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Correlation Analysis between the Community Mobility and Nighttime Lights in the City of Istanbul, Turkey

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Abstract: *The COVID-19, which emerged in Wuhan, China, in 2019, has significantly affected people's daily lives, business environment, surrounding environment, and countries' economic and social conditions. This study aims to measure the correlation between community mobility changes in six different areas and nighttime lights in the city of Istanbul, Turkey. Nighttime light data used in the study was obtained from VIIRS Nighttime Day/Night Band Composites Version 1 using remote sensing methods via Google Earth Engine platform. Then the correlation between Nighttime light values and community mobility values was investigated. It has been observed that the correlation values have changed dramatically over the years. The most significant correlation values were observed for the year 2020. This is because 2020 is the year when the pandemic is most effective, and restrictions are at the highest level in Turkey. The increase in freedom in the following years caused a decrease in the correlation. When the correlation results covering the period of February 2020 - to January 2022 were examined, it was observed that there was no significant relationship between nighttime light values and Google Community Mobility Reports' variables. Considering the correlation results for 2020, it was observed that there was a high negative correlation between nighttime light data and mobility trends for grocery and pharmacy, and mobility trends for places of work. In addition, there was a moderate negative correlation between nighttime light data and mobility trends for retail and recreation, and a moderate positive correlation between nighttime light and mobility trends for places of residence. When the correlation values of 2021 and the correlation values of the period 2021-2022 were examined, no significant relationship was observed.*

Keywords: *Nighttime light change, remote sensing, Google Community Mobility, Covid-19*

1. Introduction

The COVID-19, which emerged in Wuhan, China, in 2019, has significantly affected people's daily lives, business environment, surrounding environment, and countries' economic and social conditions. After the emergence and spread of the disease, many interdisciplinary studies have been conducted on COVID-19. In addition, many official institutions and independent societies have collected and published many datasets related to the COVID-19 to explain and understand different issues related to the pandemic. Google Community Mobility Reports (GCMR), which can be counted among these data, aim to explain how community movements have changed in six different areas based on a particular period at the beginning of the pandemic. This study aims to measure the correlation between community mobility changes in six different areas and nighttime lights (NTL) in the city of Istanbul, Turkey.

The rest of the paper is organized as follows; Section 2 discusses the related work. Section 3 explains the scope of the research. Section 4 provides a brief description of the methodology. Experiment results are presented and discussed in Section 5. Section 6 concludes the work.

2. Related Work

In this section, academic studies on detecting dimming of lights related to current epidemic lockdowns will be discussed.

Tian et al. used NTL data to address the lack of continuous work resumption rates under the epidemic in China. According to the study, COVID-19 has significantly affected the resumption of work [1].

Bragion et al. identified the nighttime radiance levels for estimating traffic flow. The authors have indicated that the changes in radiance levels at night are not all associated with traffic. The COVID-19 outbreak has also a significant effect over the traffic flow at night [2].

As-Syakur et al. used the electricity consumption to measure the impact of the COVID-19 on the socio-economic activities using satellite NTL approach. The authors indicated that the NTL data successfully determined the areas with a significantly decreased socio-economic activities. On the contrary, the increased NTL brightness indicates an increased in socio-economic activities [3].

Elvidge et al. produced annual global NTL time series using VIIRS Nighttime Day/Night Band Composites satellite imagery. They developed a novel method make a V.2 annual VIIRS NTL series from the monthly products. The aim of this novel method is to remove biomass burning, aurora, and background noise. They compared these two versions and found that V.2 had

dim lighting detections in grid cells assigned to background in the V.1 [4].

Luqman et al. introduced a new algorithm to extract the urban boundaries using remote sensing techniques.NTL is also one of the factors they considered. The overall accuracy of their methodology is ranging from 60% to 95% [5].

Liu et al. analyzed the impact of COVID-19 on people daily lives, activities, business environment, and surrounding environment using the spatial and temporal characteristics of NTL radiance and air quality index (AQI) before and during the pandemic in China. According to the results of the study, the monthly average NTL brightness is much lower during the quarantine period than before. They categorized NTL into three classes: residential area, transportation, and public facilities and commercial centers. They found that NTL has increased in the residential area and decreased in the commercial centers. On the other hand, transportation and public facilities stayed the same [6].

Elvidge et al. illustrated the changes in electric lighting across China by conducting an analysis on a reference set from a year prior to pandemic. According to the analysis's results, 62% of China's population lived in administrative units that became brighter in March 2019 relative to December 2018. In February 2020, the situation reversed. 82% of the population lived in administrative units where lighting dimmed because of the pandemic [7].

Ghosh et al. examined the changes in lighting by creating difference maps of a pre-pandemic pair and comparing it with two pandemic pairs. According to the analysis's results, 60% of the population in India lived in administrative units that became brighter in March 2019. 87% of the population lived in administrative units that became dimmer in March 2020 after the lockdown in comparison to February 2020 [8].

Chen et al. examined the usefulness of newer VIIRS lights in the estimation of economic activity by extending the previous applications of DMSP OLS NTL data. They found that the VIIRS lights are more useful in predicting cross-sectional gross domestic product than predicting time-series gross domestic product data. Because of that, considering biases that may arise from different aggregations is vital in applications of NTL in understanding socio-economic phenomenon [9].

Stokes et al. indicated that The Visible Infrared Imaging Radiometer Suite Day/Night Band (VIIRS DNB) is a vital step to track the changes in human activity. They examined multi-year (2015-2020) daily time-series data covering 584 urban areas, in 17 countries in the Middle East. They emphasized that satellite measurements provide a flexible and robust way in assessing the public response to physical distancing policies [10].

Although there are many studies in the literature using NTL data, there is no study that aims to measure the correlation between the information provided by this data and community mobility changes. The presented study aims to fill this gap in the literature.

3. Scope of Research

This study investigated the relationship between light changes in Istanbul, Turkey, and community mobility changes during the pandemic. The study area shown in Figure 1 is limited to the city of Istanbul.

Fig -1: Study area

NTL data used in the study was obtained from VIIRS Nighttime Day/Night Band Composites Version 1 using remote sensing methods via Google Earth Engine (GEE) platform [11]. GEE is a planetary-scale platform for Earth science data and analysis. The platform combines satellite imagery and geospatial datasets with remote sensing algorithm capabilities. It is possible to detect changes, map trends, and evaluate the differences on the Earth's surface using the GEE platform. Community mobility changes were obtained from GCMR[12] by Google.

The research questions focused on in the study can be listed as follows:

- What is the relationship between changes in NTL data and community mobility changes during the pandemic?
- Have the COVID-19 lockdowns and the mobility changes caused by the lockdowns affected the light changes?
- Is the NTL data in the pandemic above or below the averages realized as of 2012?

The accuracy of the results presented in the study is limited by the accuracy of satellite imagery data and community mobility reports.

4. Material and Methodology

In this section, first, the data set used in the study will be explained, and then the method followed will be explained.

4.1 Data Collection and Preprocessing

Two different data sets were used in this study. First, NTL data was obtained by remote sensing methods. Then, community mobility change data was obtained from Google. In the following part, first satellite imagery data and then GCMRwill be explained.

4.1.1Satellite Imagery Data

VIIRS Nighttime Day/Night Band Composites Version 1 [13] satellite images were used to obtain NTL data. This satellite provides monthly data for the period between April 2012 and Jan 2022.Data gaps exist for some months and some regions due to cloud covers, moonlight, and solar illumination. The resolution of the satellite imagery is 463.83 meters. This satellite imagery has two bands as listed below:

- avg_rad (unit: nanoWatts/cm2/sr) presents the average DNB radiance values.
- cf_cvg presents cloud-free coverages; the total number of observations that went into each pixel.

In this study, NTL data for the city of Istanbul were taken. Data could not be obtained for May, June, and July due to the reasons stated. For this reason, the data for these months were excluded from the scope of the study.

4.1.2 Google Community Mobility Reports

GCMR provide the movement trends by region, across six different categories of places. Google has created these reports with aggregated, anonymized sets of data from users. These users are the people who have allowed Google to track their location history. Community mobility reports show how visitors to categorized places change compared to predefined baseline days. Baseline days represent the normal values for those days of the week. The baseline defined by Google is the median value from the 5-week period Jan 3 - Feb 6, 2020. The place categories are grocery & pharmacy (G), parks (P), transit stations (T), retail & recreation (RR), residential (R), and workplaces (W).

4.2Methodology

In the first step, NTL data was obtained by remote sensing methods. VIIRS Nighttime Day/Night Band Composites Version 1 was used to obtain NTL data. GEE platform is used for data access and data download operations. VIIRS Nighttime Day/Night Band Composites Version 1 provides monthly data for 2012-2022. From the data obtained, GIF images were created showing the NTL change yearly, the NTL change before the pandemic, and the NTL change after the pandemic. These images can be accessed from the [14] link. The NTL change graph for the years 2012-2022 is shown in Figure 2.

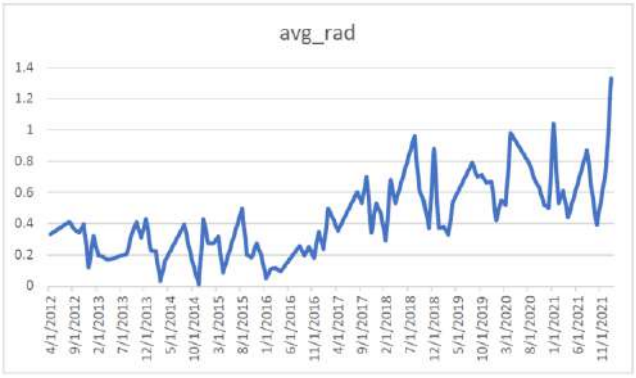

Fig -2: NTL change (2012-2022)

Figure 3 shows the monthly average avg_rad values for 2012-2022. Cells in orange indicate the active months of the COVID-19 pandemic. Two different averages were calculated on these data: (1) average by years, (2) average before the pandemic. As of 2018, an increase is observed in avg_rad values. The avg_rad values after the pandemic were above both averages.

	Jan	Feb	Mar	Apr	Aug	Sep	Oct	Nov
2012				0.331938	0.41128	0.363345	0.341001	0.394249
2013	0.320091	0.194583	0.187286	0.165487	0.206374	0.33652	0.409516	0.309428
2014	0.228907	0.221341	0.033064	0.164389	0.393329	0.241346	0.118783	0.011666
2015	0.27485	0.273015	0.31647	0.086616	0.496342	0.199333	0.181302	0.27286
2016	0.048903	0.110721	0.115547	0.091888	0.257073	0.194177	0.250286	0.179985
2017	0.235977	0.496044	0.428516	0.354623	0.60187	0.530761	0.7	0.34
2018	0.46	0.29	0.68	0.53	0.96	0.62	0.53	0.37
2019	0.37	0.38	0.33	0.54	0.79	0.7	0.71	0.66
2020	0.42	0.55	0.52	0.98	0.78	0.68	0.63	0.52
2021	1.04	0.53	0.61	0.44	0.87	0.6	0.39	0.57
2022	1.33							
MEAN	0.472873	0.338412	0.357876	0.368494	0.576627	0.446548	0.426089	0.362819
MEAN BEFORE PANDEMİC	0.294841	0.314463	0.298697	0.283118	0.514534	0.398185	0.405111	0.317273

Fig -3: The average avg_rad values

In the second stage of the study, the correlation between NTL values and community mobility values was investigated. First, monthly average values were calculated for community mobility changes. GCMR started to be published in February 2020. Therefore, the dates February 2020 – January 2022 have been taken into account at this stage. The data set included in the correlation analysis is shown in Figure 4.

	NL	RR	G	P	T	W	R
2020 Feb	0.55000001	0.8024263	4.0789022	8.08581436	5.71525424	8.63464837	-0.81415929
2020 Mar	0.51999998	-27.084104	-1.6064892	-5.45516652	-19.04032922	-15.89552239	9.29725086
2020 Apr	0.98000002	-72.032371	-27.65191	-55.89006157	-64.23809524	-62.15641026	27.91992374
2020 Aug	0.77999997	-25.154399	-7.6930693	47.13991163	-8.62577778	-24.21379898	1.47602740
2020 Sep	0.68000001	-20.773636	3.1078717	47.67295597	-2.18744395	-18.73844813	3.52021090
2020 Oct	0.63000000	-22.716443	9.95	38.50999131	11.18316832	-15.29859388	5.68549747
2020 Nov	0.51999998	-34.674783	2.2491379	6.36003521	-7.95489362	-19.50170940	10.34096916
2020 Dec	0.50000000	-51.980623	-2.3902848	-16.12288136	-26.97534922	-32.36192810	15.72572402
2021 Jan	1.03999996	-54.84874	-7.3302443	-22.87226891	-28.85012285	-33.55492270	14.51832907
2021 Feb	0.52999997	-46.927307	7.2022263	-6.00846660	-18.55222525	-26.49910072	11.56833176
2021 Mar	0.61000001	-32.232323	17.010824	2.46928328	-3.83456790	-16.89503662	8.20851064
2021 Apr	0.44000000	-42.897391	15.777874	3.80530974	-12.38167939	-26.55163728	13.63532513
2021 Aug	0.87000001	1.4751474	35.949196	73.46383363	30.37794613	-12.28866832	-0.50376569
2021 Sep	0.60000002	7.7065972	48.309233	57.84354986	38.85188356	-7.24017094	-0.12176166
2021 Oct	0.38999999	2.511335	47.286796	38.57005254	40.46898263	-3.08188586	1.42977292
2021 Nov	0.56999999	2.2934028	46.120035	35.30693069	40.39230769	-0.56532878	2.05148342
2021 Dec	0.75999999	0.0755668	48.795492	17.96286701	34.45123967	7.52644628	3.39309764
2022 Jan	1.33000004	-10.441744	38.479532	7.29396552	19.26754748	-2.01471791	7.52936170

Fig -4: Data set

The correlation analysis was calculated in 4 different ways: (1) correlation for data covering the period February 2020 to January 2022, (2) correlation only for 2020, (3) correlation only for 2021, (4) correlation for the year 2021 and January 2022. Figure 5 shows the results of the correlation analysis.

	NL
RR	-0.11014
G	-0.0662
P	-0.1607
T	-0.12699
W	-0.15888
R	0.198453

(1)

	NL
RR	-0.49917
G	-0.78799
P	-0.23689
T	-0.58624
W	-0.70235
R	0.458583

(2)

	NL
RR	-0.1658
G	-0.33189
P	-0.11062
T	-0.22816
W	-0.21126
R	0.104965

(3)

	NL
RR	-0.03705
G	-0.10804
P	-0.19028
T	-0.10297
W	0.058296
R	0.132391

(4)

Fig -5: Correlation coefficients

5. Results and Discussion

When the results of the correlation analysis are examined, it has been observed that the correlation values have changed dramatically over the years. The most significant correlation values were observed for the year 2020. This is because 2020 is the year when the pandemic is most effective, and restrictions are at the highest level in Turkey. The increase in freedom in the following years caused a decrease in the correlation.

When the correlation results covering the period of February 2020 - to January 2022 were examined, it was observed that there was no significant relationship between NL values and GCMR variables. Considering the correlation results for 2020, it was observed that there was a high negative correlation between NL and G, and W parameters. In addition, there was a moderate negative correlation between NL and RR, and a moderate positive correlation between NL and R. When the correlation values of 2021 and the correlation values of the period 2021-2022 were examined, no significant relationship was observed.

6. Conclusion

This study investigated correlation analysis between NTL data and community mobility change data. It was analyzed how much the NTL values during the pandemic period deviated from the average values calculated as of 2012. According to the findings, the average NTL values during the pandemic are above the average values calculated in 2012. In 2020, when the pandemic was most dominant, it was observed that NTL values decreased as grocery & pharmacy, retail & recreation, and workplace mobility increased, and NTL values increased as residential values increased. This confirms the fact that an increase in the duration of stay at home causes an increase in NTL values, while an increase in other mobility changes that cause a decrease in the duration of stay at home causes a decrease in NTL values.

Supplementary Material

All supporting material for the study is available at [14]: The GEE source codes, datasets, and GIF images.

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References

[1] Tian, S., Feng, R., & Wang, L. (2021, July). An Analysis for the Work Resumption Under the Covid-19 Epidemic based on VIIRS-DNB Nighttime Lights in China. *In 2021 IEEE International Geoscience and Remote Sensing Symposium IGARSS*, pp. 8376-8379.

[2] Bragion, G. D. R., Gonçalves, G. C., Dal'Asta, A. P., Santos, A. C. D. F., De Oliveira, L. M., Monteiro, A. M. V., & Amaral, S. (2021). Identifying Basal Nighttime Radiance Levels for Estimating Traffic Flow based on VIIRS/DNB data. *Rev. Bras. Cartogr*, 73(4).

[3] As-Syakur, A. R., Ariastina, W. G., Kumara, I. N., Antara, I. M. G., Osawa, T., & Cahyani, D. A. N. (2021, October). Impact of Covid-19 Pandemic on Electricity Consumption and Nighttime Lights Based on NPP-VIIRS DNB Image Products. *In 2021 International Conference on Smart-Green Technology in Electrical and Information Systems (ICSGTEIS)*, pp. 161-164.

[4] Elvidge, C. D., Zhizhin, M., Ghosh, T., Hsu, F. C., & Taneja, J. (2021). Annual time series of global VIIRS nighttime lights derived from monthly averages: 2012 to 2019. *Remote Sensing*, 13(5), 922.

[5] Luqman, M., Rayner, P. J., & Gurney, K. R. (2019). Combining Measurements of Built-up Area, Nighttime Light, and Travel Time Distance for Detecting Changes in Urban Boundaries: Introducing the BUNTUS Algorithm. *Remote Sensing*, 11(24), 2969.

[6] Liu, Q., Sha, D., Liu, W., Houser, P., Zhang, L., Hou, R., ... & Yang, C. (2020). Spatiotemporal Patterns of COVID-19 Impact on Human Activities and Environment in Mainland China using Nighttime Light and Air Quality Data. *Remote Sensing*, 12(10), 1576.

[7] Elvidge, C. D., Ghosh, T., Hsu, F. C., Zhizhin, M., & Bazilian, M. (2020). The Dimming of Lights in China during the COVID-19 Pandemic. *Remote Sensing*, 12(17), 2851.

[8] Ghosh, T., Elvidge, C. D., Hsu, F. C., Zhizhin, M., & Bazilian, M. (2020). The Dimming of Lights in India during the COVID-19 Pandemic. *Remote Sensing*, 12(20), 3289.

[9] Chen, X., & Nordhaus, W. D. (2019). VIIRS Nighttime Lights in the Estimation of Cross-

sectional and Time-series GDP. *Remote Sensing*, 11(9), 1057.

[10] Stokes, E. C., & Román, M. O. (2022). Tracking COVID-19 Urban Activity Changes in the Middle East from Nighttime Lights. *Scientific Reports*, 12(1), 1-13.

[11] Google Earth Engine. https://earthengine.google.com/Accessed: June 7, 2022.

[12] Google LLC "Google COVID-19 Community Mobility Reports". https://www.google.com/covid19/mobility/ Accessed: June 7, 2022.

[13] Earth Observation Group. https://eogdata.mines.edu/products/vnl/Accessed: June 7, 2022.

[14] Github. https://github.com/cavdarkizi/Correlation-Analysis-Between-the-Community-Mobility-and-Nighttime-Lights-in-the-City-of-IstanbulAccessed: June 7, 2022.

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