi@uniten.edu.my*,,[4]*azmira.sukri@uniten.edu.my*

[+]*Electrical and Electronics Department, Universiti Tenaga Nasional (UNITEN), 43000 Kajang, Selangor, Malaysia*
[5]zafri@uniten.edu.my

Article Info
Volume 81
Page Number: 3284- 3291
Publication Issue:
November-December 2019

Article History
Article Received: *5 March 2019*
Revised: *18 May 2019*
Accepted: *24 September 2019*
Publication: *16 December 2019*

Abstract:
— The changes in the number of population are one of the important measures for several activities such as land-use planning, environmental monitoring, construction design, soil, water and air quality observation. Urbanization accelerates the development of city and residential expansion. Proper planning of urban city needs a thorough observation to maintain good environmental and economic growth. This study was conducted to estimate and model urban population in five cities in Peninsular Malaysia (Ipoh, Johor Bahru, Klang Valley, Kuantan and Pulau Pinang) from night time light images. This image records the light intensity and helped in derive gridded urban population estimation from the number of light radiance acquired by Day/Night band of VIIRS sensor. The results show that the number of population estimation highly correlates to light intensity (R2>0.7). Validation of the polynomial model shows that the population density of estimated and actual population derived by censuses have high similarities and close into each other.

Keywords: *Night time lights, VIIRS, population density, Day/Night band, urban*

I. INTRODUCTION

Sustainable urban development is important to monitor towns' planning and development to reduce issues such as insufficient amount of housing area in town or urban area, urban poverty and many more. The urban development process, especially in Malaysia focused on the enhancement of environmental quality through several strategies which include the collection of information through census programs. Other than that, proper planning with the members that involved in decision making process consist of the Local Authority, consultants and the residents itself. This is important to ensure the quality of life especially in housing, educational, recreational, public facilities and infrastructure aspect. The statistic on the degree of urbanization in Malaysia from 2007 to 2017 shows that 75.45 percent of Malaysia's total population lived in urban areas and cities [1]. The changes in urban population influenced the production and life styles of the residents and gradually affect an environment and socio-economic. Malaysian government carried out censuses to monitor urban and rural population, their average income, age, ethnic and such. However, the time series data of the censuses done failed to visualized the spatiotemporal pattern of Malaysian population besides the census activity is time and cost consuming [2].

November-December 2019
ISSN: 0193-4120 Page No. 3284- 3291

Previous researchers identify the potential of night time light data that photographs lighting of the Earth at night. Nighttime light (NTL) data is one of an effective indicator to monitor human activity due to their close relationship with population, gross domestic product (GDP) and electricity consumption. It records nocturnal lights on the Earth's surface at night to observe human activities. Two main sources of global NTL data are the annual composite image of Operational Linescan System (OLS) onboard Defence Meteorological Satellite Program (DMSP) since 1992 and the latest is NTL images from VIIRS instruments. [3] used night time light data to simulate spatio-temporal energy consumption in China's province. Global NTL data was believed as an ideal data source for monitoring human activities intensity and this closely related to an energy consumption estimation. The estimation can be successfully done by considering regional characteristics such as spatial heterogeneity, population size, land area and other related statistical data.

NTL data can also be used to observe spatiotemporal variations of carbon dioxide (CO2) emissions. Previous study claims that the total light value of NTL data image has a significant correlation with total CO2 emission. This study helped in monitoring environmental condition, maximize energy conservation and minimize harmful gas emissions [4].

[5] in other hands used night time light data to monitor an economic development. The study aims to measure changes in economic activities at national and global scales. The study highlights the potential of remote sensing data especially night time light data in economic analysis. Other use of night time light data is an urbanization analysis, population and economic activities.

Other study done by [6] conducted a research on urban population estimation by using DMSP/OLS NTL images. The result showed that there were high potentials of night time lights in showing the presence of human existence. The mosaic of NTL images enables to line the correlation of light pixel frequency values with the number of urban population. Another used of NTL data in population estimation and modelling was performed by [7] that estimates the number of population by conversion of NTL images into binary images where the number of pixels that was used to estimate the light activity is 1-bit value. The results showed that the actual population of the study area agrees with the value of binary images. However, despite all available benefit and use of NTL data, its application in Malaysia is still limited. This is mainly due to the availability of NTL data in Malaysia is limited.

This paper aims to model the human population density in urban area in Malaysia by using NTL data for year 2013, 2014, 2015 and 2017. This can picture the trend pattern of population density in an urban area and evaluate the spatial and temporal changes. This can also project the relationship between the light radiance captured in the NTL data to human population in urban area. This study is important to observe energy consumption in the area at night.

II. Data Acquisition

Night time light data were obtained from The Visible Infrared Imaging Radiometer Suite (VIIRS) onboard Suomi National Polar-orbiting Partnership (S-NPP) satellite. S-NPP is a groundwork mission for an upcoming Joint Polar Satellite System (JPSS) in supplying data product. One of the data product is nighttime light imageries that have been widely used as a sign of human undertakings. A panchromatic Day/Night Band (DNB) pictures the

November-December 2019
ISSN: 0193-4120 Page No. 3284- 3291

visible and near-infrared (NIR) image of Earth in the presence of sunlight to night illumination and emission. The NTL data was retrieved by UNITEN's satellite receiver and archived data were connected to The Energy Sphere Satellite Monitoring Centre in UNITEN, Selangor.

Five sets of NTL data from VIIRS sensor were used in this study. The images contain NTL from cities, roads and expressway, and also flares. The cities focused in this study is the five busiest city in Peninsular Malaysia which is in Klang Valley, that include Gombak, Hulu Langat, Klang, Kuala Langat, Kuala Selangor, Sepang and Shah Alam district. Ipoh town consists of Kinta and Perak Tengah district while Johor Bahru town includes Kota Tinggi area. The other study area involved in this study is all district in Pulau Pinang state and Kuantan town in Pahang. The data also provide information on the extension of urban area coverage in degree of latitude. The night time light data were acquired in different temporal year; 2013, 2014, 2015 and 2017 to observe the changes of the population density. Fig 1 below shows the image of NTL data from DNB band VIIRS sensor.

Fig. 1Night time light data from DNB of VIIRS sensor onboard S-NPP satellite

VIIRS NTL data were acquired by DNB has a spatial resolution of 750m per pixel. This data contains light intensity values at night that can be used to measure the activity on Earth. The supporting data is the population data that was used to validate the model derived from the satellite images.

The statistical population data was provided by Department of Statistics Malaysia (DOSM) through census program. Census provides population information for each district in Malaysia for year 2017 and the population number was revised in 2018. These data were used to validate the population density result retrieved from NTL data for year 2017. The descriptive statistic for the population data were described in the following Table 1.

TABLE I
POPULATION DATA FOR FIVE CITIES IN 2017 FROM CENSUS PROGRAM

City	Population ('000)	Area (km2)
Ipoh	934.6	3922.5
Johor Bharu	1779.1	5271.63
Klang Valley	4921.7	5223.23
Kuantan	515	3042
Pulau Pinang	1746.7	1048

Table 1 shows that the highest population were recorded in Klang Valley, followed by Johor Bahru and Pulau Pinang. The lowest number of population for an urban city in Peninsular Malaysia is Kuantan and followed by Ipoh town.

III. METHODOLOGY

Four images of night time light (2013, 2014, 2015 and 2017) data were prepared by performing geometric correction, define the projection of the data to WGS 1984 Geographic Coordinate System and datum. Then, the speckle noises on the images were removed by radiometric correction. Then, all images were ready to be used in the determination of relationship between radiance intensity and population density.

November-December 2019
ISSN: 0193-4120 Page No. 3284- 3291

The spatial resolution of the night time light image is 750 m at nadir. The pixel-level images for each cities or town were reformatted to grid-level. This is to group all pixels to a grid due to the number of observations in one pixel-based image. The images then were clipped into the specific cities of the study area as shown in Fig. 2.

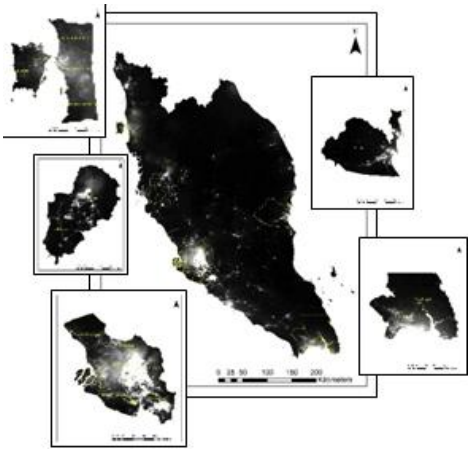

Fig. 2Five cities in Peninsular Malaysia were clipped from VIIRS night time light data

The NTL shape was extracted from raster datasets and then were converted into light features. The stable light radiance was selected from the light polygon area derived from the gridded night time light raster. The light provides an information on the human activities at night that can be used to estimate human population in an urban area. It is apparently show that the DNB sensors able to detect dim lights from rural areas while bright lights in urban areas. Lights were ranged from 0-255 radiance where 0 is no light pixel while 255 is the brightest light in a pixel. In this study, low number of light radiances show low night activity of human and low number of population in the area. The mean intensity of light was calculated statistically and the population densities were derived using Eq. 1 [14].

$$Population\ density, y = \frac{Population_{\ i}}{Area_{\ i}} \quad (1)$$

Equation above shows that the population density highly correlates proportionally with population and influenced by the study area extension. The relationship between the population densities and light intensities were determined by using either linear, exponential and logarithmic models.

Finally, for validation of population density estimation, the derived density from NTL images for year 2017 was evaluated to the data derived by censuses programs.

IV. Results and Discussion

Night time light images that were processed to obtain light features for five urban areas selected in this study. By using the method outlined, the number and density of population can be estimated. The relationship between the population numbers and light radiances were established in the following Fig. 3 to 7.

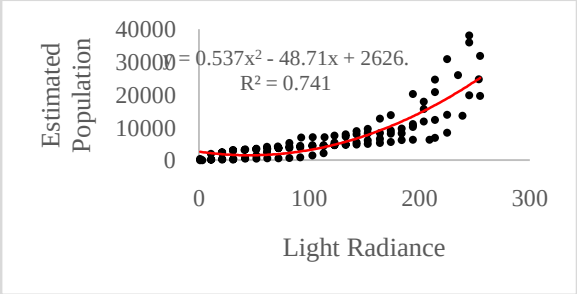

Fig 3. Relationship between light radiance and estimated population for Ipoh town from 2013 to 2015

The highest number of population in one grid of night light features reach up to 40,000 with the radiance value of 255. The correlation of coefficient, R^2 between light radiance and population estimation is 0.7412. The number of population was consistent at the lower light level and the mean value of light radiance to the number

November-December 2019
ISSN: 0193-4120 Page No. 3284- 3291

of grid is unstable with the increase in the light radiance.

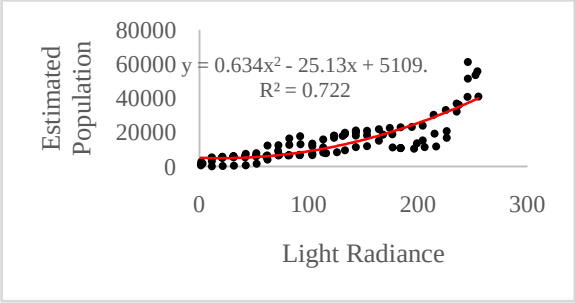

Fig. 4. Relationship between light radiance and estimated population for Johor Bahru town from 2013 to 2015

There were consistency of estimated population and light radiance plot where the coefficient of determination between then is 0.722; highly depends into each other.

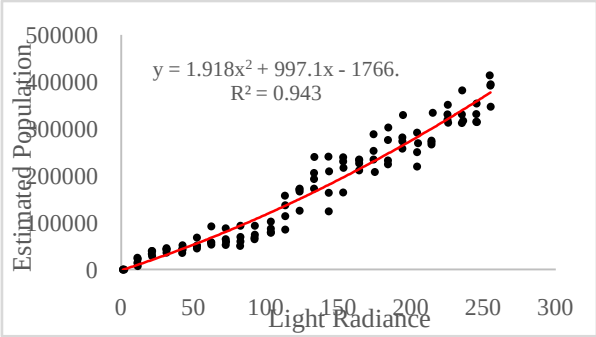

Fig. 5. Relationship between light radiance and estimated population for Klang Valley town from 2013 to 2015

There was high dependency between population and NTL radiance for Klang Valley estimation. This results in high R^2 value; 0.9436.

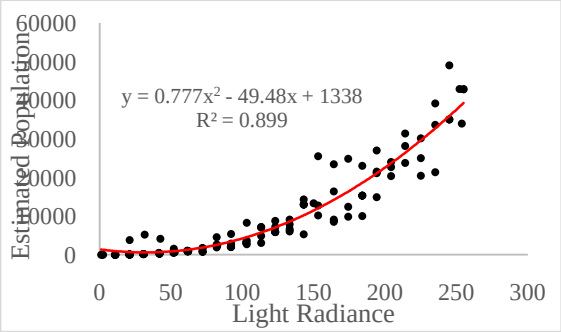

Fig. 6. Relationship between light radiance and estimated population for Kuantan town from 2013 to 2015

Fig. 6 shows that the polynomial relationship between estimated population and NTL radiance were highly correlate into each other and the variance proportion value is 0.8998.

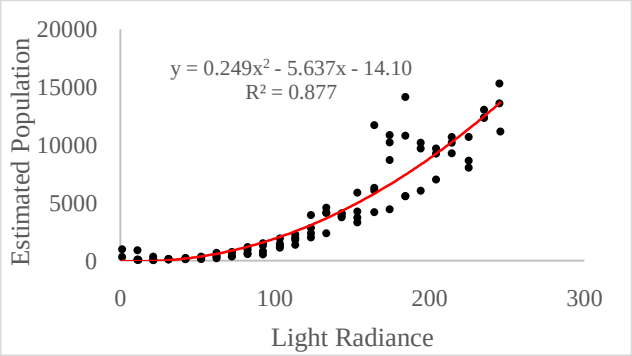

Fig. 7. Relationship between light radiance and estimated population for Pulau Pinang state from 2013 to 2015

As observed in Fig. 7, the polynomial relationship between these two variables were highly depends into each other with coefficient of determination value is 0.8775.

In general, from Fig. 3 to 7, it can be observed that there were empirical relationships between the number of population to light radiance retrieved from NTLimages. High coefficient of determination, R^2 value shows that there were strong polynomial relationships between these two variables. Population number can be estimated from

November-December 2019
ISSN: 0193-4120 Page No. 3284- 3291

the radiance number of night time light data. As shown, the lowest R^2 value is Johor Bahru and Ipoh, but it is considered as high.

Hence, Equation 2was used to retrieve the mean value of light radiance in individual cities of light grid images. $x = \frac{\sum_{j=1}^{N}(r)_{ij}}{N_i}$(2)

Where *x* is the mean value of light radiance, r_i and N_i are the radiance number of grid j and the total number of the grid in the image. Hence, the total number of population density can be derived by dividing the number of population to the total area in km^2.

The population density map from 2013 to 2015 was made from the NTLfeatures derived from NTLdata as in Figure to Figure.

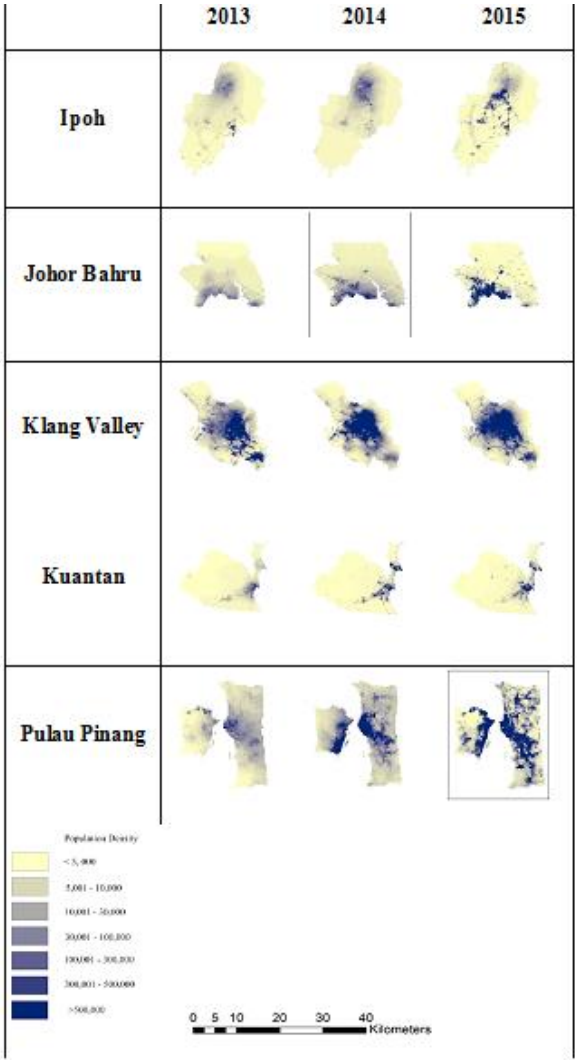

Fig. 8. Population density map for five cities in Peninsular Malaysia for 2013 to 2015 extracted from VIIRS night time light data

November-December 2019
ISSN: 0193-4120 Page No. 3284- 3291

Fig.8shows that there were differences in night lights for each city from year 2013 to 2015. This indicate different activities done in these cities. This also indicate that there were different in the number of population in each city. As we can see from the population map, there were increase in the population density in 2015 while and mainly focused in one smaller area. This may be due to the facilities and infrastructure offered in the area is well-developed hence it became the attractive spot for night activities and residence.

Klang Valley experience the highest radiance of night light. These agrees with the plot shown in Fig. 5 where it indicates the linear increase in the number of population estimated from night time light images from 2013 to 2015 especially in Shah Alam, Hulu Langat, Sepang and Gombak. The results of the population density were validated by using night time light data and census data for 2017 and the results were shown in the following figure.

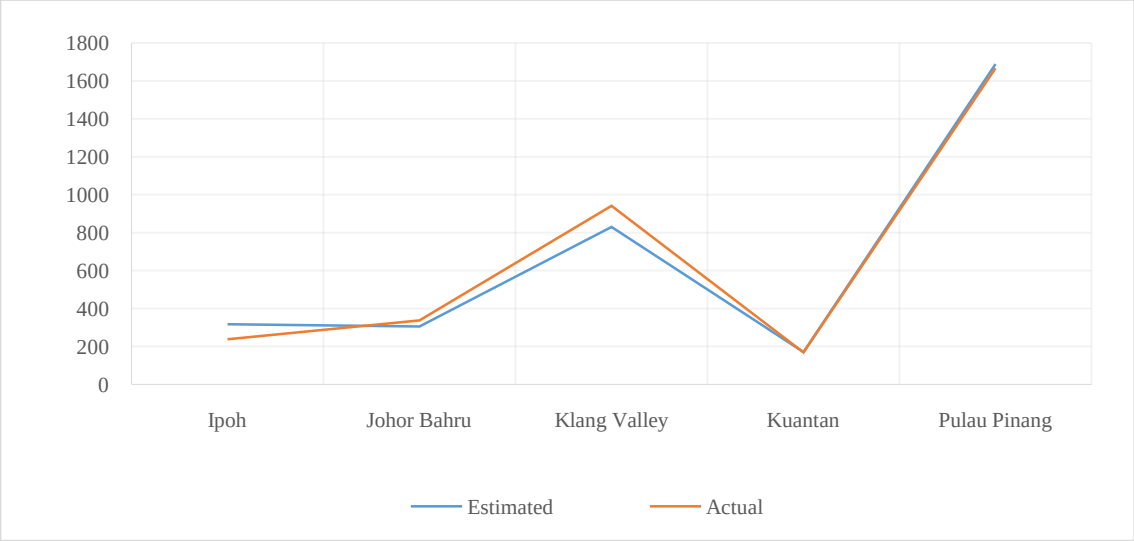

Fig. 9. The plot of estimated and actual population density in 2017

The result of population density retrieved from night time light data shows that the lowest population density is in Kuantan followed by Johor Bahru and Ipoh. The highest density was estimated in Pulau Pinang due to the high population number but smaller area compared to Klang Valley that has higher number of population and area coverage. From Figure 8, it can be observed that the estimated number of population retrieved from VIIRS night time light data has high similarities with the actual data collected by census programs conducted by DOSM. There was slight difference in population estimation in Klang Valley that may be due to the gas flares and refinement emitted by the factories in industrial area around Klang Valley. This result agrees with [14] that was introduced the methodology to model the density of population by using satellite images. Estimation done by grid-based technique may misclassify them for night time light radiance. It is recommended that the improvement of the method to distinguish the flares and refinement of light from the actual light radiance.

November-December 2019
ISSN: 0193-4120 Page No. 3284- 3291

V. CONCLUSIONS

As a conclusion, the night time light data can be used estimate the number of population and its density in urban area. Grid-based images that derived from pixel-based images collect the data of light radiance gives a variety of human well-being measurement technique. This will technically improve the night time observation of Earth and reflects human activity such as electrical energy consumption, population, carbon emission, air quality and many more.

ACKNOWLEDGMENT

Authors express sincere gratitude toresearch team who provided insight and expertise that greatly assisted the research.The paper is a continuity of the project grant U-TS-CR-17-01 funded by UNITEN R&D Sdn. Bhd, Universiti Tenaga Nasional Malaysia.

REFERENCES

[1] Plecher, H. (2019). Malaysia: Urbanization from 2007 to 2017. Statistica 2019. https://www.statistica.com/statistics/455880/urbanization-in-malaysia/

[2] Tarmiji, M., Usman, Y., Norizawati, M.A. and Aimi, S.M. (2012). Population and spatial distribution of urbanization in Peninsular Malaysia 1957-2000. Malaysian Journal of Society and Space 8. Issue 2. pp 20-29

[3] Hongwei X., Zhongyu M., Zhifu M., John Kelsey., Weihua Y. and Min Y. (2018). Spatio-temporal simulation of energy consumption in China's provinces based on satellite highttime light data. Applied Energy. Vol. 231(2018), p. 1070-1078

[4] Xiaolin C., Yutong L., Fan Z., Xueyan Z. and Feng W. (2019). Mapping spatiotemporal variations of CO2 (carbon dioxide) emissions using nighttime light data in Guangdong Province. Physics and Chemistry of the Earth, Vol. 110(2019). p. 89-98

[5] Souknilanh K., Magnus A. and Ola H. (2015). Monitoring Economic Development from Space: Using nighttime light and land cover data to measure economic growth. World Development. Vol. 66(2015). p. 322-334

[6] Amaral, S. Monteiro, A.M.V., Camara, G. and Quintanilha, J.A. (2006). DMSP/OLS Night-time Light Imagery for Urban Population Estimates in The Brazilian Amazon. International Journal of Remote Sensing. Vol. 27, No. 5, pp. 855-870

[7] Turan, M.K., Yecur, E., Sehirli, E. and Karas, I.R. (2017). Estimation of Population Number via Light Activities on Night-time Light Satellite Images. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XLII-4. Pp 103-105

[8] Tillottama, G., Sharolin, J.A., Christopher, D.E., and Paul, C.S. (2013). Using nighttime satellite imagery as a proxy measure of human well-being. Sustainability. 5, 4988-5019.

[9] Husi, L., Masanao, H., Hiroshi, Y., Kazuhiro, N., Gegen, T., Fumihiko, N. and Okada, S. (2010). Estimating energy consumption from night-time DMSP/OLS imagery after correcting for saturation effects. International Journal of Remote Sensing. Vol. 31, No. 16, 4443-4458.

[10] ChamhuriSiwar, Ferdoushi Ahmed, Ahmad Bashawir and Md. Shahin Mia, 2016. Urbanization and Urban Poverty in Malaysia: Consequences and Vulnerability. Journal of Applied Sciences, 16: 154-160

[11] Marlyana, A.M., Dasimah, O., Oliver, L.H.L., Muhammad S.H. and Maasoumeh, B. (2011). Malaysian Urban Indicators Network: A Sustainable Development Initiative in Malaysia. European Journal of Social Sciences – Volume 25, Number 1, pp. 77-84

[12] Amaral, S. Monteiro, A.M.V., Camara, G. and Quintanilha, J.A. (2006). DMSP/OLS Night-time Light Imagery for Urban Population Estimates in The Brazilian Amazon. International Journal of Remote Sensing. Vol. 27, No. 5, pp. 855-870

[13] Paul, S. and Christopher D.E. (2011). Relationships Between Night Time Imagery and Population Density for Hong Kong. Proceedings of the Asia-Pacific Advanced Network 2011. Vol. 31, pp 79-90

[14] Minghong, T., Xiubin, L., Shiji, L., Liangjie, X.,Hue, W., Qian, L., Wei, L., Yuanyuan, L. and Wenli, X. (2018). Modeling population density based on nighttime light images and land use data in China. Applied Geography 90: 239-247

[15] Maria, F.A.B., Ola, H. and Magnus, A. (2015). Nighttime light and Population Changes in Europe 1992-2012. Ambio. 44:653-665