ESTIMATION OF POPULATION NUMBER VIA LIGHT ACTIVITIES ON NIGHT-TIME SATELLITE IMAGES

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ABSTRACT:

Estimation and accurate assessment regarding population gets harder and harder day by day due to growth of world population in a fast manner. Estimating tendencies to settlements in cities and countries, socio-cultural development and population numbers is quite difficult. In addition to them, selection and analysis of parameters such as time, work-force and cost seems like another difficult issue. In this study, population number is guessed by evaluating light activities in İstanbul via night-time images of Turkey. By evaluating light activities between 2000 and 2010, average population per pixel is obtained. Hence, it is used to estimate population numbers in 2011, 2012 and 2013. Mean errors are concluded as 4.14% for 2011, 3.74% for 2012 and 3.04% for 2013 separately. As a result of developed thresholding method, mean error is concluded as 3.64% to estimate population number in İstanbul for next three years.

1. INTRODUCTION

World population increases faster and faster in the world day by day and it is estimated that world population will reach 12 billion according to The United Nations Population Organization and 80% will live in cities. The number of migration from country sides to cities in Turkey increases after 1980s and urban areas get larger and larger visibly. In Turkey, population growth generally takes place in developed cities as İstanbul, Ankara, İzmir.

Increasing the number of migration to developed cities brings about changing physical structures, socio-economic structure, unplanned and irregular urbanization, miss use of natural sources and so on. Hence, it is very necessary that cities that have a dynamic structure should be observed and monitored regularly.

At the present time, observation of dynamic structures of cities gets easy since GIS and remote sensing technologies have developed. The main source for observation of cities is satellite images. Along with development of satellite technologies, qualities and ranges of images increase.

Night-time images have usually been used to investigate global economic and demographic differences between countries in the literature. (Imhoff et al., 1997; Henderson et al., 2003; Elvidge et al., 2009). Levin and Duke (2012) utilized night-time images of Israel and West Bank to investigate economic and demographic differences. The results were compared with population data (Levin and Duke, 2012). Liu et al. (2012) have a manuscript that identifies urban expansion dynamics (Liu et al., 2012). Wei et al. (2014) performed a scientific work to uncover the changes of urban areas (Wei et al., 2014). MODIS or DMSP-OLS images have been used for the researches (Huang et al., 2016; Mertes et al., 2015; Small and Elvidge, 2013; Yi et al., 2016; Yücer and Erener, 2017).

2. MATERIAL

The images used in developed software have been obtained from National Center for Environmental Information (NOAA). NOAA has created a database named as Version 4 Defence Meteorological Satellite Program-Operational Linescan System Nighttime Lights Time Series (Verison 4 DMSP-OLS) for night-time lights images in the world. In this database, there exist night-time light images captured from 1992 to 2013 for any place in the world. The images in Version 4 DMSP-OLS have been downloaded using the link of https://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html. Each pixel on night-time images is in resolution of 30x30 arc seconds. Images are covered between -180 and +180 longitude with between -65 and +75 latitude. Images are created as composite images taken from two different satellites at nights without clouds. The images contain some positive features. Data have been obtained from OLS frames with 3000 km width. Sunlights have been removed with solar height angle correction. Light bursts have been removed with solar height angle correction. Lunar illumination, observation data among clouds, OLS thermal band data have been removed from the images using NCEP surface temperature grid. Aurora illuminances on the north hemisphere have been removed manually. In this study, processed images that contain stable lights have been utilized. The images are 8-bit, in size of 43201x16801 and format of geoTIF. The images have been cropped based on the coordinates of Turkey and obtained as geoTIF. Hence, the biggest three cities that are İstanbul, Ankara and İzmir have been cropped separately and saved as geoTIF files one by one in new created database. 34 different image files that are ordered according to years for each city have been recorded. Size of Ankara, İstanbul and İzmir images are 366x243, 233x89 and 273x190 respectively. Sample cropped images of Turkey, Ankara, İstanbul and İzmir are shown in Figure 1.

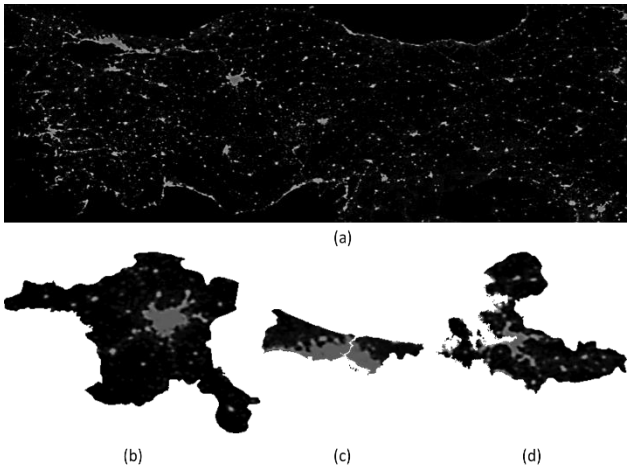

Figure 1. The cropped images in 2013 a) Turkey b) Ankara c) İstanbul d) İzmir

3. METHODS

A novel method is used to convert light activity images to binary images. The novel method includes three stages. At first stage, any number and length of horizontal pixel values are randomly selected. These selected pixels are named as random horizontal reads. At second stage, cascade arithmetic means are calculated on random horizontal reads until one mean value obtains. This process is named as cascade means. Random horizontal reads are shuffled using Bootstrap method and a new cascade mean is obtained. This process is applied along minimum 100 iterations. At the end of all iterations, this process is also applied on obtained cascade means and one cascade mean value is specified. But, first and last 2% of cascade means are not included. Confidence interval is determined as 96%. At third stage named as threshold stage, input images are converted to binary images using the specified cascade mean. Figure 2 shows a numerical sample about the process.

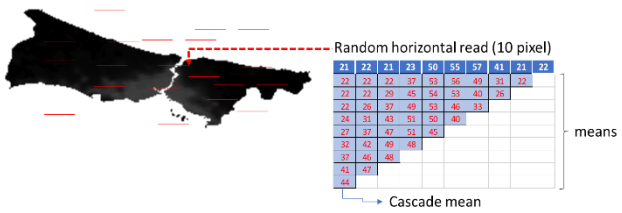

Figure 2. Cascade mean filter

Figure 3 shows the histogram of obtained cascade means and an obtained binary İstanbul image using specified cascade mean value.

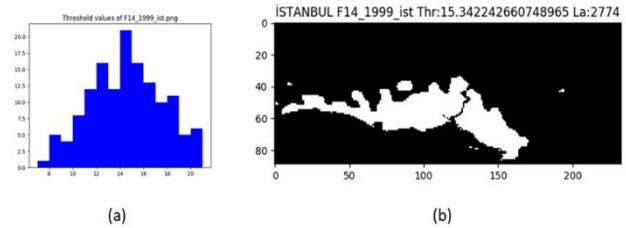

Figure 3. Histogram and binary İstanbul image using cascade mean filter a) Histogram b) Binary İstanbul image

Light activity values on obtained binary images are obtained by counting pixels which have 1-bit value. Pixel per population is calculated as dividing Light activity value by annual real population number in the city. As a result, pixel per population is used to estimate population number of a city for next years by considering light activity values and past annual real population numbers.

4. RESULTS

The cropped images for İstanbul from 1994 to 2013 are used in this study. Random horizontal reads, cascade mean histograms and cascade threshold values are calculated for all images. Images are converted to binary images using cascade means values. Light activity values are counted. To compare and estimate population numbers for next years, population numbers between 2000 and 2010 are used. Obtained threshold values, light activity values and annual real population numbers for İstanbul are given in Table 1.

Image	Year	Threshold	Light Activity	Annual Real Population
F14_2000_ist.png	2000	12,05173	3058	12,05173
F14_2001_ist.png	2001	16,74189	2628	16,74189
F14_2002_ist.png	2002	18,77983	2414	18,77983
F14_2003_ist.png	2003	19,13677	2465	19,13677
F15_2004_ist.png	2004	13,24957	2986	13,24957
F15_2005_ist.png	2005	14,49418	2796	14,49418
F15_2006_ist.png	2006	13,45334	3004	13,45334
F15_2007_ist.png	2007	16,45834	2925	16,45834
F16_2008_ist.png	2008	21,31765	2825	21,31765
F16_2009_ist.png	2009	19,26601	2970	19,26601
F18_2010_ist.png	2010	25,97099	3208	25,97099

Table 1. Obtained threshold values and light activity values

Basic statistical parameters for light activity and population numbers are given in Table 2.

Variable	Light Activity	Real Population	Pixel per Population
Mean	2843,5	12126966	4285,4
Std.	249,9	699883	327,4
Minimum	2414,0	11076840	3622,2
Q1	2628,0	11495948	4111,7
Median	2925,0	12128577	4298,7
Q3	3004,0	12697164	4494,6
Maximum	3208,0	13255685	4762,2

Table 2. Basic statistical parameter values for light activity and population numbers

Light activity values are tested with Komogorov-Smirnov to determine whether they are suited with normal distribution or not (KS: 0.173, $p > 0.150$). It is seen that Light activity values have normal distribution. Correlation pearson coefficient is calculated between real population and light activity (pearson correlation 0,532, $p = 0.092$). Therefore, it is drawn a conclusion as light activity values can be used to estimate population numbers for next years. Calculated pixel per population value using data between 2000 and 2010 and estimated population numbers for 2011, 2012 and 2013 with light activity values and real population numbers based on years are given in Table 3.

Year	Light Activity	Pixel per Population	Estimated Population	Error (%)
2000	3058	3622,249836	13104829,72	0,18
2001	2628	4296,807078	11262096,96	0,00
2002	2414	4762,19884	10345016,00	0,10
2003	2465	4746,114402	10563572,68	0,10
2004	2986	3988,859009	12796279,11	0,07
2005	2796	4337,831545	11982048,36	0,01
2006	3004	4111,686418	12873416,76	0,04
2007	2925	4298,74735	12534868,19	0,00
2008	2825	4494,571327	12106325,69	0,05
2009	2970	4348,538047	12727712,31	0,01
2010	3208	4132,071384	13747643,47	0,04
Mean	2843,54	4285,425022	12185800,84	0,06
Std.	249,87	327,3808266	1070801,34	0,05

Table 3. Estimated results for İstanbul population between 2000 and 2010

Real population for İstanbul is estimated between 2011 and 2013 by using average pixel per population and data between 2010 and 2010. Estimated population and error related to it are presented in Table 4.

Year	Light Activity	Real Population	Estimated Population	Error (%)
2011	3311	13624240,00	14189042,25	4,145569
2012	3112	13854740,00	13336242,67	3,742380
2013	3405	14160467,00	14591872,20	3,046546
Mean	3276	13879815,67	14039052,37	3,644833
Std.	149,60	268991,53	641111,61	0,555967

Table 4. Estimated population and error for Istanbul at 2011, 2012 and 2013

5. DISCUSSION

Population number is a parameter that changes every year. The fact that the population number can be estimated using light activity value and usage of 10-year data for this estimation have created effective results in this study. Estimated results with using polynomial approach are not shared. However, R value is calculated as 0.45. In this approach, 10-year data is used to estimate population number for next three years. Mean error is obtained as %3.64 for 2011, 2012 and 2013. This result comes into prominence that our presented method is a reliable and effective method. However, it is taken a consideration that each city must have own city model. In this study, the strong connection between population number and light activity is explained.

REFERENCES

Elvidge, C.D., Erwin, E.H., Baugh, K.E., Ziskin, D., Tuttle, B.T., Ghosh, T., et al., 2009. Overview of DMSP night-time lights and future possibilities. Urban remote sensing event, pp. 1–5.

Henderson, M., Yeh, E.T., Gong, P., Elvidge, C.D., Baugh, K., 2003. Validation of urban boundaries derived from global night-time satellite imagery. *International Journal of Remote Sensing*, 24 (3), pp. 595–609.

Huang, X., Schneider, A., Friedl, M.A., 2016. Mapping sub-pixel urban expansion in China using MODIS and DMSP/OLS nighttime lights. *Remote Sensing of Environment*, 175, pp. 92-108.

Imhoff, M.L., Lawrence, W.T., Stutzer, D.C., Elvidge, C.D., 1997. A technique for using composite DMSP/OLS 'city lights' satellite data to map urban area, *Remote Sensing of Environment*, 61(3), pp. 361–370.

Levin, N., and Duke, Y., 2012. High spatial resolution night-time light images for demographic and socio-economic studies, *Remote Sensing of Environment*, 119, pp. 1–10.

Liu, Z., He, C., Zhang, Q., Huang, Q., Yang, Y., 2012. Extracting the dynamics of urban expansion in China using DMSP-OLS nighttime light data from 1992 to 2008, *Landscape and Urban Planning*, 106(1), pp. 62–72.

Mertes, C.M., Schneider, A., Sulla-Menashe, D., Tatem, A.J., Tan, B., 2015. Detecting change in urban areas at continental scales with MODIS data. *Remote Sensing of Environment*, 158, pp. 331-347.

Small, C., Elvidge, C.D., 2013. Night on Earth: Mapping decadal changes of anthropogenic night light in Asia. *International Journal of Applied Earth Observation and Geoinformation*, 22, pp. 40-52.

Yi, K., Zeng, Y., Wu, B., 2016. Mapping and evaluation the process, pattern and potential of urban growth in China. *Applied Geography*, 71, pp. 44-55.

Yücer, E., and Erener A., 2017. GIS Based Urban Area Spatiotemporal Change Evaluation Using Landsat and Night Time Temporal Satellite Data, *Journal of the Indian Society of Remote Sensing*, Online.

Wei. Y., Liu. H., Song. W., Yu. B., Xiu. C., 2014. Normalization of time series DMSP-OLS nighttime light images for urban growth analysis with Pseudo Invariant Features, *Landscape and Urban Planning*, 128, pp. 1-13.